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SUSTAINABLE MANAGEMENT OF ELECTRICITY - PRACTICES OF FEDERAL UNIVERSITY OF LAVRAS

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SUSTAINABLE MANAGEMENT OF ELECTRICITY - PRACTICES OF FEDERAL UNIVERSITY OF LAVRAS

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Abstract

Considering that most of the world electrical matrix is made up of non-renewable sources, the search for safer and more sustainable energy generation solutions has grown. In view of this scenario, there is an increase in the use of renewable energy sources integrated with electrical systems. In this context, Universities have an important role in research development, implementation of environmental plans aimed at sustainability, optimization in the use of electric energy and development of the use of renewable energies. The Federal University of Lavras has an environmental plan with goals related to carbon emissions, solid waste management, rainwater collection and reuse, among others, are established. In order to achieve the goals related to sustainable electricity management practices on campus, the University has acted in several ways, resulting in approximately 30% electricity savings. This article presents the actions of the University in obtaining this result. First, we present a study on the application of energy indicators as a strategic tool to assist in the management process at the Federal University of Lavras (UFLA). Next, we discuss the energy efficiency projects developed in conjunction with the local concessionaire (CEMIG) and their impact on energy consumption. Finally, we present the proposal for the implantation of a microgrid in the internal distribution network and detail the photovoltaic generation system already installed. The evaluation of the energy indicators allowed the definition of priorities for the allocation of investments in the energy efficiency program. In addition, the results were compared to the goals outlined in environmental plan of the university. Finally, the ongoing microgrid project is presented but, to date, there are no significant data on the generation of UFLA's Solar Parking.

Keywords: Energy efficiency projects; Energy indicators; Grid-connected photovoltaic system; Microgrid.

1. Introduction

The concept of sustainable power management can be understood as a planned search for minimizing the use of non-renewable power resources, using the generated energy in a more efficient way and reducing the losses (Aduda et al., 2016; Fathi & Bevrani, 2017; Onat & Bayar, 2010). Therefore, a sustainable development is directly correlated to the use of efficient and renewable resources (Claudia Roldán et al., 2014; Güney, 2019; Østergaard et al., 2020).

The use of distributed renewable sources brings additional challenges in power planning mainly due to the intermittent power generation (Hou et al., 2020; Mer & Patel, 2016). When the level of penetration of these systems reaches or exceeds the hosting capacity of the grid, the effective integration of these energy resources is indispensable. The concepts of microgrids and smart-grids are considered promising solutions to these problems (Jirdehi et al., 2020; Kathirgamanathan et al., 2020; Yoldaş et al., 2017).

There are several initiatives around the world, where these concepts have been applied in pilot projects (Bianchini et al., 2017; Jirdehi et al., 2020; Sharma et al., 2017), such as by looking for efficiency and power quality. In Brazil, initiatives for implementing smart grids and microgrids are still growing, and the investment in the implementation of pilot projects had increased in the past years. Dranka & Ferreira (2020) presented an overview of the challenges for smart grids implementation in Brazil.

In this context, the interest of Universities in sustainable management is noticeable by their projects and research related to energy sustainability and efficiency (Ávila et al., 2017; Machado, 2019; Moura et al., 2019; Rebelatto et al., 2020). In fact, these institutions play an important role in the dissemination of technical knowledge of sustainable practices and technologies. However, many barriers have yet to be overcome to create efficient sustainable management strategies at universities. According to Ávila et al., (2017) the main problems identified in relation to sustainability were lack of support from administrative sectors, lack of technology and awareness, and absence of environmental committees.

On the other hand, there are several tools to assist Universities in the management and improvement performance related to social and environmental responsibility. Sustainable initiatives related to LiFE index (Learning in Future Environments) has been reported by Rebelatto et al., (2020), where an analysis of 100 articles related to the aforementioned themes was presented. The LiFE index was developed by the Environmental Association for Universities and Colleges and four areas stand out when educational institutions are

considered. The first area is leadership and governance which analyzes the commitment and financial support to sustainable activities and initiatives. The second is partnership and engagement which correlate the events and partnerships between universities and the private sector. The third is teaching and research which mainly considers the sustainable disciplines and extension projects. Finally, the fourth is facilities and operation which considers infrastructure, waste management and energy efficiency.

In view of this scenario and based on the UFLA's Institutional Development Plan (PDI), it is worth to mention the initiatives related to UFLA's energy management cover most previously mentioned areas of the LiFE index. For example, we have a committee to deal specifically with environment issues and policies for the efficient use of water and electricity (Environmental Committee). This committee has a coordination for power planning and management, responsible for actions that minimizes the power consumption and waste, as well new propositions for using alternative and sustainable energy sources.

Moreover, the Institutional Development Plan (PDI) and the Sustainable Logistics Plan (PDS) of the institution include several actions aimed at the efficient use of electricity (UFLA-DMA, 2019; UFLA, 2014). It worth to cite the implementation of a new internal electric grid with an exclusive feeder, seeking to reduce the number of interruptions not programmed by the electricity supply concessionaire; the implementation of energy efficiency projects; a survey of the institution's energy consumption indicators and the installation of photovoltaic solar energy generation systems.

