

ENERGY EFFICIENCY AND SUSTAINABILITY: ANALYSIS OF INDICATORS OF GENERATION, ENERGY QUALITY, AND ENVIRONMENTAL MANAGEMENT OF THE UNIEVANGÉLICA PHOTOVOLTAIC PLANT IN ANÁPOLIS, GOIÁS (2020-2023)

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ABSTRACT

This study is part of the thesis presented to the Graduate Program in Society, Technology, and Environment at the Evangelical University of Goiás (PPGSTMA), with the aim of obtaining a PhD in Environmental Sciences. The research evaluated the energy efficiency and sustainability of the UniEVANGÉLICA (UF-Uni) Photovoltaic Plant, using energy generation data from 2020 to 2023, in addition to an energy analyzer to verify the quality of the electricity generated. The theoretical studies were conducted in the PPGSTMA computer labs, while the practical investigations took place at the Photovoltaic Energy Efficiency Laboratory (LEEFOTO). The results showed that, after 72 years of existence, the Associação Educativa Evangélica (AEE) took a decisive step toward financial and energy sustainability, consolidating its institutional policies and values with the implementation of UF-Uni. The research showed that, globally, photovoltaic plants prioritize financial and performance indicators over environmental ones, highlighting the search for profitability. The use of statistical tools and time series proved effective in monitoring and projecting energy generation, highlighting the importance of university governance and artificial intelligence. It was found that the energy generated by UF-Uni meets the standards of the National Electric Energy Agency (ANEEL), although productivity was below expectations. The study recommends regular maintenance and the adoption of advanced technologies to ensure greater energy efficiency, proposing a model aligned with the Sustainable Development Goals (SDGs) and ESG principles, offering a replicable solution for other institutions and companies.

Keywords: Governance; Sustainability; Renewable energy; Energy efficiency.

INTRODUCTION

The Evangelical Educational Association (AEE), founded in 1947, evolved from a school institution to the Evangelical University of Goiás (UniEVANGÉLICA), standing out for its academic quality and sustainable practices. The construction of a Photovoltaic Plant (UF) on campus not only meets a significant part of the energy demand but also functions as a research laboratory, offering students practical experience in technological innovation and sustainability. Aligned with the SDGs and ESG principles, UniEVANGÉLICA has become a model for educational institutions and companies seeking to combine academic excellence and environmental responsibility (BOGGIAN, 2023; UNIEVANGÉLICA, 2024).

This initiative is especially relevant in a context where the global energy matrix is dominated by 68.9% non-renewable sources, while in Brazil this figure is much lower, at only 16%. However, of the 84% generated from renewable sources, 61.9% comes from hydroelectric plants (MME, 2023). The global transition

to PVs represents a significant change in energy generation and consumption, driven by both economic and environmental reasons (PEB, 2024).

Despite the recognized environmental benefits of photovoltaic solar energy, financial motivations still predominate in the adoption of this technology. In Brazil, companies and institutions, such as UniEVANGÉLICA, are leading this transition by installing large power plants and taking advantage of rooftops for small installations. Therefore, university governance, increasingly influenced by global rankings that value scientific production and social impact, is fundamental for the sustainability of higher education institutions (BOGGIAN, 2023). The application of statistical tools and time series techniques at UF-Uni demonstrates how advanced data analysis can optimize energy efficiency and strengthen university governance (ROMERO et al., 2022).

Thus, celebrating historic milestones such as the Stockholm Conference and Rio 92 Kniess (2022), this study investigates the energy efficiency of UF-Uni, proposing optimizations for sustainable energy supply and practices that reinforce the resilience of the system and the stability of the electrical grid.

METHODOLOGY

This study analyzed the electricity generation of UF-Uni, installed in a parking lot at UniEVANGÉLICA, Anápolis, Goiás, between 2020 and 2023. The plant, inaugurated in 2019, has 2,900 solar panels, occupies 5,655 m², and has a capacity of 971.50 kWp, meeting 40 to 60% of the campus's demand.

