

# The New Neighbor across the Street: An Outlook for Battery Electric Vehicles Adoption in Brazil

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## 1. Business Models for Battery Electric Vehicles

Technological breakthroughs bear the potential to reshape the entire mobility sector e.g., electrification, autonomous driving, and shared mobility. This new scenario implies that automotive and transportation BMs might look completely different in a few decades. Furthermore, 5G technology irruption is expected to greatly improve BEV communication and networking [1]. Value creation is anticipated to mutate: Mc Kinsey & Co [2] stated that shared mobility and connectivity solutions could account for up to 25 percent of total automotive profits in 2030. In fact, OEM automation is likely to have a severe impact on the workforce compelling OEMs to ensure a profit in the aftersales and data management [3]. The new circumstances will force industry players to better prepare on customer service, including the disruption of mobility as a service (MAAS) [4].

### *New Business Models Feasibility*

Electrification will likely imply a multitude of emerging BMs and the transformation of traditional BMs core elements, such as the value proposition and the revenue model, as they were defined by Lehmann-Ortega & Schoettl [5]. Value creation will display new features and involve new players. However, the environmental appeal of BEVs will remain a driver for adoption. BEV related BMs are expected to present lower environmental burdens than traditional ones. Lüdeke-Freund [6] emphasizes that, as in any BM, the business core is to create and deliver customer value while reducing the environmental impact. Thus, without financial sustainability BEVs appear only as a more expensive substitute for ICEVs, by adopting a traditional BM, electrification will bear no chances of striving in the new market [7]. Traditional ICEV business models are product-oriented; the value is focused in the vehicle purchase. A Product-Service System (PSS) refers to an entire ecosystem for business initiatives [8]. Literature offers evidence of at least three PSS types: Product Oriented, Use Oriented, and Result Oriented [9]. A more detailed definition of BM, sustainable BM, PSS and its types is found in the Supplementary material.

Cherubini et al. [10] identified ten critical factors for the success of a PSS: Two related to the vehicle (value proposition and pricing strategies to distribute the initial investment and reduce the risk); one factor bound to on-board electronics (efficient and trustworthy navigation system); three factors related to required infrastructure (alternative transport systems, divulgation campaigns, incentives,) and three related to car-energy interactions (proximity to charging infrastructure, ease of use, and standardization).

So far, experts are uncertain about which specific BMs will succeed. Nonetheless, those focused on services, instead of products, and cooperative use of goods, instead of ownership, are thought to have an advantage [4,6,10–18]. Cooperative utilization of BEVs will be driven by high tag prices, scarcity of parking spaces in urban areas, the decline of the vehicle as a status symbol, and air quality awareness [7].

It is also uncertain if established companies or new entrepreneurs are more prone to lead the market towards a sustainability transformation [14]. Governance structures inside big firms might constrain them in taking new paths for value creation, as they prefer to stay close to past successes. In contrast, new entrants ought face powerful incumbents and lack of resources to sustain research for long periods [19]. In opposition, more flexible entrepreneurship may identify new sources of value creation more easily [13]. Furthermore, there is uncertainty on how long the technological substitution of ICEVs by BEVs is going to take. Adner and Kapoor [20] believe it will arrive only in

the long term, arguing the ICEV technology is highly resilient to substitution due to the complex ecosystem established around it, whose demise might take decades.

Competitiveness is the holy grail of new BMs. Yang et al. [17] study aimed to rediscover disregarded value opportunities and to identify uncaptured value. Some uncaptured value is visible, e.g., co-products, under-utilized resources and reusable components whereas it is sometimes invisible, e.g., insufficient use of expertise. Related to electrification, competitiveness relies on several factors, such as technology maturity, business strategy and social barriers to adoption [11].

Risk management has also proven crucial. In carsharing schemes, the risks are all assumed by the service provider and are included in the fees along with electricity costs. Although carsharing promotes change in customer behavior and exhibits potential for value cocreation between customers and the carsharing provider [21] it might not be enough to guarantee the business feasibility. For instance, French carsharing service Autolib (2011–2018) operated around 4000 vehicles and 1000 EVSEs at its heyday [22]. However, an increasing debt lead to the municipality of Paris to end its contract [23]. The operator attributed the failure to changing mobility patterns of Parisians and competition.

