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CHALLENGES OF THE DEPLOYMENT OF ELECTRIC CARS IN BRAZIL

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Abstract: The insertion of electric cars in the autonomous world market is growing. The higher acquisition cost and lower autonomy of electric traction, in relation to internal combustion traction, are still the main factors that restrict the sale of this type of vehicle. Even so, in the long term, the lack of an infrastructure that supports the transition to the electric vehicle matrix, can result in a bottleneck in the change of energy source. Therefore, the main objective of this article is to present, through a literature review, the main challenges related to the implementation of electric vehicles in Brazil. The general challenges described include the study of the storage capacity of more efficient batteries and the comparative analysis between electric, hybrid and conventional cars. Meanwhile, the challenges in Brazil were portrayed from the analysis of the grid and electricity distribution matrix and through statistical data of Brazilian lithium reserves. Thus, it appears that solid-state, lithium-sulfur and lithium-air batteries have theoretical storage capacities superior to the current generation of lithium-ion batteries used in automobiles. It was also possible to verify that it is necessary to increase the supply of electric energy in Brazil, in order to meet the future demand for vehicles powered by the electric grid. In addition, a variety of information relevant to technological development research related to this topic was obtained.

Keywords: Automotive Industry; Electric Car; Electric Energy; Sustainability.

INTRODUCTION

The first evidence of an electric car goes to the Anyos István Jedlik prototype in 1828 [1], [2]. However, the title of the first invention is granted to the American Thomas Davenport, who in 1835 [3] built an electric motor and installed it in his car, which, in turn, ran under an electrified circular track [4]. With the principle of the Davenport mechanism, electric trams were developed [2].

The initial progress of electric vehicles came only from the manufacture of lead-acid batteries [5]. These, in turn, obtained their first commercialization through the product invented by the physicist Raymond Planté in 1859 [3], [6]. The Planté battery model was later optimized in 1881 by Camile Faure and applied to vehicles [3], [6].

Only in 1886 did he hear evidence of the making of the first car for internal combustion, whose inventor Karl Benz named it *Patent Motorwagen* [7]. From that time on, there was competition between electric traction and combustion traction. In New York in 1903, for example, 53% of automobiles powered by steam (external combustion), 27% internal combustion and 20% electricity were already on the market, adding up to about 4.000 cars registered in this city [8], [9].

With the discovery of oil in Texas in the early twentieth century and given the abundance of this element in the world, the autonomous industry increased the production of internal combustion vehicles. These have even increased their commercialization due to agents such as, for example, the creation of the Henry Ford series production system, which reduced the cost of these vehicles and, also, the invention of the starter (electric starter) in 1912, which replaced the crank engine (manual start) [9].

As a consequence of the oil crisis, to increase the production of electric vehicles, there was a scientific quest to increase the energy capacity of batteries, improve the performance of electric motors and develop power electronics [10]. With that, the competition started again, on the one hand the electric vehicles in face of poorly developed technologies and, on the other hand, the consolidated internal combustion vehicles.

In the current years, electric vehicles have returned to the market significantly. This was possible mainly because of the evolution of technology that brought to the market a more developed power electronics, more efficient batteries, electric motors with higher performance. As a result, machines with higher performance could be obtained.

According to the Ministry of Infrastructure [11], until April/2020, Brazil contained 105.715.592 vehicles. Of these, there were the following number of hybrid vehicles: 6.518 gasoline/alcohol/electric and 21.710 gasoline/electric [12]. Whereas, there were the following number of electric vehicles: 4.074 electric/external source and 6.601 electric/internal source [12].

The prospect is that the commercialization of electric vehicles will increase both in Brazil and in other countries, since there is a plan for the worldwide implantation of these machines. Thus, nowadays there is an investment in research related to the development of electronic components, battery manufacturing processes, improvements in refrigeration systems battery, optimization of electric motors, to make possible the spread of cars electric in autonomous industry.

The transition from the fossil energy matrix to the electric one presents challenges for its implementation. In Brazil, factors such as power generation and distribution capacity, as well as other less polluting fuels, such as biofuels, are still factors that hinder the entry of electric cars in the Brazilian market.

OBJECTIVE

Raise the main challenges of implementing electric cars in the current Brazilian scenario through the available literature and discuss the main solutions.

METHODOLOGY

This article is based on exploratory documentary research, through the collection of data from different sources, such as scientific articles and regulatory bodies of the activities that integrate the use of electric cars such as ANTT (National Land Transport Agency), created in 2001 by law nº 10.233 [13], ANP (National Agency of Petroleum, Natural Gas and Biofuels), created in 1997 by law nº 9.478 [14], and ANEEL (National Electric Energy Agency), created in 1996 by law nº 9.427 [15].

The exploratory research aims to provide the researcher with knowledge, familiarity and understanding on the research topic to be studied, using qualitative and quantitative methods in order to select and define concepts, state questions and hypotheses for future investigations [16].

Finally, the research seeks information related to the topic of study, through searches in primary sources (first degree of information) and secondary sources (result of the discussion and the result of the original sources) [17], [18] with the purpose of determine essential elements and relevant results of the studies analyzed. The literature review was carried out in national and international scientific journals, research reports, books and official government publications focused on the area related to the theme. In this sense, this work brings an analysis of the scenario of electric vehicles, addressing one of the main ways of improving battery capacity, and then deals with the current state of Brazil in relation to electric vehicles, addressing the exploration of one of the main materials for the production of batteries, the energy matrix and the Brazilian electricity distribution network, and finally, possible competitors for these new vehicles on the market.

RESULTS AND DISCUSSION

In this topic, the main challenges encountered in large-scale implementation in the Brazilian market and possible solutions will be addressed.

IMPROVED BATTERY CAPACITY

Both electric vehicles and internal combustion vehicles are mainly composed of the following systems: structure, suspension, steering, brake, engine, transmission, cooling and electric.

The vehicle internal combustion exhibit a greater number of parts, however, they operate in a simpler manner due to the majority presence of mechanical elements [19]. While, in electric vehicles, there is a more complex electronic control structure that is a barrier to the development of electric traction.

Another barrier for electric vehicles is the high initial investment required for the creation of component production lines and vehicle assembly. As already established industries vehicle combustion internal do not require capital to open assembly plants for production of new vehicles.

Because of these factors, the cost of purchasing internal combustion vehicles, compared to electric ones, is much lower. Despite this, there is a prospect that the cost of purchasing electric vehicles will decrease. However, investment in development of new technologies is essential for the spread of this type of vehicle.

