v. 3, n. 24, 2023

Journal of
Engineering
Research

CONSIDERATIONS ON THE EVOLUTION OF POWER PLANTS IN BRAZIL AND THEIR SOCIAL AND ENVIRONMENTAL IMPACTS

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Abstract: The growth of the global population, associated with the development model, requires demands for electric power, both in urban and rural areas. This implies constant investments to meet the needs. This article was based on a research and literature review, on the approaches to the themes: Brazil's energy sector, the participation of hydroelectric plants in the national energy matrix, advantages, disadvantages and socio-environmental impacts. Despite the evolution in relation to the use of renewable energy sources, mineral coal and natural gas are still a very significant portion of the world's electricity matrix. In Brazil, however, one of the most widely used sources for power generation is hydroelectric power. Given the availability of water resources in the country, the construction of hydroelectric plants has caused both environmental and social damage. The generation, transmission and distribution of energy in Brazil are components of a large system, composed mainly of the matrices: hydro, wind, thermal and photovoltaic. Although there is a gain with the generation of energy, society suffers all the effects caused by the enterprise, from before, during and after its construction to the entry and after its operation. Even though there are Environmental Licensing processes for the construction of large undertakings or high-impact projects, the current Brazilian model is still impactful, contradictory, and cause for criticism.
Keywords:energy matrix, hydraulic energy, society, renewable source.

INTRODUCTION

Energy plays a crucial role in generating wealth, social development and improving the quality of life in both developed and developing countries around the world. An efficient and universal supply of energy is considered a fundamental requirement for economic development. Access to energy is now a basic requirement for citizenship, its absence being a source of marginalization for individuals (BURIAN, 2006).

The use of renewable sources is the most valuable solution to reduce the environmental problems related to the generation of energy from fossil fuels and to achieve sustainability in the energy sector. Hydropower stands out as one of the most important renewable sources for the production of clean energy worldwide. All nations are directing their attention towards extracting energy from renewable sources (SCHOLTEN and BOSMAN, 2013).

The socioeconomic development of a country is related not only to the generation, but also to the transmission and distribution of electric energy. Over the years, the need and caution in relation to these projects have increased, since their effects can exceed the benefits and cause irreversible socio-environmental damage. The construction stage of hydroelectric plants is the most impactful, as it involves the removal and relocation of local populations, the suppression of vegetation, the opening of roads, the diversion of the river channel, the flooding of the land for the formation of the reservoir, among others. other actions (ANDRADE, et al. 2019).

From this perspective, the main objective of this research is to discuss the main environmental and social damages caused by the generation of electric energy in Brazil.

METHODOLOGY

This article was based on a research and literature review, based on the approaches of the following themes: energy sector in Brazil, participation of hydroelectric plants in the national energy matrix, advantages and disadvantages and socio-environmental impacts.

The survey was carried out based on official documents from public institutions, such as the National Water and Environmental Sanitation Agency (ANA), the Generation Information Bank (BIG), and the National Electric Energy Agency (ANEEL), as well as on research in articles, dissertations and theses.

WORLD AND BRAZILIAN OVERVIEW

On the other hand, Brazil's energy matrix is predominantly renewable, with electrical energy even more sustainable. This is due to the fact that a large part of the electricity produced in the country is predominantly generated by hydroelectric plants, representing about 60% of the total energy produced in the country.

In addition, wind energy has shown significant growth, currently around 10%, which contributes to the Brazilian electrical matrix remaining predominantly based on renewable sources (EPE 2022). Figures 1 and 2 show the percentages of the world's and Brazil's energy matrix.

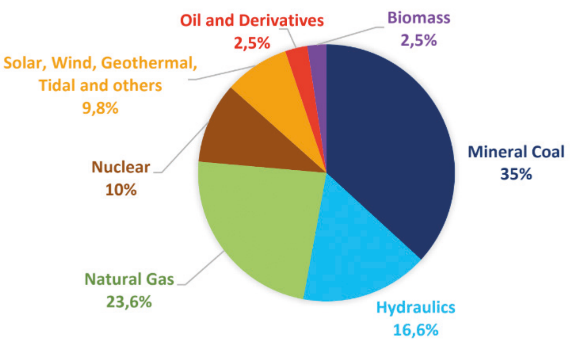

Figure 1 -World Electrical Matrix 2021

Source: Prepared by the authors based on EPE (2022).

