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Energy Perspectives for the Automotive Sector in Brazil

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ABSTRACT

The automotive sector accounts for 22 % of the National Industrial Product in Brazil. In terms of the internal market size in 2019, Brazil was the sixth largest market globally. Such important productive activity is now facing a challenge that is technological and has several implications that range from the national economy to the geopolitical front. Unlike other countries, the growing pressure to reduce carbon emissions has put pressure on the local automotive sector. To face this pressure is more than a matter of technology and has to be seen as a more complex problem given the already mentioned implications. This paper summarizes some of the main challenges in energy sources for the automotive sector in Brazil. Some of the challenges are similar to what other countries are facing, and others are specific but with possible lessons to be used by all countries.

Keywords: *Bio-Fuel, Ethanol, Automotive, Energy.*

1. INTRODUCTION

The automotive sector in Brazil accounts for about 22% of the domestic industrial production, and the current numbers of production and sales put the country as the eighth largest producer and the sixth-largest market for land vehicles in the world [1]. In terms of employment, the automotive sector employs approximately 500.000 people, and if sales and maintenance are included, the number of employees goes to 1,3 million people [2]. Most of the production is for local sale, with exports playing a minor role and most of them to the neighbouring countries such as Argentina and Uruguay, due to the agreements under the MERCOSUL trade bloc. For instance, in 2020, the total production was 2.020.229 vehicles, and the registration of locally produced vehicles stayed at 1.846.818 units [3]. However, the vehicle manufacturers have their decision centres out of the country since the leading vehicle manufacturers are foreigners (Western Europe, USA, Japan, and South Korea) [3], this fact has some consequences since, as a closed market, Brazil is not fully integrated to the global production chain of vehicles and most products are aimed for the local or S. American market. Therefore, products tend to be more outdated and investments in new products and new production facilities have to consider that export of products and most import of parts will be difficult if not faced with many hurdles primarily due to heavy taxation on imported goods.

Another critical point is that the business strategies of the car manufacturers may not be aligned with the national policies, or there will be a need to negotiate with tax breaks or stimulus policies to enhance car sales and production. One example is bio-fuel such as Ethanol as an alternative to oil-based fuels. Ethanol as fuel for automobiles has been a reality in the Brazilian market since the 1980s [4], long before the pressure to bypass fossil fuels had started. Economic and strategic reasons led to this development sponsored by local subsidies since it only served to the local market and had no use abroad when it was developed.

This sizable but insulated market is also one reason why electrification and other power sources such as Hydrogen for vehicles are much slower to become important in Brazil than in other countries. Other factors are to be seen in this article, but they are somehow related to this specificity of the Brazilian automotive market.

2. CURRENT ENERGY OUTLOOK FOR VEHICLE PROPULSION IN BRAZIL

In 2019 the total fuel consumption for road vehicles in Brazil was equal to 1,18 x 10^8 m^3. From this total, 5 % is bio-diesel, 19 % is Ethanol, 32 % is gasoline (with 27 % of Ethanol, "E27"), and 44 % is Diesel [5]. Therefore, the fleet size is 45 million light vehicles (cars, pick-up trucks) and 2 million heavy vehicles (buses and trucks – MDT and HDT) [3], [5] and the current fleet situation, per kind of propulsion, is presented on Table 1.

Table 1. Fleet of light vehicles and distribution by propulsion [5]

Manufacturing year	Number of vehicles (millions)	Diesel (%)	Gasoline (%)	Flex (any mixture of Ethanol and Gasoline) (%)	Hybrid and electric (%)
Before 1996	0,4	-	100	-	-
1997 - 2004	6,7	0,6	94,8	4,6	-
2005 - 2008	6,9	1,8	18,1	80,1	-
2009 - 2012	11,6	1,9	9,3	88,8	-
2013 - 2020	19,5	2,6	5,0	92,2	0,2

It must be noticed that local standard regulates that diesel engines are allowed only in vehicles carrying more than 9800N (cargo + passengers). This fact accounts for the small participation of this kind of propulsion in the light vehicle fleet. On the other hand, 100 % of the heavy vehicle fleet runs on Diesel [3], [5].

