A REVIEW OF ELECTRIC VEHICLE CHALLENGES IN MALAYSIA

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ABSTRACT. The adoption of electric vehicles (EVs) is increasing globally as countries strive to reduce their carbon emissions and dependence on fossil fuels. Malaysia has set a target to have 100,000 EVs on the road by 2030 as part of its efforts to achieve a low-carbon economy. However, the transition to EVs in Malaysia is not without challenges. This review article aims to evaluate the challenges of EV usage in Malaysia in term of factors that influences the EV's price which related to the EV battery technologies, as well as the development cost of EV electrical motors. The review encompasses a comprehensive analysis of existing literature published between 2016 and 2021, obtained from academic databases and relevant sources. The findings reveal that prominent challenges faced in Malaysia is the expensive price due to the high cost of EV batteries technologies, development, and the production cost. Furthermore, the review highlights the importance of considering the development cost of EV motors which that employ permanent magnets derived from earth minerals such as REE will have a significant impact on the total cost of manufacturing an EV. Overall, the cost of the battery and electric motor is what contributes to the high price of EVs. The production cost of a battery is heavily influenced by its technology's energy-efficiency requirements. Addressing these challenges requires a multi-stakeholder approach involving industry players, government bodies, research institutions, and academia. Overall, this journal review provides insights into the challenges faced by Malaysia in the areas of EV battery technologies and their cost, as well as EV motor development costs. The findings underscore the need for strategic initiatives, policy interventions, and collaborative efforts to overcome these challenges and accelerate the adoption of electric vehicles in Malaysia, contributing to sustainable transportation and reduced carbon emissions.

KEYWORDS: [electric vehicle; battery technology; electrical motor; expensive price]

1 INTRODUCTION

Currently there is a rapid expansion of the EV market around the world. Almost 16.5 million electric vehicles were on the road as of the end of 2021, which is quadruple the number from 2018. With two million electric vehicle sales in the first quarter of 2022, a 75% increase over the same time in 2021, the market for electric vehicles has continued to grow rapidly. Half of the growth in EV sales in 2021 was attributed to the People's Republic of China (China), which saw an increase of 3.3 million units in sales in 2021 compared to the global total for vehicles sold in 2020. Sales in Europe kept growing rapidly after the 2020 boom (up 65% to 2.3 million), and after two years of decline, sales in the United States also rose (to 630,000)(Dong et al., 2020; Logan et al., 2020; Wu et al., 2020)(MIDA, 2021).

The adoption of electric vehicles (EVs) is increasing globally as countries strive to reduce their carbon emissions and dependence on fossil fuels. Malaysia has set a target to have 100,000 EVs on the road by 2030 as part of its efforts to achieve a low-carbon economy. However, the transition to EVs in Malaysia is not without challenges. This review article aims to critically evaluate the challenges of EV usage in Malaysia and identify potential solutions to overcome them.(Tan, 2017)

The transport sector in Malaysia is ranked third in terms of CO2 emissions from the transport sector in ASEAN countries, with 71% coming from cars and 9% from motorcycles. To mitigate this, a sustainable and green transportation system must be adopted. Reform initiatives have been undertaken to streamline and strengthen the institutional structure and governance of the transport sector, but there are still gaps in the governance structure. A holistic approach from all stakeholders is needed to ensure the sector becomes sustainable(KeTTH., 2017).

One of the challenges facing EV adoption in Malaysia is the lack of charging infrastructure, which can lead to range anxiety and limit the practicality of EVs for long-distance travel. In addition, high upfront costs, limited availability of EV models, and the dominance of the oil and gas industry also pose challenges to EV adoption. The lack of incentives and support from the government, as well as low awareness and knowledge among consumers, are also barriers to EV adoption.(MIDA, 2021) To address these challenges, Malaysia's government needs to develop a comprehensive strategy that includes investment in charging infrastructure, incentives and policies to promote EV adoption, and public education campaigns(Muzir et al., 2022).

As the world transitions towards cleaner and more sustainable energy sources, electric vehicles (EVs) are gaining popularity as an eco-friendly alternative to traditional gasoline-powered cars. However, the performance of EVs is largely dependent on the battery technology used. Battery technology is a key factor in determining the driving range, charging time, and cost of EVs. Therefore, there is a growing need to explore and develop new battery technologies that can provide higher energy density, longer driving range, and faster charging time.

This article intends to provide an overview of the present state-of-the-art battery technologies used in electric vehicles (EVs) and the relationship with electrical motor that such influences the EV price. The article will explain the various battery types used in EVs, such as lithium-ion, nickel-metal hydride, and solid-state batteries. This article also provides a simple analysis of the battery technology used in electric vehicles, as well as the associated challenges and opportunities pertaining to power delivery to the various types of electrical motor and relationship to the power-to-weight ratio of EV. All these variables will affect the most critical EV challenge in Malaysia, which is the cost of EVs.

