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Intersections between Public Energy Management and Social Inequalities: An Assessment of the Socioeconomic Inclusion Program in Pará from the Perspective of Integrated Resource Planning (IRP)

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Intersections between Public Energy Management and Social Inequalities: An Assessment of the Socioeconomic Inclusion Program in Pará from the Perspective of Integrated Resource Planning (IRP)

ABSTRACT

Objective: To analyze the intersections between public electricity management and social inequalities within the Socioeconomic Inclusion Program (PIS) in the state of Pará. To use Integrated Resource Planning (IRP) as a theoretical-methodological framework to understand the dynamics of energy management and its connections to social vulnerability and energy exclusion.

Methodology: Theoretical-empirical research based on IRP, with a qualitative, exploratory, and descriptive approach. Literature review and secondary data analysis on electricity access, quality, and reliability in Pará.

Originality/Relevance: The study addresses a theoretical gap by investigating the relationship between energy public policies and social inequality in a region marked by energy exclusion. Contributes to the academic debate by applying IRP as an analytical tool to assess the impact of electrification policies on socioeconomic development.

Results: The PIS improved energy infrastructure and expanded household connections to the electrical grid in rural areas. However, challenges persist, including high DEC (Equivalent Duration of Interruption per Consumer Unit) and FEC (Equivalent Frequency of Interruption per Consumer Unit) rates, which compromise energy supply reliability. The program's limitations reinforce the need for more integrated and comprehensive policies that align social inclusion with continuous improvements in energy quality and access.

Theoretical/Methodological Contributions: Demonstrates how IRP can be used to identify gaps and opportunities in public energy policies. Proposes a more integrated analytical approach that extends beyond electricity provision, incorporating improvements in service quality and reliability.

Social and Environmental Contributions: Highlights the importance of more inclusive energy policies for the socioeconomic development of vulnerable populations. Emphasizes the need for sustainable and reliable energy access as a crucial factor in poverty reduction and social justice promotion.

KEYWORDS: Integrated Resource Planning (IRP). Social inequality. Energy exclusion. Energy poverty. Socioeconomic Inclusion Program.

Interseções entre gestão pública de energia elétrica e desigualdades sociais: Uma análise do Programa de Inclusão Socioeconômica no Pará sob a perspectiva do Planejamento Integrado de Recursos (PIR)

RESUMO

Objetivo: Analisar as interseções entre a gestão pública de energia elétrica e as desigualdades sociais no contexto do Programa de Inclusão Socioeconômica (PIS) do Estado do Pará, utilizando o Planejamento Integrado de Recursos (PIR) como referencial teórico-metodológico para compreender as dinâmicas da gestão energética e suas conexões com a vulnerabilidade social e a exclusão energética.

Metodologia: Pesquisa teórico-empírica baseada no PIR, com abordagem qualitativa, exploratória e descritiva. Revisão bibliográfica e análise de dados secundários sobre acesso, qualidade e confiabilidade da energia elétrica no Pará.

Originalidade/Relevância: O estudo preenche uma lacuna teórica ao investigar a relação entre políticas públicas de energia e desigualdade social em uma região marcada pela exclusão energética. Contribui para o debate acadêmico ao aplicar o PIR como ferramenta analítica para avaliar o impacto das políticas de eletrificação no desenvolvimento socioeconômico.

Resultados: O PIS promoveu melhorias na infraestrutura energética e ampliou a conexão de domicílios à rede elétrica em áreas rurais. No entanto, desafios persistem, incluindo altos índices de DEC (Duração Equivalente de Interrupção por Unidade Consumidora) e FEC (Frequência Equivalente de Interrupção por Unidade Consumidora), comprometendo a confiabilidade do fornecimento de energia. As limitações do programa reforçam a necessidade de

políticas mais integradas e abrangentes, que alinhem inclusão social com melhorias contínuas na qualidade e no acesso à energia.
Contribuições Teóricas/Metodológicas: Demonstra como o PIR pode ser utilizado para identificar lacunas e oportunidades nas políticas públicas de energia. Propõe uma abordagem analítica mais integrada, que vá além do simples fornecimento de energia, incluindo melhorias na qualidade e confiabilidade do serviço.
Contribuições Sociais e Ambientais: Ressalta a importância de políticas energéticas mais inclusivas para o desenvolvimento socioeconômico de populações vulneráveis. Enfatiza a necessidade de acesso à energia sustentável e confiável como fator essencial para a redução da pobreza e promoção da justiça social.

PALAVRAS-CHAVE: Planejamento Integrado de Recursos - PIR. Desigualdade social. Exclusão energética. Pobreza energética. Programa de Inclusão Socioeconômica.

Intersecciones entre la gestión pública de la energía eléctrica y las desigualdades sociales: Un análisis del Programa de Inclusión Socioeconómica en Pará desde la perspectiva de la Planificación Integrada de Recursos (PIR)

RESUMEN
Objetivo: Analizar las intersecciones entre la gestión pública de la energía eléctrica y las desigualdades sociales en el contexto del Programa de Inclusión Socioeconómica (PIS) del Estado de Pará. Utilizar la Planificación Integrada de Recursos (PIR) como marco teórico-metodológico para comprender las dinámicas de gestión energética y sus conexiones con la vulnerabilidad social y la exclusión energética.
Metodología: Investigación teórico-empírica basada en el PIR, con un enfoque cualitativo, exploratorio y descriptivo. Revisión bibliográfica y análisis de datos secundarios sobre acceso, calidad y confiabilidad de la energía eléctrica en Pará.
Originalidad/Relevancia: El estudio llena un vacío teórico al investigar la relación entre políticas públicas de energía y desigualdad social en una región marcada por la exclusión energética. Contribuye al debate académico aplicando el PIR como herramienta analítica para evaluar el impacto de las políticas de electrificación en el desarrollo socioeconómico.
Resultados: El PIS promovió mejoras en la infraestructura energética y amplió la conexión de hogares a la red eléctrica en áreas rurales. Sin embargo, persisten desafíos, como altos índices de DEC (Duración Equivalente de Interrupción por Unidad Consumidora) y FEC (Frecuencia Equivalente de Interrupción por Unidad Consumidora), lo que compromete la confiabilidad del suministro de energía. Las limitaciones del programa refuerzan la necesidad de políticas más integradas y abarcadoras, que alineen la inclusión social con mejoras continuas en la calidad y el acceso a la energía.
Contribuciones Teóricas/Metodológicas: Demuestra cómo el PIR puede utilizarse para identificar brechas y oportunidades en las políticas públicas de energía. Propone un enfoque analítico más integrado que trascienda el simple suministro de energía, incluyendo mejoras en la calidad y confiabilidad del servicio.
Contribuciones Sociales y Ambientales: Destaca la importancia de políticas energéticas más inclusivas para el desarrollo socioeconómico de las poblaciones vulnerables. Enfatiza la necesidad de acceso a energía sostenible y confiable como factor clave para la reducción de la pobreza y la promoción de la justicia social.