Another point that must be noticed is the "flex-fuel" vehicles that account for most light vehicles since the mid-2000s. The flex-fuel vehicles were introduced in 2003 [4], and they run on any proportion of Ethanol and Gasoline. The driver can choose which kind of fuel will be used based on the fuel cost and performance. This kind of vehicle is a development from the first generation of Ethanol fuelled vehicles that could only run with this fuel and were common until 1990 when a shortage in fuel supply led to a crisis of ethanol distribution [4]. The current technology uses the lambda sensor on the exhaust to detect the mixture of exhaust gases, and then the engine control unit can determine the fuel proportion between Ethanol and Gasoline that goes into the engine. Ethanol comes from sugar cane and is the leading biofuel used in Brazil, and it mixed with gasoline up to 27 % in volume. On the other hand, biodiesel is made of vegetable oils (soy, cotton, sunflower, palm, among others) mixed at a 5 % proportion on the mineral sourced Diesel.

Although not much relevant in fleet participation, electricity will be a source of energy for vehicles if Brazil joins the current trend of fleet electrification following markets such as Europe and the Far-east. In 2020, the total electricity generation was equal to 474.231 GWh [6], and Table 2 presents the primary electricity sources.

Another drive for the automotive sector, also linked to its energy sources, is CO_2 emissions. It became important since the mid-90s with the global worries with climate change and several government and private agents are very active in using the reduction of CO_2 and other emissions as an motivation to overhaul industry and even individual consumer habits [7], [8]. [9]. Table 3 presents a comparison of emission sources between Brazil, USA, China and Western Europe [5].

Table 3. CO_2 emissions per economic activity

Region	Net emissions (Mton CO_2 equivalent)	Deforest (%)	Agriculture (%)	Energy (excluding transport) (%)	Transport (%)	Industry (%)	Residue (%)
Brazil	1421	27	35	17	13	2	5
China	11706	-5	5	58	7	9	2
USA	5794	-4	6	58	29	4	2
Europe	3333	-7	11	59	23	9	4

Among the transportation emissions in Brazil, 91 % come from road vehicles [5]. It can be seen that the problem of emissions has different causes in each location, and putting an effort where the problems are not critical could be counter-productive once the efforts have a negligible impact on the overall problem. Alternatively, what is sold as a solution can prove useless if one does not address the real cause of the problem, as with the case with "clean" electric vehicles that charge their batteries on a coal-powered electric grid.

Table 2. Electricity sources in Brazil [6]

Source	Participation (%)
Hydro	64
Thermal (Oil & gas)	27
Wind	7
Nuclear	1
Solar	0,1
Other (incl. biomass, waste)	0,9

3. BIO-FUELS – THE ETHANOL

Since colonial times, sugar cane plantations are part of the Brazilian landscape. The first substation economic activity started by the Portuguese in their South American colony. Having large sugar cane plantations led to the production of Ethanol. Early studies to use Ethanol as fuel date back to 1925 when experimental vehicles were tested [10]. At first, Ethanol was seen as an alternative to oil-based fuels, expensive and imported since there was no oil industry in Brazil. However, the lack of a local automotive industry put an end to this alternative fuel effort. During World War II, other attempts happened due to the shortages caused by the war effort, but it was not possible to overcome some technical problems (cold start and corrosion) and create a viable industry to produce and distribute the fuel using local capital.

The 1973 oil crisis created a situation in which the spikes badly hit the country's oil prices. The military government at that time saw a strategic Achilles heel that made the transportation of people and goods inside the country vulnerable to foreign crises [4], [10]. Two efforts were started: developing local oil fields (inland and mostly off-shore) and using Ethanol as fuel for passenger cars (Proalcool). In 1975, industry and academia were tasked to develop viable engines and their components, develop and produce industrial equipment aimed at ethanol production, and create a distribution network for the new fuel. In order to make it attractive to all stakeholders, R&D, as well as the ethanol production and distribution, were subsidized [10].

