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Article

End-use energy indicator approach to improve energy performance at the National University of Colombia - Bogotá, under the parameters of the ISO 50001 standard

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Abstract: The university belongs to the services sector, which is why it cannot implement traditional industry indicators such as energy consumption per unit produced. For this reason, we propose indicators for the final use of energy. The indicators were developed through an energy review process of the information in the database of advanced energy meters with the support of the Specialist in Geographic Information Systems of the Environmental Management Office (EMO). Additionally, we considered several existing reports that characterized the final use of energy for some buildings and essential data for defining the percentages each final use will have within the conglomerate of loads registered. Continuity was also given to this process by collecting face-to-face information with the support of each building's environmental manager. This article shows the behavior of two buildings of the National University - Bogotá, the Uriel Gutiérrez building and the Roberto Franco Station, to propose an indicator of final energy use. This approach enabled determining in which end-use the load has the highest consumption, taking into account that this may contribute to the management system energy of the university. This article uses the guidelines implemented in the ISO 50001 standard.

1. Introduction

Final use energy applications are updated with the bonding of new technologies that give new added values like smart grids that provide information in real-time, save data about the history of the energy consumption, and give added value to the provision of services that allow facing challenges such as efficient online energy management.

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The National University of Colombia (Bogotá, 2016) made indicators that were adapted to campus consumption as they were proposed at the moment. In fact, the university already has smart metering in numerous of it's buildings (for example 500B Archive Building, Central Library, León de Greif Auditorium, Human Sciences Classrooms, 228 New Nursing, 453 Engineering Classrooms) time periods have been determined for the adequate study that reflects the changes in energy performance. Significant variables were also related and the analysis of the historical consumption of the campus. It was proposed that daily load curves would be seen as energy baselines, differentiated by Monday to Thursday, Friday, Saturday and Sunday. For each type of curve, the daily energy consumed the days of the week and the hour of use would be calculated, which represented relevant variables that impacted energy performance as evidenced in the analysis of the historical consumption information. At a global level, different studies have been presented that support how energy efficiency can increase with the use of smart metering systems with appropriate metrics that allow performance based on previously established objectives and the definition of management indicators, in this case with energy performance [1, 2]

The indicators that were proposed are used to measure and monitor energy efficiency within the Management System, the traditional indicators cannot satisfy the specific needs [3, 4]. These indicators use the information from the building energy review considering the most significant end-uses of energy of each building and the daily energy consumption [5].

The university network continues the improvement of the entire university although it has not telemetering coverage and just 20 meters in some buildings. There are about 47 substations including the external buildings, 129 buildings that are located inside the university of 152 buildings [6]. If there was complete measurement greater energy efficiency actions could be developed [7].

It is required to improve the energy performance throughout the University premises. For this case, the study of two buildings were taken that had their characterization of final uses of energy with Pareto diagrams and with measurement of energy consumption for these indicators. Buildings with different types of use were used, one Administrative that corresponds to 861 Uriel Gutiérrez building and another for multiple uses that have administrative areas, laboratories, classrooms and others, that correspond to the Roberto Franco Tropical Biology Station in this study, it was developed an indicator with temporary monitoring in established periods of energy consumption as well as percentages of final energy use to find a greater impact to stimulate and promote energy saving inside the selected buildings once the consumption with the greatest impact has been identified.

2. Energy consumption in the University

The energy consumption for the campus structures was defined mainly on the day they were built, more than 70 years ago, which means many of the electrical systems have not been updated to the RETIE's regulation. The buildings have old technology, the designs and devices are hard to optimize, there are different types of energy expenses, and the behavior of load variations is categorized as illumination, information display (like TV screens, video beams), computers and peripherals (laptops, PCs, printers, phones), refrigeration (snacks machines, water dispensers, refrigerators), heat production (stoves, coffee machines), communication network (routers), sound (speakers), the driving force (elevators, water pumps), HVAC (fans, air conditioners) and others such as pressure washers, hand dryers, floor polishers.

Different types of activities take place on the campus, some buildings are dedicated exclusively to some individuals. There are also buildings dedicated mainly to administrative tasks, others to classrooms and auditoriums, while others house laboratories, for example, the 411 Electrical and Mechanical laboratories building has laboratories and classrooms or 861 Uriel Gutierrez only has offices or Roberto Franco Tropical Biology Station has laboratories, classrooms, rooms, workshops and others. The daily dynamics of energy consumption in each case are different, this data was registered by the EMO (Environmental Management

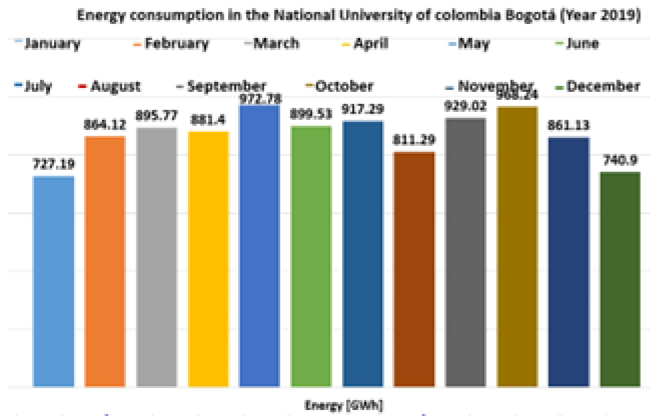

Figure 1. University's energy consumption 2019 (EMO 2019) [8].

