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Article

Energy poverty in Brazil: A systematic analysis

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Abstract: The utilization of firewood for cooking in approximately 13 million Brazilian households in 2022 raises pressing concerns regarding its multifaceted impact on key development indicators. This impact stems from the profound connection between access to modern energy sources and fundamental rights, including education, health, housing, and leisure. Despite Brazil's remarkable diversity in its energy matrix, the equitable distribution of this essential resource remains a persistent and significant challenge. To construct the present work undertaking a systematic review of the technical literature, uncovering a stark disparity in energy access closely correlated with income levels. This inequality in energy access underscores the urgent need for comprehensive analysis and intervention. The present work endeavors to delve deeper into this complex issue, aiming to illuminate the profound implications of both broad energy access and the consequences of energy deprivation on individual well-being and broader socio-economic dynamics. Also, this work aims to provide a holistic understanding of the challenges faced by communities with limited access to modern energy sources and, concurrently, the opportunities and improvements that can be brought about through enhanced energy accessibility. In addition, this study seeks to identify and evaluate potential solutions to address this critical issue. This work is driven by the recognition that equitable energy distribution is not only a matter of environmental sustainability but also a fundamental human right, pivotal to social and economic progress.

Keywords: energy; energy poverty; energy matrix; inclusion; rent inequality

1. Introduction

The concept of energy poverty is broad and involves different dimensions. ECLAC (Economic Commission for Latin America and the Caribbean) considers energy poverty when a household does not have equitable access to adequate, reliable, efficient, and safe energy services to cover its basic needs, which can support human and economic life, develop its members, and whose energy bill payment does not exceed 10% of their income [1]. The European Commission considers that energy poverty occurs when a household must reduce its energy consumption to a level that has a negative impact on the health and well-being of its inhabitants [2]. Among many other definitions, in this work we adopted the definition of the International Energy Agency [3], which characterizes the situation of energy poverty as the lack of access to modern energy sources, such as electricity, condemning the population to dependence on energy. that is available in its surroundings, generally firewood, with its limitations in energy efficiency and use, with economic, environmental, and health consequences.

Data from the recent demographic census show that 99.7% of Brazilian households have access to electricity [4], in a population of more than 203 million inhabitants.

Brazil has historically had a very unequal income distribution, and, according to the United Nations Development Program (UNDP), until 2020, Brazil ranked seventh among the 10 most unequal countries in the world, with an index of 0.533.

Therefore, there is a distinction between the availability of the service and its consumption, between having electricity available and being able to buy it. And this also applies to the consumption of gas that replaces firewood or traditional biomass in cooking food. Therefore, the fact that 99.7% of Brazilian households have access to electricity does not mean that all these consumers can pay for the service in a country with a GDP per capita of just US$1183 which is still unevenly distributed.

The annual per capita consumption profile of residential electricity reflects this inequality, ranging from 371 kWh for the lowest-income group (consumption equivalent to that of Morocco) to 2221 kWh for the highest-income group, consumption equivalent to that of Japan [5].

According to the Brazilian Institute of Geography and Statistics (IBGE), 11 million households in Brazil used firewood or charcoal for food preparation in 2016. This number rose to 13 million households in 2022 [6], which may characterize a condition of energy poverty [1], with repercussions on other development indicators, such as education, hygiene and health, housing, and leisure.

According to the 2017 World Energy Outlook report, the provision of modern, safe, and affordable energy for all citizens contributes to economic growth and poverty reduction in such a way that historically, economic advancement has been, to a large extent, the result of the change from an agrarian-based economy to an industrial one, changing energy patterns and consumption [7], so that it is possible to affirm that there is a direct relationship between access to and use of modern energy sources and economic and social development [8].

It is important to remember that the United Nations—UN—and its 193 member states agreed on a plan to achieve, by 2030, 17 Sustainable Development Goals (SDGs) for the world, aiming for societies without poverty and hunger, with quality of life and social inclusion, without burdening the planet. SDG number 7 concerns ensuring access to reliable, sustainable, and modern energy sources for all [9].

The present work aims to analyze the current scenario of energy distribution among the population of Brazil, pointing out the negative impacts on health, education, the economy, and the environment due to the lack of access to modern energy sources, mainly electricity.

2. Materials and methods

This work used data collection and analysis as a methodology based on a bibliographical review of available technical literature and access to statistical databases from institutions such as the Brazilian Institute of Geography and Statistics (IBGE), Brazilian Energy Research Company (EPE), and United Nations Development Program (UNDP). Economic and social aspects of access to energy and reflection on Brazil's energy scenario were considered, analyzing concepts of energy matrix, income distribution, energy poverty, and energy distribution planning in the country, in addition to the impacts caused on social well-being.

