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# Impacts of the Sustainable Automotive Chain: Faced with the perspective of electromobility in consolidated markets in Germany, United States and Japan

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**Abstract.** Regardless of the global crisis due to the COVID-19 pandemic, the automotive industry is advancing through new and significant global renewals that arise at the heart of some directions of the automotive segment, especially with regard to electrification and vehicular hybridization, as an adaptive response to ongoing environmental issues. Automakers and automotive dealerships show concerns about these global megatrends that should impact the sector and are emphatic, especially regarding the rapid growth of solutions and business proposals that involve changing consumer behavior, especially regarding the sustainability aspect of the product, as well as the new concept of vehicle use, rather than the purchase of the good. The planet does not have the capacity to withstand current patterns of consumption and, consequently, production. Aligned with this need, the present work aims to analyze the impact of the sustainable automotive chain against the perspective of electromobility in the consolidated automotive markets in Germany, the United States and Japan. These countries have shown to lead research on electric and hybrid motors, where it is concluded that electromobility is fully inserted in the automotive industry of Germany and Japan, with a tendency to exclude fossil fuels in a very short time. In the United States there is a coexistence of technologies from internal combustion engines with electric and hybrid combustion, demonstrating that both technologies must coexist together and be improved over time, partially meeting socioenvironmental sustainability.

**Keywords:** automotive industry, resilience, governance, production chain, sustainability.

## 1 Introduction

The global automotive industry undergoes transformations with the implementation of new technologies, which confirm the trends of the sector, with emphasis on electric and

hybrid vehicles, vehicle connectivity and autonomous vehicles. There is a revolution in the automotive product, which can significantly change the current business model, where distributors become centers of product experience and vehicles are customized to meet the needs of each consumer [1]. The transition from fossil fuel-based vehicles to electric and hybrid vehicle technologies is in line with the need to address current environmental problems by reducing exposure to various pollutants, especially those that cause the greenhouse effect. For experts, regardless of how electricity is generated, the electric vehicle emits less carbon dioxide than a hydrocarbon-powered automobile.

The benefits of electric vehicles are gradually being perceived, however, still their high costs restrict access to the majority of the population [2]. A new approach in the relationship between human beings and nature, within a complex conflict of interests, is necessary so that economic development does not preponderate under the triad of sustainability. Thus, there is governmental concern in the relations between industries and the environment that are fundamental to the sustainability of the planet as well as socioeconomic policies. Environmental impacts have increased incrementally, which causes pressure on industrial businesses [3].

The objective is to analyze the impact of the sustainable automotive chain against the perspective of electromobility in consolidated automotive markets in Germany, the United States and Japan. These countries are justified, as these have been demonstrating over the last few years greater attention to environmental aspects, including the option for electromobility, within the automotive chain, creating a parameter with the current Brazilian automotive reality.

## **2 Sociotechnical Theory - Innovation Systems**

List's classical theory [4] describes the National Systems of Economic Policy as an important milestone for the development of the theory of innovation systems. The theories concerning the sociotechnical transition demonstrate an integrated vision with the systems of innovation and of the automotive sector regarding the transition from fossil fuels to electrification, presenting an overview for the development of this technology in the country. Several authors highlight the relationship between the various forms of energy, environment and social and economic development.

There is evidence that the space in which technical change should be addressed is that of innovation, in the convergence of technology, of the economy and of the institutional context, which is dynamic and which represents the pace and direction of the change of a given technology [5].

The National Innovation System stands out for the role of the system institutions that aim at the technological advancement of a nation and, thus, stresses the need for some reorientations in countries that need to catch up with regard to a particular technology, and, in the specific case, the use of electricity in motor vehicles, whether the

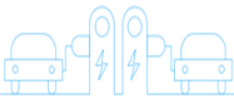



automotive sector of pure electrification and /or hybrid technologies, which is still virtually non-existent in several countries, including Brazil [6]. The author points out that to catch up efficiently, an Innovation System should be used that considers the necessary policies taking into account the current context each country.

In addition to this issue, there is the view that a Sector Innovation System can consist of a plurality of actors such as government research bodies, universities, manufacturers and suppliers, among others, which are related through cooperation, communication, competition and command, and such interactions are delineated by institutions through rules and regulations, which causes the system to modernize over time [7].

### 3 Transition of the Automotive Industry

After analyzing the grounds put forward by the various international automakers, based on the theoretical work of authors such as [8] [9] [10] [11] [12] [13] [14], and also through the information obtained in the sustainability reports of each automaker evaluated, it was possible to identify the main sustainability practices adopted in the transition to electrification process, which are based on four pillars, namely (Table 1): Environmental Regulation, Profitability of Electric and Hybrid Vehicles, Battery Charging Structure and Customer Satisfaction Index [15].

