revista GEPROS

Editor Responsável: Prof. Dr. Hermes Moretti Ribeiro da Silva

Recebido: 12/11/2022
Aprovado: 30/01/2023

Photovoltaic solar energy and sustainability in higher education institutions: a multiple case study

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RESUMO

Objetivo: identificar quais Instituições de Ensino Superior (IES) na Região Metropolitana do Cariri (RMC) usam energia solar fotovoltaica, analisar as ações de sustentabilidade praticadas pelas IES, correlacionando com os Objetivos de Desenvolvimento Sustentável (ODS).
Desenho/metodologia/abordagem: estudo de caso, sendo a fonte de dados secundários e a técnica de análise dos dados é a bibliográfica e documental.
Resultados: quatro IES fazem uso da energia solar fotovoltaica (22,22%) na RMC de um total de 18 IES, revelando predominância das IES públicas (75%) em relação às privadas (25%). Os sistemas são relativamente novos, tendo sido instalado nos últimos cinco anos. O payback simples médio encontrado de 4,9 anos. Em outras universidades no mundo, o estudo mostrou que esse prazo varia de 3 a 14,29 anos. A geração energética média mensal vai de 18.000 kWh a quase 115.000 kWh. O Objetivo de Desenvolvimento Sustentável 7 é observado em todas as IES do estudo, sendo que 1 das IES apresenta ações em todos os ODS.
Pesquisa, implicações práticas e sociais: Os resultados revelaram que a motivação maior na implantação da energia solar fotovoltaica nestas IES é a questão ambiental e social, e não a econômica, revelando ainda a predominância das IES públicas frente às IES privadas. Por ser uma região com potencial elevado para o uso de energias renováveis, o resultado encontrado se propõe ainda a incentivar o debate entre as demais IES identificas no estudo, para que as mesmas venham a adotar esta solução.
Originalidade / valor: as IES têm uma capacidade enorme para exercer influência positiva na sociedade, sendo um elo entre a pesquisa, a prática e a difusão do conhecimento. A RMC possui uma relevante estrutura educacional, com 18 IES, podendo contribuir significativamente para atender aos ODS. O artigo apresenta a estrutura e os impactos da adoção de ações de sustentabilidade nestas IES.
***Palavras-chave*:** Desenvolvimento Sustentável; Universidades; Energias Renováveis; ODS.

ABSTRACT

Purpose: *to identify which Higher Education Institutions (HEIs) in the Metropolitan Region of Cariri (MRC) use photovoltaic solar energy, then analyze the sustainability measures used by the HEIs, correlating them with the Sustainable Development Goals (SDG).*
Design/methodology/approach: *a case study, where the secondary data source and the data analysis technique is bibliographic and documentary.*
Findings: *four HEIs use photovoltaic solar energy (22.22%) in the MRC from a total of 18 HEIs, revealing a predominance of public HEIs (75%) over private HEIs (25%). The systems are new and have been installed within the last five years. The simple average payback found is 4.9 years. The study showed that in other universities worldwide, this period varies from 3 to 14.29 years. Average monthly energy generation ranges from 18,000 kWh to almost 115,000 kWh. Sustainable Development Goal 7 was observed in all the HEIs in the study, with 1 of the HEIs using measures found in all the SDGs.*
Research, practical and social implications: *Results reveal that the major motivation for implementing photovoltaic solar energy in these HEIs is environmental and social, and not economic, also revealing the predominance of public HEIs over private HEIs. Since it is a region with a high potential to use renewable energy, the results found are also intended to encourage debate among the other HEIs identified in the study and for them to adopt this solution.*
Originality/value: *HEIs has an enormous capacity to have a positive influence on society and is a bridge between research, practice, and knowledge dissemination. The MRC has a large educational structure, with 18 HEIs, and can significantly contribute to meeting the SDG. This article demonstrates the structure and impacts of adopting sustainability measures in these HEIs.*
Keywords: *Sustainable Development; Universities; Renewable Energy; SDG.*

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SOARES, C.A.B.; NADAE, J.; NASCIEMNTO, D.C.; FIRMINO, P.R.A.; MORIOKA, S.N. Photovoltaic solar energy and sustainability in higher education institutions: a multiple case study. **GEPROS. Gestão da Produção, Operações e Sistemas**, v.18, e02939, p. 103 - 135, 2023.
DOI: https://doi.org/10.15675/gepros.v18i00.2939

1. INTRODUCTION

As Sachs (1996) emphasizes, from the 1960s on, the concern with the environment has led to environmental movements, encouraged by American groups who saw the need to keep nature untouched. Therefore, the concept of sustainability has become notorious in the past decades, linked to the concept of sustainable development. Despite being terms with similar meanings, there is no consensus on the exact definition of each, but it is widely accepted to say that sustainability seeks a balance between human needs and the environment (BARBOSA *et al*., 2014). As argued by Faxina, Freitas, and Trevizan, (2021) sustainability has been used widely in different spheres of society and throughout the territory.

The Brundtland Report (WCED, 1987) defined sustainable development as one that meets current needs without compromising the needs of future generations. For Sachs (1993), the promotion of sustainable living is a central part of the development strategy in which local communities play an essential role. For Barter and Russell (2012), sustainable development is not about saving the environment, because this understanding excludes human beings from the environment. For Feil and Schreiber (2017), sustainable development is a strategy to improve life quality for society, considering environmental constraints.

Based on a compilation of actions composed of 17 goals and 169 global indicators, the United Nations (UN) established the Sustainable Development Goals (SDG), which include issues directly related to social and economic development, such as fighting poverty and hunger, health, education, equality, water, energy, sanitation, urbanization, environment, social justice, among others, according to the United Nations Development Program (PNUD) (2020a).

Thus, the Higher Education Institutions (HEIs) importance for sustainable development goes beyond graduating students but qualifies people for the sustainability of future generations (VAZ *et al*., 2010). For Kraemer (2004), the work developed within the HEIs has a multiplying effect in which the student passes on the good ideas of sustainability influencing society in several areas. The HEIs can work on sustainability both internally and externally, but for this study, we chose to analyze how HEIs organizes itself when it comes to a specific area, the energy segment, and one of the reasons for this is because of the high costs and the need to adopt clean and sustainable energies. Worldwide, universities face increasing costs of energy, which has motivated their efforts to develop sustainability programs (MOHAMMADALIZADEHKORDE; WEAVER, 2018).

Photovoltaic energy is being institutionalized in Brazil and worldwide with the goal of making the national energy matrix leaner and mainly sustainable (DA SILVA; COUTINHO, 2019). For sustainability, we can observe the benefits of renewable sources, such as photovoltaic energy, with an increase in the diversity and complementarity of energy supply and a reduction in the emission of pollutant gases (AQUINO *et al.*, 2015). Electricity produced through renewable and infinite sources, such as solar ones, contributes to the energy and economic sustainability of public undertakings (REIS; REIS JUNIOR; PERIN, 2020). Elgamal and Demajorovic's (2020) study indicates the opportunities for electric power generation in Brazil with the use of photovoltaic solar energy.