PALABRAS CLAVE: Planificación Integrada de Recursos (PIR). Desigualdad social. Exclusión energética. Pobreza energética. Programa de Inclusión Socioeconómica.

1 INTRODUCTION

According to the Institute of Energy and Environment (IEMA, 2020), approximately one million Brazilians in the Legal Amazon live without access to electricity in their homes, representing about 3.5% of the region's population. This percentage is higher than the national average for electrical exclusion, which stands at 1.2% (Federal Court of Accounts, 2021). Electrical exclusion directly impacts the quality of life of these populations, as limited access to electricity hinders socioeconomic development and overall well-being.

It is important to note that electrical exclusion in the Legal Amazon is not evenly distributed; it is more pronounced in certain territories and among specific social groups. It is estimated that 19% of the population living on Indigenous lands, 22% in conservation units, and 10% of rural settlers do not have access to electricity (IEMA, 2020). These figures highlight the greater energy vulnerability in rural areas and among social groups that already face other forms of economic and social inequality, illustrating an intersectional effect in electrical exclusion (IEMA, 2019).

In response to this situation, the "Light for All" Program (LPT), discussed by Varela et al. (2023), is a federal government initiative launched in 2003 to achieve universal access to electricity. Since its inception, the program has connected over 16 million people—or approximately 3.4 million households—to the power grid (Eletrobras, 2022). Despite significant progress, many remote and hard-to-reach areas still lack access to electricity, whether through the extension of the conventional power grid or through standalone systems.

The objective of the "Light for All" Program is to accelerate the universalization of electricity access, prioritizing low-income families registered in the federal government's social programs registry (Cadastro Único), rural settlements, Indigenous communities, quilombolas, extractive reserves, and other groups with specific social and cultural characteristics. The program's deadline was recently extended to December 31, 2026, with an additional extension to 2028 for populations residing in remote regions of the Legal Amazon (Ministry of Mines and Energy, 2023). This extension reflects the government's recognition of the challenges of energy inclusion in the region.

To complement the LPT, the "More Light for the Amazon" Program (MLA) was created in February 2020, specifically targeting populations in remote areas of the Legal Amazon. This program aims to provide electricity through renewable energy sources to about one million Brazilians who still lack access to the public electricity service (IEMA, 2020). However, on August 4, 2023, the MLA was incorporated into the "Light for All" Program, unifying the initiatives for universal access to electricity in Brazil (Ministry of Mines and Energy, 2023).

In addition to federal programs, the state government of Pará has maintained an agreement with Pará State Power Company (Centrais Elétricas do Pará S.A.) since 1998 to implement public programs focused on electrical inclusion and combating energy poverty (State Secretariat for Economic Development, Mining and Energy of Pará, 2022). The Socioeconomic Inclusion Program (PIS) aims to expand electricity to rural areas in Pará, using the extension of the conventional power grid and currently aligning with the LPT guidelines. The PIS mandates investments equivalent to 1.5% of the net operating revenue of the electricity utility operating in the state, to be used for electrification works, as guided by the state government, with the goal of supporting socioeconomic development and improving the quality of life for the people of Pará (State Secretariat for Economic Development, Mining and Energy of Pará, 2022).

Thus, the PIS is a subnational (state-level) initiative established through an agreement between the state of Pará and the current electricity utility (Equatorial Energia-Pará). It follows the LPT guidelines and aims to provide electricity to rural populations and residents of remote areas in the Legal Amazon who do not have access to public electricity distribution (Ministry of Mines and Energy, 2023). From this perspective, the PIS, as a public program aimed at addressing poverty and energy exclusion, serves as an appropriate empirical-analytical case for examining energy planning through a social lens and analyzing the attributes of energy poverty.

This study adopts the theoretical-analytical approach of Integrated Resource Planning (IRP). IRP emerged in the United States in the 1980s as an alternative planning approach in response to structural changes in the electricity sector and the oil crisis of the 1970s (Hirst, 1992; Baitelo, 2011; Biague, 2010). This approach seeks to consider all possible options—on both the supply and demand sides—to minimize costs and ensure a sustainable and efficient energy supply (Udaeta, 2012).

IRP emphasizes the importance of public participation in energy planning, involving government bodies and stakeholders to balance economic, social, and environmental dimensions. This approach incorporates considerations such as equity, environmental protection, and reliability of supply, internalizing social and environmental costs (Jannuzzi; Swisher, 1997, 1999; Baitelo, 2011).

One of the key developments in IRP, particularly in Latin America, includes studies on energy poverty (Jannuzzi; Swisher, 1997; Piai; Gomes; Jannuzzi, 2020; Marchetti; Rego, 2023). Energy poverty should not be viewed merely as a matter of access to electricity but rather as a multidimensional phenomenon involving structural inequalities, housing conditions, and individual capacities to manage energy consumption (Reddy, 2000; Day, Walker, and Simcock, 2016).

