Exploring scenarios for the possibility of developing design and production competencies of electrical vehicles in Brazil

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Abstract: The aim of this study is to analyse, under the theoretical foundation of institutional and evolutionary theory, what kind of conditions would be necessary to enable market and develop competencies for electrical vehicles development in Brazil, and the assessment of possible future scenarios. Literature, secondary data documents as well as research on patent basis and interviews with relevant actors of the sector were performed, trying to map and to prospect what kind of competencies are being developed in the country. Results showed that are some small movements made towards the development of electrical mobility in the country, mainly outside traditional automotive sector, but they lack strong coordination and the support from public policies. A possible strategy, with the development of specific products, such as small urban vehicles or applications such as buses or utility vehicles, could be one way to start the development path to a local stronger industry in the near future.

Keywords: electrical vehicles; automotive industry; scenarios; competences; Brazil.


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1 Introduction

Electric vehicles (EV) – whether they are purely electrical, hybrids or use fuel cells – are no longer a dream. Although there is no market for them yet, there has been a great deal of media and political attention about these vehicles all over the world, including Brazil. Several analysts and consulting firms are rather optimistic when predicting market penetration of EV in the coming decades (Villareal, 2011). They can be considered a real alternative to internal combustion engines (ICE) – at least for urban passenger vehicles – in an age of more restrictive gas emissions legislation and uncertain oil supplies. Many governments, such as those in Europe, the USA, Japan and China, are creating regulation and incentives to enable market for EVs (Oltra and Saint Jean, 2009; Jullien, 2007).

In the quest for environmental and economical sustainable energy sources for vehicles, Brazil has the only commercially and technically successful alternative fuel for ICE: sugar-cane ethanol. Since the 1970s, a complete value chain to produce, distribute and use sugar-cane ethanol as automotive fuel has been developed, showing that is possible to artificially build a market that is sustainable, competitive and profitable with institutional support. Notwithstanding this success, its applicability in other markets could be restricted, due to ethanol-supply challenges and uncertainties that may prevent private and public agents of potential markets from investing in the sector (Mello et al., 2005; Amatucci and Spers, 2010).

However, if Brazil wants to be an important player in the global automotive industry in the future – not only producing but also developing products that can be sold worldwide – it must develop competencies in electrically powered passenger vehicles. By developing these competencies, the country may avoid being locked in by a single technological strategy, as Arthur (1989) defines, with the ethanol-powered internal combustion (IC) engine, which may lead to a lack of strategic investment interest from decision centres outside of Brazil.

The Brazilian Government has not yet decided what type of incentives, if any, would be granted to the electric vehicle industry – the new ‘Regime Automotivo 2013–2017’ (MDIC, 2012), a set of regulations and incentives aiming to enhance competitiveness and innovation in the sector, does not address EVs. Electrical mobility raises the possibility that other players who dominate the development of electricity applications would enter the market, perhaps associated with other new capitalist ventures. The automotive
industry in Brazil has not developed competencies in this field locally, and there is concern among some actors about Brazil becoming a mere importer in this segment, losing an opportunity to consolidate its position as a relevant global developer and producer in the automotive supply chain. Other important emerging markets and producers, such as Mexico, Russia and India, are in the same situation, and the Brazilian case could be a reference for them.

If the government were to enable the development of electric vehicle technologies in Brazil, there should be an environment conducive to such development. This environment is the outcome of public policies, the socio-cultural environment, user and market sensitisation, and the alignment of science and technological regimes. In this context, state regulations are needed to create market and economic conditions to overcome the local automotive industry’s innovative inertia (Orsatto and Clegg, 1999; Geels, 2004).

The aim of this study is to analyse, under the theoretical foundation of institutional and evolutionary theory, especially taking into account the perspectives of Geels (2004) and Orsatto and Clegg (1999), what type of conditions would be necessary to encourage a market and to develop competencies for EV in Brazil and the assessment of possible scenarios that could be extrapolated to other emerging countries.

To accomplish the aforementioned goals, a review of the literature, secondary data documents, patents and interviews with relevant actors of the sector (producers associations, research institutes, companies and governmental actors) were performed in an effort to outline and to predict what types of competencies are being (or could be) developed in the traditional automotive sector and what type of institutions outside the traditional auto industry supply chain (such as universities, research institutes, or other companies) are working or planning to work in this field.

The article is organised as follows. In Section 2, the conceptual basis of the study is synthesised, and our framework for assessing possible future scenarios in the Brazilian electric vehicle industry is set. Section 3 presents the research methodology, and Section 4 presents the results of the patents research and interviews. Finally, in Sections 5 and 6, possible future scenarios are discussed and conclusions are presented, noting some study limitations and suggesting further research.

2 Conceptual basis

2.1 The automotive industry and market in Brazil – why go electric?

Brazil is the world’s 7th largest passenger and light commercial vehicle producer, with a total of 3.4 million units in 2010. The automotive industry has a significant weight in the Brazilian economy, representing 19.5% of industrial GNP (ANFAVEA, 2011). In 2010, the Brazilian market was the world’s 4th largest, with more than 3.3 million units sold; – more than 86% of this total was ‘flex fuel’ models, powered by gasoline and/or ethanol (ANFAVEA, 2011). Although Brazil is typically an entry-level segment market, its size and potential growth could indicate a potential market for electric urban passenger cars, according to Proff (2011).

In recent years, the Brazilian currency has appreciated against the US dollar and the euro, reducing the cost of imports and raising it for exports. The result is that the market share of imported vehicles, especially in segments with more sophisticated and higher
technology has been increasing, which led the government to raise import taxes and to review the free trade agreement with Mexico (Leahy, 2011). These facts – raising of imports, loss of local production competitiveness, not only in automotive sector – turned on a ‘yellow light’ for Brazil. Many authors (Bresser-Pereira, 2008; Squeff, 2012) discuss if the country is being victim of the ‘Dutch disease’, a process of deindustrialisation, a scenario where industrial policy actions are extremely necessary for a sustained strategy of economic development. In this regard, the automotive industry is considered by the federal government as strategically important for the development of the economy, being included in the ‘Plano BrasilMaior’, a set of industrial, technological and innovation policies aimed at promoting and sustaining economic growth (MDIC, 2012).

