Regional inequalities in electricity access versus quality of life in Brazil

Desigualdades regionais no acesso à eletricidade versus qualidade de vida no Brasil

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Abstract

One of the main inequalities in Brazil is related to electricity access and distribution. On average, 99.7% of the population have access to some type of energy, varying from 99.1% to 99.9% among the Brazilian states. However, 600 thousand Brazilians still have no access to electricity. This paper aims to relate the distribution of electricity to social and spatial inequalities in Brazilian regions. An evaluation concerning the Brazilian region's population, territorial area, and per capita income was performed. Regarding electricity access and distribution, an extensive assessment of the current Brazilian electricity sector was carried out. The findings showed that the north and northeast regions have lower per capita income, lower electricity consumption and lower electricity access than the other regions. Improving quality of life, job offer, and access to education are challenges to be faced, but the energy policy in Brazil does not yet properly contemplate these.

Keywords: Socioeconomic inequalities. Electricity access. Income. Energy consumption.

Resumo

Uma das principais desigualdades do Brasil está relacionada ao acesso e distribuição de energia elétrica. Em média, 99,7% da população tem acesso a algum tipo de energia, variando de 99,1% a 99,9% entre os estados brasileiros. No entanto, 600 mil brasileiros ainda não têm acesso à energia elétrica. Este artigo tem como objetivo relacionar a distribuição de energia elétrica às desigualdades sociais e espaciais nas regiões brasileiras. Foi realizada uma avaliação referente à população das regiões brasileiras, área territorial, e renda per capita. Com relação ao acesso e distribuição de eletricidade, foi realizada uma avaliação do atual setor elétrico brasileiro. Os resultados mostraram que as regiões Norte e Nordeste apresentam menor renda per capita, menor consumo de energia elétrica e menor acesso à energia elétrica do que as demais regiões. Melhorar a qualidade de vida, a oferta de empregos e o acesso à educação são desafios a serem enfrentados, mas a política energética do Brasil ainda não os contempla adequadamente.

***Palavras-chave**: Desigualdades socioeconômias. Acesso à eletricidade. Renda. Consumo de energia.*

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Introduction

Brazil is a developing country with a population estimated at 211.8 million inhabitants over twenty-six states with 5,568 municipalities and a federal district (INSTITUTO…, 2020a, 2021a). It is a large country divided into five regions where great socioeconomic differences are observed. One aspect that contributes to this reality is related to access to electricity.

In 2019, electricity was supplied by the national electricity grid to 72.2 million households, i.e. 99.5% (INSTITUTO…, 2019). Although access to electricity in Brazil is high, part of the population still lives in energy poverty. Therefore, it is important to evaluate the inequalities in electricity distribution, the energy cost, the access conditions, and their impact on the poor population's quality of life.

Energy poverty is a great problem, and the solution is not restricted to providing energy access to the population; it comprises much more than that. Many researchers affirm that there are various other problems associated with energy poverty such as income poverty, precarious housing conditions, homes exposed to high temperatures during the summer or low temperatures in the winter, high winter mortality, and the difficulty of paying high electricity bills (LIDDELL; MORRIS, 2010; BOARDMAN, 2010; BRUNNER; SPITZER; CHRISTANELL, 2012; INTERNATIONAL…, 2014; SANTAMOURIS; KOLOKTSA, 2015; FOWLER *et al*., 2015; DUBOIS; MEIER, 2016). Jamshidieini, Rezaie and Firuzabad (2019) add that electrification is one of the most important conditions for any region's urban and rural development.

Although Brazil has a huge cultural diversity and great mineral and water resources, there are still people with no electricity access. Besides, due to the lack of electricity, these people are deprived of basic rights, such as communication, proper education, and the possibility of improving their quality of life.

The lack of electricity access is not a problem only in Brazil. In Indonesia, rural electricity access is still poor, i.e. around 2,500 villages have no electricity access (FATHONI; SETYOWATIB; PREST, 2021). The distribution and access to energy from any source should be guaranteed to any country's entire population. Burke and Stephens (2018) affirm that energy democracy is part of ongoing social and environmental justice struggles.

The Proposed Amendment to Constitution No. 44, approved in 2017, amended Article 6th of the 1988 Brazilian Federal Constitution relative to electricity access (BRAZIL, 2017). This amendment to the Constitution established that access to electricity is a social right, and the supply must be equally assured throughout the Brazilian territory.

The residential electricity consumption increased 88.9% between 2004 and 2020 (EMPRESA…, 2020a). The increase in per capita electricity consumption is desirable, considering social well-being and improving life quality. However, it is necessary to guarantee the future supply of electricity and a greater spatial distribution favouring less developed regions (MATTOS *et al*., 2009).

Despite increasing over the years, electricity distribution has expanded differently and unevenly among the Brazilian regions. Energy infrastructure is fundamental to effective, efficient and inclusive energy distribution and has implications for land use and spatial planning. The energy distribution depends on production, consumption and storage and must serve a wide geographical area (RITCHIE *et al*., 2013). It is also necessary to provide electricity infrastructure uniformly in all areas to facilitate national, regional and local economic progress and ensure that the supply infrastructure can be developed cohesively to support a resilient energy system for the future.

Providing access to electrification, especially for poor people, is a condition for reaching a minimum quality of life to human and economic development. Often, choosing the place to expand electrification is based on criteria that do not consider the people's needs and local realities (TAREKEGNE, 2020).

Papada and Kaliampakos (2019) state that different populations or distinct parts of a population in the same country can present different energy poverty levels due to their particular characteristics. Access to energy resources is decisive in eradicating poverty and promoting improvements in the population's lives (ACHARYA; SADATH, 2019).

Hinestroza-Olascuaga, Carvalho and Jesus (2021) conducted a study in Bolivia and stated that poverty is considered in priority areas selected to receive access to any energy technology. They identified that different strategies to reduce poverty must be defined and adopted for populations with low education rates concerning poor housing conditions. Thus, only the electricity access evaluation is not enough to indicate the true reality of poverty. Energy poverty was also observed in Spain, mainly in thinly populated areas (ARISTONDO; ONAINDIA, 2018).

Through the knowledge of characteristics and the evaluation of the inequalities, it will be possible that each country can make policy decisions and choose strategies to reduce and eliminate such imbalances (ROSAS-FLORES; GÁLVEZ; ZAYAS, 2010).

Latin America is considered one of the most attractive emerging markets for smart grid investments, but the expansion is slow. Some reasons are due to disagreements on who pays for the meters and high upfront costs. On the other hand, the energy losses, which are already high in the region, tend to increase (SMART…, 2020a).

Some of the developing countries face significant variations in the cost of energy, high levels of energy loss and energy theft, and a regulatory framework that is still recovering from corruption. Transparency, reliability, and control are necessary to minimise these problems. Besides, despite Latin America expanding its grid, many areas still have no electricity access (SMART…, 2020b). Smart meters are no priority for energy utilities once electrification is considered the main objective.

Access to electricity is important for the economic development of countries. However, this is not the only point in the process that encompasses and includes household income, education, and housing quality. Thus, to provide electricity access, the countries must invest, at the same time, in other areas such as education and infrastructure.

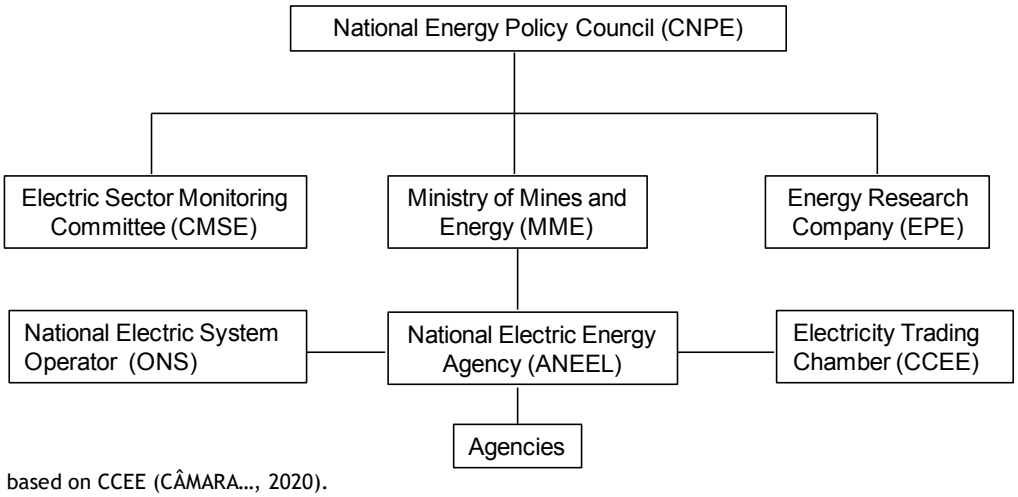
Brazil has great differences in culture, income distribution, education level, and electricity distribution and access among its regions. This paper aims to assess the distribution of electricity according to social and spatial inequalities in Brazilian regions. The Brazilian regions were characterised according to population, territorial area, population income and human development index. Besides, social and spatial inequalities among regions were also assessed. The main contribution of this paper is to inform about the electrification system and policy related to all regions in Brazil.