For Ferreira (2020), photovoltaic plants provide savings in financial resources and allow professors and students to use these plants as true laboratories to deepen their knowledge about renewable sources. Universities have a great responsibility to contribute to a sustainable world; actions towards sustainability and integrity are models for all sectors of society and solar photovoltaics contributes to this (HERNANDEZ-ESCOBEDO *et al.*, 2020). One of the disadvantages of using large solar photovoltaic systems is the loss of the use of space, which could be used for another purpose (PHILIPPI; REIS, 2016). Another disadvantage is that the system does not generate energy during the night, and loses efficiency on cloudy or rainy days (MACHADO; MIRANDA, 2015). According to Sandanayake *et al.* (2022), the residuals generated by solar systems used panels will be a worldwide problem, due to the need to dispose of these panels at the end of their lifetime.

Therefore, the objective of this article is to identify which HEIs in the Metropolitan Region of Cariri - Ceará (MRC) use solar photovoltaic energy, besides analyzing the sustainability actions practiced by the HEIs, considering the environmental, economic, and social dimensions, and correlating them with the UN's SDG.

The MRC has been selected, because according to Zucatelli *et al.* (2017), universities located in the Northeast region of Brazil are the best options for implementing solar energy projects, among other factors, for geographical reasons.

The Northeast region presents the greatest potential for photovoltaic solar energy generation, justified by the high rates of solar radiation and its extensive area, in which the state of Ceará is the leader in installed power, accounting for 13.68% of the national quantitative (OLIVEIRA; GUERRA, 2021). Ceará state has three metropolitan regions, of which the Metropolitan Region of Fortaleza (MRF) was the first to be instituted, in 1973. The Metropolitan Region of Cariri (MRC) was instituted in 2009 and, lastly, the Metropolitan Region of Sobral (MRS) was instituted in 2016.

The MRC is composed of nine municipalities, which are: Juazeiro do Norte, Crato, Barbalha, Caririaçu, Santana do Cariri, Farias Brito, Nova Olinda, MissãoVelha, and Jardim (CEARÁ, 2009, art. 1) Its population is more than 600,000 people, with a high population in its three main municipalities, which are Juazeiro do Norte, Crato, and Barbalha, according to the Brazilian Institute of Geography and Statistics (IBGE, 2020).

Besides being gifted with a natural wealth that is well known, the MRC is also constituted by expressive cultural wealth and, when it comes to higher education, the region has more than 70 different courses, offered in many different areas of knowledge. Thus, the HEIs emerge as a source of science, besides being a true granary of actions and good practices, contributing to measures to be taken to provide sustainability to the environment.

This study is guided by the research question: Which HEIs in the MRC makes use of photovoltaic solar energy? And what are the sustainability actions practiced by them, considering the UN's SDG?

This work will be conducted through a multiple case study, with secondary data being used as a source of data and the data analysis technique made through bibliographic and documental analysis. To this end, the research has a descriptive character, since it will describe the benefits to the environment as a consequence of the use of photovoltaic solar energy, and will also describe the sustainability actions that the HEIs have adopted, thus sustainably impacting the environment and the society in which they are inserted. The study was carried out in four HEIs located in the MRC, three public and one private.

2. THEORETICAL FOUNDATION

In this section characterizations of existing energy sources are introduced, classifying them between renewable and non-renewable. Then it was discussed about photovoltaic solar energy and Sustainability within HEIs and the SDG.

2.1 Energy sources

The economic development of countries is directly related to energy use, and this imposes positive pressure seeking to decrease fossil fuel consumption and environmental pollution (BAKEER; SALAMA; VOKONY, 2021). Solar energy is a reliable energy source for self-consumption (AMO-AIDOO *et al.*, 2021) and is one of the fastest-growing energy sources among renewables due to lower costs (MAKA; ALABID, 2022).

Energy can be classified according to whether it is renewable or non-renewable. Renewable energies are those that come from resources that are naturally replenished on a human scale (TWIDELL; WEIR, 2015). Furthermore, the use of renewable energy sources contributes to the development of sustainable energy systems (KOTOWICZ; UCHMAN, 2021).

Renewable energy sources play an important role in the progress of energy system goals to reduce greenhouse gas emissions (ZARE OSKOUEI *et al.*, 2021). According to the National Energy Balance - BEN (2020), Brazil is a mostly renewable country concerning the production of electricity, in which 83% of the domestic supply of electricity comes from renewable sources, represented by: hydraulic sources (64.9%), biomass (8.4%), wind (8.6%) and solar (1.0%). Although the percentage of solar energy as a renewable energy source in Brazil is only 1.0%, it must be considered the exponential increase that the sector has shown of 212% in 2019, according to the Brazilian Photovoltaic Solar Energy Association (ABSOLAR, 2020). Regarding non-renewable energy, the highlight goes to natural gas (9.3%), coal and derivatives (3.3%), nuclear energy (2.5%), and petroleum derivatives (2.0%).

Table 1 shows that in Brazil, according to the Energy Research Company (EPE, 2020), the electric energy installed capacity is 170,118 MW (megawatt), of which 1,990 MW comes from solar energy. In the Northeast (NE), the installed capacity is 36,311 MW, of which 1,532 MW comes from solar energy. Among the NE states, Ceará presents an installed energy capacity of 4,445 MW, of which 218 MW comes from solar energy. Therefore, it is clear that 4.90% of the installed electric energy capacity in Ceará comes from solar energy, which demonstrates how much this type of energy should be encouraged to provide sustainable regional development.

Table 1 - Installed Capacity of Electric Generation

TERRITORY	SOLAR (MW)			TOTAL (MW)		
	SP	APE	TOTAL	SP	APE	TOTAL
BRAZIL	2.464	10	2.473	145.067	25.051	170.118
NORTHEAST	1.529	3	1.532	33.503	2.808	36.311
CEARÁ	218		218	4.189	256	4.445

Source: Adapted from EPE (2020, p.158)
SP - Public Service (includes Independent Producers).
APE - Auto producer (includes hydroelectric plants in consortium with Public Service concessionaires, such as Igarapava, Canoas I, and II, Funil, Porto Estrela, Machadinho, and others).
Equitable distribution for frontier plants.
Does not include Micro and Mini Distributed Generation.

2.2 Photovoltaic solar energy and sustainability

Renewable energies are those that are naturally replenished, such as energy from the sun. Solar irradiation is considered infinite and free and has gigantic potential for growth (DE CASTRO *et al.*, 2020).

High rates of direct surface solar irradiation happen in much of Northeast Brazil and are the main requirement for the viability of this generation technology (PEREIRA *et al.*, 2017). Lima *et al*. (2020) emphasize that Brazil has a huge potential to take advantage of this natural wealth.

One of the points related to the generation of energy using photovoltaic systems is the level of solar irradiation, which is related to the efficiency of the system and is variable according to the geographical location. Using the SunData program, it is possible to obtain the calculation of the monthly daily solar irradiation at any point in the national territory (CRESESB, 2021).