The methodology employed in this work draws from a rigorous and comprehensive approach encompassing data collection, analysis, and the synthesis of

existing knowledge. A multi-faceted methodology was devised, leveraging the following key elements:

Systematic Review: A systematic review of technical literature was conducted to compile a comprehensive understanding of the subject matter. This involved synthesizing and critically evaluating a wide range of scholarly sources, reports, and publications relevant to energy access and its socio-economic implications in Brazil.

Brazilian Institute of Geography and Statistics (IBGE): Primary demographic and economic data were sourced from IBGE, providing a foundational basis for understanding the population and economic conditions.

Brazilian Energy Research Company (EPE): EPE data was instrumental in gathering insights into Brazil's energy landscape, including energy production, consumption, and distribution patterns.

United Nations Development Program (UNDP): Data from UNDP, especially in the context of human development indices, contributed to a nuanced understanding of the socio-economic aspects related to energy access and its impact on well-being.

Analytical Framework: The research incorporated a comprehensive analytical framework that assessed various dimensions of the energy sector. This included the examination of energy matrix diversification, income distribution, energy poverty metrics, and energy distribution planning strategies in Brazil. The integration of these elements allowed for a holistic understanding of the complex interplay between energy access and its socio-economic ramifications.

Social Well-being Assessment: A critical focus of this study involved evaluating the impacts of energy access, or lack thereof, on social well-being. This encompassed an in-depth analysis of how disparities in energy access affect education, healthcare, housing, and overall quality of life.

The utilization of these methodological components ensured a robust foundation for this work, enabling a comprehensive examination of the energy landscape in Brazil and its implications on the broader socio-economic context. Through the synthesis of data from reputable sources and the application of a multi-dimensional analytical framework, this work advances the understanding of the intricate relationship between energy access and societal well-being in Brazil.

3. Results and discussion

3.1. Access and consumption of electric power

The Brazilian Energy Research Company (EPE) is a federal public company linked to the Ministry of Mines and Energy (MME) and carries out studies and research aimed at supporting the planning of the energy sector, covering electricity, oil, natural gas, its derivatives, and biofuels. A recent study published by EPE, called Residential Electricity Consumption by Income Classes [5], shows inequality in residential access to electricity by income classes in the country, which has intensified over the last few years.

The study indicates that the population group with the highest purchasing power consumes six times more energy per capita than the group with the lowest purchasing power, reflecting growing inequality throughout the second half of the 2010s.

Using a coefficient called the "Electrical Gini Index", the study related income

profiles to the corresponding annual per capita consumption of electrical energy. As shown in **Figure 1**, the Electric Gini Index decreased between 2005 and 2014 but increased from 2015 to 2019. **Figure 2** shows the consumption by salary range.

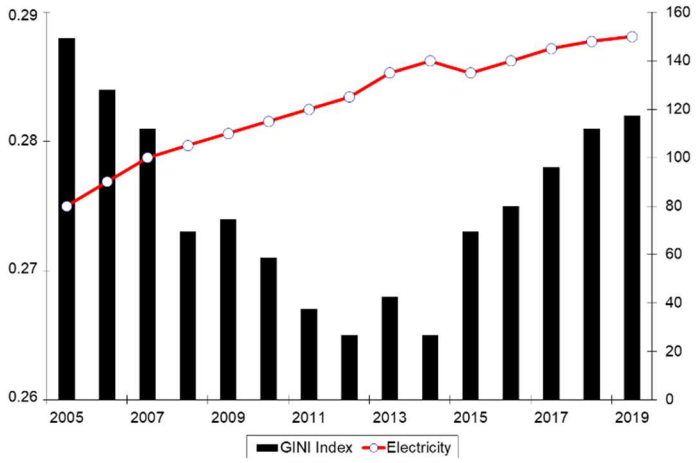

Figure 1. Electric Gini index.

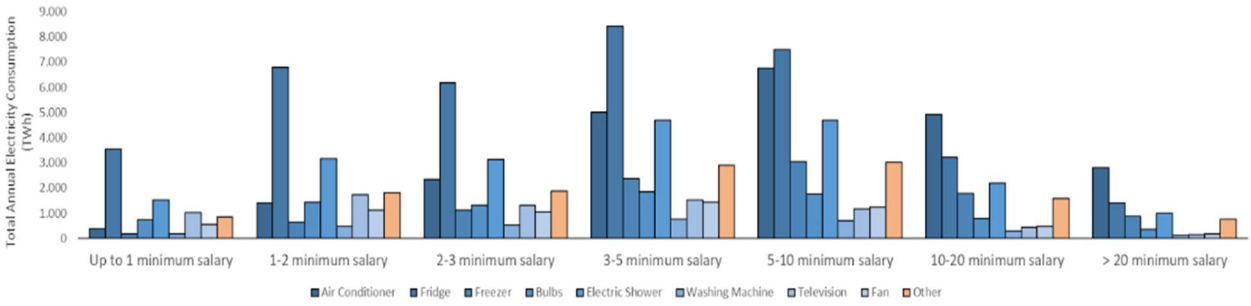

Figure 2. Consumption by salary range.