Brazilian electricity sector

In Brazil, the Ministry of Mines and Energy (MME) is the institution responsible for establishing national energy policy guidelines. Figure 1 shows the hierarchy in the electricity sector and Table 1 shows the attribution of each agency.

The Energy Research Company (EPE), linked to the MME, operates in the area of studies and research designed to subsidise the energy sector's planning and is responsible for the National Energy Balance (BEN). In the BEN, research and accounting related to energy supply and consumption in Brazil are disclosed (EMPRESA…, 2020b). Activities related to the Brazilian electricity sector are guided by rules and laws from the legislative and executive branches and regulatory agencies. Figure 2 shows the electricity flow in Brazil in 2019.

Figure 1 - **Hierarchy structure of the Brazilian electricity sector**



Source: based on CCEE (CÂMARA..., 2020).

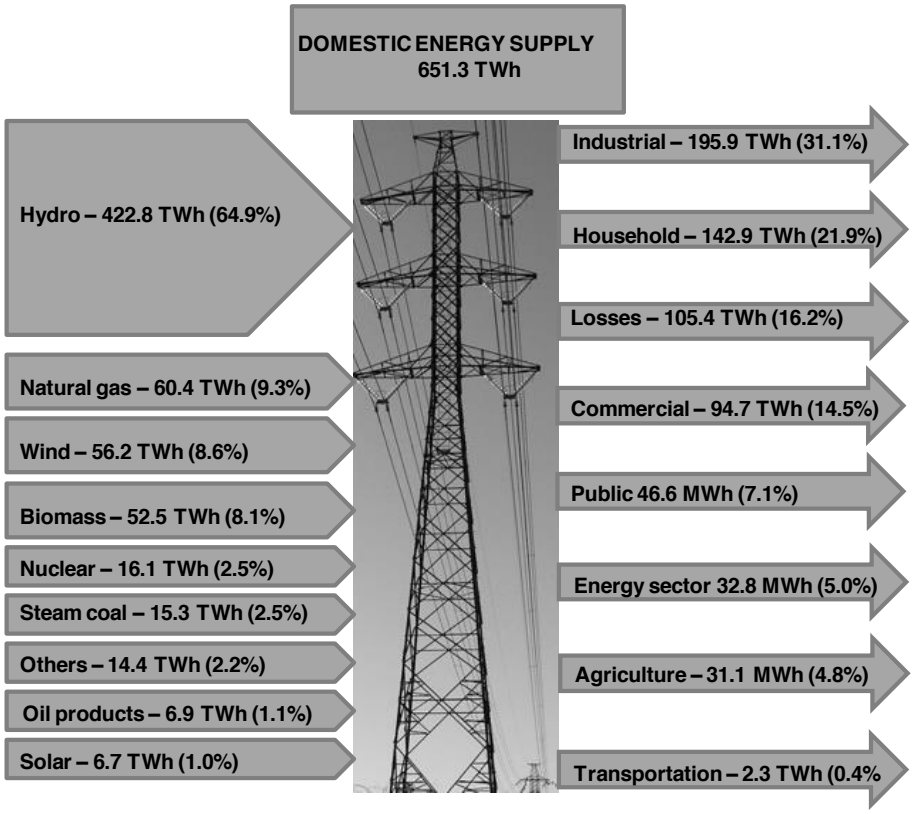
Table 1 - **Attributions of the Brazilian electricity sector agencies**

Agency	Attributions	Composition
CNPE[1]	It proposes to the President of Brazil national policies and measures for the Brazilian energy sector. It was founded in 1997.	Minister of MME[2], ten ministers of the Federal Government and three representatives chosen by the President of Brazil.
MME[2]	It is the primary institutional agent of the electricity sector with guidelines that run the granting of concessions and instructions for the bidding process in concessions related to services and public assets.	National agencies (ANEEL[5]) and ANP, and mixed capital companies (PETROBRÁS[3] and ELETROBRÁS[4]).
EPE[7]	It is an institution attached to the MME[2] whose purpose is to provide services in studies and research designed to subsidise the planning of the energy sector. It was founded in 2004.	Advisory board composed of representatives of electricity distributors, secretaries of state and energy sectors, and administrative and fiscal councils.
CMSE[8]	It was founded in 2004 to permanently monitor and evaluate the continuity and security of the electricity supply over the national territory.	Four MME members and the presidents of ANEEL[5]; ANP[6]; ONS[9]; EPE[7]; and CCEE[10].
ANEEL[5]	It is a federal agency whose main responsibility is to regulate and supervise the electricity sector according to the MME policy and to answer questions by the Federal Government and the MME[2]. It was founded in 1996.	It is composed of a board (one director-general and four directors) appointed by the President of Brazil and approved by the Federal Senate.
ONS[9]	It is a non-profit organisation. It coordinates and controls companies dedicated to the generation, transmission, and distribution of electricity. It also supervises the generation and transmission operations in the National Interconnected System (SIN) under ANEEL[5] regulation and supervision. It was founded in 1998.	It comprises associate members and participating members (generation, transmission, distribution companies, consumers, energy importers and exporters). The Minister of MME[2] and representatives of the consumer council also participate.
CCEE[10]	Since 2004, it is a non-profit civil association maintained by a group of agents operating in the energy market and subjected to ANEEL's[5] authorisation, inspection and regulation. It has the function of making energy purchase and sale activities feasible throughout Brazil.	It is composed of a board of directors, a fiscal council and a superintendent.
Agencies	Agencies that operate in the transmission, implementation, operation and maintenance of electricity. They represent the connection between the generation and distribution of electricity.	All agencies operating in the electricity sector.

Source: based on CCEE (CÂMARA..., 2020).

Note: [1]CNPE – National Energy Policy Council; [2]MME – Ministry of Mines and Energy; [3]PETROBRÁS – Brazilian Petroleum; [4]ELETROBRÁS – Brazilian Electric Centrals; [5]ANEEL – National Electricity Agency; [6]ANP – National Petroleum Agency; [7]EPE – Energy Research Company; [8]CMSE – Electric Sector Monitoring Committee; [9]ONS – National Electricity System Operator; and [10]CCEE – Electricity Trading Chamber.

Figure 2 - **Brazilian electricity flow in 2019**



Source: dased on Empresa de Pesquisa Energética (2020b).

In 2019, the electricity generation in Brazil by public service and self-producers was 626.3 TWh. Net imports of 25.0 TWh, added to the national generation, ensured a supply equal to 651.3 TWh. Public service power plants accounted for 83.7% of the total generation. From Figure 2, it can be observed that Brazil has an electricity matrix of predominantly renewable sources, with emphasis on the water source as it represents 64.9% of the domestic supply. Renewable sources account for 83.0% of the electricity supply. The industrial and residential sectors stand out with 35.9% and 26.1%, respectively, of the electricity consumption (EMPRESA…, 2020b).

Method

Figure 3 shows the flowchart of the methodology, composed of three main phases, and a parallel phase concerning Brazilian electricity policy. In Phase 1, the Brazilian regions were characterised concerning the population distribution over the territorial area.

The number of states in each region was also shown. Data such as average per capita household income, illiteracy rate, Human Development Index (HDI), infant mortality rate, and Gross Domestic Product (GDP) were obtained to compare the regions related to population social conditions. The data were collected from the Brazilian Institute of Geography and Statistics (IBGE) and the United Nations.

A panorama relative to electricity in the Brazilian regions was evaluated in Phase 2. Analyses of aspects concerning installed electricity capacity, the urban households without electricity, electricity loss, electricity generation and consumption were performed. The data survey was carried out through the Brazilian electricity agencies and the Ministry of Mines and Energy.

