

Diagnosis and recommendations for the implementation of electric vehicles in Brazil¹

Diagnóstico e recomendações para a implementação de veículos elétricos no Brasil¹

Diagnóstico y recomendaciones para la implementación de vehículos eléctricos en Brasil¹

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ABSTRACT: This study emphasizes the urgent need, as well as the challenges associated with the adoption of electric vehicles (EVs) and alternative technologies in the Brazilian transportation sector, driven by environmental and economic concerns. Transport emissions, a major contributor to urban air pollution, emphasize the reliance on non-renewable petroleum sources. Globally, policies encouraging the proliferation of EVs are becoming commonplace; however, in Brazil, electric mobility is progressing gradually due to technological uncertainties and a lack of supportive public policies. Based on a literature review and the Delphi method applied to experts, the study identified the need to overcome technological and infrastructural barriers for broader EVs adoption. Recommendations were proposed, including collaboration among automakers, battery suppliers, energy companies, and governments to stimulate demand and accelerate the adoption of EVs, considering the highlighted environmental benefits and energy efficiency of EVs, alongside the significant contribution of the transport sector to carbon dioxide (CO₂) emissions. The study emphasizes the importance of collaboration among stakeholders to promote electric mobility, improve urban air quality, and contribute to energy sustainability. Despite considerable challenges, coordinated efforts among stakeholders could accelerate the adoption of EVs in Brazil. The study contributes to the development of policies and practices that promote sustainability in the transport sector, delivering substantial environmental and economic benefits.

KEYWORDS: Technological Prospecting; Public Policies; Electric Vehicles; Sustainability; Energy Efficiency.

RESUMO: Este estudo enfatiza a necessidade urgente, bem como os desafios associados à adoção de veículos elétricos (VEs) e tecnologias alternativas no setor de transporte brasileiro, motivados por preocupações ambientais e econômicas. As emissões de transporte, um grande contribuinte para a

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poluição do ar urbano, ressaltam a dependência de fontes de petróleo não renováveis. Globalmente, as políticas que incentivam a proliferação de VEs estão se tornando comuns; no entanto, no Brasil, a mobilidade elétrica está progredindo gradualmente devido às incertezas tecnológicas e à falta de políticas públicas de apoio. Com base em uma revisão de literatura e no método Delphi aplicado a especialistas, o estudo identificou a necessidade de superar barreiras tecnológicas e de infraestrutura para uma adoção mais ampla de VEs. Recomendações foram propostas, incluindo colaboração entre montadoras, fornecedores de baterias, empresas de energia e governos para estimular a demanda e acelerar a adoção de VEs, considerando os benefícios ambientais destacados e a eficiência energética dos VEs, juntamente com a contribuição significativa do setor de transporte para as emissões de dióxido de carbono (CO₂). O estudo enfatiza a importância da colaboração entre as partes interessadas para promover a mobilidade elétrica, melhorar a qualidade do ar urbano e contribuir para a sustentabilidade energética. Apesar dos desafios consideráveis, esforços coordenados entre as partes interessadas podem acelerar a adoção de VEs no Brasil. O estudo contribui para o desenvolvimento de políticas e práticas que promovam a sustentabilidade no setor de transporte, entregando benefícios ambientais e econômicos substanciais.

PALAVRAS-CHAVE: Prospecção tecnológica; Políticas Públicas; Veículos Elétricos; Sustentabilidade; Eficiência Energética.

RESUMEN: Este estudio enfatiza em la necesidad urgente, así como los desafíos asociados con la adopción de vehículos eléctricos (EV) y tecnologías alternativas en el sector del transporte brasileño, impulsado por preocupaciones ambientales y económicas. Las emisiones del transporte, uno de los principales contribuyentes a la contaminación del aire urbano, subrayan la dependencia de fuentes de petróleo no renovables. A nivel mundial, las políticas que fomentan la proliferación de vehículos eléctricos se están volviendo comunes; sin embargo, en Brasil la movilidad eléctrica está avanzando lentamente debido a las incertidumbres tecnológicas y a la falta de políticas públicas de apoyo. Basado en una revisión de la literatura y el método Delphi aplicado con especialistas, este estudio identificó la necesidad de superar las barreras tecnológicas y de infraestructura para una adopción más amplia de los vehículos eléctricos. Se propusieron recomendaciones, incluida la colaboración entre fabricantes de automóviles, proveedores de baterías, empresas de energía y gobierno para estimular la demanda y acelerar la adopción de los vehículos eléctricos, considerando los beneficios ambientales destacados y la eficiencia energética de los mismos, junto con la importante contribución del sector del transporte para las emisiones de dióxido de carbono (CO₂). El estudio enfatiza la importancia de la colaboración entre las partes interesadas para promover la movilidad eléctrica, mejorar la calidad del aire urbano y contribuir a la sostenibilidad energética. A pesar de los considerables desafíos, los esfuerzos coordinados entre las partes interesadas pueden acelerar la adopción de vehículos eléctricos en Brasil. El estudio contribuye al desarrollo de políticas públicas y prácticas que promueven la sostenibilidad en el sector del transporte, generando importantes beneficios ambientales y económicos.

PALAVRAS CLAVE: Prospección tecnológica; Políticas Públicas; Vehículos Elétricos; Sostenibilidad; Eficiencia Energética.

Introduction

From the concerns arising from the oil crisis during the 1970s, the world became aware of the need to adopt new energy alternatives. In addition, the automotive industry

has been pressured by governments and society to develop vehicles with better energy use and environmentally less pollutants, given that, in addition to the high variability in oil prices, issues have arisen such as air pollution in large cities and the problem of climate change caused by the emission of greenhouse gases from the burning of fossil fuels (Machado, 2015; Cortezzi, 2017).

Thus, new alternative technologies have been adopted globally, such as biofuels (ethanol and biodiesel), biofuel engines (flexfuel), electronic injection systems, hybrid electric vehicles (HEV), pure electric vehicles (PEV) and battery electric vehicles (BEV) (Machado, 2015; Moraes; Barassa; Consoni, 2016).

It is noteworthy that the transport sector contributes 23% of global CO₂ emissions from fuel combustion worldwide. In Brazil, this number increases to 45%, even with the use of ethanol and biodiesel. In turn, fossil fuels represent 80% of the supply of the transport sector whereas renewable sources represent 82% of the Brazilian electricity grid (Lemme; Arruda; Bahienseb, 2019).

In this scenario, according to the International Energy Agency, IEA (2020), battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) have been strengthened due to the environmental benefits offered, such as the following:

- **Efficiency energy:** EVs are three to five times more efficient than conventional vehicles (CVs) with internal combustion engines (ICE);
- **Energy security:** electric mobility increases energy security, as it reduces dependence on oil imports to many countries;
- **Air pollution:** EVs cause zero emissions from the exhaust pipe and are suitable for locomotion in urban areas and highways, where many people are exposed to harmful pollutants from road transport;
- **Greenhouse Gas Emissions (GHG):** due to the increase in low-carbon electricity generation, electric mobility can provide a considerable decrease in GHG Emissions;

- **Noise reduction:** EVs are quieter than ICE vehicles, contributing to the reduction of noise pollution.

Higueras-Castillo et al. (2020) emphasizes that it is important to improve the current EV technology, especially with regard to the driving range which remains as a barrier and a major concern for the vast majority of customers and professionals. In this sense, EV manufacturers should keep working on extending battery life in order to mitigate customers' fear of running out of power during a trip.

