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Implementation of an energy management system based on the ISO 50001 standard in a hospital clinic

Implementación de un sistema de gestión de la energía con base a la norma ISO 50001 en una clínica hospitalaria

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Abstract

In this article, an investigation was developed in a clinic located in the municipality of Veracruz, Ver. Mexico, with the objective of implementing an Energy Management System based on the Mexican official standard NMX-J-SAA-50001-ANCE-IMNC-2019, which is consistent with the international standard ISO 50001. The study was conducted in 2020 using historical consumption data from previous years, due to the pandemic situation that developed in later years, which was atypical for this type of study. The results of the plan for the implementation of the EnMS showed that the energy source that generates the highest consumption and cost is electricity. Similarly, it was determined that the level of compliance with the standard is 38%, obtained from the diagnosis covering the Plan-Do-Check-Perform stages. Based on the energy performance indicators and the energy baseline, it was established that the most significant variables are consumption/days, where it was determined that there is a possibility of saving 15.85% in energy consumption.

Energy management system, Hospitals, PHVA

Resumen

En el presente artículo, se desarrolló una investigación en una clínica localizada en el municipio de Veracruz, Ver. México, con el objetivo de implementar un Sistema de Gestión de Energía con base a la norma oficial mexicana NMX-J-SAA-50001-ANCE-IMNC-2019, la cual tiene concordancia con la norma internacional ISO 50001. El estudio fue realizado durante el año 2020 utilizando datos históricos de consumo de años previos al mismo, debido a la situación de pandemia que se desarrolló en años posteriores y que fueron atípicos para realizar este tipo de estudios. Los resultados del plan para la implementación del SGEn mostraron que la fuente de energía que mayor consumo y costo genera es la energía eléctrica. De igual manera, se determinó que el nivel de conformidad con la norma es de un 38%, obtenido del diagnóstico que abarca las etapas de Planificar-Hacer-Verificar-Actuar. A partir de los indicadores de desempeño energético y de la línea de base energética, se estableció que las variables más significativas son las de consumo/días, donde se determinó que existe una posibilidad de ahorro del 15.85% en consumo energético.

Sistema de gestión de energía, Hospitales, PHVA

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Introduction

Richard et al (2017) mentions that energy is fundamental to an organization's operations, so it can represent a significant cost, regardless of its activity. However, in addition to economic costs, energy can impose environmental and social costs due to resource depletion and contribute to problems such as climate change.

For its part, the NMX-J-SAA-50001-ANCE-IMNC-2019 standard, when referring to energy, talks about the types of energy that can be used in equipment or in a process, such as electricity, fuels, steam, heat, compressed air, and other similar means, including the renewable type. Then, in Mexico, as indicated by Chatellier Lorentzen & McNeil (2019) non-residential buildings are the largest consumer of energy in the country presenting an electricity consumption of 66.9 TWh during 2017.

Table 1 shows the electric energy consumption rates by type of building. It should be noted that the final uses of electrical energy in non-residential buildings are mainly for air conditioning and lighting, while in the industry it is used in motors to drive different devices. The warm-humid region mentioned in the table includes the states of Veracruz, Tabasco, Campeche, Yucatan, Quintana Roo, Guerrero, Oaxaca, Chiapas, and Colima. The clinic analyzed in this study is located in the state of Veracruz. Table 1 also shows that the main energy consumers are supermarkets and hospitals.

Buildings	kWh/m^2-year
Hotels	281
Offices	199.7
Schools	98.2
Hospitals	393.4
Restaurants	336.3
Stores	229.3
Supermarkets	443.1
Cinemas	242.8

Table 1 Rates of electrical energy consumption used by building type in the warm humid region of the country
Source: adapted from Chatellier Lorentzen & McNeil (2019)

In particular, the energy impact of the health sector in Mexico, recorded an energy consumption of 16.8 million MWh in electrical energy, 18.9 million MWh in fossil energy and the emission of 12.7 million tons of CO_2 per year, according to data from the Ministry of Energy (SENER, 2015), registering Veracruz as the state with the third highest energy cost, preceded by Mexico City and Puebla, as can be seen in figure 1.

