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The Meaning of Electric Cars in the Context of Sustainable Transition in Brazil

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Abstract: The transition from fossil-fuel cars to those powered by electricity seems to occur differently in Brazil compared with what has been observed in other countries, where it is motivated by the goal to reduce CO_2 emissions and the need to reduce dependence on fossil-fuel imports. At present, fleets are reduced, values are high, and the infrastructure is incipient. This article presents a problematization of the local scenario and the results of a survey with local consumers. The goal is to determine whether this market tends towards a scenario where an electric car is perceived as a substitute for a fossil-fuel vehicle, with new technology but the same function (transportation) or if it tends towards a reinterpretation, seeing integration with the electricity grid. The results indicate gaps and opportunities in service design, public policies for smart cities, and new ICTs associated with smart grids.

Keywords: sustainable transition; electric vehicles; innovation; sustainable cities; smart grid; smart cities; energy policy

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1. Introduction

> "Essential renewable energy applications in smart city development are for green buildings (GBs) and electric vehicles (EVs). Limited resources of fossil fuels and an increase in demand for electricity have renewed interests in integrating GBs [1,2] and moving towards EVs in urban areas [2,3]".

Some benefits can be immediately associated with EVs and, more specifically, electric cars, such as greater efficiency of the electric motor; reductions in global and local pollution; noise reduction in large cities; reductions in pollution-related health problems in large centers, such as respiratory problems; the possibility of being integrated into the grid; and the possibility of new business models. In Brazil, the latter is corroborated by the Normative Resolution 819/2019 of the National Electric Energy Agency (ANEEL) [4] regarding the procedures and conditions for the accomplishment of activities to recharge EVs, which allows for the accomplishment of these activities, including commercial exploration at freely negotiated prices; in this way, spaces are created for new market opportunities.

Even with these efforts and incentives, some obstacles hinder the widespread incorporation of e-cars in the country, such as consumer doubts, which are typically related to experimentation with and adoption of new technologies, the high costs, the uncertainties generated by the short time that EVs have existed on the market, the little or insufficient charging structure [5], and the instability of the energy grid systems [6].

Unlike many countries, the adoption of EVs in Brazil is still incipient and incentive policies are scarce. These could be explored as there is a positive relationship between the EV sales volume and two demand-side policies: charging discount and infrastructure construction subsidy [7].

This study arises from the perceived necessity of finding information and of generating knowledge that may contribute to the analysis of a complex system involving the EV production chain in the country, starting by identifying the perceptions of Brazilian users, since the adoption of EVs is in the process of consolidation.

In this article, the authors provide subsidies for decision-making by the leaders of the various market segments that make up this system, which include the regulatory and governing bodies, the automobile industry, the environmental agencies, and the infrastructure sector. In this way, it may support the strategies in smartly planning new policies and markets related to electric cars and may contribute to the sustainability transition in Brazil. It is also important to emphasize that the intent is not to provide answers to predict how these vehicles can be commercially successful but instead to provide guidelines for the adoption process.

This study considers two hypotheses in the Brazilian context: electric cars as a substitute for combustions car with a similar function as a means of transportation or as a product with a new meaning if integrated into the city's electricity grid (Figure 1).

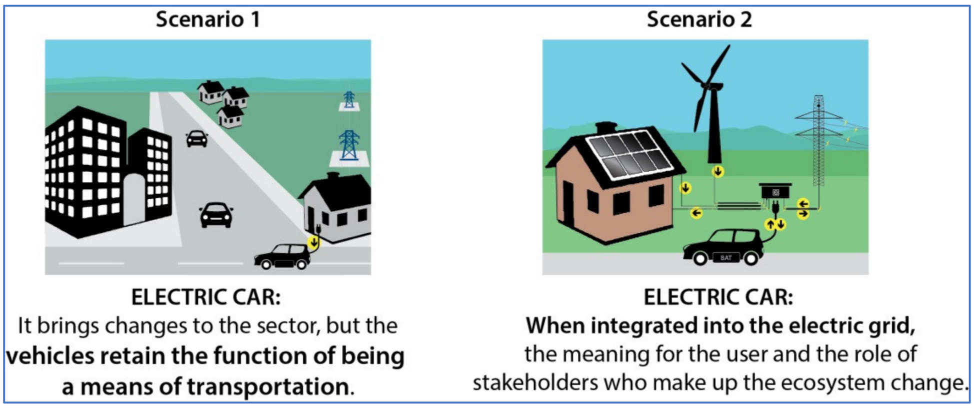


Figure 1. Two possible perceptions of Brazilian users about electric cars.

Our hypothesis is that, if perception tends towards the first scenario, then an e-car is an innovative product with new technology the following perceptions:

- To users, it maintains the same function (transportation);
- To cities, it promotes Greenhouse Gas (GHG) and particulate material reduction;
- To the market, it brings significant changes to different sectors (e.g., transport and energy); and
- Regarding regulations, new policies driven by environmental issues are required.

If perception tends towards the second scenario, then an electric car is an innovative product with new technology and a high impact on the transition toward "smart and sustainable cities":

- To users, it brings new meaning when integrated into the electric grid (besides transportation);
- To cities, it promotes GHG reduction and public health improvement (environment), and new technologies and services (mobility and economy);
- To the market, it brings significant changes to different sectors (e.g., transport, energy, and infrastructure) and new roles to stakeholders of the new ecosystem; and
- To regulators, it requires new policies oriented towards smart and sustainable cities.

This article's main contribution is to draw a panorama of the current understanding of Brazilian consumers that can support future actions taken by the stakeholders already involved in this market and potential new markets that may arise in the case of new meanings for e-cars.

This article is divided into four sections: the methodology used, the survey results, the discussion of electric cars in the context of the sustainability transition in Brazil, and the preliminary conclusions.

2. Literature Review

In the field of electric cars and their role in the sustainable energy transition, a number of concerns have been raised and discussed. In recent years, a lot of attention has been given to their role in GHG reduction and technological innovation. However, an identified gap deals with whether final users are aware of the possibility of integrating an electric car in the city grid and how they perceive this possibility.

An example among identified assets within the literature deals with aspects of EV bringing technological innovation when compared with fossil-fuel cars, and it has been recognized as a way of reducing GHG emissions [8–10].

Another aspect deals with the challenges encountered, with emerging technologies, as they reframe the meaning of a car, expanding it to beyond regular means of transportation.

Despite the extensive literature discussing both converging and divergent aspects of the role of electrification, transport, and mobility, little is found about how users perceive EVs and the possibility of integrating it into the city grid.

Concerning the meaning of electric cars to the consumer, a literature review shows that there are discussions on symbolic meaning and identity perception, environmental aspects, and functional needs. Research in the Scopus Database for "electric vehicle" and "meaning*" has returned 17 papers. The content was related to environmental issues [11,12]; technological aspects [13–15]; urban development, infrastructure, and policies [16–20]; and cultural issues, including identity questions such as gender and status, for example [11,21–23]. Although V2G is mentioned [24] and is aligned with the content of this article when it declares that e-cars "operate as 'vehicles' when drivers need them but switch to 'storage sources' when connected to the power grid", the focus relies on business models. Our search did not present any results indicating previous research related to the user perception and awareness of the electric cars as a means beyond a regular mode of transportation and part of the city grid.

Analyzing the relationship between CO_2 emissions reduction and the adoption of electric vehicles, different categories of EV, such as private cars, cargo, and buses, emerged. Comparing them, private cars and freight transportations have a significant impact on GHG emission: freight transportation is one of the key contributors to the climate change crisis due to its growing share in overall GHG emissions [25–27]; "private cars in the transport sector become major contributor to CO_2 emission than cargo turnover transport and policies aimed at the decarbonisation of private cars in the transport sector should be strengthened" [28]. These reinforce the focus of this research on private cars, as discussed in the Section The Electric Vehicle and the Environmental Demand in Brazil in this paper.

Concerning the introduction of electric cars in Brazil, some critical issues were found, such as competition with the biofuels program, mainly ethanol, and the alternative of e-cars acting not as a substitute but rather as a complement for ethanol and gasoline [29]; policies that reduce car prices needing to be developed and oriented to car manufactures [30]; the environmental impact of manufacturing an electric vehicle's battery [31]; and smart grid policies and regulation efforts beyond investments [32]. The discussions are relevant and include key aspects to the development of a still incipient market concerning both electric cars and smart grid. Researches reinforce that "Brazil is going towards a smart grid full implementation; however, it could take decades and requires adjusts from govern, regulatory agency, utilities and consumers, and more investments" [32]. However, there is a gap in the literature about user's perceptions of e-cars as part of the city grid.

