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Energy Efficiency Project for the Campuses of Unicamp

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Abstract. Unicamp is making progress in making its energy consumption more efficient through partnerships with companies in the electricity sector and projects carried out within the scope of the Coordination of Sustainability. Despite already being able to report a reduction of around 10% in energy consumption during the last four years, it is important for Unicamp to be able to accelerate the transition to a more sustainable operation. The Energy Efficiency Project aims to reduce the university's electricity consumption by 30% by 2030. For this purpose, it is divided into three sub projects aimed at saving energy, modernizing, and improving buildings and the university's sustainability indicators. The Unicamp 100% Led subproject foresees the replacement of conventional lamps by 18W LED tube lamps. The Sustainability in the Air subproject aims to replace old air conditioning equipment with efficient equipment. And the + Photovoltaic subproject aims to increase the generation of photovoltaic energy on the roofs of university buildings. The main goal of this is to report the implementation process of this project, its challenges, results achieved and indicators. The result of this explanation can be used as an example so that other universities can advance in the sustainable management of electric energy.

Keywords:

Energy Transition, Sustainable Campus, Sustainable University, Sustainable Energy Indicators.

1. Introduction

University campuses serve as focal points for activity and learning, boasting a significant energy footprint that can profoundly impact the environment and contribute to greenhouse gas emissions. An integral aspect of sustainable campus management revolves around prioritizing energy efficiency. This approach not only yields financial savings but also plays a pivotal role in addressing the urgent global climate crisis.

Efficiency measures encompass a diverse range of strategies, spanning from optimizing building designs and upgrading infrastructure to fostering energy-saving behaviours among occupants. The implementation of these measures on a university campus carries particular weight due to its scale and potential for widespread influence outside of the university.

Energy efficiency directly mitigates the consumption of fossil fuels, which are primary contributors to climate change. By reducing energy demand, campuses can lessen their dependence on non-renewable resources and curtail greenhouse gas emissions. This aligns with global initiatives aimed at mitigating global warming and transitioning to cleaner energy sources. Moreover, energy-efficient buildings and systems often result in improved indoor environmental quality and enhanced occupant comfort, contributing not only to an enriched campus experience but also to the well-being and productivity of students, faculty, and staff.

Sustainable practices cultivate a culture of environmental stewardship and responsibility within campus communities. Furthermore, investments in energy efficiency can yield substantial long-term cost savings by reducing utility bills and maintenance expenses [1]. These financial gains can be reinvested in further sustainability initiatives, thus fostering a cycle of continuous improvement and innovation [2].

Given the urgent climate crisis, universities have a unique opportunity to lead by example and drive meaningful change. Collaborative efforts among stakeholders, policymakers, and academic institutions can accelerate the adoption of energy-efficient practices and technologies, thereby contributing significantly to global sustainability efforts.

The Umwelt-Campus Birkenfeld (Trier University of Applied Sciences), considered the "greenest university in Germany" for the fourth consecutive year, is located in Rhineland-Palatinate and has been operating since 1996. It occupies 6th place in the UI GreenMetric 2021 and 2022 world rankings, and is also the best ranked in the "Energy and climate change" category in 2021. The university uses a combination of renewable energy sources, including a wood chip thermal plant and a biogas plant, as well as large-scale solar systems. This integrated and diversified approach is facilitated by Germany's advanced infrastructure for renewable energy and supportive government policies, resulting in an efficient and low-carbon operation. The integration of modern technologies and ecological construction are outstanding features, reflecting the country's high level of technological readiness [3].

With an annual solar irradiation of about 1,000 kWh/m², the Umwelt-Campus Birkenfeld is ideal for photovoltaic systems, with large roof areas oriented east-west and without shade. The modules cover the entire course of the sun, generating electricity from morning until evening, reducing peak loads on the power grid at midday. In winter, modules on south-facing façades are advantageous. In 2020, the photovoltaic systems produced about 465 MWh of electricity, with 90% fed into the public power grid and the remainder consumed directly, justified by the feed-in tariff of the Renewable Energy Act of 2012 [3].

Unicamp is making progress in improving its energy consumption efficiency through partnerships with companies in the electrical sector and projects carried out within the scope of the Sustainable Campus [4, 5]. Despite being able to report a reduction of around 10% in energy consumption with the Energy Efficiency Project, funded through extra-budgetary resources, it is important for Unicamp to accelerate the transition to a more sustainable operation through its own investments. It is worth noting that many energy efficiency actions available in the market not only bring environmental advantages to the university but also offer a very attractive return on investment, guaranteeing economic and social benefits [6].