The electricity costs and their influence on the population electricity access were evaluated in Phase 3 using data from the Brazilian electricity agencies. The presentation of results related to electricity distribution and access in the Brazilian regions was discussed to compare regional inequalities. Therefore, the data collected in the methodology phases were crossed to perform a comparative analysis.

Moreover, an approach related to the Brazilian electricity policy was described. The main subjects include

the objectives, actions, ways to implement, and the government's intention to increase electricity access. The challenges to be faced and the future changes in the population life were also discussed.

Results

Brazilian regions

Brazil is a federal presidential republic located in Eastern South America, bordering the Atlantic Ocean, mostly with a tropical climate but temperate in the south. The country is divided into five major regions, i.e. north, northeast, midwest, southeast and south, and has twenty-six states (Figure 4).

Figure 3 - **Flowchart of the methodology**

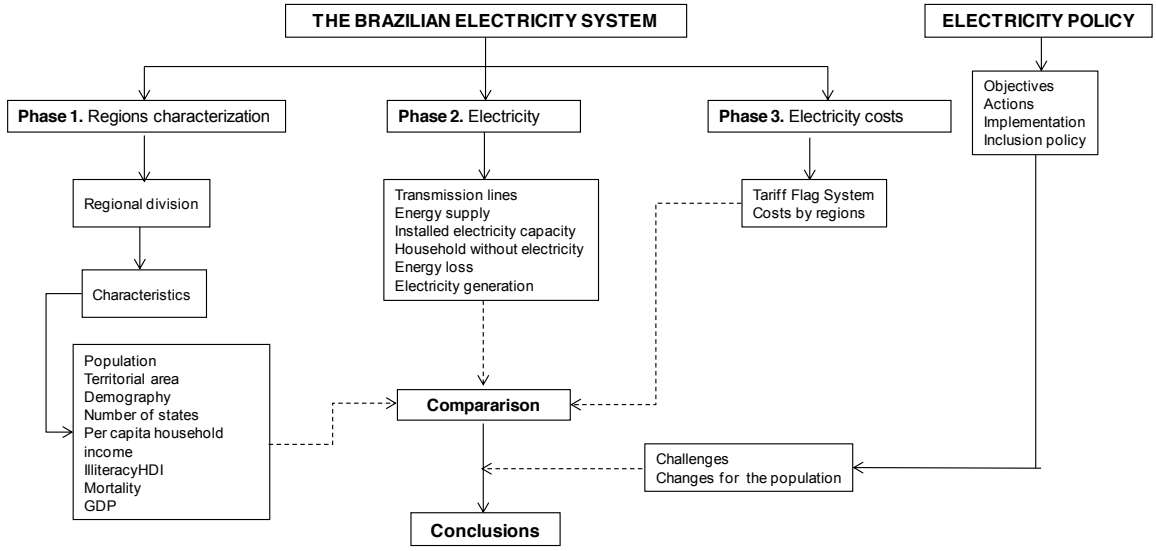
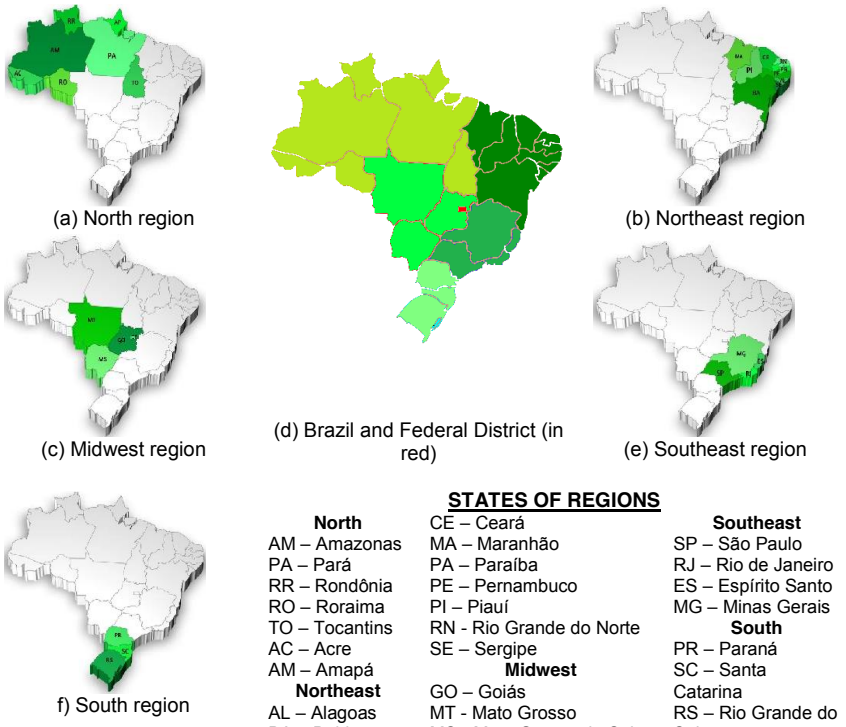


Figure 4 - **Brazilian regions and states**



Source: based on Sousa (2020).

Table 2 summarises Brazilian regions' data, such as population, area, and social and educational indicators, using 2019 as the base year. Brazil has a territorial area equal to 8,510,295,914 km^2. The north is the biggest Brazilian region, i.e. it contains 45% of the territorial area, while the south region contains only 7%. In contrast, the north region has the lowest population and population density (4.73 inhabitants/km^2). However, the differences among the regions are beyond their size and population.

In 2019, there were 209.5 million people of working age living in Brazil, but only 131.2 million (62.6%) had some income ─ 44.1% from formal jobs.

In Brazil, people under 16 cannot work, except as an apprentice (BRAZIL, 1943). As for the employed population, the Brazilian Institute of Geography and Statistics consider data of the population aged 14 and over. As for the average monthly per capita income, the northeast region has the lowest average, while the south region, the highest (96.6% higher than in the northeast). The average monthly income (considering 50% of the population with the lowest income) is lower in the northeast region.

The average monthly income from other sources was R$ 1,539 in the same year. It was found that half of the Brazilians who had the lowest income received, on average, R$ 850 per month. On the other hand, R$ 28,659 is the average monthly income of the 1% of the population with the highest income; that is, almost 34 times the income of the people who had the lowest income (R$ 850).

According to the National Continuous Household Survey (PNAD Continuous) carried out by the Brazilian Institute of Geography and Statistics (INSTITUTO…, 2020b, 2021b), the illiteracy rate of people aged 15 and over was estimated at 6.6% (11 million illiterate people). Compared to 2018, there was a reduction of 0.2% in the illiteracy rate. The northeast region had the highest illiteracy rate (13.9%), i.e. more than four times higher than the rates estimated for the southeast and south regions (both with 3.3%) (Table 2).

The Human Development Index (HDI) is used to measure the degree of development of a given society regarding education, health and income. According to the United Nations' ranking, in 2019 (UNITED…, 2020), Norway had the highest HDI (0.957) while Niger had the lowest (0.394). Brazil's HDI was equal to 0.765 (84th position among 189 countries). North and northeast regions have the lowest HDIs in the country (Table 2).

Table 2 - **Brazilian regions characteristics**

Parameters	Regions				
	North	**Northeast**	**Southeast**	**South**	**Midwest**
Population (inhabitants)	18,430,980	57,071,654	88,371,433	29,975,984	16,097,823
Territorial area (km^2)	3,853,575	1,544,291	924,620	600,000	1,606,403
Population density (inhabitants/km^2)	4.73	39.64	95.13	53.19	11.98
Territorial area (%)	45	17	12	7	19
Number of states	7	8	4	3	3 and FD[(1)]
Average monthly per capita income (R$[(2)])	950	887	1,667	1,744	1,727
Average monthly income considering 50% of the population with the lowest salary (R$[(2)])	633	569	1,010	1,102	984
Illiteracy rate of people over 15 years old (%)	7.6	13.9	3.3	3.3	4.9
Human Development Index (HDI)	0.681	0.660	0.754	0.756	0.722
Infant mortality rate (‰)	20.9	16.6	12.6	15.1	14.8
Gross Domestic Product (thousand R$[(2)])	201,511,748	367,861,916	2.40 trillions	1.12 trillions	632,890,000

Sources: based on IBGE (INSTITUTO…, 2019, 2020b, 2021b, 2021c) and United Nations (2020).

Note: [(1)]FD – Federal District, Brasília; and [(2)]*Real* – Brazilian currency; on 6th September 2021, 1 Brazilian *Real* equals US$ 0.19 and € 0.16.