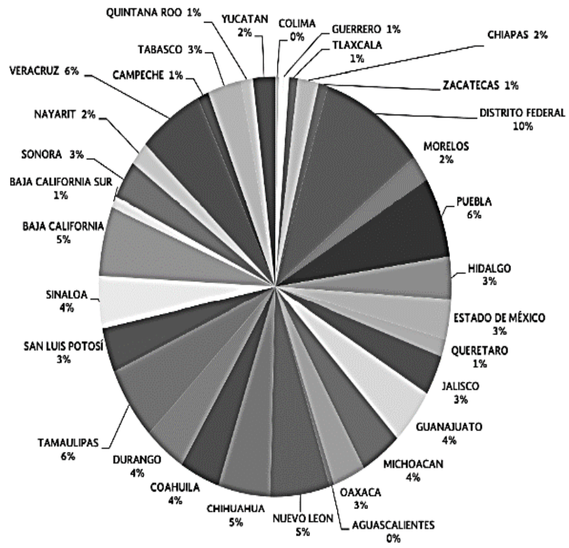

Figure 1 Energy cost in Health Care Units by state
Source: SENER (2015)

Therefore, it is recommended to take actions that improve energy efficiency and provide quick benefits to an organization, such as maximizing the use of its energy sources, which reduces both its cost and consumption, while positively contributing to the reduction of energy resource depletion and the mitigation of the effects of energy use worldwide, such as global warming ISO 50001 is based on the management system model and is the most widely used standard in the world. Jiménez Borges et al. (2018) mentions that more than eighty countries have adopted it as a national standard, given that ISO is the International Organization for Standardization and offers practical tools for the three dimensions of sustainable development: economic, environmental, and social.

The purpose of this standard is to enable organizations to establish systems and processes necessary to improve energy performance, including energy efficiency, use, and consumption. In order to reduce greenhouse gas emissions, energy costs, and other related environmental impacts, through systematic energy management (ISO, 2011).

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Mexico has achieved the reduction of energy intensity thanks to the implementation of Mexican Official Standards (NOM) that came into force in the mid-1990s (De Buen Rodríguez, et al. , 2017). The present work is based on the NOM NMX-J-SAA-50001-ANCE-IMNC-2019, which is consistent with the International Standard ISO 50001, *Energy management systems - Requeriments with guidance for use*, ed2.0 (2018-08).

The Mexican standard defines a management system as a set of elements of an organization that interact to establish policies and processes to achieve objectives, taking into account the organization's structure, planning and operations.

Therefore, an Energy Management System (EnMS) is a system for establishing an energy policy, action plans, and processes to achieve energy objectives and targets. It uses interrelated elements such as Energy Performance Indicators (EPIs) and Energy Baselines (EBCs) to demonstrate measurable improvements in energy efficiency.

Energy efficiency is making the best use of available resources. It is the ratio or quantitative relationship between an output and an energy input. It is determined by factors such as:

1. Energy culture, which corresponds to the level of information existing in the organization and company policy.

2. The maintenance of equipment to achieve optimum yields.

3. Energy control, which involves measurement methods and the implementation of appropriate administrative processes.

4. Technological innovation or updating of technical resources.

De Buen Rodríguez (2020) indicates that the two basic actions for energy efficiency are: the modification of habits or best practices, which consist of using equipment when needed and in accordance with the need for energy service; and the replacement of technology with more efficient equipment.

Therefore, the efficient use of energy must obey a programmed process with the participation of all the organization's personnel. The successful implementation of an EnMS depends on the commitment of all levels of the organization, especially senior management.

The EnMS described in this standard is based on the plan-do-check-perform (PDCP) continuous improvement framework and is incorporated into existing organizational practices.

Methodology

This section presents the diagnostic analysis of the clinic by means of proposed questionnaires that evaluate its compliance, starting with the general definition of each component of the PDCA continuous improvement framework.

Energy performance indicators (EnPI)

To carry out each of the phases, we worked directly with the clinic director, administration, and maintenance personnel; in accordance with the standard of involving senior management in the continuous improvement process, surveys were conducted on the following points:

Planning

- Preliminary activity: Initial diagnostic analysis.

- Organizational context: Determine external and internal factors affecting energy performance.

- Leadership: Communicate to staff about the implementation of the EnMS.

- Planning: Identify activities that affect energy performance, set energy goals and objectives, identify energy types, evaluate energy use and consumption, identify USE, identify EPIs and EBCs, identify opportunities for improvement and document.

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To do

- Support: Train personnel on EnMS, document training processes.