The electricity consumption of Unicamp in the year 2023 reached 60,000 MWh/year from conventional sources and 977 MWh/year from renewable sources. The implementation of large-scale energy efficiency actions, in addition to contributing to financial savings, also provides other benefits: with the reduction in electricity consumption, less thermal energy is required, reducing the use of fossil fuels and consequently greenhouse gas emissions. In addition to environmental factors, the cost of electricity can also be impacted [7, 8]. Furthermore, it's worth reinforcing that most of the electrical energy in Brazil comes from hydroelectric power plants [9], and starting in 2024, Unicamp has ensured that all energy consumed at the university comes from renewable sources, according to the contract in the free energy market [4, 5].

The Umwelt-Campus Birkenfeld and the Unicamp exemplify how universities can lead the transformation towards sustainability. While operating in different contexts, both demonstrate that significant advances in energy efficiency and sustainability can be achieved through strategies tailored to their local realities. Umwelt-Campus Birkenfeld, with its advanced infrastructure and favourable policies, serves as a model of technological integration and efficient management of renewable resources. On the other hand, Unicamp, facing unique challenges related to hydroelectric dependency and complex regulations, is implementing innovative and resilient solutions that can inspire other institutions in similar contexts. This comparative analysis underscores the importance of adapting sustainability strategies to local contexts, leveraging specific strengths and opportunities of each region to achieve positive outcomes in energy efficiency and sustainability.

The Energy Efficiency Project of Unicamp aims to reduce the electrical energy consumption of Campus Zeferino Vaz by 30% by 2030. To achieve this goal, this project will be implemented during the triennium 2022-2024, divided into three sub-projects that focus on energy savings, modernization, and improvement in the university's buildings and sustainability indicators:

- Unicamp 100% Led: Replacement of conventional bulbs (tubular fluorescents, mostly 32W) with high-quality 18W LED tubular bulbs, with a lifespan of 40,000 hours or 10 years of useful life, considering 16 hours per day, 256 days per year. Reduce the campus's annual electrical energy consumption by 10%.
- Sustainability in the air: Replace old air conditioning equipment with efficient models. It is estimated that there are more than 12,000 air conditioning units on the Zeferino Vaz campus, many of them extremely old. According to Unicamp's asset inventory, equipment from the 1970s is still in operation, as shown in Figure 2. New equipment brings significant improvements in thermal and acoustic comfort and reduces energy consumption. Reduce the campus's annual electrical energy consumption by 5%; replace equipment with compromised lifespan (>10 years); improve the thermal and acoustic comfort of users and comply with sanitary measures – HEPA filter.
- + Phovoltaic: Photovoltaic Generation on Roofs. Increase the installed capacity for photovoltaic energy production on campus; achieve a 5% reduction in the campus's annual electrical energy consumption.

This paper presents the methodology, the development of the projects, and the forecast of the results from the implementation of this project.

2. Methodology

The Energy Efficiency Project at Unicamp was developed in four stages, considering its

application in its three subprojects. The survey and analysis of current energy consumption involves conducting a comprehensive assessment of the existing energy consumption patterns across the university campus, including buildings, facilities, and infrastructure. The survey aims to gather data on energy usage, peak demand periods, inefficient practices, and areas with the highest energy consumption. Through thorough analysis, patterns and trends can be identified, providing insights into where energy-saving measures can be most effectively implemented.

After that, the next step is to evaluate and identify sustainable technologies and practices that can be integrated into the campus infrastructure. This evaluation involves researching and assessing technologies such as energy-efficient HVAC systems, renewable energy sources (like solar panels or wind turbines) and efficient lighting system. The goal is to select technologies that align with the campus's sustainability goals, considering factors like cost-effectiveness, scalability, and environmental impact. This analysis resulted in the specifics of each subproject:

- 100% LED: Replacement of conventional bulbs (mostly 32W fluorescent tubes) with high-quality 18W LED tubes, rated for 40,000 hours of use or 10 years of lifespan, assuming 16 hours per day, 256 days per year, with the aim of reducing annual electricity consumption on campus by 10%. To achieve this, the action plan established brings the definition of spaces and units for intervention; Hiring of a specialized Energy Services Company (ESCO) for supply, installation, disposal, initial and final measurement and verification of energy and demand savings in certified reports. Thinking about the complexity of the subprojects, this one was the first to start, in 2022.
- Sustainability in the Air: Replacement of old (before year 2000) air conditioning systems (window and split) with high-efficient inverter compressor split system with the aim of reducing annual electricity consumption on campus by 5%. To achieve this, the plan was established considering the registration of the equipment in use in the university system to locate every system within the scope of the project, generating a list by the faculties and institutes of the university. That list was sent to them to confirm that system, as the equipment in use list is not accurate. Since the budget for this project was pre-defined, the scope was filtered to encompass the oldest systems. That resulted in all systems before the year 2000. Furthermore, the plan considered the hiring of a specialized Energy Services Company (ESCO) for supply, installation, disposal, initial and final measurement and verification of energy and demand savings in certified reports. The estimated implementation period for this subproject was from 2023 to 2024.
- + Photovoltaic: Increase the Photovoltaic Generation by installing rooftop photovoltaic systems on campus, with the aim to achieve a 5% reduction in the campus's annual electrical energy consumption. The scope of the project includes the structural appraisal of the rooftops to verify that it can accommodate the photovoltaic system. Although this is the scope of the project there was a pre-evaluation of the building on all the campuses to determine which would be part of the project. The plan for this subproject also considered hiring of a specialized Energy Services Company (ESCO) for evaluation of the rooftops, project the system, submit the project to energy company, supply, installation, disposal, initial and final measurement and verification of energy and demand savings in certified reports. The estimated implementation period for this subproject was from 2024 to 2025.

With the survey data and technology evaluation in hand, the methodology calls for the gradual implementation of subprojects aimed at improving energy efficiency. The gradual

approach allows for manageable implementation, minimizes disruptions, and ensures thorough execution of each subproject.

Another crucial aspect of the methodology of this project is ongoing monitoring and evaluation of energy consumption and the effectiveness of implemented actions. This involves setting up energy monitoring systems and tools to track real-time energy usage, analysing data to identify deviations from expected energy patterns, and assessing the impact of implemented measures on energy savings and greenhouse gas emissions reduction. Continuous monitoring enables the identification of potential issues or inefficiencies, allows for adjustments and improvements to strategies, and provides valuable data for reporting and future planning.

3. Results and Discussions

The 100% LED project is currently at 60% implementation, with 62 thousand conventional bulbs already replaced with LED ones. During the process of surveying existing bulbs, many LED bulbs were identified as already installed, along with various types of bulbs not considered in the replacement contract and thus could not be replaced. Bulbs of other types were catalogued and may be replaced with LED or more efficient technology in the future. Moreover, a significant challenge encountered in this subproject was communicating with different faculties and institutes to ensure access for surveying all Unicamp's facilities.

A positive outcome of the 100% LED project was the integration of the existing bulb survey with the survey of internal environments at Unicamp using the ArcGIS platform. This integration also extended to external environments, considering the smart and sustainable public lighting project. The result of this process can be visualized in Figure 1. The dashboard provides characterization by bulb type, quantities and georeferenced locations, bulb wattage, and the number of points surveyed during the project, along with the percentage of bulbs surveyed and replaced.