Access to education is a fundamental right for the development of citizenship and the expansion of democracy. Public investments in education are extremely important for reducing poverty and crime, and increasing economic growth, well-being and access to fundamental rights. The education level was estimated for people aged 25 or over, as they belong to an age group that could have already finished their regular schooling process. In 2019 in Brazil, 48.8% of people aged 25 or over had finished compulsory elementary school (INSTITUTO…, 2021c).

Also, 46.6% of the population aged 25 or over was concentrated in education levels up to complete elementary school or equivalent; 27.4% had completed high school or equivalent; and 17.4%, university. As for the education level of people aged 25 and over in Brazil in 2019, 6.4% have none, 32.2% have incomplete elementary school, 8.0% completed primary education, 4.5% have incomplete high school, 27.4% completed high school, 4.0% have incomplete university while 17.0% have complete university (INSTITUTO…, 2019, 2021c). As a consequence of inequality among the Brazilian regions, the infant mortality rate is high in the north and northeast regions, which also have a lower Gross Domestic Product (Table 2).

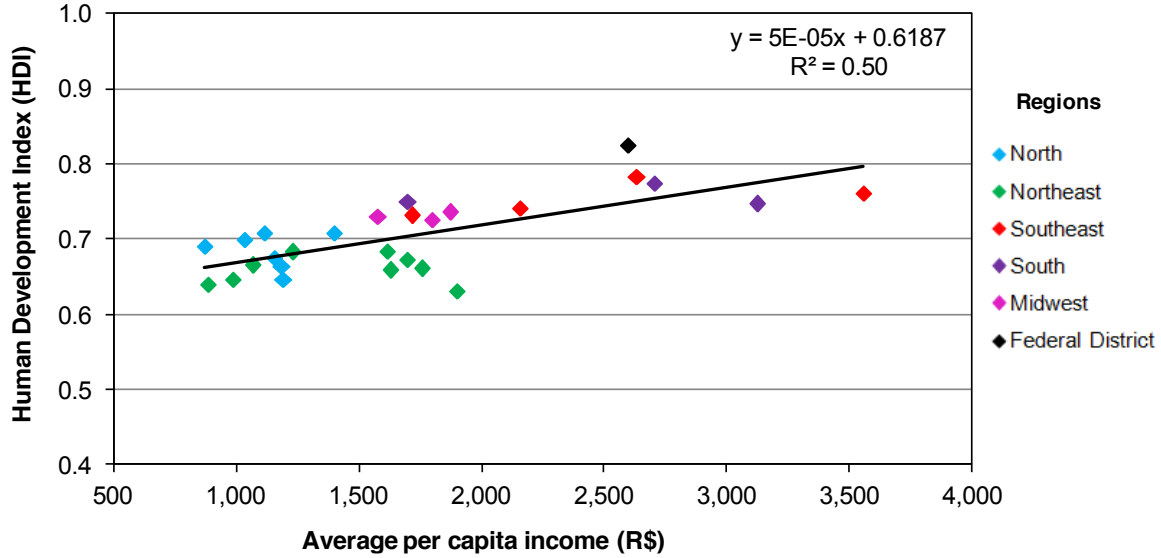
The lack of electricity leads to social inequalities and represses the development of the states and regions. Thus, a detailed analysis was performed regarding income, illiteracy, Human Development Index (HDI) and infant mortality among the states.

Correlations were performed to compare the social differences among the Brazilian regions. Figure 5 shows the relationship between the per capita household income and the Human Development Index (HDI). It can be observed that the correlation is not very significant as the coefficient of determination is 0.50, but there is a clear trend showing that the higher the income, the higher the HDI. The highest incomes and HDI are predominant in the south, southeast, and the Federal District. The differences in income and HDI between Brazilian states show that the country has different realities over its territory, especially in the north and northeast regions.

Figure 6 shows the correlation between per capita income and illiteracy rate. It is possible to state that the distribution of people who do not know how to read and write across the country's different regions shows a high concentration in the north and northeast regions. It can be observed again that the correlation is not very significant (R^2 equal to 0.52), but there is a trend showing that the higher the income, the lower the illiteracy rate.

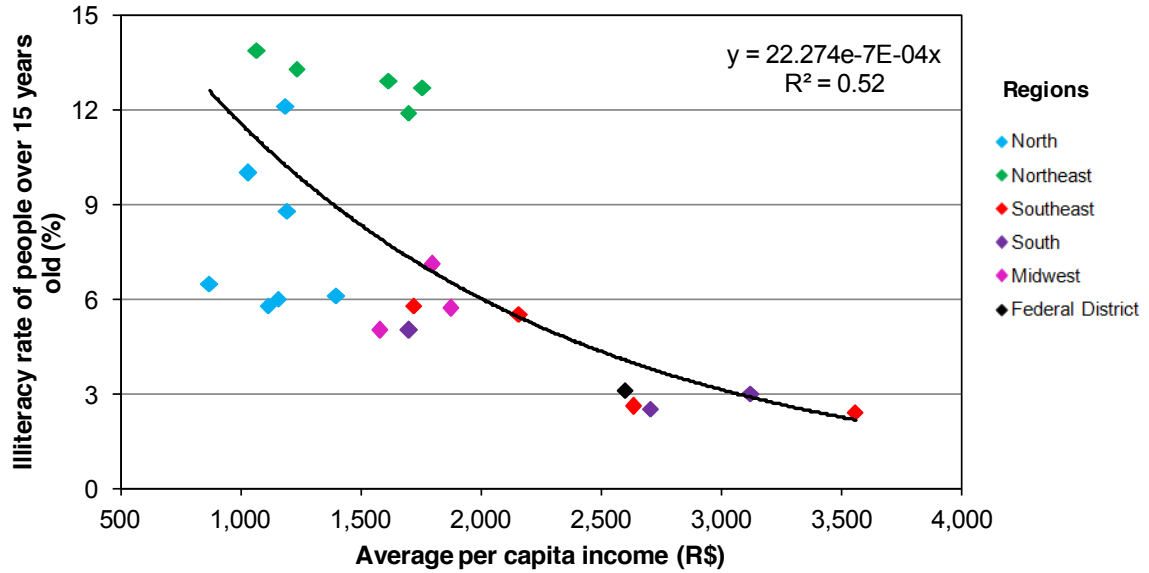
The correlation between per capita income and the probability of newborn babies not completing the first year of age is shown in Figure 7. It can be observed that there is a trend showing that the higher the income, the lower the mortality rate (R^2 equal to 0.53). The mortality of children under one year of age is an important indicator of a region's socioeconomic living conditions.

Figure 5 - **Correlation between per capita income and the HDI over the Brazilian states**



Source: based on IBGE (INSTITUTO…, 2021b) and United Nations (2020).

Figure 6 - **Correlation between per capita income and illiteracy rate**



Source: based on IBGE (INSTITUTO..., 2019, 2021c).

The lowest infant mortality rate was observed in the Espírito Santo state (southeast region), i.e. 7.8‰ deaths of children under one year of age. The highest was observed in Amapá state (north region), i.e. 22.6‰. However, all the states in the south region (Paraná, Santa Catarina, and Rio Grande do Sul), two in the southeast region (São Paulo, and Minas Gerais) and the Federal District present rates below 10‰, which are much higher than those found in the most developed countries. Japan and Finland, for example, have rates equal to, respectively, 1.8‰ and 1.7‰ for every 1,000 live births (INSTITUTO..., 2019).

Electricity consumption in the Brazilian regions

Nowadays, the main source of generation in Brazil is hydroelectricity, i.e. 62% of the installed capacity. Thermoelectric plants (natural gas, mineral coal, fossil fuels, biomass and nuclear) correspond to 28%, and 10% come from wind farms and energy importation from other countries (AGÊNCIA..., 2019).

The Brazilian electricity system allows the exchange of energy produced in all regions, except for isolated systems, located mainly in the north region. Brazil has a National Interconnected System (SIN, in Portuguese) with approximately one hundred thousand kilometres that allow electricity transmission all over the country (AGÊNCIA..., 2019).

Figure 8 shows the main electricity transmission lines in Brazil for the 2024 horizon. It can be observed that there is a lack of electricity transmission lines in the north region. The lack of electricity contributes to the weak development of the region, as shown previously in Table 2. If, on the one hand, the Amazon holds the wealth of the Amazon Forest, on the other hand, it houses a population of 400,000 people excluded from electricity and citizenship. Without being properly managed, the region's natural wealth is being subtracted qualitatively and quantitatively. As a consequence, the region remains poor (BRAZIL, 2019).