Another relevant point when choosing to use photovoltaic solar energy is the space to be used by the modules (solar panels). The modules are installed in a horizontal position, having their capture area exposed to the sun, in general, the inclination angle of the panels should be equal to the latitude of the installation site and should be positioned with the surfaces directed to the equator (MASTERS, 2004). Since the municipalities located in the MRC are geographically located below the equator, the inclination of solar panels installed in the region is determined by the latitude and the orientation of the panels is towards the North.

Therefore, solar energy is considered an original and unlimited energy source and contributes to improving energy security and sustainability, leading to reduced pollution (ABDALLAH *et al*, 2020).

In the study conducted on 50 HEIs located in the United States, Brazil, Italy, Portugal, Malta, United Kingdom, Finland, Poland, Slovakia, Denmark, Sweden, Germany, Ukraine, Ethiopia, Kenya, Ghana, Egypt, India, Malaysia, Saudi Arabia, Iran, Philippines, Liberia, Indonesia, Hong Kong, and Australia, Leal Filho *et al.* (2019) it has been observed that 72% of the HEIs answered that they use some type of renewable energy, and among them, the most mentioned is photovoltaic solar energy (70%).

Studies on the implementation of photovoltaic solar energy in HEIs have already been carried out by some authors, such as Vaziri and Kellier (2021) who presented a research project by two undergraduate students from the School of Urban and Regional Planning at Florida Atlantic University (FAU) they developed a detailed proposal for installing photovoltaic solar energy at the university in an attempt to reduce the carbon of the campus.

Hernandez-Escobedo *et al.* (2020) present their contributions to sustainability policies at the National Autonomous University of Mexico. The authors propose the implementation of a photovoltaic solar system to provide electricity to the network and reduce the electrical load in the Laboratory of Orthotics and Prosthetics and propose new guidelines for research to subsidize sustainability policies in universities and propose a financial analysis.

Bayomi (2020) presents strategies to increase energy efficiency at the main campus of King Abdulaziz University in Saudi Arabia by investigating the potential uses of solar energy for thermal cooling and electricity generation, providing a set of actions that can be gradually implemented to achieve campus energy savings.

Narváez *et al.* (2020) present the analysis of electricity consumption at the University of Unicomfacauca in Popayán-Colombia, which leads to the generation of proposals for savings, energy efficiency, and photovoltaic energy generation for self-consumption; the first stage of the study consists of performing the energy inventory of equipment and facilities; the second stage consists of diagnosis, load inventory, macro consumption analysis and definition of economy and energy efficiency measures; the third stage involves the implementation of the proposed measures taking into account the cost-benefit; in the fourth stage, the monitoring and evaluation of the implemented measures are executed.

Leal Filho *et al.* (2019) investigate the level of engagement in energy efficiency measures of a sample of 50 higher education institutions worldwide and identify which types of renewable energy are being used so far. The results show that in more than half of the universities, only a small part of energy consumption comes from renewable sources (1% and 20%), and solar/photovoltaic is the most used source (70%).

Teah *et al.* (2019) investigated a green campus initiative at the University of Tokyo that featured a megawatt-scale solar photovoltaic system on campus. The main goal was to demonstrate a project sustainability assessment structure that evaluates not only the carbon footprint and lifecycle cost of the project but also the external effect on the local community from a disaster resilience perspective.

Park *et al.* (2019) show possible optimized renewable energy generation system solutions for a public university in Thailand, Chiang Mai University. It is proposed, based on the simulation results of HOMER software, the potential configuration organized by photovoltaic panels, batteries, and converters.

Fonseca *et al*. (2018) developed a rehabilitation plan for a department at the University of Coimbra (Portugal) to analyze the improvements considered to achieve a near-zero energy building, namely lighting retrofit, photovoltaic generation integration, and energy storage capacity. Jo *et al.* (2016) have shown that a photovoltaic solar system on the Illinois State University (ISU) campus is technically and financially viable, presenting implementation designs for these systems which could be replicated for other universities.

Despite studies on the subject, research is still needed to evaluate energy sustainability in HEIs more broadly (LEAL FILHO *et al.*, 2019).

2.3 The sustainable development goals (SDG)

The SDG idea started at the Rio+20 Conference in 2012, based on a proposal by Colombia and Guatemala. In September 2014, at the United Nations General Assembly meeting, a report was submitted with a proposal of 17 goals and 169 targets, which would be the main basis for a new post-2015 development agenda, which became known as the 2030 agenda (GIGLIOTTI *et al.*, 2018). The 17 SDG are presented in Figure 1 and they are an evolution of the Millennium Development Goals (MDG), which emerged from a series of multilateral summits held during the 1990s on human development (PNUD, 2020a) and they were adopted by member states in 2000. The process of constructing the MDG included renowned experts and focused primarily on the reduction of extreme poverty.

Figure 1 - The 17 Sustainable Development Goals

Source: PNUD, 2020b.

For the achievement of the SDG, it is necessary the articulation between different areas of society and governmental entities. In the private segment, for-profit and not-for-profit institutions demonstrate attention to sustainable development by explicitly mentioning the 2030 Agenda, promoting governance changes, awards, among other initiatives (DE CASTRO *et al.*, 2019). To this end, Higher Education Institutions (HEIs) are included, in which a sustainable university can represent a model to be followed by other Brazilian universities that are seeking sustainability on their campuses (DOS SANTOS DALBELO; ROMERO, 2020).

Brazil has an important contribution to these discussions, first because it hosted Rio+20 in 2012, exactly twenty years after Eco 92, which was also held in Rio de Janeiro and hosted the United Nations Conference on Environment and Development (CNUMAD). And second, because Brazil was an example of success during the life of the MDG, achieving and exceeding most of MDG goals before 2015, according to the Government Secretariat of Brazil (SEGOV) (2017).

Thus, chronologically, the MDG was adopted by UN member countries for the period 2000 to 2015, and the SDG was adopted for the subsequent fifteen years, in the period 2016 to 2030, thus being declared in the 2030 Agenda, representing a major event in international sustainability policy (BORNEMANN and WEILAND, 2021). In its preamble, the 2030

Agenda is defined as a plan of action for people, planet, and prosperity, which seeks to strengthen universal peace and the eradication of poverty in all its forms and dimensions (PNUD, 2020b).

Furthermore, it is worth mentioning that the SDG has been implemented in commitment to five areas that are crucial for both humanity and the planet, also known as the 5Ps of sustainable development, namely: people, planet, prosperity, peace, and partnerships.

It is evident the SDG relevance for the planet, concerning sustainable development. All goals have their targets centered on people, with the eradication of extreme poverty being the biggest global challenge and an indispensable requirement for sustainable development (PNUD, 2020b). However, when it comes to sustainable energy, it is essential the targets contained in Goal 7, which is illustrated in Figure 2.

Figure 2 - Sustainable Development Goal 7

Source: PNUD, 2020b.