All automakers that operate in Brazil are subsidiaries of global companies. Fiat, Volkswagen, GM, Ford, Renault/Nissan, PSA, Toyota and Honda are currently the main players. It is important to note that Brazil is the only BRIC country that does not have a national automotive company.

The global automotive industry has few local characteristics, i.e., capital and knowledge (projects, patents, etc.) flows. Goods that are either partially or completely finished travel the world, depending on regulatory constraints (financial or other trade barriers) or internal decisions made by the companies themselves (Salerno et al., 2009). Usually, automakers divide global markets among their subsidiaries, and within this division, products manufactured in Brazil have limited global market integration so far: according to ANFAVEA (2011), more than 90% of Brazilian exports were to Latin American countries (mainly Argentina and Mexico) and South Africa.

As mentioned before, all automakers that operate in Brazil are subsidiaries of transnational firms, but this does not mean that the country is a merely producer. It has, in some cases, made use of its product development capacity, especially for vehicles focusing on emerging markets or for the development of ethanol-powered engines, although the autonomy to make decisions on new investments or new products is relatively low. When these decisions are made locally, or according to Salerno et al. (2009) definition, when Brazil is the design headquarters of an innovation project, it causes an increase in the participation of local auto parts companies in the design and supply chains, or even in the multinationals located in the country. In both cases, local engineering and production jobs tend to be created or preserved, and the spillover effects can affect other related production chains, as happened to the ethanol production value chain, described by Amatucci and Spers (2010).

Two of the major driving forces for the development of EV are the uncertainties about the oil supply and the reduction of CO₂ emissions. The fact that Brazil has developed competencies in the use of biofuels from renewable sources, especially sugar cane ethanol, combined with crescent production and the new discoveries of oil reserves in Brazilian deep waters (so called ‘pre-salt’), could lead Brazilian industry and government to a type of inertia in making decisions about new technologies in the automotive sector, as already shown by Proff (2011) in a study that included Brazilian executives, authorities and researchers from the automotive sector. Thus, a pertinent question arises: does Brazil really need investments in EV?

Becoming a design headquarters or even having the conditions to develop a new Brazilian player in the automotive sector is more likely to occur in an as-yet-undefined ‘niche’ technological system, such as electric engines, than in a stable technological regime as the traditional automotive sector, where all rules are already set.
According to Sanchez and Hang (2011), both firm structures and industry structures reflect the structure of the product architecture on which the industry is based. Industries based in non-modular, tightly integrated product architectures are characterised by a higher level of vertical integration, tending to form a closed-system industry architecture organised around a few large firms with strong vertical supplier relationships. On the other hand, open system modular architectures tend to enable and encourage a type of modular industry, where different supplier firms can ‘plug and play’ their components in a common modular architecture, encouraging the formation of a more horizontal industry structure in which a large network of cooperating and competing suppliers and assemblers develop and produce modular product variations. It is also suggested that new product markets grounded on open system modular architectures could help emerging countries to accelerate technological progress, compared with product markets founded on closed system, non-modular product designs.

Because EV product architecture is more likely to be modular (Wang and Xiao, 2011), it can contribute to new product market formation in Brazil and other emerging countries by providing platforms for accelerating technological progress and improving firm capabilities in building longer-term customer relationships and being a viable alternative for a policy to promote economic development (Sanchez and Hang, 2011). The development of the electric two-wheel vehicles in China could be an inspiration for the development of a truly Brazilian EV industry.

However, if Brazil wants to remain an important actor in the automotive scene, it is mandatory that it develop new competencies to cope with upcoming changes in the automotive market and to avoid being locked in a single, mature technology, such as ethanol-powered IC engines.

2.2 Automotive industry – a landscape in change: how these changes could affect the industry in Brazil

A major challenge for automakers in the early 21st century, in addition to the uncertainty of the oil supply, is the issue of environmental sustainability arising from the increasing pressure from legislation on emissions (Oltra and Saint Jean, 2009) and social movements and initiatives that are guided by the advocacy of related issues such as global warming and urban mobility, such as the ‘World Car-free Day Network’.3

To cope with those challenges, the car industry has directed its efforts toward the development of more-efficient engine technologies. However, the industry keeps sending mixed signals: on the one hand, it has been systematically increasing R&D investments and working on initiatives such as the development of hybrid/battery vehicles, and on the other hand, much of this innovative effort is incremental, directed to the continuous improvement of the established and dominant IC engines technology (Oltra and Saint Jean, 2009).

As a matter of fact, one can say that automotive technology today is in an era of ‘ferment’ as defined by Tushman and Anderson (1986). The search for a better engine (i.e., environmentally, technically and economically feasible) is resulting in a prolonged period of technological uncertainty, experimentation and the co-existence of multiple options (Geels, 2004).

So far, there has been no sign that any of the studied alternatives (such as pure electrical, hybrids or better IC engines) would prevail as a dominant design. Hence, the
industry would most likely have to accept the possibility that there would no longer be a unique dominant design and that in different countries or regions, different local designs may survive or even prosper (Freyssenet, 2009; Anderson and Tushman, 1990; Suarez and Utterback, 1995).

To explain the transitions and changes in technological systems, Geels (2004) and Geels and Schot (2007) proposed a model of the evolution of socio-technical regimes, which encompasses scientists, policy makers, users, special-interest groups, cognitive routines, regulations and standards, the adaptation of lifestyles to technical systems, and sunk investments in machines, infrastructures and competencies.