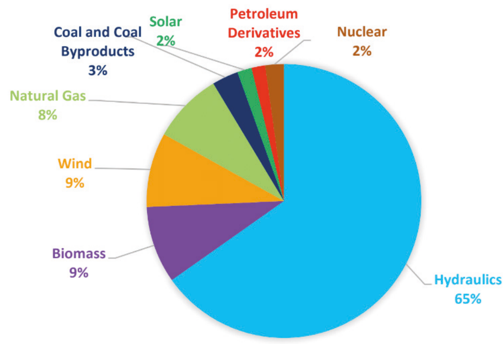

Figure 2 -Brazilian Electrical Matrix 2021.

Source: Prepared by the authors based on EPE (2022).

The physical, geographic characteristics and availability of water resources in Brazil are fundamental factors for the position of third largest hydraulic potential in the world. Despite the abundance of these water resources in the country, the construction of hydroelectric plants has caused both environmental and social impacts (EPE 2022).

BRIEF HISTORY OF THE BRAZILIAN ELECTRICITY SECTOR AND THE PARTICIPATION OF HYDROELECTRIC PLANTS

Mendes (2005) points out, in his studies, that, in Brazil, since the end of the 19th century, there were already the first signs for the exploitation of hydraulic energy, especially in the states of Minas Gerais and São Paulo. Then, some attempts were made to invest in hydroelectric power generation. In the first decade of the 20th century, this type of energy surpassed thermoelectric plants and became the main source of energy in the country.

The change in the dominance of multinational companies began to be noticed during the government of President Getúlio Vargas, which began in 1930. Faced with the crisis of the agro-export model, the Vargas government wanted to diversify the structure and encourage the national industry. This way, interventionism in the economy became evident in the electricity sector. The gold clause, which provided for the correction of tariffs based on the price of gold, was extinguished; as well as new hydraulic uses were also suspended (GONÇALVES JÚNIOR, 2007).

During the mid-twentieth century, the Brazilian growth, expansion and development plan was conditioned to the expansion and progress of the energy matrix. The solution found by the government was the construction of large hydroelectric plants, which caused socio-environmental damage. The Kubitschek government was marked by accelerated growth, with the construction of several hydroelectric plants, the foundation of the second federal company dedicated to generation (Furnas Centrais Elétricas S/A, more popularly known as Furnas) and the creation of the Ministry of Mines and Energy - MME (GOMES & VIEIRA - 2009).

The production of electricity grew in the 70s and 80s, due to the rapid economic and population growth in the country. Given that the country has an extensive territory and an extensive network of rivers in watersheds, one of the most logical strategies, considered by both the government and the private sector, was to intensify obtaining electricity from water resources. Thus, Eletrobrás began studies and research with the aim of identifying the best stretches of rivers with potential for the construction of hydroelectric power plants. Several plants were built during this period, such as Tucuruí in Pará, which began operating in 1984; Itaipu Binacional (integration of Brazil and Paraguay) in 1984; and the hydroelectric plants of Sobradinho in northeastern Brazil in 1982 and Ilha Solteira in the states of Mato Grosso do Sul and São Paulo in 1973,

According to Fernandes et al. (2017), the planning crisis occurred simultaneously with the crisis of the developmental State. Thus, the 1980s and 1990s were marked by the decline of planning and the predominance of focused and circumstantial stabilization plans. in thisAt the time, it was easy to see that it would not be possible to manage the crisis in the electricity sector without a profound change in the institutional model.

At the end of the 1990s, in December 1996, the National Electric Energy Agency (ANEEL) was created by Law 9,427/96,it was conceived as an autarchy under a special regime, which must enjoy technical and administrative autonomy. The reform of the electricity sector adopted a strategy that sought to simultaneously reduce the public debt, expand companies' investment capacity and improve production efficiency.

