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Research paper

The current Brazilian energy model: 2016 to 2020

O atual modelo energético brasileiro: 2016 a 2020

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ABSTRACT: Power production growth in Brazil is a reality. Therefore, it is necessary carrying out analyses about energy sources to achieve sustainable and feasible development. A country with huge hydroelectric potential has the production of clean energy in comparison to other energy sources as positive feature. Observing the power generation sector's origin, and comparing and understanding its dynamics, are duties of both the State and the community. The aim of the review in the present article is to objectively understand the Brazilian energetic potential and its several sources. Accordingly, a bibliographic review was conducted to better understand the Brazilian energetic scenario. Brazil accounts for the biggest biodiversity on the planet, as well as for having great climatic variety, such as equatorial, tropical and altitude tropical, sub-tropical, semiarid and Atlantic tropical climate. Brazilian power supply is in the hands of big power plants, like hydroelectric, thermo-electric, wind and solar plants. Hydroelectric plants correspond to approximately 59% of the country's total installed capacity; moreover, it is often presented as clean and renewable energy source. Yet, although there is much to be developed when it comes to the sustainability of the hydroelectric source, it remains as the most feasible and cleanest Brazilian energy channel.

Keywords: Brazil. Sustainable Development. Energy. Renewable Energy.

RESUMO: O crescimento da produção energética no Brasil é evidente. E uma análise sobre as fontes de energias é necessária para um desenvolvimento sustentável e economicamente viável. Um país com um potencial hidrelétrico torrencial tem como ponto positivo uma produção de energia limpa em comparação com outras fontes. Observar a origem, comparar e entender a dinâmica do setor energético é um dever do Estado e da comunidade. A revisão do artigo propõe um entendimento objetivo do potencial energético brasileiro e suas diversas fontes. Desta forma, foi realizada uma revisão bibliográfica para melhor entender o cenário energético brasileiro. O Brasil possui a maior biodiversidade do planeta e tendo uma grande variedade de climas, como o equatorial, tropical, tropical de altitude, subtropical, semiárido e tropical atlântico. O fornecimento de energia elétrica brasileiro está centralizado em grandes usinas, como, hidrelétricas, termelétricas, eólicas e solares como as principais. As usinas hidrelétricas correspondem a aproximadamente 59% de toda a capacidade instalada de energia elétrica no Brasil, regularmente apresentada como uma fonte de energia limpa e renovável. Mesmo com muito a ser desenvolvido, no que tange a sustentabilidade desta fonte, ainda é o canal energético brasileiro mais viável e limpo.

Palavras-chave: Brasil, Desenvolvimento Sustentável, Energia, Energia Renovável.

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INTRODUCTION

Although access to energy in Brazil is not acknowledged as social right by the 1988 Federal Constitution, it is essential for the population's quality of life; therefore, access to it must be ensured by the State. Constitution Amendment Proposal n. 44, from 2017 (BRASIL, 2017), which is still under appreciation by the National Congress, aims at increasing the status of need to ensure access to electric power countrywide. The struggle for this right is basically justified by the guarantee of human dignity, as provided on article 6, of the Brazilian Constitution. It is so, because access to, and the use of, electric power allows the population to enjoy several assets and services that depend on this resource.

Brazil is in the group of countries known as BRICS (Brazil, Russia, India, China and South Africa). This group is formed by emerging countries (VIEIRA; VERÍSSIMO, 2009) that often face economic growth demands, climate changes and lack of accessible and sustainable energy (GONZÁLEZ, GONÇALVES; VASCONCELOS, 2017).

It is worth highlighting that nowadays' scenario on climatic changes shows the urgent need of having national authorities placing the environmental matter on the very core of debates concerning their economy. They must seek environmentally adequate solutions aimed at reducing their dependence on using fossil and non-renewable fuel as alternative energy source energia (NASCIMENTO, 2019). The use of renewable energy focuses on balancing several interests from different perspectives, namely: social, environmental and economic. This observation is possible due to social-profile pressure, given the environmental damage caused by electric power generation, as well as to the goal of meeting economic-growth demands (GONZÁLEZ, GONÇALVES; VASCONCELOS, 2017).