BM are expected to become more complex, which does not necessarily mean new products or services but new ways to deliver a service and capture value from it [16]. A summary of key parameters to achieve the financial viability, key elements to be defined in the value proposition and key elements in the electrification value chain is displayed in **Error! Reference source not found..** Although promising, the synergic deployment of these parameters can prove complex. Definitions of value proposition, value chain and business model elements are found in **Error! Reference source not found..**

**Table 1.** Key parameters for business models success in the BEV sector.

Parameter	Features
<b>Key parameters for service-focused business models</b>	
Optimized use of vehicle capacity	Carsharing and vehicle fleets management allow increasing the number of users to abate operation costs, dividing the capital investment among many customers.
Extended utilization concepts	Based on the use of extended functionalities and incorporation of new tools. For instance, off-peak charging, when energy is cheaper and even potentially feeding power back into the grid during peak hours in the future.
Life extension	Using batteries, no longer fit to be used in the vehicle, for other uses, specifically stationary applications. It aims to increase their residual value and dilute environmental burden.
Complements for increasing acceptance	For instance, real-time and customer-oriented information about the nearest available EVSE being integrated into the BEV navigation system. Moreover, to address range anxiety, the backup support of an ICEV could be offered for long journeys.
<b>Key elements to be defined in the business model value proposition</b>	
Battery and vehicle ownership	One question summarizes it all: who owns the battery and for how long? OEMs, leasers, final customer?

Metering and billing for EVSE	Considering the EVSE systems can be public, semi-public or private. How to integrate into a reliable system which also allows roaming?
Integration of BEVs to public transport	How to successfully integrate the use of BEVs to urban public transport systems? It should include GPS services and foresee future development of connectivity with the grid. Especially for last mile trips
<b>Key elements in the electrification value chain</b>	
Vehicle and battery production	Technological development of the battery and the design of pure native electric vehicles, reduction of tag prices.
Charging infrastructure	Standardization and construction of a network able of metering as billing tasks.
Data management and additional services	The definition of a BM able to reach profitability. Stakeholders will be daunted to invest in networks until BEV sales and charging infrastructure pick up scale.
End of life	It will settle once a considerable BEV fleet is reaching the end of their lives. Second-life and recycling are expected to thrive, depending on a sufficiently large price gap between second-life and new batteries

Adapted from Kley et al. [16], Laurischkat et al. [12], Weiller & Neely [11].

**Table 2.** Business models elements and definitions.

Study	Term	Definition
Lehmann-Ortega & Schoettl [5]	Elements of a business model	<p>(i) The value proposition: considered as the value of a product as promised by the manufacturer to any clients in exchange for their money. For instance, in the traditional ICEV model, the manufacturer offers a quality vehicle</p> <p>(ii) The value chain configuration: describes the possible activities, executed by the different shareholders, in the entire business environment of the product. For instance, the fueling, maintenance, insurance, and other services in the aftersales of a BEV purchase;</p> <p>(iii) The revenue model: defines the form of retribution for the product obtained. The revenue model for traditional ICEVs refers to the money the customer pays the OEM in the form of a tag price.</p>
Lüdeke-Freund [6]	Sustainable business model	A sustainable business model is one that creates competitive advantage through superior customer value and contribution to the sustainable development of the company and society.

Mont [8]	A Product-Service System (PSS)	A system of products and services, supporting networks and infrastructure that is designed to be: competitive, able to satisfy customer needs, and present a lower environmental impact than traditional business models.
Teles et al. [9]	A Product-Service System types (PSS)	Literature offers evidence of three PSS classes: Product Oriented (PO), Use Oriented (UO), and Result Oriented (RO). PO refers to businesses, which in addition of selling a product, provide a service associated to it, e.g., after purchasing a car it needs repairing, maintenance, insurance and financing. Ownership is transferred to the customer during purchase. In UO, the company does not offer a physical product, but guarantees its availability through lease agreements, often shared by multiple users, however, the ownership is not bestowed to the customer. Carsharing is a good example. Finally, in RO scheme, a firm provides the customer with a particular result, for instance, being transported from point A to B. Service provided is paid by the result. Uber and Cabify are good examples