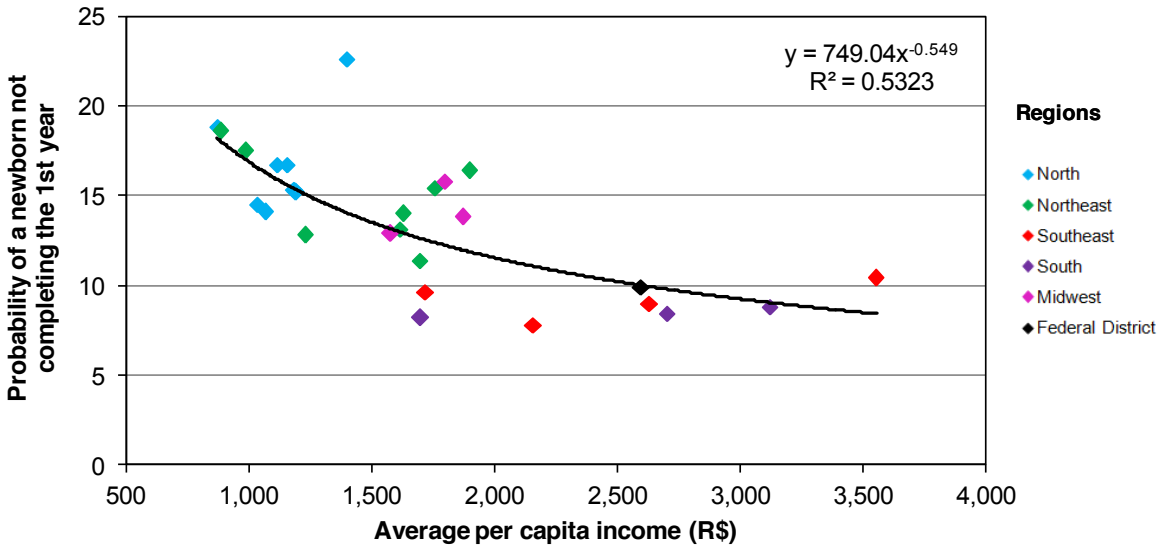
The National Interconnected System (SNI) encompasses four subsystems located in the Brazilian regions and has mainly hydroelectric plants distributed in sixteen hydrographic basins. In recent years, wind farms, mainly in the northeast and south regions, have contributed to increasing electricity production (ALUPAR..., 2021a).

The SNI consists of substations and transmission lines at voltages equal to or greater than 230 kV. SNI planning is the responsibility of MME, ONS and EPE that hold bids for the concession for up to thirty years. Due to Brazil's size, the transmission lines interconnect long distances, and, in general, the plants are located far from the large centres of energy consumption.

In Brazil, there is regional seasonality due to rainfall regime variation that affects hydroelectric power generation. The rainy seasons occur in different periods in the south, southeast, north and northeast regions. In that case, the high voltage transmission lines (500 kV or 750 kV) allow places with insufficient energy production to be supplied by other regions' generating facilities (BRAZIL, 2019; ALUPAR..., 2021a;

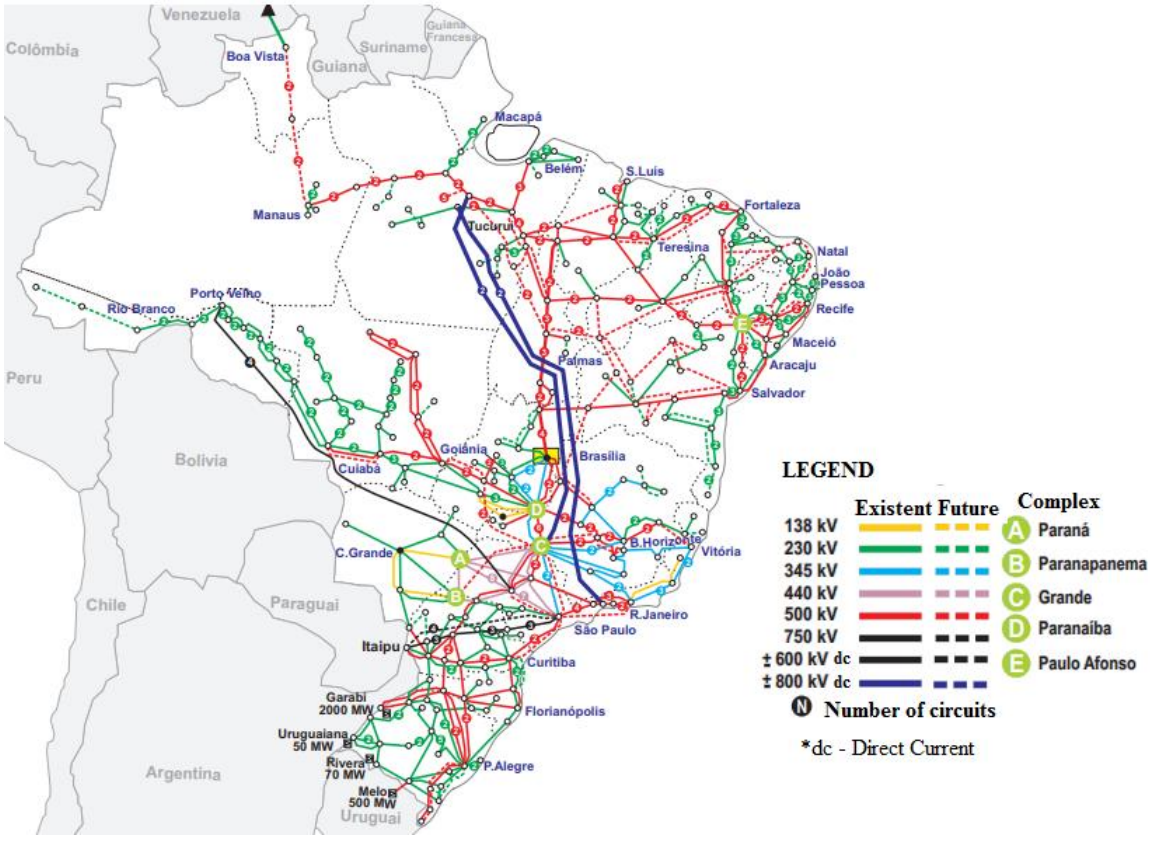
EMPRESA…, 2020c). Brazilian electricity market supply is almost totally interconnected (Figure 8); however, there is a need for expansion, especially in the north region.

Figure 7 - **Correlation between per capita income and the probability of newborn babies not completing the first year of age**



Source: based on IBGE (INSTITUTO..., 2019, 2021c).

Figure 8 - **Main electricity transmission lines in Brazil for the 2024 horizon (no scale)**

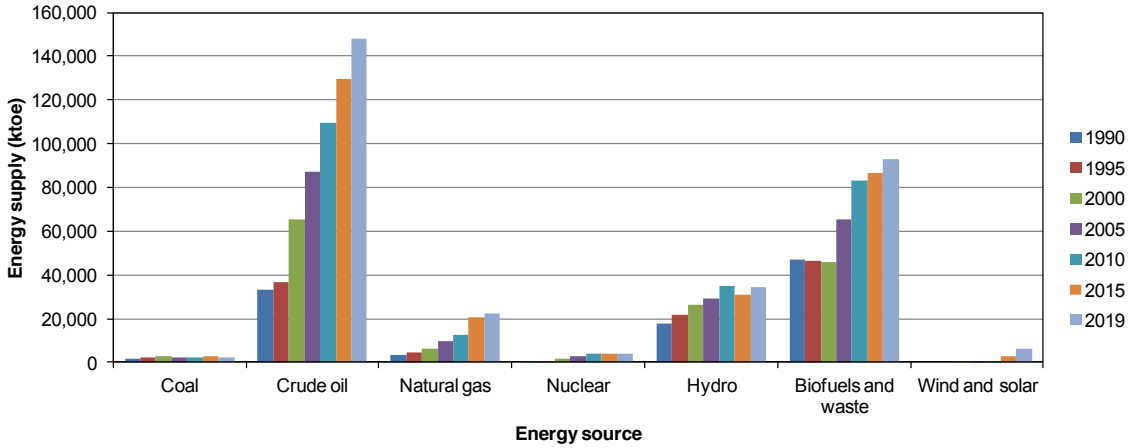


Source: based on Operador Nacional do Sistema Elétrico (2020).