In 1980, ethanol-powered vehicles were a reality in Brazil [4], [10]. Five years later, almost all passenger cars in Brazil ran on a locally produced biofuel. [3] Engines were developed to use Ethanol within the limits of the technology of that time, with compression ratios of 15:1 being common. It must be reminded that electronic management of engines was not available in 1980, so higher compression ratios for gasoline engines were not common then. [4]

This scenario continued until 1990 when a change in the policy of subsidies to ethanol production led to the reduction on supply with the sugar cane production diverted to produce sugar, that had an attractive price in the international market at the possibility of revenue in stable foreign currency (instead of weak local currency, badly affected by inflation) to the producers [4], [10]. With a drastic reduction in supply, the ethanol fuel vanished from the refueling stations, and consumer confidence also vanished, with many cars converted to run on gasoline at a substantial cost to their owners [10]. On the other hand, Ethanol was used mixed to gasoline to replace led-based anti-knocking additives. The amount of Ethanol in gasoline was increased to reach 27 % as the current specification. This fact helped keep the production of Ethanol linked to the consumption of gasoline. However, bio-fuel as a source of energy for vehicles was not feasible until the development in the early 2000s of the "flex-fuel" engines that can run on any mixture of gasoline and Ethanol. The idea came up to recreate the industry of Ethanol as a fuel [4]. As by-products, the industry would have to do local engineering development to take advantage of this option of fuel that was of low cost at that time.

In 2003 the first "flex-fuel" passenger vehicle left the assembly lines. Local engineering from international companies such as Bosch, Magnetti-Marelli, and the engineering of the car manufacturers (VW, Fiat, Ford, and GM – the main participants on the Brazilian market) were involved in developing these systems that were aimed only for use in the Brazilian market [4], [10]. As shown in Table 2, the Brazilian consumer adopted the idea mainly because it gives the option to choose which fuel will be used based on price and performance. A "rule of thumb" known to many motorists is that Ethanol is worth it when its price per liter is smaller than 7 % of the regular gasoline price. This rule is based on the different values of calorific power of Ethanol compared to the octane.

In technical terms, the flex-fuel engine used the emission sensor ("lambda sensor") to evaluate the fuel mixture based on the gas emission. With proper mapping installed on the electronic engine control unit is possible to adjust the engine to the right mixture of Ethanol and gasoline [11], [12], [13]. The automotive industry later used this development in markets where Ethanol is now mixed with gasoline at different proportions, such as the USA, where E10 is now standard (Ethanol at 10 % mixture with gasoline).

In terms of emissions, ethanol results have shown that if one considers the whole cycle from the oil field to the vehicle wheel or from the sugar cane field to the wheel, Ethanol presents a much better result with 46 gCO_2/km while gasoline (with 27 % of Ethanol) generates 151 gCO_2/km. It considers that carbon is captured at the sugar cane fields as the crop grows [5].

Suppose the current standard for electric and hybrid passenger vehicles is used, considering electricity production and fuel consumption. In that case, the equivalent emissions of electric vehicles are about 37,5 gCO_2/km in Europe and 150 gCO_2/km in China if the emissions to produce electricity are considered. [14].

Ethanol is competitive in Brazil as fuel for internal combustion engines, but it can be used on the Hydrogen cycle if Hydrogen is used as an energy source for vehicles [15], [16]. It must be noticed that the use of Ethanol in fuel cells could benefit from infrastructure already in use to produce, distribute and sell Ethanol. On the other hand, Hydrogen has as a drawback the need for an infrastructure to be created to produce and distribute it as fuel [5].

