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Energy efficiency management according to ISO 50001: A case study in the brick industry

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Abstract

This research presents the methodology and results of implementing energy efficiency management in the brick industry, given the problem of high electricity consumption in the production processes. Based on the ISO 50001 standard, energy efficiency management has as its structure the PHVA methodology of the Deming cycle and indicators that meet the standard's requirements. Energy consumption in tons of bricks produced is established as an indicator, allowing proposals for improving performance and efficient energy use, as well as implementing a management system, minimizing energy waste, and implementing engineering tools in the processes. Energy consumption data were collected before and after implementation, these data were analyzed, and the decrease in monthly electricity consumption was verified through a pre-test conducted at the beginning of the research, recording parameters of 543,800 kWh. After implementation, a post-test was conducted, recording parameters of 500,296 kWh, resulting in a saving of 43,504 kWh; in monetary units, the saving is S/18,067.21 for each month of production. Obtaining an annual decrease of 522,048 kWh, represented in monetary units S/216,806.53 (US$ 59,891.30 exchange rate S/3.62). Therefore, it is proven that implementing the methodology is feasible through the management of energy efficiency based on ISO 50001 and contributes strategically to the brick industry by increasing the efficiency associated with the reduction of 8% monthly electricity consumption.

Keywords: Energy efficiency management, ISO 50001, energy performance, energy consumption improvement.

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1. Introduction

The world is facing a great need to produce energy with less carbon emissions; in order to meet the demand in the face of global economic development [1], it depends on the actions taken to save energy and the efficient use required by industries in their production process [2], [3]. An Energy Management System (EMS) is a set of elements that establishes a framework and manages policies, processes, and procedures in the organization [4], [5]. Energy savings, some without capital investment, can be achieved by applying energy management methods [6], applying statistical tools to improve energy efficiency in the production process. [7]. Also, replicating concepts and nomenclature facilitates the transfer of experiences in optimizing resources. [8], [9]. A baseline of energy consumption is necessary to develop an energy reduction strategy, seeking to define key performance indicators (KPI). In general, organizations do not have predictive maintenance plans [10]. The ISO 50001 standard is an innovative strategy to optimize energy, considering the proposed solutions that generate benefits, particularly monitoring performance indexes [11] and analyzing the main causes of inefficiency.