Piai, Gomes, and Jannuzzi (2020) analyze energy poverty in Brazil, while Marchetti and Rego (2023) propose a method for assessing the social impacts of energy planning in Peru. Both studies are grounded in the theoretical-methodological framework of IRP, offering insights into how IRP can be applied to address energy poverty and its social impacts, underscoring the importance of considering social dimensions when planning and managing energy resources in unequal contexts.

In this research, we adapt and apply an analytical framework of attributes related to energy poverty (focusing on the social dimension of the PIS). The objective is to analyze the intersections between public electricity management and social inequalities within the scope of the Socioeconomic Inclusion Program (PIS) in the state of Pará. This is done through the proposition of an analytical framework based on Integrated Resource Planning. The study seeks to understand how PIS impacts social disparities, particularly in terms of access to electricity and the quality of life of communities in Pará.

2 PROPOSITION OF AN ANALYTICAL FRAMEWORK BASED ON INTEGRATED RESOURCE PLANNING (IRP)

Godard (2002) notes that from the 1970s onwards, awareness began to emerge regarding the relationship between environmental problems and the prevailing model of economic and technological development, highlighting the need to integrate environmental policies into collective economic and political decision-making processes. Within this context, during the 1980s, the concept of sustainable development was developed and disseminated through the Brundtland Report (1988), defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Since then, various public planning approaches have incorporated sustainability concerns and its multiple dimensions. Among these approaches, Integrated Resource Planning (IRP) was developed in the context of energy management.

Integrated Resource Planning (IRP) is a process aimed at optimizing the use of energy resources by considering all supply and demand options to minimize environmental impacts and ensure socioeconomic sustainability (UDAETA, 2012). Relva (2022) reinforces the importance of this approach for sustainable energy sector management, integrating technical, economic, social, and environmental aspects to enable more efficient decision-making. Additionally, Jannuzzi and Swisher (1997) and Reis, Fadigas, and Carvalho (2012) emphasize IRP's role in promoting balanced energy management that considers not only economic and environmental factors, but also social and political aspects in sector planning.

Although originally designed for the energy sector, IRP distinguishes itself from traditional energy planning by incorporating social, political, and environmental concerns (Jannuzzi & Swisher, 1999). Its emphasis on public participation and risk and uncertainty assessment supports its alignment with the principles of sustainable development in diverse contexts.

Traditional energy planning was predominantly technical and economic, focused on expanding energy supply to meet growing demand, with an emphasis on minimizing financial costs and maximizing technical efficiency. This approach often disregarded environmental and social impacts, prioritizing large, centralized projects such as hydro and thermal power plants, without considering energy efficiency or decentralized generation (Reis, Fadigas & Carvalho, 2012).

In contrast, IRP proposes a more holistic analysis that includes multiple dimensions—economic, social, and environmental—within the decision-making process. It adopts a participatory approach, involving civil society, community organizations, and consumers in planning. Operationally, IRP seeks to balance energy supply and demand through measures such as energy efficiency programs, integration of renewable sources, and decentralized generation. Moreover, IRP promotes systematic assessments of social and environmental impacts and uses analytical models to consider different energy development scenarios. This approach enables the identification of more sustainable and inclusive solutions, ensuring a fairer distribution of energy benefits (Hirst, 1992; Reis et al., 2012).

Thus, IRP is a fundamental approach in energy resource management, designed to optimize their contribution to sustainable development. However, recent discussions in contexts of social inequality, especially in Latin America, have sought to advance IRP to incorporate issues of energy poverty and the social impacts of energy policies in settings marked by significant disparities, which present additional challenges and complexities.

The topic of inequalities, exclusion, and energy poverty is complex and intertwined with various social, economic, and environmental dimensions. Reddy (2000) defines energy inequality as the "lack of choice regarding access to adequate, affordable, viable, high-quality, healthy, and environmentally beneficial energy sources for economic and human development." This lack of access to electricity extends beyond physical comfort, also affecting fundamental social rights such as education, health, and political participation (Gomes, 2018).

Access to electricity is essential for economic development and job creation, acting as a catalyst for local productive activities and the emergence of new opportunities (Rosa et al., 2003). However, the impacts of energy access on employment generation vary depending on the energy sources used. Goldemberg (2008) observes that sectors based on renewable energy or focused on energy efficiency tend to create more jobs than those centered on fossil fuels. According to the author, an aggressive strategy promoting efficiency and clean energy could enable Brazil to create significantly more jobs than under a scenario maintaining the current energy model.

In this context, Silva, Ramos, and Pinto (2023) identify that the adoption of technologies such as electric vehicles faces barriers including high costs, lack of infrastructure, and low public awareness—obstacles that also apply to implementing sustainable energy solutions in low-income communities. These challenges underscore the need for integrated policies and educational actions that promote both access to and acceptance of these technologies in socially vulnerable contexts.

Energy poverty, in turn, is a central concept in this debate. For Castaño-Rosa, Solís-Guzmán, and Marrero (2020) and Constanza et al. (2019), it refers to the inability to meet basic energy needs, whether due to economic constraints, high prices, or inefficient housing. Various methodologies have been proposed to measure this phenomenon, including the use of minimum thermal comfort thresholds, the proportion of income allocated to energy expenses (García Ochoa, 2014), or the criterion that energy expenses exceeding 10% of income indicate energy poverty (Boardman, 1991).

Energy poverty significantly impacts social exclusion, affecting people’s quality of life and well-being. Calil (2021) argues that energy poverty is a multidimensional issue, involving economic, socio-environmental, political, cultural, and technological factors. The distinction between energy poverty in developing and developed countries is crucial to understanding the different forms of energy exclusion. In developing countries, energy poverty is generally understood in absolute terms, related to the lack of access to basic energy services (Thomson et al., 2020; Sokolowski, 2019; Sovacool, 2012). Sovacool et al. (2021) highlight that "policy responses to climate change may lead to economic displacement, unemployment, embedded externalities, and human rights violations." This shows that although transitions to low-carbon technologies are essential to mitigate climate change, they may paradoxically intensify existing vulnerabilities and injustices, particularly in already marginalized communities. In developed countries, energy poverty is analyzed in relative terms, focusing on energy expenses in relation to income (Buzar, 2007), with causes extending beyond low income to include broader infrastructural and environmental inequalities (Bouzarovski & Robison, 2022). In short, although energy poverty is related to and overlaps with income poverty, it is not reducible to it (Middlemiss & Simcock, 2019).