The International Energy Agency (IEA) showed a panorama about the Brazilian energy policies (INTERNATIONAL..., 2020, 2021) and observed that they fit well against the world's most immediate energy challenges. Almost everybody has access to electricity across the country, and renewable meets about 45% of primary energy demand. Since 1990, the total primary energy demand has doubled, led by high electricity consumption and demand for transport fuels. Large hydropower plants account for around 80% of domestic electricity generation, giving the electricity system a great deal of operational flexibility. Other sources for power generation are growing, such as natural gas, wind and bioenergy. Figure 9 shows the total energy supply in Brazil according to the source from 1990 to 2019, in which crude oil, biofuels and waste, and hydro are more used (INTERNATIONAL..., 2020; ALUPAR..., 2021b). Besides, the participation of electricity installed according to the energy generation type in 2019 (Figure 10), in which the greater were hydropower plants (60.5%), wind power plants (9.0%), biomass (8.6%), natural gas (7.9%) and petroleum products (4.5%) (INTERNATIONAL..., 2020; ALUPAR..., 2021b).

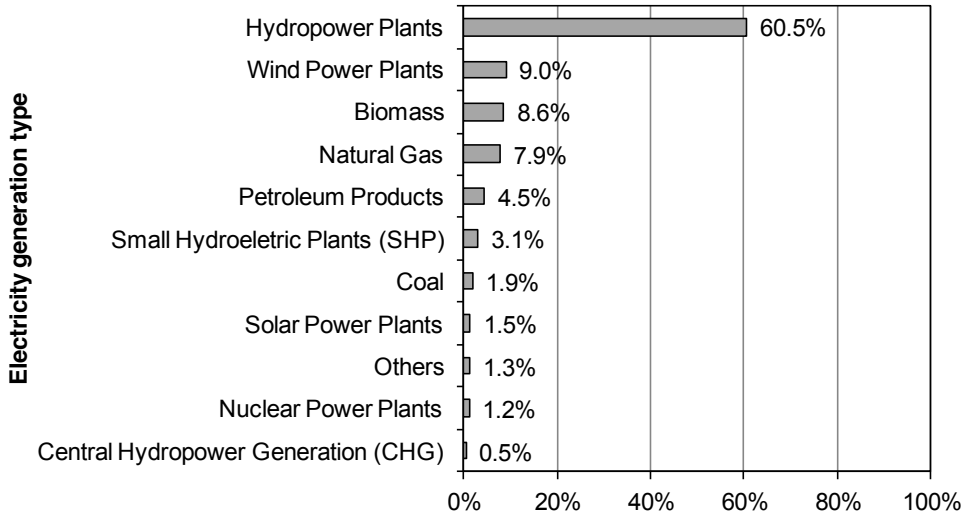
The comparison among the Brazilian electricity capacity installed and per capita income for each region in 2019 is shown in Figure 11. It can be observed that the southeast region comprises the major percentage, followed by the northeast and north regions. The percentage among regions appears to be similar for most regions. However, for each state, a more in-depth analysis shows that the installed capacity of electricity generation is irregular (Figure 12). Also, it is observed that the installed capacity of electricity is not directly related to per capita income.

Figure 9 - **Energy supply according to the source in Brazil from 1990 to 2019**



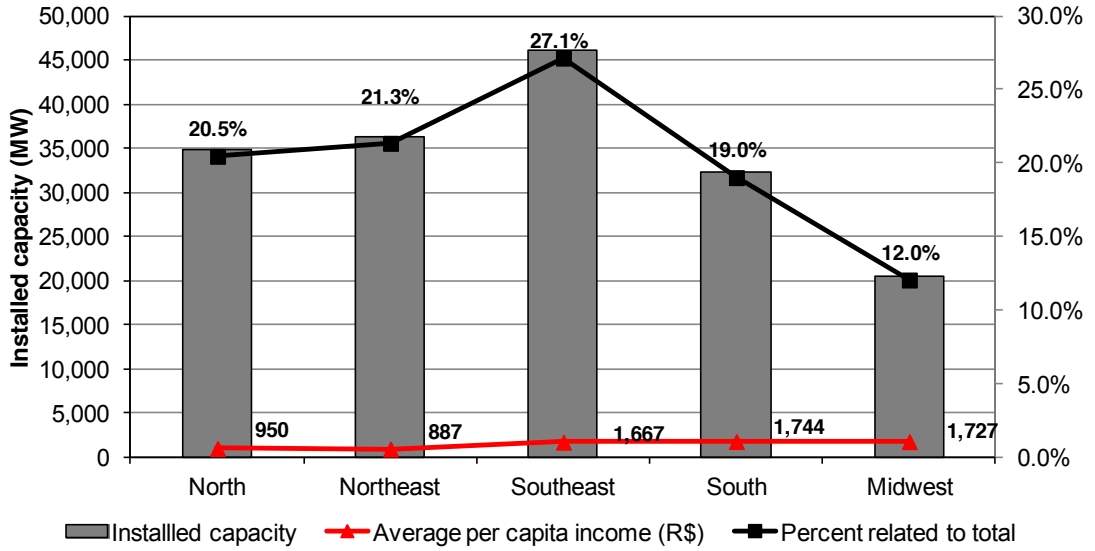
Source: based on International Energy Agency (2020, 2021).

Figure 10 - **Participation of electricity according to the generation type**



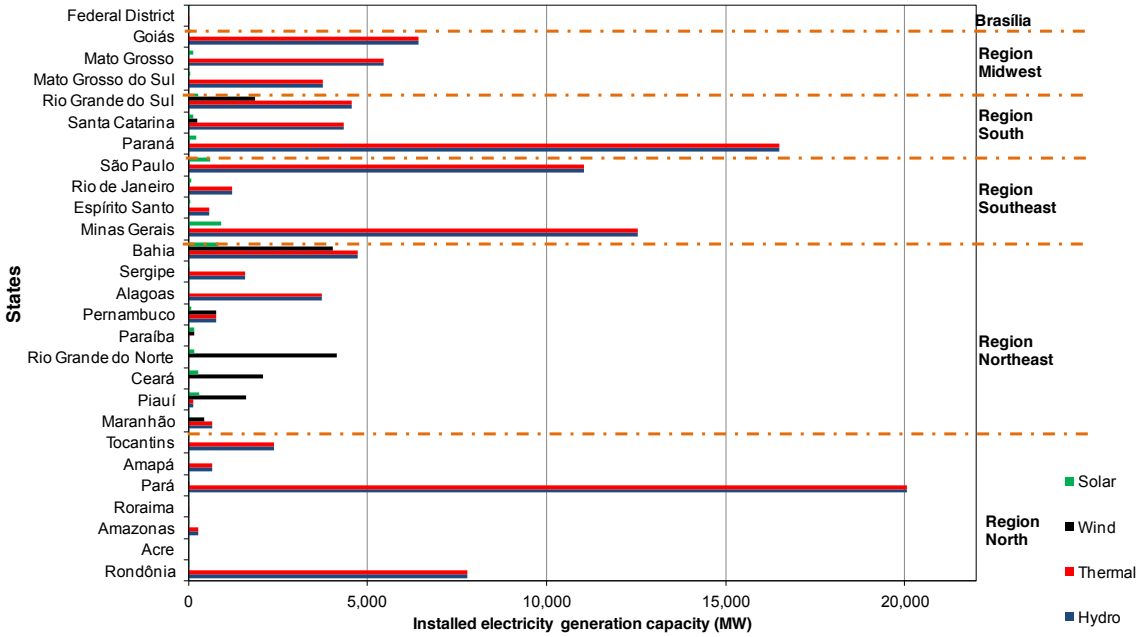
Source: based on International Energy Agency (2020).

Figure 11 - **Installed electricity capacity for regions and per capita income in 2019**



Source: based on IBGE (INSTITUTO..., 2021b) and Empresa de Pesquisa Energética (2020c).

Figure 12 - **Source of installed electricity capacity for each state in 2019**



Source: based on Brazil (2019).