- Operation: Establish equipment operation criteria and communicate them to relevant personnel, take into account design and installation improvement opportunities, and document the operation process.

Checking

Performance evaluation: Verify that the USEs determine energy performance, implement energy performance monitoring and analysis methods, document information generated, and plan an audit program.

Performing

Improvement: Investigate causes and correct nonconformities, review by top management, record and document information generated.

In accordance with the above, the following results were obtained.

For the Planning phase of the organization's context section, it was determined that 86% of what is established in the standard is fully complied with, in leadership with 84%, and for planning, the results were similar, with 34% total compliance, 33% partial compliance, and 33% non-compliance.

In the To do phase, regarding support, a total compliance of 33% was established and 60% for partial compliance; and for operation, only 12% compliance and 63% partial compliance were determined.

For the Checking phase, with respect to performance evaluation, only 8% is complied with, while 46% is partially complied with.

Finally, in the Act phase, in the area of improvement, considering that the clinic had not implemented an EnMS before, there is no methodology to identify and correct nonconformities, so 80% do not comply, while the remaining 20% comply partially.

Results

In general terms, a summary of compliance and non-compliance with the standard can be seen in the diagram shown in Figure 2 below.

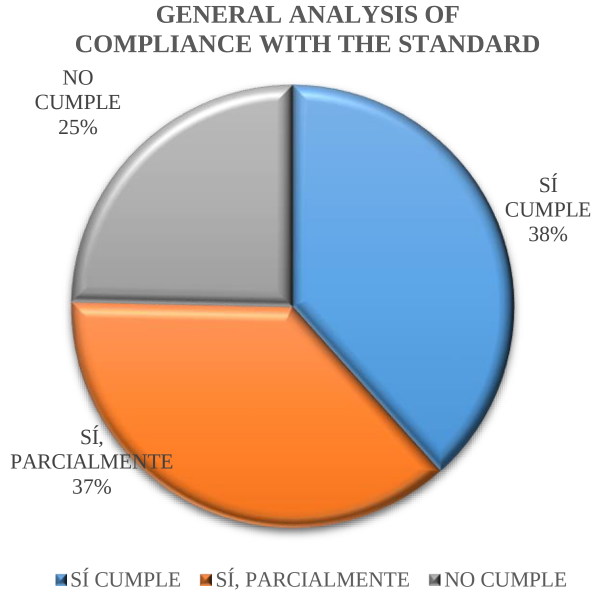

Figure 2 Results of the diagnostic analysis of the standard in the clinic
Source: Own elaboration

Attention to nonconformities in the EnMS.

Based on the results of the surveys, we proceeded to address the nonconformities of the standard, for which a schedule of activities was established. It should be noted that the standard is flexible during the execution of the PHVA cycle, so it allows modifying or improving the activities to be carried out depending on the importance given by the organization to the execution of the plan.

The activities to be incorporated in the organization to comply with the schedule are described below.

Planning

It is important to identify factors that influence the context of the organization, such as financial, legal, social, external and internal factors. In terms of leadership, it is necessary to incorporate the topic of energy savings in conversations and in the decision-making process with management staff, in order to integrate the EnMS into the organization's philosophy. Otherwise, the EnMS would only remain at a documentary level without being applied in daily work practices.

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For the planning section, it is first necessary to perform an energy performance assessment. For this, Flores Díaz et al. (2016) indicate that organizations should identify legal requirements and those that are linked to energy use, consumption and efficiency. For the detection of energy performance improvement opportunities, energy consumption and use data were collected, including relevant variables. Also, energy sources were identified, including diesel fuel, LP gas and electricity. Figures 3 and 4 show the forms of utilization and storage for the first two mentioned above.

Figure 3 Emergency electric generator of the clinic, operated with diesel
Source: Own elaboration

Figure 4 Clinic's stationary LP gas tank for restaurant and laundry use
Source: Own elaboration

Regarding electrical consumption, the distribution of the power (W) of connected loads is as follows: the greatest electrical demand corresponds to the central or package air conditioning systems with 31% of the clinic's total power; in second place are the X-ray area and the operating room area, both with 17%, while the administrative area corresponds to 8%.

Figure 5 shows a diagram of the costs generated by water and electricity consumption during 2019, due to the amount of information available and because, due to the pandemic situation in the following years, a decrease in the usual flow of work was generated.