In this model, a given socio-technical regime is stable within a certain set of standards (values, rules and standards of learning). These standards provide stability and generate levels of expectation for its stakeholders. In addition, a socio-technical regime has inertia linked to investments that does not allow constant changes: “People adapt their lifestyles to the artifacts, new infrastructures are created, industrial supply chains emerge, making it part of the economic system dependent on the artifact. Thus technological momentum emerges” [Geels, (2004), p.911]. This momentum creates a dependency path that encourages the adoption of incremental innovations, leading to particular paths and trajectories in a given system. Geels (2004) identifies three levels of structuring activities in a socio-technical regime: niches, patchwork of regimes and landscape (Figure 1).

**Figure 1** Multiple levels of socio-technical regimes

![Multiple levels of socio-technical regimes](source:image)
In niches, operating rules (technical and social ‘rules of the game’, which are actions and interactions played by actors, firms, public authorities, users, suppliers, etc., in trying to reach their goals and to increase resource positions), values (how the actors see those rules) and cognitive trajectories and paradigms are still unclear, with space for experimentation and learning.

As technological trajectories narrow, the structuring level, as well as the innovative inertia, increases. Thus, ‘niches’ are the right system for radical innovations and the emergence of new players and new businesses models. One can say that the automotive industry is currently in a typical ‘landscape’ regime, and new technologies in propulsion are ‘niches’ systems, the evolution of which might lead to transformations in the current landscape, thus creating new possibilities for businesses and paving the way for new players.

Geels (2004) explains the transition from one system to another with the notion of tensions and misalignments that can occur from time to time in the internal dynamics of a given socio-technical regime, such as political and business cycles, technological trajectories, cultural movements and hypes, and the lifecycles of industries, which generate fluctuations and variations in actors’ aims, perceptions and activities.

As long as socio-technical regimes are stable and aligned, radical novelties have few chances to succeed in the market and remain stuck in niches. If those tensions and misalignments occur, they create ‘windows of opportunities’ for the breakthrough of radical novelties. The causes for those tensions could arise from changes in the scenario level (e.g., climate change), internal technical problems and shared perception of the problems, negative externalities (such as pressure from societal groups), changing user preferences or strategic and competitive moves from firms (Geels, 2004).

Freyssenet (2009, 2011) identified these tensions, misalignments and the evolution of the socio-technical regime at birth (early 20th century) and the current automotive industry, in what he called ‘conditions for a car revolution’: the crisis of the previous transport system, the emergence of various technical solutions coming from other industries, the formation of a coalition of economic, political and social forces to impose one solution, and macro-economic decisions and public policies for a broad diffusion of a chosen standard.

On the basis of evolutionary economics, institutional theory and the sociology of technology, Geels and Schot (2007) proposed the term ‘socio-evolutionary’ to explain the process of transition in socio-technical regime evolution pathways. In this socio-evolutionary process, there are two types of evolutionary change:

a) evolutionary-economic, where rules change indirectly through the market selection of product variations

b) social-institutional, where actors directly negotiate rules in communities.

The dynamic interaction between those two levels of change would lead to four transition pathways (Geels and Schot, 2007):

- **Transformation**: This pathway occurs when a regime is pressed by outside actors, such as social movements, and new rules are adjusted by incumbent firms after institutional power struggles and negotiation.
• **Reconfiguration:** Innovations initially developed in niches are adopted in regimes to solve local problems, triggering adjustments in the basic architecture of the regime. The main actors are the current regime’s firms and their suppliers.

• **Technological substitution:** When a ‘specific shock’ happens in the scenario at a moment when niche innovations have developed sufficiently, the innovations will break through and replace the existing regime, such as the development of organic chemistry to replace scarce natural raw materials during the First World War. There is tension between incumbent and new firms.

• **De-alignment and re-alignment:** When changes in a scenario are divergent, large and sudden, regime problems increase, leading to de-alignment (divergence among actors) and the erosion of a regime. If niche innovations are not fully developed, room is made for the emergence of multiple niches and new actors that co-exist and compete for attention and resources. Eventually, one niche innovation could become dominant, re-aligning a new regime. Geels and Schot (2007) described the transformations in North American society in the late 19th century and the replacement of horse-based urban transportation with automobiles in this pathway.

Freyssenet (2011) described three possible future scenarios for the development of engine technologies in the medium term in worldwide terms: diversity, progressiveness and rupture. In the first scenario, each automaker will find a diverse niche in different countries or regions that support the type of motorisation that is most favourable to them.

The second scenario, progressiveness, states that the transformation in automobiles would be progressive, from petrol-fuelled ICE to gas or agro-fuelled ICE, to hybrids and plug-in hybrids, to EV with batteries, and finally to fuel-cell engines. It depends on a relatively stability in oil prices and climate change pressures and tends to favour the larger traditional automotive groups.

The rupture scenario is marked by the rapid increase of a market for EV, mainly related to oil prices and dependency and stricter gas emission reduction goals. It depends on the orientation of governments to create infrastructure and financial conditions. It would favour traditional companies that are already investing heavily in electricity, such as Nissan, Chinese Carmakers, newcomers and start-ups that are creating new business models in EV.

Based on the current scenario of the global automotive industry – a crisis in traditional markets, low profitability, the emergence of new players, external pressures for a sustainable technological evolution for its products – Freyssenet (2009) identifies a ‘Second Automotive Revolution’, i.e., a window of opportunity for the development of new technologies, markets or even players in the near future, changing the current global automotive industry landscape as we know it today. This could be positive for Brazil, if its local industry and government see this as a real opportunity to develop the country as a relevant player in the global automotive industry and to think strategically about it in the medium term.