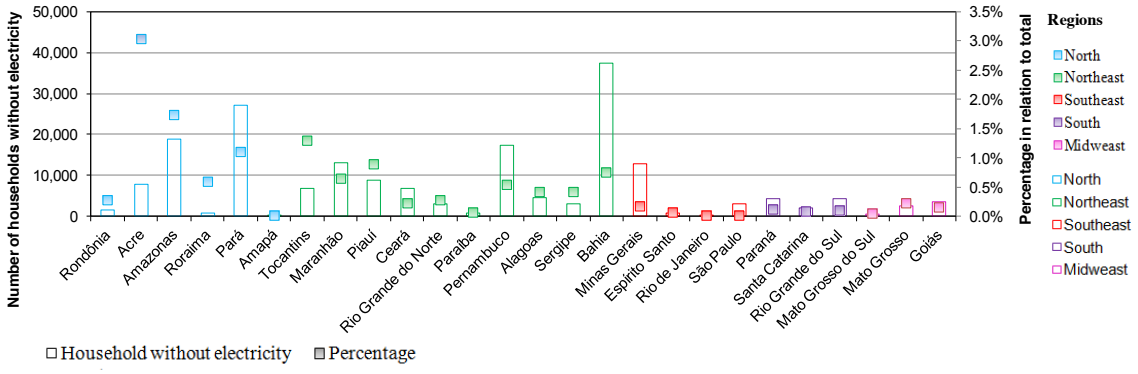
When the number of households without electricity access considering only the urban population is compared (Figure 13), it can be observed that the situation is more precarious in the states from the north and northeast regions. Often there are isolated communities that live in the countryside, with no electricity access, that, in general, use fossil fuels or other energy generation alternatives.

As for the electricity generation in each state and region in 2019 (Figure 14), it is possible to observe that the electricity generation varies among the states, prevailing in the southeast and south regions. Although states such as Rondônia and Pará in the north region have higher generation, other states such as Acre, Amazonas, Amapá and Tocantins have low generation.

Considering the population growth and the installed electricity capacity from 2012 to 2019, Figure 15 shows that the north, southeast, south, and midwest regions have installed capacity to supply the increasing

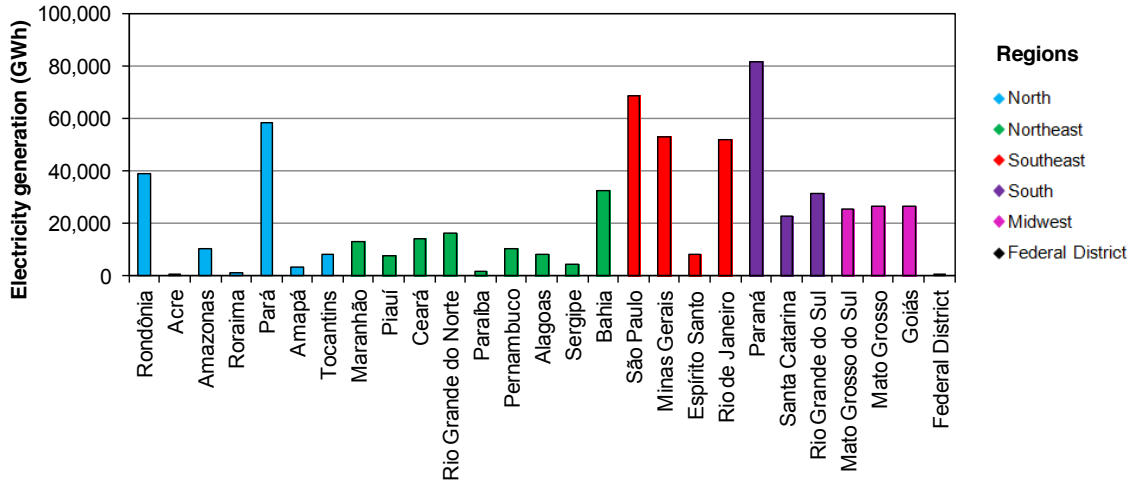
population. On the other hand, in the northeast region, only from 2016, the installed electricity capacity met the demand related to the population's growth. The increase of installed electricity capacity in the northeast region can be attributed to other sources' progress, such as wind energy. Based on these data (Figure 15), the problems of access to electricity do not seem to be due to the lack of installed capacity.

Figure 13 - **Urban households without electricity access in each state in 2019**



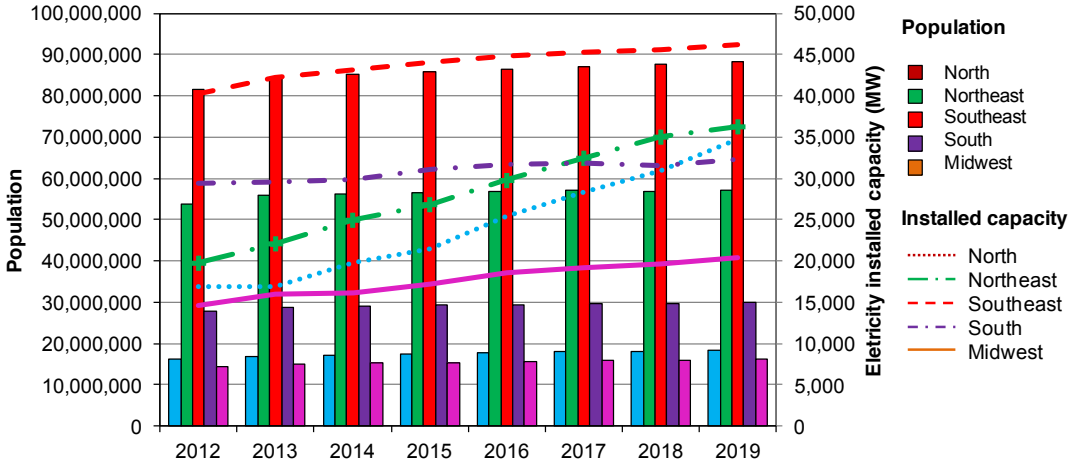
Source: based on Brazil (2019).

Figure 14 - **Electricity generation in each state**



Source: based on Empresa de Pesquisa Energética (2020c).

Figure 15 - **Installed electricity capacity and population in each region**



Sources: based on Empresa de Pesquisa Energética (2020c) and IBGE (INSTITUTO..., 2020a).

Besides the installed electricity capacity, it is important to assess the regions' consumption over time. Besides the installed electricity capacity, it is important to assess the regions' consumption over time. From 2012 to 2019, the electricity consumption was lower for the north and the northeast regions, and higher for the southeast and south (Figure 16).

In addition, many comparisons already presented in this paper corroborate that the electricity access and distribution in the north and the northeast regions represent Brazil's inequality. One alternative to reduce the inequalities is to invest in modern technologies to reduce consumption, obtain better efficiency, and expand public light for the population.

Electricity costs

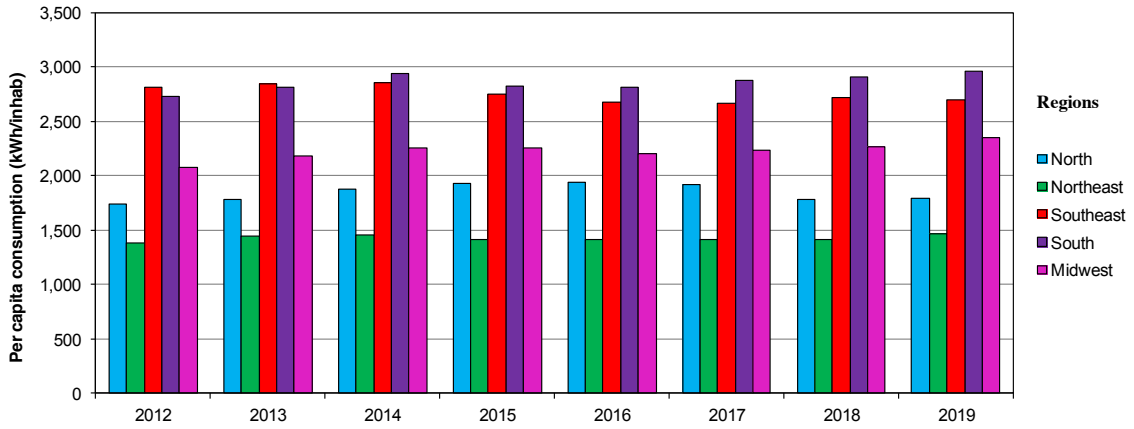
Brazil's electricity cost is considered to be the 37th highest in the world. On average, the cost is lower than in most European countries but higher than in developing countries (JORNAL…, 2021). The quality of the service, measured by the frequency and duration of interruptions, presents adequate considerations, according to the National Electric Energy Agency.