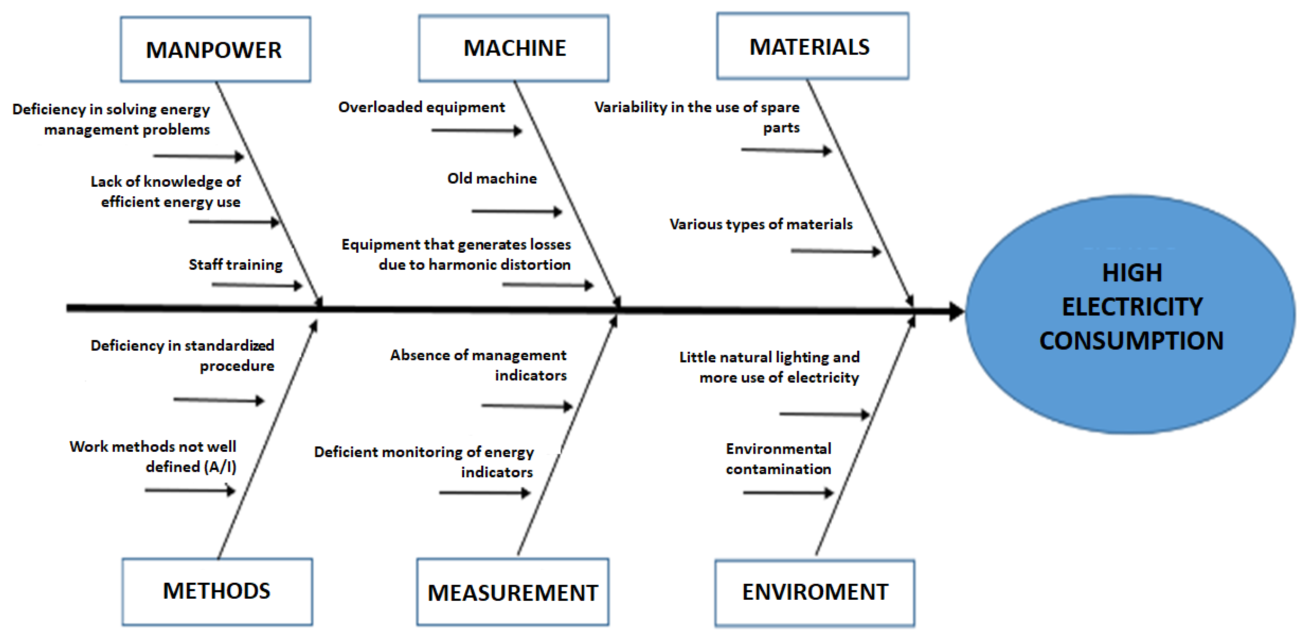

Figure 1. Ishikawa diagram.
Source: Authors

The Ishikawa diagram tool was used to analyze the root cause of the problem of high electricity consumption [12] (Figure 1). Likewise, to efficiently identify effective measures to increase energy efficiency in the manufacturing process in the production sector [13].

2. Methods

The methodology used to develop an energy management system [14], focused on the study and analysis of energy performance, should diagnose the use and consumption of energy [15], which allow a proper atmosphere for the development of energy management standards [16], energy can be managed because it is a resource that can achieve many benefits [17], such as reducing costs and increasing competitiveness [18], [19]. Energy use is the form or type of application in production processes [20]. Consumption is the allowable amount used; Energy efficiency is the quantitative relationship between the energy required and the energy used [21], for which we will use the continuous improvement cycle [22]. The PHVA cycle is a four-stage approach:

1. Plan: Establish energy policies, and understand the risks and opportunities by conducting an energy review through the collection, analysis, and interpretation of energy data. Establish trends, energy uses, baseline performance indicators, objectives, targets, and actions.
2. Do: Implement action plans and act on data analysis to drive new energy performance standards.
3. Verify. Monitor, measure, analyze, evaluate, evaluate, audit, and Conduct energy performance energy reviews against objectives and targets and report results.
4. Act: This is where management takes action to ensure continual improvement of the energy management system and address compliance or non-compliance.

Achieving continuous improvement involves systematically implementing possible solutions, analyzing the results, putting into operation those that work in the processes concerning policies and objectives, generating its own management system, and continuously improving energy performance [23].

I. Implementation of energy efficiency management

The implementation of the energy management system based on ISO 50001. It is based on the continuous improvement cycle. The first stage corresponds to the preparatory stage, in which the company's current energy management status is evaluated, defining achievable savings goals and activities. The second refers to the training plan and the implementation of the energy management system in the company, taking into account management indicators, control variables, the definition of a monitoring system, and energy diagnosis. Finally, it refers to operating the system and making it sustainable, ensuring continuous improvement [24].

A. Stage zero: General requirements,

The initial scenario is identified, and the commitment is established.

- A management representative is appointed whose responsibilities are: to propose and define objectives, follow up the process, Stakeholders, and develop the energy management program.
- A committee was formed, which will be in charge of the energy management program, composed of the general manager, production manager, and plant maintenance manager.
- Energy efficiency policies were established within the company.

B. Stage 1: Planning

In this stage, the activities related to the energy performance diagnosis are planned, analyzing and identifying energy use and consumption:

- Energy performance indicators (IDEn) are established.
- The energy baseline is established (LBEn).
- The activities within the plant are determined in the production processes lines 1 and 2.

In order to establish the energy performance indicators (EPI) in the company, it was necessary to gather historical information on energy use, consumption, and production.