Therefore, if Brazil wants to be an important player in the global automotive industry, be competitive with other emergent countries, such as India and China, and avoid being locked in a single mature technology, such as ICE, Brazil needs to become a design headquarters in order to develop competencies in developing and producing electrically powered (pure electrical, hybrids or fuel cell) vehicles and to remain competitive in a
possible future scenario in which there is increasing importance of EV over traditional ICE.

2.3 How to develop the electric mobility industry in Brazil?

Based on the discussion above, it is clear that to develop competencies, market and industrial conditions to design and to produce electric automobiles in Brazil, some changes have to occur in the current socio-technical system. However, the issue of creating an appropriate policy framework to account for the necessary radical innovation in the sector is still under discussion. Neo-classical approaches based on externalities and market failures cannot be the basis for designing and development policies. Evolutionary approaches, which evolve from theory and experience to build policies to improve the National System of innovation, could be more appropriate, but their effectiveness has not yet been proven (Nill and Kemp, 2009).

2.3.1 The political ecology framework

Orsatto and Clegg (1999) presented a framework that explores the larger context in which political and economic factors determine the willingness of companies to develop environmental strategies. Their analysis seeks to demonstrate that the study of business-environment relationships requires an organisational analysis at the field level. They coined the expression ‘Political Ecology of Organisations’ as the terrain of political and strategic actions in which environmental strategies and practices are embedded. This framework could be used to facilitate the understanding of the case for the implementation of EV.

According to these authors, technology studies and market trials have shown that the main problems of introducing EV into the market are not technical. Instead, the problems are related to the difficulty in breaking the ‘locked-in’ situation created around the automobile system, and the authors’ framework suggests a systematic analysis of the circuits of power aimed at identifying the pressure points that can trigger this transformation.

The framework sets the relationships among the environmental/political factors, the triggers that can transform the circuits of power and promote changes in system integration and social integration. The first of these concepts refers to the relationships between actors, and the second refers to the relationships between the parts of the social system including meaning, language and symbolism that can facilitate or restrict the reception of the change. For example, in the case of the automobile, there is strong system integration that is possibly the most important reason why the industry does not implement more radical solutions (e.g., the supply chain, fuelling system, and maintenance network). In regard to social integration, Orsatto and Clegg (1999) state that EV, as they are being promoted have not yet been established as a meaningful transportation solution capable of overcoming the barriers to redefine technological competencies, resources and skills throughout the industry. New actors and agendas can transform the legitimacy of the circuits of power, and they are represented in the framework as the agency, the standing conditions and the obligatory passage points (Figure 2). The first two are the forces capable of inducing or restricting the change, while the last represents the elements that secure the stability of the circuit of political ecology.
Based mainly on the industrial framework of Orsatto and Clegg (1999) and the socio-technical evolutionary model of Geels and Schot (2007), this section proposes a set of criteria for assessing possible future scenarios for EV in Brazil and offers recommendations for public policies at four levels of analysis: market, competencies, public policies and regulation and infrastructure, as shown in Figure 3. These four levels of analysis encompass the conditions and characteristics that affect electric vehicle development in Brazil.

- **Market**: Is related to the potential market size for electric automobiles, local attractiveness, the potential for growth, and population purchasing power. Currently, Brazil is considered a very attractive market for automobiles (it is the 4th-largest world market), but it is a market where prices matter because purchasing power is lower compared with developed countries; the selling prices in the local market are some of the highest in the world. Hence, the potential market for EV could be considered small (considering that EV would also be very expensive) in the short term.

- **Public policies and regulations**: This item encompasses governmental regulations, such as environmental and safety standards, tax policies and incentives, trading agreements, local content production and development requirements, and industrial policies for local production enhancement. Recently, the Brazilian Government launched a set of regulations and incentives to enhance local production and development and reduce the production tax (IPI) for more energy efficient vehicles, but there was no explicit mention of EV. Given the high costs and low production scale for EV, successful initiatives, such as those made by Japanese, US, French and Chinese firms, for example, are based in strong government incentives and subsidies. It is unlikely that a large market and industry for EV could be developed without...
governmental incentives in Brazil. The ethanol value chain’s history could be an example of a successful public effort that could inspire initiatives for the local development of EV.

- **Competencies**: Are mainly related to technological competencies to develop and to produce locally. Resources invested in R&D in companies, in research institutes and universities, and in several patents are examples of indicators for local competence development. In the more than 50-year history of local automotive industry, Brazil has developed significant competence in the traditional automotive sector but not for electronics and EV, as shown in our empirical data.

- **Infrastructure**: Is related to the availability of power production and distribution for EV. Local energy companies (such as Itaipu, CPFL and even Petrobras) have declared an interest in the sector and have worked together with other players on projects related to EV, but they are all isolated initiatives.

The result of the aspects discussed above, together with the consideration of the future scenarios proposed by Freyssenet and a set of empirical data collected by the authors, leads to a set of recommendations for public policies to enable an electric-based vehicle industry in Brazil, as discussed in Section 5.

**Figure 3** Framework to assess possible future scenarios for electrical mobility in Brazil

3 **Research methodology**

After discussing some references that propose different frameworks to understand and to analyse changes in and evolution of technological paradigms, the authors tried to explore evidence of the creation of local competencies related to EVs in Brazil.

First, the patents granted and/or invented in the country were reviewed. The results based on this research are shown in the next item.
Eleven interviews were then conducted with different professionals, representing not only companies that still belong to the automotive supply chain but also outsiders who are interested in exploring ways to enter the new automotive supply chain that may exist with EVs and their components, systems and infrastructure. With this information, the authors discuss the results based on three scenarios for the future of the EV supply chain in Brazil, considering the possibilities of implementing both design and production competencies in the country.