Complementary services are fundamental in establishing the surrounding ecosystem of electric transport. Data on vehicle consumption and performance will likely be monetized in the future. The massive use of data and artificial intelligence is expected to increase the efficiency of energy use. In fact, researchers are currently able to estimate the required public EVSEs, given a certain share of BEVs in the car fleet, for a specific area [24]. Another additional services might include parking, or complementary services to provide flexibility in urban areas, e.g., a membership for carsharing and car or bicycle rentals with discounts [12].

## 2. Available Charging Technologies

AC charging is available for several types of plugs: type 1 also known as SAE J1772 and type 2, standardized by the German Association of Automotive Industry as VDE-AR-E 2623-2-2. Tesla possesses its own exclusive connector while Chinese OEMs possess their own, which is similar to type 2 connectors. Regarding DC we found CCS combo 1, mainly used in the USA. CCS combo 2, mainly used in Europe. CHAdeMO, built by Japanese OEMs. Tesla DC connector and Chinese GB/T technology [25–27]. A classification of different charging technologies is included in Martinez-Lao et al. [27] and Dericioğlu et al. [26] while a brief summary can be found in Section 2.1.

### 2.1. Charging Infrastructure Classification

Charging infrastructure can be classified according to the power provided to the vehicle. Slow charging units, or Level 1 (L1) charging, deliver power at up to 3 kW with some devices working at 6 kW. Charging times vary depending on the vehicle and the EVSE. A full charge on a 3-kW station, for a 30 kWh BEV, usually takes 6–12 h; these devices are usually found at homes. Semi-fast chargers, also known as Level 2 (L2), are typically found at 7 kW–22 kW (single or three-phase 32A). A 7-kW charger connected to a 30 kWh BEV takes 3–5 h to charge while a 22-kW charger takes about 1–2 h. These EVSEs are commonly found in workplace parking spaces. Finally, Level 3 (L3) or fast chargers are generally placed in highway convenience stores, gas stations or in heavily visited places, such as malls.

Fast charging devices supply the highest power, usually from direct current (DC), but are also available in alternating current (AC) for a few models like the Renault Zoe [66]. Fast stations can

recharge a vehicle to 80% in 20–40 min. The charging unit diminishes the power flow once the battery is charged at around 80%, aiming to extend its life. The concern of decreasing the lifetime of the grid transformer due to overloading is a constraint also. Fast charging can be demanding; a conventional fast charging EVSE supporting four sockets, would need charging capacity in the megawatt range [65]. One demand-side approach for dealing with the high power demanded by fast-charging stations might be a dynamic pricing scheme for charging. In contrast, studies suggest that fast charging stations present the largest charging efficiencies of all EVSEs [66].

## 2.2. Charging Infrastructure Deployment Globally

Building a widely available public charging infrastructure has been identified as one of the main drivers for vehicle electrification, an appropriate distribution of EVSEs would eliminate range anxiety [28]. The installation and operation of EVSEs demand the cooperation of grid operators, in charge of electricity distribution and charging station operators, who remotely control the EVSE. Equally important are the city planners, financial entities and EVSE manufacturers. These players are defined more in depth ahead in this chapter. This articulation requires government support and clear policies to facilitate cooperation among stakeholders [29]. Private charging does not require large articulation or cooperation.

Currently, there is no standardization of charging technology, in fact, competition for market supremacy is very much going on [30] and can be perceived by the number of different charging plugs available in the market. OEMs dedicate efforts to gain an advantage by developing plugs and communication protocols to connect batteries to EVSEs [26]. Plug technology competition will award the OEMs supporting the surviving technology by assuring a position in an established supply chain and granting an extensive EVSE network [30].

Parallely, a whole business ecosystem of additional services is being created around EVSE deployment. Additional services for EVSE localization are expected to be crucial. GPS based maps to localize EVSEs can be currently found in the United Kingdom [31], the US [32,33], The Netherlands [34], Austria [35], Estonia [36], New Zealand [37], and the entire Europe [38]. These applets include location, EVSE technical specifications and availability.