In this field, it is also important to highlight that some implemented solutions have not succeeded in the market due to various aspects that impacted both challenges and failures related to electric car projects. A key identified aspect deals with the lack of knowledge regarding the role of consumers in achieving a different result [33]. We see this knowledge gap as a key aspect of most service implementations, which can push or jeopardize their role in the market. According to [33], "these factors cut across environmental attitudes and resistance to change among users, mismanagement and strategic blunders involving corporate strategy, and higher than expected capital costs for vehicles. In addition, the fact that Danish society is only 'passively' greener than other societies, and because electric vehicles require active changes to behavior or lifestyle, electric vehicle implementation in Denmark was still an uphill challenge".

By addressing the consumers and their perceptions as key players in the path towards sustainable transition in Brazil, we contribute to filling the existing gap in the literature by focusing on electric vehicles and the global south. To gather a deeper understanding of such perceptions, we devised research that covers a survey with potential consumers of private electric cars and an analysis of the scenario of the integration of EVs within the city electric grid (market, regulation, and SDG contributions). For this article, we provide the summarized results of the initial survey carried out in the early stages of the research project, presented in the following sections.

3. Methodology

First, a thorough examination was made of the academic research on electric vehicles and official Brazilian reports related to GHG emissions and the electric energy production chain. The results supported the problem statement and the elaboration of instruments.

Second, exploratory research was carried out using an online survey, primarily to find quantitative and some qualitative data on Brazilian consumers' perceptions of electric cars. Four types of perceptions were developed, which were distributed into four groups of people:

1. Those who own an electric car;
2. Those who own a fossil-fuel car;
3. Those who do not have a car and want to;
4. Those who do not have a car and do not want to.

The questionnaire was made available in June 2020 via the Google Form platform. A total of 641 answers were collected, representing a statistically significant sample with a sampling error of 3.88% in an infinite population, considering a 95% confidence interval.

The questionnaire addressed specific issues about the perception of electric cars and collected socioeconomic data from respondents (age, income, education, and gender). An analysis was performed regarding the education level and income of the public consulted. In this scenario, the confidence interval of the different groups is 90%. The sampling errors are presented in Table 1:

Table 1. Confidence interval and sampling errors—total sample and stratified samples.

Groups	Sampling Errors	Confidence Interval
General	3.88%	95%
Master's or doctorate degrees	6.54%	90%
University degree or *latu sense* post-graduate	3.97%	
Elementary degree	11.48%	
Remuneration above ten minimum wages	4.44%	
Remuneration between six and ten minimum wages	7.75%	
Remuneration between three and six minimum wages	9.73%	
Remuneration below three minimum wages	12.81%	

Of the total, 482 (75%) refer to those who own a car and 159 (25%) refer to those who do not own a car. The quantities by groups of respondents are shown in Figure 2.

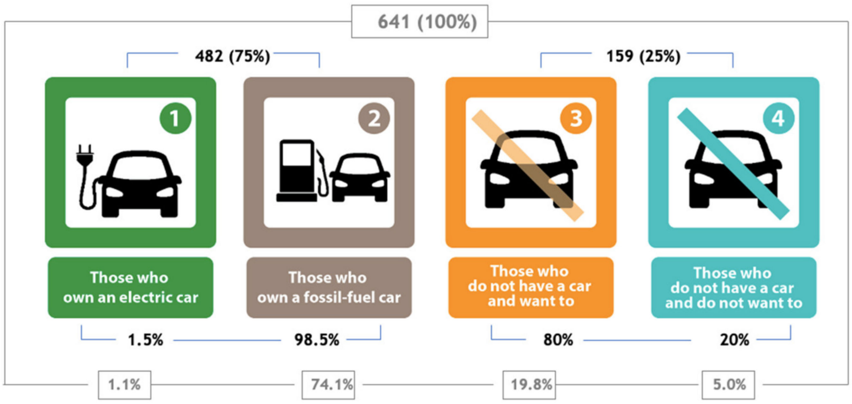


Figure 2. Sample by groups of respondents.

Figure 3 contains a flowchart of the research.

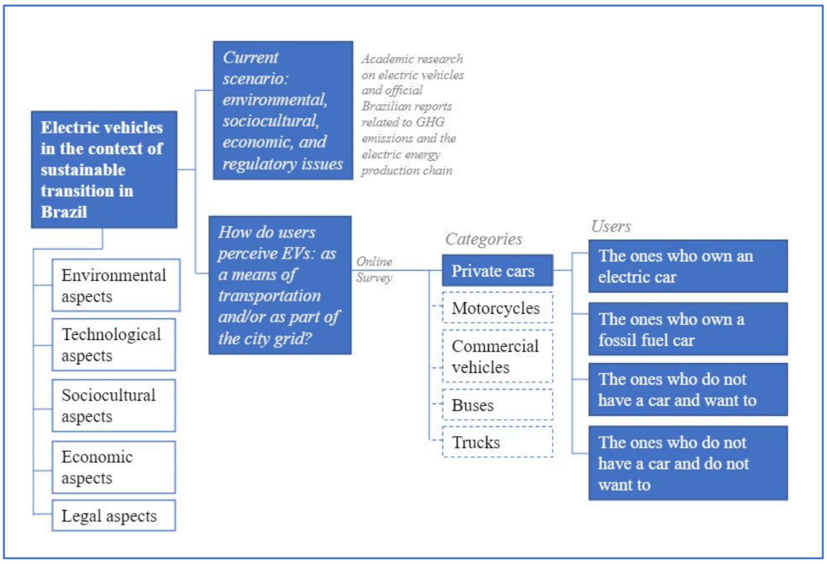


Figure 3. Research flowchart.

4. Survey Results

This section presents the survey results that most contribute to the objective of this research: to identify how Brazilian users understand electric cars and to contribute to decision-making by the main stakeholders involved. Two possible scenarios were analyzed (electric car as a means of transport and as part of the electrical system, as shown in Figure 1) and four different user groups (Figure 2). The research sought to anticipate the scenario trends from the perspective of potential car users.

When asked what is the first concept that comes to mind when they hear the expression "electric car"; the answers varied, with environmental aspects and sustainability predominating (Figure 4). This question was an open question to evaluate the users' "top of mind" concept(s) related to electric cars.

For the purposes of consolidation and analysis, the responses were categorized. For example, the different concepts provided and grouped into the "environmental and sustainability issues" category included environment, ecology, zero pollution, clean air, and sustainability. Other recurrent answers were related to financial and technical associations with the future and modernity, and the Tesla brand (mentioned by 7% of respondents). The other brands mentioned were Toyota (Prius), BMW, Nissan (Zoe), Mitsubishi (Imiev), Renaut, and GM (Bolt), and together, they represented less than 2% of the associations (Figure 5).

Figure 4. Word cloud with concepts spontaneously provided by the respondents.

Regarding knowledge of the possibilities of integrating electric cars into the grid, this subject was unknown to most respondents (Figure 6).

Current electric car users (group 1) represent a minority and were mainly motivated by its efficiency (Figure 7). Environmental issues also appeared but without great relevance. These users do not use the battery to store energy and do not integrate the vehicle into the grid. Since there are no current policies related to this issue, there is no way to predict how behavior would change if there were any policies, if at all. However, these users sought technological innovation with no change in meanings. Current prices should be taken into consideration to increase the number of users. Users did not show any concern for the infrastructure and have early adopter profiles, being strongly motivated by new technology and its experience. For this group to seek integration into the grid, it is necessary to revise the current legislation.

Potential users (groups 2 and 3), those who own a fossil-fuel car and those who do not have a car and would like to have one, have different profiles from the first group (Figure 8). The majority of this group would like to have an e-car, and environmental concern is clearly present. Attraction to new experiences with an e-car (efficiency and silence, for example) was also representative, according to their perspective. Still, insecurities regarding the available infrastructure and battery autonomy as well as current values are significant obstacles. A lack of information as well as some doubts pertaining to experimentation with and adoption of something new are other aspects that were shown. To reach this group, besides price reductions, an increase in infrastructure is fundamental. They are open to new information, and the number of people who indicate that they would consider the possibility of integration into the grid is not significant. These users indicate that they are inclined towards the possibility of migration into the second scenario. Incentives, information, and conditions to incorporate these new habits are necessary.

Users who do not own a car and do not intend to have one (group 4) do not comprise either of the aforementioned two scenarios (Figure 9). However, they should not be disregarded, since the reasons that lead to this position are subject to change: one-fourth do not need a vehicle today; 13% made this decision due to financial reasons; 18% of reasons are related to stress, traffic, and parking difficulties associated with owning a vehicle; and 15% do not know how or do not like to drive, do not have a driver's license, or feel insecure due to age. Although most of them are aware that electric vehicles can be integrated into the grid, 70% ignore the possibility of supplying energy to their own homes. At present, users in this group are not vehicle consumers and do not fit in either of the two scenarios. However, with the change in meaning and the possibility of the emergence of autonomous vehicles, there is a chance of migration. To achieve this, it is necessary to reduce prices and to increase information. This group is composed of users with a disruptive profile.