Office) and is shown in Figure 1. The total measurement of the electrical energy consumption of the campus is carried out through an advanced energy meter located in the main substation until 2019.

A monthly variation can be observed given factors like occupancy, according to the academic calendar, for example, the month that shows the lowest consumption of the year is January, as it presents a difference of approximately 15% with May (that is the month with the highest consumption).

In Figure 2, the daily profiles are shown and obtained by processing the general information of the total consumption of the campus. These are known as Load Curves which show the energy consumption during the daylight hours and the patterns that are usually associated with the activities carried out together with their corresponding schedules.

The potential benefits of the characterization of the demand in the short term can highlight the monitoring of consumption to make a prediction. This allows to schedule maintenance, the identification and correction of corrupt or non-existent measurements of energy consumption. To allow the Planning of the system, the measurement was carried out from zero to 24 hours, it is possible to highlight; from Monday to Thursday are very homogeneous and Fridays, Saturdays and Sundays differ from the rest, with Sunday being the day with the lowest consumption, on the 20:00 to 6:00 time frame (night time), which registered a 45% of the maximum value of the day, a very high value considering that the operation of the university and development of its activities is normally daytime. It is necessary to review in greater depth the aspects that concern these consumption [8, 9].

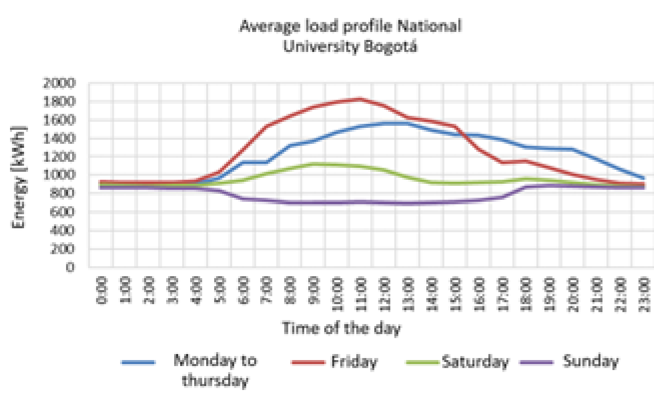

Figure 2. University's energy consumption in a common week in the year 2019 (EMO 2019) [8].

Two buildings of different types of consumption will be analyzed and with their parameters, the indicators of energy use will be considered, one is the Uriel Gutierrez Building (offices) and the other is the Roberto Franco Station (mixed use). The ISO 50001 standard proposes parameters to establish an Energy Management System (EMS) and defines the processes for improving energy performance under an energy baseline (LBE), which facilitates the monitoring and quantification of the improvements that may take place. The LBE accounts for energy performance for the duration of a reference, it is associated with a scenario before initiating energy performance improvements.

3. Key performance indicators

Energy baselines (LBE) can be developed to be reference points to quantify the changes in energy performance, the LBE indicates the state in which the energy performance is prior to the improvement actions so that the evolution can be determined and the impact of the actions for these indicators.

The indicators proposed in the development of this research are intended to be used with the support of the energy measurement that has been distributed throughout the campus. It will allow monitoring of energy efficiency within the Management System; the traditional indicators that are proposed for example in the industrial field do not allow to satisfy the specific needs of each building since the university belongs to the services sector and the main objective does not correspond to producing articles for sale, but rather it intends to provide educational service. For this indicators of final energy use are suggested.

In order to calculate the indicators, it is necessary to start from the availability of energy consumption data from buildings, which is why advanced measurement in each structure is important as this resource is expanded until the measurement of energy is achieved on every building, as a second step to guarantee a true and uninterrupted record for a better analysis of the data. The office also carries out the collection of information on the final uses of the electrical energy of the buildings through energy review reports.

The main indicator proposed in this study corresponds to the indicator of the final use of energy. It is not enough to contemplate studies on useful energy, this study could be assessed by reviewing the energy labels of the different electrical and electronic equipment to know its efficiency, in future interventions it is recommended to delve into this topic since useful energy is given as the electrical energy available to final consumers, that is, the product of the final energy and the efficiency of the equipment used in final consumption.

3.1. Energy Consumption in Building 861 Uriel Gutiérrez

The building was designed for the National Administrative Center for public functions, this is shown in the wide circulation halls. The offices and dependencies are distributed in two articulated volumes in the building, it has extensive reforms and adjustments in the administrative sector and it has 5 floors that have 66 offices.

The energy use attributed to the 861 Uriel Gutierrez Building, is made up of areas such as halls, computer areas, offices, bathrooms, service areas, and others where most of the load is concentrated and has an important contribution. The Table 1. provides a deeper look at this information.