In the future, Smart Charging (SC) will imply larger network complexity for public charging. SC can be defined as externally controlling variables in the charging process (charging time and duration, intensity, direction of power flow), allowing the BEVs to deeply integrate into the whole power grid [39]. For SC, the presence of the electricity local provider or distribution system operator (DSO) is quite relevant. Other important roles are the transmission system operator (TSO), responsible for network frequency stability, and the balance responsible party (BRP) which predicts and trades energy for net stability. So far, there are no established standards for SC although some protocols already exist, e.g., OpenADR, which is generic and aimed at demand-response; IEEE 2030.5, aimed at in-house smart grid solutions and OSCP, primarily aimed at network availability forecasts [40]. Eurelectric [41] defined different BMs for public EVSE. The main differences dwell on who is the owner of the EVSE and who is in charge of the sales. A summary of those market schemes for public charging is found in Section 2.3, **Error! Reference source not found..**

The system created when a BEV integrates into the electricity grid to purchase or sell energy is known as Vehicle-to-Grid (V2G). Although it promises a flexible charging [42], larger transmission efficiency and even lower environmental burdens [43] V2G will display low potential for grid services as long as BEVs remain a niche product [11]. Thus, it is unlikely that OEMs, DSOs or software companies could prioritize the development of architecture to enable V2G services without a significant BEV fleet. This study deemed V2G as unfeasible in Brazil, for at least, the next decade.

## 2.3. Public Charging Market Schemes.

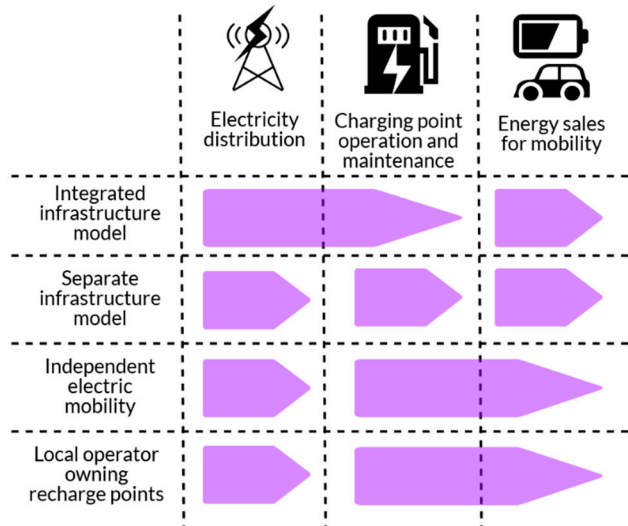
The “Integrated Infrastructure” scheme implies that the public EVSE is integrated into the DSO assets. Thus, the DSO is responsible for installation and operation of the equipment. This scheme represented the Brazilian case for public EVSE before the Brazilian National Agency of Electric Energy (ANEEL) resolution N°819-2018 which legalized the sale of electricity. Before resolution

Nº819-2018, electricity sell was illegal. Under this model, any commercial relationship happens between the DSO and the final consumer. The required investments for infrastructure development and any complementary services are financed through charges included in the cost of the network. Thus, the infrastructure costs are integrated into the regulated electricity tariff.

In the “Separate infrastructure” model, the EVSE does not belong to DSO assets. In this case, a CPO exists to guarantee access to the charging network for all sellers of energy, in case there is more than one. In this scheme the CPO and the energy vendor are separate entities, so the CPO charges the energy seller an access rate to the EVSE, which renders the electricity used in mobility more expensive than the regulated tariff.

The “independent electric mobility” requires the participation of a new agent, the EMSP, who in addition to owning the EVSE, offers a set of mobility services for the customers (parking, rental, etc). On a similar scheme, a local operator owns the EVSE, thus, the EVSE and the sale of electricity are controlled by parking operators. These players install EVSE in parking spaces and control the sale of energy as well.

Finally, in order to verify the transactions between the different agents, a CH platform is included, whose task will be to organize the energy and financial balance of the EVSE network between the CPOs and the EMSPs [44].