Other tools that can be used to assist Universities in energy management, in the path of sustainability, are the energy indicators. The energy indicators are commonly used as instruments for assessing energy use in order to identify the relationship between administrative or physical information, and electrical or cost quantities (Fernandes, 2004; Kathirgamanathan et al., 2020). Their results are generally used for awareness and guidance of users and also for comparison with other similar units (Li & Tao, 2017; Mardani et al., 2017; Pitt & Michaud, 2015; Vigna et al., 2018; Yu et al., 2020).

Given the above, the aim of this paper is to present the actions taken by the Federal University of Lavras to achieve sustainable development and the goals outlined in its environmental plan. To fulfil this objective and as the main contribution, we present a study of energy indicators as a tool for power management and decision-making. In this work, we also apply these indicators to guide the actions for reducing the energy consumption by means of the national Program of Energy Efficiency (PEE) with excellent cost-benefit ratio.

As a complementary contribution, we propose to model the local grid as a small microgrid. This paper proposes the use of microgrid concept to solve the possible problems caused by the intermittency of renewables sources. In addition, we present the detailed design of solar photovoltaic system (PV). However, the microgrid concept and the PV system implantation are still ongoing.

2. Methods

This research has been conducted in the campus of Federal University of Lavras, state of Minas Gerais, Brazil. The constructions and facilities of the campus are diverse and involve students' accommodation, multi-sport gym, soccer courts and stadium, university restaurant (UK), cafeterias, community center, university integration center, support foundations, 21 didactic-scientific departments, and others.

According to the University's portal, the campus has an area of 500 hectares, that is six million square meters, with approximately 237250 square meters of built area. In addition, in the first period of 2019, there were 11100 undergraduate students, 1850 graduate students, 766 teachers, 581 administrative technicians, totaling 14941 individuals who used the institution's spaces.

All data needed for this work were collected from electricity bills, the mass memory report data from UFLA energy meters and the University's portal, as previously described. The physical information of the campus facilities areas were available from the main administration. We analyze data from a minimum period of 24 months aiming to consider the seasonality of energy consumption. This definition of this time window was based on the manual of general guidelines for the conservation of electricity in public buildings.

The methods were divided into three main parts: the energy indicators formulation and definition, energy efficiency projects and microgrid modelling. Each one will be described in the following details.

2.1. Methods for energy indicators

The energy indicators used in this work were based on [Morales \(2007\)](#) and could be divided into global, specific and financial. Global indicators use technical information to characterize the unit. They are responsible for pointing out the efficiency in the use of electricity in general. They are used in the early stages of characterization, indicating technical or behavioral flaws. The specific indicators take into account physical information, occupation

and end uses in order to assess the behavior in the use of electricity. Financial indicators demonstrated how resources are distributed and used within the institution.

In this work we linked the habits of energy usage to information such as: area and purpose of use, equipment used, number and type of users, time of use, among others. These types of data were necessary for the initial characterization of the units. In addition, they were essential for the elaboration and choice of the indicators used and the most efficient action plan. The energy indicators proposed for evaluation of UFLA scenario were the percentage consumption ratio of reserved hours, average monthly consumption by users, the consumption indicator by built area, the financial indicators by built area and the financial indicators by total number of users. They will be described below.

2.1.1. Percentage consumption ratio

The indicators of energy consumption by time of use takes into account the seasonality of consumption. This indicator was called *PCR* (Percentage Consumption Ratio in the Reserved Period) and aims to characterize the energy consumption in reserved period of the consumer unit in relation to its total consumption (Saidel et al., 2005).

$$PCR = \frac{\text{Energy reserved period (kWh)}}{\text{Total installation energy (kWh)}} \quad (1)$$

For this indicator, consumption information should be separated by time of use. According to ANEEL Normative Resolution N° 414/2010 (ANEEL, 2010), Brazilian distributors can define 3 consecutive daily hours where there is greater consumption. This set of hours is called peak hour, at that time the amount charged per kilowatt (kWh) hour is higher. The rest of the day is off-peak.

Thus, the *PCR* indicator was used to assess consumption during peak and off-peak hours or at specific times. Through its use, it is possible to ascertain the energy consumption at a specific time of interest, providing data for decision making to manage energy use during peak hours, for example. For the seasonality to be considered, the period from August 2016 to August 2018 was used.

2.1.2. Average monthly consumption by users

The average monthly consumption by users (*ACU*) evaluated the energy consumption per user. The users were separated into specific groups for better evaluation of the indicator (Saidel et al., 2005). The *ACU* was characterized by the ratio between the average monthly consumption and the number of users in the group under evaluation:

$$ACU = \frac{E_a}{N} \quad (2)$$

where, E_a is the average monthly energy (kWh / month) and N is the number of people who fall into the group under analysis.