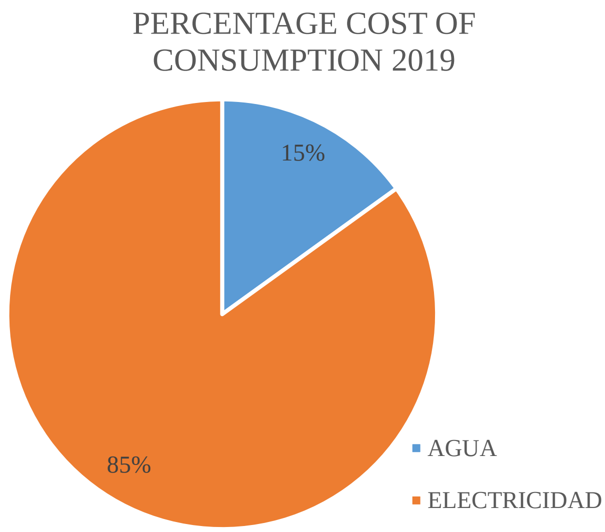

Figure 5 Percentage cost of energy sources in the clinic during 2019
Source: Own elaboration

Considering that the highest costs were for electricity consumption, it can be determined that the study to be carried out to implement the EnMS will be focused on the electrical area.

Based on the data obtained about the loads connected in the clinic, the USE (significant energy uses) can be determined. Central or package air conditioners (AAC) stand out with 9063.12 kWh/month, followed by mini splits with 3183.02 kWh/month and elevators with 2168.64 kWh/month. Table 2 shows the consumption of specific medical equipment.

EQUIPMENT	kWh/month
Fixed X-ray	267.86
Autoclave	121.71
Compressor	63.92
Oxygen plant	38.35
Electrocautery	30.17
Anesthesia machine	10.29
Yellow bulb RX	9.72
Ultrasound	9.72
Surgical Light	7.54
Ring light	5.76
Incubator	5.14
Ophthalmoscope/Otoscope	4.08
Negatoscope	1.48
Defibrillator	0.4
Stretchers light	0.35
Computerized radiography	0.2

Table 2 Medical equipment
Source: Own elaboration

Baseline

According to the ISO 50001 (2018), the energy baseline is defined as a "quantitative reference that provides the basis for comparison of energy performance."

According to the Technical Guide for the implementation of Energy Management Systems in the framework of a Learning Grid (Richard et al, 2017) the energy baseline can be represented by absolute energy consumption values or normalized consumption values by means of relevant variables (climate, production data). It can be the historical consumptions or the consumptions calculated considering that the organization would not have carried out actions to improve energy performance. A period appropriate to the use and consumption of energy in the organization must be considered.

The most common is to consider the cycle of the relevant variables defined in the energy performance diagnosis, generally 12 months, for climatological data or the company's production cycle. Some organizations change their energy baseline every year and usually measure the current year's results against those of the previous year. In this case, this practice should be documented. Do not forget that the energy baseline is established according to the scopes and limits defined for the EnMS, i.e., if the EnMS does not include all areas of the plant, the energy baseline cannot be the total energy consumption of the plant.

The energy baseline (EBCs) reflects a specific period of time as a reference point, in this case it was the consumption recorded in the invoices during 2019. While, the proposed energy performance indicators (EPIs) was: kWh/days, kWh/patient, kWh/temperature. Together, the EBCs and the EPIs will function as a tool for continuous monitoring of energy performance.

In table 3 the values and days of consumption were obtained from the invoices provided, the average monthly temperature for the state of Veracruz was consulted in METEORED and the number of patients was an estimated 1.5 patients attended per day at the clinic, the number of days billed was 1.5.

Month	Consumption [kWh]	Days	°C	Number of patients
January	8000	-	23	-
February	7200	31	23	46.5
March	9280	-	26	-
April	**8160**	**28**	**29**	**42**
May	13280	-	29	-
June	15360	32	29	48
July	14240	29	29	43.5
August	13600	-	28	-
September	16320	33	28	49.5
October	13920	30	27	45
November	**11200**	**33**	**25**	**49.5**
December	**9760**	**29**	**22**	**43.5**

Table 3 2019 data to determine EBCs and EPIs
Source: Own elaboration

The proposed NDIs are intended to analyze the relationship between consumption and the independent variables. It is important to mention that the EPIs can be changed, increased or deleted depending on the needs of the clinic and/or taking into account if there are other relevant factors that could arise in the course of the implementation of the EnMS.