3.2. Access and consumption of gas for cooking food

According to González-Eguino [10], there are few options for energy sources in poorer areas, with traditional biomass being used more, which can characterize a situation of energy poverty. In turn, Giannini Pereira et al. [8] verify that the lack of access to modern energy sources can limit income generation opportunities and further worsen the poverty situation, particularly in rural areas where opportunities are limited. scarce, making these households powerless in the face of their social exclusion and having difficulty escaping poverty in future periods.

According to the International Energy Agency [7], a significant portion of the world's population uses traditional biomass as a source of energy to prepare their meals.

In Brazil, the use of traditional biomass in rural areas is high, reaching 59% of families in 2016, according to data released by the Continuous National Household Sample Survey (PNAD) carried out by the Brazilian Institute of Geography and Statistics [6].

Faced with the scarcity and vulnerability faced by families in relation to energy shortages and aiming to reduce this impact, the government implemented public policy programs with the aim of allowing people in extreme poverty to have access to and enjoy modern energy services. To this end, in 2001, the Ministry of Health and the

Ministry of Mines and Energy jointly launched the Bolsa Alimentação and Auxílio Gás aimed at improving the food and nutrition of Brazilians [11]. The Gas Aid consisted of providing R$7.50 (US$1.99) monthly to families, helping to purchase a 13-kg gas cylinder of Liquefied Petroleum Gas—LPG, also called "cooking gas".

The implementation of Vale Gás (VG) emerged in the context of the liberalization of oil derivative prices in Brazil, which began in the 1990s and culminated in the end of the LPG subsidy policy, which lasted from 1954 to 1995, and had the main objective is to help families purchase and replace gas cylinders, in addition to encouraging the replacement of firewood with LPG. According to Coelho et al. [12], programs focusing on replacing firewood with modern fuels, such as LPG, were implemented across the country, offering assistance to facilitate access to LPG for those most in need. The Vale Gás (VG) program was short-lived and in 2000 it became part of the broad social assistance program called Bolsa Família (BF).

Before the creation of the BF, in 2006, Brazil had 59 million people living in poverty and 25 million in extreme poverty in 2001 [13]. Although these numbers showed a slight drop during the 2000s, it was only after the implementation of the BF that a significant reduction occurred, reaching 14 million people in poverty and 5 million in extreme poverty in 2014 [13].

In this way, the BF has emerged as a valuable resource for low-income families, not only providing financial security but also guaranteeing food security and facilitating access to education. However, there are serious questions regarding the continued effectiveness of the BF in promoting access to energy for the most disadvantaged groups, especially regarding the lack of resources for cooking food. In effect, the inclusion of Vale Gás in Bolsa Família resulted in an indicative amount for the purchase of gas cylinders, but which was not linked to this acquisition. Thus, families were free to use the subsidy to purchase LPG to meet other needs, such as food or purchasing school materials, for example. In fact, research conducted in Amazonas demonstrates how the neediest families exchanged the subsidy for cooking gas for food and school materials [14].

According to Gioda [15], the use of firewood by the low-income population appears to be directly related to the price of LPG. **Figure 3** presents data from the Energy Research Company [16], in which residential firewood consumption decreased from 2007 to 2013, while there was a corresponding increase in LPG consumption. This corroborates the statement by Coelho et al. [12], that LPG subsidies contributed to a reduction in firewood consumption by families. On the other hand, it can be seen in the same figure that, from 2017 onwards, there was an increase in the consumption of residential firewood and, at the same time, a reduction in the consumption of LPG, suggesting its replacement with firewood in this period.

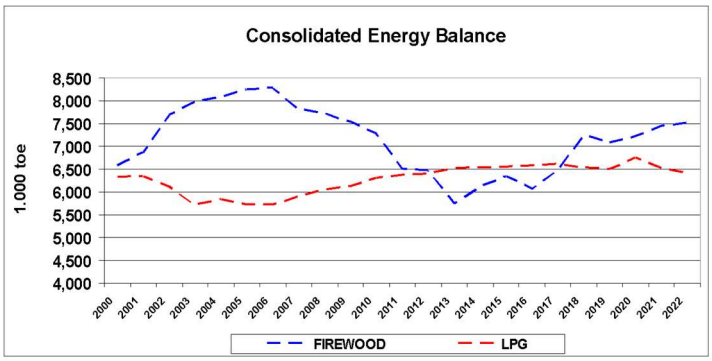

Figure 3. Firewood and LPG consumption in the Brazilian residential sector (2008–2019).
Font: EPE, 2023 [5].