2 LITERATURE REVIEW OF EVs BATTERY SYSTEM.

The performance of electric vehicles is heavily reliant on the battery technology employed, with power delivery will influencing the range, weight, and cost of the batteries(Tomaszewska et al., 2019). Therefore, it is vital to understand the many types of batteries, their advantages, disadvantages, and restrictions, as the performance of EVs is highly dependent on the battery technology employed. EV battery systems are essential components of modern electric vehicles that store and provide energy to power the vehicle's electric motor. Li-ion batteries are becoming increasingly popular due to their high energy density, long cycle life, and low self-discharge rate. Active thermal management and advanced BMS technologies are essential for maintaining optimal battery health and preventing catastrophic battery failures, which could impact both the safety of passengers and the environmental impact of disposing of batteries (Hasan et al., 2021; Rezvanizaniani et al., 2014; Shobana, 2020; Song et al., 2022; Thakur et al., 2020; Xing et al., 2011).

The battery is an electrochemical energy storage device that converts chemical energy into electrical energy. Primary battery and secondary battery are the two different types of electrochemical batteries. With electric vehicles, a secondary battery with a higher specific energy is employed. Since batteries are the only source of driving power for EVs, advancements in battery technology have a significant impact on the industry. The early EV system makes use of a lead-acid battery. Following that, researchers continued to work on the EV system and suggested storage batteries with higher specific energy and power densities. More specific power and energy, high capacity and energy density, extended cycle life, high temperature tolerances, and effective batteries were required for EV. Lead-acid batteries, sodium-sulphur batteries, zinc-air batteries, nickel batteries, and Li-ion batteries are among the various types of rechargeable batteries used in EVs. In the modern EV system, Li-ion-based batteries are most suited and most relevant (Hasan et al., 2021). Figure 1 shows an example of a typical EV automotive system architecture (Joe Bush, 2020).

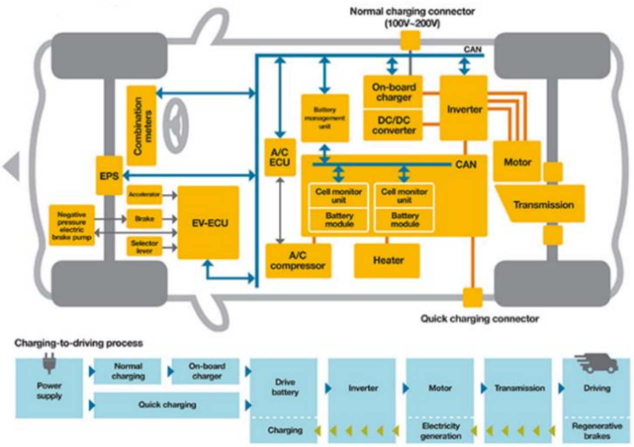

Figure 1. An example of a typical EV automotive system architecture

3 METHODOLOGY

The methodology of this study is a scoping review technique. The first step is to clarify the query, "What factors cause the price of an EV to be prohibitively expensive?" The second step is to locate relevant research publications and studies published between 2016 and 2021. Using databases such as Scopus, IEEE Xplore, Science Direct, and Google Scholar, the most recent and relevant literature is gathered for this study. Inclusion and exclusion criteria have been established to assure the selection of research that addresses the EV transition, market movement, and the effect of battery technology and electric motor powertrains on the overall pricing of EVs. When extracting and organising crucial findings, various battery technologies and electric motor powertrain types of cost implications, market trends, technological developments, power efficiency, and power density are also considered. The collected data sheds light on the market dynamics of EVs over the past five years, with a particular focus on the impact of battery technology and electric motors on EV price. The findings of the study will contribute to a better comprehension of the technological and market changes that have occurred during the transition from ICE to BEV vehicles. The examination of the effect of the electric motor powertrain on the overall cost of BEVs will be beneficial to policymakers, industry stakeholders, and researchers involved in the development and implementation of sustainable transportation solutions. This study's methodology is depicted in the diagram below.

