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Efficiency and Rational Use of Energy at UNAH-CU: Addressing Sustainable Development Goals 7 and 11

***Abstract*— The global agreement of nations, formalized by the Paris Agreement, has increased policies and actions worldwide to combat climate change. In line with these global efforts, this study examines Sustainable Development Goals (SDGs) 7 and 11, specifically within a Honduran institution. To that end, a bibliometric and systematic literature review was conducted to identify global lines and approaches related to these SDGs. In addition, strategies for rational energy use and efficiency at the National Autonomous University of Honduras, University City Campus (UNAH-CU), were implemented. This included the development of an energy monitoring platform, which resulted in monthly savings of US$ 974 and a 37.2% reduction in building energy consumption. In addition, the study provides a techno-economic assessment of replacing inefficient sodium vapor lamps with efficient LED lighting in specific areas of UNAH. The results highlight significant improvement opportunities for public institutions in Latin America and underscore the impact of targeted policies and actions to achieve the SDGs.**

Keywords*—*Sustainable development goals, SDG 7, SDG 11, energy efficiency, bibliometric analysis.

I. Introduction

A. General Considerations

Since the Conference of the Parties (COP21) signed in Paris in 2015 to keep the global average temperature below two °C and in line with the 2030 Agenda for Sustainable Development, which includes 17 Sustainable Development Goals, many countries have implemented policies and actions in line with these goals, with targets defined according to each country's reality, to contribute to the celebrated global agreement [1]. Honduras contributes less than 0.05% of the world's emissions. However, in recent years, the country has been hit hard by the effects of climate change, in addition to experiencing a severe energy crisis. Based on this, the energy sector has developed solid policies and actions to achieve its goals and increase its resilience to climate change. By 2030, Honduras is committed to implementing climate change adaptation and mitigation actions to reduce greenhouse gas emissions by 16% [2], [3].

B. Literature Review

A bibliometric analysis was performed using the SCOPUS database, focusing on implementing energy management systems and their connection to various Sustainable Development Goals (SDGs). The search used four specific terms: "Sustainable Development Goals," "SDG," "7," AND "11." This initial search yielded 175 studies. The search was refined to include only documents within Energy and Engineering to narrow the scope to the energy sector. This resulted in a final set of 80 papers, which formed the basis for the bibliometric evaluation.

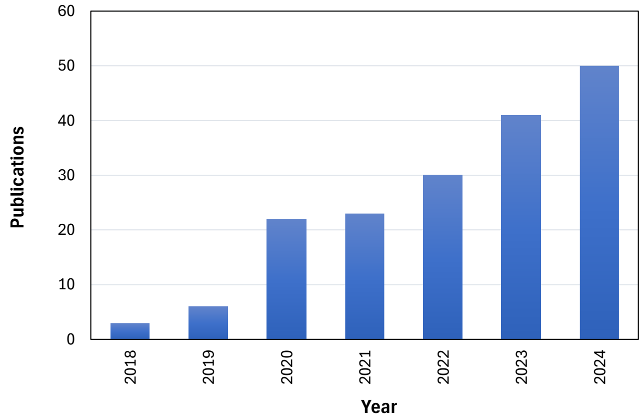

Fig. 1. Publications per year related to SDGs 7 and 11.

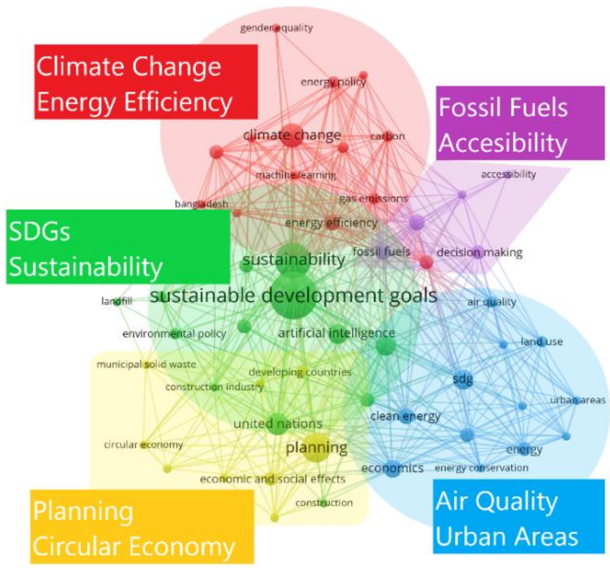

Fig. 2. Thematic map of keywords related to SDGs 7 and 11

Figure 1 shows the growth of SDGs 7 and 11 studies in recent years. By August/2024, publications have exceeded those of previous years, highlighting the global interest in addressing the SDGs in their studies. A thematic map of keywords was created using the VOSviewer software, as shown in Figure 2, to visualize the main keywords in the studies and their relationship between them. It shows that five strings can be obtained within the keywords of the 80 studies considered. These strings inform how the studies related to the SDGs present approaches such as circular economy, planning, fossil fuels, air quality and urban areas, and energy efficiency, all related to sustainability and climate change, essential categories in the 2030 Agenda.