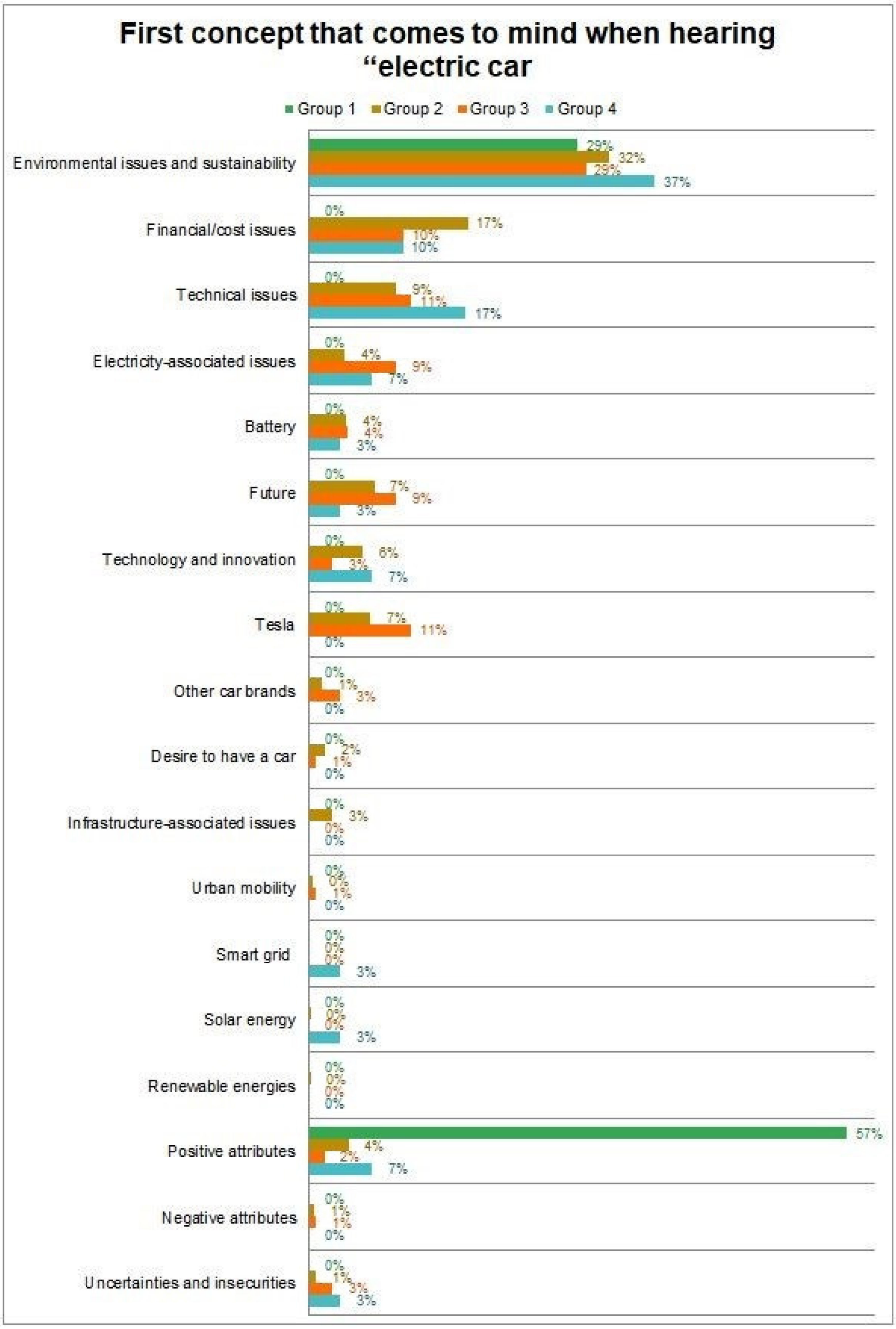
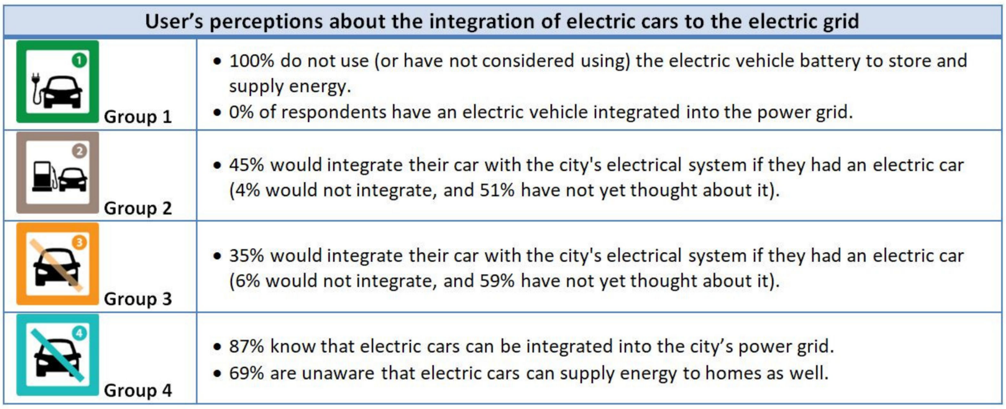


Figure 5. Concepts associated with electric vehicles (spontaneous citation).



User's perceptions about the integration of electric cars to the electric grid	
Group 1	• 100% do not use (or have not considered using) the electric vehicle battery to store and supply energy. • 0% of respondents have an electric vehicle integrated into the power grid.
Group 2	• 45% would integrate their car with the city's electrical system if they had an electric car (4% would not integrate, and 51% have not yet thought about it).
Group 3	• 35% would integrate their car with the city's electrical system if they had an electric car (6% would not integrate, and 59% have not yet thought about it).
Group 4	• 87% know that electric cars can be integrated into the city's power grid. • 69% are unaware that electric cars can supply energy to homes as well.

Figure 6. User's perceptions about the integration of electric cars to the electric grid.

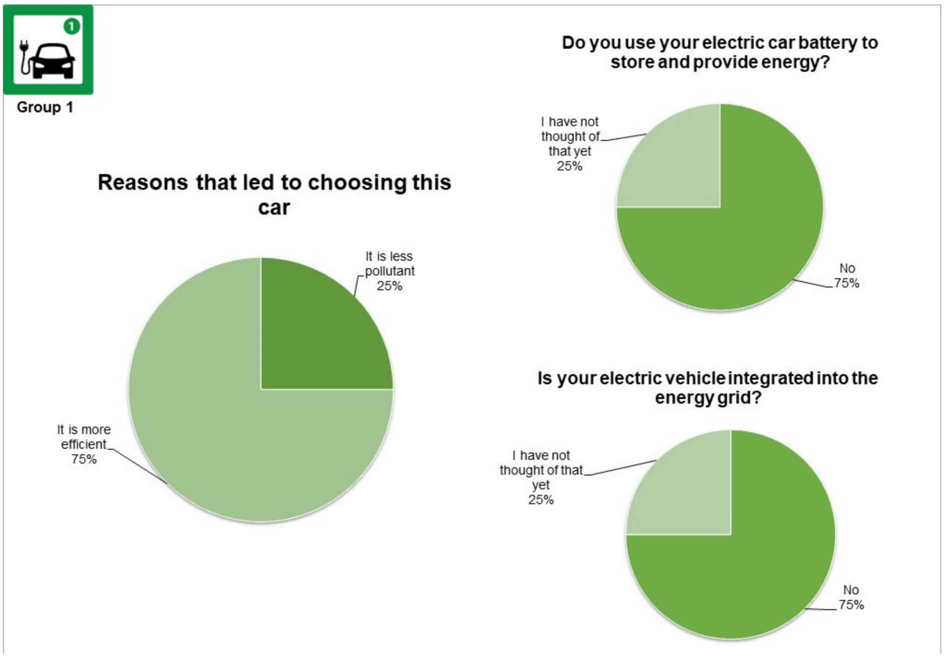


Figure 7. Main perceptions among the users of group 1.

In summary, the first group, with the early adopter profile, seeks new experiences and is attracted by the new technology presented by electric cars. They represent a minority. The novelty attracts groups 2 and 3, but the prices make it unfeasible to them. In addition, insecurities are still high. They see electric cars as a means of transportation (scenario 1) but have information and desires that allow them to migrate to the second scenario without great effort. The latter group does not belong to either of the first two scenarios. However, with advances in the conditions necessary for the establishment of scenario two, which is hypothetical at present, this group may come to integrate EVs. It is important to emphasize that the second scenario incorporates the first one, as it also serves as a means of transportation and contributes to the reduction in GHG emissions. However, it suffers from the influence of the three essential components of smart cities: smart environment, smart mobility, and smart economy. This means that the regulatory measures, policies, and incentives must have a systemic vision of the scenario and must seek solutions that integrate these different themes to achieve meaningful advances in cities and the country. Issues related to renewable energies, electric mobility, energy storage, autonomous vehicles, smart grids, the programmed adaptation of the automotive, oil and gas, and electric sectors, among others, must be analyzed in a strategic and integrated form.