At UFLA, for the calculation of the *ACU*, the information present in the Institutional Development Plan (IDP) (UFLA, 2016) was considered. The groups considered were: students (ACU_S), professors (ACU_P), administrative technicians (ACU_{AT}) and total users (ACU_{TU}). Each of the indicators by group was calculated considering the University's total energy consumption in the month and the number of individuals in each group, as previously described.

2.1.3. Consumption indicator by built area

The consumption indicator per built area *CBA* is obtained by means of the ratio of energy consumption in a given period, by the product of the total useful area of the unit and the desired time interval:

$$CBA = \frac{E_a}{A} \quad (3)$$

where, E_a is the average monthly energy (kWh / month) and A is the total useful area (m²).

To calculate the indicator by area built at UFLA, values of the institution's built area were obtained through the Institutional Development Plan – IDP (UFLA, 2016) and were used in the management reports. The evaluated period was from January 2018 to August 2018.

2.1.4. Financial indicators

Financial indicators can be classified in relation to several variables, here we consider the financial indicator by build area (*FIBA*) and financial indicator by number of users (*FIU*), given by:

$$FIBA = \frac{C_e}{A} \quad (4)$$

$$FIU = \frac{C_e}{N_u} \quad (5)$$

where, C_e is the monthly cost of electricity (R\$), A is the total useful área and N_u is the total number of users.

2.2. Methods in energy efficiency projects

UFLA's energy efficiency plan includes, among other sustainability projects, a project to reduce electricity consumption and implement process automation through equipment efficiency, energy management and the use of energy generation from renewable sources. One of the first solutions to reduce electricity costs is the replacement of fluorescent lamps for LED lamps. The use of LED lamps can reduce energy consumption by up to 50% and it has been a very common practice in energy efficiency projects (Napitupulu & Mawengkang, 2017).

Between 2016 and 2018, seeking to achieve energy efficiency goals, the university submitted projects annually for the Program of Energy Efficiency (PEE) funded by the local energy concessionaire (CEMIG). The Brazilian concessionaires release project calls for energy efficiency every year in order to comply with regulations established by Brazilian National Electric Energy Agency (ANEEL). These regulations require the concessionaires to allocate a portion of their revenue to Energy Efficiency Projects (CEMIG, 2012; Dranka & Ferreira, 2020; Silva et al., 2017).

The project is accompanied by Measurements and Verifications in order to confirm the projected consumption and savings. The entire process was prepared in accordance with the provisions of Energy Efficiency Program Procedures - PROPEE and the International Performance Measurement and Verification Protocol - PIMVP - January 2012 - EVO 10000 - 1: 2012. Another important step in the process is correct disposal of materials that have been replaced. For lighting and air conditioning equipment, disposal must be guaranteed and follow Brazilian solid waste management policies.

2.3. Microgrid pilot

The UFLA's coordination for power planning and management aims to create a microgrid in the campus. The main idea was to isolate a portion of the distribution grid which would be

managed individually. This microgrid will be composed by critical loads and distributed generation units allowing proper monitoring of main electrical variables.

A long-term prospect of this microgrid is presented in Figure 1. The proposed microgrid will be formed by:

- a. Photovoltaic Generation Systems: its operation is connected to main grid in order to reduce energy bills according to Brazilian regulations. In the future, they can be used to increase the available energy in the microgrid and consequently its reliability and autonomy (ITEM 1);
- b. Energy storage systems aim to reduce the consumption in peak hours where energy is more expensive and even supply the demand for this microgrid under conditions of island operation (ITEM 2);
- c. Grid-forming converters: used to provide voltage and frequency reference for the microgrid when operating islanded and coordinate the connection and disconnection of the microgrid to main grid (ITEM 3);
- d. Synchronous generators: powered by alternative energy sources such as ethanol or biofuel, and used to complement the power generated by photovoltaic systems (ITEM 4);
- e. Critical Loads: they are chosen based on criteria defined by UFLA's coordination and previous information of demand, such as energy indicators. Now the veterinary hospital, the engineering department and the illumination strategic areas represent them (ITEMS 5, 6 e 7);
- f. Center for data, supervision and control, training and research: its objective is to maintain an exclusive server for assessment of distributed generation and the microgrid status, enabling the real-time execution of innovative power quality and energy efficiency algorithms, detection of load centers and defining the priority places for allocation of loads, among others. Summarizing, it will be the center of information for sustainable power management (ITEMS 8, 9 e 10);
- g. Exclusive feeder: aims to supply the crescent demand of the University, with the possibility of meeting up to 6000 kW of contracted demand (ITEM 11); and
- h. Smart meters and switches: they will allow the data collection of energy consumption for feeding the algorithms of power management and control the power flow into the microgrid (ITEM 12, 13).