**Figure 1.** Market schemes for public charging infrastructure. Adapted from Eurelectric [41].

#### 2.4. Vehicle-to-Grid (V2G)

The system created when a BEV integrates into the electricity grid to purchase or sell energy is known as Vehicle-to-Grid (V2G). V2G takes advantage from the fact that private vehicles remain parked most of the time [45]. It promises a flexible charging process by controlling the intensity, duration and direction of the power flow [42], it also offers to increase power transmission efficiency and help reduce the peak demand, hence, implying lower environmental burdens [43]. Likewise, efficiency in the use of transformers and power lines can be higher. Furthermore, V2G could provide frequency regulation services, diminishing the amount of investments required as a consequence of the hour depending nature of renewable energies [46]. In fact, the potential of V2G as grid stabilizer has been documented in Brazil, Drude et al. [47]. However, the authors concluded that tariff regulations may lead to a destabilization in case too many cars offer their internal storage for V2G grid support.

Nevertheless, V2G poses challenges in terms of infrastructure planning, network loading, power quality aspects, etc. [28]. Some other concerns are the issues of legal control and ownership. For instance, a BEV owner entering a V2G agreement might render the vehicle warranty void. Moreover,

the costs of battery degradation, due to use for V2G applications are undetermined yet; a reward scheme for consumers would be required [11].

Implementation of V2G requires communication architecture between the BEV, the EVSE operator, and the grid operator in order to control the charge and discharge processes. Although it is already feasible, as evidenced by the European standard IEC 61851 [40], V2G will display low potential for grid services as long as BEVs remain a niche product [11]. It is unlikely that OEMs, DSOs or software companies could prioritize the development of architecture or communications to enable V2G services without previous significant increments in BEV sales, complementary energy technologies and charging infrastructure development. In fact, only a few BEV models currently comply with software requirements for V2G, one of them is the Mitsubishi iMiEV [48].

Although economic analyses of V2G are based on plenty of assumptions which cause high variances in the results, some studies have exposed the difficulty of V2G to generate an attractive return for BEV users, especially considering the battery life diminishing due to V2G use. Peterson et al. [49] estimated end-user incomes as low as 10 to 100 USD year<sup>-1</sup> as a consequence of low amounts of electricity sent back to the grid and low prices of electricity. Brandt et al. [15] analyzed a German scenario for V2G deployment on parking garages, which act as intermediaries between the owners and the grid since they have permanent access to an expressive number of vehicles and can rely on existing infrastructure. The authors discovered that the revenues from V2G services are inferior to the investments, in fact, switching the charging time to an off-peak hour proved more advantageous than any possible revenues from frequency regulation. For V2G services to be attractive, electricity prices would require to be substantially higher. In the case of parking garage operators in Germany, the financial sustainability is unlikely. One conclusion is that the potential of BEVs to provide frequency regulation services may be exaggerated, which debunks previous research on V2G potential for grid services.

### 3. BEV Initiatives in Brazil

#### 3.1. Vehicle Releases

Many of the large OEMs established in Brazil have been testing their BEV models as part of partnerships without selling them directly. Nissan tested some LEAF models for use as police cars in Rio de Janeiro as early as 2013 [50]. LEAF private sales are expected to arrive only in 2019 [51]. Renault also established partnerships for the use of Zoe models in private fleets [52] and in urban mobility projects such as the Eco-elétrico project in Curitiba, Paraná, which deployed BEVs and battery electric busses (BEB) in the city [53]. Toyota was also implicated in projects with municipal administrations, perhaps the most prominent in São Paulo city, whose target was to incorporate the Prius model within the municipal taxi fleet [54]. Moreover, Toyota is still selling the Prius, the most sold HEV in the world and BMW will continue offering its full-electric i3. Volkswagen is considering releasing its e-Golf and Golf GTE, Hyundai its Ioniq model, and Volvo its HEV SUV XC60. Chevrolet has yet to confirm its full electric Bolt [55,56].