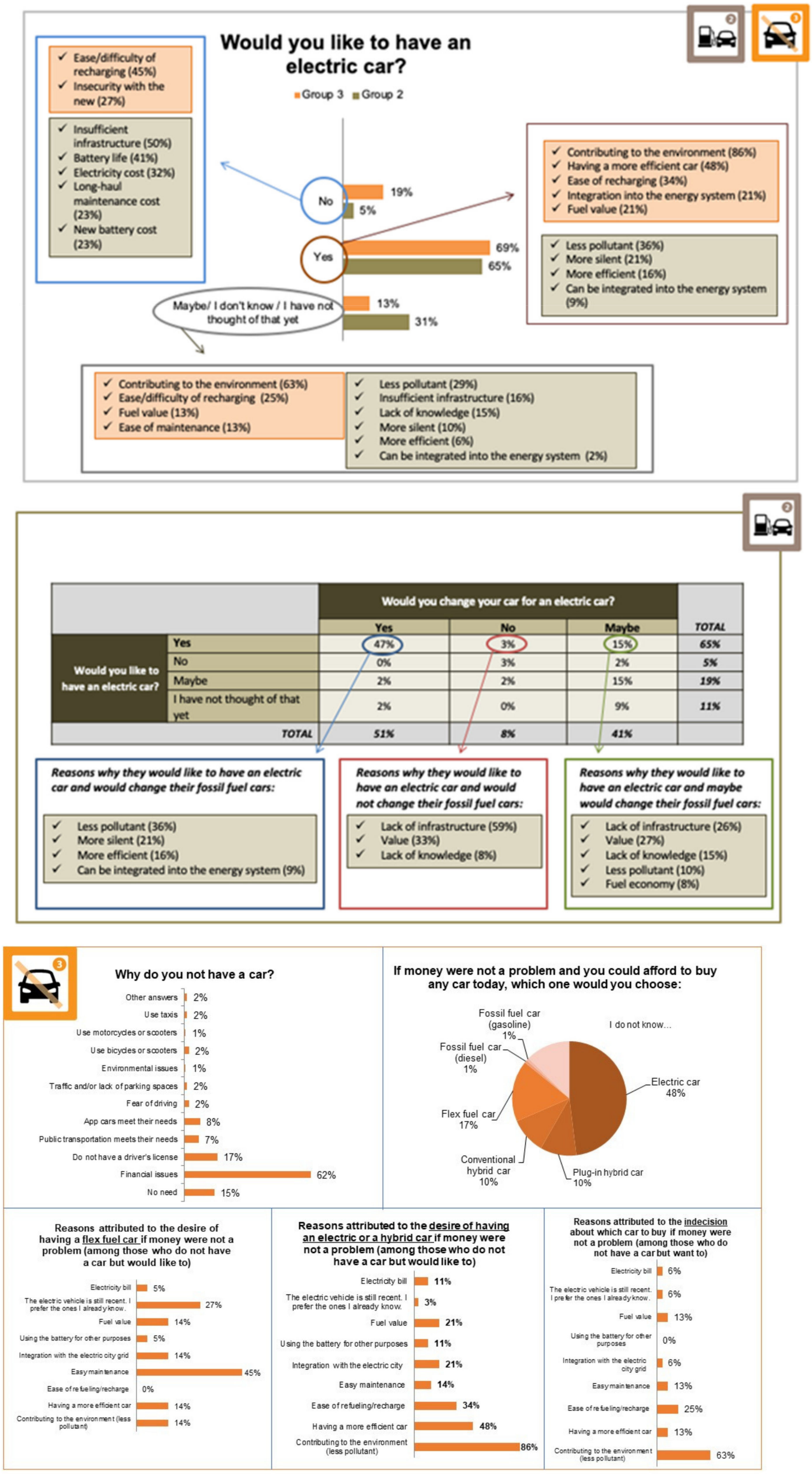


Figure 8. Perceptions about electric cars—groups 2 and 3.

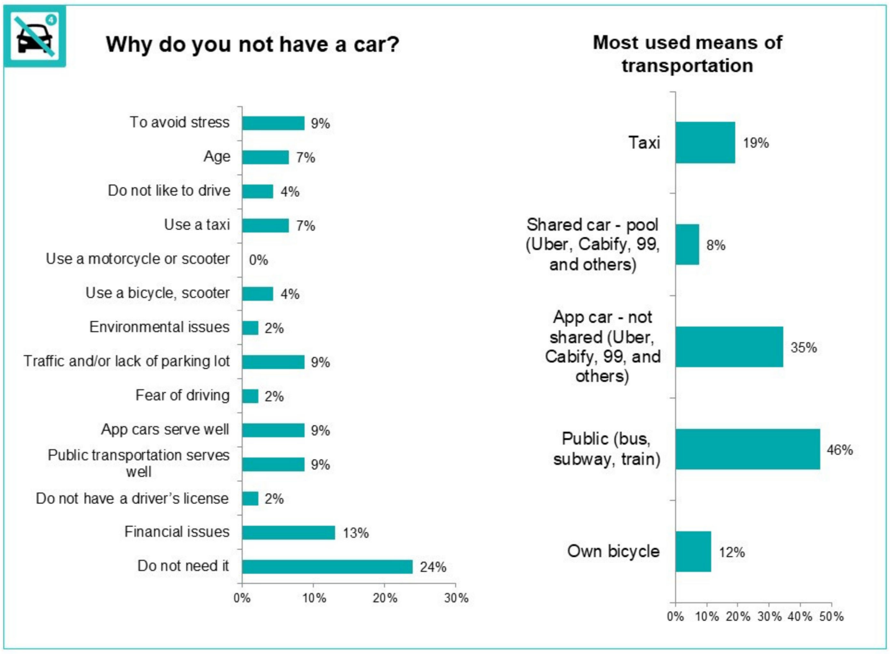


Figure 9. Perceptions about electric cars—group 4.

Figure 10 summarizes the information about the groups researched.

User profile	Main motivators (electric car)	Main obstacles (electric car)	Relationship with the technical attributes of the new technology	Relationship with environmental issues	Present scenario	Relationship with Scenario 1 (electric car as means of transport)	Relationship with Scenario 2 (electric car as part of the grid)
1. Owns an electric car – *"Early adopters"* profile	Engine efficiency	Not identified	Great appeal (mainly the engine efficiency)	Little concern	Scenario 1	They integrate this scenario	A little propensity for a change
2. Owns a fossil fuel vehicle	Less pollutant (36%); More silent (21%); More efficient (16%)	Insufficient infrastructure (50%); Battery life (41%); Values (33% out of the ones who would not change their fossil fuel vehicle for an electric one, even though they desire an electric car); Lack of knowledge (15%)	Medium importance, showing some knowledge (it is a factor of appeal, but insecurities are stronger issues)	Medium concern	Scenario 1, but with the possibility of migration to scenario 2	They integrate this scenario	There is a propensity for a change to this scenario
3. Does not have any vehicle, but would like to have one	Contribution to the environment (86%); Have a more efficient car (48%)	Ease/difficulty to recharge (45%); Insecurity with the new (27%); Values (62% do not have a car due to financial issues)	Medium importance, but in a superficial way (efficiency is mentioned, but not silence, for example)	High concern	Scenario 1, but with the possibility of migration to scenario 2	They integrate this scenario	There is a propensity for a change to this scenario
4. Does not have any vehicle, and does not think of having one – *Disruptive* profile	Not identified	Present lifestyle eliminates own vehicle and other means serve well (53%); Impossibility to drive – do not like, or cannot (15%)	It is not an appeal	All of them are concerned, but only 2% related their own decisions about a vehicle to environmental issues.	They are not consumers, but concerning the meaning attributed, they make up Scenario 1	They see any vehicle as a means of transport, but they are not consumers	With the change in meaning and the possibility of the emergence of autonomous vehicles, there are chances for migration.

Figure 10. Summary of the collected and analyzed information.

This research began with the vision of potential users of electric cars and aimed to inform how other stakeholders may manage their strategies to achieve the goals formed in the face of electric car innovations in the Brazilian scenario. It is essential to keep in mind that, during consultations with users, latent needs and desires are often not stated. Considering that this specific market is still in its infancy in Brazil, this research should not be understood as market research: non-existing markets cannot be analyzed. Therefore, the research also addresses the meaning of the benefits that innovation can generate, even if they are not yet directly associated with electric cars, due to the lack of interaction or knowledge. The results can be analyzed and (re)interpreted by the different key stakeholders that make up the entire chain of this sector to construct the planned future. The collected data aim to contribute to this process.