- Energy performance indicators (EPIs) are established to establish the baseline and the energy indicator kilowatt hours consumed between tons produced (KWh/Ton). This historical data is important to evaluate the energy performance trend of previous years and serves to project and set future goals.
- Historical energy consumption data establishes the energy baseline (LBEn) [25].

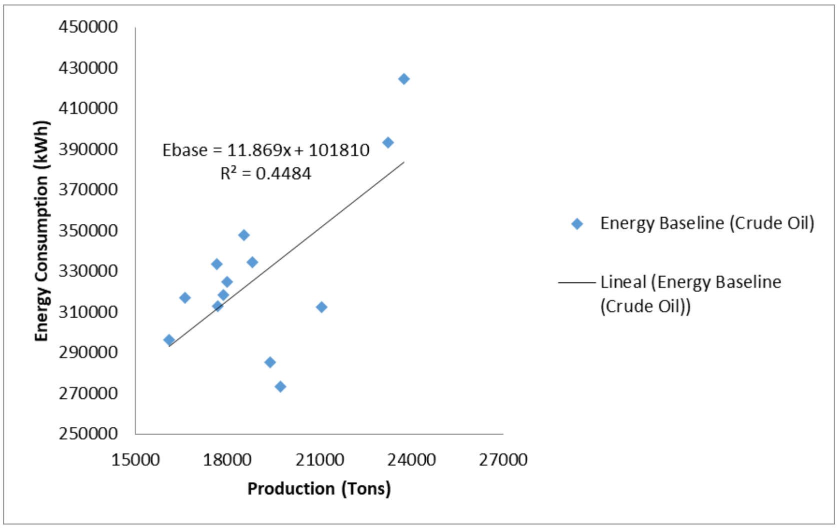

Figure 2: Energy baseline
Source: Own elaboration.

Figure 2 shows the scatter plot of Energy vs. Production, noting its direct approximation by a line and expressed in a linear equation: 11.869×P+101810, where the energy not associated with the process is equivalent to the intercept value. Enap = 101810. The savings that could be obtained are projected since there are different energy consumptions for the same production and the construction of the target line, which is drawn considering the same value of the slope m = 14.767 since it is assumed that so far, there is no change on the equipment, areas or processes; this line passes through the center of the data related to the lowest consumption, corresponding to the practice of greater efficiency in the processes.

➢ Target line: Once the adjustment of the data, energy baseline [26], and construction of the target line, the graph is obtained.

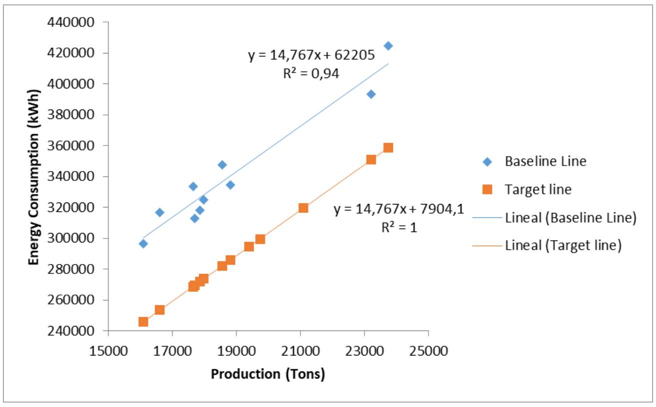

Figure 3: Energy target line
Source: Own elaboration.

We have an equation for the target line =14.767×P+7904.1 where the intercept Emeta = 7904.1 kWh represents the potential savings per month, which, if multiplied by the unit cost of active energy taking into account the value of the last billing, we have 0.41 soles per kWh, which translates into a potential savings of 3,240.64 soles per month projected, as shown in Figure 3.

➢ **General review of the company.**

A general review was conducted to determine the type of organization and the industrial sector it belongs to. Through visits, surveys, and interviews with personnel, information is collected on products, production processes, procedures, physical assets, work schedules, personnel involved, etc. Based on this information, the information to be collected is established. It is verified that the organization hires energy in medium voltage 10 kV and the contracted power of 1500 kW. It has 03 transformers, one of 500kVA, 600kVA, and 1000 kVA, which feed energy to the entire plant.