The purchasing power of gas for cooking food and electricity can be analyzed based on the data in **Table 1**, which compares the value of gas, electricity, and the minimum salary in force in the country, from 2013 to 2022. The quantities are those usual for residential consumption.

Table 1. Comparative value of LPG, electricity, and minimum salary (2013–2022).

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Brazilian minimum salary (US$)	314	308	236	253	294	261	253	203	192	213
Liquefied Petroleum Gas—LPG (13 kg)	19	18	15	16	19	19	18	14	17	21
LPG (13 kg)/Brazilian minimum salary (%)	6	6	6	6	6	7	7	7	9	10
Residential electricity (100 kWh)	20	21	22	20	20	20	20	15	16	16
Residential electricity (100 kWh)/Brazilian minimum salary (%)	6	7	9	7	7	8	8	7	8	8

Font: EPE, 2023 [5].

In 2002, to achieve universal access to electricity in Brazil, electricity distributors were required to respond to new requests for residential electrical connection within three days in urban areas and within five days in rural areas, without charging fees. final consumer costs [16]. The Brazilian government provided financial assistance to energy distribution companies so that all new electrical connections could be installed free of charge for the end user. Based on these measures, Brazil launched the Luz para Todos Program in 2003, with the objective of providing access to electricity for the rural population still unserved, which corresponded to more than 2 million homes, according to IBGE [17], located in areas with a low Human Development Index (HDI) [17].

But access to electrical energy is only one part of access to energy, in its broadest sense, as shown by the Internal Electricity Supply (OIEE) and the Internal Energy Supply (OIE). According to the National Energy Balance 2023 [18], the residential sector consumed, in 2022, only 27% of the energy available by the OIEE and less than 11% of the energy available by the OIE. Still regarding the OIE, BEN 2023 highlights the growth in the share of firewood as a source of residential energy, from 24% in 2013 to 26% in 2022, a setback in social, environmental, and energy efficiency terms.

When a household does not have access to adequate, reliable, efficient, and safe energy services to cover its basic needs, which allow it to sustain human and economic

life, develop its members, and whose energy bill payment does not exceed 10% of their income, energy poverty occurs according to the Economic Commission for Latin America and the Caribbean—CEPAL [19].

The data presented allows us to verify that, in addition to the observed inequality in the country's income distribution, there is inequality in the consumption of electricity by different income classes, imposed by economic and social restrictions. The reality of the two extremes of the income distribution is very different and is evidenced by the figures for electricity consumption and the appliances with the greatest impact on this consumption [20–22]. In the lowest income brackets, with earnings of up to 10 minimum salary and which account for 80% of the population, the appliance with the greatest impact on consumption is the refrigerator. In the highest income brackets, with earnings above 10 and above 20 minimum salaries, which account for 20% of the population, the device is air conditioning [23–25].

Another relevant issue is the household use of firewood for cooking which, due to its low energy efficiency, can have negative effects on health and the possibility of accidents such as burns and fires.

Furthermore, energy poverty hinders individual access to formal education burdens those who provide basic services at home, most of them women, and, collectively, impedes social and economic advances [1].

4. Conclusions

Energy poverty, as demonstrated by the lack of secure and financially feasible access to modern energy sources, presents a significant challenge, particularly for low-income populations and those residing in remote areas far from urban centers. The repercussions of this energy deprivation reverberate throughout affected communities, directly impacting their quality of life and access to education. These groups often find themselves expending a considerable amount of time and resources on resolving energy-related issues, diverting a substantial portion of their monthly income to sustain an inefficient and unreliable energy service. These circumstances create a formidable barrier to social and economic advancement.

The present work has revealed that the mere availability of access to modern energy sources does not guarantee consumption, given the stark disparities in purchasing power within the population and the associated costs of these services, thus characterizing a state of energy poverty. Acknowledging the pivotal role of energy as a prerequisite for development and an enhancer of overall well-being, it is imperative to devise and enhance public policy initiatives that ensure every low-income family can access and afford electricity beyond basic subsistence levels.

Considering these findings, it becomes evident that a fundamental transformation in public energy distribution policies is imperative. Such policies must not only strive to enhance the continuity of energy access but also incorporate charging mechanisms that are grounded in socioeconomic assessments, thus ensuring that pricing structures are tailored to the income levels of the population. By doing so, it can work towards eliminating the stark disparities in energy access and consumption, fostering a more equitable and inclusive energy landscape that supports the socio-economic progression of all segments of society. The mission ahead is clear: to bridge the energy poverty gap and promote a more just and prosperous future for all.

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Conflict of interest: The authors declare that they have no conflict of interest.

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