5. Discussion

The electric car market in Brazil is new and in the process of maturation and consolidation. This section discusses the environmental, cultural, social, economic, and regulatory issues, aiming to provide an overview of the transition process that is taking place in the Brazilian market. This information supported the construction of the survey data's collection instruments.

5.1. The Electric Vehicle and the Environmental Demand in Brazil

The use of electric vehicles has been recognized as a useful way to address environmental pollution and to combat climate change [34,35]. In Brazil, environmental concerns have been increasing. Recently, obligations have taken over what were once voluntary movements. For example, in September 2016, Brazil concluded a process of ratification of the Paris Agreement and delivered its Nationally Determined Contributions (NDC) to the United Nations. Based on that, Brazil's targets for GHG emissions were no longer intentions and turned into official commitments. The Brazilian NDC is committed to reducing GHG emissions by 37% of the 2005 levels by 2025 and by 43% by 2030. The country is committed to increasing the sustainable bioenergy share in its energy matrix to approximately 18% by 2030, to restoring and reforesting 12 million hectares of forests, as well as to reaching an estimated share of 45% of renewable energies in their energy matrix in 2030 [36]. However, this target was reached in 2018, when the share of renewable energies in Brazil exceeded 45% [37–39] (Figure 11). Besides this, regarding only the Brazilian electric matrix, the renewable energies share exceeded 80%, more than three times the result of the world and the Organisation for Economic Cooperation and Development (OECD) countries. This makes Brazil a low-carbon country in terms of the energy sector. According to the 10-year Plan of Energy Expansion 2029 in Brazil, "the Brazilian energy sector stands out for having an energy matrix with a high share of renewable sources, which is a fact verified in a few countries in the world. GHG emissions per consumed energy unit in Brazil are low compared to other countries" [40].

Despite the promising results achieved with clean energy, Brazil ranks sixth in terms of GHG emissions, representing approximately 3.2% of the world's total. Different from other countries, where the increase is mainly caused by the energy sector, in Brazil, in addition to the growth in energy consumption per capita, agricultural activity and deforestation (changes in the use of land, above all, deforestation in the Amazonia and Cerrado regions) also have great impacts on the emission of GHG, as can be seen in Figure 12 [41–45].

Therefore, even though the energy matrix in Brazil is considered clean, if the motivation to use electric cars is considered a uniquely environmental issue, aiming to combat environmental pollution and to contribute positively to avoiding climate change, some factors must be highlighted for decision-making:

- Comparing the efficiency of the electric motor to the internal combustion engine (ICE), from 90 to 97% efficiency can be seen in the electric motors used in vehicles, while the most modern internal combustion engines show an efficiency in the range from 35 to

40%. Thus, fossil-fuel cars need around 2.5 times more energy for the same traveled distance, which leads to higher CO_2 emissions [46].

- The transport sector in Brazil is responsible for 32.7% of the country's energy consumption, surpassing the industry sector for the second consecutive year [47].
- Among the vehicle categories, private cars and heavy trucks are the main emitters of CO_2 [28] and, therefore, the ones that generate the most significant impact on the transport sector in Brazil [48–50] (Figure 14). For this reason, they should be the priority in the case of public policy interventions.
- Among the fuels currently used in the country, there are two factors to consider: the type and CO_2 emissions. Regarding the type of fuel consumed, there was an increase in ethanol and gasoline and a decrease in diesel usage in the last ten years. Regarding CO_2 emissions, diesel is the most polluting, followed by gasoline and ethanol. When analyzing the entire life cycle, from cultivation to end use, with the burning of fuel, diesel and gasoline have significantly higher impacts than ethanol (considering the production phase). Ethanol's use as a fuel can reduce the GHG emissions derived from vehicles (Figure 13) [51–53].

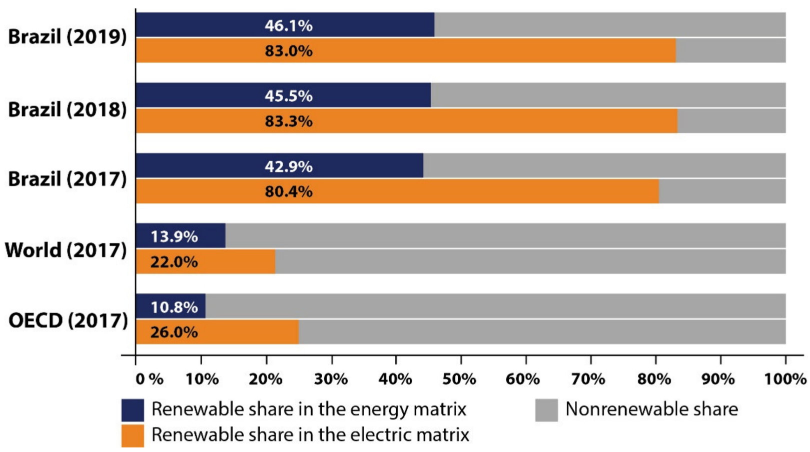


Figure 11. Renewable energies in the Brazilian energy and electric matrices. Adapted from EPE(2018, 2019, and 2020).

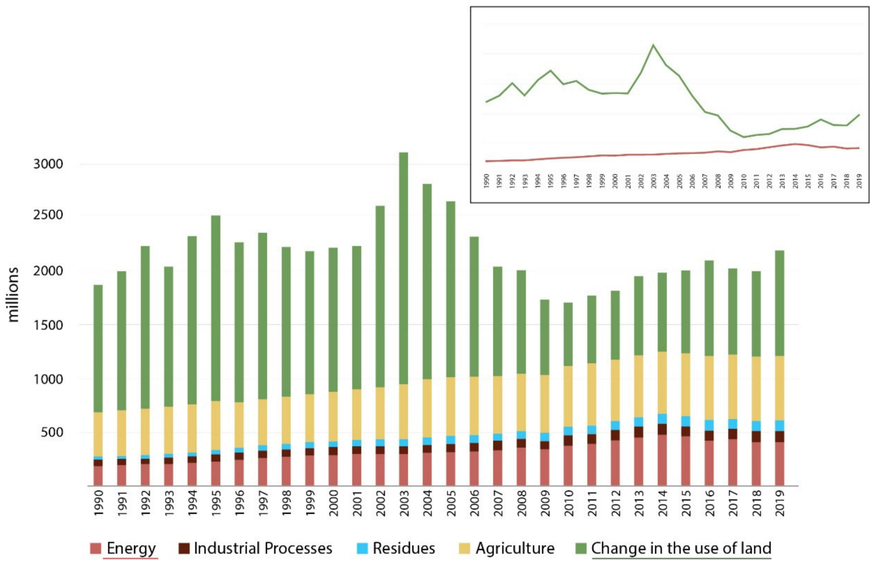


Figure 12. GHG in Brazil between 1990 and 2019 (in MtCO2e). Source: Adapted from Climate Observatory (2020).

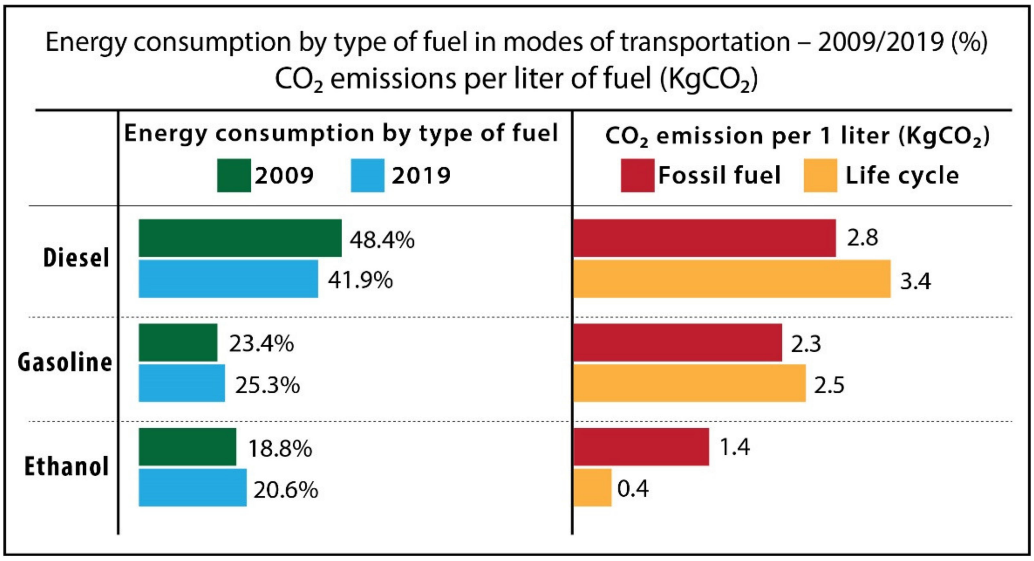


Figure 13. Types of fuel (transport consumption and CO_2 emissions). Adapted from EPE (2010 and 2020) and Sustainable Construction Brazilian Council - CBCS (2010).