Furthermore, Koroma et al. (2022) and Freitas and Marchesini (2022) highlight that extending the lifespan of electric vehicle batteries is crucial for improving environmental performance. According to the authors, these batteries retain 60% to 80% of their capacity after initial use and can last another 8 to 10 years in less demanding applications, providing environmental benefits and conserving natural resources. According to the Brazilian Electric Vehicle Association, ABVE (2024), EV batteries can have a "second life" in stationary applications, such as in solar or wind energy storage systems for homes and businesses.

Bai et al. (2020) observe that the growth and popularity of lithium-ion batteries in expanding markets, such as consumer electronics, electric vehicles, and renewable energy storage, are attracting significant interest and investment in the sector. According to the authors, the increasing demand is resulting in large volumes of used lithium-ion batteries, creating the need to develop recycling technologies that are both economically and environmentally sustainable for end-of-life battery management.

Abdelkareem et al. (2023) highlight that efforts are being made to minimize the environmental impact of battery manufacturing through the optimization of production processes and the sustainable sourcing of raw materials. Additionally, the authors state that there are initiatives to recycle and reuse battery materials, which contribute to the reduction of greenhouse gas emissions and the overall environmental footprint. These aspects impact the planning of electric vehicle (EV) charging infrastructure, as higher

capacity batteries can increase EV range for longer trips, reducing the need for a high density of charging stations (Shen et al., 2019).

However, according to Pamidimukkalaum et al. (2024), the main barriers to EV adoption remain the limited availability of charging stations and the reduced driving range. The lower autonomy of EVs compared to conventional vehicles raises concerns about flexibility and the need to plan routes in advance. Furthermore, the longer time required to recharge batteries compared to refueling gasoline vehicles is also a significant barrier. Thus, in order to stimulate customer demand and accelerate EV adoption, a combined effort from car manufacturers, battery suppliers, energy providers, and governments is needed (Porchera et al., 2016; Deng, 2020).

In this context, this work aims to carry out a technological prospecting study on the potential for the implementation of electric vehicles in Brazil, which is of great relevance from an environmental, economic and social perspective, since it represents a future trend in the automotive sector in the country, as it has been in other countries.

To achieve this objective, this study used the Delphi technique and the Lawshe technique in addition to the bibliographic review technique.. The bibliographic review was used to contextualize the scenario, identify relevant issues and conduct an analysis of the state of the art in the matter. The Delphi technique is used to develop the opinion of experts and obtain consensus on future developments and events formulated as "projections". The Lawshe technique was used as a support tool for the technological prospecting study in order to find the statistical response of the group regarding the application of the Delphi technique.

1. Theoretical Foundation

1.1 Electric vehicle (EV)

According to data from the IEA (2020), the sales of battery electric vehicles (BEVs), globally, increased 14% in 2019 compared to 2018. Conversely, plug-in hybrid electric

vehicles (PHEVs) showed a decrease of 10% in sales. The number of EVs increased from 50% in 2012 to 68% in 2018, and the Chinese market has dominated battery electric vehicle (BEV) sales by 79%. The United States, in turn, had a share in the sales of PHEVs from 34% in 2018 to 26% in 2019. Europe remained an intense market in PHEVs sales, according to the percentages presented for each country: Finland (76%), Sweden (61%) and the United Kingdom (49%). However, the sales of PHEVs in 2019 had a decreasing share in each country compared to 2018.

In 2020, with the restrictions of the COVID-19 pandemic, registrations of conventional new cars decreased; however, the global share in sales of electric cars increased by 70%, as approximately 3 million new electric cars were registered this year. Europe, for the first time, led with 1.4 million new records. China followed with 1.2 million records, and the United States registered 295,000 new electric cars (IEA, 2021).

According to the IEA (2021), several factors contributed to the referred number of electric car registrations in 2020, such as the following:

- In Europe, despite the economic downturn, 2020 was the target year for the standards of carbon dioxide (CO₂) emissions of the European Union that limit the average emissions of CO₂ per kilometer traveled for new cars. In addition, many European governments have increased EV subsidy schemes as part of stimulus packages to combat the effects of the pandemic. Thus, in European countries, BEV records accounted for 54% in 2020;
- In China, the main political actions silenced incentives for the electric car market and, reflecting economic concerns related to the pandemic, several cities have relaxed vehicle registration policies to allow more internal combustion engine vehicles to be registered to support the local auto industry;
- In the United States, federal incentives decreased in 2020 due to federal tax credits for Tesla and General Motor, which account for the majority of electric cars.

Although the global market for all types of cars has been significantly affected by the economic repercussions of the COVID-19 pandemic, the global stock of electric cars reached the mark of 10 million in 2020, an increase of 43% compared to 2019. BEVs accounted for two-thirds of new registrations of electric cars and two-thirds of inventory in 2020. China, with 4.5 million electric cars, continues to have the largest fleet, although Europe has the largest annual increase, reaching 3,2 million in 2020 (IEA, 2021).

Silva (2017) notes that countries such as the United Kingdom and France will no longer produce internal combustion engines (ICEs) starting from 2040. The Netherlands and India will no longer commercialize as from 2030, and from that same year, it is also expected that sale is prohibited in Germany. In Norway, the government plans strong actions to achieve the goal of zero new fossil fuel cars sold starting in 2025.

In addition, several others have set targets for the sale of electric cars: Austria, China, Denmark, France, Germany, India, Ireland, Japan, the Netherlands, Portugal, South Korea, Spain, the United Kingdom and the United States (California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island and Vermont), since, according to Deton (2018), EVs have significant benefits (some offered only by BEVs) to the environment, particularly in urban environments, such as zero exhaust emissions, silent and ease driving, particularly in traffic with intense stops and starts.

According to Arioli et al. (2016) and Pickett et al. (2021), EVs use electric motors to drive their wheels, which derive part or all of their energy from batteries; that is, the energy used to drive an electrified car can be totally or partially electric. Conversely, the distance that an EV can travel between recharges is known as the range. The authors clarify that EVs are classified into three categories: Pure electric vehicle (PEV) or battery electric vehicle (BEV); Hybrid electric vehicle (HEV); Hybrid plug-in electric vehicle (PHEV).

The PEV or BEV does not have a combustion engine, but its traction is provided by one or more electric motors, and this model is powered entirely by electricity, which can be provided by batteries, fuel cells, photovoltaic plates or through connection to the power grid (Vasconcelos, 2017; Gomez, 2016). The authors note that the energy of this

type of vehicle can also be regenerated by the deceleration and braking of the car. The EV is suitable for urban use due to its limited autonomy, which allows the cars travel an average of 250 kilometers (km) at a full load.

Regarding the BEV or PEV refueling time, Arioli (2016) states that the recharge of these cars can be divided into three classifications:

1. **Slow:** requires 6 to 22 hours to fully recharge, on the state of the charge and battery capacity. It is the most appropriate type for residential installations, since the vehicle can be recharged throughout the night;
2. **Semifast:** the time varies between 1 and 4 hours and can be understood as the intermediate between slow and fast charging. The electrophores for this type of charging has more appropriate application for places such as shopping malls, supermarkets, and gas stations, among others.
3. **Fast:** requires about 30 minutes for a range of approximately 80%. To recharge the remaining 20%, a longer time is needed due to the electrochemical characteristics of the batteries. The author emphasizes that fast charging should not be used frequently as it accelerates the degradation of the battery, because it requires more energy than in a residential installation, this infrastructure must be implemented in specific locations.

