Reducing the ecological footprint of the State Polytechnic University of Carchi

Darwin Fabricio Casaliglla Ger
Docente Universidad Politécnica Estatal del Carchi. Ecuador, darwin.casaliglla@upec.edu.ec

Jorge Iván Mina Ortega
Rector Universidad Politécnica Estatal del Carchi. Ecuador, jorge.mina@upec.edu.ec

Elizabeth Josefina Guevara Guevara
Docente Universidad Politécnica Estatal del Carchi. Ecuador, elizabeth.guevara@upec.edu.ec

Erick Patricio Herrera Granda
Docente Universidad Politécnica Estatal del Carchi. Ecuador, erick.herrera@upec.edu.ec

Judith Josefina García Bolivar
Docente Universidad Politécnica Estatal del Carchi. Ecuador, judithj.garcia@upec.edu.ec

Abstract

In the State Polytechnic University of Carchi UPEC, an impact is generated in the environment due to the daily activities carried out by the administrative staff, teachers, students and the university community in general, therefore, it seeks to provide the university community with tools to generate changes in their habits and also encourage the use of new practices in their spaces that help reduce the impacts that it generates on the environment, for which, through the GISS Sustainable Society Research Group, a series of actions and strategies to mitigate the ecological footprint in the university. In the strategy of the reasonable use of energy, it is sought through energy saving and efficiency of the UPEC university campus, to contribute favorably to said goals. The equipment used both inside the buildings and outside that use electrical energy for its operation has been analyzed and it has been determined that they must be replaced with technologies that are more friendly to the environment, which is why 1.413 tube fluorescent luminaires are replaced by LED luminaires inside the buildings and 63 lighting lamps in green areas by LED lamps powered by photovoltaic energy, allowing an estimated annual energy saving of 82. 603,58 KWh/year, avoiding the emission of 18.63 tons of CO2 contributing to the improvement of air quality and reducing the ecological footprint of the university campus by 5,25 hectares per year.

Keywords: *Energy efficiency, energy saving, solar energy, ecological footprint, CO2 emissions.*

INTRODUCTION

The deterioration of the natural environment due to the excessive use of natural resources is the current model of development,which has led us to face challenges such as climate change and the greenhouse effect. Given this, there have been a series of initiatives that seek to mitigate and reduce the effects generated by the problems mentioned above.

One of them is the 17 SDG Sustainable Development Goals approved by the UN that are universally applicable in which governments must take measures to promote the well-being of their inhabitants while preserving the planet and that, the public and private sectors, civil society and practically everyone, must contribute to achieve the goals in each of the SDGs.

In the P olitechnic E statal University of the UPEC arch, an impact is generated in the environment due to the daily activities carried out by the administrative staff, teachers, students and university community in general, so it seeks to provide tools to the community to generate changes in their habits and also encourage the use of new practices in their spaces that help reduce the impacts that it generates on the environment(Carchi State Polytechnic University, 2022)

As previously shown, in the UPEC, through the Sustainable Society Research Group GISS, a series of actions and strategies have been proposed to mitigate the ecological footprint in the university, thus contributing to the achievement of the different goals of the SDGs. In the strategy of the reasonable use of energy, it is sought through the energy saving and efficiency of the UPEC university campus, to contribute favorably to these goals and improve the position in the GreenMetric ranking, which classifies higher education institutions according to their sustainability policies. . In the indicators used by GreenMetric, energy use is the most important among those that include the use of energy-efficient appliances, renewable energy use policy, total electricity use, energy conservation program, green building, climate change adaptation and mitigation program and greenhouse gas emissions reduction policy. (University of Valladolid, 2021) . According to the 2020 ranking, the Carchi State Polytechnic University is ranked No. 4 nationally and ranked 442nd globally among 956 higher education institutions.(GreenMetric, 2022)

From the point of view of environmental impact, a university can be considered as an integrated system within its environment, with inputs associated with the consumption of natural resources: water, materials (construction of buildings), paper and fossil fuels (electricity, heat energy, mobility) and outputs (waste production) and in this document, the results obtained from the proposed actions in the(López Álvarez & Blanco Heras, n.d.) field of he use of energy, which are based on the goals of goal No. 7 Affordable and Clean Energy of the SDGs, which among the most important are:

- By 2030, double the global rate of improvement in energy efficiency.
- By 2030, significantly increase the share of renewable energy in all energy sources(United Nations, 2015) .