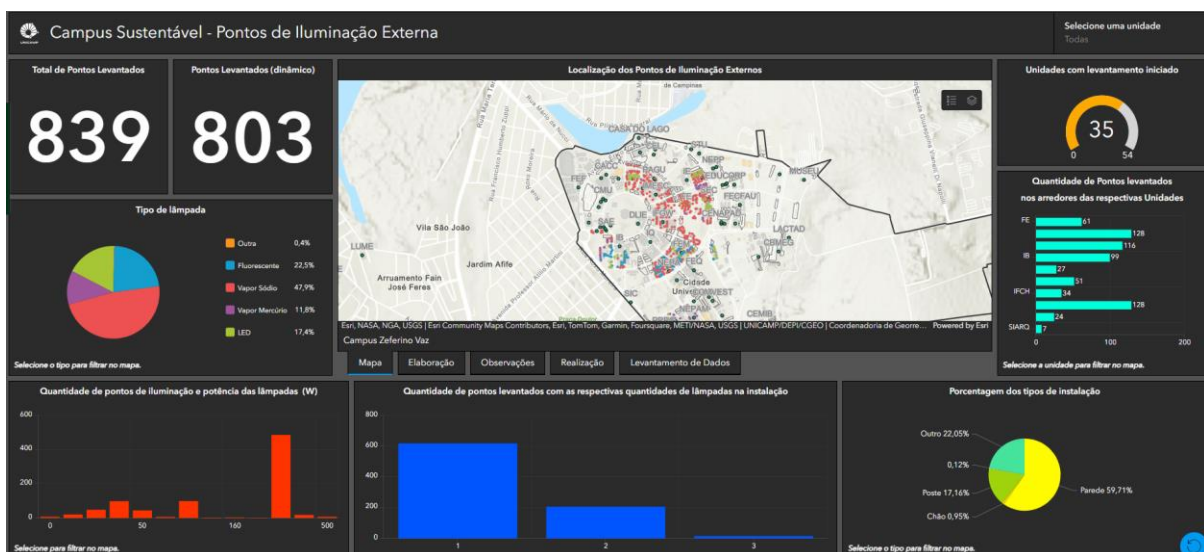


Figure 1. Dashboard of the public lighting survey

<https://atlas.unicamp.br/apps/3359a861ba4549c7a8b7d6092e8f1e19/explore>

The Sustainability in the Air project had its contract signed in April 2023, with the survey of existing equipment eligible for replacement, as specified in the methodology,

commencing in late April. It is estimated that 1800 air conditioning units, over 20 years old, will be replaced at the university. The primary challenge of this project is believed to lie in the selection of equipment, given the presence of numerous units between 10 and 20 years old at Unicamp, which exhibit low energy efficiency and were not included in this tender. This project is expected to continue to encompass all equipment that does not have an A rating in energy efficiency.

Meanwhile, the + Photovoltaic project is in the process of developing technical materials for procurement through Brazil's new bidding law, with the procurement expected to take place in 2024. Analyses of building rooftop structures have already been conducted, considering shading, load capacity, roof configuration, and the lifespan of the solar array. Some rooftops have undergone structural reinforcement to accommodate photovoltaic panels. Additionally, the rooftops have been analyzed for solar incidence using the Helioscope software, a solar plant design tool enabling fine-tuning in simulation with meteorological data, modules, and inverters to identify optimal points for solar energy capture. Figures 2 and 3 depict the results of the Helioscope simulation for the buildings of the Institute of Language Studies. Figure 2 provides an estimate of annual photovoltaic energy production at 408 MWh, 1,409.8 kWh/kWp, with a performance rate of 79.1% related to one specific building. This software also provides an estimate of electricity generation per month, considering the seasons of the year, and also indicates the percentages of sources of system loss. Figure 3 proposes the distribution of solar panels on rooftops for maximum efficiency, considering shadows and local vegetation. These studies have been conducted across the entire Zeferino Vaz campus of Unicamp, considering buildings without existing solar energy generation.