HEVs rely on more than one engine for propulsion, and the most commonly used and studied type of hybrid vehicle is the one that combines an ICE and an electric motor (EM) (Nybroe, 2015). The EM is powered by batteries that are charged by the electrical energy produced by a generator connected to the ICE, which, in turn, uses chemical energy from some type of fuel (Arioli, 2016). The advantage of hybrids is the greater autonomy; on the other hand, they are not completely free of emissions (Vasconcelos, 2017), but they promote the reduction of emissions between 30% and 40% (Barassa & Cosoni, 2015). Furthermore, Veza et al. (2023) clarify that HEVs improve fuel efficiency without the need for external recharging.

Regarding the PHEV, this model has two distinct engines (combustion and electric), which can be fueled with both traditional fuels (gasoline and diesel, since there are no plug-ins to alcohol) or by the electrical network (Vasconcelos, 2017), and the battery is responsible for powering the electric motor. In addition, the PHEV has the additional capacity to store electricity from the grid in the battery to replace the traditional fuel while driving. Therefore, the main advantage of PHEV is that its users can reduce emissions and increase efficiency without having to radically change their habits and it can also use fossil fuel for long trips and electricity for short trips (Nybroe, 2015).

According to Santos (2022), although HEV models have small batteries compared to other electric vehicles, which prevents them from being driven solely by the electric motor, they also do not offer recharging via the electric grid. As a result, energy is generated by the combustion engine and harnessed by the Kinetic Energy Recovery System (KERS). PHEVs, on the other hand, have larger batteries than HEVs, allowing for all-electric electric operation over distances ranging from 30 to 120 km. Furthermore, Santos emphasizes that this capability, combined with grid charging, makes PHEVs ideal for short and routine trips without activating the internal combustion engine.

1.2 Brazilian Scenario

At the global level, there are several environmental and sustainability objectives driving electric vehicle policies at all levels of governance, and most automotive markets offer some form of subsidy or tax reduction for the purchase of an individual or business electric car, in addition to support the implementation of loading infrastructure (IEA, 2020). Conversely, in Brazil, the incentives for EV consumption are still low because the market for this vehicle is in the process of structuring, that is, the introduction of EVs in the country is still in its early stages (Aguiar et al., 2019).

According to a study by the São Paulo Power and Light Company, within the scope of the Emotive Project/Ods Practices Bank (2018), the consolidation of electric mobility in the country still depends on means to overcome the main technological obstacles,

such as, the high cost of acquiring the electric vehicle, caused by the lack of domestic production and of taxation, in addition to the incipient charging infrastructure, as well as the creation of incentive policies.

However, according to movE Eletromobilidade (2024), the mobility scenario in Brazil is shifting significantly towards more sustainable options, given that the Brazilian legislation supports this transition through tax incentives and exemptions, making electric vehicles more attractive. An example of this is the Mover Program, launched by the Federal Government in 2023, which promotes decarbonization and encourages the production of less polluting vehicles (movE Eletromobilidade, 2024).

Data from the Brazilian Association of Electric Vehicles, ABVE (2022) show that the fleet of electrified cars and light commercial vehicles in circulation in Brazil has already reached 79,817 units since 2012. Of this total, more than 5,000 vehicles in circulation in the country are 100% electric. Already in 2024, the growing supply of electrified models significantly contributed to the market's growth. Between January and July 301 models of light electric vehicles were registered in Brazil. As a result, the Brazilian market then managed to surpass the symbolic milestone of 300,000 light electric and hybrid vehicles in circulation, encompassing different electrification technologies since the beginning of ABVE's historical series (ABVE Data, 2024).

According to the results of the Emotive Project/ODS Practices Bank (2018), there is evidence that electric mobility has significant potential in Brazil, driving the creation of a new value chain in the country's economy, in addition to meeting the opportunities of offering new services to customers, such as recharge infrastructure operators; installers of electropost stations; Vehicle to Grid which has the function of returning the energy of electric vehicles to the grid or to homes; car sharing; electric taxis; second life for batteries (reuse); and safety for EVs.

In addition, the Brazilian electricity sector is able to incorporate the increase in electricity consumption that will be caused by the expansion of the number of electric vehicles operating in the country, given that the tests performed show that, taking into

account a ratio of 5% of introduction of electric vehicles in the total fleet, 80% of the distribution networks did not present any damage or problems; thus, they would not need any adjustments or additional investments to receive this new demand. With regard to energy supply, São Paulo Power and Light Company clarifies that, according to its projections, the use of this technology would add between 0.6% and 1.6% to the total energy consumption in 2030 to serve a fleet of electric cars between 4 million and 10.1 million units (Emotive Project/Ods Practices Bank 2018).

Novais (2016) points out that there are several reasons to develop the use of electric vehicles in Brazil for example, the reduction of CO2 emissions and preservation of the planet against disasters resulting from climate change; due to the efficiency of electric vehicles, it would avoid the annual energy waste equivalent to the production of eight Itaipu hydroelectric plants.

Additionally, Novais (2016) highlights the more efficient use of oil, for example, in the production of industrial raw materials for several segments of use in combustion engines; the feasibility of the emergence of a national automotive industry; the emergence of new business models for the energy sector; the promotion of the development of high-energy storage system technology, economically boost the use of energy from non-periodic sources such as solar and wind, as, according to Alanazi (2023), renewable energy sources like solar and wind can power these vehicles, reducing dependence on fossil fuels and increasing energy sustainability.

Novais (2016) also emphasizes the advantage of the emergence of a modern industry, especially in the BRICS (a group of five major emerging countries - Brazil, Russia, India, China, and South Africa) for the production of engines, inverters, and inputs in the electric mobility area, favoring exportation, including the generation of employment and income; leveling the load curve in Brazil, currently with excess energy during the night, which will favor the recharging of electric vehicles.

Moreover, Novais (2016) points out as an advantage the reduction in health costs and deaths due to improved quality of life and productivity of people and companies as a

result of the reduction in gas and noise pollution; providing efficient and rational public transportation for the population, thus favoring the implementation of efficient and smart cities, given that, according to Alanazi (2023), electric vehicles (EVs) are a fundamental part of many smart initiatives is to significantly reduce emissions and improve air quality in urban areas through the spread of electric cars.

Despite the advantages, many users compare EVs with conventional vehicles based exclusively on the purchase price, thus creating an obstacle to their commercialization. In some cases, they are not aware that the total cost of an EV is lower than that of an ICE, especially in terms of supply, as a result of lower energy consumption and negligible direct CO₂ emissions. In addition, small electric vehicles have lower maintenance costs than conventional vehicles because they are simpler and require fewer replacement parts and do not have items such as gearboxes, fuel pumps, oil filters, belts, injectors, radiators and alternators (Heinicke; Wagenhaus, 2015; Castro, 2019; Ortar; Ryghaug, 2019; Masiero, 2017). Vasco (2020) found that the maintenance of electric vehicles, in general, can cost 35% less than a traditional vehicle.