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Poverty and energy exclusion are intrinsically linked to society's structural inequalities, requiring public energy management to recognize and act upon these vulnerabilities. In this context, mitigating energy poverty in developing countries demands integrated strategies that consider resource availability, economic accessibility, and environmental sustainability (Ruiz-Rivas, Martínez-Crespo & Chinchilla-Sánchez, 2024). IRP emerges as an essential tool to promote equitable energy access, optimize distribution, and reduce socioeconomic vulnerabilities.

From a global perspective, Sovacool and Griffiths (2022) draw attention to the so-called "decarbonization divide," noting that while developed countries reap the benefits of transitioning to low-carbon technologies, communities in developing nations often face socio-environmental exploitation from resource extraction and waste disposal. In Brazil, this scenario is exacerbated by the difficulty in integrating sustainable strategies into local energy planning. Bernardes, Szklo, and Schaeffer (2023) observe that many municipal climate mitigation and adaptation plans show weaknesses in articulating with energy policies, compromising the adoption of approaches such as IRP. In this regard, Piai, Gomes, and Jannuzzi (2020) emphasize the importance of incorporating advanced technologies and innovative business models into IRP as a way to ensure not only energy efficiency but also social inclusion and local development, especially for low-income populations.

In this scenario, effective public policies must ensure a just and equitable energy transition. Implementing IRP can be a strategic mechanism for balancing sustainable development, social justice, and energy efficiency, minimizing environmental impacts and ensuring the right to energy for historically marginalized populations.

Thus, the findings underscore the relevance of integrated policies that combine energy efficiency and renewable sources as central strategies to reduce energy poverty and promote sustainability. They also highlight the importance of energy planning that prioritizes equity and inclusion (Baitelo, 2011; Sovacool & Griffiths, 2024).

From this perspective, Piai, Gomes, and Jannuzzi (2020) stress the need for adequate regulations and financing schemes to make these solutions feasible for low-income consumers. Therefore, the study concludes that implementing policies based on IRP has the potential to contribute to reducing energy poverty in Brazil by integrating technological solutions, public policies, and financing strategies for the most vulnerable populations. It confirms that IRP can be an effective tool to promote energy equity and sustainability, especially in highly unequal contexts (D'Sa, 2005).

Also in the context of inequality, Marchetti and Rego (2023) present an Accounting and Valuation (AV) methodology based on the IRP framework to analyze the social impacts of implementing new energy resources. This methodology was applied in a case study in a rural region of Peru to assess energy poverty by identifying and evaluating the social impacts of different energy resource implementations. The AV methodology developed in the study converts social attributes such as job creation, human development, population displacement, and comfort perception into quantitative values, allowing for comparison between resources and helping to choose energy solutions that minimize negative social impacts and promote greater equity in energy planning.

Marchetti and Rego (2023) thus indicate that the AV methodology was effective in quantifying the social impacts of different energy resource options in the region studied. Small

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hydropower plants without reservoirs were identified as the best option due to their lower social and environmental impacts compared to large-scale hydroelectric plants. The study demonstrates that this methodology can support the selection of energy resources that minimize population displacement and job losses, contributing to more sustainable and socially just planning.

The studies by Piai, Gomes, and Jannuzzi (2020) and Marchetti and Rego (2023) provide a solid foundation for understanding how IRP can be instrumentalized to reduce inequalities and ensure universal access to energy, especially in remote and socially vulnerable regions. Both studies highlight the importance of addressing the social dimension in energy resource planning, while also identifying gaps in how IRP currently addresses this dimension. It is considered that analyzing multiple aspects of the social dimension in the planning and implementation of energy strategies plays a crucial role in understanding the intersections between public energy management and social inequalities, with particular emphasis on critical conditions of electricity exclusion and energy poverty.

Piai, Gomes, and Jannuzzi (2020) propose an analytical-applied definition of energy poverty that encompasses multiple attributes, going beyond mere physical access to energy by considering accessibility, reliability, and quality (Table 1). The authors highlight Brazil's challenge in providing accessible energy services, particularly for low-income consumers, emphasizing the need to incorporate accessibility into energy efficiency programs.

Table 1 – Attributes of Energy Poverty and Intersections with Social Inequalities.

Attribute	Definition	Indicators
Accessibility	It refers to the ease and convenience with which people can use energy resources, considering proximity, cost, and the availability of infrastructure.	- % of Poverty in the Municipal Population
		- HDI (Human Development Index)
		- % of the population with access to the electricity grid
		- Cost of energy in relation to household income
		- Number of households with adequate energy infrastructure
Reliability	Ensuring a constant and consistent supply of energy, minimizing interruptions that could hinder the reliable use of energy services	- Frequency of power supply interruptions
		- Average duration of interruptions
		- % of households with continuous access to energy
		- Reports on service reliability by consumers
Quality	Refers to the standards of energy services, ensuring they are efficient, safe, and suitable for consumption.	- Energy efficiency index of households
		- % of households served by safe and clean energy sources

Source: Piai, Gomes, Jannuzzi (2020).

Therefore, the integration of attributes such as accessibility, reliability, and quality within the social dimension of energy supply reinforces the importance of strategies that prioritize socioeconomic inclusion and address energy poverty. In this study, these attributes and their intersections with social inequalities are applied to the analysis of a specific public program (the PIS), in order to investigate its outcomes in the social dimension in a broader and more structured manner.

3 METHODOLOGY

This study adopts a qualitative methodological approach based on the case study method. As described by Yin (2010), the case study is an empirical investigation that explores contemporary phenomena within real-life contexts, especially when the boundaries between the phenomenon and the context are not clearly defined. Almeida (2016) complements this view by emphasizing that the case study seeks a holistic understanding of a specific social phenomenon or event, capturing various dimensions related to it. Both authors highlight the importance of empirically outlining each case within the context of specific events and characteristics, enabling an in-depth and contextualized analysis.