The workers in the 861 structure work regularly from 7:00 am to 7:00 pm between Monday and Friday, on weekends and holidays, they do not work. Due to the situation in the country because of the COVID-19 pandemic, the facilities are not being used entirely. The information used on the energy consumption was obtained from a load survey of the facilities, carried out by the EMO (ENVIRONMENTAL MANAGEMENT OFFICE) guided by the guidelines defined in the ISO 50001 standard where the nominal power of the equipment is recorded and the approximate hours of use in a month estimated from interviews with the person in charge and observation by the team of the Office [10]. The lifted electric load has different measurement periods regarding the sample, on one hand, only the lifting electric load elaborated

Types of space	Number	Capacity (number of people)
Building service area	5	N/A
Auditoriums	2	20
Classrooms	0	0
Bathrooms	14	N/A
Cafeterias / Restaurants / kitchens	6	12
Commercial Premises	0	0

Table 1. Spaces found within the building 861 Uriel Gutiérrez (EMO 2019).

in 2019 is available and for the energy obtained, was the last available information at the moment when the study was made. The energy consumption registered by the building 861 Uriel Gutierrez is shown in Figure 3.

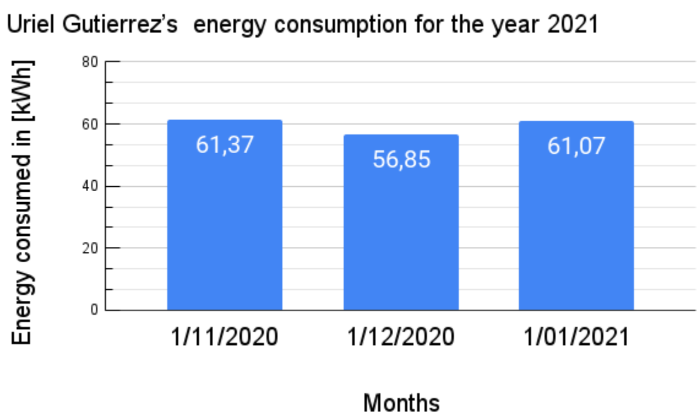

Figure 3. Building Uriel Gutierrez's energy consumption for November2020, December 2020, and January 2021 (EMO 2021) .

Figure 4 is the pie diagram made from the information collected in the building for end-uses of electrical energy, where the energy consumption for each type of equipment is connected to the energy net. In this case, the communications refer to racks, modems, phones, within the computers and peripherals, illumination, heat production, refrigeration and others make reference to elements that are not listed.

According to the electrical lifting load that was made in 2019, the station has a monthly energy consumption of 11974.52 [kWh] with a 6107[kWh] corresponding to the communication net followed by computer equipment at a 3592.4[kWh]. In the third place, we find the illumination equipment for the office work jobs with a 718.5[kWh] heat production at a 598.7[kWh] refrigeration with a 478.98[kWh] and others accounting for a 3% this information is shown in Figure 5, [11].

In Figure 5 and Figure 6, the daily consumption patterns follow the expected behavior according to office hours.

On Fridays, consumption decreases since the workday on Fridays is shorter and the activities in the afternoon are restricted by the university directives, Figure 7 shows this behavior. On Saturdays, consumption decreases because there are few classes and the working hours are half of the usual so fewer people attend the campus. This behavior is shown in Figure 8, and Figure 9 shows the energy consumed on Sundays, which is approximately 43% of the energy consumed on business days (Monday through Thursday), values that exceed those expected.

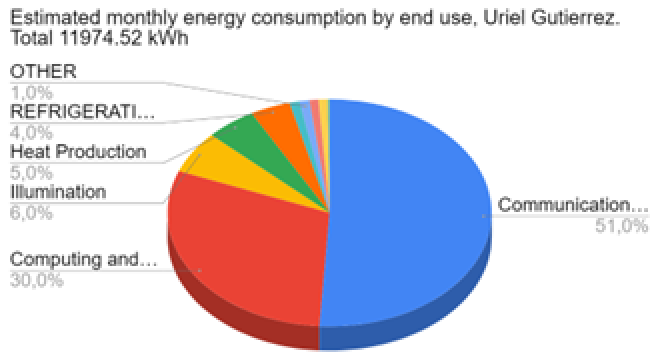

Figure 4. Estimated monthly energy consumption for the Building Uriel Gutierrez (EMO 2019).

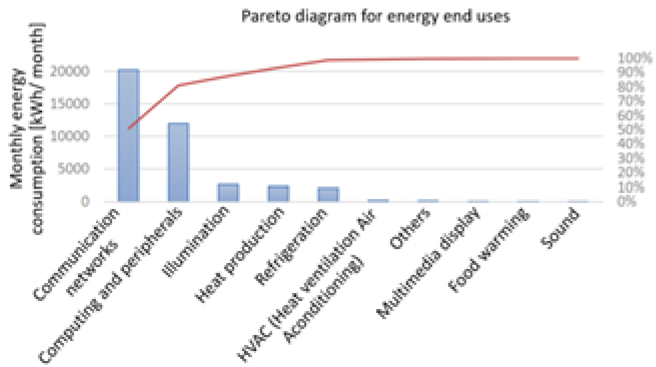

Figure 5. Pareto's diagram for final uses of energy in Uriel Gutierrez (EMO 2019).