For Reis and Silva (2017), the manufacture of hybrid engines is more feasible for the Brazilian reality, given that there are few battery charging stations in Brazil. The manufacture of a flex ethanol hybrid engine, with national technology and parts, would lead the country to a considerable position in the international automotive context. The authors clarify that the production of this model would enable a lower cost to the final consumer favoring the introduction of electrophores in several cities, as well as the laws and guidelines for the regulation of this service.

In addition, Gomez (2016) emphasizes that it is important that Brazil continues to use ethanol and other types of fuels from renewable sources for electricity generation and, therefore, provides support to the national energy matrix in the inclusion of new technologies in transportation, as is the case for electric vehicles.

However, Brazil still lacks public policies for the dissemination of EVs. According to Consoni et al. (2018), in the country, there is not a direction in the articulation between

actors, as well as actions that favor the insertion of EVs and their industry in the country, with the lack of national agreement on urban mobility as the main reason for this absence. of a contextual factor that stimulates the direction of both public and private actions toward electromobility.

According to Testi (2023), incentives for electrification in Brazil are essential for a more sustainable energy matrix. Firstly, public policies encourage electric vehicles and renewable energy, aiming to reduce emissions, foster innovation, strengthen the production chain, and create jobs. The author emphasizes that, in addition, to boost vehicle electrification, it is crucial to encourage the national production of vehicles and components, as well as to implement quotas for companies that invest locally and gradually adjust the import tax as strategic measures. The author also highlights that the Government should create a favorable environment for the manufacturing of electric and hybrid vehicles by developing the entire production chain, ensuring that Brazil keeps pace with the global trend and remains competitive.

In this context, Testi (2023) notes that the rapid expansion of Chinese multinationals was facilitated by Chinese state support and the ability of these companies to outperform competitors. Thus, considering that Brazil has the largest domestic market in Latin America and a diversified manufacturing sector, it is essential to develop a long-term economic strategy with China. According to the author, this would boost bilateral cooperation towards a more sustainable and a mutual beneficial future.

According to a study conducted by Risso (2018), it is possible to argue that the public policy analysis model for the Brazilian EV industry is composed of seven elements:

- 1.** Financial incentives are essential for the industry, for the acquisition of EVs, for Research, Development and Innovation and for the implementation of recharging infrastructure. In addition to facilitating the process of importing automobiles parts and technologies;

2. Industry Standards: fundamental for the stakeholders of the energy sector to execute their projects for EVs, such as: definition of the type of plug for recharging to be developed; regulation of the charging model, national operation for smart grid networks. According to the author, industry standards are important knowledge sharing mechanisms, increasing the economic efficiency of innovation.
3. Purchases of the public sector, which has high mobilizing power, both in direct purchases and in the decision to purchase by companies of which the public sector is a relevant shareholder, thus enabling the initial development of the local industry; public transport system (bus), taxi fleet and fleet of public vehicles, which are interesting niches to initiate actions, expanding the experiences with EVs and the public interest in this regard;
4. International agreements that favor national adjustments to legislation and procedures;
5. Environmental and innovation regulations to impose new vehicle emission and vehicle restriction limits (rotation, superstructure);
6. Cooperation programs in research to exchange knowledge and adapt initiatives based on international experiences to the Brazilian reality;
7. Transfer and diffusion regarding the actions taken directly by the companies, currently without great influence of national public policies.

1.3 Delphi technique and Lawshe technique

Before starting the chapter that deals with the research methodology, a theoretical foundation was sought in the literature on the Delphi technique and the Lawshe technique, as can be observed below.

The classic Delphi method was invented in the 1950s by the RAND Corporation to predict the nuclear weapons capacity and strategic direction of its Soviet rivals due to a military context, as well as the Cold War tensions. However, it was not until 1975 that the method began to draw public attention, when Linstone and Turoff (1975) published their

first book on the classic Delphi method. Since then, many variations of the method have been developed, because of the technique's ability to gather insights from a panel of experts relatively quickly and to eliminate the contaminating biases that can arise from group interactions. However, there are four distinct characteristics that remain the same for any Delphi study design: (1) Anonymity; (2) Iteration; (3) Controlled feedback; (4) Statistical response of the group (Fritschy; Spinler, 2019; Flostranda; Pittb; Bridson, 2020).

The Delphi technique, according to Bokrantz et al. (2017), aims to develop the opinion of experts and obtain consensus on future developments and events formulated as “projections”. In addition, integration with the Delphi method in scenario planning (i.e., Delphi-based scenarios) can improve the quality of the study in terms of creativity, objectivity and credibility.

Lawshe’s technique, initially proposed in a seminal article in 1975, has been widely used to establish and quantify the validity of content in various fields, including health, education, organizational development, personal psychology, and market research (Wilson; Pan; Schumsky, 2012).

The Lawshe technique was used as a support tool for the study of technological prospecting and to find the statistical response of the group regarding the application of the Delphi technique. Each criterion of the questionnaires is evaluated among three categories: Essential; Important, but not essential; Not important.

According to Ayre and Scally (2014), the item that is considered “Essential” by a critical number of expert panels remains at the end of the instrument, and items that cannot reach this critical level are discarded. The authors state that the CVR (Content Validity Index) proposed by Lawshe (1975) is a linear transformation of a proportional level of agreement on how many “experts” in a panel evaluate an item where “CVR” is the content validity ratio; “Ne” is the number of panel members indicating an “essential” item; and “N” is the number of panel members, according to the formula: $CVR = ne / (N/2)$.

Lawshe (1975) suggested that the transformation (from proportion to CVR) could be easily verified if the level of agreement among the panel members was greater than 50%. As a result, Lawshe provided a table of critical CVR values ($CVR_{critical}$) calculated by his colleague Lowell Schipper, where $CVR_{critical}$ is the lowest level of CVR.

Later, Wilson, Pan and Schumsky (2012) found inconsistencies in the calculations proposed by Lawshe and published a new article correcting the original table. Ayre and Scally (2014), in their studies, reviewed the original calculation methods of the Lawshe method and proposed methods for initial calculations of critical values and exact binomial probability tables, using a 5% significance level. Thus, in cases where the calculated CRV was greater than the critical CVR, the items were maintained. However, in cases where the calculated CRV value was less than the critical CVR, the items were excluded from the questionnaire. Thus, the calculation of the critical CVR is obtained by the following formula, where “ $n_{critical}$ ” is the minimum number of specialists required to agree on an essential item; “ N ” is the size of the panel of experts; “ P ” is the probability of success = $\frac{1}{2}$ and $\alpha = 0.05$ ($n_{critical} = CRITBINOM(n, p, 1-\alpha)$).

For this study, due to the characteristics of the criteria established for analysis, it was decided to adapt the three categories defined by Lawshe to: Agreement; I do not agree; I do not know how to answer.

2. Methodological procedure

This technological prospecting study aims to investigate the potential for the implementation of electric vehicles in Brazil. According to Gil (2017), regarding the approach, this study is characterized as predominantly qualitative, as it seeks to evaluate the views of experts on the topic of electric mobility in the first questionnaire. However, a quantitative technique (Lawshe technique) is also used in the second questionnaire to find consensus in the responses.