The lack of energy is a problem that affects 860 million people worldwide and achieving SDG 7 is a major challenge for society (GROENEWOUDT; ROMIJN; ALKEMADE, 2020). According to Bisaga *et al.* (2021), there is a bidirectional relationship between SDG 7 and the others, in which both sustain and benefit each other. In this way, renewable energy offers solutions to the global energy crisis, especially in relation to access, as stated in SDG 7 (BARAU; ABUBAKAR; IBRAHIM KIYAWA, 2020).

3. METHODOLOGICAL PROCEDURES

This study has a qualitative and descriptive nature and can be categorized as bibliographic research that uses multiple cases as an approach (VERGARA, 2013). According to Bauer and Gaskell (2015), qualitative research uses texts as a source of data and interpretation as analysis. And, complementarily, Yin (2005) explains that multiple or collective case studies are considered those in which the researcher jointly studies more than one case to investigate a given phenomenon, and the evidence resulting from this type of study is considered more convincing.

Concerning the technical procedure of data collection, the research is a bibliographical and documental type. Bibliographical research is developed based on already prepared material, consisting mainly of books and scientific articles, while documentary research is based on materials without analytical treatment (GIL, 2008). Through the documentary analysis provided, it will be verified which SDG are attended by each HEIs.

In Brazil, HEIs are classified according to their administrative category into private and public, and these are maintained by the Public Power, at Federal, State or Municipal level. Private HEIs are those managed by individuals or private legal entities, either for-profit or not-for-profit. Thus, among the private HEIs, those without profit purpose are further classified into a community, having in its keeper entity representatives of the community; confessional, attending to certain confessional and ideological orientation; and philanthropic, providing services to the population, in a complementary character to the State's activities (art. 19 of LDB) (BRAZIL, 1996). As for the academic organization, they are classified as University, University Center, College, or Federal Institute of Education, Science, and Technology of Ceará (IFCE).

Considering the State data, Ceará holds a prominent position in the Northeast region, being the third state with the largest number of HEIs. According to INEP (BRAZIL, 2019), Ceará has 93 HEIs. When the numbers are analyzed in relation to the administrative category, they reveal that there is a huge disparity between public HEIs and private HEIs, with a high concentration by the private HEIs, divided into 86 private HEIs (92.5%) and only 7 public HEIs (7.5%), according to Table 2. Concerning the number of public HEIs, they are divided into 4 federal (57.1%) and 3 states (42.9%). When analyzing the academic organization of private HEIs, there is also a similarity with the Brazilian scenario, in which there is a high concentration of College (83.7%), followed by University Centers (15.1%), and lastly, University (1.2%). Comparing the organization types in the Universities there is a predominance of public universities (85.7%) compared to private universities (14.3%). For the College type of organization, the numbers reveal the opposite extreme, with the totality concentrated in private Colleges (100%). This scenario repeats itself for the University Centers, with a total concentration of private ones (100%). In the case of IF/CEFET, again, there are no private administrative categories.

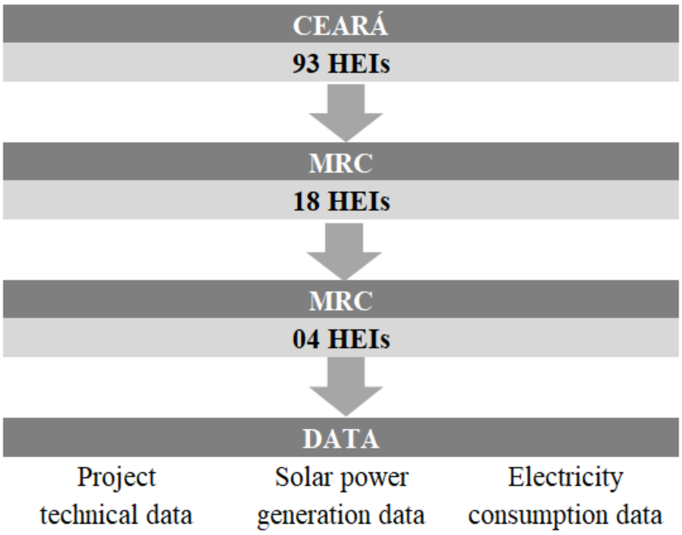
Table 2 - HEIs by Academic Organization and Administrative Category - Ceará, 2019.

Administrative Category	Institutions				
	Total General	Universities	University Centers	Colleges	IF and CEFET
Ceará	93	7	13	72	1
Public	7	6	-	-	1
Federal	4	3	-	-	1
State	3	3	-	-	-
Municipality	-	-	-	-	-
Private	86	1	13	72	-

Source: MEC/INEP Higher Education Census (BRAZIL, 2019)

The methodological flow of the research follows the steps presented in Figure 3. Thus, initially, it was identified the quantity of HEIs located in the MRC. From then on, it was verified which ones have photovoltaic solar energy generation systems; for this, the authors contacted the 18 HEIs, through e-mails and calls. Then they collected information from each HEI: technical data of the project; solar energy generation data; and monthly electricity consumption data, covering the period of one year. All the data was requested from the HEIs, which sent the reports, project documentation, energy consumption records, websites, and other selected documents for analysis.

Figure 3 - Methodology flow



Source: Made by the author (2021)

It is important to emphasize that the electric energy consumption data analyzed refer to the period from April 2019 to March 2020, therefore, prior to the social isolation implied by the COVID-19 pandemic in Brazil, which brought the interruption of HEIs classes. This period has been defined this way to avoid distortions in electric energy consumption, since as of April 2020 the HEIs was not fully operating in relation to the face-to-face functioning of students, professors, and technical-administrative staff, therefore having their energy consumption drastically reduced for this reason.

4. RESULTS

In this part, it will be shown the results found in the research conducted, making a characterization of each of the HEIs, and also the solar energy generation system of each one of them. Finally, a comparison was made in relation to the consumption data of the four HEIs, and also the technical data of the systems of each one of them.

4.1 HEIs in the metropolitan region of Cariri

Before analyzing the scenario of this study, in this case, MRC, it is necessary to observe that the organization of the data provided by INEP refers to the HEIs in its corporate name but makes no mention of the number of campuses it has. As an example, we will mention the case of the Regional University of Cariri (URCA), where in the INEP's relation it will appear registered only as one unit, located in the city of Crato. However, if the campuses were considered, the number counted would be four: Pimenta campus, São Miguel campus, Crajubar campus, and Pirajá campus. Therefore, for the HEIs analysis in the MRC, the quantitative per campus was considered, because it is reasonable to consider that an HEI can install the photovoltaic solar energy generating system on each campus, individually.

According to IBGE (2020), the MRC holds a total population of 612,956 people. Juazeiro do Norte is the main city, which represents 45% of the MRC population, followed by the municipalities of Crato (21.70%) and Barbalha (9.99%), forming the CRAJUBAR triangle, which represents a high population density (76.76% of the MRC population). Juazeiro do Norte also presents the highest GDP per capita of the MRC (R$ 17,725.52), followed by Barbalha (R$ 14,320.84) and Crato (R$ 10,262.41). In relation to the municipal HDI, in the first place is the municipality of Crato (0.713), followed by Juazeiro do Norte (0.697) and Barbalha (0.683). The data are presented in Table 3.