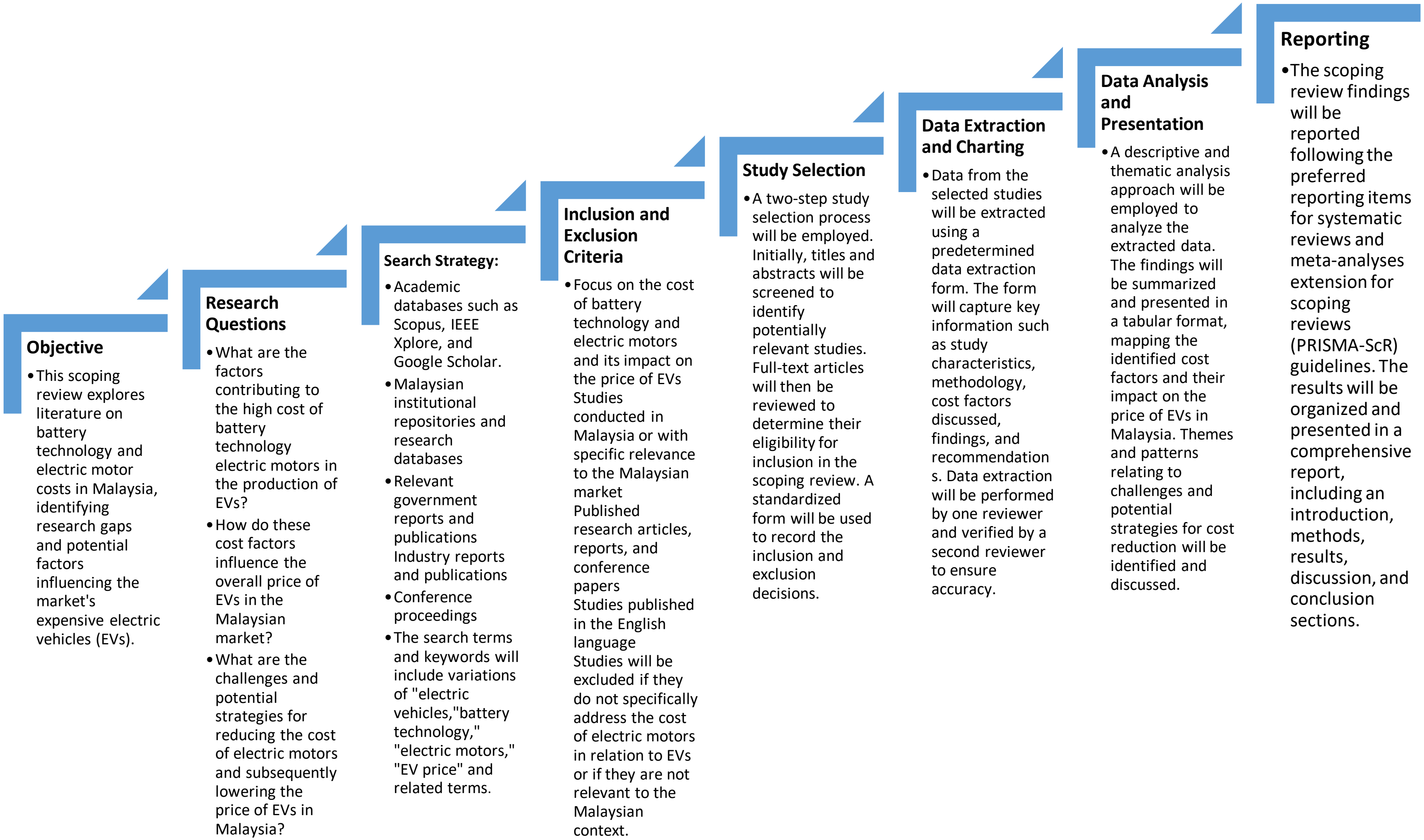

Figure 2. Scoping Review Methodology for Electrical Motor Power Train for Electrical Vehicle Review

4 RESULT AND DISCUSION.

4.1 Battery Technology That Affects the EV's Price

There are numerous battery types used in electric vehicles. These are the most prevalent type of battery used in electric vehicles. They are portable, have a high energy density, and can be swiftly recharged. NiMH batteries have been used in electric vehicles for many years. NiMH batteries are a rechargeable battery type. They have a lower energy density than Li-ion batteries but are less expensive. Solid-state batteries: These batteries are still in the development stage, but they are anticipated to offer greater energy density, faster charging periods, and enhanced safety compared to existing battery technologies. These batteries have been utilised in electric vehicles for many years, but they are cumbersome and have a low energy density. Sodium-ion batteries are a promising alternative to lithium-ion batteries because they are less expensive, have a better energy density, and are friendlier to the environment. These batteries use oxygen from the air to create electricity and are affordable, lightweight, and have a high energy density. These batteries store energy in liquid electrolytes and can be quickly recharged by replacing the exhausted electrolyte with a new one. Designed to deliver high power and rapid charging, hybrid capacitors are a mix of a battery and a capacitor(Chen et al., 2020; Jiang et al., 2020; Ren et al., 2021; Shobana, 2020; Teoh et al., 2018; Tie & Tan, 2013; Tomaszewska et al., 2019; Turksoy et al., 2020).