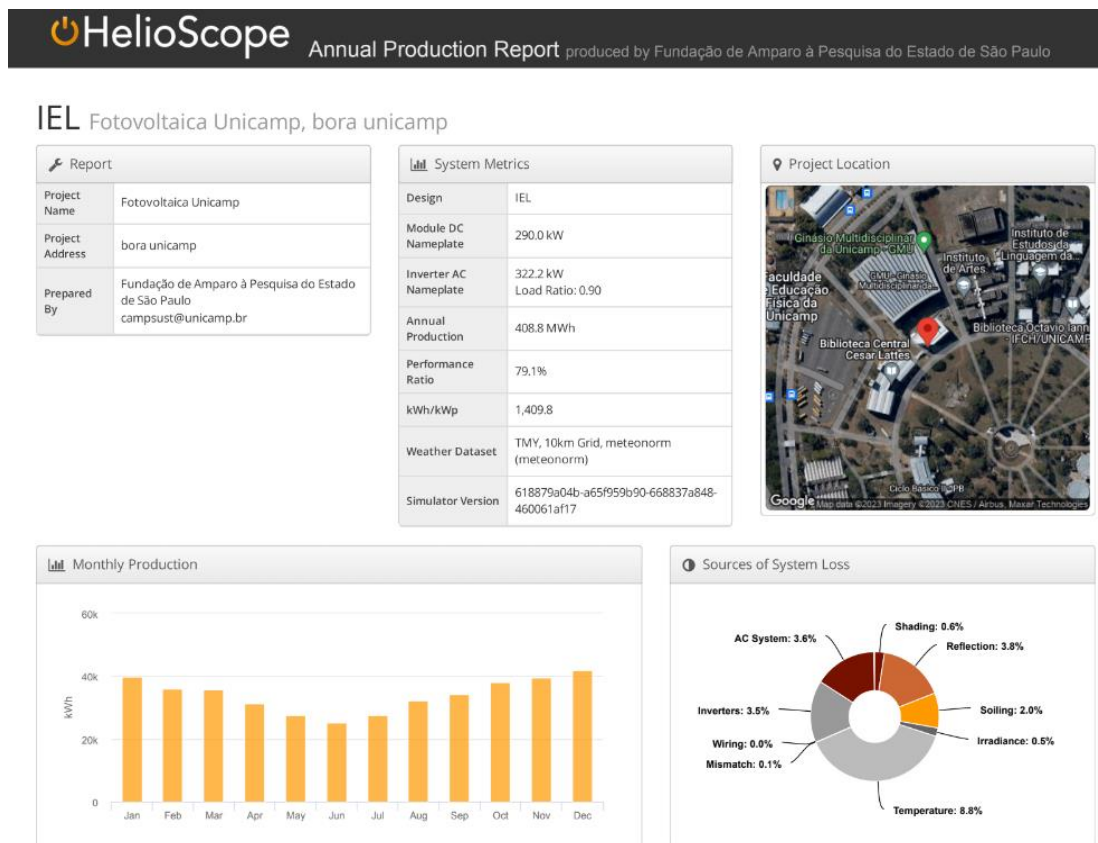


Figure 2. Simulation of the HeliScope for the IEL/Unicamp building.

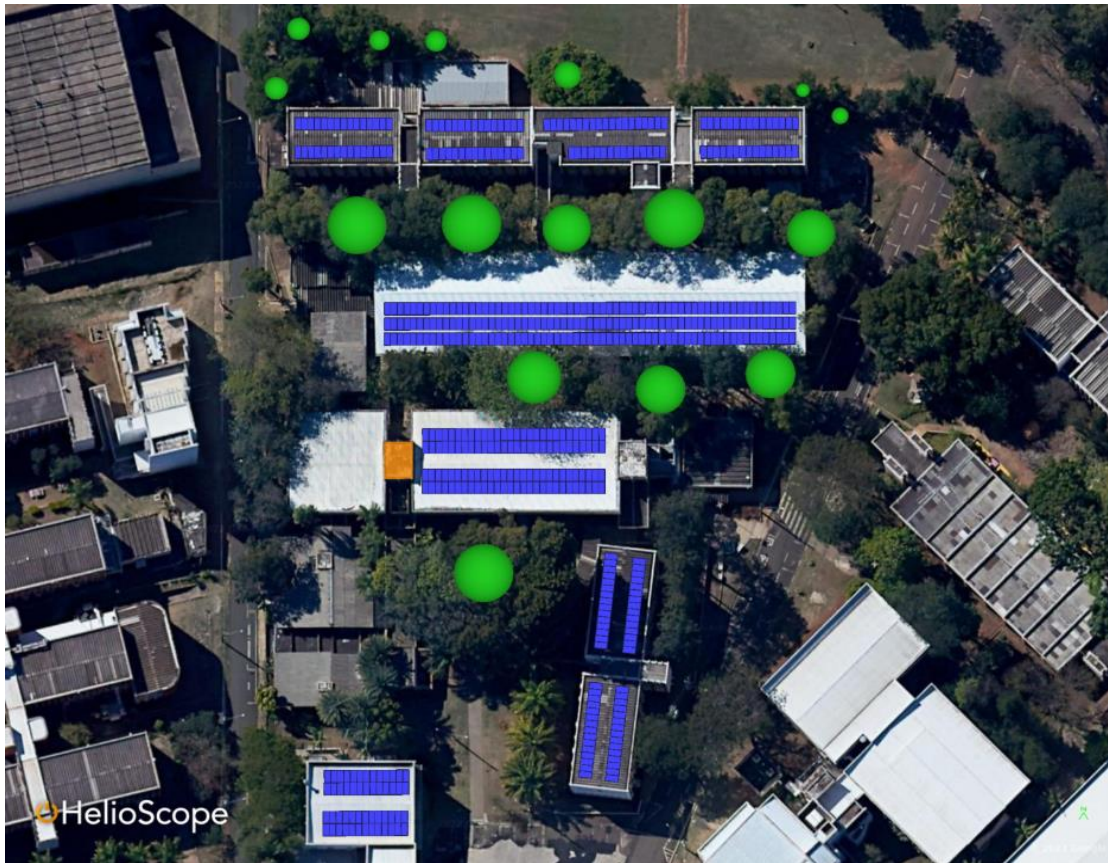


Figure 3. Simulation of the HeliScope for the IEL/Unicamp building.