#### 3.2. Private Institutions Initiatives

Private initiatives play an important role, the Brazilian Electric Vehicle Association (ABVE), strives to promote the widespread use of BEVs in the country. It promotes partnerships between regulation agents, business entities, and users. Additionally, it acts in the registration of companies intending to form a network of business partners. Furthermore, it promotes initiatives, such as the Green Urban Mobility Zones (MUV), which are areas prioritizing the circulation of zero tailpipe emission vehicles within its boundaries. ABVE also organizes C-Move, an electromobility workshop, which takes place every year presenting proposals from different players in the market [57]. For instance, during 2018 edition, it was announced the release of a *flex-fuel* Toyota Prius, making it the only HEV in the world able to work on ethanol. Subsequently, Toyota confirmed the production of this model in Brazil will commence still in 2019 [58]. In the same way, start-ups based on vehicle sharing played a starring role, for four [59], and two wheelers [60], even via applet [61].

### 3.3. Funding and Promotion Institutions

At the federal level, there are 3 institutions which foster the vast majority of initiatives for technological innovation on electromobility: The Funder of Projects and Studies, FINEP [62], the National Council for Scientific and Technological Development (CNPq) [63] and the Brazilian Development Bank (BNDES) [64]. BNDES acts as the main long-term credit provider, financing both, technological innovation and purchase of components and vehicles. There is ample evidence of BNDES involvement in partnerships with research institutions in battery and automotive technology [65,66]. Efforts to develop technology not available in Brazil are eligible for different BNDES credit options, such as the Technological Innovation Line and the Innovative Capital Line. Moreover, CNPq provides financial support to diverse research groups. A search in CNPq index shows 32 results for research partner groups. The rewards of funding are expected to be represented in technology development, in the period between 1995 and 2014, 161 patents related to BEV technologies were included in the National Institute of Intellectual Property (INPI), 20 of those patents were developed in Brazil [66]. In the period 2015–2016 13 other Brazilian patents were registered.

Not every project is backed by those 3 agencies, The Ministry of Science, Technology and Innovation (MCTI) in partnership with CNPq have promoted the training of technicians on BEV and battery technology [66]. In another example, the Brazilian Ministry of Industry, Foreign Trade and Services (MDIC) in partnership with the German Ministry of Economic Cooperation and Development is promoting the PROMOB-e project. Promob-e activities include governance studies and start-up support [67], aiming to assist Brazil in the formulation of public policies for the deployment of electrification [68]. The cooperation is expected to share expertise and to identify troublesome aspects. For instance, the disadvantages of non-standardized charging plugs. Special attention should be paid to the Mobility City Lab [69] which focuses on the interaction of innovative technologies, efficient business models and governance approaches for sustainable city development. The project included an on-site assessment in the city of Joinville, Paraná.

### 3.4. EMOTIVE, VAMO and Carro Leve Experiences

EMOTIVE, VAMO and Carro Leve experiences have been the subject of diverse studies in electromobility. Lima et al. [70] explored different business models for mobility services in 20 countries including 2 schemes in Brazil, Carro Leve and VAMO. The authors concluded that carsharing business models, display some particularities, such as: the aim to reduce the cost of car ownership, including the battery, and the absence of smart recharge infrastructure. On the other hand, carsharing do not encourage technological innovation, since it does not require changes in the existing technologies for its operation. Interestingly, in 25% of all cases, the companies provided aggregated services.

Teles et al. [9] evaluated the sustainability performance of EMOTIVE and VAMO projects, in the context of PSS, by identifying in them the sustainability factors identified by Barquet [18] namely; design for environment, identification of economic value, action towards social well-being, encouragement of user behavior change and innovation in different levels. Interestingly, the results displayed positive results for both projects for all factors.

An analysis for grid impact of BEV adoption in Brazilian conditions was conducted based on EMOTIVE data. Mariotto [71] projected a total 1,25 million of BEVs and 4,45 million plug-in hybrid electric vehicles (PHEV) in 2030, which would represent 3,9% and 14% of the total Brazilian light vehicle fleet in that year, consequently creating a rise in electricity demand, modifying the operational and planning conditions of the grid as a consequence of a new load curve. Findings confirm the exacerbation of some undesired effects, such as: (i) reduction in voltage magnitude, (ii) rise of voltage unbalances, and (iii) overload of transformers and conductors. In order to face the challenges, three mitigation actions recommended: (i) updating of distribution infrastructure, (ii) use of hour-based rates, and (iii) smart recharges of electric vehicles. Considering a scenario where users are incentivized to recharge on off-peak hours, the need for investment in network infrastructure would be reduced 60% compared to a scenario of no incentives.