The focus given to the SDGs is strongly linked to the economic situation of each country. The study in [4], focusing on SDG 11, evaluates the practices of different countries. The authors show a greater interest in disaster prevention in developing countries and other issues, such as access to green spaces. Developed countries, on the other hand, prioritize the conservation of local flora and fauna and air quality. The article concludes that the practices of developed countries are more process- and technology-oriented.

Studies on the analysis of the SDGs have also been presented in different countries. The authors in [5] have analyzed SDG 7, which evaluates the application of the SDGs in Indonesia and Bangladesh. The studies address the impact of implementing clean sources, considering each country's current policies. The results show that with energy efficiency measures, the final consumption of gross domestic product (GDP) is reduced by 8.6% compared to 1% considering current policies. Studies on other countries are presented in [6], where the Brazilian scenario is evaluated in terms of compliance with the SDGs based on current policies and those that could guarantee compliance with the goals set.

The study in [7] presents a real-time management platform based on meters installed in buildings. The software can support energy efficiency and power quality studies by visualizing graphs and bars and elaborating invoices from meters geolocated in a university's various meters. With the help of this platform, case studies of actions associated with Sustainable Development Goals have been presented in [8], [9], [10]. Based on real case studies, the authors deal with studies focusing on implementing energy efficiency measures in motor drive systems, electric mobility, renewable energies, and building efficiency [11], [12], [13].

C. Motivations and Contributions

SDG 7 focuses on ensuring universal access to affordable, reliable, and clean energy for all, including energy efficiency, as it aims to optimize energy consumption at the residential, commercial, and industrial levels, thereby reducing operating costs and greenhouse gas emissions. In this sense, energy efficiency measures such as replacing inefficient lighting equipment, occupancy sensors, and monitoring systems improve the overall performance of systems. Concerning SDG 11 on sustainable cities and communities, integrating energy efficiency, lighting, and consumption monitoring systems in urban planning and public buildings will promote more sustainable and efficient urban development, thus ensuring sustainable cities. This paper presents a case study of SDGs 7 and 11 applied to a university institution in Honduras, considering the sustainable agenda adopted by different countries worldwide and the economic opportunities. To this end, the main contributions of this work are:

- A bibliometric and systematic literature review with a focus on SDGs 7 and 11, with an emphasis on the categories of engineering and energy, which allowed the identification of global trends in scientific publications, which will be discussed later in the systematic review;
- Presentation of an energy monitoring and verification system applied to a building in the UNAH based on energy efficiency measures and rational use of energy;
- Technical-economic feasibility study for replacing public lighting in public university facilities.

Based on the above specific objectives, the study's contribution allows for identifying the SDGs' scientific relevance in recent years and the opportunities for implementation in university institutions based on internal policies and actions to achieve the defined objectives.

The article is organized as follows: Section II presents the methodology used to develop this study. Section III presents and discusses two case studies of actions related to SDGs 7 and 11 at the National Autonomous University of Honduras. Section III is divided into two subsections: Section III-A discusses the economic opportunities associated with replacing public lighting at UNAH-CU. Then, Section III-B discusses the implementation of energy efficiency measures and a monitoring and verification platform for the savings developed in the proposed project. Finally, Section IV presents the final considerations, acknowledgments, and references.

II. METHODOLOGY

The methodology used to carry out this study is detailed in Figure 3. First, a search for articles related to the Sustainable Development Goals was conducted using the Scopus platform and based on the strings specified in Sections I-B. Then, articles about SDGs 7 and 11 were selected for discussion based on a selection that considered criteria such as number of citations, year of publication, and association with this study. Finally, in Section III, the energy efficiency measures implemented at UNAH-CU are presented through two case studies; the first (Section III.A) is on public lighting at the University, in which the energy efficiency (EE) opportunities existing in these systems, which usually go unnoticed, are shown. Then, in Section III.B, the rational use of energy is applied to the UNAH law school, the economic results and the monitoring system will be presented, systems that can be installed in new and existing buildings, private and public, to identify the consumption patterns and thus the economic opportunities. Section III.C discusses the institution's consumption history and associated costs to quantify EE actions' impact in economic terms on energy invoices.