Hence, it can be observed that, from the environmental perspective, the transition to a uniquely electric fleet in Brazil does not seem to be a pivotal need. On the other hand, there is an increase in the ethanol share among the fuels used. Therefore, the adoption of ethanol hybrid cars (electric and ethanol) indicates an adequate solution to the matrix of transport. Moreover, the already existing distribution infrastructure and the high investments necessary to fully adopt electric cars justify this solution [54].

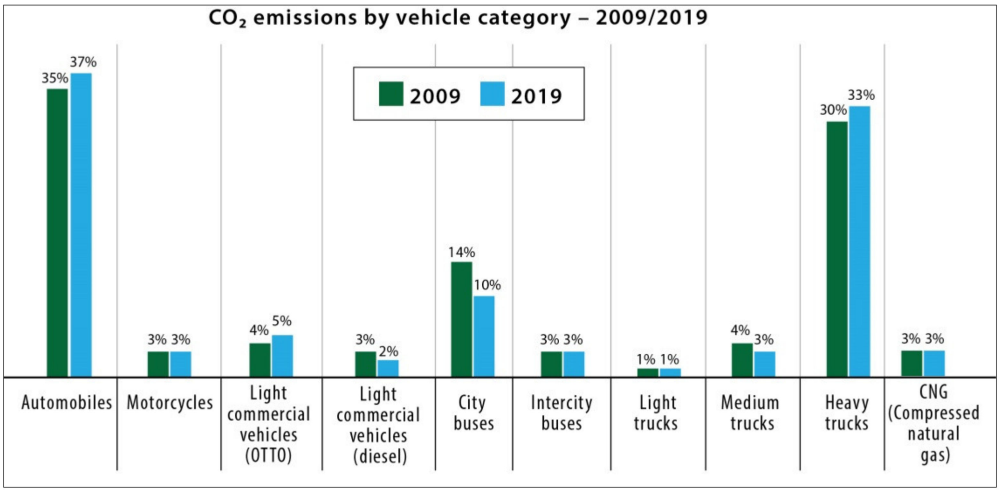


Figure 14. CO_2 emissions by vehicle categories—2009/2019. Adapted from Brazilian Ministry of the Environment—MMA (2011, 2013).

5.2. Electric Cars Integrated into the Electric Grid in Cities: A Possible New Meaning for Electric Cars in the Brazilian Market

In addition to the environmental aspect, electric cars can also be considered a tool to balance the incompatibility between energy supply and demand [24,55,56] through the vehicle's intelligent ways of charging from and discharging to the grid [57,58]. In the context of the insertion of sources of intermittent energy generation (solar and wind, for example), this means that, more than a means of transport, electric cars could be incorporated into the electrical system, guaranteeing firm and higher quality energy, to reduce consumer interruptions and to improve the voltage and frequency levels of the power grid [59]. In this regard, it is essential to highlight the projected growth in the installed capacity of intermittent sources in the system: wind (from 9% to 16%) and solar (from 2% to 8%) in the Brazilian electrical matrix, between 2019 and 2029 [40].

Looking at electric cars from distinct perspectives, other applications arise. For example, electric cars, when integrated into the power grid, can change the demand curve for electric power and can still make money on the car, acting as a battery bank for the electric system. Battery charging can occur at alternative times, such as when energy is cheaper (at dawn, for example), and provides energy at the time of day when energy is most expensive and demand is highest. In addition, in an environment with the future expectation of intense solar and wind power insertion and with hydroelectric plants representing more than 60% of all electricity generation, it is of the utmost importance that storage systems are installed in the country to guarantee firm and stable energy. Electric cars can also function as energy stores, reducing the investments needed for significant storage levels and mitigating transmission losses. In this way, EVs can also contribute to a more stable system and a lower total cost for the electric energy generation, transmission, and distribution companies. In addition, consumers may take advantage of tariff modicity.

Numerous types of services, including ancillary services, can be provided by EVs with two-way charging in a smart grid (Figure 15).

"Most analysts focus on the potential for electric vehicles to decrease dependency on petroleum fuels and reduce GHG emissions when charging with non-fossil sources of electricity. In addition, there may be benefits to the grid itself. First, EVs can increase the grid's stability with coordinated charging (in a grid-to-vehicle or G2V mode). Second, EVs can strategically return stored electricity to the grid to increase capacity and provide ancillary services such as frequency regulation and reserve capacity (in a vehicle-to-grid or V2G mode) [60]. Finally, EVs plugged into homes, office or businesses (in a vehicle to buildings or V2B mode) can provide backup and emergency services to consumers and can activate charging in response to the grid's need for end-use consumption when prices are negative." [61].

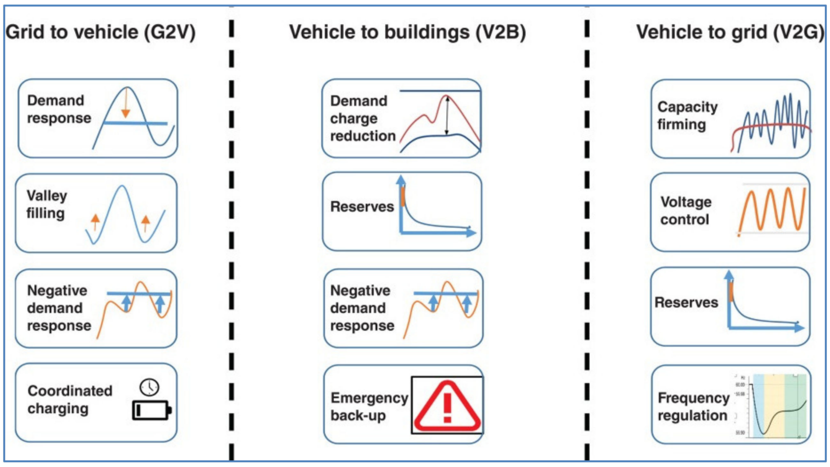


Figure 15. Business models for electric cars. Reprinted from Brown et al. (2018).

Therefore, electric cars go beyond a technological innovation for the means of transportation: they can represent a change in meaning, whether for consumers of electricity, electricity, or vehicle owners. Hence, the main questions grounding our survey were as follows: Do consumers in Brazil have this perception? How do they perceive electric cars? Do potential consumers of electric cars still see them as a means of transportation that, compared with combustion cars, is less polluting and brings technological innovations, or do they already attribute another meaning to it, related to its incorporation into the electric power system? Are energy concessionaires, regulators, car manufacturers, and government leaders ready for the changes demanded by the adoption of electric vehicles?

5.3. Electric Vehicles and Alignment with the Sustainable Development Goals (SDGs): Brazilian Context

The adoption of electric cars may support achieving the SDGs, mainly concerning the following objectives:

- SDG 7—Ensure access to affordable, reliable, sustainable, and modern energy for all. This goal, above all, when considering business models that integrate electric cars into the power grid, is to allow for the insertion of more extensive projects for solar and wind generation (target 7.2) and to provide greater efficiency to the electrical system (target 7.3).
- SDG 9—Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation. This goal, mainly concerning target 9.4, is to upgrade infrastructure and to retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes.
- SDG 11—Make cities and human settlements inclusive, safe, resilient, and sustainable. This goal particularly concerns the following targets: 11.2, which aims to provide access to safe, affordable, accessible, and sustainable transport systems for all, improving road safety, notably by expanding public transport; 11.6, which aims to reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality.
- SDG 13—Take urgent action to combat climate change and its impacts. This goal mainly concerns target 13.2, aiming to integrate climate change measures into national policies, strategies, and planning.

Brazil's attempts towards achieving such SDGs is of median effort (Figure 16) [62]: regarding the goals related to climate change and clean energy (SDG 7 and SDG 13), it is on track to achieving the established goals; concerning the SDG 9 targets, it is stagnant, and there are still significant challenges; and regarding the goals of SDG 11, it is developing at a moderate pace and still faces challenges in their full achievement.

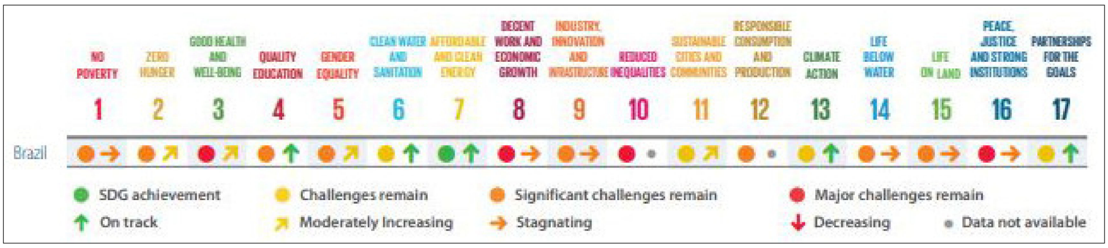


Figure 16. SDG achievements. Reprinted from The Sustainable Development Report 2020—The Sustainable Development Goals and COVID-19 (2020).