**Table 1** - Market Situation of International Electromobility.

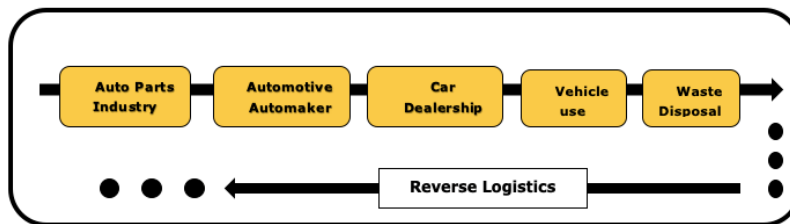
 <b>Charging Infrastructure</b>	 <b>Environmental Regulations</b>	 <b>Customer Satisfaction</b>	 <b>Electric Vehicle Profitability</b>
- Availability of the charging network, especially fast charging.	- Regulatory sanction in many markets for not complying with current legislation.	- Low customer demand for electric vehicles.	- Lower profitability of electric vehicles when compared to combustion vehicles.
- The charging experience is not yet attractive to the user.	- Decreased incentives by governments as technology advances.	- Conversion of sales below 5% of the total vehicles sold.	- Lower after-sales revenues are few components that have wear and tear.
- The charging time of the batteries is an impediment.	- Legislation for installation of charging points.	- Electric vehicle buyers are more technological, have preference for digital channels and customization.	- High cost of batteries for replacement.
- Installation of residential charging plants.	- Appropriate legislation for reuse and disposal of batteries.	- The main concerns are batteries (durability and replacement) and charging.	- Network of distributors with little specific knowledge about electric vehicles.

It is important to highlight the main role of the automotive chain, starting from suppliers, through the automotive industry and its distributors until reaching the final customer. It is evident for the process of transition from fossil fuel to electrification the need for engagement between all links, creating a unit to ensure and meet the needs from the beginning to the end of the chain.

The competitiveness of companies in the automotive segment necessarily involves the effective development of their production chain, the so-called levels 1 and 2, but also the expansion of the production scale and the reduction of their costs. For most automakers, the supply chain follows the model called Global Sourcing, that is, few suppliers around the world who end up being installed near the automakers with dedicated supply to them - level 1, and national auto parts suppliers who can integrate the main chain or are responsible for the replacement of auto parts, called level 2 [16].

In this sense, it is important and urgent to evaluate the automotive chain in relation to the business model based on electromobility, through a business plan that takes into account not only the comparison between the effectiveness of electric models and to internal combustion models, but all the infrastructure necessary to make the project viable and also arouse the interest on the part of the consumer to purchase an electric vehicle at a cost, at this time, even greater when compared to combustion vehicles [17].

The principles of sustainability and social responsibility must go beyond companies, they need to be adopted throughout the value chain, ranging from the extraction of the raw material to the final disposal of waste, taking into account the life cycle of the products, and most environmental impacts from the automotive industry have direct influence through the production and use of the vehicle or indirect, by the distribution of the raw material and final disposal of the products, occurring diffusely and consequently reaching the whole society [18], as observed in the figure 1.



**Fig. 1** - Automotive Value Chain.

The environmental crisis is the epicenter of a great global transformation, in which the industrial era, within its economic and developmental rationality, has transformed the relationship between man and nature, opening an unprecedented crisis in the aspect of sustainability [19].

Currently the consumers are more demanding and enlightened about legislation that, in turn, is stricter, which suggests that automakers and their network of dealerships, suppliers, auto parts factories, carriers must innovate technologically to be able to meet environmental performance constraints, in addition to anticipating future trends, within legal limits [20].

This discussion deepens the theme of governance from the transition to sustainability, where, in order to achieve certain challenges, it is necessary to have a governance that can recognize the multiplicity of existing interests and their various spaces of dispute, in addition to public policies, in order to develop more sustainable innovation systems through a process of learning and experimentation [21] [22].

The national automotive chain has undergone changes related to electromobility and becoming a technological ecosystem due to the need imposed by the global concern regarding the environment, especially in relation to greenhouse gases and CO<sub>2</sub> emissions, aiming to meet the commitments made by Brazil and other countries that are signatories to the Paris Agreement. The initiatives for national electromobility are at an early stage, however the experiences of innovation systems, especially in countries such as Germany, the United States and Japan, such discussions are at a more advanced stage, since eco-innovations are absolute realities and make up the so-called sustainable innovation systems, demonstrate the importance of this technological model for replacing fossil fuels for electrification [23].