The 2030 Agenda was created in 2015 during a meeting in the United Nations (UN) to guide global development and its effects. This document proposes seventeen targets to be reached by the signatory countries. These propositions are known as Sustainable Development Goals (SDGs), and they aim at promoting human development in harmony with economic and environmental development, among other factors that are intrinsically related to them. It is important highlighting Sustainable Development Goal 7 (IPEA, 2018):

> SDG 7: Significantly increasing the participation of renewable energy in the global energy matrix; doubling the global rate of energy efficiency improvement; reinforcing international cooperation to make the access to research and clean-energy technologies easier.

After disclosing the relevance of a responsible energy development, it is essential discussing its sources to achieve a strong and solid economy. Electric power supply in Brazil is in the hands of big power plants, mainly hydroelectric, thermo-electric, wind and solar power plants (MAESTRI; ANDRADE, 2022). According to the Energy Research Company (EPE, 2016), hydroelectricity has been the main Brazilian power generation source for decades, given its competitiveness and abundance, at national level.

The Brazilian hydroelectric potential is estimated at 172GW, and 60% of this total has already been used. All these potential results from the country's large territorial surface, with several plateaus and mighty rivers.

The energy-use matter is in the core of current debates about the planet's environmental future. Its spatial distribution, and the fastness of such a development, are the factors about to determine the evolution of the climate change process. Moreover, energy uses have environmental impact that exceed extraction processes and pollution related to power generation itself. It is so, because they presuppose the implementation of

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transmission networks capable of multiplying the territorial impact of power generation technologies (OLIVEIRA, 2018).

Accordingly, the aim of the present article was to conduct a bibliographic review about the Brazilian energy scene to better understand its power-generation potential, several sources and growth, from 2016 to 2020.

METHODOLOGY

Data about the Brazilian energy scene was collected to gather information about Energy distribution, based on Brazilian regions;

- Installation capacity, based on power-generation source;
- Main electric power generation types in Brazil; and
- Generation, based on renewable x non-renewable energy.

Information was collected from official reports issued by the federal government and from the website of the International Agency of Energy (INTERNATIONAL ENERGY AGENCY, 2019). It was done by comparing installed to estimated electric power generation potential, in Brazil.

RESULTAS AND DISCUSSION

Energy distribution by regions in Brazil

Access to electric power in Brazilian residences used to almost reach universal coverage; 99% of units had access to this service in 2019, whether supplied by the general network or by alternative sources (IBGE, 2019).

Brazil's installed power generation capacity increased 4.5% between 2018 and 2019, mostly because of the major contribution from hydroelectric generation (EPE, 2021).

Approximately 40% of the Brazilian population lives in the Southeastern region (IBGE, 2019), which is the most populous region in the country, with the highest rate of electric power generation in it. This number corresponds to 30% of the total power generation in the country, as shown in **Figure 1**, which depicts the electric power generation rate per Brazilian region, based on generation of 621,219 GWh.

The Southeastern Region holds most of power plant reservoirs' storage capacity in Brazil (EPE, 2021). Brazil's dependence on power generated in big hydroelectric plants turns it into a hostage of reservoirs capable of generating energy. Thus, the country is exposed to hydrological risk at times of drought, a fact that forces the use of thermal power generation, at much higher costs (DELAPEDRA; SILVA, 2021).

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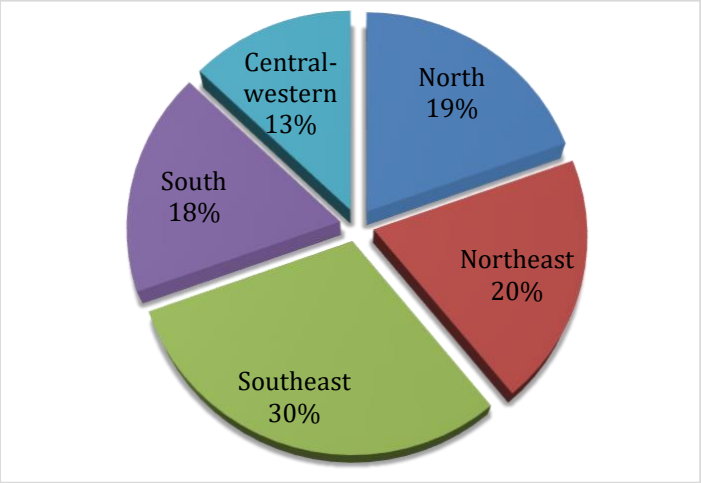
Figure 1. Electric power generation per Brazilian region (GWh)



Source: EPE, 2021.