The theoretical research, carried out in the PPGSTMA laboratories, involved documentary research and literature reviews on UniEVANGÉLICA's evolution towards sustainability. The technical studies focused on recent articles, dissertations, theses, and books on solar energy, performance, and environmental impact. Meanwhile, practical research conducted at LEEFoto evaluated the plant's efficiency using an energy analyzer to measure critical variables such as power factor and harmonics, in accordance with ANEEL standards.

RESULTS

Based on studies on institutional websites, books, and other documentary sources, it can be concluded that AEE, 72 years after its founding, has made significant progress toward energy and environmental sustainability. Although

efforts began in 2011, the project was consolidated in 2016, when the institution won the PEE CELG D Public Call No. 002/2016. In partnership with the companies Vitalux-Ecoativa and the National Electric Energy Agency (ENEL), construction began on its photovoltaic plant (UNIEVANGÉLICA, 2018).

Opened in 2019, UF-Uni has the capacity to generate up to 40% of the campus' energy demand and was recognized as the largest photovoltaic parking lot in the country at the time (UNIEVANGÉLICA, 2019). Another highlight is LEEFoto, inaugurated in 2021 in partnership with FAPEG, which promotes research, training, and consulting in energy efficiency (UNIEVANGÉLICA, 2021).

Studies on the systematic review of global goals for the installation of UF's highlighted that the global electricity matrix is predominantly sustained by non-renewable sources, mainly fossil fuels such as coal and natural gas. In contrast, the Brazilian electricity matrix is composed mainly of renewable sources, with more than 60% coming from hydroelectric plants. Research indicates that FPs may be a viable solution for diversifying energy matrices, especially in Brazil, due to the high level of solar radiation (PEB, 2024). Table 1 presents the stratification of global objectives for the installation of FPs.

Table 1. Stratification of the selection of scientific studies related to the implementation of UF's

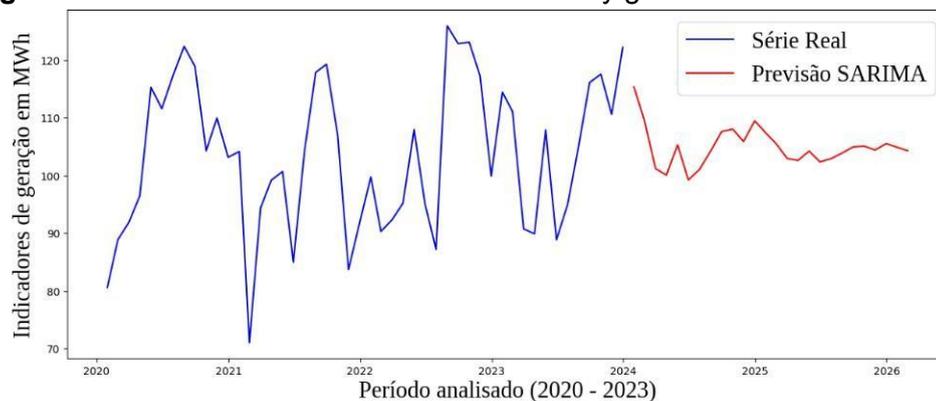
Indicators analyzed	Total age	Percent centage	Subdivision of indicators	Period s estuda				
				2023	2022	2021	2020	2019
Consequences Environmental	6	19.4%	Environmental impacts	4				
			Environmental benefits	1		1		
			Governance	2				
<i>Performance</i> code Generation	24	77.4%	Productivity	6			1	1
			Use of algorithms	4				1
			Operational optimization	4		1	2	2
Not directly correlated	1	3.2	***				1	
Total	31			21	0	2	4	4

Source: Prepared by the authors (2024)

This review points out that, although UFs are important in the global energy matrix due to their relevance for sustainable development, global objectives for their implementation focus on financial and performance indicators, while environmental indicators are often secondary,

highlighting the need for greater balance. The application of statistical tools, through time series, has proven effective in monitoring and projecting energy generation, Figure 1, reinforcing the importance of university governance and the use of artificial intelligence for optimization.