The relevant role that electromobility has in the global automotive industry makes us come across a little of this industry in the leading countries in this area, as we will see below.

#### **4 Demonstrative Experiences in Germany, United States and Japan**

The need to develop new ways of reducing emissions of pollutants generated by conventional combustion engines, as well as improving energy efficiency, sustainable urban mobility imposes on the automotive industry the creation of different transport solutions, offering new services with several possibilities, including electromobility through the development of vehicles with electric motorization, called hybrid electric vehicles (VEH) or pure electric vehicles (VEP), as well as innovation in public transport based on the improvement of transport systems and carsharing, which is the rental of short-term vehicles shared by users [8] [9].

Electromobility is one of the most studied research themes in recent years [24] [10] [25]. and, due to its complexity and importance on the world stage, it cannot be independently analyzed. It is necessary to discuss by the automotive industry with the var-

ious actors in the energy sector and public managers about the development of all recharge infrastructure, transmission networks, technical homologation and legal incentives for less polluting technologies.

The relevant role that electromobility has in the global automotive industry makes us come across a little of this industry in Germany, the United States and Japan, leading countries in this area.

#### 4.1 Germany

Germany is the world's 4th largest market in car and energy commercial sales [26]. It's behind China and Japan, this one by a small margin. Its domestic market is equivalent to 1/4 of the American market and 1/5 of the Chinese market. In terms of vehicle density, it is the third largest market with 557 cars per 1,000 inhabitants [27]. In eastern European countries that are part of the European Union, the presence of German automakers is significant, dominating the market with 60% of sales and 65% of production.

The annual report of the Verband der Automobilindustrie Association (VDA) - German Industry [28], shows that the electric vehicle market in Germany grew by 117% over the previous year, reaching the level of 55,000 battery electric vehicles and plug-in hybrids, increasing the share to 1.6% of the total market. This share is still small, but it has been increasing significantly every year. The hybrid engine is able to increase the effectiveness of the drive system, thus reducing fuel consumption by around 25%, as well as CO<sub>2</sub> emissions considering that the reduction is obtained mainly when using the vehicle in urban paths, due to the recovery of energy that is spent on braking through a fully electric driving, for some time, depending on the autonomy and performance of the vehicle. On the other hand, the internal combustion engine has been operating close to its ideal condition, which is why hybrid vehicles can only achieve moderate efficiency gains. However, global efforts to reduce CO<sub>2</sub> emissions point to a clear trend of power train electrification making hybrid units the medium-term standard.

Germany does not practically perform R&D with alternative fuels, whether fossil or renewable, whether liquid or gaseous. In the country, the options are to stay in the current dominant design (ICE<sup>1</sup> + gasoline or diesel) or seek electrification/hybridization of engines. It seems that the main role that Germany will play, is the extended maintenance of ice powered by gasoline and diesel, in view of the experiments with gaseous fossils (CNG<sup>2</sup> and LNG<sup>3</sup>) do not exist in this country, a phenomenon that also occurs with Japan. Germany, as well as Japan, through its automakers, are surely revealing to the world their intention, if technologically advanced to the development of

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<sup>1</sup> ICE – Internal Combustion Engine

<sup>2</sup> CNG – Compressed Natural Gas

<sup>3</sup> LNG – Liquefied Natural Gas



a new dominant design or the maintenance of the current one, it will be the next challenge between these two countries [27].

For several years, Germany has been the leading country in electromobility technologies, where demand for electric vehicles exceeded 200,000 units at the end of 2019, with the German automotive industry expected to reach 1 million units by 2022 with a diversity of more than 100 different passenger car models and investment of approximately €40 billion in this segment [29].

## 4.2 United States

The United States is the country whose strategies in technological development in motorization has been highlighted. Taking China as the world reference (base 100), it is perceived that the United States, the second largest market in the world, has 99% of the size of the Chinese market [30]. In 2018, 13.1 million cars and light vehicles were sold in the U.S., equivalent to 18% of all sales worldwide.

In this context, the United States is configured as a laboratory of robust experiments for strategic projects involving the maintenance of internal combustion engines. These figures attest to the greatness of the market and that American automakers are at the forefront of efforts to preserve the current dominant design in motorization. These automakers have unveiled a number of strategic actions such as: expansion of production plants and transmissions, investments in downsizing engine emission control systems, fuel economy systems including stop-start systems, exhaust gas recirculation systems (EGR), new transmissions with higher speeds, introduction of different materials technologies such as powder metallurgy into engine blocks, turbocharging [30].