Materials and methods

The type of research that is most appropriate for this research is exploratory and descriptive research with which it is intended to describe situations, facts, characteristics and properties that guide the preparation of this study. Then, we proceed to interpret and analyze the information collected to establish a conceptualization of the economic, social field and fundamental methodology for energy efficiency in the UPEC.

With this information, energy solutions are proposed to the UPEC university campus. In the case of improving energy efficiency in the UPEC, the equipment used both indoors and outdoors that use electrical energy for their operation has been analyzed.

Interior of the buildings. Anenergy-efficient building is one that minimizes the use of conventional energies, in order to reduce their energy demand, produce in situ if possible and make rational use of the final energy required. (Pascual, 2014.)

The UPEC facilities are relatively new, in which the elevators are efficient due to the technology they have and thehigher percentage of energy consumption is due to the lighting of classrooms and offices of administrative staff. For this lighting, old technology lamps based on fluorescent tubes with the following characteristics are used:

Table 1. Specifications of old lamps (fluorescent tube) for building interiors

Description	Feature
Color:	**White**
Power consumption [W]:	**32.**
Color temperature [K]:	**6500**
Color of Light	**Cold White Light**
Life	**1 5,000 hours**

Therefore, the luminaires are replaced with impact technology (LED tubes), whose specifications are found in Table 2:

Table 2. Specifications of new lamps (LED tube) for building interiors

Description	Feature
Color:	**White**
Power consumption [W]:	**18**
Color temperature [K]:	**4100**
Color of Light	**Cold White Light**
Life	**50,000 hours**

In addition, the installation of motion sensors is carried out in the communal areas of the classroom building No.4 allowing the lighting of the luminaires only in the event that there is the presence of people and there is no waste of lighting without the presence of people.

Exterior of the buildings. Lighting continues to be the cause of high energy consumption on the university campus and therefore, it is necessary to look for alternatives that favor the reduction of energy consumption. The luminaires of parking lots and green areas are made of sodium vapor technology, with the following technical characteristics:

Table 3. Outdoor sodium vapor lamp specifications:

Description	Feature
Color:	**White**
Power consumption [W]:	**150**
Color temperature [K]:	**2000**
Color of Light	**Warm light**
Life	**24.000 hours**

That is why, at the State Polytechnic University of Carchi, the need to cover the demand for public lighting within the campus was raised, with renewable energy.

For which the following studies were carried out:

- Initially, the use of wind energy is considered. Wind energy is one that takes advantage of the kinetic energy that the wind has to generate electricity, through the use of wind turbines, which have blades or blades, which are moved by the wind and they are connected to a rotor that transmits the movement to an electric generator. Therefore, the wind data is taken from the weather station that is located on the university campus and the studies and modeling of the wind potential at the site are carried out. It is important to note that wind data are not sufficient to characterize a typical year. A statistical treatment of the data is carried out as follows:

- Grouping and distribution of such data into classes or categories. This will determine the frequency of each of the classes, that is, the number of these in each category. (Eraso Checa & Escobar Rosero, 2018)

- For the ease of computer tools for the corresponding calculations. The class interval will be 1m/s. This determines the number of classes. In addition, its accuracy will be better the smaller the class interval. The center of the class is considered an integer to facilitate the relationship with the power graphs of the wind turbines.

- The relative and cumulative frequencies are calculated and organized in a table containing the classes, frequencies and calculations mentioned above. With these the average speed and the standard deviation are calculated.

