ENERGY TRANSITION AND ENERGY POVERTY IN OFF- GRID SYSTEMS : ENERGY SUSTAINABILITY IN THE BRAZILIAN AMAZON REGION

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Overview

The transition to a sustainable energy paradigm has become a focal concern in the contemporary era, underscored by its urgency and global significance. In this context, the examination of off-grid systems has garnered significant scholarly interest, highlighting a critical area for advocating and implementing this transition. Brazil's distinction of hosting one of the largest interconnected electricity systems globally, managed by the National Interconnected System (SIN), stands in stark contrast to the challenges faced by geographically isolated regions. These regions, referred to as Isolated Systems (SISOL), face technical and financial barriers to integration with SIN and are predominantly dependent on non-renewable energy sources derived from oil.

One of the major challenges in planning and operating Brazil's National Interconnected System (SIN) is addressing the so-called "Isolated Systems" or off-grid systems. These systems are public electricity distribution services that, under normal conditions, are not electrically connected to the SIN due to technical or economic reasons. Off-grid Systems are predominantly located in the Brazilian Amazon (accounting for 99.63% of the units), a region that hosts one of the world's largest biodiversity reserves. The operation of the off-grid system in such a region raises significant sustainability concerns.

Energy poverty in the isolated systems of the Brazilian Amazon represents a complex, multifaceted challenge that significantly impacts both the socioeconomic development and environmental sustainability of the region. This issue is marked by limited access to reliable, affordable, and clean energy sources for a substantial portion of the Amazonian population. The off-grid systems in the Amazon are predominantly powered by diesel generators, which present a range of challenges: **Environmental Impact**, as these systems are highly polluting, accounting for nearly 10% of the SIN's greenhouse gas emissions despite representing only 0.6% of Brazil's total energy consumption; **Economic Inefficiency**, as electricity generation in isolated systems is prohibitively expensive due to reliance on diesel fuel and small-scale operations; and **Logistical Challenges**, as the transportation of diesel fuel to remote power plants often faces significant hurdles, particularly in areas accessible only by river.

In this paper, we address energy poverty in the Amazon off-grid system, where the supply of electricity is unreliable due to technical and economic difficulties in transporting fossil fuels. We highlight the importance of transitioning from non-renewable energy sources to more sustainable alternatives, particularly photovoltaic (PV) generation and Energy Storage Systems (ESS).

Methods

The research was exploratory and descriptive, based on bibliographic and documentary analysis. Secondary data were collected and subjected to qualitative content analysis. The methods employed in this study comprised bibliographic and documental research. Bibliographic research was conducted through Sectoral Libraries and online scientific databases, enabling the collection of secondary data from articles, books, and supplementary texts. These sources supported the development of the literature review, which was essential for the thematic analysis and discussion of this study. Documental research, on the other hand, was carried out using Google and Google Scholar search tools to access secondary data from governmental portals, facilitating a deeper understanding of the phenomenon under investigation (i.e., off-grid Systems).

The data collected in this study included both quantitative and qualitative elements and were analyzed using content analysis. In the bibliographic research, data were qualitatively analyzed, with researchers exercising subjectivity in selecting articles, books, and supplementary texts deemed scientifically relevant for addressing the research theme. Data obtained from documental research were analyzed using distinct methodologies: a quantitative approach was employed when data were organized into spreadsheets and automated formulas were

applied to generate tables, maps, and charts, while a qualitative approach was used to select and synthesize relevant information about the phenomenon under study. These qualitative findings formed the foundation for the thematic discussion presented in this study.

Results

The findings indicate that, while Isolated Systems provide electricity to remote areas and foster local socio-economic development, they present significant challenges in terms of both environmental and economic sustainability. The dependence on non-renewable energy sources, such as diesel, results in harmful environmental impacts and drives up energy costs for consumers, raising concerns about the long-term viability of these systems.

The research suggests the need for additional approaches, including distributed generation and the use of hydrogen as an energy carrier, to ensure a steady and reliable energy supply. Beyond the environmental benefits, transitioning to renewable energy sources offers substantial economic and social advantages, such as reduced operating costs and the promotion of sustainable tourism practices. The scenario in Fernando de Noronha provides valuable insights for other isolated territories, demonstrating the feasibility and desirability of transitioning to a clean and renewable energy paradigm for environmental conservation and local economic improvement..

Conclusions

The findings advocate for the integration of photovoltaic (PV) systems and energy storage solutions (ESS) to significantly reduce dependency on fossil fuels in the Amazon off-grid system.. However, achieving full energy autonomy remains a formidable challenge. The research underscores the need for supplementary strategies, including distributed generation and the use of hydrogen as an energy carrier, to ensure a stable and reliable energy supply. Beyond the environmental advantages, transitioning to renewable energy sources offers substantial economic and social benefits, such as reduced electricity costs. The situation in Amazon off-grid system provides valuable insights for other isolated regions, illustrating the feasibility and desirability of shifting to a clean and renewable energy paradigm for both environmental conservation and local economic development.

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