However, with large works on hold since the end of the 1980s due to the serious fiscal crisis, with a broad reform in progress and with institutions created to manage the sector still being structured, the country experienced the consequences of the lack of planning and investment (PEREIRA, 2020).

From 1992 to 2002, installed electrical capacity grew by less than 40%. This fact, combined with a severe drought, reduced hydroelectric power generation capacity, causing energy rationing in 2001. In that year, the Electric Energy Crisis Management Chamber (GCEE) was created, which issued measures to emergency in order to reduce demand.(GOMES AND VIEIRA, 2009; LANDI, 2007).

As of 2004, the electricity sector underwent a new institutional reform: the creation of Public-Private Partnerships, the decentralization of ANEEL in 2009, the National Plan for Dam Safety in 2010, the 2019 General Framework for Regulatory Agencies and, finally, in 2020, the National Basic Sanitation Plan. These changes are in effect to this day.

SOCIAL AND ENVIRONMENTAL IMPACTS

Despite all the advantages arising from the construction of hydropower dams, which are materialized by the increase in the supply of jobs and by the increased demand for goods and services that drive the local economy, the socio-environmental impacts cannot be ignored. It is important to point out that these benefits are well observed during the initial construction phase, but it is necessary to consider the consequences and costs in later stages, especially the operation phase of the projects.

Rivers form hydrographic basins, units that function as ecosystems and, therefore, must be considered in an integrated and synergistic way. The construction of hydroelectric power plants has been the subject of impact studies since 1970, either as required by the World Bank or by the extinct National Department of Water and Electric Energy (DNAEE), which is currently controlled by ANEEL.

One of the actions that emerge from these socio-environmental studies is the attempt to save the flora and fauna of the area that will be flooded for the formation of the reservoir, the construction of ladders for fish, which, of course, does not work properly, maintaining the impacts of the dams on fishing, and other actions that may be mitigating and/or compensatory. However, there are adverse social effects. Rosa (1989) had already warned of the problem of the regional insertion of water plants in relation to riverside communities affected by the expropriation of large areas for the construction of reservoirs, thus recognizing the worsening reaction of these communities, especially when there is the presence of of indigenous communities, admitting that this is a delicate and more complex matter.

The displacement of people from their homes due to the fact that they are in a place that will be directly or indirectly affected by the work in question is a relevant social impact (Sánchez, 2008). However, the instability and uncertainty of prior planning are characteristics present in the process of identifying those affected, who need resettlement, configuring a logic of production of compensatory policies that ignores the dynamics of production of demands and conflicts in scenarios of large projects, in which inclusion measures are based on arbitrary classification mechanisms of those not included, which exclude them from recognition as subjects with the right to compensation and/or mitigation (OLIVEIRA et al., 2014).

The impacts and causes of conflicts during the implementation phase of the HPP include changes in the river environment, resulting in a decrease in fish diversity and tourist potential, as well as flooding of mineral deposits, resulting in the loss of mineral resources. In addition, floods can affect arable land, leading to the relocation of farmers to less fertile areas without adequate access to water. The loss of vegetation cover also affects the fauna, while the rural population is forced to resettle or be relocated, causing the disruption of social relations. The flooding of road infrastructure interrupts transport links, resulting in the breakdown of neighborhood ties and requiring an increase in demand for health and environmental sanitation services, which overloads existing services, leading to a drop in the standard of care. On the other hand, the creation of jobs can increase the population contingent and cause impacts on social relations. In the operation phase of the UHEs, conflicts may arise due to changes in water quality, compromising other uses, and changes in the structure of fish communities, resulting in a reduction in fish diversity and population stocks. In addition, the high cost of implementation can also be a conflicting factor (MME – 2007; MATIELLO and QUELUZ

- 2015; ELIAS - 2009). and the alteration in the structure of fish communities, resulting in reduced fish diversity and population stocks. In addition, the high cost of implementation can also be a conflicting factor (MME – 2007; MATIELLO and QUELUZ - 2015; ELIAS - 2009). and the alteration in the structure of fish communities, resulting in reduced fish diversity and population stocks. In addition, the high cost of implementation can also be a conflicting factor (MME – 2007; MATIELLO and QUELUZ - 2015; ELIAS - 2009).