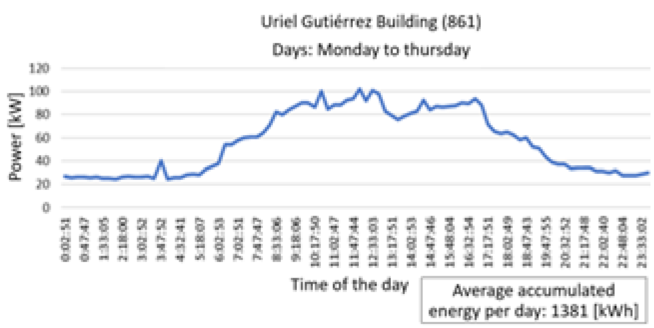

Figure 6. Energy consumption in the Building Uriel Gutierrez in a common week in Monday to Thursday in the year 2019 (EMO 2019).

High magnitude short duration load variations occur every day, including Sundays. The causes behind this behavior are still unknown [3, 4].

3.2. Energy consumption in Roberto Franco Station

The Station wants to develop, coordinate, and promote projects associated with the creation and dissemination of knowledge and conservation of biodiversity (ethnic groups, cultures, biota and others) of the Colombian Orinoquence region, also generating comprehensive, participatory and management instruments. The station is located in Villavicencio – Meta, it is 450 meters above sea level directly affecting the temperature of the area, which is between 20°C to 32°C different from Bogotá, where it is between 8°C - 19°C. The energy use attributed to the Roberto Franco Station is made up of areas such as halls, laboratories, computer areas, offices, lounges and rooms where most of the load is concentrated and has an

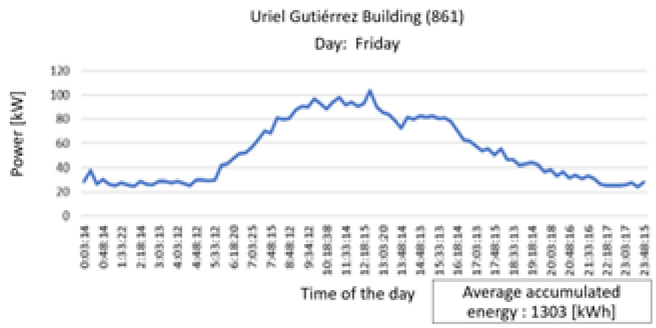

Figure 7. Energy consumption in the Building Uriel Gutierrez in a common week in Friday in the year 2019 (EMO 2019).

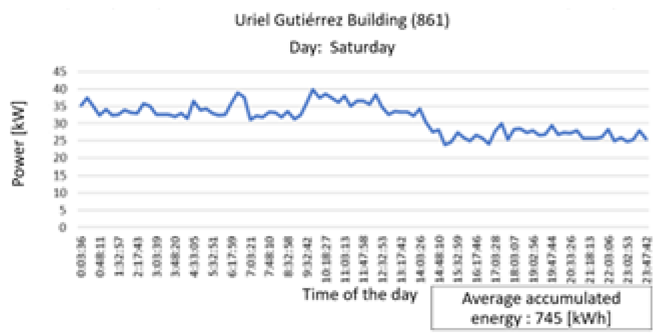

Figure 8. Energy consumption in the Building Uriel Gutierrez in a common week in Saturday in the year 2019 (EMO 2019).

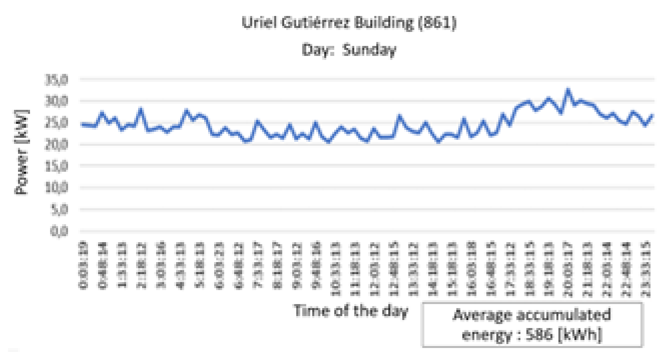

Figure 9. Energy consumption in the Building Uriel Gutierrez in a common week in Sunday in the year 2019 (EMO 2019).

important contribution, Table 2 shows this information more profoundly. The building works regularly from 8:00 am to 6:00 pm between Monday and Friday, on weekends and holidays, it does not work. Due to the situation in the country because of the COVID-19 pandemic, the facilities are not being used entirely.