- The mean speed and standard deviation for pooled data are calculated with:

$$\langle v \rangle = \sum_{i=1}^{k} f_i v_i$$

$$\sigma = \sqrt{\sum_{i=1}^{k} f_i v_i^2 - \langle v \rangle^2}$$

Where:

⟨v⟩ is the average speed

fies the relative frequency

σ Standard deviation the typical.

Subsequently, the use of solar energy as outdoor public lighting is analyzed. It is proposed the installation of solar lamps each with its own photovoltaic panel, which are able to capture the energy emitted by the sun and accumulate it during the day in a battery and then be used at night in outdoor lightingr. These photovoltaic lamps use LED technology, with better performance than sodium vapor lamps, as mentioned in the results section.

Photovoltaic lamps are disconnected from the public electricity grid, that is, their lighting is completely renewable.

Ecological footprint

With the information of total energy savings per year, we proceed to calculate the CO2 emissions that would be stopped emitting by improving lighting technology both indoors and outdoors, using the expression:

$$EnE = C \cdot FE$$

Where: EnE are the emissions not emitted in(tCO_2)

C is the consumption in(MWh)

FE is the$_{CO2}$ emission factor of Ecuador's national interconnected system in $\left(\frac{tCO_2}{MWh}\right)$

The previous expression is used directly in the case of having the information of the **respective** consumptions(López & Blanco, 2007) and with the emissions not emitted, the ecological footprint is calculated using:

$$H = \frac{EnE}{CF} + SC$$

Where: H is the ecological footprint saved in $\left(\frac{ha}{año}\right)$

CF is the fixing capacity of the forest mass $\left(\frac{tCO_2}{ha/_{año}}\right)$

SC is the surface of the campus $\left(ha/_{año}\right)$

Results and discussion

Interior of buildings

1413 fluorescent lamps are replaced to LED type, in order to reduce energy consumption. In addition, LED luminaires have better performance than other luminaires, among the most important, they haveconsiderably long useful life (greater than 50,000 hours), lowmaintenance costs, energy efficiency higher than other types of luminaires, do notgenerate ultraviolet radiation, or infrared radiation, and Instant ignition at 100% intensity and on a regular basis, among others (Flores, 2016)

In table 4, there is an installed power saving of 14W for each lamp changed according to the specifications of tables 1 and 2. Therefore, the energy savings in monthly KWh is as follows:

Table 4. Energy savings in KWh nor consumed (indoors):

DESCRIPTION	QUANTITY	UNIT
Number of LED lamps	1413	In the
Fluorescent lamp power	32	In
LED lamp power	18	In
Power saving	14	In
KW power saving	0,014	KW
Hours on lamps 8h00 - 22h00	11	hours
Hours on lamps 22h00 - 8h00	1	hours
Days per month average	22	days
Energy saving in KWh 8h00 - 22h00 per month	4787,24	Kwh
Energy saving in KWh 22 h00 - 8h00 per month	435,20	Kwh
Energy savings in monthly KWh	5222,44	Kwh
Energy savings in annual KWh	41779,52	Kwh

For annual energy savings, it is estimated 8 months of ignition because the lamps were replaced in the classrooms mostly, the missing 4 months correspond to the vacation periods of the students. In addition, the energy consumption sheets show different rates per KWh according to the time slot, allowing to estimate the economic savings for having replaced the 1413 lamps, as shown in table 5.

Table 5. Economic savings in monthly dollars (indoors):

DESCRIPTION	QUANTITY	UNIT
Cost KWh hours 8h00 - 22h00	0,065	usd
Cost KWh hours 7h00 - 8h00	0,054	usd
Monthly economic savings 8h00 - 22h00	311,17	usd
Monthly economic savings 22h00 - 8h00	23,50	usd
Total economic savings per month	334,67	usd

Exterior of buildings

Table 6 shows the results of the statistical treatment of wind data from the UPEC weather station, which serve to determine the average speed and standard deviation in order to determine if the place has a wind potential that allows the installation of a wind turbine or microgenerator.