In many cases, a simple linear relationship is adequate to determine the relationship between variables. The ISO 50006 (2014) explains that, in a scatter diagram, if the points appear to be scattered around the trend line, it is indicative of the presence of relevant variables. On the other hand, if the points appear as a random cloud with no obvious relationship, it is likely that the variable is not relevant.

For this case, the response variable was defined as consumption in kWh, and the independent variable as the days billed, number of patients and average ambient temperature. Lara Izaguirre et al. (2019) mentions that the coefficients of determination (R^2) indicate the proportion of variance of the variable y in relation to the independent variable x. Where if R^2 tends to zero, the model does not adequately represent the data. But if it tends to 1, the model adequately represents the data explained by the linear regression model.

For the first case, the consumption data were evaluated with respect to the days billed, as shown in figure 6.

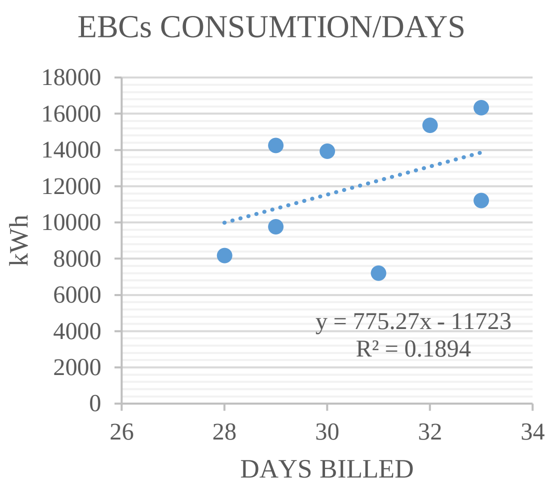

Figure 6 EBCs calculated with EPIs kWh/day
Source: Own elaboration

It was found that the variable days billed is not very significant for electricity consumption, based on the correlation coefficient R^2 of 0.1894. For it to be significant, the value should be in the range of 0.7 to 1.

Figure 7 shows the estimated target line for the same data.

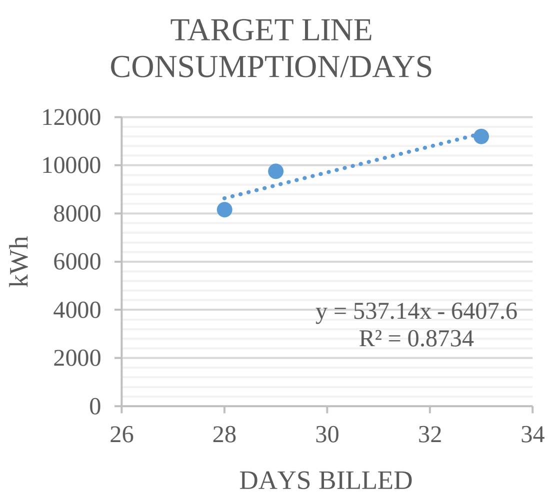

Figure 7 Estimated target line with EPIs kWh/day
Source: Own elaboration

From the baseline, the points of best performance were obtained, i.e., the months with the lowest billing (marked in bold in table 2), which would represent the efficiency that can be achieved in the clinic. The R^2 coefficient obtained based on these points is 0.8734, indicating that there is a valid relationship between consumption and days billed. It should be remembered that these calculations are only estimates, since they depend on the clinic's commitment to implement energy efficiency actions.

With the equations obtained from the EBCs and the target line, the monthly savings potential can be estimated, assuming that x is equal to 30 days:

Where the target line has the equation:

$$y = 537.14x - 6407.6 \quad (1)$$

$$y = 9706.6$$

And where the EBCs has for equation:

$$y = 775.27x - 11723 \quad (2)$$

$$y = 11535.1$$

The electrical consumption saving (ECS) would be:

$$ECS = 11535.1 - 9706.6$$

therefore:

$$ECS = 1828.5\ kWh/month$$

which corresponds to 15.85%.