Capacidade de instalação por fonte de geração de energia

Brazil accounts for the greatest biodiversity on the planet, besides its large variety of climates (ABRANCHES, 2020). Thus, the country is in an advantageous position when it comes to availability of natural resources. However, this profile brings along a great managerial challenge to make sure that these resources will be sustainably explored (PEREIRA JR., 2011).

Renewable energy in Brazil is three times higher than that of the world average; thus, it turns this country into the "greenest" ones. Its carbon intensity is close to 0.15 kgCO_2/US$ppp, but this number is smaller than that recorded for Europe (0.18 kg CO_2 /US$ppp), United States (0.29 kg CO_2 /US$ppp) and China (0.47 kg$CO_2$ /US$ppp), which are the biggest economies in the world (BELANÇON, 2021). Hydroelectric power plants stand out, among renewable energy sources, for their highest installed power-generation capacity in Brazil. **Figure 2** shows the energy generation sources and their power generation capacity (in MW), from 2016 to 2020. Approximately 45% of the country's installed capacity, in 2019, already resulted from renewable sources; this is a significant number, if one considers that, back in 2016, this participation recorded 33%.

The Brazilian Hydrothermal electric sector is featured by remarkable presence of large reservoirs located in several watersheds (PEREIRA JR., 2011). As shown in **Figure 2**, hydroelectric power plants account for the highest installed power-generation capacity in Brazil; moreover, solar and nuclear energies are among the sources that have mostly grown. These sources were featured as renewable energy, with low concentration of polluting gas emissions into the environment.

However, factors, such as rain shortage and variation in power plant reservoirs' volume, which affect power generation, boost the increased use of other renewable sources, such as the solar and wind ones. This diversified energy matrix can make the Brazilian electric power sector more sustainable and efficient.

The year of 2021 was marked by conquests and advancements in the Brazilian power generation sector, with emphasis on electric power generation and transmission. A historical record in the expansion of power free-market plants was registered; it recorded more than

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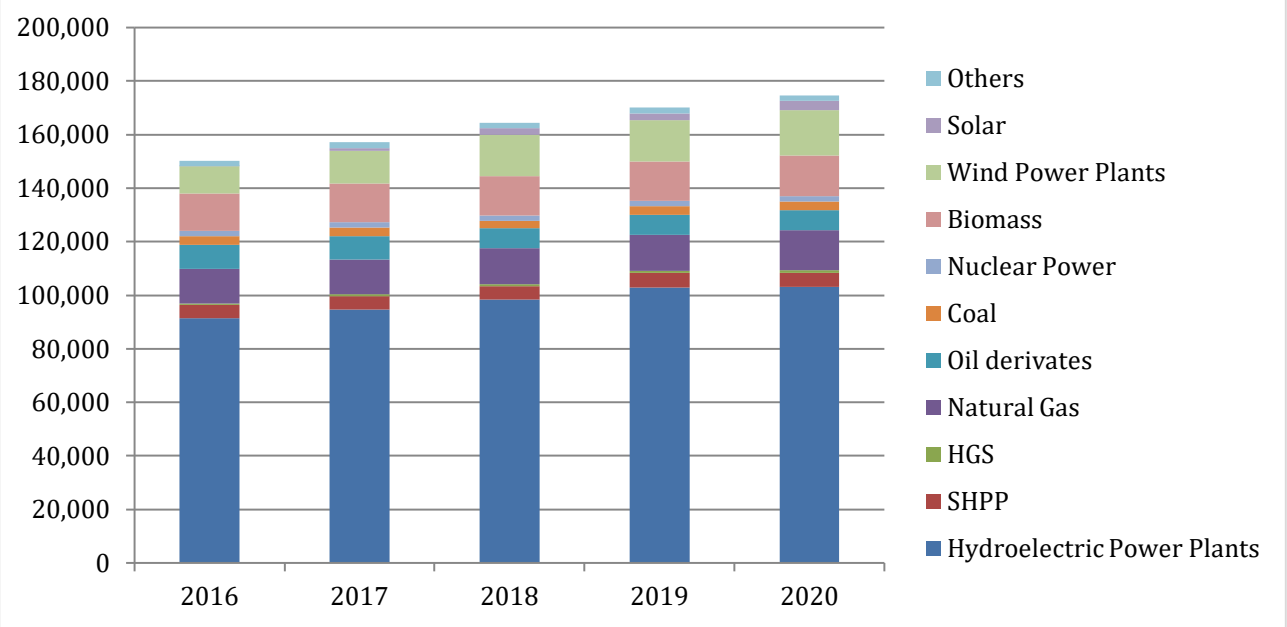
3 GW installed. Wind and solar plants accounted for 75% of implemented power-generation facilities (EPE, 2021).