According to the Automotive Business magazine, the electrification of vehicles brought to market new technologies such as, for example, the rear electric axis used by automakers Great Wall and Changan and the gearbox for electric motors used in electric model Audi E-Tron, both provided by Schaeffler [20]. In addition, there is the study carried out by Maxion on the manufacture of chassis and wheels with less mass [20]. Whose technologies and studies aim to improve the performance of electric vehicles.

Another expectation is the development of the electronic part of the battery management system (SGB). According to Lorentz et al. [21], the challenge of the electronic part of the current SGB is to achieve an accurate and simultaneous measurement of the battery current and the voltage of the cell blocks, and also the communication of data in different voltage domains, maintaining the security of the system. Due to these difficulties, there is the technique of inserting algorithms in the cloud SGB platform, to improve battery monitoring and diagnosis [22], [23]. This method is known as "*Battery in the Cloud*" [24], [25], the result of which is greater scalability, profitability, safety, reliability and optimal operation [26].

Still, one of the decisive factors for cost reduction and greater autonomy of electric vehicles is the battery. According to Azevedo (2018) [27], current batteries represent a major technological advance for electric traction. These batteries exhibit higher energy density (energy storage capacity) with lower cost per kilowatt-hour (kWh), than those of a few years ago [28].

However, the energy density of current generation lithium-based batteries is still low. They are lithium cells store about 690 Wh/L (watt hour/liter volumetric energy density unit) while the hydrous ethanol is about 6.260 Wh/L, while the regular gasoline has about 8.890 Wh/L [29].

Increasing the energy density of batteries can be achieved with the addition of cells within the battery system. However, this measure will cause an increase in battery mass which, consequently, will reduce the vehicle's efficiency [30].

Battery cells, depending on the manufacturer, are organized in different ways to meet the vehicle's energy demand. To acquire a higher energy density, it can be increased the number of parallel connections between the cells and the battery module [31].

Is the result in increased system capacity while keeping the pressure in the end is the battery [31], [32]. However, this terminal voltage, which is high as the number of connections in series increases, is essential for the good performance of the vehicle.

It should if noting also that there are problems as an increase of serial links to increase the tension in the end is the battery (keeping the system capacity) [31], [32]. Multiple connections in series, in turn, can meters generate a non - equalizing voltage during charging due to variation of internal resistance, and also the loss of the chemical properties cells [33].

However, the most effective measure to improve the energy density of batteries is the use of cells with a high energy density. Figure 1 shows the energy density gravimetric (Wh/kg) and volume (Wh/L) the energy storage systems.

The cells most suitable for use in electric and hybrid vehicles are those that exhibit greater energy efficiency with a smaller size and mass. In Figure 1, it is possible to analyze the cells that have greater storage capacity, correlating their size and mass.

Among the energy stores with technology under development and developed, it is worth mentioning the Li-ion cells. These are the technology most used by the biggest battery producers: LG Chem, Panasonic and Samsung [28]. The use of lithium is due to its characteristics, being the lighter metal and the less dense solid element, in addition to having its own electrochemical potential for application in batteries [34].

According to Ruiz and Persio [35], the most commonly used Li-ion batteries in electric and hybrid vehicles are those with positive electrode of NMC (LiNiMnCoO$_2$), NMC – LMO (LiNiMnCoO$_2$ - LiMn$_2$O$_4$), NCA (LiNiCoAlO$_2$) and LFP (LiFePO$_4$). Since NMC and NMC – LMO batteries are the most used by *Original Equipment Manufacturers* (OEM) BMW, General Motors, Toyota, Mitsubishi, Daimler, Renault, Nissan, while NCA batteries are used by Tesla and LFP batteries by Chinese OEMs [35].

According to *The Faraday Institution* [37], among the most promising technologies composed of lithium, is the Li-S cell with theoretical densities of approximately 2.500 Wh/kg and 2.800 Wh/L. Theoretical densities

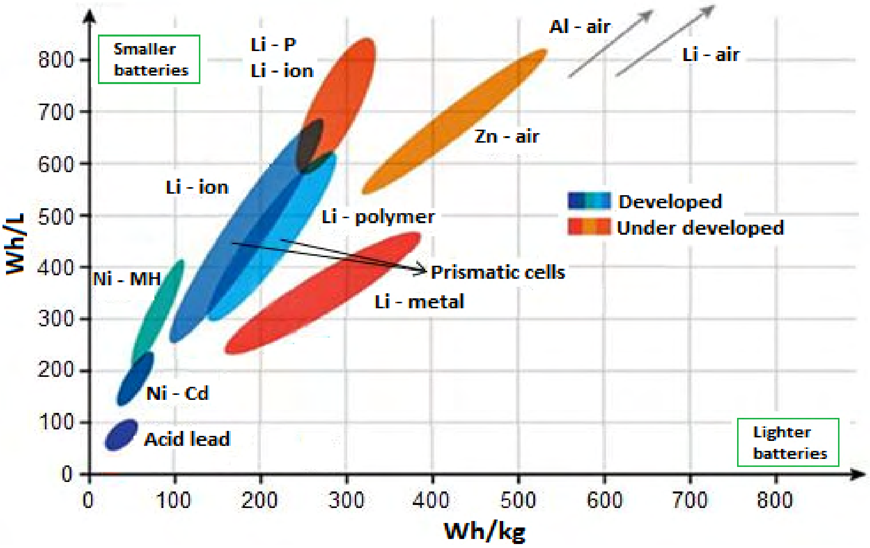

Figure 1 - Energy Storage Systems.

Source: FREITAS, 2012. Adapted.

which are higher than those of the current battery Tesla, in cylindrical cells with NCA positive electrode and negative electrode silicon/graphite which t and m is about 270 Wh/kg and 650 Wh/L in practice [37]. However, now the cell are Li-S displays m about 350 Wh/kg [38] and 300 Wh/L [37] in practice.

In addition, lithium can be applied as a negative electrode metal (Li-metal). However, its use may require the use of solid electrolytes to prevent explosions [39], [40]. Solid-state batteries, in turn, are achieving high energy density in laboratories [40].

Another energy storage that should be highlighted is the Li-air cells. Zheng et al., cited by Cremasco [41], calculates or for these cells a maximum theoretical gravimetric energy density between 1.300 Wh/kg and 2.600 Wh/kg, whereas a voltage operates tion between 2.9 V and 3.1 V with specific electrode. Meanwhile, other authors describe that Li-ar cells can provide theoretical gravimetric energy density of up to 3.000 Wh/kg [42] to 3.500 Wh/kg [43].