In summary, regarding the SDGs that can be boosted by the adoption of electric cars, foreseeing strategic actions and national policies, the following can be said:

- Brazil has achieved the goals related to clean and accessible energy (SDG 7) but needs to install distributed systems for solar and wind generation;
- There are still challenges associated with CO_2 emissions associated with energy (SDG 13), but the country is developing well, and should reach its goal by 2030;
- There are significant challenges related to the quality of the public transport system, including its infrastructure, and the country is stagnant (SDG 9); and
- There are challenges to be faced concerning people's satisfaction with public transport, in which the country is developing at a moderate pace (SDG 11).

The goals related to SDGs 7, 9, 11, and 13 must be relay targets so that Brazil can contribute effectively to its 2030 Agenda and thus achieve the goals of sustainable development. This perspective is in line with that of Oliveira et al. (2019) [63]. In this scenario, aiming to contribute to achieving the SDGs, creating strategies for members of the public that are not assisted by public transport, and reporting complete dissatisfaction can be introduced into the EV market in Brazil.

5.4. Electric Cars in Brazil: Relevant Aspects in the Current Scenario

The fleet of e-cars in Brazil is still small. In 2018, the estimated number was 10,590 electric and hybrid vehicles, according to the Infrastructure Brazilian Center (CBIE). This is equivalent to almost 0.05% of that year's existing fleet. The vehicles priced above USD 22,300.00 represented only 4.5% of the total sales in Brazil, independent of type. This means that it is a market niche for luxury vehicles. In 2019, there was an increase in sales and the fleet reached 11,858 cars, 5% of which were fully electric and the remaining of which were hybrids or plug-in hybrids. According to research carried out by Bright Consulting [64,65], the projections for 2020 were a setback to the pre-2019 framework due to the COVID-19pandemic. However, the electric fleet has reached a total of 19,745 vehicles (Table 2) [66].

Table 2. Total number of EVs sold in Brazil per year (2018–2021). Source: ABVE, adapted from the authors.

Year	Total Number of EVs Sold in Brazil
2018	3970
2019	11,858
2020	19,745
2021	7290 (Jan–Apr)

Another relevant issue related to electric cars in Brazil is the average acquisition values that varies from approximately USD 30,000.00 (JAC) to USD 150,000.00 (Porsche) (Figure 17) [67,68]. These values are compatible with values for luxury fossil-fuel cars. Additionally, the costs of maintenance and fuel are relevant. In Brazil, gasoline is considered expensive and ethanol is considered an alternative that could be economically more attractive to consumers. Even though the values may vary according to the sugar cane crop and the estate, ethanol may be a good option. Solely considering the environmental aspects and the values of electric cars in Brazil, users may not realize the considerable advantages in transportation running on electricity compared with the ones running on ethanol.

Batteries are also a factor of uncertainty for a Brazilian driver. The problems related to the battery are, for instance, the inexistence of clear rules regarding the battery destination (disposal, reuse, and second-life battery), its life, and the consequent need for replacement. Until recently, the battery life cycle was expected to last two years in the vehicle. Then, it would need to be replaced. After that, it would become stationary and could have other uses in distributed hybrid solar systems. In 2019, Elon Musk announced that the commercialized battery of the Tesla Model 3 had a life cycle that could vary from 300,000 to 500,000 miles, that is, approximately 500,000 to 800,000 km [69–71]. A new promise is the commercial launch of a battery with a life cycle of 700,000 to 1,000,000 miles. Considering that, on average, a fossil-fuel engine lasts for around 250,000 km, compared with the technology announced regarding electric vehicles in 2019, this is equivalent to half the time needed before battery replacement is required. With the new technologies and new materials (graphene, sodium, and solid-state, for example) tested for battery manufacturing, the need for battery replacement is no longer at the same level as it is currently understood.

Charger standards are also a challenge in the electric car market in Brazil, as there is still no defined standard and several types are used.

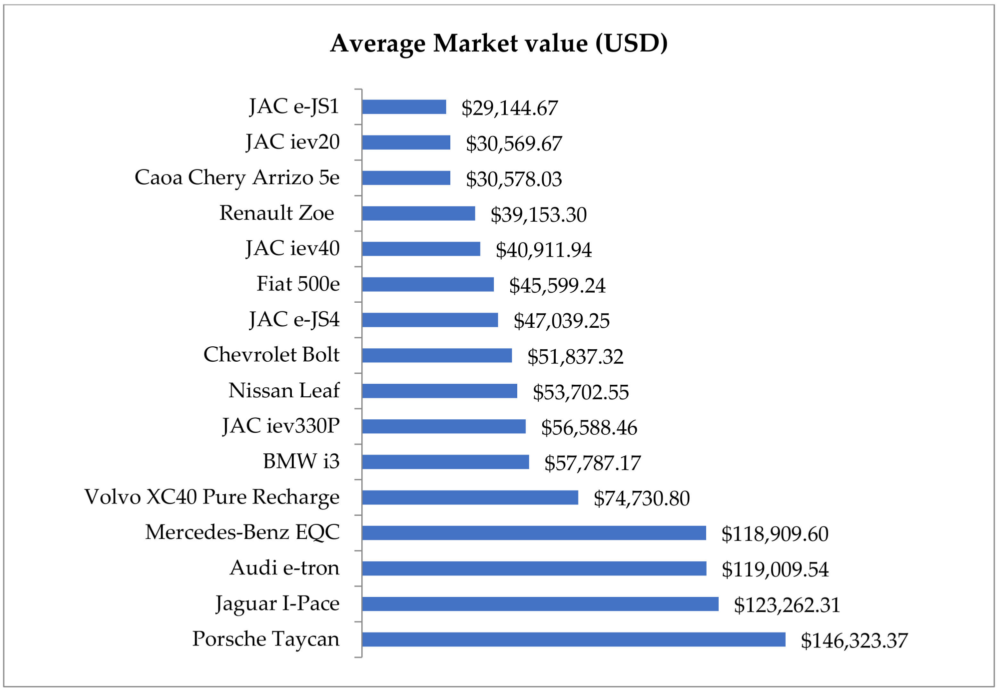


Figure 17. EV acquisition values in Brazil in 2021 (in USD, considering the rate BRL 1,00 to USD 0,19). Source: FIPE—Institute for Economics Research Foundation.

Concerning the current legislation, Aneel Normative Resolution 819/2018 [4] regulates the following:

- Charging stations for electric vehicles are allowed to be used only in one way (G2V—grid to vehicle)
- The registration of charging stations is open to any interested party. Thus, any interested player is allowed to carry out recharging activities for EV, including activities for commercial exploitation at freely negotiated prices, the so-called public recharge, and the local distributor can install charging stations in its area of operation for public recharging of electric vehicles.

Considering the regulations mentioned above and that many consumers already use smart meters for distributed generation in the country, it would be relevant to review this rule, enabling the vehicles to supply energy to the grid (V2G). In this case, the change in the meaning of the electric cars perceived by Brazilians is significant. Furthermore, as mentioned earlier in this paper, once the transportation sector in Brazil is responsible for the highest energy consumption, and cars and heavy trucks are the ones that mainly emit CO_2, public policies that consider electric vehicles are necessary to reduce the greenhouse effect, mainly because this country has one of the cleanest electric matrices worldwide.

Incentives are scarce in the country. In seven Brazilian states, owners of vehicles powered by electric motors are exempt from the Tax on Motor Vehicles (IPVA) and, in three states, electric vehicles have a differentiated IPVA rate. The other 17 Brazilian states should adopt this policy.

Finally, at present, the time needed to refuel is considered a disadvantage for a Brazilian user. However, this issue suffers from the impacts of interpretation when it no longer refers to the habits of fossil cars. The lack of knowledge about the estimated value required to keep the vehicle loaded can also be a barrier. In Brazil, both electricity and fuel are considered expensive. However, when considering a person who travels 1000 km per month with a car, the amount spent on fuel can be around six to eight times more than that for electricity recharging. Thus, these factors are relevant to better understanding and analyzing the data obtained in the research.

5.5. Electric Cars and the Innovation Issue

EVs are constantly associated with technological innovation. However, when thinking about innovations in electric cars, from the perspective of the "car system" (Figure 18) composed of subsystems (engine, body, chassis, electronic components, electrical components, and others), it could be considered an incremental innovation [72] because it refers to a modification to the subsystem, driven by new technology, of a product in which the primary function is as a means of transportation.