This study focuses on one of the challenges of EV sales in Malaysia which revolves around the price. Public perception states that EVs are expensive due to taxes imposed by the government. However, after import duties, excise duties, and electric vehicle sales tax are fully exempted, EV prices are still far from the affordability of the M40 and B40 groups. This proves that EV prices are indeed still expensive due to several factors, especially the cost of a battery used by EVs. The price of an EV in Malaysia is still expensive for most middle (M40) and low (B40) income groups. Even after the government gave a 100% tax relief initiative in 2022 (Koty, 2022)(Awani, 2021) . For comparison and the list is as in the table below before and after the tax exemption(Muzir et al., 2022; WapCar, 2023).

Table 1: Retail Price of EV Comparison between before and after the tax exemption

Car Model	Retails Price before Tax Relief (RM)	Retails Price After Tax Relief (RM)
MINI Electric Cooper SE	221, 878.00	199, 164.00
Nissan Leaf	188, 888.00	168, 888.00
BMW i3s	278, 800.00	268, 824.00
Porsche Taycan	584, 561.00	622, 275.00

Based on Table 1, it was determined that the difference between EV prices in Malaysia before and after tax is approximately 10%. This suggests that the expensive price of an EV is not solely attributable to taxation, but rather to the expensive production costs caused by the electric motor powertrain system and battery technology in use.

4.2 Batteries Power Delivery and Relationship to The Electric Motor Drive Characteristic.

The curb weight of the vehicle is one of many variables that affect how much power of an EV battery should be delivered. Curb weight, which refers to a vehicle's weight while it is empty of people and goods, can have an effect to the electric motor designed in terms of power and torque. Overall, the curb weight of the vehicle and the weight of the EV battery system have a significant influence on the EV's performance, affecting things like power density and efficiency (Baek et al., 2019; Chopra & Bauer, 2013; Kaleg et al., 2015; Miri et al., 2021; Sagaria et al., 2021). As comparison for B segment for ICE vehicle as follows in the Table 2 below.

Table 2: Internal Combustion Engine (ICE) power to Curb Weight of B segment vehicle

Brand	Curb Weight (Kg)	ICE Power (Kw) /Torque (Nm)
Proton Persona	1175	79.78/150
Perodua Myvi	1025	76.06/136
Toyota Vios	1015	77.55/138
Nissan Almera	1114	73.83/152

The design of an EV places great emphasis on dynamic factors such as drag coefficient, chassis rigidity, and mass for the entire EV. This is because it has a significant relationship with the battery design (output power of the battery) and the travel distance of an EV(Ravindra Jape & Thosar, 2017). If the parameters for ICE vehicles are considered, the power-to-weight ratio for the B segment is around 50–70 watts/kg. This means that for an EV to function properly, the development and design of the EV battery and powertrain which is types of electric motor need to consider the power output that has been benchmarked by the ICE vehicle(Garcia-Valle & Lopes, 2013).

The price of batteries is one of the primary factors contributing to the expensive nature of electric vehicles. It is estimated that the battery accounts for between one-fifth and one-half of the entire cost of an electric vehicle. This is because the cathode, one of the fundamental materials required for battery production, is expensive. The cathode is one of the two electrodes that store and discharge charge. Materials such as cobalt, nickel, lithium, and manganese could be used as cathodes, but each has a high cost. In order to reduce the cost of batteries by altering their composition, a substantial quantity of research has been conducted. Figure 2 illustrates the cost per dollar per kilowatt-hour of the various battery technologies utilised in electric vehicles. As shown in Table 4, lithium-ion batteries have a greater energy density and a lower production cost, which has led to their widespread adoption by EV manufacturers.(Muzir et al., 2022)

The power delivery of a battery will greatly affect its development cost due to materials, R&D and the relationship between supply and demand.