The case examined in this article is the Socioeconomic Inclusion Program (PIS) in the state of Pará, focusing on initiatives aimed at expanding access to electricity in rural areas and traditional communities, taking into account aspects such as accessibility, reliability, and quality of energy services. The importance of multiple contextual dimensions—technical, political-institutional, socioeconomic, and environmental—is recognized in relation to both public energy management in Pará and the state's social inequalities. Thus, the method is considered appropriate for the proposed research design. Furthermore, the multiplicity of contextual dimensions and of the phenomenon under analysis provided by the method is also aligned with the multiple elements and dimensions analyzed through Integrated Resource Planning (IRP), the theoretical framework of the study.

The spatial scope used to delimit and conduct the research is the state of Pará, located in the Northern Region of Brazil, bordering the states of Amapá, Maranhão, Tocantins, Mato Grosso, Amazonas, and Roraima, as well as the countries of Guyana and Suriname. This Brazilian federal unit encompasses a geographical area of 1,245,870.700 km², representing 14.7% of the national territory (IBGE, 2021).

Data collection for this research relied on secondary sources, including bibliographic and documentary reviews over a five-year period, from 2019 to 2023. The literature review focused on guidelines from the Brazilian energy policy as applied to Pará and on the social inequalities observed in the state. The documentary survey included technical reports, statistical yearbooks, and bulletins obtained from official agencies and research institutes. The main sources consulted were the Ministry of Mines and Energy (MME), the National Electric Energy Agency (ANEEL), the Brazilian Institute of Geography and Statistics (IBGE), Equatorial Energia Pará, and the State Secretariat for Economic Development, Mining and Energy (SEDEME).

The phenomenon under study in this research, therefore, corresponds to the intersections in the state of Pará between public electricity management and social inequalities

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based on the PIS, which defines the case delimitation. The analysis was based on the analytical-conceptual attributes of energy poverty as proposed by Piai, Gomes, and Jannuzzi (2020). Through this case study, the aim is to highlight the relationships between public electricity management actions and the dynamics of inequalities in the state, in order to clarify their intersections and how they function.

4 RESULTS

4.1 The Socioeconomic Inclusion Program (PIS): context and descriptive analysis

The Socioeconomic Inclusion Program (PIS) is a social interest program managed by the State Secretariat for Economic Development, Mining, and Energy (SEDEME). It enables the execution of electricity projects and initiatives of social interest in the state of Pará. Currently, its actions are implemented by Equatorial Energia-PA through a Commitment Agreement, which ensures a flow of investments to support the socioeconomic development of the state through the implementation and expansion of the electrical system in areas of social interest across municipalities in Pará.

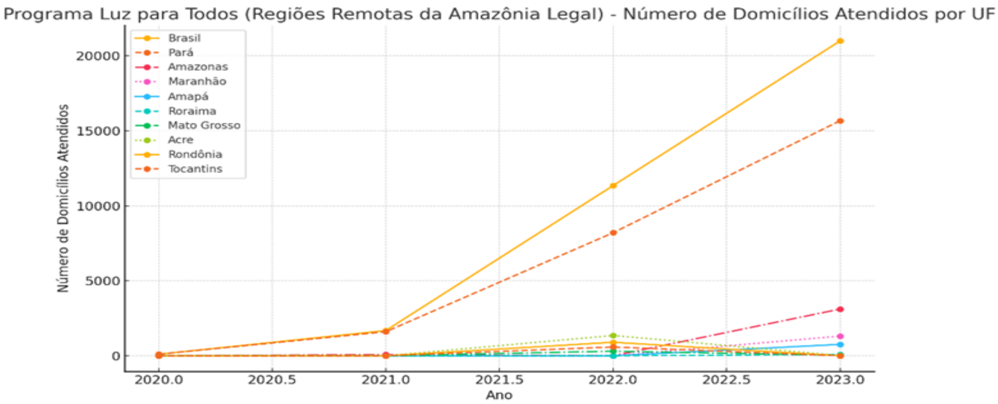
The PIS includes the following types of projects:

1. Projects for the expansion and improvement of electricity networks of social interest, in compliance with the legislation and regulatory guidelines established by the granting authority for the public electricity distribution service;
2. Projects to implement electricity networks to regularize informal (clandestine) consumers;
3. Projects for the expansion of electricity networks to replace isolated generation systems, in compliance with the legislation and regulatory guidelines established by the granting authority for the public electricity distribution service;
4. Projects involving isolated electricity generation to serve consumers in areas where network expansion is not feasible, as well as projects that require financial participation from the consumer (ANEEL, 2022).

The implementation of the PIS in the state highlights the formulation and execution, at the state level, of a public energy management program aimed at universalizing access to electricity. A comparison between PIS service data and the general figures on lack of access to electricity in Pará reveals a significant disparity.

An analysis of data from the "Luz para Todos" (Light for All) Program, particularly in remote regions of the Legal Amazon (Figure 1), reinforces the importance of these joint actions. The data show progressive coverage in the state of Pará, emphasizing the fundamental role of the program in promoting access to electricity in hard-to-reach areas. In 2020, Pará was responsible for serving all 105 households connected nationwide. However, expansion in the state grew significantly in the following years, with 1,605 households served in 2021 and an even more substantial increase in 2022 and 2023, with 8,201 and 15,677 households served, respectively.

Figure 1 – Number of Households Served by State (Remote Regions of the Legal Amazon).



Source: Prepared by the authors (2023).

This increase in the number of households served in Pará, compared to other states in the Legal Amazon, highlights Pará’s dominant role in terms of service coverage, representing a large share of the total number of connections made in Brazil. Between 2020 and 2023, Pará accounted for 74% of all connections nationwide, underscoring the strategic importance of its inclusion in the program.