Using renewable energy sources and not requiring large constructions, Small Hydroelectric Power Plants (PCHs) have a smaller impact compared to Hydroelectric Power Plants (UHEs). They have a lower implementation cost and a shorter implementation period, are adaptable to small watercourses and are exempt from concession, permission or authorization. In addition, they have the advantage of enjoying tax, financial and commercial benefits. However, it is important to note that these plants still have negative environmental and socioeconomic impacts, albeit on a smaller scale compared to large hydroelectric plants. The main consequences of these impacts are similar, but to a lesser extent, and include reduced power generation capacity. (LATINI and PEDLOWSKI, 2016).

With the flexibility of being built in both urban and rural areas, the Thermoelectric Plants (UTEs) can be activated in emergency situations to meet peak energy demands. In addition, they use a variety of fuels, including coal, natural gas and biomass. However, it is important to highlight that, in general, these plants are non-renewable energy sources. The environmental impacts of UTEs are significant, with high emissions of greenhouse gases and other pollutants. The cost of operating and maintaining these plants is considered high or high (EPSTEIN, 2010).

Adequate to supply small energy demands, which can be built in areas with less water availability, the Small Hydroelectric Generating Centers (CGH) have a reduced flooding area, resulting in lower losses due to evaporation and infiltration. Unlike larger plants, CGHs do not have a flow regulation reservoir, which can result in some instability. In terms of environmental impacts, they generally have a smaller impact, but in many cases they are treated by regulatory bodies as larger enterprises. In addition, they tend to be located in isolated regions, which increases the cost of connecting to the electricity grid (MELLO, 2016).

Finally, Photovoltaic Plants (UFVs) are a renewable and clean energy source, characterized by low emissions of greenhouse gases and other pollutants. They can be built in both urban and rural areas, providing flexibility in terms of size and power generation capacity. They dispense with the need for concession, permission or authorization. Incidentally, the cost of operation and maintenance tend to be relatively low. Its negative impact is more related to the fauna and flora in the process of its installation, consequently in the presence of a floating population brought for the construction of large enterprises (SILVA et al. 2018).

RESULTS

According to data from the ANEEL Generation Information Bank - BIG (2023), the generation, transmission and distribution of energy in Brazil are a large-scale system, with multiple owners, predominantly by hydro, wind, thermal and photovoltaic matrices. Examples are: Hydroelectric Generating Center (CGH), Undi-electric Generating Center (CGU), Wind Generating Center (EOL), Small Hydroelectric Power Plant (PCH), Photovoltaic Solar Generating Center (UFV), Hydroelectric Power Plant (UHE) and

Thermonuclear Power Plant (UTN).

The system is interconnected and consists of four subsystems: South, Southeast/Midwest, Northeast and most of the North region (with the exception of some isolated locations in the states of Rondônia, Acre, Amazonas, Roraima, Amapá and Pará). The connection between the electrical systems results in the creation of the National Interconnected System (SIN), allowing the transmission of energy between the subsystems and the exploration of the diversity of the regional electrical matrices (ANEEL 2023).

The distribution of energy matrices are mostly formed by PCHs, and these are located in the south and southeast regions of Brazil, close to large electricity consumer centers.

The increase in the number of projects, such as PCHs and CGHs, resulting from tax incentives and simplification of licensing, has caused negative impacts in economic, social and environmental terms, which must be analyzed with caution to avoid irreversible damage to rivers and the communities where they are located. implanted (LATINI - 2016; MATIELLO and QUELUZ - 2015, ELIAS - 2009).

Although it is said that PCHs and CGHs are "clean sources" and various incentives are granted, scientific research has shown that, despite being smaller, they require greater attention from society, since they alter the hydrological characteristics of aquatic ecosystems and cause negative impacts to the biota, both at individual, population and community levels, especially when they are built in sequence in the same river (QUEIROZ et al. 2013).