In fact, in the United States there is pioneering activity related to world industry with regard to motorization. There is virtually no technological movement around motorizations that is not taking place in the United States. Forty percent of the strategic actions focused on this sector, there is a predominance of internal combustion engines, and these are developed in the United States. This refers to a finding: that if there is a possibility of preserving this engine, this will be done by the effort made in that country and, from the companies that develop their technological mechanisms there. It is unlikely that other countries will find the conditions to preserve it in isolation. It seems essential that there is also the participation of other actors, such as systemists – manufacturers and suppliers of national and international auto parts, universities and government, as inducers of this scenario [30].

Several U.S. studies show that the vision of the development and dissemination of electric vehicles is part of an aggressive industrial strategy and the search for technological leadership [31] [32].

When it comes to electric vehicles in the United States, it is important to note that in the early 2000s, a vehicle manufacturer named Tesla Motors appears in the American automotive market [33]. Tesla produces and sells directly to end customers primarily

through the online sales channel, and does not have dealerships representing the Tesla brand within the U.S. territory. Vehicles are produced in a system that seems to have a more sustainable basis and providing access to urban mobility solutions for more and more consumers [34].

According to Tesla's sustainability report [35], the organization's challenge is to accelerate the world's transition to sustainable energy, highlighting the full environmental impact, from the manufacturing phase of the products to the emissions generated by vehicles during their use.

## 4.2 Japan

Japan is considered the country that dominates hybrid (HEVs) and electric (EVs) vehicle technologies, which would allow one of its automakers to be the first mover when emissions standards become much more stringent globally. Japanese automakers have played a substantive role in the development of new motorization technologies [36].

Japan presents itself as a country in the search for technologies, especially in the area of alternative designs to the internal combustion engine, in which it is in 3rd place behind the United States and Germany. This makes Japan an important player in the international scenario of motorization technologies and a stage of powerful experiments in terms of strategic projects, involving technological alternation to the combustion engine [36].

Japan's investment in the electric vehicle segment is based on the problems related to CO<sub>2</sub> emissions in the transportation sector, the constant concern with oil, from the economic and energy security aspects and, finally, the strategy of technical and economic development of the automotive sector in the country, transforming Japan into an industrial power and global technological innovation [37]. Japanese institutional actions aimed at electric vehicles have as a challenge the social-environmental development linked to the demands of society, such as energy efficiency, sustainability, safety and connectivity.

The Japanese automotive market is dominated by local automakers, and these automakers together currently have almost 80% market share, which operate in a society that will continue to be increasingly concerned about climate change, believing that the business model will accelerate through the sharing of vehicles in relation to 'private property and also by other forms of use. In this society, it will be possible to expand the effects of CO<sub>2</sub> reduction by the use of electric and hybrid vehicles, which in turn will lead to an increase in business opportunities globally [37].

In this way, it is visible that the countries evaluated here (Germany, United States and Japan) have a more demanding manufacturing and consumer market from the product aspect and also more significant in global numerical terms. An international market analysis is important to position some strategic milestones, shown in Table 2.