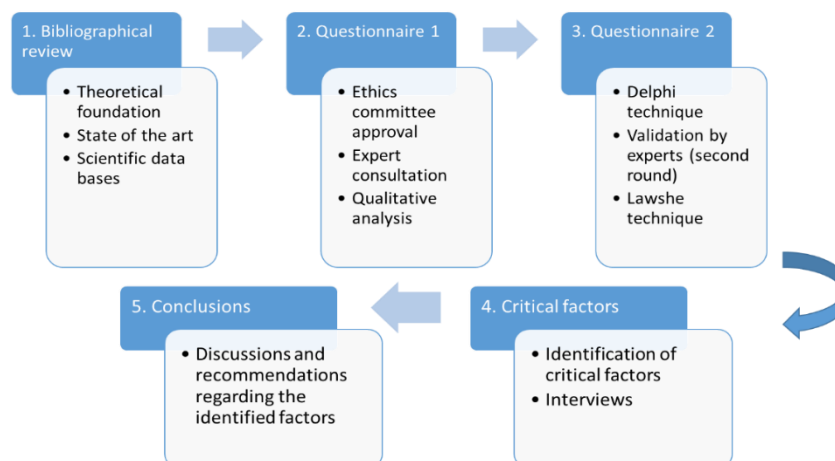
Regarding the objective, this is an exploratory research because it involves a bibliographical review and survey to enable a greater familiarity with the problem in order to make it explicit or construct hypotheses. In addition, the exploratory nature of the research is consistent with Mayerhoff's (2008) definition of prospective studies as exploring something that should happen or that we want to happen in the future. It can also be defined as the study of the future in order to develop strategies for shaping a desirable future.

It is noteworthy that propection studies are the exploration of something that should happen or that we want to happen in the future. They can also be defined as the study of the future in order to develop strategies for shaping a desirable future (Mayerhoff, 2008). According to the author, the study of technological propection forms the basic tool for grounding in decision-making processes at several levels of modern society, whose purpose is not to unveil the future but to guide and test possible and desirable visions for decision-making that will contribute to the future.

Among the methods addressed by Mayerhoff (2008), those based on “visions” and on the subjective constructions of experts, were adopted in this study. Caruso and Tigre (2004) define “vision” as the anticipation of future possibilities based on unstructured interactions between experts, each of whom relies solely on their knowledge and subjectivity.

Figure 1 presents the five stages of this work, which are consistent with the characterization of the research described previously.

Figura 1 - Stage of the research



Source: Prepared by the authors.

Stage 1 corresponds to the bibliographical review carried out with the aim of obtaining theoretical foundations on the topic of electric mobility, as well as a basis for the study of technological prospecting. To select the relevant publications, Google Scholar and CAPES journal databases were consulted. Among the publications consulted, 55% are national (21% theses and 34% articles, books and websites specifically on the topic of electric mobility) and 45% are international (Elsevier, MDPI, SCImago, Taylor & Francis and others).

Stage 2 matches to the application of a first round of questionnaires to a target audience, for a qualitative analysis, with the objective of determining, based on the participants' view, what are the challenges that are impacting the slow insertion of electric vehicles in Brazil compared to what has been happening globally.

This first instrument, developed based on the bibliographical review, was an integral part of a research project submitted to the UNICAMP Research Ethics Committee (CAAE: 46491321.1.0000.5404), which was approved on July 22, 2021. To respond to the questionnaire, the target audience selected for the research agreed to a Consent Form Free and Informed.

Stage 3 corresponds to the application of a second round of questionnaires to the 50 respondents of the first instrument, most of whom have expert profiles, due to their

high level of knowledge on the topic of electric mobility and also their extensive experience in the area of technology and exact sciences in academia or in organizations in the segment.

In addition, all of them saw the need for improvements so that the diffusion of electric vehicles occurs in Brazil. Therefore, the objective of the second round of questionnaires was to apply the Delphi technique in order to obtain consensus regarding the factors identified and to seek to proposed solutions to the challenges encountered.

In this way, feedback was provided to the participants on the percentages of responses from the first questionnaire so that they had the opportunity to review their answers and provide additional arguments.

In this phase, a quantitative analysis of the responses is performed, using the Lawshe technique as validation tool. It is noted that the second questionnaire was also submitted to CEP-UNICAMP (CAAE: 46491321.1.0000.5404), obtaining approval on December 17, 2021. In addition, the participants agreed once more to the Free and Informed Consent Form.

Stage 4 presents the discussions and recommendations regarding the factors identified in stage 3, which are considered to be impacting the slow insertion of EVs at the national level. In this stage, an interview was also conducted with the president of the Brazilian Association of Electric Vehicles (ABVE) in 2022.

Stage 5 shows the final considerations (conclusions) and, consequently, answers to the problems of this research.

3. Application of the Delphi technique

The application of the Delphi technique was a tool for conducting the technological prospecting study because it is able to provide communication with a target audience to consider hypothetical views of the research population on the subject of electric mobility and, based on this, understand why electric vehicles are slowly

inserted in the Brazilian scenario. In this study, two rounds of questionnaires were applied, and the first instrument was developed based on a literature review, as shown in section 1, and demonstrated in **Table 1**.

Table 1 - Summary of the preparation of the first questionnaire.

| Stages/Questions | Source |
|---|--|
| Knowledge about the electric vehicle (VE) theme | (Deton, 2018); (Gomez, 2016); (Arioli, 2016); (Castro, 2019); (Vaz; Barros; Castro, 2015); (Risso, 2018). |
| Main barriers to the insertion of EVs in the Brazilian market | (Vaz; Barros; Castro, 2015); (Vonbun, 2015); (Gomez, 2016); (Consoni et al., 2018). |
| Motivation to acquire an electric vehicle (EV) | (ABVE, 2020); (Nardini, 2015); (Barassa, 2015); (Gómez; Arruda, 2015); (Moraes; Barassa; Consoni, 2016). |
| Type of EV that would best adapt to the Brazilian market | (Aguiar et al., 2019); (Arioli et al., 2016); (Barassa; Consoni, 2015); (Gomez, 2016); (Reis & Silva, 2017). |
| Open questions on the subject of electric mobility | (Aguiar et al., 2019); (Vaz; Barros; Castro, 2015); (Gomez, 2016); (Guil, 2016); (Novais, 2016); (Risso, 2018); (Projeto Emotive/Banco de Práticas ods, 2018); (Feistel, 2016); (Pinto, 2017); (Vonbun, 2015); (Arioli, 2016). |

Source: Prepared by the authors.

It is highlighted that the questionnaires were submitted to the Research Ethics Committee (CEP) of UNICAMP for reviewing and authorization. The first questionnaire was registered under CAAE nº 46491321.1.0000.5404 and approved under CEP Opinion nº 4.862.757 on July 22, 2021. Similarly, the second questionnaire was registered under CAAE nº 46491321.1.0000.5404 and approved under CEP Opinion nº 5.175.404 on December 17, 2021.

Table 2 shows the results of the first round of questionnaires, which included the participation of a target audience consisting of 50 people (among them: professors and researchers from academies and research centers; executors and collaborators of the São Paulo Power and Light Company Emotive project; segment; graduate students and potential EV consumers) who could expose their points of view and thus allowing a qualitative analysis of the information. In order to have a qualitative analysis, this first instrument allowed the participants to openly expose their points of view.