Performing the same analysis with the kWh/patient and kWh/temperature EPIs to continue with the evaluation of the relationship between consumption and the independent variables, it was observed that the correlation coefficient in all cases was less than 0.7, which established that they were not relevant indicators for the study. In the case of consumption/patient, it is recommended that a record be kept of the number of patients attended in order to estimate a more significant relationship. Although the R^2 coefficient is low for the aforementioned indicators, it should be noted that the behavior of the line is due to the fact that the highest consumption was due to both the number of patients attended and the average temperature in November, followed by December, which had a higher number of patients compared to April, despite having a low average temperature of 22°C, as shown in table 3.

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Based on the analyzed, energy goals and objectives were proposed as energy goals and objectives to reduce energy consumption by at least 15%, corresponding to 1730.4 kWh/month, such amount is equivalent to 1.007 Ton of CO_2 eq/MWh that would no longer be emitted to the atmosphere, applying the factor 0. 582 Ton of CO_2/MWh of Emission of the National Electric Sector of 2017, whose value updated to 2021 is 731.9592 Ton of CO_2 eq/MWh using a factor of 0.423, reported by the Energy Regulatory Commission (CRE, 2021).

At the same time, the measures proposed to be implemented are as follows:

- Disconnect equipment at the end of working hours to avoid "vampire" consumption.
- Turn off lights in areas that are not in operation.
- During the day, take advantage of natural light and do not turn on lights (depending on the work area, such as offices and consulting rooms).
- Close the doors of unoccupied facilities to reduce the strain on the air conditioners.
- Replace window air conditioners with mini splits.
- Replace light bulbs with LED bulbs in facilities under renovation.
- Reduce consumption of air conditioners during cold seasons.
- Post signs to remind important aspects of the operation of the facilities and allow energy savings ("Remember to turn off the light when leaving", "Disconnect your computer before leaving", etc.).
- Keep a weekly record (at most) of the meter to visualize the progress of the system.

To do

In terms of support, it is recommended to differentiate the profile of people and create a training program accordingly, so that everyone has general knowledge about the concepts of energy, energy efficiency, USE, etc., but only personnel in specific areas such as the operating room and X-ray, have access to information on maintenance and operation of their work equipment for efficient management that does not compromise their safety. This is because the staff influences the energy performance of the clinic, therefore, they need to be competent and aware of the impact they have on the operation of the EnMS. Regarding operation, it is important to determine the operational control criteria and maintenance criteria. These criteria serve to identify activities that affect equipment performance. However, they can also be applied for the design of new facilities, or for modifications of equipment, systems and processes that have an impact on energy performance. For these cases, internal communication between energy procurement personnel (in the case of implementing renewable energy sources) and those who manage energy performance activities must take place in order to prevent and control risks.

Checking

To verify, in terms of performance evaluation, it is known that a continuous evaluation system allows for the timely identification of the actions necessary to ensure compliance with energy objectives and goals. In this case, it was proposed to reduce monthly electricity consumption, so weekly monitoring is recommended to observe whether energy deviations are generated. In order to review the effectiveness of the EnMS, it is necessary to implement an internal audit process. Once the audit has been carried out, corrective and preventive actions must be implemented.

Performing

In the area of improvement, the review by top management should take place shortly after completion of the energy performance assessment together with the inventory of opportunities for improvement, or until after the internal audit has been performed.

The results of this review should be: recommendations for the new expected energy consumption (for the next period), changes in the EnMS, updates in the energy policy and in the established objectives.

This is due to the fact that an EnMS is permanent, so the continuous improvement of the process and its design and implementation activities must be guaranteed.

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Conclusion

In Mexico, non-residential buildings such as supermarkets and hospitals are the main energy consumers. Therefore, implementing an energy management system (EnMS) in a health care unit helps to mitigate the problem with greenhouse gases and save resources, both energy and economic.

In the case study, electricity was identified as the main source of consumption, as well as the USE determined by central air conditioners, mini splits, elevators and computer equipment. The EPIs as energy consumption in kWh per month evaluated by days billed, temperature and average number of patients attended, which allowed determining EBCs during 2019 and proposing an energy target line. A 15.85% savings in energy consumption was calculated, which can be achieved as long as senior management remains committed and energy efficiency measures are implemented, as well as communication with the clinic staff to ensure the success of the EnMS.

If the observations are taken into account, as well as the implementation of the proposed recommendations, the clinic can be re-evaluated to identify the new level of compliance with the standard, with the expectation of exceeding the 38% obtained in the initial diagnosis. If a high percentage is obtained and if it is the clinic's wish, an internal audit could be carried out in order to obtain an official ISO 50001 certification.

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