4 Current status of electric vehicle development in Brazil

4.1 Patent search results

To map and to predict what type of competencies are being developed in electric mobility in Brazil, data on patent applications from 2002 to 2011 were researched in the World Intellectual Property Organization (WIPO) database, using the patentscope search engine. We searched for all the patents for electric vehicle core technologies granted in Brazil, and within these results, for patents whose applicants were Brazilian residents. The following International Patent Classification (IPC) codes were used, which encompass pure electrical, hybrid and fuel-cell engines technologies:

1. **B60 K**: Arrangement or mounting of propulsion units or of transmissions in vehicles.
2. **B60 L**: Propulsion of electrically propelled vehicles, supplying electric power for auxiliary equipment of electrically propelled vehicles.
3. **B60 M**: Power supply lines.
4. **B60 W**: Joint control of vehicle sub-units of different type or different function; control systems specially adapted for hybrid vehicles.
5. **H01 M**: Processes or means, e.g., batteries, for the direct conversion of chemical energy into electric energy.

The total number of patents granted in a given country indicates how many patents are granted for the subject, but it does not reflect which of them were actually developed in the country. For example, a Japanese company could ask for a patent in Brazil, if it intends to commercialise its product there. That is the reason why the authors compared the total number of patents registered in Brazil with the patents whose applicants are Brazilian residents. The latter number would yield a more accurate picture of the competencies that are being developed locally (Organisation for Economic Co-operation and Development, 2009).

The results, shown in Table 1 and Figure 4, indicate that a total of 1,889 patents were granted in the period 2002–2011 in Brazil, and only 30 (or 1.6% of the total) were invented there, which means that 98.4% were invented in other countries and granted in Brazil. As a comparison, in overall patenting activity in Brazil, Oliveira-Souza (2011) found that an average of 75.6% of the patents granted in Brazil were invented abroad in the last 30 years.
These data raise the hypothesis that global companies intend to sell or even produce in Brazil because they are asking for patents there, but actually there is very little, if any, local technology development. All of the patents invented in Brazil were developed by universities, research institutes or companies that do not belong to the traditional automotive sector.

Table 1 – Patents granted and patents invented in Brazil concerning EV, from 2002–2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Granted in Brazil (by IPC code)</th>
<th>Invented in Brazil (by IPC code)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B60 K</td>
<td>B60 L</td>
</tr>
<tr>
<td>2002</td>
<td>116</td>
<td>14</td>
</tr>
<tr>
<td>2003</td>
<td>80</td>
<td>10</td>
</tr>
<tr>
<td>2004</td>
<td>11</td>
<td>27</td>
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<tr>
<td>2005</td>
<td>99</td>
<td>15</td>
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<tr>
<td>2006</td>
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<td>12</td>
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<tr>
<td>2007</td>
<td>68</td>
<td>15</td>
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<tr>
<td>2008</td>
<td>69</td>
<td>7</td>
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<tr>
<td>2009</td>
<td>33</td>
<td>6</td>
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<tr>
<td>2010</td>
<td>37</td>
<td>7</td>
</tr>
<tr>
<td>2011</td>
<td>100</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>658</td>
<td>144</td>
</tr>
</tbody>
</table>

Figure 4 – Evolution of patents granted and patents invented in Brazil concerning EV, from 2002–2011 (see online version for colours)
<table>
<thead>
<tr>
<th>Interview 1 – Electrical Supply Company</th>
<th>Competences</th>
<th>Market</th>
<th>Public policies and regulations</th>
<th>Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lacking competences to develop batteries and electric engines. Lack of financial support to develop specific competences. Traditional manufacturers already joint ventured with potential global electric suppliers. Lack of coordination of existing competences.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Electric engine, control systems and wiring systems can be locally developed. Partnerships among energy provider, local manufacturers and traditional battery supplier.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sodium batteries are likely to be developed in Brazil (existing research) while Lithium requires availability and stronger cooling system. Lack of coordination and a strategic plan with clear direction in Brazil.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Electrical vehicles use impact on energy demand is low and can be absorbed</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Resistance to traditional manufacturers to the electric vehicle.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>National industry may not be the solution. Without release of importation, critical mass will not be formed. Without critical mass, development will not occur.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Opportunities to apply electric power in other types of vehicles, from bicycles to trucks and buses. Start should be from extremes, not full scale production of passenger cars. Financing lines to cleaner buses exist.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Interviews at the Brazilian Association of Electric Vehicles to try to influence policies. Brazilian market will suffer pressure to join global strategies.</td>
<td>-</td>
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<td>-</td>
</tr>
</tbody>
</table>

Table 2: Summary of interview results
| Interview 4 - Research institute | Except for the battery, all the other competences are available. In the universities, there are plenty of competences, focused in basic research, but disconnected with any product development. | Needed financial support to competence development. | Ethanol itself does not solve the environmental issue. | Electric vehicles, once gain scale globally, will overcome the Ethanol program. Brazilian policies must take this in consideration. | Ethanol itself does not solve the environmental issue. |
| Interview 5 - Electrical engines supplier | Competences to develop electric vehicle exist. Electrical engines are more standardised than combustion engines and easier to maintain. | Lack competences in battery technology. | Industrial induction electric engine already produced with scale and production capacity are ‘not much’ different from those specified to electric cars. Successful experiences: hybrid buses, solar energy boats. Development for mashes and urban mobility solution. | Resistance to traditional manufacturers to loose their ‘core’ ICE engine technology. Engines with permanent magnets are not ideal for electric cars. Rare earths dominated by China. | Manufacturers with importation tax relief to sell existing vehicles without local development. Oil and sugar cane industry lobby. | Brazilian cleaner energy matrix. |
| Interview 6 - Public university researcher | Technical competences exist: technical schools, automotive engineers society, suppliers, energy providers. Prototype developments in Brazil are still behind the world development. | Difficult is to integrate existing competences. Lack of local industry and supply chain. A major assembler locally installed must push the development but Brazil is still isolated in the Ethanol base. Global manufacturers tend to keep the development in their design centres in Europe, USA and Japan. | Industrial electric engines, with permanent magnets (still penalty in terms of weight and control). Possibility for new business models (smart grid). Urban transportation is the only technical and economical application (autonomy and speed). | Lack of scale of production. High initial investments for battery production. Access to batteries raw material (rare earths and lithium). China monopoly on battery raw materials. Structural costs and vehicle sales price. | Governmental support is needed. | Government must regulate infra-structure (energy supply and trade) and this can delay the development. |