This way, they are increasing the load and fragmenting river courses, which impairs their connectivity. The aggravating factor is that the adverse consequences of these works have not yet been properly analyzed. Thus, according to information from ANEEL (2023). Brazil currently has 426 PCHs and 724 CGHs, totaling 1150 plants, in addition to 31 PCHs and 2 CGHs under construction and with the perspective of, in the following years, building 77 PCHs and 2 CGHs.

As shown in Tables 1A and 1B, it is possible to notice a progression in the number of photovoltaic plants in the period of one year (Figure 3).

Source	Granted Power (kW)	Supervised Power (kW)	Quantity (ud)	% Power Inspected
UHE	103,454,926.00	103,008,362.00	223	56.25
PCH	7,245,669.32	5,607,600.57	541	3.06
CGH	856,486.92	842,527.92	735	0.46
UFV	44,399,452.31	5,022,930.61	9,571	2.74
UTE	54,134,957.81	44,860,612.71	3,224	24.5
EOL	35,557,268.86	21,796,178.86	1,197	11.9
UTN	3,340,000.00	1,990,000.00	3	1.09
CGU	50.00	50.00	1	0
Total	**248,988, 811.22**	**183,128, 262.67**	**15,495**	**100**

Table 1A–Power plants in operation in Brazil in May/2022

Source: Elaborated by the authors, based on data from ANEEL (2022 and 2023).

Source	Granted Power (kW)	Supervised Power (kW)	Quantity (ud)	% Power inspected
UHE	103,175,523.00	103,195,357.00	215	53.44
PCH	5,719,975.57	5,712,117.57	426	2.96
CGH	879,650.16	878,791.16	724	0.46
UFV	9,383,000.73	9,340,508.15	18,147	4.84
UTE	47,743,366.01	46,229,208.41	3,023	23.96
EOL	26,002,123.86	25,704,523.86	929	13.31
UTN	1,990,000.00	1,990,000.00	two	1.03
CGU	0.0	0.0	0.0	0.0
Total	**194,893, 639.33**	**193,050, 506.15**	**23,466. 00**	**100**

Table 1B–Power plants in operation in Brazil in May/2023

Source: Elaborated by the authors, based on data from ANEEL (2022 and 2023).

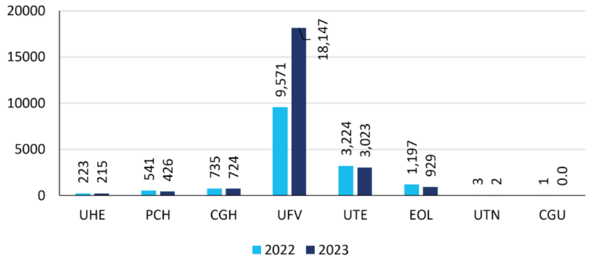

Figure 3 - Number of plants in operation in Brazil in 2022 and 2023

Source -Elaboration of the authors, based on ANEEL data (2022 and 2023).

Meanwhile, in Tables 2A and 2B, which show the number of plants under construction, from 2022 to 2023 there was an increase in wind and photovoltaic plants (Figure 4).

Source	Granted Power (kW)	Quantity (ud)	% power granted
UHE	141,900.00	1	0.89
PCH	408,003.10	31	2.55
CGH	7,700.00	4	0.05
EOL	5,818,250.00	156	36.35
UFV	4,026,977.60	106	25.16
UTE	4,255,393.50	56	26.58
UTN	1,350,000.00	1	8.43
Total	**16,008,224.20**	**355**	**100%**

Table 2A - Plants under construction in Brazil in May/2022

Source: Elaborated by the authors, based on data from ANEEL (2022 and 2023).

Source	Granted Power (kW)	Quantity (ud)	% power granted
UHE	49,998.00	1	0.0
PCH	412,076.00	31	43.81
CGH	4,600.00	two	0.0
EOL	6,040,845.00	153	0.0
UFV	5,800,675.80	140	0.0
UTE	4,658,470.00	46	56.19
UTN	1,350,000.00	1	0
Total	**18,316,664.80**	**374**	**100%**

Table 2B - Power plants under construction in Brazil in May/2023

Source: Elaborated by the authors, based on data from ANEEL (2022 and 2023).