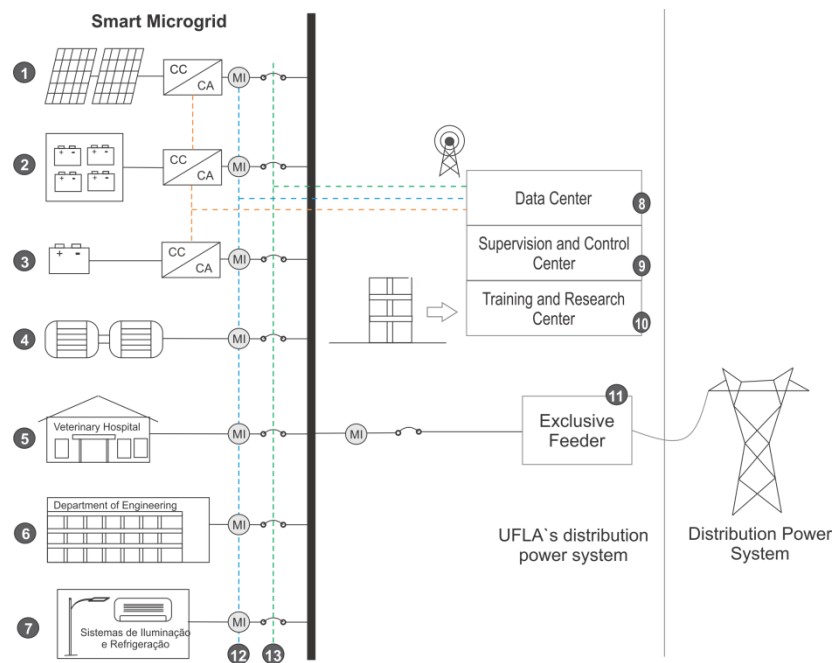


Figure 1. Prospect of a microgrid in UFLA distribution power system

For now, only the exclusive feeder and the photovoltaic system are already installed in the campus distribution grid. The exclusive feeder has been installed in 2015 in order to provide more reliability because it had more direct path between the Lavras substation and the University. The modernization of the system concludes with the installation of two feeders for contingency situations and protections through automatic reclosers and telecontrol. On the other hand, the photovoltaic system will be described in detail in the results.

3. Results and Discussions

3.1. Energy indicators

Figure 2 and 3 show the daily UFLA's profile of electricity consumption, also known as load profile, in the school period of 2018, collected from mass memory report data from UFLA meters. These data were analyzed for two periods with different load profile, the school period (November 24, 2018 to November 30, 2018) and school holidays (February 3, 2019 to February 9, 2019). The mean values and standard deviation for each of the weeks evaluated are shown in Table 1. During weekdays, between 7 am and 5 pm, there is a greater standard deviation. At these times, most of activities on campus are developed.

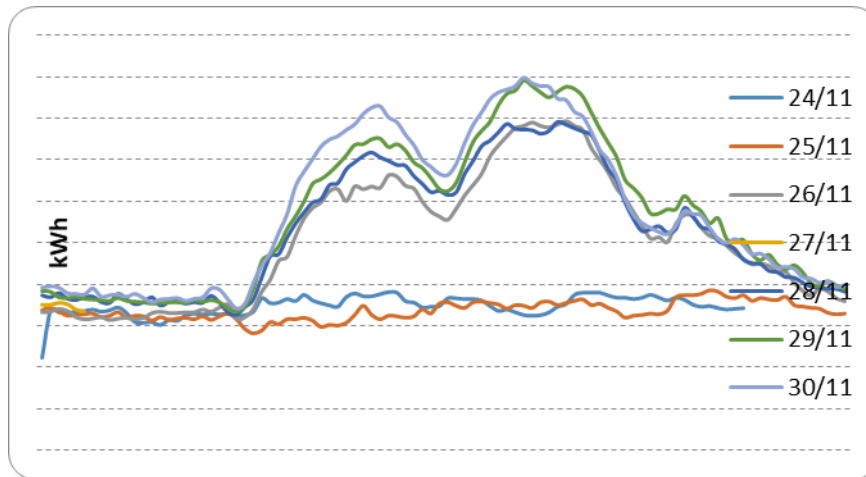


Figure 2. Profile of electricity consumption at UFLA in the school period of nov/2018

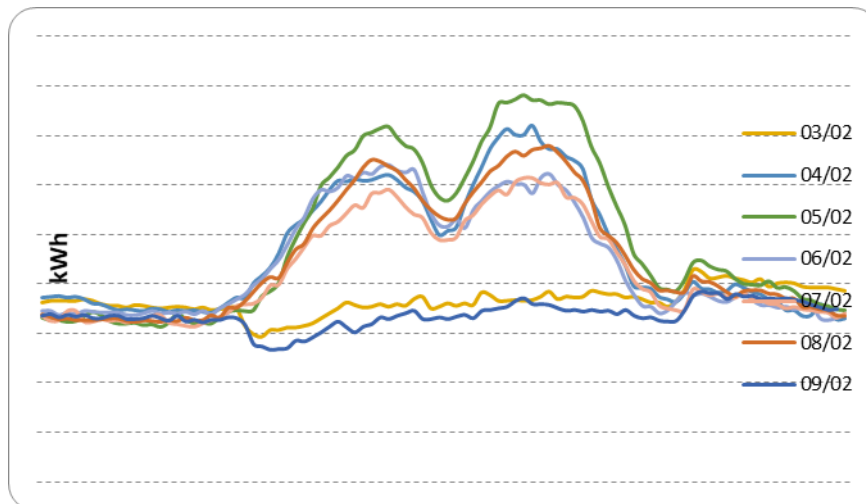


Figure 3. Profile of electricity consumption at UFLA in the school holidays of feb/2019