C. Stage 2: Making, Implementation, and Operation

- Procedures related to energy use, energy consumption, and energy efficiency are identified and evaluated [27], aligning with the technical standards of the quality of electricity supply NTCSE.
- Data was collected on the use and consumption of energy used in line 1 and 2 processes.
- Monthly energy consumption records from previous years were analyzed.
- Factors that increase energy consumption, major consuming equipment, and the variables that affect it were identified. Data is collected through validated instruments on the use and consumption of electrical energy in production.
- All processes and production lines are audited to determine the organization's and industrial processes' real energy status. It also identifies potential savings and opportunities to improve energy performance, allowing to focus actions where the energy impact is higher. The information collected must be collected in a clear, orderly manner and through reliable procedures and equipment.

This information is generated on energy use and consumption, production processes, physical assets, personnel involved, and consumption associated with personnel.

Table 1. Recording of energy parameters in the plant.

Installed Power	Active Power (KW)	Reactive Power (Kvar)	Apparent Power (KVA)	Power Factor (PF)	Voltage (V)	Current (A)	Flicker	THDv %	THDi %	K Factor
TRANSF. 1 - 500KVA	636.50	640.60	888.00	0.94	459.46	1236	0.76	9.3	28.64	4.87
TRANSF. 2 - 600KVA	544.06	346.90	589.83	0.95	232.64	1543.99	0.86	6.386	24.4	2.95
TRANSF. 3 - 1000KVA	784.60	570.54	899.56	0.96	460.80	1181.99	1.28	3.59	13.1	3.34
Total	1,965.16		2,377.39			3961.98				

Table 1. Recording of energy parameters in plant.
Source: Own elaboration.

To verify the initial state that allows us to know the real energy state of the organization and the industrial processes of energy performance, we used energy quality recorders installed during the research period, obtaining the results in Table 1.

Analysis of the initial state of energy performance

The Active Power registers parameters of 1,965 kW in its maximum demand, and the contracted power is 1,500 kW; it should be noted that if the active power exceeds the contracted power, the energy supplier charges a penalty for the excess.

The Reactive Power registers parameters of 1,558 kvar, which a capacitor bank must compensate; by not covering the total compensation, reactive energy is injected into the transformer generating overloads, increasing the apparent power, and decreasing the power factor from 0.90 to 0.98.

The apparent power registers parameters of 2,377 kVA delivered from the 500, 600, and 1,000 kVA transformers (total of 2,100 kVA) indicate that the installed power is being exceeded.

Table 2. Analysis of plant energy performance

Month	Total kWh/month	Cooked kWh/month	Crude kWh/month	Cooked Product (Ton)	Crude Product (Ton)	Production (Tons)	INDICADOR KWh/Ton
jul-20	576940	258584,57	318355,43	16862,75	17873,13	34735,88	16,61
ago-20	606260	258584,57	347675,43	17741,79	18559,56	36301,35	16,70

sep-20	592240	258584,57	333655,43	16703,53	17649,30	34352,83	17,24
oct-20	575360	258584,57	316775,43	17219,20	16620,54	33839,73	17,00
nov-20	593220	258584,57	334635,43	16694,25	18831,39	35525,64	16,70
dic-20	554940	258584,57	296355,43	14478,30	16107,99	30586,29	18,14
ene-21	543800	258584,57	285215,43	15962,54	19412,12	35374,66	15,37
feb-21	583480	258584,57	324895,43	15539,12	17991,92	33531,04	17,40
mar-21	531840	258584,57	273255,43	16275,30	19744,90	36020,20	14,77
abr-21	571540	258584,57	312955,43	14962,10	17706,06	32668,15	17,50
may-21	570840	258584,57	312255,43	14641,89	21092,43	35734,32	15,97
jun-21	651780	258584,57	393195,43	16455,33	23228,91	39684,23	16,42
jul-21	683180	258584,57	424595,43	21907,44	23759,43	45666,87	14,96

Source: Own elaboration.