Another study to meet the energy density to Li-ar, was realizad the by Imanishi and Yamamoto [44]. These authors calculated for a reversible and non-aqueous Li-air battery, with open circuit voltage of 2.96 V, power densities of 3.460 Wh/kg and 6.940 Wh/L for the discharge state [44]. Therefore, for this condition, the density of volumetric energy theoretical maximum of Li-air battery (6.940 Wh/L) [44] is greater than hydrated ethanol (6.260 Wh/L) and less than that of regular gasoline (8.890 Wh/L) [29].

Several researches are being carried out to develop Li-air batteries that have the energy efficiency described in theory. However, the implementation of battery Li-air in the automotive industry is in long-term, since it is the technology is being studied.

Other studies are aimed at cells composed of hydrogen gas (H_2). This element, in turn, is used to store energy [45] and release it when required, in the form of heat [46]. Moller et al. [47] add that the hydrogen gas exhibits distinct characteristics, such as, for example, the higher density of gravimetric energy, the higher speed of diffusion in the air, and it also has a low density as liquid and gas. However, the gaseous form makes it difficult to store it in a dense form. There are still few studies related to hydrogen gas in batteries, which, in turn, may be of paramount importance in a few years due to its great energy potential.

Still, in the work of Moller et al. [47] is highlighted on the study of complex metallic hydrides, since they can be used to store hydrogen in the solid state and, still, they can be used as electrolytes, as electrode materials and as solar heat stores. Therefore, research on complex metal hydrides may become relevant for the development of batteries.

In addition, the industry seeks to develop cells with a higher energy density than the current generation of commercial Li-ion. However, the demand for greater storage capacity and long load tracks can m generate one des case as the requirements related to the life of batteries [40].

The degradation of the battery, or reduction of the useful life, occurs due to factors such as, for example, temperature, intensity of use, depth of discharge, working voltage and time of use/rest [48]. The tually, the battery life is guaranteed for 8 to 10 years, with a mileage generally about 150.000 km [48].

The aging of the battery can be classified into two types: Calendar of aging, which is related to deterioration in rest periods (when there is no current flow from the battery) [49]; and cycle aging (degradation when charging and discharging the battery) [50]. Where, calendar aging occurs mainly due to temperature and state of charge [50]-[52]. Meanwhile, aging of the cycle can occur due to factors such as, for example, temperature, state of charge and depth of discharge [52].

Finally, according to the design, quality and battery charge status at the end of life, you can perform remanufacturing, reuse and recycling [53]. Whereas, the disposal the heavy metals battery, which are toxic and must be performed appropriately [54].

BRAZIL'S SCENARIO

To assess the possible deployment of electric vehicles in Brazilian territory, we analyzed some factors: the abundance of materials for the production of batteries, in this case, lithium, and the current state of the electricity generation and distribution network.

Plenty of Lithium

As one of the main materials used for the manufacture of batteries, lithium is an indispensable resource for a country that intends to change the energy matrix of vehicles. According to the US Geological Survey [55], South American countries have approximately 60% of the world›s total lithium. Of the 800 million tonnes identified, 21 million are in Bolivia; 17 million in Argentina; 9 million in Chile; 400 thousand in Brazil; and 130 thousand in Peru [55].

Although Brazil has 400 thousand tons of this mineral resource, currently only 95 thousand tons in reserves that can be explored (Figure 2). Brazilian production is estimated at 300 tons by the USGS in 2020 [55].

The low amount of lithium in Brazilian territory is a bottleneck if the country wants to produce batteries for electric and hybrid vehicles in the country. However, as shown in Figure 2, Bolivia, Argentina and Chile, have a high amount of lithium, becoming key points in the transition from the current fossil vehicle matrix to the electric one on a global scale. The geographic proximity and commercial relations already established between these countries and Brazil, may also facilitate the import of lithium for the production of batteries, facilitating the implementation of industries for the production of electric vehicles in the Brazilian market.

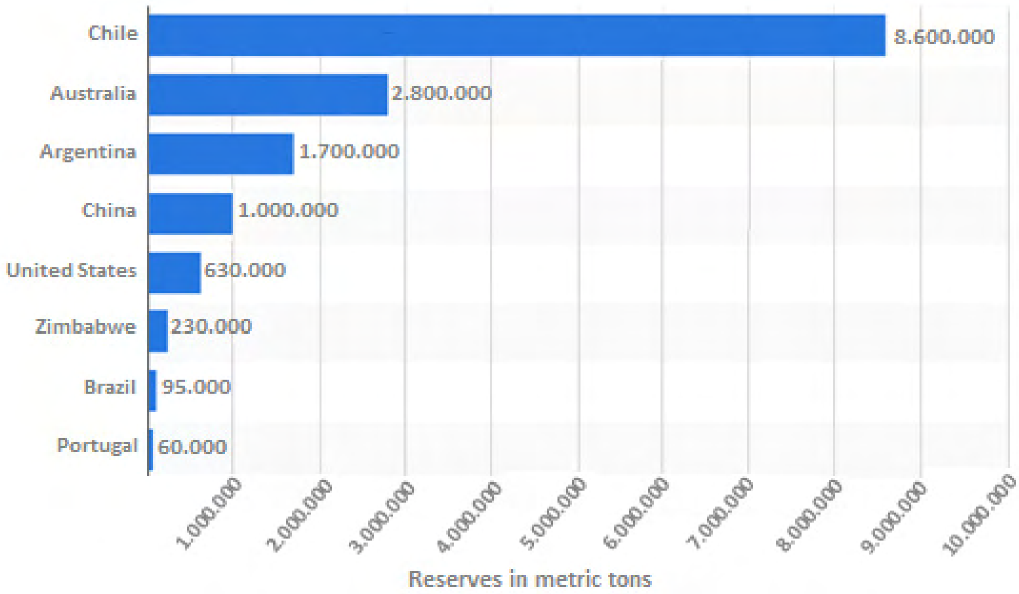

Figure 2 - Countries with Largest Lithium Reserves in 2019.

Source: USGS, 2020.