Figure 2. Installed electric power generation capacity in Brazil (MW)



SHPP: Small Hydroelectric Power Plant: HGS: Hydraulic Generating Station.
Source: EPE, 2021.

Main types of electricity generation in Brazil:

Solar Energy

In the last few years, renewable energy showed high growth rates in Brazil, mainly solar energy, which recorded the highest growth. According to the Statistical Electric Energy Year Book, the Brazilian territory had 24 solar power plants in 2016, and this number had grown 137 times, up to 2020 - it reached 3,287 solar power plants. This energy source accounted for the most significant increase in 2020, and recorded power generation of 10,717 GWh. It was responsible for generating 1.73% of the total power generated in the country.

Solar electric power generation growth in Brazil depends on interdependent initiatives (CARSTENS; CUNHA, 2019) and it implies having the government accountable for technological transmission to solar energy (MAESTRI; ANDRADE, 2022). Desta forma, é necessário promover incentivos fiscais e financeiros, que favoreçam o desenvolvimento da economia e atividades no setor.

Wind Energy

Since 2016, the Brazilian electric generation sector has been facing significant changes in the way power is produced and distributed. Renewable energy growth is one of the greatest elements responsible for such a change, mainly the Wind Energy. Back in 2020,

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wind energy accounted for generating 57,051 GWh of power in Brazil, and it corresponded to 9.18% of the total power generated in the country (IAE, 2020).

The installed power-generation capacity per wind power plant also showed significant growth; it recorded increase by 69% in the number of plants between 2016 and 2020. This number corresponds to the small fraction of 9.80% of the total installed capacity. According to the president of the Brazilian Association of Wind Energy, Brazil ended 2020 with 686 wind power plants (ABEEÓLICA, 2021).

Biomass Energy

Biomass energy is a renewable source resulting from organic waste, such as sugarcane bagasse and wood chips (HUNT, STILPEN; FREITAS, 2018; NASCIMENTO, 2019; KUMARI; EBRABATA, 2019; BHATIA et al., 2021). Between 2016 and 2019, biomass energy installed capacity increased by 8%; in 2020, Brazil presented biomass electric power generation capacity of 15,011 MW. Biomass energy source is more stable than the solar and wind ones. Therefore, it becomes an interesting option to ensure energy security at times of water crisis. Biomass energy is one of the main bets for renewable energy generation and for distributed generation. These changes are relevant for the future of the electric power generation sector, which needs to adjust itself to challenges imposed by climate changes and by technological advancements.

Energia Hidrelétrica

Hydroelectric power became essential to nowadays world, since almost all human activities depend on its consumption. Currently, approximately 20% of all power produced in the world results from hydroelectric plants. The first hydroelectric facility to operate, in history, was designed by Nikola Tesla, in 1987, in Niagara Falls, USA (TERRIN; BLANCHET, 2019).

Brazil is the third biggest hydroelectric power producer in the world; it is only behind Canada and the United States. It also occupies the third position in the ranking of hydraulic potential; it is only overcome by Russia and China (TERRIN; BLANCHET, 2019).