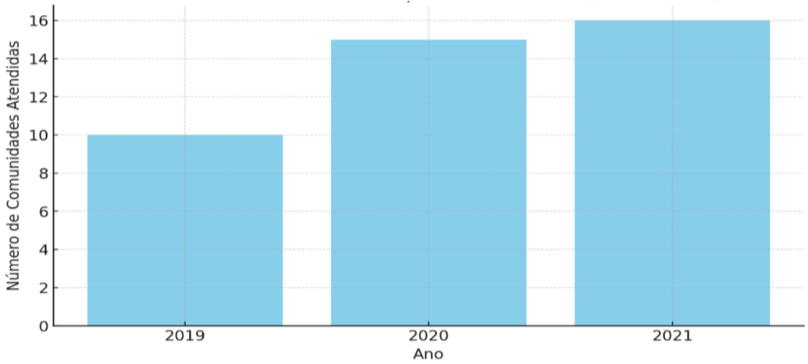
On the other hand, states such as Amazonas, Maranhão, and Amapá showed more modest growth in service provision, indicating that the program’s focus was directed primarily toward Pará. This may point to a greater need for action and infrastructure in remote areas of that state. The ongoing increase in the number of households served by the Luz para Todos (Light for All) program in Pará reflects progress in reducing social inequality in access to electricity. However, it is still essential to monitor how these services are distributed across other regions of the Legal Amazon to ensure a more equitable development in terms of electricity access.

Beyond the number of families served by both PIS and PLT, it is acknowledged that other factors are also relevant for assessing the program’s implementation—such as the level of community involvement from the planning to the completion stages, and the impacts generated, particularly in reducing the social inequalities imposed by lack of electricity access (Tarekegne, 2020). Data on these aspects were not found in the documents made available on the PIS.

Figure 2 presents the initial implementation phase of the Socioeconomic Inclusion Program (PIS) in the state of Pará, based on data provided by SEDEME. During this period, 3,531 families were served, demonstrating a significant effort in expanding the electricity grid to socially vulnerable communities. This phase was marked by coordination between the state government and strategic partners to carry out electrification projects in isolated areas where electricity access remained a critical challenge.

Periódico Eletrônico Fórum Ambiental da Alta Paulista
Electronic Journal Environmental Forum of Alta Paulista
ISSN 2966-2931 Suporte Online / *Online Support* - ISSN 1980-0827 Suporte CD-ROM / *CD-ROM Support*
Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 1, 2025

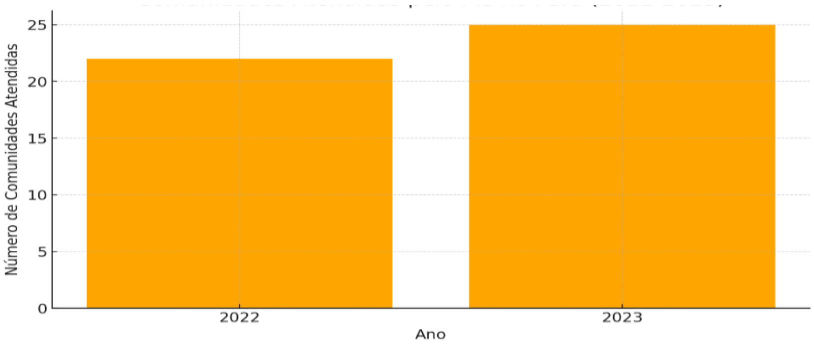
Figure 2 – Evolution of the Socioeconomic Inclusion Program (PIS) from 2019 to 2021 – Communities Served.



Source: Prepared by the author, based on SEDEME-DIREN (2023).

Figure 3 presents the results of the PIS during the subsequent period (2022 to 2023), under the management of Equatorial Pará. During this interval, 1,948 families were served, reflecting the continued efforts to universalize access to electricity.

Figure 3 – Evolution of the Socioeconomic Inclusion Program (PIS) from 2022 to 2023 – communities served.



Source: Prepared by the author, based on Equatorial-Pará (2023).

The analysis of the data provided by Equatorial Energia (2022–2023) and SEDEME (2019–2021) reveals an ongoing effort to reduce energy exclusion in Pará. Between 2019 and 2021, 3,531 families were served, followed by a sharp decline in 2022, with only 285 families benefiting. In 2023, there was a significant recovery, with 1,663 families attended. However, when compared to IBGE data (2022), which indicates that 1% of Pará's population (approximately 81,161 people) still lacked access to electricity in 2022, it becomes clear that the services provided, although significant, do not yet cover the entirety of this excluded population. This disparity highlights the urgency of intensifying efforts to universalize electricity access, since the lack of energy exacerbates social inequalities, limiting access to essential services such as education, healthcare, and communication, especially in remote areas of the state. The data also point to indicators of energy reliability, specifically the SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) (Figure 4), which reveal critical aspects of the electricity supply in areas served by the Socioeconomic Inclusion Program (PIS) during the years 2022 and 2023. Data for the previous years (2019 to 2022) were not made available.

Periódico Eletrônico Fórum Ambiental da Alta Paulista
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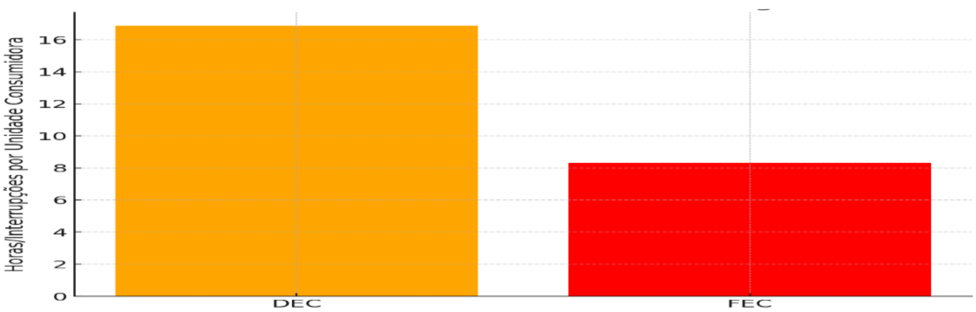
Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 1, 2025

Figure 4 – Graph of Energy Reliability Indicators (SAIDI and SAIFI) of the PIS.