The energy consumption registered by the Station Roberto Franco is shown in Figure 10. The information was obtained with the energy bill. November 2020 it registered 1897 kWh, December 2020 it registered 1900 kWh, and January 2021, 1720 kWh [12]. The lifting electric load has different measurement periods in regard to the sample, on one hand, only the study elaborated in 2021 is available and for the energy obtained, was the last available information at the moment when the study was made.

Types of space	Number	Capacity (number of people)
Waste area	1	N/A
Kitchen	4	2
Cellar	1	N/A
Waiting rooms	3	N/A
Offices	5	N/A
Lounges	7	N/A
bedrooms	8	8
library	1	4
Workshop	1	N/A
Audience	1	N/A
Hallways	2	N/A
Museum	1	N/A
Bathrooms	6	N/A
Parking	1	N/A

Table 2. Spaces found within the building.

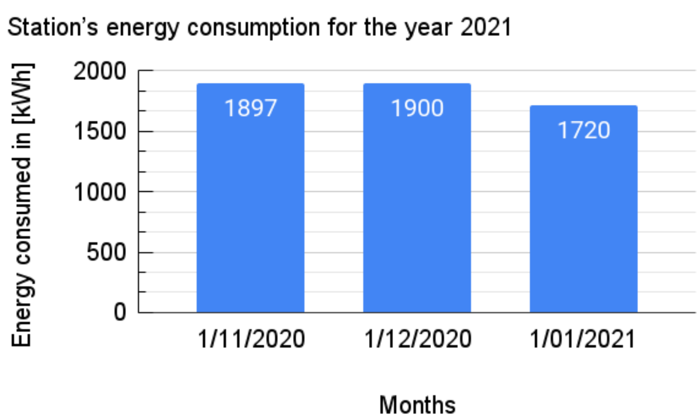

Figure 10. Station's energy consumption for November2020, December 2020, and January 2021 (EMO 2021).

Figure 11 is the pie diagram made from the information collected in the building for end-uses of electrical energy where the energy consumption for each type of equipment connected to the energy net is shown. In this case, refrigeration refers to refrigerators located in kitchens and snack bars. The work tools such as emery and a lathe can be found. computation makes reference to desktop computers and laptops that were found at the time of the survey, peripherals refers to fixed equipment such as computer speakers, printers, paper shredders and communication racks. Food preparation is referring to microwave ovens. and electric stoves. Finally, video reproduction equipment refers to televisions and video beams.

According to the lifting electric load that was made in the year 2021 the station has a monthly energy consumption of 1322.8166 [kWh], with a 63.22% corresponding to refrigeration due to the high presence of refrigerators that consume a lot of energy, followed by the tools of the complex with a 22.24% since its use is even greater than in other properties. In the third place is the computer equipment for the office work jobs with a 5.61% [13], the fans and air conditioners in the refrigeration section of rooms correspond to a 4.85% due to the temperature that Villavicencio normally handles, which is between 20 °C to 32 °C, that leads to the use of equipment to cool the air down allowing for the tasks to be performed comfortably. The

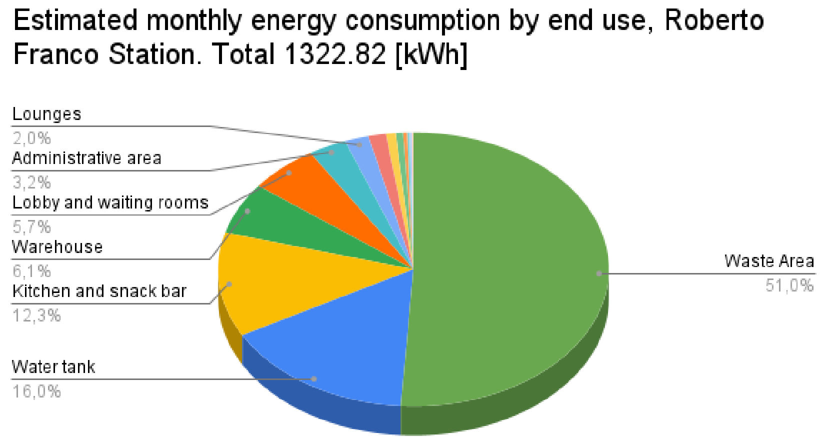

Figure 11. Estimated monthly energy consumption for Roberto Franco Station.

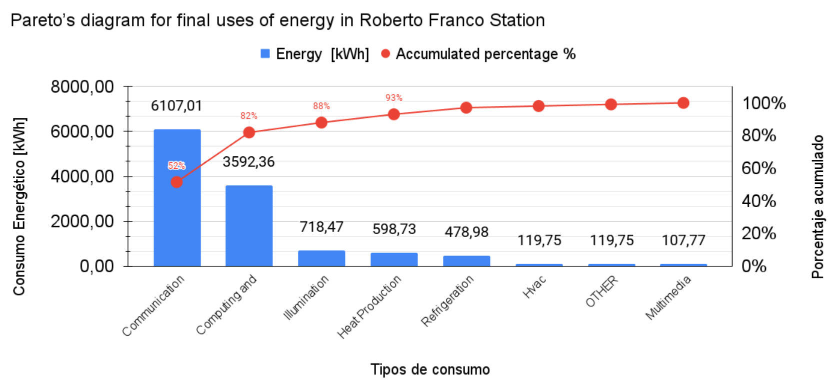

Figure 12. Pareto's diagram for final uses of energy in Roberto Franco Station.

next consumption corresponds to lighting with a 2.32% of the total with technologies of both LED bulbs and tubes and fluorescent tubes followed by elements for food preparation with a percentage of 0.93% followed by video playback with a 0.49% with elements for the projection of images such as video beam and TV. Finally, peripherals can be found in the last place, with a percentage of 0.34%, this information is shown in Figure 12.