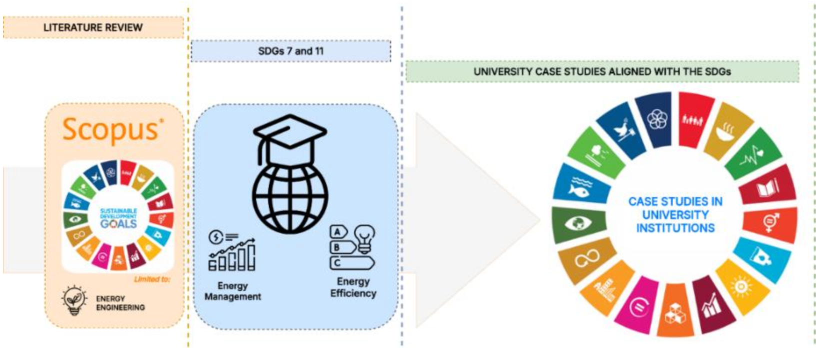

Fig. 3. Methodology used for work development

III. Results and Discussion

To achieve SDGs 7 and 11 for the National Autonomous University of Honduras, University City Campus (UNAH-CU), it is necessary to understand the overall demand behavior of UNAH-CU. Figure 4 illustrates the load curve obtained from the main meter discharge—the power demand over seven days (Monday - Friday). By definition, the area under the curve is the energy demand. [14] This energy is the consumption of buildings, companies, lighting, or any other device connected to the network in a given time. The load maintained a constant behavior during the analyzed period. The highest consumption is maintained from Monday to Friday when there is more activity. The days of lower consumption are Saturdays and Sundays since there are distance learning students and courses on Saturdays, and the facilities are used.

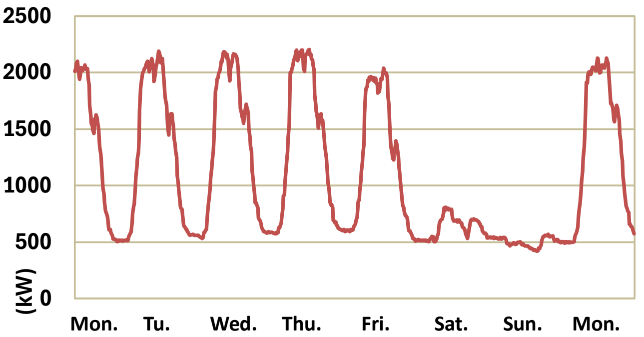

Fig. 4. February weekly load curve of UNAH-CU in 2020 year

The data analysis shows that the peak demand occurred on Monday, February 18, at 2:30 pm, reaching 2969.8 kW, while the lowest demand was recorded on Sunday, February 10, at 4:30 pm, reaching 417.91 kW. The peak demand in the afternoon is consistent with our assumption that the use of air conditioning systems increases during the summer season. In contrast, the minimum demand likely corresponds to early morning loads such as street lighting (161 kW), server equipment, cooling systems, and laboratory operations. An analysis of a typical week shows that demand is highest from Monday to Friday and tapers off over the weekend. An inventory was made of the number of sodium and mercury vapor lamps, in which a general count was made of 457 lamps currently used in the public lighting system of (UNAH-CU), which have a useful life of 24,000 hours. The type of lamp (sodium or mercury vapor) and the power consumed were noted to determine the capacity of the new LED lamp to be implemented, which has a useful life of 50,000 to 100,000 hours.

A. *Public lighting inventory at UNAH-CU*

The survey was conducted in three stages to identify energy-saving opportunities in the University's public lighting [15]. It included buildings equipped with 76 units of 400W lamps because they provide greater visibility and 40 of 250 W. The parking lots have 93 units of 250W lamps with a lower luminosity since they are not located at medium heights also, 52 of 400W and 16 of 150 W. Finally, the accesses to the buildings (sidewalks, roads inside the university, student creativity areas, etc.), where there are 99 of 250 W, 41 of 400W and 18 of 150W lamps, as shown in Table I. It should be noted that most lamps installed on campus are high-pressure sodium, and a few are high-pressure mercury. The daily electric power consumption is 12 hours from 6:00 pm to 6:00 am, and monthly and yearly, the current lamps of the university street lighting are shown in Table II. Table II shows the active power consumed by the installation of the LED lamps, including the 17 power of the LED lamps already installed in the University, which consumes 2.55 KW. This would give a total of 68.55 KW.