Table 2 - Results of the first round of questionnaires.

| | Criteria | Respondents |
|----|--|--------------------|
| 1 | According to the degree of importance, the main barriers to the insertion of EVs in Brazil are: | |
| | The price of the car. | 100% |
| | The absence of public policies of any nature. | 70% |
| | The incipient recharge infrastructure. | 68% |
| 2 | According to the degree of importance, the main motivations of the Brazilian consumer for the purchase of an EV are: | |
| | Fuel economy. | 90% |
| | The maintenance cost. | 58% |
| 3 | The prospects for the insertion of EVs in the Brazilian market are: | |
| | Low or slow. | 38% |
| | Gradative. | 24% |
| 4 | The main reasons that lead countries such as China, the United States, European countries, among others, to have a greater number of electric vehicles compared to Brazil are: | |
| | Public policies of incentive of any nature | 74% |
| 5 | Whether Brazil meets the conditions for the massive increase of EVs in the industry: | |
| | Does not meet. | 42% |
| | Yes, it does. | 40% |
| 6 | There will be a negative impact on the Brazilian electricity sector in the case of mass adoption of the three types of EVs: | |
| | There will be a negative impact on the electricity sector | 66% |
| 7 | Whether the manufacturing process of EVs, including the manufacture and disposal of batteries, will cause greater negative impacts to the environment compared to ICE: | |
| | It will not cause major negative impacts to the environment. | 46% |
| | Yes, it will cause greater negative impacts to the environment: | 12% |
| 8 | Recharge time considered adequate to attract the consumer of an EV: | |
| | Between 5 to 30 minutes | 60% |
| 9 | Main impediments to the expansion of recharge infrastructure in Brazil: | |
| | The costs. | 36% |
| | The lack of incentive public policies, in addition to planning. | 32% |
| 10 | The consumer class of vehicles that currently has the easiest ability to migrate to an EV: | |
| | Upper class | 42% |

Middle and upper class

26%

Source: Prepared by the authors.

The second round of questionnaires was made available to the 50 respondents of the first round, however, with the participation of 33 respondents, (a return rate of 66%) which represents a reliable percentage according to Marconi and Lakatos (2005). The questionnaires sent to respondents achieve an average return of 25%.

It is observed that, this second instrument was developed based on the results of the first questionnaire for each participant to inform whether they “agree”, “do not agree” or “do not know how to answer”, thus enabling a quantitative analysis. However, in each criterion, there was a field to add clarifications, if necessary.

In order to quantify the data obtained in this second round of Delphi, the Lawshe technique was applied, as shown in Table 3, and in each column, the following are described: the criteria; the number of respondents who agreed with the criterion (ne); the total number of respondents (N), (those who answered “I do not know how to answer” were not included); the percentage of respondents (% ne); the calculated CVR, the critical CVR and the decision to “Maintain” (items in which there was consensus and that were validated among the experts) or “Exclude” (items in which there was no consensus and were not validated among the experts).

Table 3 - Results of the application of the Lawshe technique.

| Criteria | ne | N | % ne | CVRcalc | n critical | Critical CRV | Decision |
|--|----|----|------|---------|------------|--------------|----------|
| 1 According to the degree of importance, the main barriers to the insertion of EVs in Brazil are: car price; absence of public policies of any nature and incipient recharge infrastructure. | 31 | 33 | 94% | 0,8787 | 21 | 0,27272727 | MAINTAIN |
| 2 According to the degree of importance, the main motivations of the Brazilian consumer for the purchase of an EV are: fuel economy and maintenance cost. | 30 | 32 | 94% | 0,8750 | 21 | 0,3125 | MAINTAIN |

| | | | | | | | | |
|----|---|----|----|------|--------|----|------------|----------|
| 3 | The prospects for the insertion of EVs in the Brazilian market are low or slow to gradual. | 29 | 32 | 91% | 0,8125 | 21 | 0,3125 | MAINTAIN |
| 4 | Public incentive policies of any nature are the main reasons that lead countries such as China, the United States, European countries, among others, to present a greater number of electric vehicles compared to Brazil. | 29 | 32 | 91% | 0,8125 | 21 | 0,3125 | MAINTAIN |
| 5 | Brazil does NOT meet the conditions for the massive increase of EVs in the industry. | 19 | 28 | 68% | 0,3571 | 18 | 0,28571429 | MAINTAIN |
| 6 | There will be a negative impact on the Brazilian electricity sector in the case of mass adoption of the three types of EVs. | 15 | 30 | 50% | 0,0000 | 19 | 0,26666667 | EXCLUDE |
| 7 | The manufacturing process of EVs, including the manufacture and disposal of batteries, will NOT cause greater negative impacts to the environment compared to ICE. | 19 | 29 | 66% | 0,3103 | 19 | 0,31034483 | EXCLUDE |
| 8 | Between 5 and 30 minutes is the recharge time considered adequate to attract the consumer of an EV. | 25 | 30 | 83% | 0,6667 | 19 | 0,26666667 | MAINTAIN |
| 9 | The costs and the lack of public incentive policies, in addition to planning, are the main impediments to the expansion of the recharge infrastructure in Brazil. | 27 | 31 | 87% | 0,7419 | 20 | 0,29032258 | MAINTAIN |
| 10 | The Upper Class is the one that has the greatest ease to migrate to an EV today. | 32 | 33 | 97% | 0,9394 | 21 | 0,27272727 | MAINTAIN |
| 11 | Public transport, cargo and fleet of taxis should be the first to invest in the exchange of ICE vehicles for 100% electric vehicles, reducing noise and air pollution. | 31 | 32 | 97% | 0,9375 | 21 | 0,3125 | MAINTAIN |
| 12 | Electric vehicles can boost the search for renewable energy sources. | 33 | 33 | 100% | 1,0000 | 21 | 0,27272727 | MAINTAIN |
| 13 | With the advancement of technology, the introduction of electromobility in Brazil | 16 | 30 | 53% | 0,0667 | 19 | 0,26666667 | EXCLUDE |

| | | | | | | | | |
|----|--|----|----|-----|---------|----|------------|----------|
| | should start with battery electric vehicles (VEBs) (100% electric). | | | | | | | |
| 14 | Brazil should go through a massification of Hybrid Electric Vehicles (HEVs) and plug-in Hybrid Electric Vehicles (PHEVs) before the diffusion of 100% electric vehicles. | 21 | 30 | 70% | 0,4000 | 19 | 0,26666667 | MAINTAIN |
| 15 | It is estimated that the number of EVs in Brazil grows between 5% and 10%: | | | | | | | |
| | a. Short term (between 2022 and 2030). | 14 | 28 | 50% | 0,0000 | 18 | 0,28571429 | EXCLUDE |
| | b. Medium term (between 2031 and 2040). | 17 | 27 | 63% | 0,2593 | 18 | 0,33333333 | EXCLUDE |
| | c. Long term (between 2041 and 2050). | 11 | 27 | 41% | -0,1852 | 18 | 0,33333333 | EXCLUDE |
| 16 | The solution of obstacles to the implementation of EVs in Brazil depends on the creation of public policies, such as: | | | | | | | |
| | a. Exemption from import taxes | 27 | 33 | 82% | 0,6364 | 21 | 0,27272727 | MAINTAIN |
| | b. Purchase based on the exchange rate, enabling the exchange of the “traditional” vehicle used for a zero km BEV | 17 | 25 | 68% | 0,3600 | 17 | 0,36 | EXCLUDE |
| | c. Long -term financing, with lower interest rates. | 24 | 30 | 80% | 0,6000 | 19 | 0,26666667 | MAINTAIN |
| | d. Manufacture of parts in the national territory and efforts to develop its own technology. | 28 | 31 | 90% | 0,8065 | 20 | 0,29032258 | MAINTAIN |
| | e. Creation of barriers to combustion vehicles. | 18 | 30 | 60% | 0,2000 | 19 | 0,26666667 | EXCLUDE |

Source: Prepared by the authors.