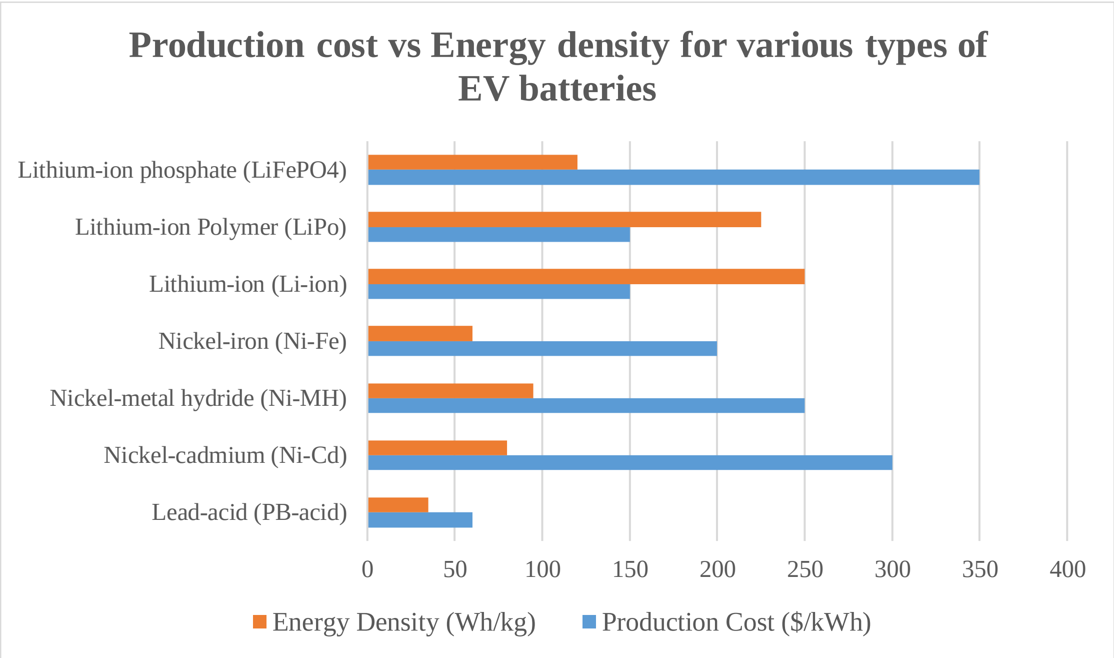

Figure 2: Production cost vs Energy density for various types of EV batteries

4.3 Electrical Motor Cost Development.

Basically, electric motors consist of two types, namely AC motors and DC motors. But for both types of motors, there are only a few types of motors that can be developed into a power train of battery-electric motors that are efficient in energy, high in power and torque at all rpm speeds, reliable, with low maintenance and development costs, and others. Figure 3 shows the variant of electrical motor and some of the electrical motors generally used in the EV (Aiso & Akatsu, 2022), (Bhatt et al., 2019; Ravindra Jape & Thosar, 2017).