Electric Power Matrix

The electricity system is composed of the processes of generation, transmission and distribution of electricity [56], [57]. Where energy losses in the transmission network and losses in the distribution network can occur. The first can be defined as the difference between the energy generated and the energy delivered in the distribution networks [57]. Meanwhile, the second refers to the difference between the electrical energy received in the distribution networks and the commercialized electrical energy [56].

The investment in the electricity generation and distribution network infrastructure is of great importance for the popularization of vehicles powered by the electric network (plug-in). Through the development of these sectors, the mass addition of plug-in vehicles in traffic becomes viable.

Survey of Electric Fleet

As the Ministry of Infrastructure [11], until April/2020, the Brazil contained 790 car electric plug-in. The fleet of this number of rechargeable batteries, in turn, does not represent a major change in the levels of the energy reservoirs and does not lead to an overload in the system, if there is no uncontrolled loading during peak hours. [7].

To understand the relationship between the energy demands demanded by a plug-in electric car, one can consider Noce's description [7]. This author explains that for a popular car, such as Electric Palio, whose autonomy is about 90 km for an energy of 19.2 kWh, about 0.213 kWh/km is consumed. Thus, running 15.000 km/year, a Palio with electric traction consumes about 3.195 MWh/year [7].

According to the Ministry of Infrastructure [11], by April/2020, Brazil contained 105.715.592 vehicles, where 57.072.928 are automobile (vehicle, motor driven, intended If the transport of up to eight passengers, excluding the driver) [59]. Thus, considering that the pictured Electric Palio model, running 15.000 km/year, electricity consumption of approximately 182.348.005 MWh/year (182 TWh/year), constituted this car fleet. This consumption, in turn, requires the amplification of the supply of energy electrical Brazilian [9].

PRODUCTION AND CONSUMPTION OF ELECTRICITY

Figure 3 shows the relationship between the consumption of transmission and distribution networks and the generation of electricity in the years 2010 to 2019 in Brazil.

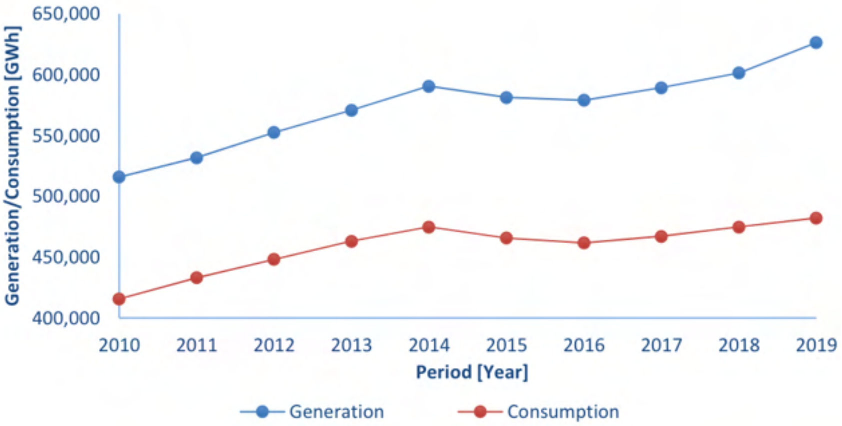

Figure 3 - Consumption of Transmission and Distribution and Electricity Generation Networks 2010-2019.

Source: BUSINESS ENERGY RESEARCH, 2014, 2020. Adapted.

According to the Energy Research Company [62], at 2019 to power electric was generated: 397.877 GWh by hydro power plant, 60.188 GWh of natural gas, 55.986 GWh per wind farm, 52.111 GWh by biomass, 16.129 GWh for nuclear power plant, 15.327 GWh by coal, 7.846 GWh by oil products, 6.651 by solar plant and 14.210 GWh by other sources.

While, according to the same company, in 2019 the energy electric was consumed: 167.684 GWh in the industrial sector, 142.781 GWh in homes, 92.075 GWh in trade, 28.870 GWh in the rural sector, 15.958 GWh in the public service, 15.850 GWh in street lighting, 15.752 GWh in government and 3.257 GWh in own consumption.

Thus, considering only the total electricity generated (626.324 GWh), the total electricity consumed in the transmission and distribution networks (482.226 GWh) [60] and the total losses in the transmission and distribution networks (105.647 GWh) [63], [64], in 2019, there is a remainder of 38.451 GWh of energy. Whose margin is not enough for a fleet composed by about 57 million cars plug-in, which it was estimated would require about 182 TWh/year, considering the model Electric Palio.

The Company Energy Research [66] and rough that the consumption of electricity (consumption of the transmission and distribution networks, self-generation of electricity and consumption through micro and mini distributed generation) increases between 2019 and 2029, with growth of around of 3.8% a year, reaching approximately 793 TWh in 2029. Meanwhile, between 2019 and 2029, classic self- production (self-production generated and consumed *in loco*) is expected to grow by an average of 3.5% per year, where in 2029 there will be a large self-production of electricity (steel, pulp and paper, petrochemical, etc.), non - injected into the network, equivalent to about 85 TWh [65], [67].

Comparing the years 2019 and 2029, the participation of hydroelectric plants is expected to decrease, being offset by the increase in installed capacity of wind and solar sources [65]. Meanwhile, there will be an increase in the performance of natural gas in electricity generation [65]. By 2029, it is expected that there will be an electricity generation composed of 80% from renewable sources [65].

Still, according to the Energy Research Company [64], an increase in the internal supply (production and imports) of electricity is expected, between 2019 and 2029, at an average rate of 3.8% per year, reaching around 942 TWh in 2029. Therefore, considering only the prediction of supply domestic electricity in 2029 (942 TWh) and electricity consumption (consumption of the transmission and distribution networks, self-generation of electricity and consumption through micro and mini distributed generation) in 2029 (793 TWh), there is a difference equivalent to 149 TWh [65], [67].

Considering the demand for consumption of a fleet of 57 million plug-in cars, consisting of the pictured Palio Electric car, the necessary 182 TWh/year would not be reached in 2029. However, the Energy Research Company clarifies that in the forecasts made in the horizon of 2029, the electric energy demands of vehicles powered by the electric network were not considered, since, these types of vehicles will represent an insignificant participation in the fleet in 2029.

Import Energy Electric

One option to meet demand would be to import energy from neighboring countries. Despite data from the Energy Research Company [64], showing that Brazil has a remainder of 38.451 GWh between the production, consumption and losses of electricity in 2019, Charadia [69] contradicts these data. This author states that, Brazil does not provide domestic electricity demand, since the country imports electricity from its neighbors [69]. The country exports electricity in low quantities, however, the amount of imported energy is much higher than that exported.