Table 3 - MRC - Demographic Indicators, GDP and HDI

MUNICIPALITY	Population Estimated	%	Area (km²)	%	Density Demogr.	GDP per capta	HDI
Barbalha	61,228	9.99	479.18	9.54	128	14,320.84	0.683
Caririaçu	26,987	4.40	623.82	12.41	43	7,476.01	0.591
Crato	133,031	21.70	1,009.20	20.08	132	10,262.41	0.713
Farias Brito	19,389	3.16	503.57	10.02	39	8,195.13	0.609
Jardim	27,181	4.43	457.03	9.10	59	7,529.39	0.642
Juazeiro do Norte	276,264	45.07	248.00	4.94	1,114	17,725.62	0.697
Missão Velha	35,480	5.79	651.10	12.96	54	13,585.53	0.631
Nova Olinda	15,684	2.56	284.40	5.66	55	8,311.80	0.625
Santana do Cariri	17,712	2.89	768.76	15.30	23	6,921.76	0.609
MRC	**612,956**	**100.00**	**5,025.09**	**100.00**	**122**		

Source: IBGE (2020)

When analyzing the HEIs reality in the MRC, it is possible to observe a number of 18 HEIs, 9 public and 9 private, that have more than 70 different courses being offered in the most different areas, including exact, human, and biological sciences, such as administration, odontology, medicine, production engineering, civil engineering, materials engineering, theology, industrial automation, mathematics, theater, design, psychology, law, geography, and many others. This quantity is huge even when only campus courses are considered, in other words, when online courses and semi-online modalities are not considered. The list can be seen in Table 4:

Table 4 - List of Higher Education Institutions in the MRC and campus undergraduate courses offered.

City	HEI	Category	Quantity of courses
Barbalha	UFCA	Public	1
Crato	FACULDADE BATISTA DO CARIRI	Private	1
	IFCE	Public	2
	URCA - Pimenta	Public	10
	URCA - São Miguel	Public	1
	UFCA	Public	2
Juazeiro do Norte	URCA - Crajubar	Public	5
	URCA - Pirajá	Public	2
	UFCA	Public	13
	IFCE	Public	5
	FATEC - CENTEC	Private	5
	UNILEÃO - Lagoa Seca	Private	10
	UNILEÃO - Saúde	Private	5
	ESTÁCIO	Private	6
	CENTRO UNIVERSITÁRIO PARAÍSO	Private	13
	FACULDADE PADRE CÍCERO	Private	6
	FJN (UNIJUAZEIRO)	Private	29
	FACULDADE UNINASSAU	Private	2

Source: Made by the author (2021)

Through the research conducted, it was concluded that among the 18 HEIs analyzed, four HEIs have a photovoltaic solar energy generator system (22.22%), three public HEIs, and one private HEI. The numbers reveal an opportunity, considering the fact that this potential is available to all HEIs, due to the benefits of geographical location.

4.2 HEIs characterization with photovoltaic solar energy generating system and its sustainability actions

Among the four HEIs identified as users of the photovoltaic solar energy generation system, three are public and one private. The public HEIs identified were the Federal University of Cariri (UFCA), Juazeiro do Norte campus; the Federal Institute of Education, Science and Technology of Ceará (IFCE), Juazeiro do Norte campus, and Crato campus. The private HEI identified was the University Center Doutor Leão Sampaio (Unileão), Lagoa Seca campus. Next, the data from the systems of each HEIs will be introduced. All information provided by the HEIs was verified by the authors.

4.3 Federal University of Cariri (UFCA) Juazeiro do Norte campus

UFCA is located in the macro-region of Cariri/South Central Ceará and includes 42 municipalities. The UFCA campuses are located in Juazeiro do Norte, which is the headquarters, Crato, Barbalha, Brejo Santo, and Icó, where the Institute for Semi-Arid Studies - Iesa/UFCA also operates (UFCA, 2021a). UFCA has a portfolio of 21 undergraduate courses and 15 graduate courses, four master's degrees, and one doctorate. The campus identified in the research is located in Juazeiro do Norte-CE, inaugurated in 2008, and has 13 undergraduate courses and 6 graduate courses.

On the HEI institutional website, there is a list of sustainability actions (UFCA, 2021b), contributing directly and indirectly to the implementation of an institutional sustainable culture and achieving the goals related to sustainability present in the UFCA strategic reference. In the portal, it is possible to identify the sustainability activities in all its campuses and sectors (UFCA, 2021c), having Sustainable Management Policy (PGS) and Sustainable Logistics Plan (PLS) as its main guiding instruments.

The UFCA portal (2021b) has documents and information regarding the Good Practices Manual, Sustainability Catalog, Solid Waste Management Plan, and Controlled Chemicals. Thus, we can see that the HEI has a wide range of sustainability actions, among which is included the solar energy generating system.

According to the institutional website, in the Sustainability Catalogue (UFCA, 2021d), 45 sustainability actions were identified, in education, research, extension, culture, and management areas, executed in 2020 and based on sustainability dimensions and the relationship of these actions with the SDG.

According to data from UFCA (2021d), investment in a sustainable energy source is in line with government policies and the guidelines of the Federal University of Cariri, in its Sustainable Logistics Plan. The action is also planned in the Institutional Strategic Planning of the Federal University of Cariri - PEI UFCA 2025, aligned with the Strategic Goal OE-15 Resize and expand the physical and technological infrastructure, focusing on sustainability.

4.4 University Center Doutor Leão Sampaio (UNILEÃO) Lagoa Seca campus

The University Center Doutor Leão Sampaio (UNILEÃO), a private institution, is located in the municipality of Juazeiro do Norte. Founded more than twenty years ago, it has 15 undergraduate courses, more than 30 postgraduate courses, and 03 master’s degrees. In its portal (UNILEÃO, 2021a) is already an institutional mission, UNILEÃO makes explicit its commitment to development, and among its values, two of them mention the care for the environment: Social Responsibility and Sustainability.

On the HEI institutional website, there is a list of sustainability actions (UNILEÃO, 2021b), in which the sustainability policy is the premise for the development of its mission, vision, and values. According to data from the HEI itself, contained in the 2021 Sustainability Report, the sustainable management of UNILEÃO acts in the construction of an environmental policy that consists of spreading, in all campuses, sustainable practices introduced in the daily life of the Institution (UNILEÃO, 2021c).

Among the HEI sustainable initiatives, ecoefficiency and solar energy stand out; paper recycling; water reuse; internal and external green areas; management of Geopark Araripe; Environmental and Social Education Program; and also, the virtual actions, such as promoting debates with nationally renowned speakers.