The production in the brick company is divided into two processes; the first one is the firing process, where the drying is with forced ventilation of hot air to enter the kiln then, and the second process, raw, is the drying in the open air that serves as a reserve when the demand for bricks is increased using the bricks in reserve to be entered into the kiln for the firing process.

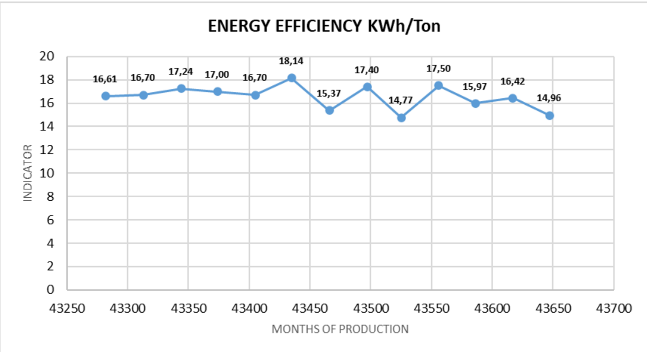

Figure 4: Energy performance
Source: Own elaboration.

To establish the guidelines of the ISO 50001 standard, an indicator should be established taking as a reference the energy consumption in kWh between the tons produced, thus obtaining the first indicator, as shown in Figure 4, of energy performance.

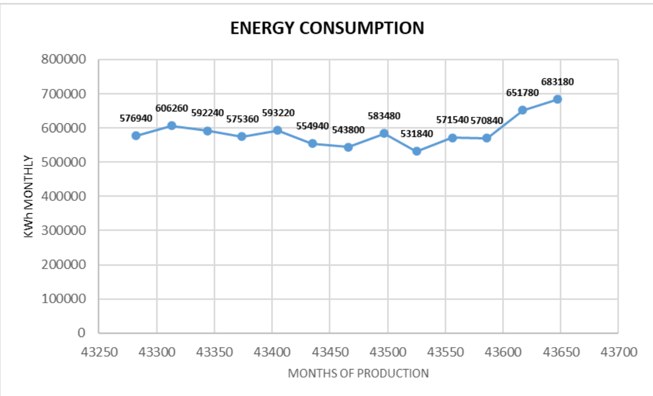

Figure 5: Energy consumption
Source: Own elaboration.

Figure 5, the energy consumption graph, shows the variability of monthly energy consumption in kWh, the amount of energy used in the production process. Electrical energy is used in all processes, from the preparation of raw materials to the finished product.

Energy analysis in Lines 1 and 2

The energy analysis of the two production lines was carried out and compared with the consumption indicator, showing a variable trend as shown in the following graph in Figure 6, forming minimum and maximum peaks generated in the second shift of production when only one production line operates, the consumption indicator is higher since there are electric motors of common use, such as the milling area that work for both lines, when one line is operating, they are operating under the same energy consumption, these motors are considered as motors of common areas and are the largest consumers of energy. Likewise, electric motors start with an old technology (star triangle); it is required to use an improved technology, such as Soft Starter, with modern technology that allows control of the start and stop, contributing to reducing the starting curve.

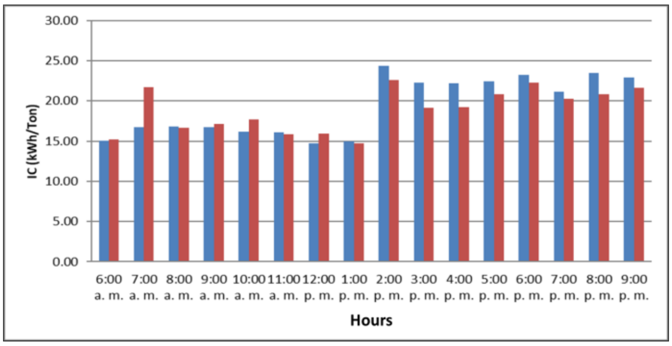

Figure 6. Production lines 1 and 2.
Source: Own elaboration.