4. Discussion

According to **Table 3**, there is a consensus among experts responding to the Delphi technique regarding criteria 1, 2, 3, 4, 5, 8, 9, 10, 11, 12, 14, 16a, 16c and 16d. Therefore, these items were considered valid as they demonstrate that they influence

decision making regarding the future of electric mobility in the country, as we will see in the discussion below.

In criterion 1, there was unanimity among respondents that the high price of the car, which is linked to the cost of the battery, is the main barrier for the insertion of EVs in Brazil. Previous research has indicated that although Brazilians are concerned about issues such as global warming and air pollution, people in general are unwilling to pay a higher price to buy low-carbon cars. In this case, the electrified technology needs to have a cost closer to that of conventional vehicles. The following factors are the absence of public policies of any nature and incipient recharge infrastructure.

The result of criterion 2 shows that the main motivation for the Brazilian consumer for purchase an EV is fuel economy and maintenance costs. However, the study participants emphasize that the environmental appeal and the existence of tax subsidies have been the two reasons that most drive the change from combustion to electric engines in other countries. Thus, both the subsidy and the environmental appeal are linked, and both impact the final EV price.

Regarding criterion 3, the majority of respondents agreed that the prospects for the insertion of EVs in the Brazilian market are low or slow to gradual due to the high costs of automobiles, as well as all the technology involved, in addition to the lack of public policies and also the lack of planning between the areas of transportation, energy and the environment.

With regard to criterion 4, most respondents agreed that public incentive policies of any nature are the main reasons that lead countries such as China, the United States, European countries, among others, to present a greater number of electric vehicles compared to Brazil. These countries have greater government incentives, technology, infrastructure to enable the use and greater purchasing power by the population. In addition to this, more integrated public policies from environmental issues (such as agreements to reduce CO₂) and efficiency energy to incentive policies for infrastructure, direct subsidies to purchase, special credits and even a policy for the green industry.

The evaluation of criterion 5 indicates that Brazil does not meet the conditions for a massive increase in EVs in the industry, at least in the short term, since most respondents justified that there is still a lack of companies, skilled labor and supporting infrastructure. As an example, several Brazilian states still have problems with energy demand due to insufficient infrastructure. Moreover, the market is still too small to justify its domestic production. Even if the manufacturing were to take place in the country, a significant number of parts would still be produced abroad.

Regarding criterion 8, the consensus found by most experts was that the recharge time considered adequate to attract the consumer of an EV is between 5 and 30 minutes, not only because it will be more commercially attractive but also it will facilitate long trips. It is noteworthy that the ideal would be the instant recharge or the same time in which an MCI is supplied; however, the existing fast recharge equipment, which recovers approximately 80% of the autonomy in approximately 30 minutes, has a very high cost and may also reduce the battery life.

The evaluation of criterion 9 shows a consensus among respondents that costs (and who will bear them) and the lack of public incentive policies, in addition to planning, are the main impediments to the expansion of recharge infrastructure in Brazil, since both items represent similar impediments because the costs are not paid simply for the sale of the recharge service. Also, the fact that there is no payback (the high cost of infrastructure associated with the small number of consumers) means that the business does not pay, making it unfeasible for someone to invest. Moreover, public policies for incentives and planning are seen as impediments because, currently, the market is still small. There is also the need for an expansion of the transmission and distribution infrastructure to meet the demand, in addition to a decarbonization policy of the transport sector that includes an increased supply of EVs, both light and heavy passengers, as well as providing support for the installation of electrophores.

As for criterion 10, there was a consensus among respondents that the upper class is the one that has the greatest ease of migration to an EV today because it is the

population with the highest income, and also companies that operate with fleets, such as taxis, may be a niche depending on public policies.

With regard to criterion 11, there was a consensus by most respondents that public transport, cargo and taxi fleets should be the first to invest in the exchange ICE vehicles for 100% electric vehicles, reducing noise and air pollution. Given that, according to criterion 12, all respondents agreed that electric vehicles can boost the search for renewable energy sources because they are a more environmentally sustainable alternative.

Regarding criterion 14, there was a general opinion among the respondents that “Brazil should undergo a massification of HEVs and PHEVs before the diffusion of 100% electric vehicles” because these automobiles have been the preferred alternative for the transition from combustion engines to BEVs. In addition, HEVs (plug-in or not) are the ones that best adapt to the Brazilian market due to insufficient supply infrastructure. In addition, hybrids can help popularize electrified vehicles, establishing new suppliers in the Brazilian production chain (in the medium term) and allowing a transition to new technologies.

Finally, there was an agreement among respondents regarding criterion 16 (A, C and D) that the solution of obstacles to the implementation of EVs in Brazil depends on the creation of public policies, such as a. Exemption from import taxes; c. Long-term financing, with lower interest rates; and d. Manufacture of parts in the national territory and efforts to develop its own technology.

On the subject of criteria 6, 7, 13, 15 (A, B, C) and 16 (B, E), there was no consensus among experts responding to the Delphi technique. Thus, these items were invalidated because there are still uncertainties about decision-making regarding the future of this technology in Brazil, as we will see in the discussion below.

Concerning criterion 6, there is no consensus among experts that there will be a negative impact on the Brazilian electricity sector in the case of mass adoption of the three types of EVs, given that some of the participants consider that “no” will have a

negative impact. Provided that, the growth will not be immediate but rather gradual. There will be a need for adjustments and reinforcements in the power grid due to the increased insertion of EVs, but it will be possible to adapt the electrical sector as the load increases. Contrary to the negative impact, there will be the creation of opportunities and new investments in energy generation since Brazil has the potential to generate electricity to meet the demand, especially from renewable sources (solar, wind, etc.). Conversely, the other part of the experts believes that “yes”, that is, there will be a negative impact on the Brazilian electricity sector in the case of mass adoption of the three types of EVs, because there will be an increase in demand that is not supported today by the precarious infrastructure, consequently, an increase in power generation and, in some cases, significant impacts on the distribution system, such as overload in electrical transformers.

With regard to criterion 7, that the process of manufacturing the EVs, including the production and disposal of the batteries, will NOT have a greater negative impact on the environment compared to the MCIs, there is also no consensus among the experts as some of the respondents agreed that there will be a negative NO impact, given that the EVs are cleaner and simpler and their production requires less mechanical structure. In addition, the process of battery production, reuse and recycling is evolving rapidly, with a second life expectancy for this component after 10 to 15 years in vehicles with stationary storage systems and, perhaps, a third life as a frequency regulator, transmission and substations. Therefore, reusing electric batteries will offset the emissions from battery manufacturing. For that reason, when considering the entire lifecycle of EVs, including battery recycling, these automobiles have less impact. Furthermore, another part of the respondents considers that there will be a negative impact on the environment, especially at the beginning of the insertion, with improvements over the years, mainly due to the current batteries (lithium battery, highly polluting and energy-consuming for its manufacture) and because the elements of an EV strongly depend on mineral extraction. For this reason, the chain should be considered

in its entire cycle (from production to disposal) since discards will occur more frequently, and the impact will be greater.