Table 6. Statistical treatment of wind data

Center interval	Class frequency nor	Relative frequency ni/N	Cumulative relative frequency Be	fi we	fi vi^2
0,25	3743	0,222	0,222	0,055	0,014
1	3379	0,200	0,421	0,200	0,200
2	2161	0,128	0,549	0,256	0,512
3	1670	0,099	0,648	0,296	0,889
4	1805	0,107	0,755	0,427	1,709
5	1541	0,091	0,846	0,456	2,280
6	1040	0,062	0,908	0,369	2,216
7	727	0,043	0,951	0,301	2,108
8	490	0,029	0,980	0,232	1,856
9	228	0,013	0,993	0,121	1,093
10	85	0,005	0,998	0,050	0,503
11	26	0,002	1,000	0,017	0,186
12	3	0,000	1,000	0,002	0,026

With this information and using the formulas of the previous section, the mean speed and standard deviation of the study site are calculated, taking into account the results shown in Table 7.

Table 7. Mean speed and standard deviation on the UPEC university campus

Velocidad media <v> (m/s)	2,784
Standard deviation σ (m/s)	2,417
$\frac{\sigma}{\langle v \rangle}$	0,868

The average speed obtained on site is not sufficient to promote the installation of a wind microgenerator. According to (Mendoza, 2018) y (Villarrubia, 2012), average speeds below 3 m/s at a height of 10m are not feasible for the installation of wind turbines due to the low potential of the wind resource. In the university campus of the UPEC there is an average speed of 2.78m / s at the height of the weather station. The relationship allows to verify that the data meet the Weibull probability density function $\frac{\sigma}{\langle v \rangle}$, however in this case it is not necessary to check it because the site does not have enough wind potential.

Subsequently, the replacement of sodium vapor lamps by solar lamps is analyzed. Su uses the information obtained from Prediction of World Energy Resource POWER, which is part of , which shows a set of renewable energy data and projects the (National Aeronautics and Space Administration NASA, n.d.)behavior of different climatic parameters with the help of information obtained by satellite and the same that is directed to users in renewable energy, sustainable buildings and agroclimatology.

Figure 1. Captura tomada de Prediction of worldwide energy resource

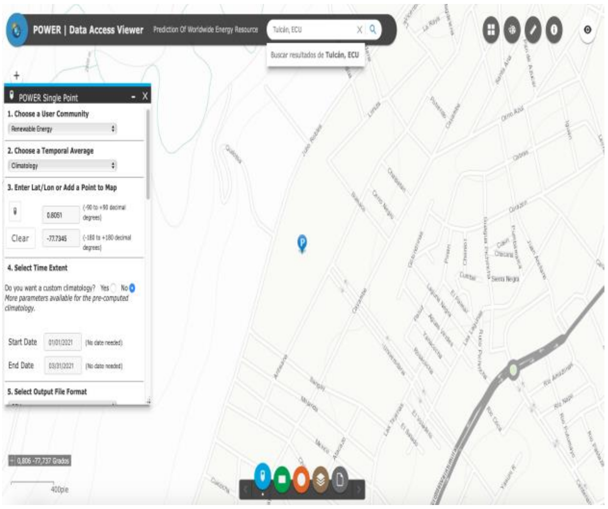

Figure 1 shows the POWER interface, in which the geographical location of the UPEC university campus is entered, in order to obtain the information of average solar radiation per month in that location, which is shown in the following table 8, in which, different parameters such as radiation on horizontal surfaces are observed, on vertical surfaces, with different angles of inclination and the optimal angle of inclination that the panels should have depending on the month in which it is.