This fact can be explained by the seasonality of the rains that supply the hydroelectric plants, responsible for the generation of 397.877 GWh (398 TWh) in 2019 [60]. In the months with little or no rain, water levels of these plants are below what is needed for one generation sufficient or cost effective, being necessary to the import of electricity.

To verify if the energy demand in 2029 will be achieved, can the nalisar the Brazilian import electricity (Figure 4).

According to the Energy Research Company [70], in 2019, Brazil imported 25.156 GWh of electricity which, in turn, is equivalent to about 4.02% of the generation of electricity in 2019 (626.324 GWh). In the period under analysis, the largest import was 41.313 GWh, in 2016. While, in the period under analysis, the lowest import was 25.156 GWh, in 2019.

Considering the demand that the current car fleet would demand, if it were composed of the pictured Palio Electric model (182 TWh/year), and the difference between supply (production and imports) and consumption forecast for the year 2029 (149 TWh/year), 33 GWh/year would still be needed to supply the plug-in car market. In this analysis, in turn, plug-in cars that already make up electricity consumption and the growth of the car fleet were not considered.

Figure 4 shows that energy imports decreased from 2016 to 2019, showing a downward trend. Therefore, this demand could only be met if, by 2029, energy imports from neighboring countries increased.

Performing this simple analysis, with estimates from government agencies and data on the energy produced and imported, it is already possible to realize that the implantation of electric vehicles in Brazil will only be possible with the supply of more energy.

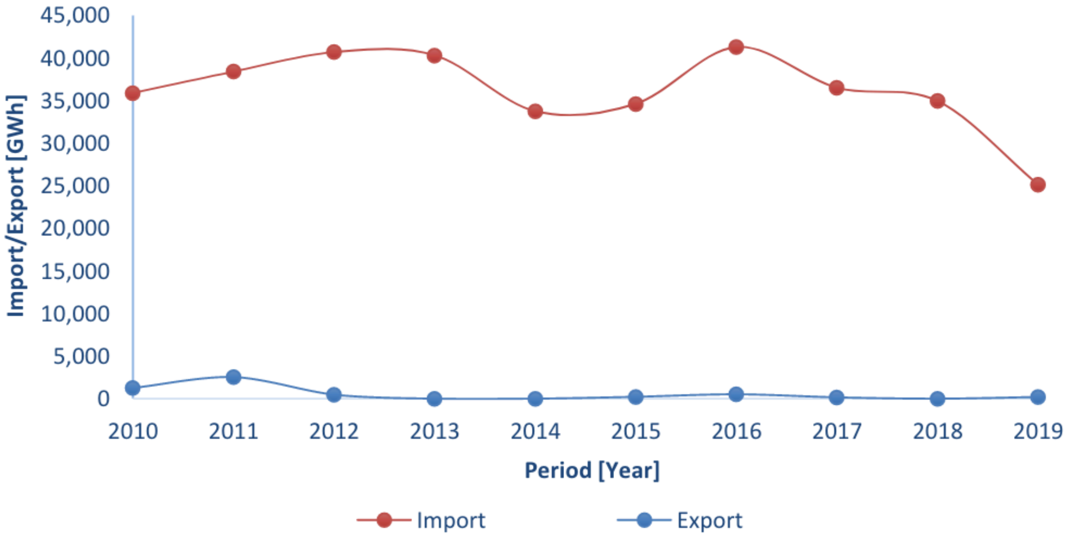

Figure 4 - Import and Export of Electric Energy 2010-2019.

Source: ENERGY RESEARCH COMPANY, 2020c. Adapted.

Points of the recharge

Another important factor to be considered, is the low number of charging stations in the country. However, this scenario is not an impediment, since 60% [71] to 80% of electric vehicles refills are held in homes at night, due to autonomy current the electric vehicle plug-in [9]. Nevertheless, the development of recharging infrastructure is indispensable for the transportation of vehicles fed into the grid.

The energy distributors, in turn, will need to adapt according to the growth of the fleet with power supply. As the number of plug-in vehicles increases, the greater the demand for energy, especially during peak hours, between 6 pm and 9 pm [72]. In this way, the provision of a Dual Tarifa, where the recharge rate (energy consumption) during peak hours is higher than that of ordinary times, can result in a lower consumption during peak hours [73].

At the end of 2019, Brazil reached 150 charging stations [74] - [76]. Among the locations where these charging stations are distributed, there is the Rio de Janeiro - São Paulo corridor, the "largest electric corridor in Latin America" [74]. In this electric corridor, created by BMW Group Brazil and EDP Energies of Brazil [77], [78], were invested about R$ 1 million to install six stations to recharge in Ipiranga gas stations [78], [79].

REGULATIONS

Due to the need to expand the charging stations, the National Electric Energy Agency approved Normative Resolution No. 819/2018 which, in turn, refers to the regulation of charging activities for plug-in vehicles [80]. In this resolution, it is granted to any interested this the ren the service (distribution companies, gas stations, shopping centers, entrepreneurs, etc.) recharging activity [80]. This measure is aimed at a larger number of institutions is inserted the in the Brazilian refill services, thus reducing the uncertainty for those who wish to invest in vehicles plug-in.

To encourage the purchase of electric cars, the Brazilian government carries out either an exemption or a tax rate for users. The import tariff for electric cars has been zeroed and for hybrid cars ranges from 0% to 7% [20], [81]. Meanwhile, Tax on Industrialized Products (IPI) have rates of 7% to 18 % for electric and 7% to 20% for hybrids, according to the weight and energy expenditure of the vehicle [20]. In addition, some Brazilian states and cities offer exemption and rates from the Motor Vehicle Property Tax (IPVA) for owners of electric and hybrid cars [20], [82], [83].

Still, with the free trade agreement between the European Union (EU) and the Southern Common Market (Mercosur), signed on 28 of June of 2019, it is expected that there is a reduction of duties and taxes [84]. Thus, one may have to reduce the cost the production of vehicles because the lowest cost invested in parts automotive imported [84]. While, according to the magazine "Automotive Business", 58% of 673 Brazilian automotive leaders did not evaluate or were not informed enough about the influence of the instance in the free trade agreement between the EU and Mercosur [20].