4. Approach to energy baseline

The energy baseline is the quantitative reference that provides the status of the energy performance of a certain process, area or equipment. It is essential for the control of energy consumption and performance because it is a tool that helps to identify potential energy savings.

The baseline is established from the information of the initial energy review, from the historical data on the behavior of consumption. For this, a suitable period of time must be determined that reflects the changes in energy performance, a significant variable must also be related (for example, production in the case of industries). In cases where a variable such as production is not applied, the baseline is built from the energy consumption data. Considering the requirements set out above and the analysis of the historical consumption of the campus [14].

It is suggested to do semi-annual and annual analyses of the information; this is necessary to calculate the total energy consumed for that period. The value is obtained by calculating the sum of the energies associated with the daily curves, taking into account the corresponding number of days that make up each period, as given by,

$$\text{Total} \cdot \text{energy} \cdot \text{period} = \sum_{i=1}^{n} \left(d_i \cdot E_{\text{daily}_\text{i}} \right), \tag{1}$$

where d_i is the number of days type i in the period and $E_{\text{daily}_\text{i}}$ is the Daily energy consumed on day type i.

A baseline can be established for total campus consumption. Ideally, a baseline should also be established for each building on campus. This requires smart energy metering with reliable registration in each structure, the improvements achieved in energy performance can be quantified; if the organization has established related goals, the comparison between the LBE and the respective IDE will allow identifying the degree of progress towards the fulfillment of goals and the moment in which these have been fulfilled, a diagram about the energy performance is shown in Figure 6, it shows how these elements interact to quantify the improvements that are achieved in an organization thanks to the implementation of action plans and other elements of an EMS(Energy Management System) [15, 16].

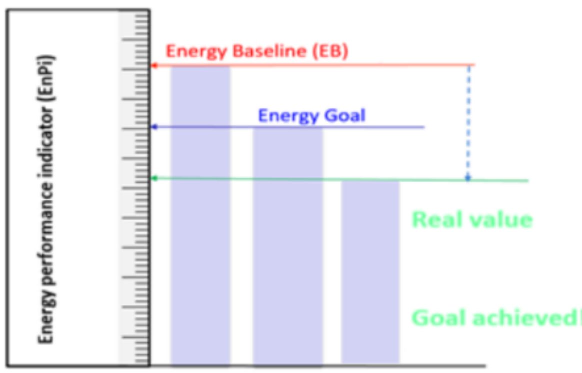

Figure 13. Energy performance improvement measurement using energy baselines and energy performance indicators (adapted from GTC ISO 50006) [17].

The energy performance indicators (EnPi) allow for establishing the energy behavior in a specific period of time, the monitoring of the standardized energy performance with the action plan of the ISO 50001 standard. After comparing the LBE with the value of a IDE obtained after implementing the actions associated with the 'Do' stage of an SGE (action plans, efficiency criteria in maintenance and operation, energy efficiency criteria in purchases and designs, etc.) the improvements achieved can be quantified and verify whether the actions taken play a fundamental role in saving or not, a process described in the Figure 13.

5. Defining the evaluation indicator by type of building

Energy performance indicators (IDE) are quantitative and measurable values that are established to track, monitor and control energy performance over time. The IDE must be able to be monitored in time intervals consistent with the energy policies of the University; An IDEs based on intraday smart metering is proposed that is related to hourly energy consumption [18, 19]. If energy consumption has or does not have a consistent plan, it must be determined by KPIs (Energy Key Performance Indicators) that must be able to be monitored in intervals that are congruent with energy regulations [10, 20]. KPIs must have some features like relevance (where the goals have to be described), availability, they must be calculated based on available information, they have to be simple, reachable for whoever interprets it, be valid, be formed by parameters that correlate substantially, specificity, actually reflect what needs to be measured, reliability, they have to identify several situations through their change, they must present suitability (far enough extent to assess) and have the ability to fully express what they estimate [21, 22].

For the Eq. (2) is needed information about the energy consumption of the building and the different end-uses, that, it is necessary to carry out an electric load survey to be able to carry out the IDE corresponding to energy by end-use, considering the ISO 50001, the energy performance indicators are given by,

$$IDE(Euse) = \frac{\text{Energy}_{\text{finaluse}}[kWh]}{\text{Energy}_{\text{total}}[kWh]}, \tag{2}$$

that can be applicable to any type of building, regardless of whether it is for classrooms, offices, laboratories or mixed. Table 3 shows the end use energy consumption in the Roberto Franco Station, where the communications network is the final use with the greatest impact on consumption, this behavior will be directly related to the end use indicator.