The electricity tariff considers three distinct costs, i.e. energy generated, transmission and distribution, and social taxes. In addition to the tariff, the Federal, State, and Municipal Governments charge two different taxes and public lighting fees. Energy costs represent the largest portion of the cost, 53.5%, the costs with taxes are 29.5%, and with distribution, to maintain and operate the distribution system, 17.0%.

Due to the COVID-19 pandemic, through Provisional Measure No. 950/2020, a 100% tariff discount was established for electricity consumption of up to 220 kWh/month for the social tariff beneficiaries. The payment exemption was valid for three months until June 30, 2020 (BRAZIL, 2020). For example, in 2020, 36,000 families registered for a social tariff at the electricity distributor in Santa Catarina state among three million consumer units, representing 1.2% (CENTRAIS…, 2020). On the other hand, in Amazonas state, 170,000 families are beneficiaries of the social tariff among one million consumer units, representing 17.0%. Due to the COVID-19 pandemic, the Amazonas Government signed an agreement to include 220,000 families as beneficiaries of the social tariff until the end of 2020, representing a total of 39% (AMAZONAS, 2020).

Since 2015, the electricity bill is calculated considering the Tariff Flag System, which has three colours, i.e. green, yellow and red. When there is less rainfall and reservoirs are getting empty, it is necessary to activate more thermal power plants, which are more expensive to operate than the hydroelectric system. Because of this difference in energy generation costs the tariff flags were created (AGÊNCIA…, 2020).

Figure 16 - **Evolution of annual per capita consumption from 2012 to 2019**



Source: based on Empresa de Pesquisa Energética (2020c).

This system indicates whether there will be an increase in the electricity tariff to the consumer, depending on electricity generation conditions (ANEEL, 2020). From 2015 to 2019, 50% of the time, the red flag prevailed while green and yellow flags correspond to 28.3% and 21.7%, respectively. The green flag indicates favourable conditions for energy generation, and in this case, there is no increase in the tariff. On average, the cost of electricity in Brazil is R$ 0.30. For the yellow flag, the generation conditions are less favourable, and the tariff receives an increase of R$ 0.01343 (an increase of 4.48%) for each kWh consumed. The red flag has two levels. At level 1, the generation conditions are more expensive, and as a consequence, the tariff is increased by R$ 0.04169 (an increase of 13.47%) for each kWh consumed. At level 2, even more expensive generation conditions are observed. The increase is R$ 0.06243 (an increase of 20.81%) for each kWh consumed. Only the state of Roraima (north region) is not included as it is considered an isolated system. In 2019, the monthly average energy consumption in Brazilian homes was 162.2 kWh per month, in which the highest average consumption was 208.8 kWh in Rio Grande do Sul state (south region), and the lowest was 113.3 kWh in Sergipe state (northeast region) (EMPRESA…, 2020c).

The Gini index measures the degree of income concentration through the difference between the poorest and the richest income. Numerically, it varies from zero to one, where the zero value represents the situation of equality, and the value one is the opposite.

The relationship between the Gini index and electricity tariff rates for all regions from 2012 to 2019 showed that the highest electricity tariff occurs in the north region, where per capita income is the second-lowest in the country. Compared to the south, southeast and midwest regions, concerning per capita income, the least developed regions of the country (north and northeast regions) have the highest tariffs. In contrast, the lowest tariffs are found in more developed regions.

According to the Gini index, the major inequality occurs in the northeast region, while the south region presents better socioeconomic conditions in Brazil. These facts discourage the establishment of industries, expansion of trade, job creation, and income growth in less developed regions. It also enlarges social and economic inequalities over Brazilian regions.

The reasons for the higher tariff costs in less-favoured regions can be listed as being due to high investments to connect locations far from the existing power grids; high network operation and maintenance costs, normally installed in regions with dispersed consumers that are difficult to access (without roads, basic sanitation and infrastructure); population with low consumption and low capacity to pay for services rendered.

A survey conducted by the Brazilian Association of Energy Traders in 2019 showed that 87% of consumers consider their energy bill expensive. In many cases, the electricity bill compromises 12% of the household income. Also, at least 64% of consumers say they make an effort to save energy not to affect the family budget significantly. Due to the high temperatures in the Brazilian summer, there is a tendency to increase the use of equipment such as air-conditioning, increasing electricity consumption, on average, by 7%. On the other hand, a large portion of the electricity bill in Brazil is due to taxes (INSTITUTO…, 2020b).

Currently, there are 237 isolated locations in Brazil, most of them in the north region, in the states of Rondônia, Acre, Amazonas, Roraima, Amapá and Pará. Electricity consumption in these locations is low and represents less than 1% of the total, supplied mainly by local diesel oil thermal plants (WORLD…, 2020).

This paper showed that there is a growing demand for public policies to minimise inequalities in the distribution of electricity and social problems in Brazil. At the same time, public managers must evaluate and monitor the efficiency of public policies. It was also observed that, according to geographic distribution, the country has unequal social, economic and electricity access. According to the data collected by IBGE (Table 2), all states in the north and northeast regions presented poverty indicators.

To minimise the inequalities in the electricity sector, the governments must maintain the policies for more developed regions and provide improvements related to education, income, and expansion of electricity network in the less-favoured regions, i.e. north and northeast.

The Brazilian electricity system faces challenges common to other countries, such as the lack of inclusion, high prices, growing threats of climate change, slow progress in energy efficiency, and mainly, becoming a sustainable energy sector with priority use of renewable sources.

The country currently needs to expand the electricity system, but there is no clear definition of the model to be adopted, considering the environmental impacts generated. Although hydropower plants are predominant, responsible for 80% of the electricity consumed in Brazil, only 35% of the potential is used. Considering

that the potential is located in an Amazon area, the environmental and logistical limits are significant, which increases the marginal costs of exploration. Nowadays, the model adopted for constructing new hydropower plants (SANTANA, 2021).

One of the great difficulties for exploiting the new hydroelectric sources is the distance from the large consumption centres, which occurs mainly in the Amazon region (north). Therefore, the consequences of the lack of energy distribution are reflected in the results found in the north region. In this sense, the need for additional investments in long transmission lines for the flow of electricity production is urgent.

In addition to the government action plans, as providing electricity for all regions to minimise de inequalities must also ensure that everyone has conditions to pay the electricity bill. It means that electricity supply must be accompanied by the improvement of infrastructure, sanitation services, education and per capita income.

In conclusion, the exclusion in access to electricity is strongly associated with a lack of offer, especially in the north region. On the other hand, it is essential to consider that the policies must always be accompanied of mechanisms that enable poor citizens to pay for such services. In other words, more investments in infrastructure and public services such as health and education are needed for the less favoured population.

Conclusions

Brazil is a country with demographic, social and economic differences. The south, southeast and midwest regions have higher per capita income and are more developed. On the other hand, the north and northeast are less-favoured regions, with lower access to electricity.

Through this study it was possible to relate social and spatial inequalities to the supply of electricity and its consequences for developing the Brazilian regions. The differences in income and HDI over Brazilian states show that the country has different realities over its territory. One policy implication of minimising electricity access inequality is diversifying the energy matrix, mainly through investments in renewable energy.

Brazil has sufficient installed capacity for electricity generation, but there is an irregular distribution over the country. Brazil faces losses in the electricity system, mainly in urban areas, due to clandestine connections or electricity theft. However, if the electricity access and distribution were more egalitarian and the tariffs were lower, the population would be willing to pay for the electricity bill.

This study showed that the electricity production sector access and distribution affect consumption and vary according to per capita income. Another policy implication of increasing electricity access and distribution is the establishment of industries, expansion of trade, jobs creation, and income growth in less developed regions. It also enlarges social and economic inequalities among Brazilian regions.

In conclusion, providing electricity access similarly to all states would improve quality of life and education to the population and increase income. The inequalities can be minimised by providing infrastructure to all areas, including the electricity system. Reducing socioeconomic inequalities among regions would improve the quality of the electricity supply and provision of this service, especially in the north and northeast regions. Access to electricity in less-favoured regions will provide a technological evolution and provide better conditions for the population. Social inequality is still one of the main problems that Brazil faces. However, regardless of source and low cost, access to electricity is a basic need to guarantee a future with more opportunities for Brazilians. Providing electricity access equally to all Brazilians will improve their quality of life and education, and in turn, this will contribute to increasing their incomes.

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