The Energy Research Company [85] makes the following recommendations for the development of public transport policies: support for technologies related to electromobility, considering the particularities of the country; achievement and goals for adoption of electromobility based on regular monitoring and review of the market and of innovation technology; balancing the pace of entry, avoiding tax destruction and solutions that are difficult to sustain and/or disseminate; avoid policies that promote technological lock-in that would therefore cause competitiveness.

COMPETITION

According to the Ministry of Infrastructure [12], gasoline and diesel are some of the main sources of power for vehicles in Brazil. Still, it is seen that there is an interest in the use of ethanol (alcohol) and biodiesel in vehicles, so that there is, mainly, the attenuation of external dependence on oil and the reduction of local pollution generated by vehicle emissions [86]. With that, there are laws for the mandatory addition of ethanol to gasoline and biodiesel to diesel oil.

Gasoline without ethanol is called gasoline A, whereas gasoline containing anhydrous ethanol is called gasoline C. According to Law No. 13.033/2014, it is mandatory that automotive gasoline sold in Brazil has an ethanol content anhydrous between 18% to 27.5% by volume [87], [88]. The mandatory percentage of anhydrous ethanol mixed with gasoline varied as follows: 20% from October/2011 to April/2013, 25% from May/2013 to 15/March/2015 and 27% from 15/March/2015 to date current [87].

Meanwhile, the mandatory addition of biodiesel to diesel oil sold to the final consumer was instituted with Law No. 11.097/2005 [89]. In 2008, the mandatory value of 2% by volume of biodiesel was fixed [62]. Subsequently, there was a gradual increase in the minimum mandatory percentage of biodiesel, reaching a value of 12% in volume, in March/2020 [62].

In addition, Law No. 13.263/2016 was instituted, which grants the National Energy Policy Council (CNPE) to raise the mandatory percentage of biodiesel to the 15% range [62]. As a result, CNPE Resolution No. 16/2018 was implemented, which proposed an increase in biodiesel of 1% per year, in order to reach 15% in 2023 [65].

In view of the demand for oil products and biofuels and the imposed standards, the market for oil products and biofuels is built. Figure 5 shows the production of oil products and biofuels in Brazil.

According to Figure 5, in 2019, 40.914.849 m^3 of diesel oil, 23.888.068 m^3 of gasoline, 24.899.178 m^3 of hydrated ethanol, 10.407.819 m^3 of anhydrous ethanol and 5.901.104 m^3 were produced of biodiesel [90].

Among the products shown in Figure 5, the one that is most produced in the country is diesel oil. This, in turn, is equivalent to about 38.59% of the production of these products in 2019. Since diesel oil has an expressive performance in public road transport [4] and in road cargo transport in Brazil [91].

Figure 6 shows the import of oil products and biofuels carried out by Brazil.

According to Figure 6, in 2019, Brazil imported the following volume: 13.007.765 m^3 of diesel oil, 4.828.412 m^3 of gasoline A, 134 m^3 of hydrated ethanol and 1.457.468 m^3 of anhydrous ethanol [90].

According to Figure 6, there is a significant Brazilian dependence on diesel oil in the analyzed period. This can be concluded, due to the high volume of diesel oil imports. This, in turn, is equivalent to about 67.42% of imports of these products in 2019.

On the other hand, there is a small import of hydrated ethanol in Brazil. In the analyzed period, the lowest volume of imported hydrated ethanol was 134 m^3, in 2019. While, in the period under analysis, the highest volume of imported hydrated ethanol was 38.165 m^3, in 2018.

Figure 7 shows the export of petroleum products and biofuels carried out by Brazil.

According to Figure 7, in 2019, Brazil exported the following volume: 44.805 m^3 of diesel oil, 3.018.715 m^3 of gasoline A, 617.230 m^3 of hydrated ethanol and 1.315.765 m^3 of anhydrous ethanol [90].

Comparing the products under analysis, there is a high gasoline export in 2019 in Brazil. However, the export volume of gasoline

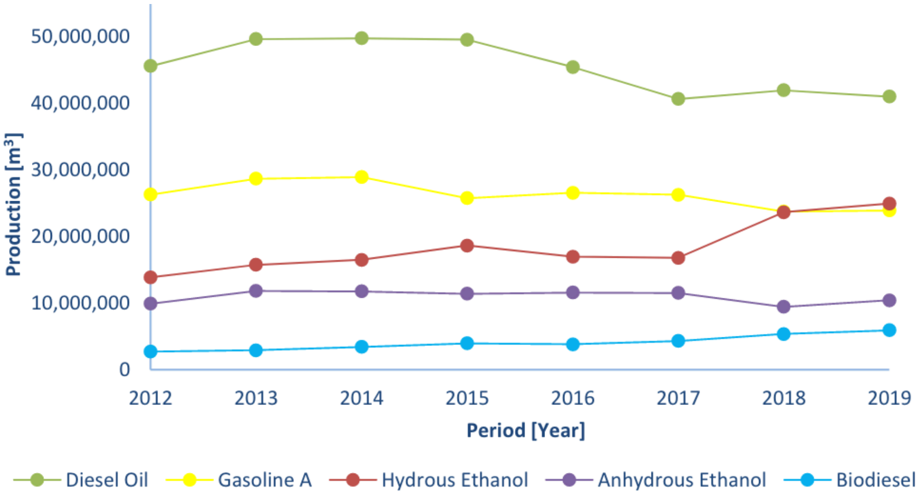

Figure 5 - Production of Petroleum Derivatives and Biofuels 2012-2019.

Source: NATIONAL PETROLEUM AGENCY, NATURAL GAS AND BIOFUELS, 2020. Adapted.

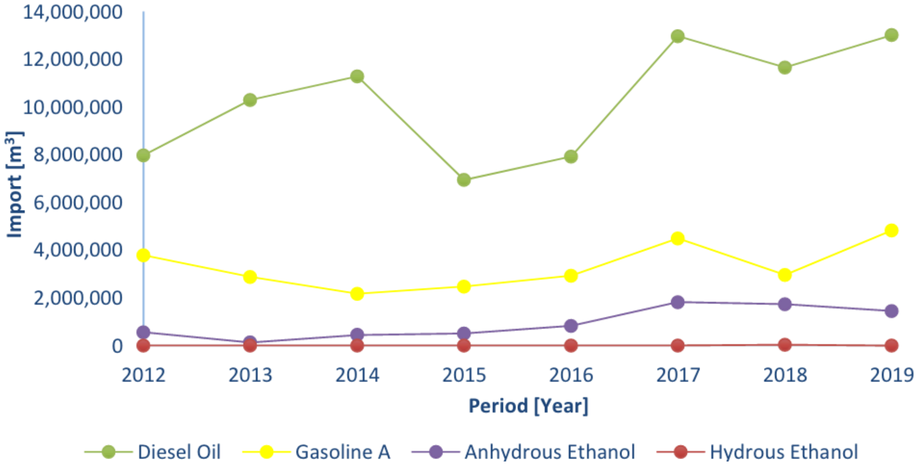

Figure 6 - Import of Petroleum Derivatives and Biofuels 2012-2019.