	Consumption[KWh]		
Final energy use	**Nov 2020**	**Dec 2020**	**Jan 2021**
Communication networks	967	969	877
Computing and peripherals	569	570	516
illumination	114	114	103
Heat Production	95	95	86
Refrigeration	76	76	69
Hvac	19	19	17
OTHER	19	19	17
Multimedia display	17	17	15
Food warming	17	17	15
Sound	4	4	3

Table 3. Energy consumption per final use for Roberto Franco Station.

If the consumption energy values are taken according to the final use and they are plotted according to Eq. (1), also if it is taken into account that the distribution of the elements is the same, maintaining the same percentages in the final uses, it could be assumed that month by month this indicator would not change but it would give an indication of the measure of energy spent in the final uses. The above indicator can be presented graphically, calculating their value for each hour of the day and presented by day, week or month. It is necessary to validate these indicators with real and reliable information to choose the ones that will be used in each case.

Figure 14 shows the relation between the final use energy consumption and the total energy consumption. In the Uriel Gutierrez Building are three main areas to improve its high energy consumption; in the Communications area,the Computer and peripherals and the illumination.

This indicator shown in the Figure 15 the relation between the energy consumption areas and the total energy consumption. In the Roberto Franco Station are three main areas; the Waste area, the water tank and the kitchen.

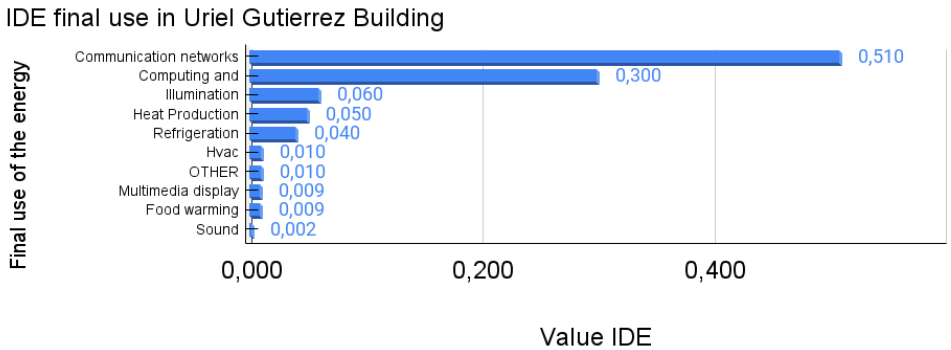

Figure 14. IDE (E use) Uriel Gutiérrez building.

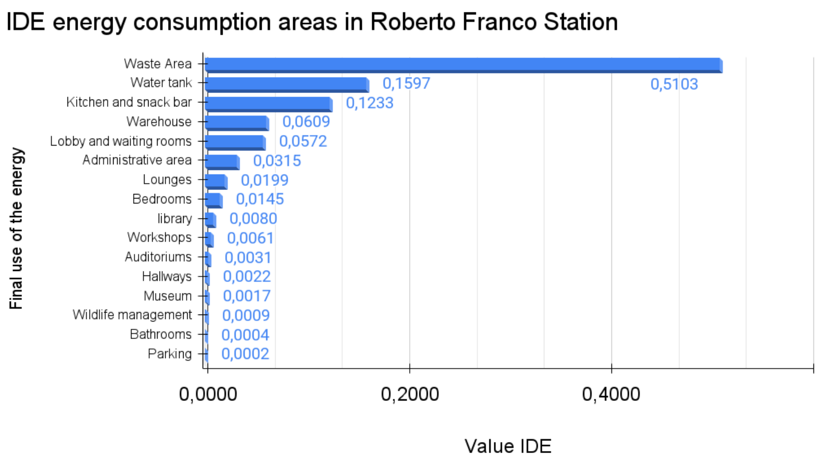

Figure 15. IDE (E use) Roberto Franco Station.

6. Conclusion

The indicator of final use of energy based on consumption can be implemented in any structure. It is a strong indicator that tells us directly the energy consumed associated with the user, discriminated by the destination of energy use and allows traceability in where the most important electrical energy expense occurs, so its implementation can be seen associated with the three study buildings, that is, it works for the different types of buildings Administrative buildings, laboratories, classrooms, Storage, Sports, Libraries. An intelligent energy measurement system is required that feeds the energy performance indicators, in the same way, to be able to implement the IDE by uses it is necessary that an electrical load survey of each building is carried out at the university and the typology of each building, must be known.

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References

[1] Unidad de eficiencia energética. Memoria de actividades periodo 2019. Technical report, Universidad Rey Juan Carlos España, 2019.

[2] Alberto Jáñez Morán, Paolo Profaizer, María Herrando Zapater, María Andérez Valdavida, and Ignacio Zabalza Bribián. Information and communications technologies (icts) for energy efficiency in buildings: Review and analysis of results from eu pilot projects. *Energy and buildings*, 127:128–137, 2016.