At HEI there is a policy of separating paper residual from ordinary waste, through the availability of appropriate containers in all areas of the institution. This action allows the residual to be properly destined for recycling, which happens through a partnership between HEI and the Engenho do Lixo Association, an NGO from Juazeiro do Norte. In 2019, more than 2.3 tons of paper were recycled, representing more than 120 trees that were no longer cut. Atypically, in 2020, instead of recycling, the HEI stopped using about 2 tons of paper, implementing evaluation processes and activities in technological methods; also a digital signature was implemented in the financial area contributing to a significant reduction in the use of paper.

UNILEÃO has a Water Treatment Plant (WTP), which can reuse up to 12,000 liters of water daily. In 2020, 4.38 million liters of water were treated and reused in garden irrigation, campus cleaning, and civil construction.

Unlike the other HEIs analyzed, UNILEÃO has in its Park, additionally, a heliotropic solar energy generator system (a word derived from heliotrope, movement of flowers, leaves, and stems that follow the apparent movements of the sun), equipment with the capacity to carry out solar tracking (SILVA, 2019).

4.5 IFCE - Juazeiro do Norte campus

The IFCE has its rectory based in Fortaleza. According to data extracted from the HEI website, the institution was created in 2008, with the integration of the Federal Center for Technological Education of Ceará (CEFET) with the Federal Agrotechnical Schools of Crato and Iguatu (IFCE, 2021), associated with the Ministry of Education. It is an autarchy of a legal nature, with administrative, patrimonial, financial, didactic-pedagogical, and disciplinary autonomy. For the purpose of applying the provisions governing the regulation, evaluation, and supervision of the institution and higher education courses, the IFCE is equivalent to federal universities.

The IFCE has 109 years of existence, consolidating itself as an inclusive HEI, always seeking to provide humanistic, technical, and professional training, thus providing social, political, cultural, and ethical inclusion. It is possible to identify the concern and engagement with regional development already in its institutional vision: to be a reference in learning, research, extension, and innovation, looking for a social transformation and regional development; and also its commitment to sustainability, recorded in its values: ethical commitment to social responsibility, respect, transparency, excellence and determination in its actions, in line with the basic precepts of citizenship and humanism, with freedom of expression, with feelings of solidarity, with a culture of innovation and with fixed ideas on environmental sustainability.

The sustainability actions adopted by IFCE can be consulted by the community through the document Guidelines for saving water and electricity (IFCE, 2019). Through a series of actions and measures developed by the Rectory of IFCE, aiming to reduce the wasteful consumption of natural and financial resources for the sake of sustainability, the booklet with guidelines for servers was prepared by the Pro-Rectory of Administration (Proap). The initiative is part of the institution's strategic planning for the next five years, including a 15% reduction in the cost, and 20% reduction in the consumption of electricity, and a 25% decrease in water consumption.

4.6 IFCE - Crato campus

As the actions taken at the IFCE institution were already covered in the previous sub-item, in this part of the text only the data from the Crato campus regarding the solar energy generating system will be presented, since the sustainability actions are institutional initiatives and therefore, applicable to all IFCE campuses.

5. DISCUSSION

The Figure 4 briefly presents the technical data of the four systems analyzed, which allows for comparative visualization of each of them. UNILEÃO has 2,454 modules (solar panels), that is, almost 1,000 more than the sum of the other three HEIs. For this same reason, UNILEÃO's system is capable of generating an estimated 56% more energy than the other three HEIs combined. Regarding average monthly consumption, UFCA is ahead of the others, with a consumption 28.51% higher than the second-placed UNILEÃO. In relation to the amount paid in the energy bill, in the period of one year analyzed, UNILEÃO spent close to R$ 1 million, followed by UFCA with expenses close to R$ 900,000. The average simple payback was 4.9 years. In other universities, it was found simple Payback of 3.75 years in the United States (AL-ABOOSI; AL-ABOOSI, 2021); of 4.3 years in Peru (CAMARENA-GAMARRA; CALLE-MARAVI; NAHUI-ORTIZ, 2020); of 4.32 years in Jordan (ALSHARE *et al.*, 2020); 6 to 8 years in Brazil (BRANCO and AFFONSO, 2020); 10.3 years in Algeria (BOURAHLA *et al.*, 2019); and 12.9 years in Japan (TEAH *et al.*, 2019).

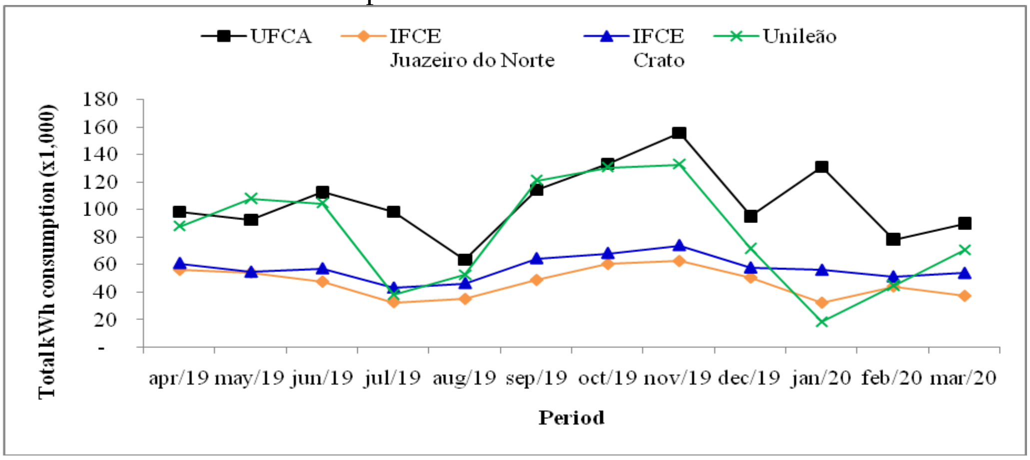
Figure 4 - Technical data of each HEI solar energy generating system and consumption for the period April 2019 to March 2020.

DESCRIPTION	UFCA	IFCE (JN)	IFCE (CRATO)	UNILEÃO *1	UNILEÃO **2
Quantity of modules	636	474	380	816	1,638
Module power (W)	350	390	390	255	308
Total module power (kW)	222.6	184.9	148.2	208.1	504.5
Estimated monthly generation (kWh)	30,051	24,956	18.480	25,200	89,500
Quantity of inverters	12	3	2	10	9
Inverter power (kW)	15	50	60	20	60
Total power of the inverters (kW)	180	150	120	200	540
Average monthly consumption (kWh)	105,465	47,231	57,607	82,062	
Consumption in the period (kWh)	1,265,575	566,772	691,278	984,747	
Invoice: average monthly value (R$)	74,644	34,163	35,748	82,426	
Invoice: amount paid in the period (R$)	895,735	409,965	428,987	989,111	
Simple payback (years)	5	3	5	6.5	5
Start of operation	11/2020	01/2019	***06/2021	02/2016	09/2018