Table 1. Average and standard deviation of energy consumption in the school period and holidays

	Weekdays		Weekends	
	School period	Holidays	School period	Holidays
Average (kWh)	272.53	228.91	170.08	183.65
Standard deviation (%)	30.85	27.75	6.9	7.45

Another point is the considerable difference in the average consumption during the studied periods. During the holiday period, there is a decrease in the average consumption of weekdays (Monday to Friday) of approximately 16% and on weekends, it is approximately 7.4% lower compared to the school term. For one month, this difference is equivalent to

approximately 760 kWh of savings. This period can be strategic to implement saving measures, e.g., maintenance and overhaul of equipment for improvements in relation to energy consumption.

Regarding to the energy indicators, the first analyzed result is the percentage consumption ratio of reserved hours (*PCR*). Figure 4 shows the results of applying the PCR indicator in two intervals: peak hours, from 5 pm to 8 pm, and off-peak hours, remaining hours of the day. Table 2 shows the average and standard deviation of the PCR for off-peak hours (*PCR_{OPH}*) and peak hours (*PCR_{PH}*).

The *PCR_{OPH}* indicates that on average approximately 90% of the total electricity is consumed during off-peak hours. This indicator and its variations were used to assist in the choice of the tariff modality, since UFLA's facilities fall into group A4.

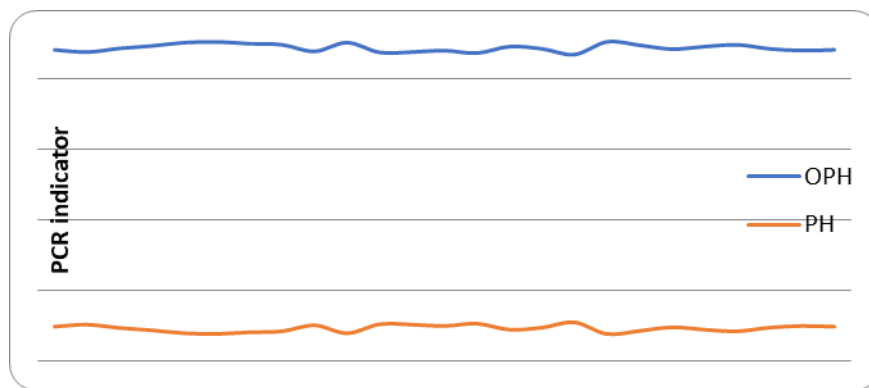


Figure 4. Percentage consumption ratio (*PCR*) at UFLA, off-peak hours and peak hours

Table 2. Average and standard deviation of PCR for off-peak hours and peak hours

	Average	Standard deviation (%)
<i>PCR_{OPH}</i>	0.896	0.01
<i>PCR_{PH}</i>	0.104	0.01

Next indicator analyzed was the average monthly consumption by users. The average values and standard deviation of the indicators of average monthly consumption (*ACU*) for each evaluated group are shown in Table 3.

Table 3. Average monthly consumption by users

	Average (kWh/month/user)	Standard deviation (%)
ACU_S	48.62	17.00
ACU_P	813.31	13.32
ACU_{AT}	1038.06	15.65
ACU_{TU}	44.01	16.85

The relationship between the total number of users and the institution's annual energy consumption in the year of 2016 to 2018 is shown in Figure 5. It shows that when there is an increase in the number of significant users, the same increase does not happen for consumption. At UFLA, for an increase of approximately 13% in the group of users, there was an increase of approximately 1% in the annual consumption of electricity.

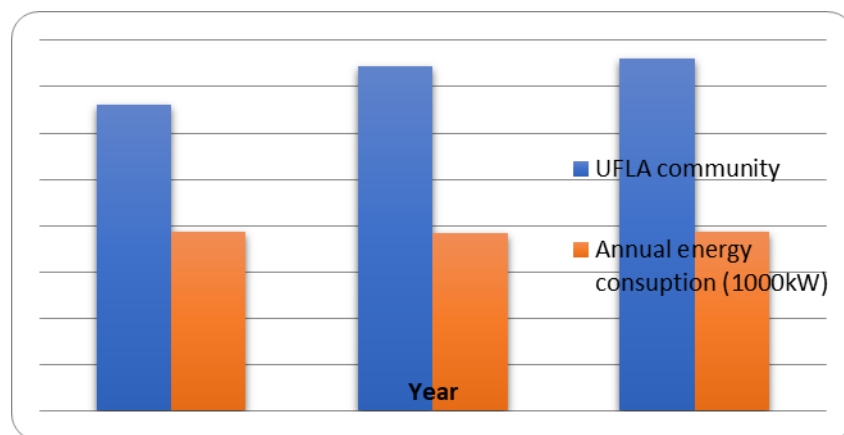


Figure 5. Annual energy consumption and UFLA community

The third indicator discussed was the consumption of energy by built area. The global results for the consumption related to the total built area of UFLA's campus are shown in Table 4. Considering the different physical structures of UFLA, the calculated indicator is a source of data that can assist in the projects of new buildings in the Institution, with the implementation of sustainable installations with the use of solar energy, rainwater capture, for example.