**Table 2**
Summary of interview results (continued)
<table>
<thead>
<tr>
<th>Interview 7 – Start-up VE producer manager</th>
<th>Competences</th>
<th>Market</th>
<th>Public policies and regulations</th>
<th>Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competences exist in universities, research institutes, traditional auto industry suppliers. There is ongoing development in battery and electric engine technology.</td>
<td>+</td>
<td>–</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>Electric vehicles will be competitive only together with a new lighter vehicle concept that in turn does not depend on Lithium batteries.</td>
<td>–</td>
<td>+</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Brazilian production taxation model penalises greener vehicles compared to conventional vehicles.</td>
<td>–</td>
<td>–</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>Interview 8 – Autoparts supplier</td>
<td>Academic knowledge development in the area of batteries, engines and power electronics. Competences can be developed following the path of importation, CKD, participation in projects.</td>
<td>–</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>There is no business model consolidated and there fore, incentives and opportunities exist. Larger developments in public transportation sector, with heavier vehicles, engines and batteries.</td>
<td>–</td>
<td>+</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Incentives and regulations can force traditional industry to invest in R&amp;D focusing in innovation and cleaner vehicles.</td>
<td>–</td>
<td>–</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>Brazilian protectionist policies tend to let local industry behind the rest of the world.</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>Pure battery electric vehicles (on the contrary of hybrid vehicles) depend much more on the infrastructure.</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>Pure electric vehicles in a continental country such as Brazil can be ineffective or limit the application to urban areas.</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>Competences</td>
<td>Market</td>
<td>Public policies and regulations</td>
<td>Infrastructure</td>
<td></td>
</tr>
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</tr>
<tr>
<td>Interview 9 – Start-up battery and fuel cells producer</td>
<td>Different and isolated initiatives: Poli, COPPE, Lesteec, Itaipu, CPFL. Technology is available.</td>
<td>Low level of competences available, dependent on established automakers that dominate the market. Lack of coordination. Lack of government and private investment for development.</td>
<td>Lack of environmental legislation pushing new technology.</td>
<td>Bus or smart grid applications can be successful.</td>
</tr>
<tr>
<td>Interview 10 – Start-up VE producer manager</td>
<td>Technical competences are not the most important neither the bottleneck. Competences available in the academy and other entities (related to the new business model).</td>
<td>Possible new business model for sales, production and development (collaborative, modular, networking).</td>
<td>Lack of marketing competences to convince consumers with respect to autonomy. High initial investments for Lithium battery required.</td>
<td>National manufacturers and sugar cane alcohol production association’s lobby. Unions and supply chain resistance to new paradigms. Bureaucracy to receive investments from public funds. Lack of entrepreneurship and risk capital in the area. Lack of ‘induction’ to new business model. Lack of support to small players and startups.</td>
</tr>
</tbody>
</table>
4.2 Interview results

The authors conducted 11 interviews, with:

1. Director of LACTEC, a research institute linked to the State of Paraná Government.
2. Project manager of an EV project conducted by CPFL, a local electric energy company. This project is also supported by a traditional automaker that operates in Brazil (Fiat).
3. Manager of a start-up company that develops and produces lithium batteries and fuel cells.
4. Managers of two start-up companies that are developing small urban EV.
5. Project manager of Magnet Marelli Brazil, in charge of a group of project and other initiatives related to the effort of developing firm competencies in EV.
6. Representative from Federal Government Innovation Funding Agency (FINEP).
7. President and Director of Associação Brasileira de Veículos Elétricos (ABVE), a non-governmental association created to promote the use of EV in Brazil.
8. Professor from the University of São Paulo, Mechanical Engineering Department, that studies electric vehicle development.
9. Engineering Manager from Weg, a Brazilian traditional electric engine producer and developer.
10. Researcher and consultant who specialises in the power industry; this interview was conducted to obtain a better understanding of the electric sector in Brazil.

The authors also participated in a meeting organised by the Industrial Federation of a Brazilian state, with the objective of bringing together entrepreneurs and traditional players of the automotive sector and discussing actions to enhance the development of competencies in Brazil. At this meeting, it was possible to informally interview many actors and collect more impressions from people who are involved with EV initiatives.

The main results of the interviews, focused on the positive and negative aspects of the current status of development for EVs in Brazil with respect to the criteria defined in Section 2.3 are presented in Table 2.

The main conclusions that arose from the interviews were the following:

- Various specific competencies are spread across the country. Initiatives in investing in different areas (batteries, embarked control systems, electric engines, etc.) are not integrated. The initiatives depend on individual interest, and there is a lack of a strong integrator or an actor that can align efforts more effectively to create local EV projects, including the design and/or production of a complete EV.
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- In some cases, niche market products could be developed with a group of companies and institutions with different competencies acting and working together. This may be the most probable outcome (low-volume niche products) if no important entrepreneur takes the initiative to integrate a major programme to develop and/or produce EVs in the country.

- There seems to be no public interest in investing more heavily in the development of technologies for EVs. According to the interviewees, this lack of interest is the result of the strong influence that the major auto assemblers and Petrobras, the powerful Brazilian public energy company, play in the auto industry.

- Auto assemblers and traditional auto-parts suppliers do not seem to be interested in having local EV development and production; some of them are making investments in their headquarter design centre. A possible exception is Fiat, which supports an EV project developed with electric companies.