Source: Prepared by the authors (2024).

With a DEC value of 16.86, this means that, on average, each consumer unit experiences more than 16 hours of power outage per year, while the FEC of 8.3 indicates that these interruptions occur approximately eight times per consumer unit throughout the year. These values point to serious challenges regarding the maintenance and consistency of the electrical infrastructure. The frequency and duration of the outages suggest that the network, although present, is not sufficiently reliable to ensure continuous and quality power supply. This is particularly concerning in low-income and remote communities, where energy infrastructure is already precarious.

Therefore, while the Socioeconomic Inclusion Program (PIS) contributes to the expansion of electricity coverage, the reliability analysis reveals that mere network expansion is not enough. It is necessary to invest in structural improvements to reduce the DEC and FEC indexes, ensuring that the supply is stable and sustainable in the long term. This includes not only network maintenance but also investments in monitoring technologies and more efficient systems capable of predicting and preventing failures in the electrical system.

Thus, the indicators suggest a need for greater focus on the quality of electricity supply to families served by the PIS, and not just on expanding coverage. Moreover, they suggest that the reliability of service directly affects access to electricity, which must be safe and consistent for all the communities served.

Challenges related to reliability and the quality of electricity supply also play a crucial role in the effectiveness of the PIS. The concept of quality is directly linked to the use of safe, clean, and efficient energy sources, as evidenced by the “Luz para Amazônia” program, which carried out 33,844 installations, improving access to renewable energy sources in remote areas. However, the fact that the PIS does not include energy efficiency projects, focusing only on the extension of transmission lines, reveals a critical gap in energy access policies for the regions and families served. The lack of initiatives aimed at energy efficiency means that, despite expanding access, communities remain dependent on more expensive and inefficient energy sources, perpetuating inequalities. Figure 4 shows initiatives aimed at improving energy service.

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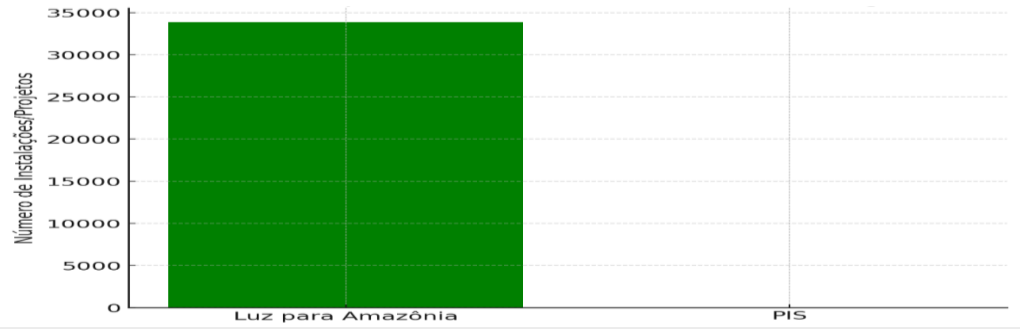
Figure 5 – Graph of Initiatives for Improving Energy Quality



Source: Prepared by the authors (2024).

Figure 4 compares the "Luz para Amazônia" program, with 33,844 installations, to the Socioeconomic Inclusion Program (PIS), which has no registered energy efficiency projects, highlighting a significant gap in the state's energy policy within the parameters of the PIS.

This reveals the relationship between reliability and quality, where frequent and long interruptions, as demonstrated by the high DEC and FEC indexes (Figure 4), negatively affect the quality of energy services. The absence of investments in energy efficiency worsens this situation, as inefficient systems increase operational costs and hinder the implementation of improvements that could reduce the impact of interruptions.

Without improvements in the quality and efficiency of the system, higher costs continue to fall on low-income populations, who already face difficulties in paying for the service. Thus, while the PIS expands access, it must also prioritize the integration of improvements in the quality and reliability of energy supply, with the goal of ensuring a sustainable and equitable energy service.

4.2 Analysis of the PIS Based on the Analytical Framework

Therefore, the Socioeconomic Inclusion Program (PIS) in the state of Pará, although aimed at promoting access to electricity in socially vulnerable areas, faces significant challenges regarding the attributes of accessibility, reliability, and quality:

A) Accessibility:

The high number of households connected to the power grid (5,479) between 2019 and 2023 through the PIS, which represents 67.51% of the total service provided (including network extensions and consumer unit/family connections), indicates good coverage of basic infrastructure. However, the cost of energy relative to household income—an average of R$2,255.75 (Equatorial Energia-PA, 2023)—remains a significant challenge for low-income populations. This suggests that although infrastructure may be in place, economic access remains limited for many.

Regional and socioeconomic disparities are evident, especially when considering that rural and low-income areas face more severe challenges in terms of energy accessibility. This perpetuates a cycle of inequality, where the poorest have the least access to basic energy services.

B) Reliability:

Reliability indicators, such as the DEC (Equivalent Duration of Interruption per Consumer Unit) of 16.86 and the FEC (Equivalent Frequency of Interruption per Consumer Unit) of 8.3, indicate an infrastructure that still faces significant challenges in terms of maintenance and service consistency (based on 2022–2023 data).

Communities in less developed areas suffer more frequent interruptions, directly affecting quality of life and local economic capacity. Energy reliability is closely tied to economic development, as frequent outages can negatively impact commercial and productive activities.

C) Quality:

The percentage of households served by safe and clean energy sources, such as in the "Luz para Amazônia" program with 33,844 installations, is a positive indicator of initiatives to improve energy quality in remote areas.

However, the observation that the Socioeconomic Inclusion Program (PIS) does not include energy efficiency projects highlights a significant gap in energy policy. Without investment in energy efficiency, many communities continue to depend on less efficient and more expensive energy sources, exacerbating inequalities and limiting cost reduction and environmental impact.