Table 4. Consumption by built area

	Built area (m ²)	CBA (kWh/month/m ²)	Standard deviation (%)
UFLA	237,250	2.72	9.85

Considering the diversity of constructions, based on the analysis of representativeness within the university, the places chosen for calculating the *CBA* were students' accommodation, classrooms, university library, community center, university restaurant, didactic-scientific departments and pro-rectories. The results of *CBA* by places are presented in Table 5 and Figure 6. In this case, it is worth mentioning that these indicators should not be evaluated alone because the differences between the places are not taken into account in this indicator. The key point is the built area and not the final use of electricity in each area. However, it is possible to obtain results that signal an order of priority for actions of sustainability and energy efficiency.

Table 5. Consumption by built area in the specific places at UFLA

Place	Built area (m ²)	CBA (kWh/month/m ²)	Standard deviation (%)
Didactic-scientific departments	135,418	4.77	9.85
Classrooms	16,960	38.10	9.85
Students' accommodation	9,078	71.18	9.85
Community center	6,621	97.60	9.85
University library	5,024	128.62	9.85
Pro-rectories	4,269	151.37	9.85
University restaurant	3,311	195.17	9.85

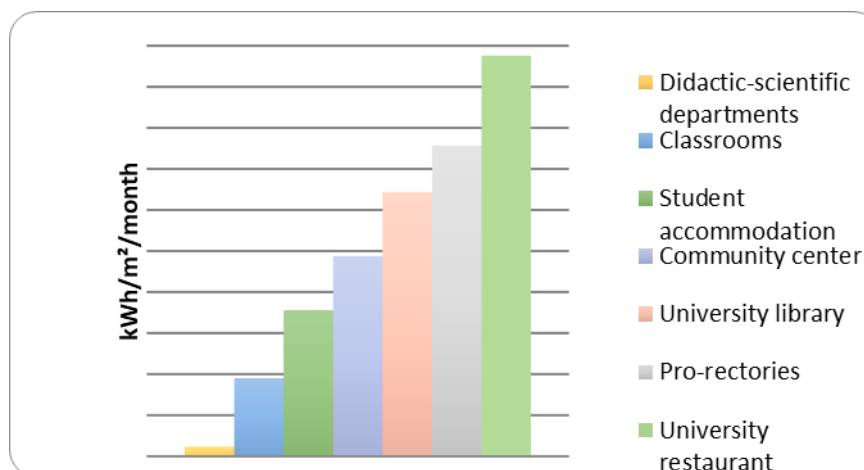


Figure 6. Consumption by built area in the specific places at UFLA

From the results of indicators by specific areas of UFLA, an order of actions priority can be defined: university restaurant, pro-rectories, university library, community center, accommodation, classrooms and didactic departments scientific. This ranking provides a parameter for initiating actions, but as previously discussed, it is not possible to disregard the particularities of each environment, such as the university restaurant that uses many industrial equipment. For other locations, educational campaigns can bring good results.

After obtaining monthly electricity costs for the year of 2018, the average of the period was used to calculate the financial indicators (Table 6). Through them, it is possible to point out the contribution portion of each specific variable with the total cost of electricity, in addition to making a direct link between the amount spent on energy and total costs of the units.

Table 6. Financial indicators per built area and user

	Average	Standard deviation (%)
<i>FIBA</i> (R\$/month/m ²)	1.23	13.74
<i>FIU</i> (R\$/month/user)	21.48	17.83

Financial indicators make it possible to associate the amount spent by the institution in relation to its total cost. Associated with the consumption indicator by built area *CBA*, *FIBA* is also an aid tool for decision making in relation to projects to be built, exchange and maintenance of air conditioning and other devices, updating of the lighting system, among others.

In order to enrich the analysis of indicators by area built in specific locations of UFLA, the financial indicators were calculated and shown in Table 7 and Figure 7.

Table 7. Financial indicators of monthly cost per m² built at the specific locations of UFLA.