Also embedded in the context of EMOTIVE, Pinto et al. [72] studied the impacts from household BEV charging. A set of residential EVSEs were installed in an urban low-voltage electricity network. The measurements were intended to, firstly, capture the variations on the group of adjacent residences, and secondly, the variations at the house where the charging was taking place. Three EVSEs were installed, for slow, semi-fast, and fast charging. For slow recharge the equipment provided up to 3.7 kW to the vehicle while for semi-fast and fast charging the power involved was 22 kW and 40 kW. The fast charging EVSE demanded a connection to high voltage network due to tension and current requirements. The charging process caused a voltage reduction of 0.8 V. Nevertheless, the values remained within the limits established by ANEEL standards [73]. Indeed, the impact of BEV charging in the residence tension was insignificant, it would have required 4 simultaneous recharges to have caused tension violation. For the adjacent residences there were no violations either. Summarizing, the verified impacts of residential BEV charging on primary distribution systems are non-significant. The economic results displayed an increase of 43% in energy consumption when compared to the same residence without the BEV. However, it was estimated an economy of 70% when compared to gasoline cost per kilometer.

Still within EMOTIVE sphere, Arioli et al. [74] reported the detection of residual current (leakage) in the BEVs and reported about some users failing to do fast charging during peak hours. The project BEVs were estimated to have spent only 31% of what would have been spent with equivalent ICEVs per total distance travelled. Moreover, it was concluded that to recharge a BEV in a local grid powered by a diesel generator, it is indispensable to perform an adequate sizing to cope up with the BEV power demand.

#### 4. Policies with Environmental Background

Back in 1986, the Automotive Air Pollution Control Program (Proconve) was created by the Brazilian Institute for the Environment (IBAMA), well before the BEVs could have been considered as an option for environmental damage mitigation. Other cases of sustainability-guided policies are: The National Policy on Climate Change (PNMC), created in 2009, which endeavored to ensure that economic and social development contribute to the protection of the global climate stability [75]. The 2016 National Plan for Adaptation to Climate Change (PNA), which promote the reduction of national vulnerability to climate change by managing the associated risks [76]. The climate law issued by São Paulo state (No. 16802), compelling public transport to emit less pollutants [77].

Another significant policy was the Program for Promotion of Technological Innovation and Strengthening of Vehicle Productivity Chain (Inovar-Auto), active from 2013 to 2017. It granted incentives to encourage technological innovation and production chain development. The incentives were applied in the form of reductions in the industrialized products tax (IPI) for OEMs certifying R&D efforts in Brazil. To be eligible, OEMs needed to comply with standards to increase energy efficiency [78]. For cars assembled locally, instead of imported, the rates dropped from 35% to zero, 2% or 5% depending on the vehicle share produced locally. Tax reductions for HEVs were dependent on energy efficiency features, the more efficient the vehicle, the greater the tax deduction. Nevertheless, pure BEVs were not eligible. Inovar-auto plan resulted in an average improvement of 15.4% on Brazilian fleet energy efficiency [79].

Furthermore, Inova Energia Plan (2013–2017), was a pioneering initiative developed jointly by the Funding Authority for Studies and Projects (Finep), BNDES and ANEEL. It was the first institutionalized action regarding BEVs and HEVs implementation [80] and presented a structured plan, with clear resources and objectives. This public policy instrument resembled international tools intended to promote innovation in the industrial network. In the private sphere, we found the creation of the National Institute of Energy Efficiency (INEE). A non-profit non-governmental organization founded in 1992, looking forward to promote efficiency in energy use. **Error! Reference source not found.** presents a comparison for Proconve, Rota 2030 and Renovabio policies [81–84].