4. FLEET ELECTRIFICATION AND ITS CHALLENGES IN BRAZIL

Electrification is becoming the standard for the automotive industry in the most advanced markets such as Western Europe and the Far East [14]. However, it is happening at a much slower pace in Brazil despite the substantial market size [5]. Several reasons contribute to that, including the slow economy that has been failing to recover since 2015 [1], and that led the industry to operate with overcapacity and avoid long-term investments with grim prospects for return. Furthermore, electrification demands new investments in power generation and distribution. Apart from infrastructure, the automotive industry would have to invest in new components production lines such as batteries and electric motors [5]. Such investments are not small, and with the current economic outlook in Brazil, they are being postponed [1].

Brazil is well-positioned in raw materials for electric vehicles in terms of reserves of such materials, as shown in Table 4. However, not being part of the production chain of industrialized goods for the global automotive industry, due to its closed economy, it is possible that the country could end as an exporter of raw materials other than an exporter of industrialized goods.

Table 4. Battery Raw materials reserves and production. Leading producer and Brazil relative ranking position [5].

Material	Reserves (Mton)	Production (kton/year)
Lithium	9,2 Chile	45 Australia
	0,1 Brazil (7th)	2,4 Brazil (5th)
Nickel	21 Poland	853 Poland
	16 Brazil (3rd)	61 Brazil (8th)
Graphite	90 Turkey	700 China
	70 Brazil (3rd)	96 Brazil (3rd)
Manganese	0,52 S. Africa	5,8 S. Africa
	0,27 Brazil (2nd)	1,7 Brazil (4th)

Electrification may signal the end of the automotive industry in Brazil if the local industry does not start to be more integrated into the global production chains. Although the pressure to reduce emissions is global, the country does not have the political leverage to counterbalance the movement towards decarbonization of transportation, even if the numbers show that transportation is not the primary source of emissions in Brazil.

Local solutions such as Ethanol in combustion engines may be temporary or destined to be used only locally. Product lines will be outdated and detached from the main markets without sales that justify more substantial investments. Deindustrialization is also a risk that has to be taken into account. If the automotive business becomes not sustainable, the international companies may leave the Brazilian market. The end of local production of vehicles, either passenger or cargo, would bring dire economic consequences to Brazil [1], which could not be sorted out quickly.

The other scenario, the use of Ethanol in fuel cells, can be a possible local adaptation for a technology that can be used in other markets. However, the exact condition prevails, i.e., the local industry has to integrate with the global production chains of vehicles and parts.

The most optimistic expectation for 2035 puts 62 % of Brazil's vehicle sales composed of different hybrid and electric vehicles. The sales would amount to 2.5 million new vehicles per year [5]. The only economic outlook that allows for this is to have local production. Imports of fully assembled vehicles in such quantities are not sustainable, as the main export raw materials and food, no matter how agriculture and mining do develop in the next decade. [1], [5]. It must be noticed that increased cultivated areas may not be possible due to external political pressure to reduce deforestation.

5. SUMMARY AND CONCLUSIONS

The current state of the automotive industry in Brazil has led the county to a kind of "crossroads" in which political decisions may lead to the end or the continuation of vehicle manufacturing in Brazil. Solutions that work only in Brazil and maybe in its neighbours, such as Ethanol for combustion engines, are not interesting in the long term for an industry that aims to standardize its product lines in other to achieve higher gains with production scales.

The idea that a relatively large market can stay relatively isolated from the global industrial trends does not stand anymore given the worldwide push to electrify the automotive product line, either with battery-powered vehicles or Hydrogen based fuel cell vehicles. The amount of investments to completely overhaul the auto industry will have to be made, taking into consideration that vehicles will share components that will be produced at different parts of the world and if the Brazilian industry will carry on existing, it will have to be competitive and ready to be integrated into the global production chain.

The challenge is not only for the industry. Academia, politicians, and society face the reality that a once successful model may have to be changed, or the risk is the end of significant economic activity.

The current trends will demand a balance between what is in the national interest and what the country can accept to be part of a globalized economy. This balance is not easy, and the solutions are not clear. The problem goes beyond technology and science, but it has ramification in politics, economy, societal and even geopolitics as a complex problem.

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