Figure 1. Time series forecast of future electricity generation



Prepared by the author with data provided by AEE.

The results of this study compare the original series of electricity generation data with the future forecast, showing that the forecast is accurate for the next 12 to 15 months. These studies also summarize the Institution's historical progress in addressing the energy issue, using statistical tools to better manage the photovoltaic plant's energy generation, enabling more accurate future forecasts.

The energy efficiency assessment of UF-Uni used generation indicators from 2020 to 2023, compared to the Distribution Rules and Procedures (PRODIST), Module 8, of ANEEL (ANEEL, 2017). The results show that the energy generated is within Brazilian standards, although productivity is below expectations. Regular maintenance and the adoption of advanced technologies are recommended to increase energy efficiency. These findings can be used in future research to monitor and improve energy quality, as well as provide a methodological model for analyzing generation quality and indicators.

CONCLUSION

The analysis of the UniEVANGÉLICA Photovoltaic Plant (2020-2023) highlights its commitment to sustainability and energy efficiency. The methodology applied demonstrated that, despite the challenges, the plant can optimize energy generation, contributing to cost reduction and sustainable development. The

resulting institutional project is aligned with the SDGs of the 2030 Agenda, ESG principles, and UN guidelines, serving as a replicable model for other institutions and companies.

REFERENCES

ANEEL. **National Electric Energy Agency – ANEEL Procedures for Electricity Distribution in the National Electric System – PRODIST Module 8 – Electric Energy Quality National Electric Energy Agency.** Available at:

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BOGGIAN, L. C. C. **Governance and the Environment: Photovoltaic Energy and its contribution to the 2030 Agenda through sustainable development goals at UniEVANGÉLICA.** 2023. 199p. Thesis (Doctorate in Environmental Sciences) - Graduate Program in Society, Technology, and Environment (PPGSTMA), Evangelical University of Goiás (UniEVANGÉLICA) – Anápolis, 2023.

KNISS, C. T. et al. **50 years of Stockholm '72 and 30 years of Rio '92: Reflections on Contemporary Brazil and the Challenges for a Sustainable Future.** [s.l: s.n.]. v. 12

MME. **Summary Report of the National Energy Balance 2023 – Base year 2022 (BEN 2022).** Brasília/DF: Ministry of Mines and Energy - MME, 2023. Available at:

<https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-675/topico-631/BEN_Síntese_2022_PT.pdf>. Accessed on: Jan. 23, 2024.

PEB. **What are the government incentives for the use of solar energy in Brazil. 2024.** Available at: <<https://portalenergiabrasil.com.br/energia-solar-7-icentivos-no-brasil/>>. Accessed on: Jan. 23, 2024.

ROMERO, H. F. M. et al. Applications of Artificial Intelligence to Photovoltaic Systems: A Review. **Applied Sciences (Switzerland)**, v. 12, p. 31, 2022.

UNIEVANGÉLICA. **Contract signed for construction of the largest Urban Photovoltaic Power Plant in Brazil . 2018.** Available at on: <<https://www4.unievangelica.edu.br/noticia/6216-assinado-contrato-para-construcao-da-maior-usina-fotovoltaica-urbana-do-brasil>>. Accessed on: July 29, 2024.

UNIEVANGÉLICA. **UniEVANGÉLICA inaugurates largest solar parking lot in the country. 2019.** Available at: <<https://www4.unievangelica.edu.br/noticia/6525-unievangelica-inaugura-maior-estacionamento-solar-do-pais>>. Accessed on: Mar. 25, 2024.

UNIEVANGÉLICA. **UniEVANGÉLICA opens Laboratory for Energy Efficiency Laboratory. 2021.** Available at <<https://portalcontexto.com/unievangelica-inaugura-laboratorio-eficiencia-energetica-fotovoltaic/>>. Accessed on: March 25, 2024.

UNIEVANGÉLICA. **Who We 2024.** Available at: <<https://www4.unievangelica.edu.br/pagina/quem-somos#:~:text=Mission, social and sustainable development.>>. Accessed on: July 16, 2024.