TABLE I. Total Power in kW, Public Lightning UNAH-CU

Lamps Location	Number of Lamps	Total Power (kW)
Buildings	117	40.5
Parkings	165	48.3
Streets	158	72.1
Total Power (kW)	**440**	**161.0**

TABLE II. Total Power in kW with new LED Lamps

Number of Lamps	LED Lamp Power (W)	Total Power (kW)
457	150	68.55

Replacement of all high-consumption lighting fixtures with energy-efficient, low-consumption LED fixtures is an investment of USD 154,447. The total installed power is 68,550 kW, and the consumption is 24,678 kWh. UNAH-CU would pay a cost of USD. 5,637.5 per month. With these results, it is clear that the reduction in electricity consumption represents a percentage of 42.58%, saving a total of USD. 7,603 per month, which, according to the calculations, will pay back the investment in LED lamps in 1 year and nine months.

B. Energy Savings Project at the Law School

University institutions are characterized by the different types of buildings used for administrative, teaching, and service purposes. This section presents the results of an energy efficiency project in a Faculty of Law classroom building. For this purpose, an ION 7350 meter was installed in the Law Building of the UNAH-CU to control the building's energy and electricity consumption in 20 classrooms. Figure 5 shows the screen of the software that allowed the results to be obtained. The maximum power registered and consumed by the building was 50.16 kW, as shown in Figure 6 [16].

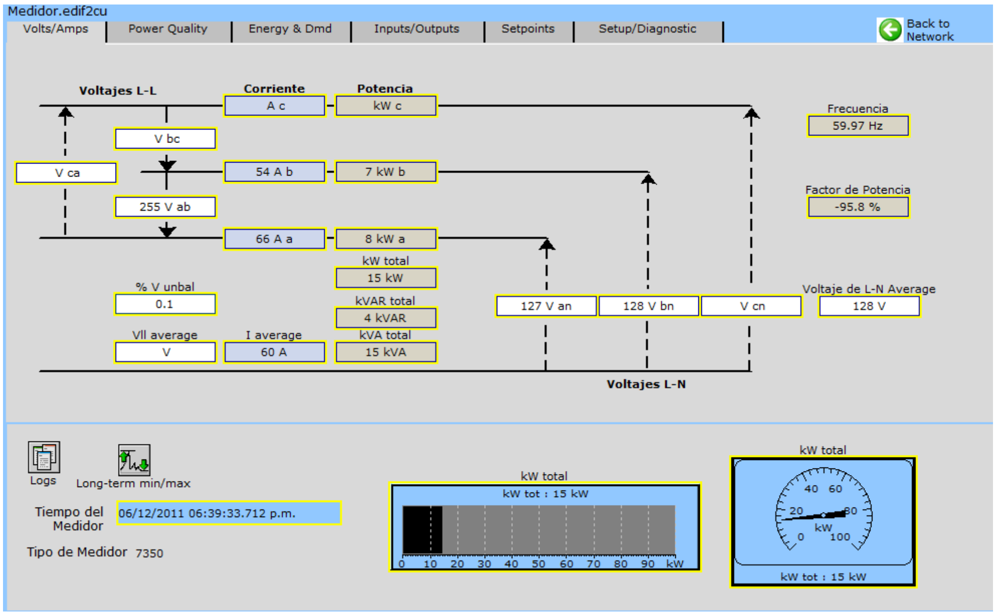

Fig. 5. Real-time building consumption monitoring system display.