**Table 2 – Summary of Outstanding Actions Related of Electromobility.**

COUNTRY	AUTOMOTIVE INDUSTRY	MAIN INITIATIVES	STANDALONE TECHNOLOGIES	ENERGY ECOSYSTEMS
GERMANY	VOLKSWAGEN	Electrification E-mobility program. By 2030: launch of 75 all-electric vehicles and 60 hybrid vehicles.	It does not have a specific program for the development of autonomous technology in vehicles. It develops semi-autonomous systems.	Development of technologies for the use of biofuels and improvements in hybrid systems.
	MERCEDES-BENZ	AMBITION 2039 Program. By 2020 - launch of 5 electric models and 20 plug-in hybrids. By 2039 - zero CO2 emissions in all vehicles.	Develops R&D program for autonomous technologies in its vehicles.	Strong research and development for biofuel use and also for new fuels from hydrogen.
	BMW	By 2021 - Forecast of 25% of all production in Europe will be electrified. By 2025 - Forecast of 33% is electrified. By 2030 - Forecast of 50% of vehicles produced are pure	Development of autonomous and semi-autonomous technologies for vehicles.	Significant development to improve the efficiency of combustion engines, as well as improvement of electric motors after the year 2000.
UNITED STATES	GM	Development of electric, autonomous and connected vehicles. By 2030 - Zero emission and zero accidents.	Expressive development of autonomous technologies for electrified vehicles, especially the most popular vehicles.	Improvement of biofuel technology and significant improvements in electric vehicle batteries.
	FORD	Reduction of carbon emissions according to legislation. By 2050 - Completely carbon neutral.	Development of autonomous technologies for vehicles with strong concern with zero accidents.	Development of the combination of technologies from motorcycles to combustion with electric.
	TESLA	Development of low-cost electrical vehicles. Battery technology with longer service life than the vehicle itself. Direct marketing to the final consumer.	State-of-the-art technological innovation in autonomous vehicle systems, which are being implemented in other brands.	Continuous search for innovation in cutting-edge technologies, transforming concepts into reality, transforming the generation, storage and use of electricity in electromobility.
JAPAN	TOYOTA	Program: Toyota Environmental Challenge 2050. By 2030 - Reduction of 90% of Cos emissions through electric vehicles.	It does not present any specific autonomous vehicle systems programs.	Strong development of hybrid and pure electrical technologies, with mastery of higher performance batteries.
	NISSAN	Program: Nissan Sustainability of CO2 until 2022 in Japan.	Develops an autonomous technology project with the objective of zeroing fatalities in traffic accidents.	Significant developments of pure electrification technology as well as vehicular hybridization.
	HONDA	Program: Vision 2030 Mobility, robotics and renewable energy.	It has been developing autonomous technologies through partnerships with other automakers.	Development of new technologies in electric and hybrid motors, as well as development of new fossil fuels.

In this context, the arrangement of the production chain in the countries studied has been facing different market situations in the face of the definitive establishment of the transition from fossil fuel to electrification. This is the panorama found in the countries listed, from the point of view of the technological development of electromobility,

which has been treading a path to be followed by the majority of the world's automotive producers scattered throughout the planet.

## 5 Conclusion

All the evidence indicates that the countries covered here, which have more robotic automotive markets mainly in relation to socio-environmental sustainability, demonstrate a current scenario where hybrid or purely electric vehicle technologies have been consolidating mainly because they are considered countries with educational level and high per capita income, where consumers agree to pay more for new technologies through a process of replacing technologies, being more willing to take the risks inherent to technological advances in electric and hybrid motors, as well as the development of new batteries.

In this same view, these countries are more prone to the insertion of electromobility due to public policies regarding the use of new automotive technologies that seek to reduce greenhouse gas and pollutant emissions. Electromobility becomes indispensable for the mitigation of climate change, where the life cycle of the electric vehicle is relevant, from its production, through use to reaching the final disposal and reuse.

Facing the scenario presented, the automakers studied are adapting their electromobility strategies with internal analyses and market situations pointed out, defining procedures and goals that meet the needs of consumers, allied to the economic and financial balance of the entire automotive chain.

From this perspective of transition management, it is sought the best strategies for the sectors of innovation in renewable energies and, more specifically, in the automotive electrification sector, through a new technological arrangement that necessarily involves the transition from the fossil fuel powered engine to new propulsion systems using electric motors, being necessary the construction of technological integration networks to stimulate the entire development and learning curve of the most varied technologies in the development of electromobility [38].

Given the significant uncertainties of the automotive market, it is important that automakers develop strategies for electromobility focused on key issues, starting with a new brand positioning that explores where, how and when to compete, ensuring profitability in an increasingly electrified world.

The transition from fossil to electrification involves not only technological changes, but also policies and behavioral scans exactly in the convergence between energy use systems and production systems [39]. Therefore, the control of the actions of public and private actors is necessary to meet society's demand for sustainable urban mobility through the use and development of less polluting electric vehicles and greater energy efficiency.

Therefore, electromobility seems to be a global trend, but its implementation should occur differently in the most diverse countries, with Germany and Japan being a faster

transition with the almost immediate replacement of combustion engines by electric and hybrid engines, or even more slow and gradual as the North American, where there is a prolonged process of coexistence of automotive technologies, still allowing significant use of fossil fuels. On the other hand, in several other countries and even in Brazil, there are numerous barriers to entry to new automotive technologies, and electromobility is certainly an agent of change, but not being able to define the time of these changes.

In Brazil, it is noticed that electric and hybrid vehicles have seen an increase in the last 5 years, but their absolute numbers still represent 0.35% of the total vehicles sold in the country, a percentage much lower when compared to other relevant countries in Europe, the United States and Japan. The lack of demand on the part of the Brazilian consumer for new automotive technologies still needs to be better understood, becoming evident the need to create public policies to encourage greater use of electromobility, as well as the development of all the loading infrastructure and technical support necessary for the users of this new technology.

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