[3] Lamberto Tronchin, Maria Cristina Tommasino, and Kristian Fabbri. On the "cost-optimal levels" of energy performance requirements and its economic evaluation in italy. *International Journal of Sustainable Energy Planning and Management*, 3:49–62, May 2014.

[4] Sandra Téllez-Gutiérrez, Oscar Duarte-Velasco, and Javier Rosero-García. Demand-side management strategies based on energy key performance indicators in real-time: Case study. *CT&F-Ciencia, Tecnología y Futuro*, 10(1):5–16, 2020.

[5] Lamberto Tronchin, Maria Cristina Tommasino, and Kristian Fabbri. On the "cost-optimal levels" of energy performance requirements and its economic evaluation in italy. *International Journal of Sustainable Energy Planning and Management*, 3:49–62, 2014.

[6] Universidad Nacional de Colombia Sede Bogotá. Situación física de algunos edificios de la ciudad universitaria / universidad nacional de colombia sede bogotá, 2012. Available at http://www.unal.edu.co/Postmaster/2012/Planta%20fisica%20sede%20Bogota.pdf.

[7] Alfamicro. Smart campus – building-user learning interaction for energy efficiency., 2021.

[8] Sandra Téllez and Omar Prias. Oficina de gestión ambiental, informe: Desempeño energético: Diagnóstico global y propuesta de indicadores y línea base. Technical report, Universidad Nacional de Colombia Sede Bogotá, 2019.

[9] Oficina de Gestión Ambiental. Indicadores energéticos componente antrópico, 2022. Available at https://ogabogota.unal.edu.co/componente-antropico/energia/indicadores/.

[10] Adriana Palencia, David Rojas, Juan Campos, and Omar Prias. Implementacion de un sistema de gestion de la energia, guia con base en la norma iso 50001. *Red Colombiana de Conocimiento en eficiencia energética - RECIEE*, 2:28–37, Jan 2019.

[11] Sandra Téllez, Omar Prias, and Luis Miguel Venegas. Informe técnico final: Revisión energética edificio 861 - uriel gutiérrez. Technical report, Oficina de Gestión Ambiental, 2020.

[12] Oficina de Gestión Ambiental Indicadores energéticos. Cargas y eficiencia energética en edificios, 2021. Available at https://ogabogota.unal.edu.co/componente-antropico/energia/cargas-energeticas/.

[13] Sandra Tellez and Pierre Medina Wintaco. Oficina de gestión ambiental, informe técnico final: evisión energética estación de biología tropical roberto franco (e.b.t.r.f.). Technical report, Universidad Nacional de Colombia Sede Bogotá, april 2021. Available at https://ogabogota.unal.edu.co/.

[14] Dasheng Lee and Chin-Chi Cheng. Energy savings by energy management systems: A review. *Renewable and Sustainable Energy Reviews*, 56:760–777, 2016.

[15] Jaime D Pinzón, Alejandra Corredor, Francisco Santamaría, Johann A Hernández, and Cesar L Trujillo. Implementación de indicadores energéticos en centros educativos. caso de estudio: Edificio alejandro suárez copete-universidad distrital francisco josé de caldas. *Revista EAN*, 77:186–200, 2014.

[16] Henri Makkonen, Ville Tikka, J. Lassila, Jarmo Partanen, and P. Silventoinen. Green campus-energy management system. *International Conference and Exhibition on Electricity Distribution (CIRED 2013)*, pages 1–4, 01 2013.

[17] Sandra Téllez and Omar Prias. Oficina de gestión ambiental, informe: Desempeño energético: Diagnóstico global y propuesta de indicadores y línea base. Technical report, Universidad Nacional de Colombia Sede Bogotá, 2019.

[18] Alejandro Gaviria Arias and Milton Favian Sandoval Mera. Implementacion y evaluacion de un sistema de gestion de uso eficiente de energia en la universidad autonoma de occidente. Master's thesis, Universidad Autonóma De Occidente, 2012.

[19] Choong Weng Wai, Abdul Hakim Mohammed, and Low Sheau Ting. Energy management key practices: A proposed list for malaysian universities. *International journal of Energy and environment*, 2(4):749–760, 2011.

[20] SV Sreedevi, Prakash Prasannan, K Jiju, and IJ Indu Lekshmi. Development of indigenous smart energy meter adhering indian standards for smart grid. In *2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy (PESGRE2020)*, pages 1–5. IEEE, 2020.

[21] Zoran Morvaj and Vesna Bukarica. Immediate challenge of combating climate change: effective implementation of energy efficiency policies, 2022. Avaliable at https://www.osti.gov/etdeweb/biblio/21403731.

[22] D Goldstein and Joe A Almaguer. Developing a suite of energy performance indicators (enpis) to optimize outcomes. *Proceedings of the 2013 ACEEE Summer Study on Energy Efficiency in Industry, Washington, DC, American Council for an Energy-Efficient Economy*, 2013.