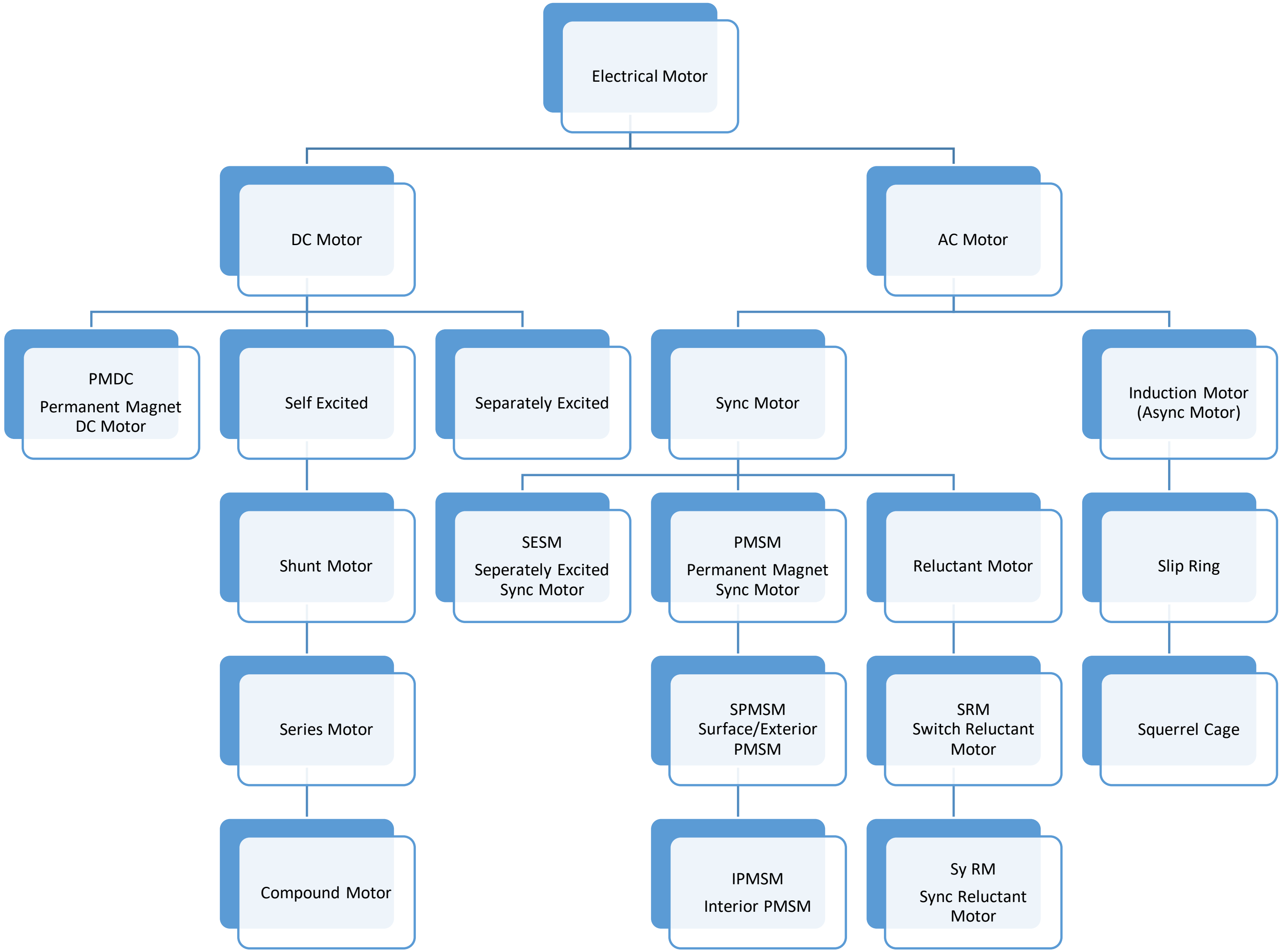

Figure 3. The Variant of Electrical Motor And Some Of The Electrical Motors Generally Used In The EV

Although a variety of motor types are available for electric vehicles, the majority of EVs presently utilise the DC motor family due to the influence of variables such as vehicle specifications, energy source, and drive specifications. To increase the vehicle's efficacy, the automaker creates a dependable electric propulsion system. DC motors are utilised due to their availability and ease of implementation. In addition, its initial torque at rest is greater. AC motors are as adaptable as possible to driver specifications. They can serve as a generator and charging batteries. It can adapt to irregular terrain and transmit a greater amount of acceleration. EV manufacturers use five varieties of motors: Brushless DC motor (BLDC), Permanent Magnet Synchronous Motor (PMSM), AC Induction Motor (ACIM), Interior Permanent Magnet Motor (IPMM), and Permanent Magnet Switched Reluctance Motor (PMSR). BLDC motors are durable, low-maintenance, 85–90% efficient, and lightweight. In terms of speed regulation, BLDCs are more efficiently regulated than ACIMs. Most of electric vehicles use induction motors because they are resilient, mechanically robust, and 85 to 97% more efficient. The motor can be initiated under load with conventional utility power in the absence of inverters. When supplied with the available power, they maintain a constant velocity. The torque output is reduced, and the inverter can draw electricity from a DC source or a battery.(Bhatt et al., 2019; Sneha Angeline & Newlin Rajkumar, 2020). Table 3 shows the some of the various electrical motor's characteristic which used in the EV(Bhatt et al., 2019; Ravindra Jape & Thosar, 2017).

Table 3: Comparison of the characteristics of different types of EV motors(Loukas, 2022)

Characteristic	**DC Motor**	**AC Induction Motor**	**PMSM**	**PM SRM**
Power density	Low	Medium	Very High	Medium
Efficiency	Low	Medium	Very High	Medium
Controllability	Very High	Very High	High	Medium
Reliability	Medium	Very High	High	Very High
Technological maturity	Very high	Very High	High	High

Magnetic materials are a crucial aspect of the EV motor market. From 2015 to 2020, the market share of PM motors for electric vehicles remained above 75%. Magnets used in these motors typically contain an abundance of rare earths, particularly neodymium, as well as a series of heavy rare earths such as dysprosium. The efficiency and power density of these PM motors are superior. In addition to a supply chain that is primarily based in China, REE raise concerns regarding mining and waste. In 2011, China restricted exports of these materials, resulting in a fivefold increase in price compared to the previous year. Due to these factors, some of EV makers, such as Renault's wound rotor design for the Zoe and Audi's induction motor for the E-Tron, have developed motors without REE. While Renault was the first manufacturer to employ a wound rotor design, BMW's fifth-generation drive incorporates a similar design. However, the price of rare earths has stabilised and remained relatively consistent, and others, including Tesla and Audi's next-generation vehicles, have adopted PM designs. The price of neodymium has increased substantially during the first half of 2021, causing renewed market uncertainty. IDTechEx predicts that PM designs will continue to dominate electric motors in the future, albeit with a focus on rare-earth and especially heavier rare-earth reductions. Figure 4 is a pie chart illustrating the percentage of the three most prevalent types of electric motors for EVs in 2020..(Dr James Edmondson, 2022)