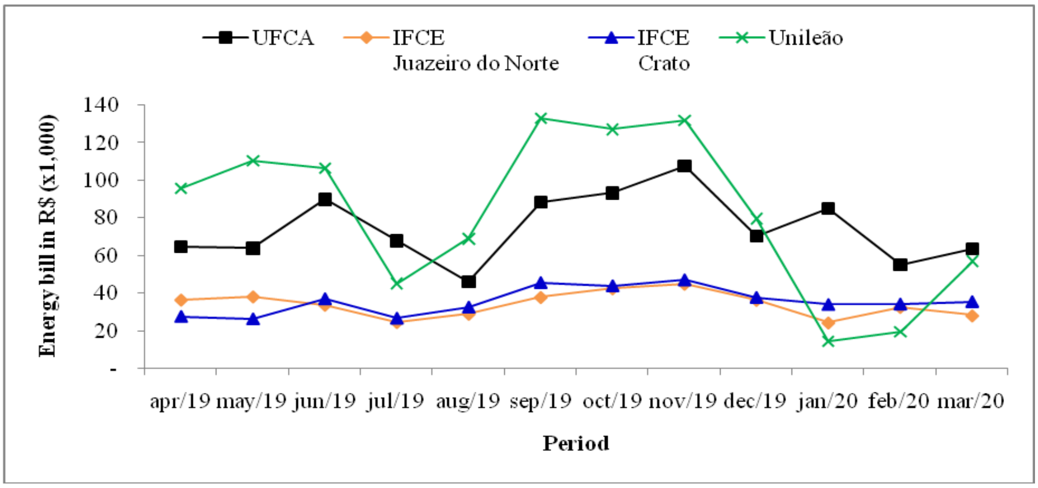
** Conventional system, similar to the other HEIs.*
*** Heliotropic system*
**** Scheduled start due to supplier delay. The system was installed on 12/2020.*
Source: Made by the author (2021).

Figure 5 shows the monthly consumption in kWh and the monthly invoice in R$ of the four HEIs under study during the analyzed period.

Figure 5 - Monthly consumption in kWh (a) and monthly bill in R$ (b). The period from April 2019 to March 2020.



(a) Monthly consumption



(b) Monthly invoice

Source: Made by the author (2021)

The results found revealed that the universities in the MRC that make use of solar energy (22.22%) are at a lower level than universities around the world when compared to the study by Leal Filho *et al.* (2019). The sustainability actions adopted by HEIs are wide-ranging, covering from active participation in project design to monitoring the installation of the panels, as happened with the students of the technical course in Renewable Energy Systems at the IFCE in Juazeiro do Norte. This reveals that the motivations go far beyond economic factors. This fact demonstrates the importance that HEIs gives to sustainable development.

The research highlights that the HEIs solar systems are relatively new, although the oldest system has been in operation for 5 years and the most recent one has already been installed and is only not in operation due to a delay by the supplier.

The four identified HEIs offer 30 undergraduate courses, which represents the capacity for a multiplying effect in several areas of society. The electrical energy produced by the HEIs solar energy generating systems contributes to the energy and economic sustainability of the enterprises and has even provided energy self-sufficiency in one of the HEIs, due to the reduction in consumption imposed by the isolation caused by the COVID-19 pandemic since March 2020.

It was evidenced that photovoltaic plants provide savings in financial resources. UNILEÃO was the pioneering HEI in the MRC to adopt the solar energy solution, an action that should be adopted by the other HEIs in the region. Currently, the HEIs has at its disposal a balance of approximately 600,000 kWh, enough to reduce the consumption of future bills for at least 7 months. However, none of the HEIs examined used laboratories by professors and students to improve their understanding of renewable energy sources, research, and advances in this sphere, as presented by Ferreira (2020), which shows a rich opportunity to expand knowledge on the subject.

As emphasized by Hernandez-Escobedo *et al.* (2020), actions toward sustainability and integrity are models for all areas of society, and this can be seen in the actions adopted which mention the SDG. As expected, the sustainability actions referring to SDG 7, efficient energy use, are observed in all HEIs analyzed. Besides this, the adoption of other actions correlated to the other SDG was also verified, as shown in Figure 6. It is noteworthy that these actions are explicit in the available documents on the website’s institutions, with the possibility that more goals are being accomplished, but have not been reported by the HEIs.

Figure 6 - Sustainability actions of Higher Education Institutions that make mention of the Sustainable Development Goals.

SDG	UFCA
1 NO POVERTY	UFCA Solidária / Obtaining organic products from family agriculture
2 ZERO HUNGER	UFCA Solidária / Collection of water and bananas at banana farms
3 GOOD HEALTH AND WELL-BEING	Community garden NGO Nosso Lar / Health in the diet of young students / League of Mental Health (LISAM) / Teaching practice and continuing education / Healthy life at school project
4 QUALITY EDUCATION	Purification and characterization of bioactive proteins from plants found in the Chapada do Araripe region / Community library as a public information space / Development of historical series prediction models / Numerical study of the interaction between coupled chaotic oscillators / Impact evaluation: PACCE in the academic community-UFCA / GuiaMe PET: to provide high school students with knowledge about career, job market, and selection processes / Solidary consulting project (CONSOL) / Financial education in schools project / Andanças cultural project
5 GENDER EQUALITY	Women and philosophies
6 CLEAN WATER AND SANITATION	Constructed wetlands applied to the treatment of effluents from rural biodigesters / Implementation of an irrigation management system / Monitoring of UFCA's effluent treatment plants
7 AFFORDABLE AND CLEAN ENERGY	Use of photovoltaic solar energy
8 DECENT WORK AND ECONOMIC GROWTH	Use of regional plants and/or their products in the feed of slow-growing broilers / Research project on worker health: promotion of occupational health and overall quality of life improvement
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Study of solutions for functions supported on collapsible soils / Industry 4.0 research project: economic and social consequences
10 REDUCED INEQUALITIES	Laboratory of Urban Studies, Sustainability and Public Policies (LAURBS) / The collection, audiovisual recording, transcription, and critical study of the manifestations musicals of the caririense culture
11 SUSTAINABLE CITIES AND COMMUNITIES	Study of areas degraded by erosion/slides in the metropolitan region of Cariri cearense / Application of tilapia fish scales for the adsorption of industrial pollutants / Reuse of disposable material through the production of musical instruments
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Elaboration of videos for teaching sustainable production
13 CLIMATE ACTION	The surface cover and microclimate of the mesoregion of southern Ceará
14 LIFE BELOW WATER	Trace metal biogeochemistry in estuaries: monitoring environmental changes in the Parnaíba River delta
15 LIFE ON LAND	Decentralized water supply technologies in the rural areas of the Cariri region of Ceará
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	The expansion of Brazilian higher education as a strategy for territorial development: the case of the brand-new federal universities
17 PARTNERSHIPS FOR THE GOALS	