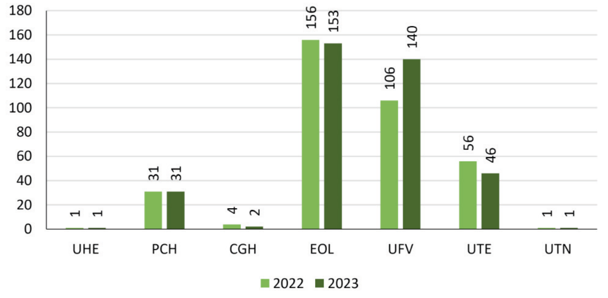

Figure 4 - Number of plants under construction in Brazil in 2022 and 2023

Source: Elaborated by the authors, based on ANEEL data (2022 and 2023).

In short, in tables 3A and 3B, the number of plants with construction not started between 2022 and 2023photovoltaic and wind power plants predominate (Figure 5).

Source	Granted Power (kW)	Quantity (ud)	% power granted
CGH	2,000.00	1	0
EOL	7,913,510.00	220	16.49
PCH	1,186,706.65	80	2.47
UFV	35,182,780.00	872	73.31
UHE	311,998.00	4	0.65
UTE	3,392,811.00	60	7.07
Total	**47,989,805.65**	**1,237**	**100%**

Table 3A - Plants not started in Brazil in May/2022

Source: Elaborated by the authors, based on ANEEL data (2022 and 2023).

Source	Granted Power (kW)	Quantity (ud)	% power granted
CGH	6,400.00	two	0.0
EOL	18,885,420.00	444	0.0
PCH	1,107,212.65	77	0.0
UFV	102,096,003.60	2,392	0.0
UHE	262,000.00	3	0.0
UTE	3,551,710.00	46	0.0
Total	**125,908,746.25**	**2,964**	_

Table 3B - Plants not started in Brazil in May/2023

Source: Elaborated by the authors, based on ANEEL data (2022 and 2023).

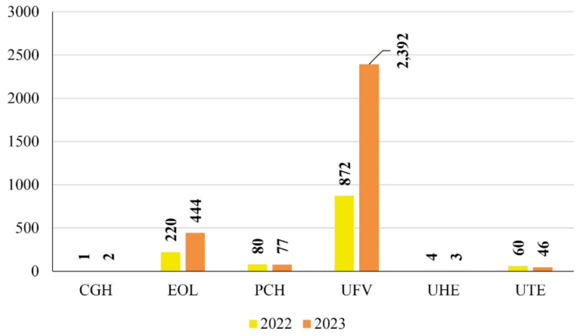

Figure 5 - Number of plants with construction not started in Brazil in 2022 and 2023

Source: Elaborated by the authors, based on data from ANEEL (2022 and 2023).

FINAL CONSIDERATIONS

With an overview of the situation, it is clear that, in society, hydroelectric projects have the gain of economic growth, provided by the generation of electric energy. Meanwhile, from a regional perspective, the population suffers all the consequences of the impacts caused by the project, from the reservoir to the entire watershed.

Therefore, the Environmental Licensing process is of paramount importance for the construction of large enterprises or projects of great impact, such as hydroelectric plants. In recent years, there has been great institutional and regulatory progress, such as the need to carry out the Environmental Impact Study (EIA) and the Environmental Impact Report (RIMA), as well as Strategic Environmental Assessments (SEA) in large river basins, where several plants are or will be installed.

Despite the existence of these mechanisms, the current Brazilian environmental impact assessment model is still quite contradictory, criticized and discussed. Among the main shortcomings is the lack of effectiveness in implementing the actions proposed in the EIA and integration with the SEA, as well as a little synergistic and integrated view of the impacts, both on the part of entrepreneurs and on the part of public managers.

This indicates the need for constant improvements throughout the environmental licensing process, as well as in alternative energy generation technologies with low socio-environmental impact. However, the progress in environmental licensing processes achieved in recent decades is at risk, both in the federal government and in the states, due to the weakening of management bodies, the reduction of revenues and personnel, the approval of bills and infra-legal norms. that are not compatible with the necessary advances and international treaties, among other factors that aim to weaken the control, inspection and environmental licensing in Brazil.

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