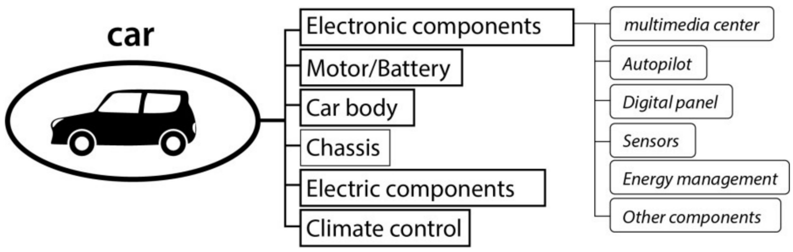


Figure 18. Example of the "car system" and its subsystems. Adapted from Pugh (1991).

When analyzing the "car system" from 100 years ago and of the current electric car, it is notable that current cars retain similar characteristics and maintain the function of a means of transportation. New technology now allows cars to be powered by electricity. The business models and meanings, however, remain the same.

Technologies also bring innovation to EV factories. Tesla factories entirely devoted to producing electric cars are examples of that. The company has established a closed-loop, green, vertically integrated supply chain consisting of batteries, electric cars, and charging infrastructure to meet its customer's needs [73]. Nonetheless, considering the user's point of view, the meaning of electric cars remains a means of transportation.

Considering the possibility of integration into the electricity grid, a new type of innovation may arise: "disruptive of meaning." In the context of fossil-fuel cars, the function of the batteries that make up the electric subsystem and other components is to fulfill the role of starting the engine (ignition system). In electric vehicles, the new components of the "electrical components" subsystem may have new meanings: the battery, more than just making the car move, is now able to be integrated into the city's electrical system and has the capacity to store energy, expanding the function of the car, which had been only to transport the user. This function gains more importance as the intermittent characteristics of renewable energy sources still lack solutions for delivering "steady energy" to the system. It is a radical and meaningful change.

Radical changes in meanings call for radical changes in sociocultural models. This process is not immediate, as seen in earlier projects dealing with electric car adoption [33]. Users need to understand the radical new language and message, to find new connections with their sociocultural context, and to explore new symbolic values and patterns of interaction with the product. In other words, radical innovations of meaning call for profound changes in sociocultural regimes, in the same way that radical technological innovations call for profound changes in technological regimes [74]. This change in meaning must consider the need for future changes in Brazilian legislation. At present, only G2V is allowed in this market. Thus, there is a need to adapt the regulations to allow for more modern business models (V2G and V2B).

The key issue is identifying how potential consumers in Brazil perceive electric cars: as an innovative means of transportation or using a new interpretation, giving these products new meanings beyond the function of transportation. This understanding is relevant. The way the market absorbs the product will guide the required measures: if perceived as a means of transportation, then the car's production chain will be impacted and must adapt to the new reality; if perceived as part of the electrical grid, then a new system is formed, composed of different actors and demanding other measures. The agencies responsible for regulation and incentives, in turn, have a fundamental role in the strategic measures that will guide and encourage those involved, from the primary suppliers to the final consumers, directly impacting the success of the new product and its associated services.

While existing literature discusses the role of EV from technology and environmental perspectives [11–15,22,23,75], user perception and how it impacts the market adoption are scarcely presented as key factors impacting the overall scenario, as seen in the Brazilian case.

Electric cars, as a form of innovation, require a change in user perception, and it is essential to identify their sociocultural and emotional aspects. This type of innovation, by nature, requires questioning the values and symbolic patterns of interactions with the product and demands more time than other types of innovation before its wide adoption by a market. In this context, it is valuable to keep in mind that the emotional impact of experiences greatly influences the meanings that are attributed to them. It is a slower process: a negative emotion is more difficult to forget in the same way that emotional bonds make one loyal. Prioritizing the emotions and meanings of users' experiences is a crucial factor. In this sense, different stakeholders must be invited to participate in and compose the new scenario.

6. Conclusions

According to the survey results, electric cars are currently perceived only as a means of transport. The possibility of integrating it into the grid is unknown to most potential car users. There is no resistance from users regarding the integration of electric cars into the city's energy system, but there is a lack of knowledge. The main barriers to the acquisition of electric cars, at present, are the current values and the currently existing infrastructure.

Other conclusions of the study that can be highlighted are as follows:

- Concerning climate change and the reduction in GHG, as the Brazilian electric matrix is clean and the country uses ethanol as fuel, the transition to a solely electric fleet in Brazil is not considered an emergency if the appeal is only environmental, as occurs in other countries. Still, from the perspective of contributing to GHG reduction, Brazil has other issues that need more attention and more aggressive policies, such as illegal deforestation activities.
- Regarding achieving the SDGs, electric cars have little influence on the goals related to environmental issues (SDG 7 and SDG 13). However, if EVs are introduced to the market with strategies and technologies that can serve audiences who do not own a car (groups 3 and 4) and depend on public transportation, they will be able to contribute to overcoming significant challenges for the country.
- Regarding regulations, the country lacks public policies in the electric mobility sector. These, if oriented towards smart cities, can contribute significantly to advances in the transition from current cities to smarter and more sustainable cities.
- The growing incentive for the 5570 municipalities to make cities smarter includes investments in smart grids. Moreover, the increase in the share of solar energy in the Brazilian matrix, the growth in the number of prosumers, and measures focused on distributed generation are growing in scope and importance. Urban mobility is also a topic of discussion in smart cities. That is, among the two scenarios presented in this study, the second seems to make more sense in the Brazilian context.
- Brazil is lagging behind other countries that already make full use of electric cars. New technologies offer longer-lasting batteries and more affordable values. The business models that make it possible to integrate cars with the city grid and to re-signify them to users can be considered a starting point for the emergence of new services.
- Despite the exponential growth of EV's sales in Brazil, the present scenario points that the future of electric cars in Brazil is highly dependent on the market values and the development of the infrastructure, especially those related to recharging activities. Therefore, incentive policies focused on those two issues are highly suggested.

To follow a long-term trend regarding the users, it is crucial to know their profile and how future drivers and new citizens think. These will be the consumers of vehicles as a means of transportation, and the residents that are integrated into the electric energy grid.

Finally, the results indicate that there are research gaps and opportunities for new studies and new markets for service design in electric mobility and smart cities; public policies for smart cities; communication about EVs themselves, and new businesses associated with EV and their integration into the electrical system; service technologies (ICT) associated with smart grids; and the battery industry. In addition, to effectively contribute to decision-making by the main stakeholders involved in the entire production chain, it is essential to hear the most impacted sectors (electrical, oil and gas, and automotive) and the regulatory agencies. Table 3 summarizes the conclusions.

This article contributes to the sustainability transition studies by contextualizing the electric car market in Brazil, by identifying if consumers perceive EVs as a substitute for combustion cars, in which the primary function is as a means of transportation, or as part of the city's electrical system, expanding its meaning and use and, therefore, creating new markets and opportunities for the sustainable transition. Furthermore, this study raises key aspects such as a lack of knowledge about V2G among final users, how it would operate as part of the grid and as a means of transportation, and reduced incentives to adopt policies to regulate insecurity regarding insufficient infrastructure that needs to be taken into account in the new research and developments in this field.

Table 3. Conclusions.

Conclusions	
Current user's perceptions on the meaning of the electric cars	Electric cars are currently perceived only as a means of transportation.
Current perception of the possibility of integrating EVs in the city grid	Unknown to most potential car users. There is no resistance from users. There is a lack of knowledge.
Climate change and the reduction of GHG	The transition to a solely electric fleet in Brazil is not considered an emergency—Brazilian electric matrix is clean, and the country uses ethanol as fuel. Brazil has other issues that need more attention and more aggressive policies, such as illegal deforestation activities.
SDG	Currently, electric cars have little influence on the goals related to environmental issues (SDG 7 and SDG 13). However, if EVs are introduced to the market with strategies and technologies that can serve audiences who do not own a car (groups 3 and 4) and depend on public transportation, they will be able to contribute to overcoming significant challenges for the country.
Regulation	The country lacks public policies in the electric mobility sector. These, if oriented towards smart cities, can contribute significantly to advances in the sustainable transition.
Current EV market	Brazil is lagging behind other countries that already make full use of electric cars.
Market opportunities	Recent technologies offer longer-lasting batteries and more affordable values. The business models that make it possible to integrate cars with the city grid and to re-signify them to users can be considered a starting point for the emergence of new services.
Gaps and opportunities for future studies and new markets	There are research gaps and opportunities for novel studies and new markets for service design in electric mobility and smart cities; public policies for smart cities; communication about EVs themselves, and new businesses associated with EV and their integration into the electrical system; service technologies (ICT) associated with smart grids; and the battery industry.

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