Hydroelectric-source power is a reliable technology that, within the greenhouse gas emission context, presents the additional advantage of being a renewable generation source (EPE, 2021). Hydroelectric power plants correspond to approximately 60% of all installed power generation capacity in Brazil. Therefore, the country has mostly depended on hydroelectric power, as shown in **Figure 3**, since this is the major power generation source in Brazil – it corresponds to 63.81% of the country's electric power potential.

A lot is said about the impact of using fossil fuel, but hydroelectricity was, and still is, often referred to as clean and renewable energy source, although there is a considerable number of studies that have shown these technologies' social and environmental impacts, as well as their carbon emissions (OLIVEIRA, 2018). Brazil still faces challenges regarding the full transition to renewable energy, such as lack of investments in technology and infrastructure, and resistance from some sectors in society.

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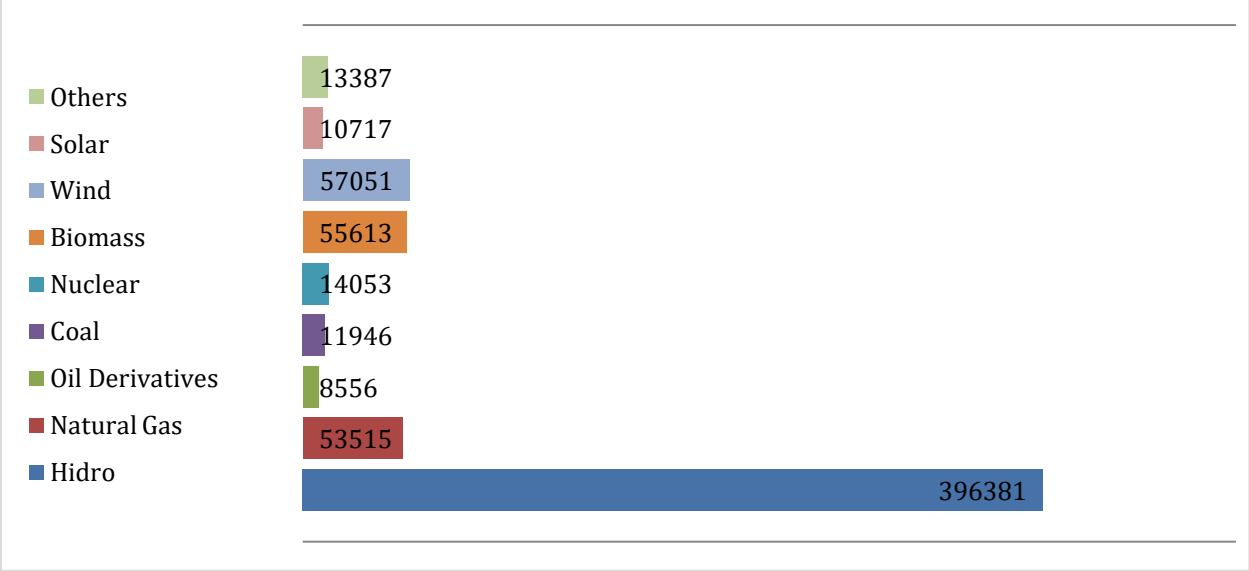
Figure 3. Electric power generation source in Brazil (GWh), in 2020



Fonte: EPE, 2021.

Geração por energias renováveis x não renováveis

Brazil can generate non-renewable energy, as shown in **Figure 2;** its generation capacity from petroleum and coal derivatives dropped from 13% to 5%, between 2016 and 2020. Consequently, it reduced power generation from these sources.

According to ANEEL (2022), Brazil accounts for the cleanest energy matrix in the world. These renewable sources' participation in its matrix reached 85%, in 2022: approximately 60% of hydraulic source, 8% of biomass, 11% wind source, 2% centralized solar and 5% distributed generation, mainly from solar panels.