In regard to criterion 13, there was also no consensus among the experts that the introduction of electromobility in Brazil should start with BEVs (100% electric) as the technology advances. Those who agreed with this criterion believe that it does not make sense to have two propulsion systems in a vehicle, since hybrids (plug-in or not) are an obsolete technological step and with a tendency to disappear around the world because they are the worst of both worlds, with more parts and risks of problems, maintenance and costs, not to mention that it keeps consumers captive to gas stations, fossil or not. In addition, hybrids do not have the benefits of low maintenance of an electric vehicle and are not completely emission-free, i.e., they can help reduce CO2 emissions by up to 40%, which limits the benefits of the vehicle.

In criterion 15 (a; b; c), there was no consensus among experts, since opinions were divided on whether the estimated EV growth, between 5% and 10%, in Brazil would be: a. in the short term (between 2022 and 2030); b. in the medium term (between 2031 and 2040) or c. in the long term (between 2041 and 2050). There were also those who agreed that this proportion of growth would occur in each period. Therefore, this item was invalidated due to the absence of prediction of the insertion of this technology in the future.

Finally, regarding criterion 16 (b; e), there was also no consensus among experts that “the solution of obstacles to the implementation of EVs in Brazil depends on the creation of public policies, such as “b”: “The Purchase is based on the exchange rate, enabling the exchange of the “traditional” vehicle used for an BEV of zero km” or “e”: “Creation of barriers to combustion vehicles.”

Participants in the study emphasized that creating barriers for combustion vehicles does not seem to be the appropriate path. Although in many countries the creation of barriers to ICEs is a favorable factor for the insertion of EVs, in Brazil, the most viable would be to create concessions and incentives for EVs. Even if it is considered that

the prohibition of the manufacture and the subsequent circulation of an ICE, strengthens the VE, it is up to Brazil to consider that the combustion car is already a costly item and that it is not accessible to all population. Hence, the ideal for the country would be the creation of a policy of incentives for EVs, as well as free trade with a focus on the development (and promotion) of new technologies, to increase its competitiveness in the long term.

5. Recommendations

Questioned about what can be done to find solutions to the challenges that are impacting the slow insertion of EVs in Brazil, the respondents to the Delphi rounds issued the following recommendations:

- Actions among three actors (consumer, producer and government) that stimulate the transition from ICE to EV;
- Government actions encouraging this insertion in the Brazilian market and local production, incentives for the purchase of EVs, incentives to use in transport companies and heavy vehicles for urban use, and the beginning of the introduction of EVs by the public sector showing the real gains of this technology, with electric buses and electric fleets, in environmental and public health issues (reduction of particulate matter, noise reduction, among others);
- Disclose the benefits and policies to encourage the use of EVs and create regulations and standards for vehicular emissions, reduce import taxes for EVs, and simultaneously prepare recharge infrastructures;
- Search for synergies with other sustainable transport initiatives (for example, hydrogen and biofuels), in addition to investing in renewable energy;
- Invest in technological development (factories, supply network, improvement of the electricity grid, development of new sources and intelligent recharge solutions, in research (for nationalization of components and reduction of imported ones) and subsidies (for the acquisition of vehicles by the nonindustrial consumer) to favor the

spreading of this technology and the acquisition of EVs by a significant part of the population.

- Develop strategies to promote Hybrid Electric Vehicles (HEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) in the country is essential in this transitional phase, given the current inadequate infrastructure to support fully electric vehicles in Brazil.

6. Conclusions

With respect to the factors identified, it is possible to state that the greatest challenges for the insertion of electric mobility in the country are, first, the high cost of acquisition of the electric vehicle, and this is linked to the price of the battery (which can correspond to up to 50% of the value of the car). Additionally, this component is not yet fully developed, causing another obstacle to the dissemination of EVs, which is the limited autonomy. Other impeding factors are the long recharging time of EVs, the insufficiency of electrophores and the strong dependence on imports - a factor that increases the costs of the car due to the taxes added by the import process, restricting the purchase to a consumer class with greater purchasing power and preventing the massive insertion of EVs in the Brazilian scenario.

The limitations of this study include the following items, which did not reach consensus among experts and should be the subject of future studies:

- Estimated growth of EVs in the Brazilian scenario;
- Estimate the introduction of 100% EVs, since it was identified that the country must first undergo a massification of HEVs, given that hybrids can play a crucial role as a technological bridge, facilitating consumer adaptation to the new electric technologies and driving the development of the infrastructure.
- Estimate of when the Brazilian industry will be able to massively produce EVs;
- Impacts of EVs on the Brazilian electricity sector;

- Impacts of EVs on the manufacturing process, including not only the manufacture and disposal of batteries but also the study on recycling industries.
- The social and economic impacts of the transition to electric vehicles in Brazil, including the potential creation of jobs and the development of new production chains.

On the other hand, despite the limitations, it is observed that the projections for the coming years are promising. According to ABVE (2024), the charging infrastructure in Brazil is growing rapidly, with an increase of 179%, which has been promoting jobs, income, and investments in several areas such as vehicle production, equipment, components, parts, software, and services. It is noteworthy that Brazil has a unique profile in terms of the possibilities for decarbonizing its transport matrix, particularly due to the availability of biofuels (EPE, 2024). In this scenario, the electrification of light vehicles has gained traction in recent years, despite challenges such as the cost of the vehicles and charging infrastructure (EPE, 2024).

According to ANFAVEA (2024), the sales of hybrid and light electric vehicles may surpass those of combustion vehicles by the end of this decade, reaching 1.5 million in 2030 and potentially representing more than 90% in 2040. In contrast, in the heavy-duty segment, EPE (2024) highlights that sales with new propulsion technologies could reach 60% in 2040. Furthermore, in areas such as urban buses, electric versions could surpass 50% by 2035.

ANFAVEA (2024) also highlights that this progress involves the development of a comprehensive ecosystem, which includes the supplier chain, charging infrastructure, energy generation and distribution, and also biofuel production.

Glossary

Battery Electric Vehicles, BEV;
Brazilian Electric Vehicle Association, ABVE;
Carbon Dioxide, CO₂;
Content Validity Index, CVR;
Electric Motor, EM;
Electric Vehicle, EV;
Greenhouse Gas Emissions, GHG;
Hybrid Electric Vehicle, HEV;
Internal Combustion Engines, ICE;
International Energy Agency, IEA;
Pure Electric Vehicle, PEV;
Plug-in Hybrid Electric Vehicle, PHEV;
Research Ethics Committee, CEP.

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Taxonomia

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|---|--|
| <p>Raquel Teixeira Gomes Magri</p> | <p>Conceptualization (equal); data curation (Lead); formal analysis (Lead); funding acquisition (equal); investigation (lead); methodology (equal); visualization (lead); Project administration (lead); writing original draft preparation (lead); review and editing (supporting).</p> |
| <p>Robert Eduardo Cooper Ordoñez</p> | <p>Conceptualization (equal); formal analysis (supporting); funding acquisition (equal); Investigation (supporting); Methodology (lead), validation (lead); supervision (lead); review and editing (lead).</p> |

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