Therefore, while efforts exist to improve energy access and quality in different regions, significant challenges related to cost, accessibility, and reliability remain—especially in low-income and underdeveloped areas. Addressing these issues is essential for reducing social inequalities and promoting inclusive and sustainable development. Policies and initiatives that directly address the gaps in accessibility, efficiency, and reliability can contribute significantly to a more equitable distribution of energy resources and improved quality of life in marginalized communities.

Table 2 summarizes the dimensions analyzed in the PIS and their relationship to energy poverty in Pará, reinforcing the need for public policies that integrate economic, social, and technological aspects to promote sustainable and equitable development. The use of specific indicators, such as access percentages and reliability indexes, highlights the gaps and opportunities for improving the program—especially in areas with greater social vulnerability.

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able 2 – Attributes of Energy Poverty and Intersections with Social Inequalities in Pará

Attribute	Indicators	Intersections with Social Inequalities
Accessibility	- 67.51% of households served between 2019 and 2023 by the PIS (5,479 families).	Although the PIS connected 67.51% of the estimated target of 8,116 families between 2019 and 2023, the high cost of electricity remains a barrier for low-income populations. This highlights the need for differentiated tariff policies to ensure the sustainable use of energy, especially in regions with greater economic vulnerability.
	- Average cost of electricity in relation to household income: R$ 2,255.75 per month.	The high cost of electricity in relation to income perpetuates the cycle of inequality, limiting the effective use of energy for basic services such as education, healthcare, and communication.
Reliability	- SAIDI: 16.86 (System Average Interruption Duration Index – average outage duration per consumer unit).	The DEC (16.86) and FEC (8.3) indices reflect the low quality of service continuity, especially in remote areas of Pará. This fragility directly impacts local economic development and quality of life, as essential services such as healthcare and education depend on a stable energy supply.
	- SAIFI: 8.3 (System Average Interruption Frequency Index – average number of interruptions per consumer unit).	
Quality	- 33,844 installations under the "Light for the Amazon" program.	The expansion of the "Light for the Amazon" program with 33,844 installations is a significant achievement, but the lack of attention to energy efficiency within the PIS represents a major gap. Without investments in sustainable and safe technology, many communities continue to rely on more expensive and environmentally harmful energy sources.

Source: Prepared by the authors based on Piai, Gomes, Jannuzzi (2024).

Although the Socioeconomic Inclusion Program (PIS) represents an important initiative to promote access to electricity and reduce social inequalities in the state of Pará, there are significant challenges to be overcome regarding the accessibility, reliability, and quality of the electrical services provided. It is essential that effective measures be implemented to address these challenges and ensure that the program adequately meets the needs of the most vulnerable communities. This analysis can be related to the Integrated Resource Planning (IRP) in its social dimension, considering the data presented on the social aspects of the PIS, which reveal relevant points and challenges to be addressed.

However, these intersections highlight the need to consider factors beyond the mere number of families and communities served. It is crucial to assess the level of community involvement at different stages of the PIS projects—from conception to completion—to ensure that their needs and realities are properly considered. Moreover, it is important to evaluate the social impacts caused by the program's implementation, especially regarding the reduction of social inequalities resulting from the lack of access to electricity.

The approach proposed by Piai, Gomes, and Jannuzzi (2020) regarding energy poverty is highly relevant to this analysis. They emphasize the importance of considering not only physical access to energy but also aspects such as accessibility, reliability, and quality of energy services. In the context of Pará, where access to electricity is still a challenge for many low-income populations, this approach highlights the need to incorporate these aspects into energy efficiency programs, in addition to PIS, to ensure they effectively meet the needs of the most vulnerable communities.

Therefore, the analysis of PIS data suggests the importance of a holistic approach that considers not only the quantity but also the quality and social impact of the energy services offered. This requires a more comprehensive evaluation of the projects, including community engagement and consideration of the multiple aspects of energy poverty, to ensure that the program effectively contributes to reducing social inequalities in access to electricity in the state of Pará.

5 CONCLUSION

The analysis of the intersections between public electricity management and social inequalities in the state of Pará, based on the Socioeconomic Inclusion Program (PIS) and the Integrated Resource Planning (IRP), reveals the complexity and relevance of this issue for the social and economic development of the Amazon region. Throughout this study, it was possible to identify how the implementation of energy policies can directly impact the most vulnerable communities, both positively and negatively.

Through the analysis of the attributes of the social dimension in the context of the IRP, the importance of considering not only technical aspects but also the needs and realities of local populations was emphasized. The PIS, as an example of a socioeconomic inclusion program, demonstrates how specific actions can be implemented to promote access to electricity and, consequently, improve the quality of life of communities in Pará.

However, it is crucial to acknowledge that challenges still remain. The lack of comprehensive data on the social impact of PIS and other similar initiatives highlights the need for a more holistic approach in evaluating energy policies. Additionally, the issue of sustainability and environmental impacts must also be considered, especially in a region as sensitive as the Amazon.

For future research, it is suggested to conduct a more in-depth analysis of the effects of PIS and other energy policies on reducing social inequalities, as well as studies on the effectiveness of different approaches to promoting access to electricity in remote areas. Furthermore, incorporating a gender perspective and other forms of social vulnerability can further enrich the understanding of these dynamics.

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DECLARATIONS

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Writing – Original Draft: Juciana Nunes Cardoso

Writing – Review & Editing: Diana Cruz Rodrigues

Final Review and Editing: Diana Cruz Rodrigues and Bruno Rafael Dias de Lucena

Supervision: Diana Cruz Rodrigues

CONFLICT OF INTEREST STATEMENT

We, Juciana Nunes Cardoso, Diana Cruz Rodrigues, Bruno Rafael Dias de Lucena, and Sandra Maria Costa Monteiro, declare that the manuscript entitled *Intersections between public electricity management and social inequalities: An analysis of the Socioeconomic Inclusion Program in Pará from the perspective of Integrated Resource Planning (IRP)*:

1. Financial Ties: "No institution or funding agency was involved in the development of this study."
2. Professional Relationships: "No professional relationship relevant to the content of this manuscript has been established."
3. Personal Conflicts: "No personal conflict related to the content has been identified."