- Petrobras also does not seem to be very interested in EVs, despite some small initiatives. Almost all of its investments are focused on petrol gas, ethanol or biofuels.

- On the other hand, in 2011, the Brazilian Government created a fund for granting resources to product development projects for EV. After six months, no project was presented for funding, indicating the low level of local development and the poor coordination of the actors so far involved in the sector.

- Ethanol flex-fuel engines are very similar to the traditional gasoline engine. Indeed, the ethanol-powered engine is the same as the one that uses gasoline, with minor changes. Therefore, it has been completely incorporated by the local assemblers and by Petrobras. In fact, investing in ethanol represents, in one way or another, the reinforcement of the main gasoline fuel engines because they work together. Ethanol is, of course, a renewable resource, and because it emits less CO₂ in ‘well to wheel’ terms, it represents a substantial difference when compared with gasoline. However, EVs could emit much less CO₂ compared with ethanol engines, considering the fact that, in Brazil, electric power is generated mainly by its hydrographical resources.

- There is still no significant societal concern about emission and pollution levels related to the use of vehicles in Brazil, and the electric solution for automobiles is still more expensive than traditional ICE. These two factors mean that the market for EV is not very attractive for investments, at least in the short term for the major players in the sector.

- The country most likely would not exhaust its oil resources in the 30 to 50 years, given that huge oil reserves have been recently discovered. Thus, the interplay of the presence of petrol resources, the availability of ethanol, the lack of interest from the market and the political interest of Petrobras and the main automakers and traditional auto-parts producers might explain the absence of a more integrated set of initiatives (both public and private) toward an investment in EVs design and production in the country.
5 Possible scenarios for EV in Brazil

The scenario of an eminent transformation in the automobile industry – called ‘The Second Automobile revolution’ proposed by some authors (Freyssenet, 2009) – may be understood in two ways:

1. Growing markets in BRIC countries at rates never seen before in the USA, Europe and Japan, and therefore, opening opportunities for the development of the local industry in those countries.
2. The movement of the industry toward cleaner alternatives, specifically concerning energy and engine and driving systems in vehicles induced by social pressures.

This section aims at predicting the situation in Brazil, assuming that this ‘revolution’ continues. It will outline three possible future scenarios described by Freyssenet (2011) for the development of engine technologies worldwide: diversity, progressiveness and rupture based on the historical path of development of the Brazilian automotive industry.

In the last 60 years, the Brazilian automotive industry has completed four clearly defined steps (Humphrey et al., 1998; Zilbovicius et al., 2002):

1. Port of vehicles, no local assembly, supply chain and development.
2. Assembly of vehicles from four major players supplied by local auto-part makers and no local development; restricted imports.
3. Local assembly of vehicles by all major global players supplied by global auto-parts makers, pushed by liberalisation and foreign-investment incentive policies, resulting in the participation of local engineering in some global projects, the import of vehicles from specific segments (luxury and newcomers).
4. Same as above, but with rapid increase in the number of local factories (manufacturers aiming at producing models that had been imported, e.g., Toyota, Hyundai, or newcomers, e.g., Chinese automakers JAC and Chery).

In fact, these steps have been linked to growing market importance and attractiveness, government influence through regulations and the development of the ‘global’ strategy of the main manufacturers. For the purpose of this perspective, considering the worldwide move toward producing more EV, the authors will highlight four possible outcomes for Brazil:

1. Brazil will remain an importer of EV.
2. Brazil will locally assemble EV, receiving ‘technology’ from the decision centres of each manufacturer (CKD type).
3. Brazil will locally assemble EV with the participation of local engineering and supply chains in the development of these vehicles.
4. Brazil will develop a local industry supported by local capital and players from other segments.

Depending on the worldwide trajectory for the electrification of vehicles and the development of the Brazilian scenario, the authors suggest four possible outcomes:
5.1 Lock-in

This perspective is likely to be observed in Brazil if the global automotive industry moves toward the scenarios of diversity or progressiveness already described by Freyssenet (2011), who also suggested that in this scenario, there is a risk of decreasing economies of scale by raising costs for manufacturers to offer, develop and improve different options of products. In this case, one might speculate that the consequences for Brazil, an agro-fuel oriented country, is to be locked in a progressively obsolete technology, that would not receive significant investments for further development – something that may be actually occurring currently, if one considers the fact that most of the new IC engines developed in companies headquarters are not available in Brazilian market (Simões, 2009).

Considering the assessment framework described in Section 2.3, with this perspective, as long as the possible market demand for EV can be supplied via imports, one concludes that the remaining Brazilian industry still based on IC engines will survive based on existing local competencies and production capacity, with incremental investments or adjustments to reflect market expansion. If a significant number of EV are imported (depending on policies and infrastructure to encourage product dissemination, as well as consumers attractiveness to the technology), one or more global players could be interested in local production, thus initiating a movement toward the next perspective as described below. So far, only few initiatives were taken by local governments in order to create market, such as the suspension of circulation restriction in the city of São Paulo and reduction of ownership taxes in some states. On the other hand, the federal IPI (industrialised products tax) for EVs is charged at its highest rate (25%), which currently undermines market potential to EVs due to high prices – a Ford Fusion hybrid is sold for approximately US$ 65.000.

5.2 Follow the ‘leader’

Freyssenet’s progressiveness scenario suggests that a consistent change in propulsion technology will occur from ICE to HEV, EV up to fuel cells throughout the industry globally. To cope with the industry paradigms of economies of scale, global sourcing and product platforms lead to the conclusion that the local assembly of EV in Brazil will be pushed.
For infrastructure, the local supply chain has to be pushed in the same way, and it can be weakened if major EV components, such as batteries, engines and control systems, are supplied from abroad, or it can be strengthened if these items are supplied internally. This balance will be affected by regulation as well as by incentives in R&D, which also reflects the competencies that are likely to be required in this perspective. Assembly technology and capacity could be adapted from existing facilities. This perspective would represent no participation of the local industry in global vehicle projects and, compared with the current level of engineering activities in Brazil within the current vehicle designs, a step backward.