The sustainability projects at Unicamp highlight significant theoretical and practical implications for the field of energy efficiency and sustainability, both in academia and public policy. The successful implementation of the 100% LED project illustrates the potential of technological advancements to drive sustainability in large institutions. This case supports theories about the role of technological innovation in achieving energy efficiency, reinforcing the notion that adopting modern technologies, such as LED lighting, can significantly reduce energy consumption and carbon footprint.

The integration of the bulb survey with the ArcGIS platform demonstrates a practical application of systemic thinking in sustainability. By viewing the campus as an interconnected system, the project highlights how data integration and real-time monitoring can optimize resource management, a central concept for environmental and sustainability studies. The Energy Efficiency Project also emphasizes the need for organizational change and effective communication strategies to achieve environmental goals related to the challenges faced in communication and coordination between various faculties and institutes underscore the importance of organizational behaviour in implementing sustainability initiatives.

The findings from Unicamp's sustainability projects can inform public policies, providing a successful model for large-scale energy efficiency programs. Policymakers can leverage these insights to develop regulations and incentives that encourage other institutions to adopt similar measures, promoting large-scale energy conservation. The economic benefits observed from the energy savings achieved by the 100% LED project highlight the importance of investing in sustainable technologies. This case can serve as a practical example for governments and private entities to justify the initial costs of such

investments, considering the long-term financial and environmental gains.

This project also sets a precedent for data-driven decision-making in sustainability with the use of ArcGIS platform to monitor and manage energy consumption. Public policies can incorporate requirements for data collection and analysis to improve transparency and accountability in energy use, leading to more informed and effective sustainability strategies.

4. Future Perspectives

The Energy Efficiency Project at Unicamp embodies a proactive and comprehensive approach to mitigating energy consumption and reducing environmental impact. Through meticulous planning and execution, Unicamp is establishing a notable example of how academic institutions can lead the advancement towards sustainability. By addressing energy efficiency on various fronts, from lighting to air conditioning systems and renewable energy generation, Unicamp is not only reducing its carbon footprint but also fostering a culture of environmental responsibility within its academic community.

The progress achieved thus far, with 60% implementation of the 100% LED project and the initiation of sustainability measures in air conditioning systems, demonstrates Unicamp's dedication and commitment to achieving its energy efficiency objectives. Challenges encountered, such as communication barriers and complexities in equipment selection, are being met with perseverance and strategic planning, ensuring the project's long-term success.

Looking ahead, the integration of photovoltaic generation on rooftops holds the promise of further enhancing Unicamp's sustainable energy initiatives. Through meticulous analysis and planning, coupled with technological advancements and partnerships with specialized service providers, Unicamp is poised to significantly reduce its reliance on conventional energy sources while harnessing the potential of renewable energy.

The methodology outlined in this work not only serves as a blueprint for Unicamp but also offers valuable insights for other academic institutions and organizations aiming to embark on similar energy efficiency ventures. By prioritizing energy efficiency, universities not only contribute to global sustainability efforts but also inspire future generations to adopt environmentally conscious practices.

This project also brings the opportunity for future research that can explore the broader socioeconomic impacts of energy efficiency projects, including job creation, economic development, and social acceptance of sustainable practices. Understanding these dimensions can help design holistic sustainability programs that benefit both the environment and society.

As Unicamp continues its journey towards a more sustainable future, it stands out as a beacon of hope and a testament to the transformative power of collective action and innovation in the fight against climate change. With unwavering commitment and collaboration, Unicamp is paving the way for a greener and more sustainable world. The Energy Efficiency Project is essential not only to reduce operational costs but also to position our institution as an example of sustainability. With the collaboration of everyone, we can create a more efficient, sustainable campus aligned with contemporary environmental challenges.

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