Table 8. Solar radiation parameters on the UPEC university campus in Kwh/m2/day

PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SURFACE_HORIZONTAL	3,84	3,44	3,41	3,68	3,54	3,35	3,35	3,52	3,95	4,11	4,05	3,75
SURFACE_LAT_MINUS15	3,97	3,47	3,37	3,54	3,35	3,14	3,14	3,35	3,85	4,11	4,15	3,88
SURFACE_LATITUDE	3,86	3,45	3,41	3,67	3,53	3,34	3,34	3,52	3,95	4,11	4,06	3,76
SURFACE_LAT_PLUS15	3,98	3,47	3,35	3,52	3,31	3,1	3,1	3,32	3,82	4,1	4,15	3,89
SURFACE_VERTICAL	2,27	1,7	1,45	1,43	1,4	1,33	1,29	1,31	1,42	1,83	2,22	2,25
SURFACE_OPTIMAL	3,98	3,48	3,41	3,68	3,54	3,35	3,35	3,52	3,95	4,13	4,15	3,89
SURFACE_OPTIMAL_ANG	19	10,5	2	0	0	0	0	0	0	7,5	16	20
SI_EF_TILTED_SURFACE_OPTIMAL_ANG_ORT	S	S	S	N	N	N	N	N	N	S	S	S

There are all-in-one photovoltaic lamps on the market, in which, on the LED lights are the panelis responsible for collecting the energy from the sun, which is why the Surface Latitude data from table 8 will be taken to select the appropriate lamp for the site. It is not considered photovoltaic systems with centralization of panels due to the amount of physical space required for it.

The average annual radiation in the UPEC is 3.67 Kwh / m2 / day, the best is presented in the month of October with 4.11 Kwh / m2 / day and the month with the lowest radiation are June and July with 3.34 Kwh / m2 / day, data that will be considered for the selection of the photovoltaic lamp.

Additionally, there is the luminous flux on the university campus, using:

$$\phi_t = \frac{S \cdot E_m}{C_u \cdot C_m}$$

Where:

ϕ_t is the luminous flux (lumens)

S surface of the area to be illuminated

E_m Illumination level (lux)

C_u Utilization coefficient

C_m Maintenance coefficient

The average illuminated surface is 60m^2, , according to $C_u = 0{,}95 C_m = 0{,}8$ its technical regulation RTE INEN 069 "Public Lighting", the average lighting level for walkways and pools is , (Ecuadorian Standardization Service, 2013)so, the necessary luminous flux on the $E_m = 20\ lux$ university campus of the UPEC is:

$$\phi_t = 1578{,}95\ lúmenes$$

With these characteristics, both solar radiation and required lumens, the photovoltaic lamp that is available in the market is selected, which has characteristics shown in table 9

Table 9. Specifications of outdoor photovoltaic lamps:

Description	Feature
Color:	White
Power consumption [W]:	1000
Color temperature [K]:	6500
Color of Light	Cold White Light
Life	50.000 hours
Luminous flux	45,000 lumens

Therefore, the monthly energy and economic savings are estimated by changing the lighting technology of the university campus, knowing the parameters of table 10. In this, the energy savings are determined in the two existing billing time slots in the area, since in each of them there is a different cost of KWh consumed.

Table 10. Energy savings in monthly KWh not consumed (outdoors):

DESCRIPTION	QUANTITY	UNIT
Number of external photovoltaic lamps installed	63	In the
Antique outdoor lamp power	150	In
Photovoltaic outdoor lamp power	1000	In
Power saving	150	In
KW power saving	0,150	KW
Hours on lamps 8h00 - 22h00	4	hours
Hours on lamps 22h00 - 8h00	8	hours
Days per month	30	days
Energy saving in KWh 8h00 - 22h00 per month	1134	Kwh
Energy saving in KWh 22 h00 - 8h00 per month	2268	Kwh
Energy savings in monthly KWh	3402	Kwh
Energy savings in annual KWh	40824	Kwh

With this information, the monthly economic savings can be estimated by replacing outdoor lighting technology, being the data shown in table 11:

Table 11. Economic savings in monthly dollars (outdoors):