Place	Built area (m ²)	FIBA (R\$/mês/m ²)	Standard deviation (%)
Didactic-scientific departments	135,418	2.29	13.82
Classrooms	16,960	18.31	13.82
Students' accommodation	9,078	34.21	13.82
Community center	6,621	46.91	13.82
University library	5,024	61.82	13.82
Pro-rectories	4,269	72.75	13.82
University restaurant	3,311	93.80	13.82

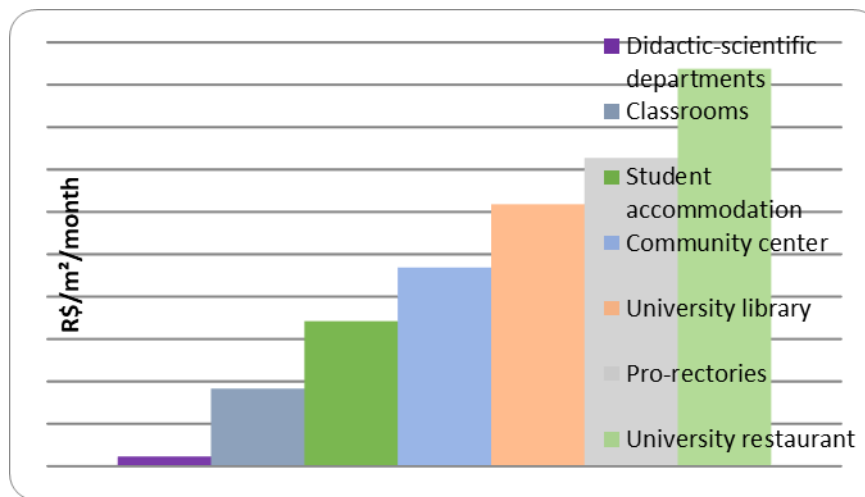


Figure 7. Financial indicators per built area specific locations of UFLA

Therefore, with the results obtained, it is possible to establish a monetary relationship for each chosen space in addition to pointing out the monthly contribution portion of each location in relation to the total energy cost of the campus. Having the same priority list of the indicator by area constructed and as previously discussed, it is not possible to disregard the particularities of each studied area.

3.2. Energy efficiency projects

The first stage of the PEE UFLA-CEMIG was approved in 2016. During the execution of the project, LED lamps replaced 7,349 conventional lamps and 33 old air conditioners were replaced by more efficient ones. The institutional coordination of power planning and management chose the locations of its installation strategically to serve areas of higher energy consumption based on UFLA's energy indicators. The energy indicators are detailed discussed in the next section and has been used for decision-making of investments directed for electricity.

Figure 8 shows a night aerial photo of the UFLA University Restaurant and Community Center, one of the places where the exchange for LED lamps was implemented in the first stage of the project. It is observed the region of greater circulation of people already with LED lighting (lighter lamps) and still others with traditional lighting. In the first stage, the total investment was R\$1,561,712.03. 983.99 MWh/year. The second and third stages of the project, approved in 2017 and 2018, has provided for the exchange of 17,329 and 8,886 lamps with LED technology respectively. Investments were R\$ 1,737,886.13 and R\$ 1,117,088.98 for the second and third stages, respectively.

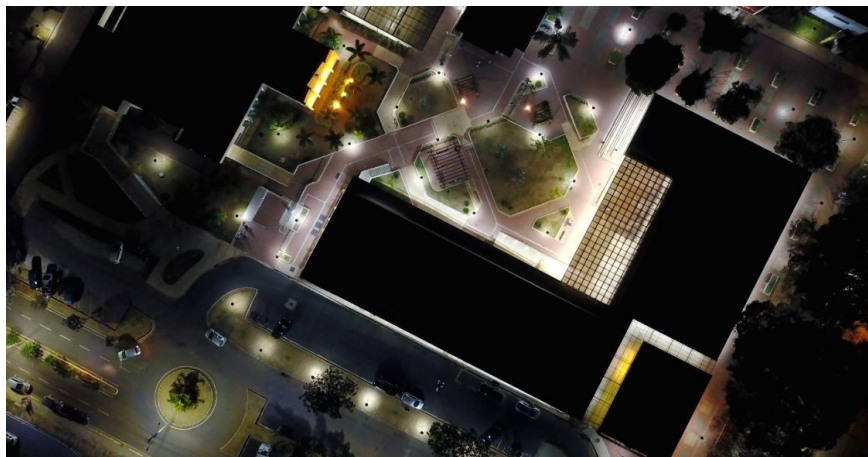


Figure 8. Superior Night View of the Community Center of the Federal University of Lavras
(Source: [UFLA-DMA, 2019](#))

At the end of the execution of three stages of PEE, the institution estimated a decrease in the peak demand of 433.24 kW and a decrease in electricity consumption of 2,264.22MWh/year. Figure 9 presents a night aerial photo of UFLA, where it is already possible to observe that most of the public lighting in the most frequented areas already has lighting with LED technology.



Figure 9. Superior Night View of the Federal University of Lavras at the end of the three stages of the PEE
UFLA-CEMIG

(Source: [UFLA-DMA, 2019](#))

The implementation of these energy efficiency projects resulted in a 30% reduction in installation consumption. This saved electricity serves more than 100 days of UFLA total consumption. It still needs to be considered that the University continues to grow and inaugurate new works. The installed equipment and lamps are more energy efficient and do not contain heavy metals or polluting gases that cause damage to the atmosphere. In addition, a specialized company carried out the replacement of the lamps, minimizing environmental impacts as much as possible. At the end of each stage of the project, training was given at UFLA on the conscious use of electric energy, aiming to reinforce the importance of the participation of academic community for the project success.