**Table 3.** Basics of Proconve, Rota 2030 and Renovabio policies.

	<b>Proconve</b>	<b>Rota 2030</b>	<b>Renovabio</b>
Objectives	Reduce and control the emission of air pollutants and noise for all of the vehicles sold nationally.	<p>Expand the global insertion of the Brazilian automotive industry into the global market by exporting vehicles and auto parts.</p> <p>Not intended to increase competitiveness only through cost reduction but through technological differentiation as well.</p>	<p>Promote the proper expansion of biofuels in the energy matrix emphasizing on the reliability of fuel supply.</p> <p>Ensure predictability for the fuel market by inducing energy efficiency gains and reduction of greenhouse gas emissions in the production, marketing and use of biofuels.</p>
Strategy	<p>Establishing maximum levels of emission of pollutants for light and heavy-duty vehicles.</p> <p>Forced substitution of the most polluting models and improvement in the designs of models already in production.</p> <p>Evaporative emission control.</p> <p>Catalyst adequation and electronic injection systems for use with ethanol blended gasoline.</p> <p>Development of engines with new technologies.</p> <p>Creation of the PROCONVE monitoring Committee to evaluate the execution of the established targets.</p>	<p>Creation of research and development stimulation policies.</p> <p>Establishment of mandatory requirements for the commercialization of new vehicles, including the labeling program for energy efficiency and vehicle safety for 100% of the vehicles sold in the country.</p> <p>Tax benefit for OEMs investing in research and development in the country.</p> <p>Importation tax exemptions for auto parts without equivalent national production.</p>	<p>Establishment of national emission targets for the fuel matrix, for a 10-year period.</p> <p>The issuing of a certification for producers bestowing a grade depending on the carbon intensity of the biofuel produced. This grade will accurately reflect the individual contribution of each producer to the mitigation of GHG emissions.</p> <p>The certification is the base for a decarbonization credit, which will be a financial asset traded on the stock exchange.</p>

1986-Current day		2018–2033	2016-Undefined. Goals reassessed every ten years
Problems to tackle	Urban pollution due to tailpipe emissions.	The low competitiveness of the national automotive industry, which results in low integration into global value chains.	
	Health issues related to air quality.	The risk of transferring research and development activities to other hubs, with the consequent loss of high-skilled jobs;	Unreliability on biofuels production
		Technological lag, especially in energy efficiency, structural components and driving assistive technologies	Emission of GHG.

## 5. ANEEL

Several factors urged ANEEL to take a stance on electricity sell for BEVs charging. Externally, the rapid development of a BEV industry in which Brazil is being left behind. Locally, the submission to congress of bills PL 4751/2012 and PLS 780/2015, which proposed the compulsory installation of public EVSEs in highways and the creation of tax exemptions for BEVs purchased by differently abled people and to be used as cabs [85]. Furthermore, bill PLS 454/2017 pretends to establish a ban for ICEVs selling in Brazil from 2060 onwards [86], analogously to other countries [87].

The Agency opted for a minimum regulation of the subject, aiming to avoid interferences in the pricing process and to permit the market to evolve by itself [88]. ANEEL's normative resolution, also introduces a register of public EVSEs, with the purpose of mapping the infrastructure available in the country [89]. Private operators are now able to sell electricity, unlike fossil fuels and ethanol, which are controlled by Petrobras.

What ANEEL expects is to create a safe framework for entrepreneurs investing in infrastructure. Regarding vehicle and battery security the agency declared that DSOs will not bear any responsibilities due to overload. The CPOs must ensure the protection against potential overloads [90]. The agency looked forward to guarantee 3 principles; (1) allow any interested party to provide charging services; (2) guarantee minimum interoperability requirements for EVSE ;and (3) create a registration of all EVSE installations, both public and private [91].

The resolution represents a milestone for electrification in the country. Prior to it, the public EVSE in the country were not allowed to charge for the energy transferred to the vehicles, due to lack of regulation. Thus, installed EVSEs were not able to create a profit, wiping out any interest from entrepreneurs [92]. The new regulation makes energy trading possible and enables commercial recharge of BEVs, at least in the legal field. The new regulation will force the electric firms to innovate, DSOs are not used to competition but electrification will likely compel them to adopt customer-centered strategies [91].

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