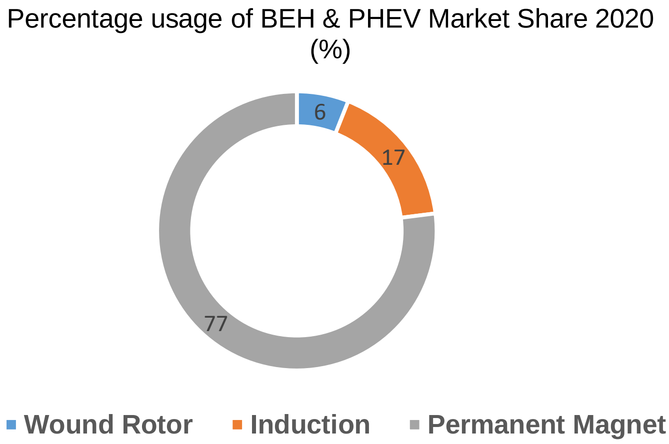

Figure 4: Percentage usage of BEH & PHEV Market Share 2020

Acceleration and driving performance of an EV are heavily influenced by the battery system and electric motor capacity. It is expressed in the form of a weight-to-power ratio, which determines acceleration and pace. However, the mileage will be contrary to the acceleration and speed. It is difficult to develop a battery and electric motor system for EVs with very high performance without sacrificing driving range. This will be the primary challenge referred to as efficacy. Table 4 presents a few EV brands available in Malaysia, along with key specifications such as battery storage capacity (kWh), batteries technology, electric motor types and technology, and most importantly, power-to-weight ratio.

Depending on a few variables, the production cost of an electric vehicle (EV) motor employing a permanent magnet AC synchronous motor (PMSM) can vary. This includes the type and quality of permanent magnets employed, the manufacturing process, labour costs, basic material costs, economies of scale, and overhead expenses. Several factors influence the manufacturing costs of an EV motor, such as the permanent magnet used in the rotor of PMSMs. The high magnetic properties of rare earth magnets, particularly neodymium-iron-boron (NdFeB) magnets, make them a common component in PMSMs. As previously stated, the price of rare earth magnets can fluctuate based on market conditions and supply. For a notion of the cost trends, you can consult sources such as Adamas Intelligence or industry reports that track rare earth magnet prices. Second, manufacturing and assembly costs contribute to the total cost of production. These costs can be affected by labour expenses, energy costs, basic material prices (other than magnets), automation level, and production volume. To optimise efficiency and reduce labour costs, manufacturers may employ a variety of production techniques, such as automated winding procedures. Implementing sophisticated automation and lean manufacturing techniques can also influence production costs.(Bhatt et al., 2019)

With its mature techniques and low-cost advantages, the Induction Motor (IM) has effectively penetrated the EV market, but its efficiency performance is not conducive to EV mileage. In addition to having the highest efficiency, the EV motor must have the widest constant power range feasible to maximise the energy recovered by regenerative braking. With its high efficiency and broad constant power range, the PMSM is the ideal EV motor for regenerative deceleration. The benefits of PM motors include high efficiency, high torque density, and suitability for long-range EVs; however, the PM's high price presents a challenge. Due to its superior resistance to high temperatures and dependable mechanical structure, the SRM has a broad speed range, but its low torque capacity limits the energy recovery effect.

Rare Earth Element (REE) particulate matter is costly due to the limited yield of rare earth elements and its non-renewable nature. Electrical motors which using in EV, the application of low-cost PM without REE has garnered increasing interest. Four types of PM material are presently used to manufacture motors: AlNiCo, ferrite, NdFeB, and SmCo, with the latter two containing REE. The REE, such as Nd and Sm, can be manufactured into high-energy-density particles. However, these two elements have limited reserves and dispersed distribution in nature, resulting in high prices and a volatile supply. Due to its high coercivity, NdFeB-based PMs are currently preferred for PM electrical motors.

As shown in Table 4, magnets with low energy density and low coercivity cannot meet the requirements of high-performance EVs. However, their low cost makes them very attractive for low- and medium-performance EVs. However, the low coercivity contributes to an exceptional ability to diminish the field, thereby enabling a greater speed. This high speed generates a low torque capable of producing the same amount of power, conserving the EV's storage capacity. In contrast to the conventional flux-weakening control mode, which requires continuous current to modify the magnet remanence, AlNiCo-PM only requires a brief current pulse to be injected into the stator to change the magnetization level. As a result, copper loss can be reduced, and motor performance can be improved. This variable magnetic flux characteristic is utilised by flux memory motors.

Due to the limited yield of REE and their non-renewable nature, the application of low-cost PM without REE in electric motors has garnered interest. AlNiCo, ferrite, NdFeB, and SmCo are the four varieties of permanent magnets, with NdFeB-based PM being the preferred option due to its high coercivity. AlNiCo-PM requires only a transient current pulse to change the magnetization level, resulting in reduced copper loss and enhanced motor efficiency. (Wang et al., 2021)

Table 4: Permanent Magnet using REE material and the Price of REE

Property	Alcino	Ferrites	Samarium cobalt	Neodymium
Remanence (Br, T)	0.7-1.28	0.23-0.41	0.83-1.16	1-1.41
Coercitive force				
(Hc, kA/m)	37-143	50-290	480-840	760-1030
Max energy Product $(BH)_{max}$, kJ/m3	10.7-71.6	8.35-31.8	130-240	220-336
Price, USD/kg	58	7.1	100	75