Source: NATIONAL AGENCY FOR PETROLEUM, NATURAL GAS AND BIOFUELS, 2020. Adapted.

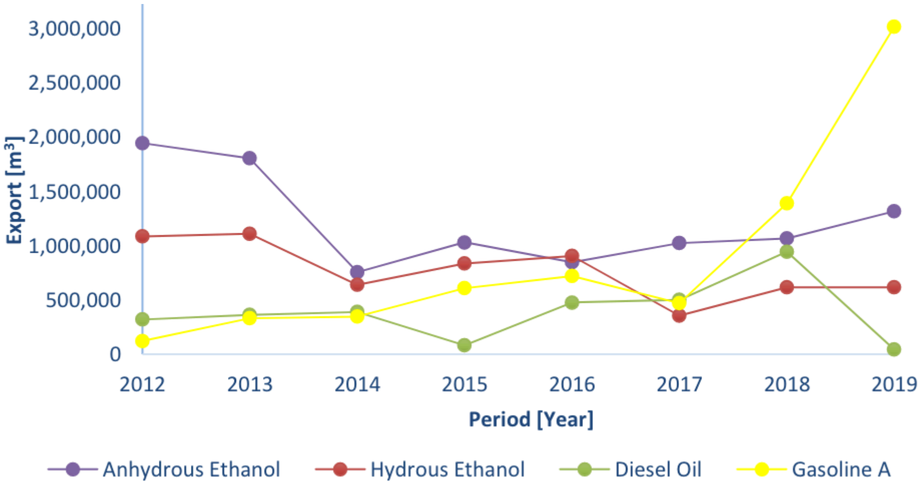

Figure 7 - Petroleum Derivatives and Biofuels Exports 2012-2019.

Source: NATIONAL AGENCY FOR PETROLEUM, NATURAL GAS AND BIOFUELS, 2020. Adapted.

A in 2019 (3.018.715 m^3) is lower than that of import gasoline A in 2019 (4.828.412 m^3).

Also, according to Figure 7, there is a small export of diesel oil in 2019 in Brazil. Where the volume of diesel oil exports in 2019 (44.805 m^3) is lower than the volume of diesel oil imports in 2019 (13.007.765 m^3).

Figure 8 shows the sale of oil products and biofuels in Brazil.

As shown in Figure 8, in 2019, the following volume was sold in Brazil: 57.298.448 m^3 of diesel oil, 38.165.037 m^3 of gasoline C, 22.544.085 m^3 of hydrated ethanol and 5.871.088 m^3 of biodiesel [90].

In this way, it is possible to observe the significant Brazilian consumption of diesel oil and gasoline C. Where, diesel oil is equivalent to about 46.25% of the sale of these products in 2019. While, gasoline C is equivalent to about 30.81% of the sale of these products in 2019.

An Analysis of Electric and Hybrid Cars

In Brazilian traffic there is a larger fleet of hybrids, compared to the electrics. According to the Ministry of Infrastructure [12], until April/2020 the country was composed 6.516 car hybrid the gasoline/alcohol/electric and 12.407 hybrid cars to gasoline/electric. The step that in the same period had been 790 electric cars/source external and 343 electric cars/internal source [12].

This scenario is due to the hybrid car, in the current market, presenting greater autonomy and exhibiting a lower acquisition cost, due to the use of more accessible technologies [92]. Still, hybrid cars t is m advantages over cars conventional, for example, the fuel economy, the tax incentives, to drive more efficient and commonly one lower maintenance costs.

To analyze the fuel economy of a hybrid car, a survey was made of the average cost of gasoline and ethanol in Brazil in April/2020. Whose prices medium were equivalent to R$ 4,253 and R$ 3,451, respectively [93], [94]. E m then was researched consumption by kilometers traveled in urban areas, and some cars: the Ford Fusion 2.0 EcoBoost AT gasoline consumes 8.6 km/L, the Ford Fusion 2.0 *Hybrid* CVT petrol consumes 16.8 km/L [95], the Toyota Corolla 2.0 (Flex) gasoline consumes 11.6 km/L, the Toyota Corolla 2.0 (Flex) ethanol consumes 8 km/L, the Toyota Corolla 1.8 *Hybrid* (Flex) gasoline consumes 16.3 km/L and the Toyota Corolla 1.8 *Hybrid* (Flex) ethanol consumes 10.9 km/L [96] (Figure 9).

Knowing that in Brazil a car runs on average 15.000 km per year [7] and considering the average cost of fuel in April/2020 in a year are spent fuel about: R$ 7.418,02 with the Ford Fusion 2.0 EcoBoost AT gasoline, R$ 3.797,32 with the Ford Fusion 2.0 *Hybrid* CVT petrol, R$ 5.499,57 with the Toyota Corolla 2.0 (Flex) gasoline, R$ 6.470,63 with the Toyota Corolla 2.0 (Flex) ethanol, R$ 3.913,80 with the Toyota Corolla 1.8 *Hybrid* (Flex) on gasoline and R$ 4.749,08 with the Toyota Corolla 1.8 *Hybrid* (Flex) on ethanol.

It is noted that the Ford Fusion 2.0 *Hybrid* CVT gasoline has lower consumption than the vehicles analyzed, consuming about half of the last placed, Ford Fusion 2.0 EcoBoost AT gasoline. Followed by the most economical are the Toyota Corolla 1.8 *Hybrid* (Flex) in gasoline and the Toyota Corolla 1.8 *Hybrid* (Flex) in ethanol.

Another parameter that can be assessed is the cost of maintenance. In Figure 10 is represented maintenance costs by rotated kilometers of the car Ford Fusion, Toyota Corolla and Renault Zoe.