(a) UFCA

SDG	UNILEÃO
1 NO POVERTY	
2 ZERO HUNGER	
3 GOOD HEALTH AND WELL-BEING	Indoor and outdoor green areas: minimize the impact of urbanization and preserve the environment
4 QUALITY EDUCATION	Management of AraripeGeoPark. Environmental and Social Education Program
5 GENDER EQUALITY	Diversity of people gathered in the same physical space
6 CLEAN WATER AND SANITATION	Water reuse: more than 4 million liters of treated water and reused in 2020
7 AFFORDABLE AND CLEAN ENERGY	Eco-efficiency and solar energy. Use of photovoltaic solar energy
8 DECENT WORK AND ECONOMIC GROWTH	Training for development: University for the Best Age Program, contributing to the valorization of the elderly
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Entrepreneurial and technological attitude, in search of didactic-pedagogical and structural improvements for the academic community
10 REDUCED INEQUALITIES	
11 SUSTAINABLE CITIES AND COMMUNITIES	
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Paper Recycling
13 CLIMATE ACTION	
14 LIFE BELOW WATER	
15 LIFE ON LAND	
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	Training for development
17 PARTNERSHIPS FOR THE GOALS	

(b) UNILEÃO

SDG	IFCE CRATO AND JUAZEIRO DO NORTE
1 NO POVERTY	
2 ZERO HUNGER	
3 GOOD HEALTH AND WELL-BEING	Making it viable to save money without reducing the comfort, well-being, and safety of the community involved
4 QUALITY EDUCATION	Produce, disseminate, and apply scientific and technological knowledge in the formation of citizens, aiming at their social, political, cultural, and ethical insertion
5 GENDER EQUALITY	Basic precepts of citizenship and humanism, with freedom of expression, with feelings of solidarity
6 CLEAN WATER AND SANITATION	Water conservation and rational use program
7 AFFORDABLE AND CLEAN ENERGY	Conservation program and rational use of electricity and water. Use of photovoltaic solar energy
8 DECENT WORK AND ECONOMIC GROWTH	To be a reference in teaching, research, extension, and innovation, aiming at social transformation and regional development
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Culture of innovation with ideas fixed on environmental sustainability
10 REDUCED INEQUALITIES	
11 SUSTAINABLE CITIES AND COMMUNITIES	
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	
13 CLIMATE ACTION	
14 LIFE BELOW WATER	
15 LIFE ON LAND	
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	To be a reference in teaching, research, extension, and innovation, aiming at social transformation and regional development
17 PARTNERSHIPS FOR THE GOALS	

(c) IFCE CRATO AND JUAZEIRO DO NORTE

SDG 17 is about strengthening the means of implementation and revitalizing the global partnership for sustainable development, so it is a goal that focuses on international cooperation policies, in which developed countries should assist developing countries. It covers goals for Finance, Technology, Capacity Building, Trade, and Systemic Issues. For this reason, it is not observed in the HEIs.
Source: Made by the author (2021).

Concluding the analysis, the quantity of 22.22% of HEIs in the MRC that adopted the solar energy generating system in this research is ratified. Public HEIs predominates in 33.3% of solar energy use, compared to 11.1% of private HEIs. This fact reveals the major motivation being ecological and social, not only economic. Otherwise, the private HEIs predominance should be noted, since they are the ones with their own capital, the basic need for profit, and have the economic dimension as a great motivator.

In their study, Kristiawan, Widiastuti, and Suharno (2018) identified that only 57 from a total of 3225 universities in Indonesia use renewable energy sources such as solar energy, corresponding to 1.77%. The research presents a feasibility analysis of developing photovoltaic energy generation plants at a university in the southern part of Java Island, Indonesia. The simple payback found in the study was 14.29 years.

In a study conducted in Connecticut state in the United States, Lee *et al.* (2016) they emphasize that only 7 HEIs have an installed photovoltaic system out of 28 HEIs, corresponding to 25%. The study evaluates the economic viability of photovoltaic solar systems on the University of New Haven (UNH) campus under realistic constraints by analyzing actual solar panel data on campus. During the study, it was found a simple payback of 11 years.

Ayadi, Al-Assad, and Al Asfar (2018) emphasizes that in Jordan 11 HEIs use solar photovoltaic energy system out of a total of 30 HEIs, corresponding to 36.67%. The study investigated different technical solutions for a photovoltaic solar system for the University of Jordan (UoJ). During the study, it was found a payback of 3 years.

6. CONCLUSION

This study demonstrated the benefits that sustainability actions and the use of photovoltaic solar energy provide to the educational area, more precisely to Higher Education Institutions, and also analyze which actions of the Sustainable Development Goals are practiced by HEIs. SDG 7 is observed in all the HEIs during the study, evidencing the use of photovoltaic solar energy as a propitious solution for the MRC. Furthermore, one HEI adopts actions related to all SDG, except SDG 17 (which is related to the global partnership between developed and developing countries).

Public HEIs are the majority when it comes to the use of photovoltaic solar energy in the MRC. However, it is reiterated that the merit of the pioneering use of this technology in the MRC belongs to private HEI, despite the fact that its use encourages the practice. It was also found that there is a strong concentration of HEIs per municipality, with 75% of the analyzed HEIs in Juazeiro do Norte and 25% located in Crato. Barbalha has no HEIs with a solar energy generating system, and the other cities of the MRC have no HEIs. These numbers reveal the importance of this research since the percentage of HEIs with solar energy is still low in a scenario where less than 25% of HEIs have adopted this practice.

It has also promoted awareness about the low environmental impact of this energy generation system and its contribution to achieving sustainable development. Tangible results have been achieved with the execution of the research, such as the dissertation document itself, articles published in journals, and the offering of small courses.

It was also verified that many sustainability actions are developed and documented by the HEIs, and they could be exposed to the local society, for the purpose of raising awareness of such a relevant agenda. Added to this fact is the increased friendly use and digital disclosure that the world began to experience in 2020.

Regarding the management implications, this study is expected to be useful as a basis for the implementation and encouragement of other HEIs in the MRC, given the environmental, social, and economic benefits for society as a whole. In this way, it is possible to contemplate a more sustainable MRC with greater use of available renewable resources. The society can also exert positive pressure with the intention to demand more HEIs engaged in the technologies valorization that benefit and preserve the environment. The average simple payback of 4.9 years found in the study proves to be a great result, different than international studies which reach up to 14.29 years. The photovoltaic systems installation in HEIs besides generating renewable energy can also be used as a promoter of the awareness level of the university community regarding renewable energy and sustainability efforts as a whole.

In terms of theoretical implications, the research contributes to the state of the art on photovoltaic solar energy use considering its application in the context of the Metropolitan Region of Cariri and also Brazilian and international studies on the subject.

Regarding the social implications, the study contributes to the search for a holistic view of the studied phenomenon in order to understand the reality from the perception of local agents (HEIs), allowing the interpretation of the regional reality.

For future research, the possibility of evaluating the energy efficiency of the solar energy generating system of each analyzed HEI is emphasized; to verify the use degree of more efficient equipment, such as led lamps, lamps with a presence sensor for automatic switching on and off; energy consumption per shift; the number of students attending each HEI. Additionally, the scenario of HEIs adept to the solar energy generation system in the MRC can be updated, in order to check the evolution of the subject, besides verifying the sustainability actions in the other HEIs which do not make use of photovoltaic solar energy.

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