Consequently, there are two primary factors that contribute to the high price of an EV: the battery technology employed and the type of electric motor, both of which are influenced by the acceleration and speed performance requirements of a vehicle. Although the government has eliminated a few taxes on EVs, it has not substantially reduced the cost of these vehicles. In addition, it has been demonstrated that electric motor powertrain technology employing REE materials is more efficient in terms of power savings and extended travel distance, but has no significant impact on acceleration performance, making it difficult for EV prices to decrease. Most EV manufacturers utilise lithium-ion batteries and permanent magnet applications for the motor's electrical components, according to Table 5 below. I propose that the government, as a policymaker, is already on the correct track to reduce the price of electric vehicles (EVs). The elimination of various tariffs on EVs has been accomplished, but it is insufficient. Therefore, additional factors may be considered by awarding grants to GLC or any entity prepared to invest in the addition of more fast-charging stations, thereby reducing users' distance anxiety. In addition, the government must implement numerous other initiatives, such as tax breaks for the initial purchase of an electric vehicle (EV), free parking spaces, and other benefits for EV drivers. All of these are significant factors that can increase the number of EV purchasers and have a substantial impact on the demand and supply factors. I believe only these factors will be the primary determinants of EV price reduction. When large-scale production occurs and supply exceeds demand, production costs will decrease.

Table 5. Types of electric motors and battery technology used in the most representative Segment B and C of EV models in the Malaysia's market.

Brand	Year	Power (kW)	Torque (Nm)	Types of motor	Types of Battery	Battery capacity (kWh)	Range (km)	Weight (kg)	Power-to-weight ratio (watt/kg)
BYD Atto 3	2023	150	310	Permanent magnet AC synchronous motor	Lithium-ion	60.5	480	1750	85.7
Renault Zoe	2022	80.54	225	Externally Excited Synchronous Motors (EESM)	Lithium-ion	52	395	1502	53.6
Mazda MX-30	2022	106.6	271	Permanent magnet AC synchronous motor	Lithium-ion	35.5	199	1645	64.8
Nissan Leaf	2022	110.36	320	AC synchronous motor	Lithium-ion	40	270	1544	71.6
Hyundai Ioniq 5	2022	125.3	350	Permanent magnet AC synchronous motor	Lithium-ion	58	385	1985	63.1

5 CONCLUSION

Electric vehicles (EVs) have garnered significant attention as a sustainable transportation alternative, but their widespread adoption faces obstacles, notably in the areas of battery technology and motor types, which have a significant impact on the price of EVs. Battery Technology Obstacles Battery technology is one of the primary obstacles for electric vehicles. The cost of battery packs is a significant portion of the total pricing of an EV. While battery costs have been consistently declining, further reductions are necessary to make EVs accessible to the average consumer.

Another difficulty is energy density. The energy density of existing battery technologies is inferior to that of conventional fossil fuels. Batteries with a greater energy density would enable extended driving ranges, reducing range anxiety and enhancing the practicality of electric vehicles. To enhance energy density and advance battery technologies, continued research and development efforts are necessary.

The types of EV Motor type which use REE for PM motor influences the price of the vehicle. The simplicity and low cost of brushed DC motors make them suitable for cost-effective EVs. However, they have limitations in terms of efficiency, dependability, and maintenance needs, resulting in higher ownership costs over the long term.

In contrast, induction motors are extensively used in EVs due to their high efficiency and dependability. They are less expensive than other motor types, making them prevalent in mid-range electric vehicles. Because induction motors have fewer moving parts, they require less maintenance, which contributes to their overall affordability.

Permanent Magnet Synchronous Motors (PMSM) provide superior power-to-weight ratios and high efficiency, making them suitable for high-performance electric vehicles. Nevertheless, they typically employ rare earth magnets, which can substantially increase their price. PMSM motors are more expensive than other motor varieties due to the availability and price volatility of rare earth elements, which increase their overall cost. The challenges posed by battery technology and motor varieties have a significant impact on the cost of electric vehicles.

The challenges associated with battery technology include the price of battery packs, the need to increase energy density, and the development of a reliable charging infrastructure. To address these obstacles, ongoing research and development must be conducted to reduce costs, increase energy density, and establish an accessible recharge network.

The price of an electric vehicle is also affected by the motor model chosen. Brushed DC motors are inexpensive but have limitations, whereas induction motors provide a good balance between affordability and efficacy. Due to the price of rare earth magnets, PMSM motors can be more expensive despite their high efficacy.

Automobile manufacturers, battery manufacturers, and policymakers must collaborate to overcome these obstacles. Continuing innovation and investment in battery technology, as well as optimising motor technologies and exploring alternative materials, will help make EVs more affordable and appealing to a wider spectrum of consumers. By resolving these obstacles, we can hasten the transition towards a greener and more sustainable transport system.

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