DESCRIPTION	QUANTITY	UNIT
Cost KWh hours 8h00 - 22h00	0,065	usd
Cost KWh hours 7h00 - 8h00	0,054	usd
Monthly economic savings 8h00 - 22h00	73,71	usd
Monthly economic savings 22h00 - 8h00	122,48	usd
TOTAL ECONOMIC SAVINGS PER MONTH	**196,18**	**usd**

Ecological footprint

The CO2 emissions that were stopped being emitted by improving lighting technology both indoors and outdoors arecalculated, with:

$$EnE = C \cdot FE$$

The emission factor is 0,2255 $\frac{tCO_2}{MWh}$ according to (Technical Commission for the Determination of Greenhouse Gas Emission Factors CTFE, 2019)

The total energy consumption saved per year by adding the results of tables 4 and 10 is: 82603,58 $\frac{KWh}{año}$

So the emissions not emitted per year in the UPEC is:

$$EnE = 82603{,}58\ \frac{KWh}{año} \cdot 0{,}2255\ \frac{tCO_2}{MWh}$$

$$EnE = 18{,}63\ \frac{tCO_2}{año}$$

To determine the ecological footprint it is necessary to know the fixing capacity of the CF forest mass, which for the country is 36 $tCO_2/ha/año$ according to (Mogrovejo, 2017).

In addition, the surface of the UPEC university campus is 4,73 ha

So the ecological footprint saved is:

$$H = \frac{18{,}63\ \frac{tCO_2}{año}}{36\ tCO_2/ha/año} + 4{,}73\ ha/año$$

$$H = 5{,}25\ ha/año$$

As theecological footprint is an indicator that measures the area required to obtain the resources of a certain population, this data obtained indicates that 5.25 hectares per year are being conserved by replacing the lighting technology in the buildings and green areas of the UPEC university campus.

Conclusions

These efficiency and energy saving initiatives at UPEC contribute to the goals of goal No. 7 Affordable and Clean Energy of the SDGs, since more energy-efficient lighting technologies were sought and replaced and the use of renewable energy is considerably increased.

The place (university campus) does not have good wind potential, considering the information of the existing weather station, it was determined that the site does not have an adequate wind potential and therefore, does not have the necessary characteristics to install a wind turbine. The average speed obtained is 2.78m/s at the height of the weather station, being insufficient according to several authors cited.

The change of fluorescent tube luminaires to LED type in the interior lighting of the buildings is justified by the lower energy consumption, equivalent to a saving of 14Wh per unit, in addition to that, the benefits of this type of technology, such as the useful life greater than 50,000 hours, bajos maintenance costs and superior energy efficiency make this type of technology to be used appropriate. Similarly, thereplacement of sodium vapour outdoor luminaires with solar-powered LED luminaires entails the same and better performance than those mentioned above.

The estimated annual energy savings on the university campus by replacing 1413 photovoltaic lamps with LED lamps is 41,179.58 KWh generating an annual economic saving of 2,677.36 usd.

The estimated annual economic savings due to the replacement of sodium vapor lamps to LED lamps with photovoltaic energy is 2,354.16 usd due to energy savings of 40,824 KWh per year.

The emission of 18.63 tons ofCO_2 per year is being avoided, by replacing the aforementioned lighting technologies both inside and outside buildings, contributing to improving air quality, mitigating climate change and reducing greenhouse gas emissions.

By carrying out these actions, the ecological footprint of the State Polytechnic University of Carchi is reduced by 5.25 hectares per year, improving its environmental image in front of society in general, positioning it in the GreenMetric ranking being a competitive advantage in relation to other universities in the country.

Recommendations

Make a comparison between the actual energy consumption before and after executing these actions, comparing the electricity consumption sheets issued by the supplier on a monthly basis. In this study, this action was not considered, because the planned consumption of recent years was in the Covid-19 pandemic, which is why there were no students on campus, being an impediment to make this comparison.

1413 fluorescent lamps were changed to LED lamps, however, this represents approximately 30% of the total luminaires in the interiors of the UPEC buildings, so, it is recommended for future research, to project the change of all luminaires.

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