Renewable energies – water, wind, solar and biomass – are pointed out as key-technologies to encourage energy security and economic growth. These technologies have also presented high capacity to help mitigating anthropogenic climate changes (FERREIRA et al., 2022). Renewable energy generation in Brazil, reached 72.2%, in 2019, whereas such a generation in Central and South America (except for Brazil), altogether, recorded 38.81%, as shown in **Figure 4**. This number places Brazil as leader in the Americas in the ranking of clean energies; in other words, this is the "greenest" country.

Concern with using non-renewable energies is linked to environmental pollution, because fossil fuel burning produces greenhouse gases that have several adverse effects on human health (PERERA, 2017; BHATIA et al., 2021). In the last few years, the Brazilian power-generation sector faced significant changes, mainly when it comes to the country's energy matrix. Between 2016 and 2020, there was great effort to diversify its energy sources and to broaden the participation of renewable sources in it, to ensure energy security and to reduce environmental impacts.

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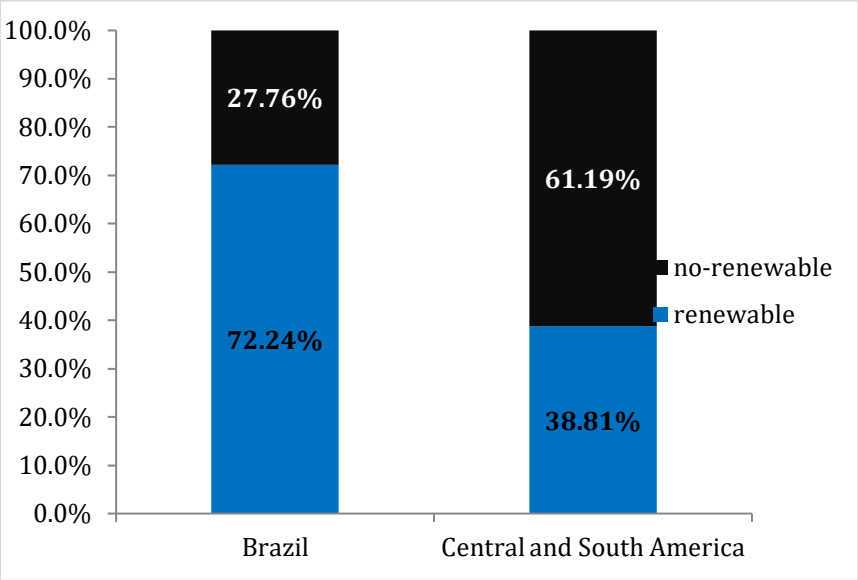
Figure 4. Generation of renewable and non-renewable energy in Brazil, and in Central and South America



Source: International Energy Agency, 2019.

Investments are essential and unavoidable for the electric power generation sector to develop with responsibility. According to Art. 1 of law n. 9.991, from July 24, 2000, it is mandatory to have investments by concessionaires, permissionaires and authorized electric power companies. They consist in a yearly amount of, at least, 0.75% of gross operational revenue invested in research and development in the electric sector, and of 0.25% investment in final-use energy-efficiency programs.

CONCLUSIONS

Data shine light on the Brazilian hydroelectric potential. As already known, this country has large territorial extension and several hydrographic basins with high power generation capacity from river strength – it represents 63.81% of the electric potential generated in Brazil. Although there is still a lot to be developed, when it comes to the sustainability of this source, it remains as the most feasible and the cleanest Brazilian power-generation channel. It is important considering the availability of resources in a country to define its best power production type and the one that can be the most sustainable for its nation and biota. Accordingly, creating projects to a country's energetic development, such as Brazil, which has large territorial extension, means observing the particularities of each of its regions.

Briefly, the 2016-2020 Brazilian energy model aimed at diversifying its energy matrix and to broaden the participation of renewable sources in it. It was done to make sure of reaching energy security and of reducing environmental impacts. Furthermore, the expansion of the distributed generation model allows consumers to generate their own power from renewable sources, like solar panels. These measures can increase energy matrix diversity and allow the population to have more power-consumption autonomy.

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Wind and biomass energies, in their turn, have shown upward development trend towards both overcoming climate change challenges and achieving technological advancement to add to renewable energy generation diversity in Brazil.

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