5.3 Co-developer

This perspective follows the previous one but with a more robust participation of local competencies in EV design. If the country wants to be part of the global development of EV, within the scenario of progressiveness, to remain competitive within the transnational companies’ development strategies, Brazil would have to develop competencies in EV. Currently, Brazilian subsidiaries compete with other subsidiaries or even headquarters to host the production and/or development of new projects. In a scenario of increasing electrification of the global automotive industry, if Brazilian subsidiaries do not have enough competencies in this area, they could be pushed out of the major global projects. The authors suggest that being a co-developer of EV would also allow the Brazilian industry, given some surrounding conditions, to trigger an industry based on local technology and capital, spilled over from the main stream of production and vehicle design.

5.4 Leapfrogging

The rupture scenario described by Freyssenet (2011) suggests that newcomers and start-ups outside the traditional set of global automakers would benefit from the rapid demand for vehicle electrification and would enter this market. The Brazilian industry, in this scenario, could ‘leapfrog’ the technological trajectory and initiate the local design and production of EVs. This will surely demand competencies in electric vehicle and components design at a much deeper level than previous perspectives, as well as political conditions and coordinated development of the mobility infrastructure. Though this is a possible achievement, it is likely to be more viable if applications in specific niches and local producers are considered. In fact, some initiatives can be observed in this direction currently concerning buses and compact vehicles for off-road applications segments. For example, see companies like Eletra (electrical buses developer and producer, http://www.eletrabus.com/) or VEZ (start-up company for small urban vehicles, http://www.vezdobrasil.com.br/).

As already discussed in Section 2.2, if Brazil wants to remain competitive in global automotive industry, it must develop competences in electro mobility. This is more likely to occur, as mentioned above in the ‘co-developer’ or ‘leapfrogging’ scenarios. In both cases it is required a high level of involvement of local suppliers and assemblers in product manufacturing and development, which implies at least, to become a design headquarters, as defined by Salerno et al (2009), and thus having autonomy to increase the participation of local suppliers in development projects. It also presents an
opportunity to create a local champion in electro mobility, a company capable of inducing the development of this industry.

Some initiatives, though incipient, as demonstrated in Section 4, already exist, but there is a lack of a strong integrator or an actor that can align efforts more effectively to create local EV projects, including the design and/or production of a complete EV. Niche market products could be developed with a group of companies and institutions with different competencies acting and working together. This may be the most probable outcome (low-volume niche products) if no important entrepreneur with governmental incentives, takes the initiative to integrate a major programme to develop and/or produce EVs in the country.

As discussed by authors as Villareal (2011) and Wang and Kimble (2011) successful initiatives, such as those made by Japanese, French and Chinese firms, are based in strong government incentives and subsidies to create market and enhance local players – this should be the development path also in Brazil, if the country intends to be a global relevant player in the automotive industry in the future.

6 Conclusions

The aim of this study was to analyse, under the theoretical foundation of institutional and evolutionary theory, what type of conditions would be necessary to develop market and competencies for EV in Brazil.

As expected, the research showed that Brazil has not yet developed significant competencies in this field compared with other countries. Interviews showed that this is the case for what is being done both by the traditional automotive sector (automakers and auto-parts suppliers) and by entities such as universities, research institutes or start-up companies. There are some small movements made toward the development of EV in the country, but as results showed, they lack coordination by a strong entrepreneur and the support of public policies.

Can the country afford to loose the window of opportunity to develop local competencies and establish a local player in the sector? The answer is definitely no. To remain an important player in the global automotive industry, or to have a local producer, Brazil cannot leave electric vehicle technology behind. Although this transition is unlikely to happen in the short term and in the ‘leapfrogging’ strategy, an evolutionary approach from ‘locked-in’ (or importer) to ‘local producer’ and ‘co-developer’ could be the best way for Brazil to participate in future global markets. However, this evolution depends on public policies and regulations to enhance market, competencies and infrastructure to develop it.

A possible strategy of the development of specific products in niches, such as small urban vehicles or applications such as buses or utility vehicles, could be one way to start the development path to a stronger local industry in the near future. To start this development, the role of the governmental regulations and incentives to create market and enhance competencies and investments in infrastructure is fundamental. Without this ‘kick-off’, it is unlikely that the country would become a local producer or developer for electrical vehicles.

From the evidence found in the Brazilian electric mobility scene, hypotheses and future research plans can be derived and therefore improve the discussion on the subject that can help not only Brazil but also other emergent economies in the matter.
In addition to its intended contribution(s), this work has limitations. The main limitation, inherent in the research method, is the impossibility of generalising the conclusions. More in-depth research in this area could contribute to increased knowledge of factors capable of improving the development of electro mobility in emergent economies.

References


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Notes

1 According to Bresser-Perereira (2008), The Dutch disease is a major market failure originated in the existence of cheap and abundant natural or human resources that keep overvalued the currency of a country for an undetermined period of time, thus turning non-profitable the production of tradable goods using technology in the state-of-the-art. It is an obstacle to growth on the demand side, because it limits investment opportunities.

3 For an example, see the movement webpage: http://www.worldcarfree.net/wcfd/.

4 Geels (2004) defines a socio-technical system as a “somewhat abstract, functional sense as linkages between elements necessary to fulfill societal functions (e.g. transport, communication, nutrition)”. This encompasses production, distribution and use of technology and consists of the artefacts, knowledge, capital, labour, cultural meaning, etc., necessary to create and produce technology to fulfill societal functions.


7 http://carros.ig.com.br/carroverde/fusion+hibrido+consome+como+popular/3332.html.