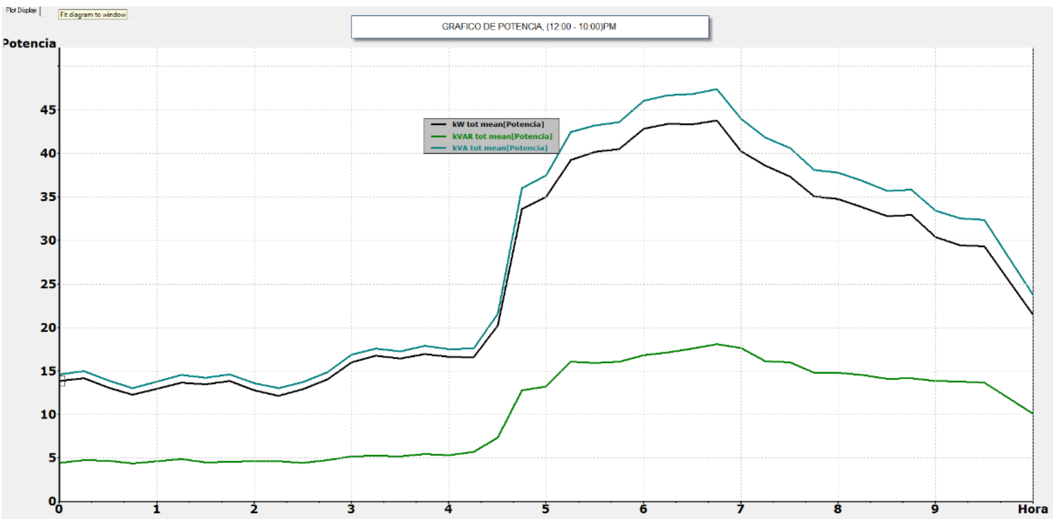

Fig. 6. Building measured active power for a day.

As a pilot project for the entire UNAH-CU and to save electrical energy in the building, the following actions were carried out in a total of 20 classrooms:

- *Elimination of unnecessary lights in the classrooms.*

To this end, the DIALux software was used; the DIALux is a lighting simulation software used to design and optimize lighting systems in indoor and outdoor spaces. It allows users to simulate light distribution and calculate illumination levels, supporting energy efficiency decisions. In this study, DIALux helped identify and eliminate unnecessary lights in classrooms with lumens measurements. It was concluded that the number of luminaires installed in the classrooms was oversized compared to what was needed (see Table III). A total of 53 redundant lamps were removed from the classrooms, all of which were unnecessary, resulting in a 19.6% reduction in the building's energy consumption.

- *Installation of motion sensors in all classrooms*

Next, with infrared, ultrasonic, and photocell technology, Hubbell ATD2000C and motion sensors were installed. This resulted in an additional 17.6% reduction in the building's energy consumption.

After the rational energy use measures were completed, the building's peak power was reduced from 50.16 kW to 39.12 kW, resulting in a USD—974 monthly reduction in the building's new electric bill.

TABLE III. TOTAL POWER IN KW IN UNIVERSITY

Lamps Location (Number of Classrooms	Existing Lamps	Necessary Lamps
First Floor (1)	18	12
Second to Fourth Floor (9)	12	8
First Floor (2)	10	8
First Floor (1)	8	6
First and Fourth Floors (7)	6	4
Non-necessary Number of Lamps		**16**

C. *UNAH Annual Energy Billing*

The cost of the annual energy consumption of the UNAH-CU main meter is approximately $1.43 million, which represents 0.3% of the UNAH-CU budget. UNAH-CU keeps a monthly historical record of this consumption. This record makes it possible to monitor the consumption process and can lead to decisions to reduce unnecessary consumption. Table IV summarizes kWh's 2006, 2007, 2013, and 2018 energy consumption. It shows that energy consumption increased by 195% from 2006 to 2018; therefore, the energy bill also suffered [14].

During this period, three new buildings were constructed in UNAH-CU: Alma Mater (643 kW), Health Sciences Building (65 kW), and Sports Center (68 kW), all built according to SEAPI, as buildings that consume with a high degree of rational use of energy and energy efficiency. Table V and Figure 7 show the composition of the maximum and minimum demand of the UNAH-CU obtained with the information extracted from the smart meters installed by SEAPI in some buildings of the UNAH-CU, including the new buildings mentioned above and some buildings for which at least motion sensors have been installed. As can be seen, in addition to the critical project to change the public lighting, which has been described in detail in this publication, the UNAH can still act with actions for rational use of energy and energy efficiency on 51% of the energy demand, corresponding to the remaining buildings and businesses. Since these buildings are not yet equipped with smart meters and are very old, it is necessary to eliminate excess lighting, install appropriate motion sensors, and replace T12 lamps with more efficient ones.The buildings that have not yet implemented rational energy use and efficiency measures are summarized as nine buildings, plus the shopping center and the stores. Regarding the missing buildings, even though their electricity and energy consumption have not been recorded because smart meters have not been installed, it is assumed that the savings that could be obtained by installing motion sensors, eliminating excess lighting fixtures, and replacing T12 lamps with more efficient ones are approximately 11.2% of the total consumption. Similarly, according to references [7-12], the average savings would be roughly $572/month, which, when added to the savings in the ten buildings, would result in $68,640/year.