The maintenance cost of cars increases, irregularly, with the mileage driven. With 60.000 km covered, the sum of the maintenance cost is approximately: R$ 5.918 with the Ford Fusion 2.0 EcoBoost, R$ 4.465 with the Ford Fusion 2.0 *Hybrid*, R$ 3.872 with the Toyota Corolla 2.0 (Flex) and the Toyota Corolla

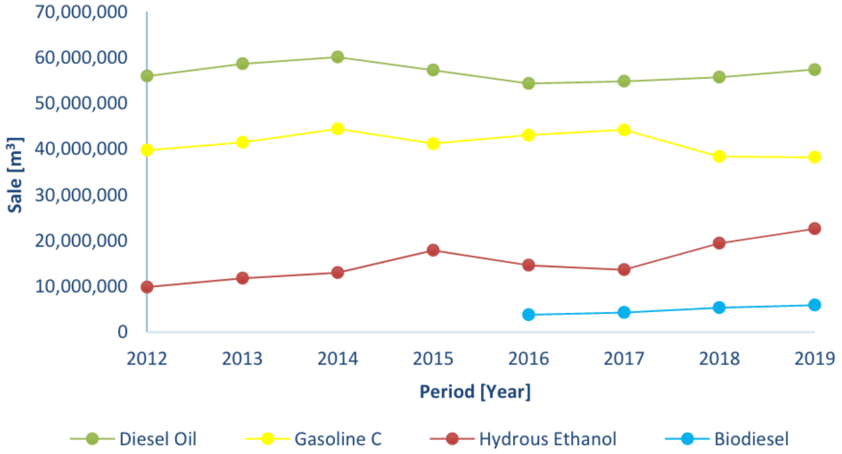

Figure 8 - Sale of Petroleum Derivatives and Biofuels in Brazil 2012-2019.

Source: NATIONAL AGENCY FOR PETROLEUM, NATURAL GAS AND BIOFUELS, 2020. Adapted.

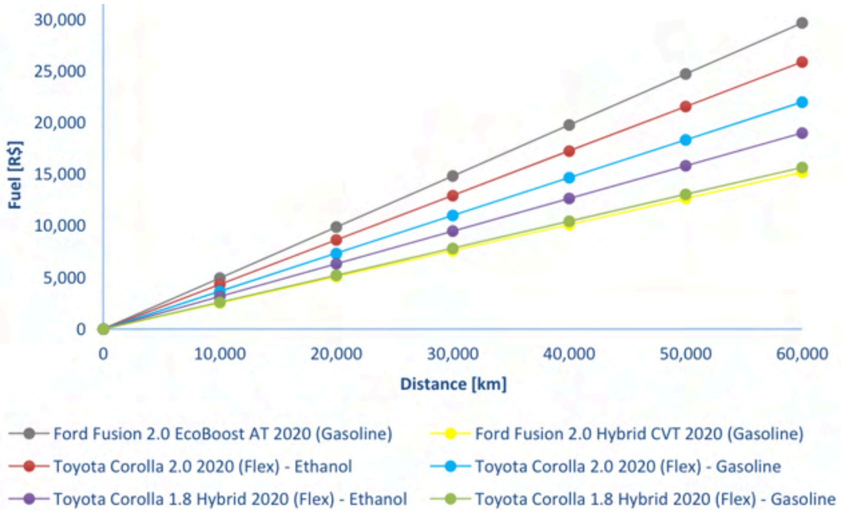

Figure 9 - Kilometers traveled in Urban Environment by Average Fuel Cost in April/2020.

Source: FIGUEIREDO, 2020; OLIVEIRA, 2020a, 2020b; SIQUEIRA, 2020. Adapted.

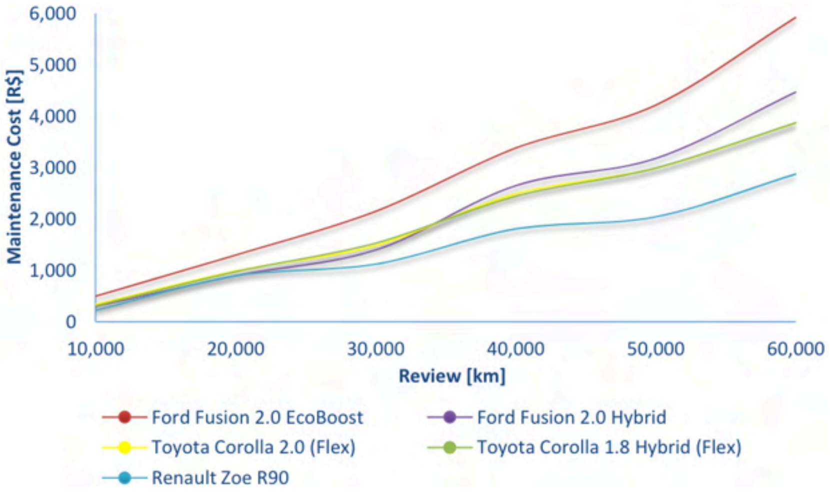

Figure 10 - Kilometers Driven by Cost of Maintenance.

Source: OLIVEIRA, 2019a, 2019b, 2020a. Adapted.

1.8 *Hybrid* (Flex) and R$ 2.872,56 with the Renault Zoe R90 [95], [97], [98].

Considering the vehicles under analysis, hybrid cars stand out, second only to the Renault Zoe R90 electric car. In this evaluation, it can be seen that a hybrid car consumes less fuel than a car conventional and also that automobiles is electric and hybrid requires m less maintenance than conventional cars [99], [100].

However, it should be noted that in this section the performance of cars with similar standards was analyzed. In view of this, it has not been evaluated at a cost of popular cars acquisition, since it is a current challenge the design of electric cars and hybrids with good performance, the cost of popular acquisition.

CONCLUSION

In summary, this work was designed to explain, mainly, the Brazilian challenges facing the mass deployment of electric cars. This article was the beginning of a study related to the market involving electric cars, whose objective is to collaborate with the development of this sector.

In view of the above, it was observed that among the most promising energy storage is a battery lithium-sulfur battery and lithium-air. However, this science needs to evolve to develop batteries that reach, in practice, values higher than those of ordinary gasoline and hydrated ethanol.

Taking into account that the current generation of batteries is made up of lithium, the exploration of this metal for the production of batteries in South America would be possible, since it is estimated that 60% of the total world lithium is concentrated in the countries of that region.

In Brazil, the massive replacement of fossil vehicles for those powered by an electric grid requires investments to generate electricity or import energy from neighboring countries.

Although the government facilitates the commercialization of electric vehicles, hybrid vehicles currently offer more advantages to the Brazilian consumer.

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