3.3. Microgrid pilot and grid-connected photovoltaic system

Currently, UFLA is powered by a voltage of 13.8 kV through an exclusive feeder direct from the substation of local Energy Distribution Company of Minas Gerais State– CEMIG-D, located in the City of Lavras, as previously described. This feeder allows the possibility of being served by two other non-exclusive feeders as a contingency, and the opening and closing electrical networks can be performed remotely by CEMIG-D through 5 microprocessors.

At the connection point between Energy Distribution Company and UFLA, there is a sheltered substation containing indirect measurement, a 15 kV circuit breaker operated via an indirect relay of SEG MRI1 model with timed overcurrent protection and phase and neutral
DOI: <https://doi.org/10.7454/jessd.v4i1.1059>

instantaneous (ANSI 50, 50N, 51, 51N). There is no remote activation of this internal circuit breaker, which is a problem in the case of temporary power outages that require the displacement of a professional to reset the circuit breaker.

The own electricity distribution network at the University basically consists of a compact protected 15 kV network, pole transformers located close to the consumption points and a low voltage underground network. On campus, there are 5 ecobicycles with single-phase inverters of 5 kW each, connected to the electrical network through the low voltage 220V circuits in 4 transformers, with the structure showed in Figure 10.



Figure 10. Ecobicycle – 5kW

(Source: [UFLA, 2016](#))

UFLA currently has 10 grid-connected inverters powered by photovoltaic panels and in full operation. There are 7 three-phase inverters of 36 kW connected to an exclusive 13.8/0.38kV transformer installed on UFLA's solar parking lot, two inverters of 5kW and one inverter of 4kW around the campus. In the implementation phase, twenty-seven more inverters of 36 kW will be installed on the ground next to the solar parking lot, as shown in Figure 11, totaling an installed power of 1.263 kW inverters.



Figure 11. Solar Parking and Solo Plant – 1.263 kW
(Source: UFLA, 2016)

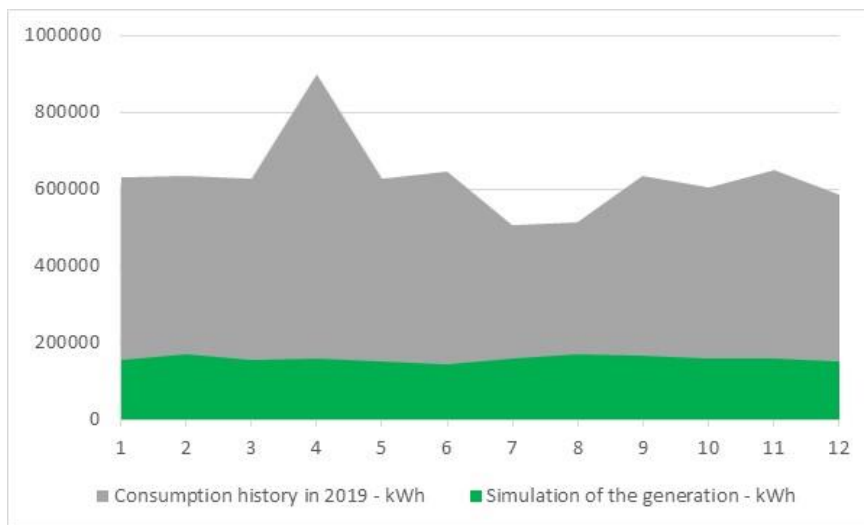


Figure 12. UFLA's consumption history in 2019 x Simulation of the generation of the system being implemented

In accordance with Normative Resolution N° 482/2012 (ANEEL, 2012), the power of the PV on-Grid Systems to be installed can have maximum contracted demand, which in the case of UFLA is 2.600 kW, currently. Within 4 years, the expectation is to have at least 2600 kW of installed inverter power, and therefore exceed 50% of UFLA's total consumption, as shown in Figure 13. This far, there is no power injection into CEMIG-D electrical network, since the installed power in operation is very small in relation to the University's demand, even with the solar parking system coming into operation. The forecast is that there is no power injected into the network.

4. Conclusion

The energy indicators by built area, equivalent user, and finance allow the establishment of priorities in the investment in energy efficiency within the Institutional Development Plan of UFLA. Because of the implementation of energy efficiency projects that has a cost benefit ratio, the return on investment of public money is around 3 to 4 years.

To date, there are no significant generation data at UFLA, with the entry into operation of the Solar Parking and the system on the ground. In the future, it will have an expressive amount of energy generated in the microgrid. This will bring greater complexity in the operation and protection of the University's electrical system. Beside a great impact on the operation of the University, it is may be required to implement the safe work practices and specific training for electricians and workers. The implementation of a microgrid pilot project will allow an assessment of ancillary services in an electrical grid infrastructure planned to serve smart and human cities.

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Author Contribution

Isadora Nascimento Della-Sávia Braga do a conceptualization and validation. 1*, Silvia Costa Ferreira are responsible with the methodology and analysis. Marcelo Arriel Rezende doing a data curation. The whole authors writing original draft preparation and Isadora Nascimento Della-Sávia Braga doing a review before article publishes.

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