Finally, Table VI shows the savings that could be obtained in the UNAH bill by implementing rational energy use measures in buildings, such as public lighting. These savings result in USD 159,876 per year, approximately 11.2% of the total annual bill of UNAH-CU. The focus is on the nighttime peak demand that occurs around 6:00 p.m. Through the public lighting project, 92.45 kW can be reduced, and through energy savings in the buildings, another 110.4 kW can be reduced, for a total of 202.85 kW, which implies a reduction of the peak power to 2,766.15 kW, a decrease of 6.8%.

TABLE IV. TOTAL ENERGY IN KWH, UNAH-CU

	Energy Consumption kWH			
Month	**2006**	**2007**	**2013**	**2018**
January	300300	296800	273000	321300
February	144200	170100	189000	365600
March	343000	347200	365400	662400
April	395500	416500	369600	671600
May	354900	353500	456400	821100
June	418600	392700	421400	648600
July	291200	291200	327600	786600
August	347200	390600	491400	740600
September	330400	330400	453600	731400
October	329700	330400	529200	611800
November	379400	355600	541800	821100
December	406000	368200	497700	685400
Total MWh	**4042.41**	**4045.21**	**4918.11**	**7869.52**

TABLE V. TOTAL POWER IN KW IN UNAH-CU [17], [18], [19], [20]

Building	Peak Active Demand (kW)	Minimum Active Demand (kW)
Alma Mater	623.0	51.0
F1	120.19	6.98
D1	87.31	3.84
A2	58.65	2.02
Sports Building	68	-
Faculty of Odontology	133	0
Faculty of Health Sciences	65.0	3.0
Public Illumination	0	161
Total kW	1,115.15	227.84
UNAH Main Electric Meter	**2,696.,60**	**417.91**
Buildings and Stores without Meter Active Power (kW)	**1581.45**	**190.07**

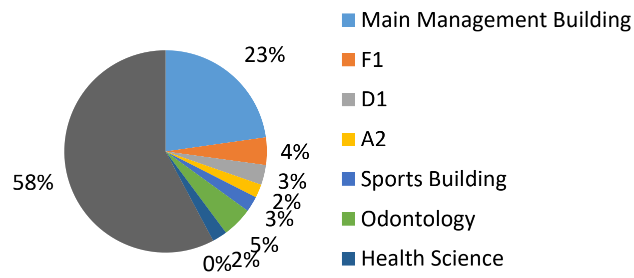

Fig. 7. Active power kW distribution by buildings at UNAH-CU.

TABLE VI. ANNUAL SAVINGS ACHIEVEMENTS IN UNAH-CU

Annual Savings (USD) (*)	USD
Savings in Energy Efficiency Public Lamps at the University	91,326.00
Savings due to Rational Energy Use, Actions in Buildings	68,640.00
Total Savings (USD)	**159,876.00**

(*) The total investment cost, including motion sensors, installation costs, and others, is about 55,000 USD, all covered in the first year of revenues.

IV. FINAL CONSIDERATIONS

Since the Paris Agreement and the 2030 Agenda were signed in 2015, actions to combat climate change have grown exponentially. This study presents the results of energy efficiency proposals and actions related to Sustainable Development Goals 7 and 11. With this objective, the proposed project to modify the public lighting of the UNAH-CU represents 57.0% of the estimated savings that can be achieved and is an easily implemented project.

The rational use of energy applied to classroom buildings requires more implementation work (Table 6) since it is necessary to determine the number of excess lights in the classrooms, if applicable, which is determined by using software such as DIALUX or field measurements of lumens, as a second action requires the installation of adequately calibrated motion sensors. The third measure is energy efficiency, which can be achieved by replacing T12 fluorescent lamps with T8.In buildings with intelligent metering, as shown in Table 5, it is essential to review the lighting situation to determine if rational energy use and efficiency measures can be implemented to increase energy savings [4-7]. It has been estimated that UNAH-CU can reduce its electrical energy consumption by 11.2% and 6.8% of its peak power by focusing only on rational energy use measures for lighting (without considering energy efficiency measures). Additional savings could be achieved through other energy efficiency projects to save energy in air conditioning, so research in this area is recommended. Finally, the study presented can be replicated in private, public, and commercial institutions aiming at energy efficiency and rational energy use in buildings with characteristics similar to those analyzed.

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