The variability in the shifts of the workers can be verified (Figure 6): the first shift starts at 6:00 am and ends at 2:00 pm, and the second shift starts at 2:00 pm and ends at 10:00 pm. It is verified that the indicator decreases when the two production lines are working, and when one production line is working, the indicator rises after 14:00 hours.

At this stage, the improvement is implemented, and the deficiencies in the system are corrected.

The procedures are carried out in order to improve consumption; the energy efficiency management system, based on the continuous improvement cycle, procedures are put into action, good practices that aim to propose actions to improve energy performance through the diagnosis of all areas of consumption route, considering specific demand indicators with which it was possible to identify potential savings and finally propose actions to improve energy performance, taking into account the information analyzed, we proceed to sensitize workers in order to report on the proposal and implementation of the methodology of work. The institutional coordination required for implementing the new processes was carried out with the general manager, who authorized the professionals in charge of plant and energy control to carry out the on-site sampling, recording energy consumption by circuit, system, and production line.

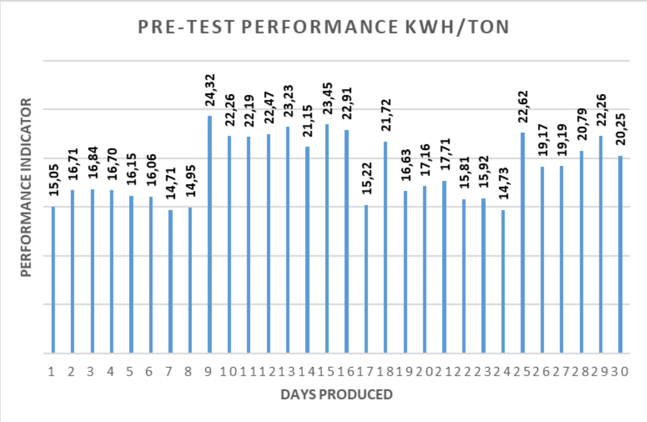

Figure 7: Pre -Test Performance
Source: Own elaboration.

The data collection of kilowatt hours consumed and tons produced is performed from the totalizer, with which we obtained an initial indicator called pre-test in each production line 1 and 2, considering the production in tons per hour and kW consumption, it was recorded from the indicators of the energy performance of the pre-test based on the current situation of the company, as shown in Figure 7. When the indicator is lower, it means that energy use is efficient, and when the indicator rises, it means that there is energy waste that affects energy consumption.

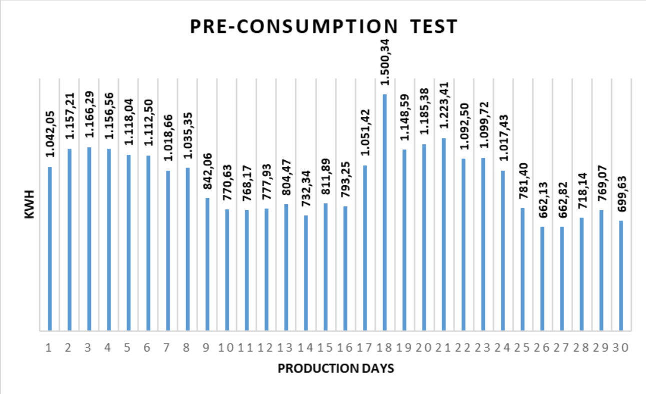

Figure 8. Energy consumption Pre-Test
Source: Own elaboration.

Recording of electrical energy consumption in the plant, called Pre-Test, high parameters are recorded. The records are important because they show the energy consumption and the indicator's trend, as shown in Figure 8.

Improvement proposal

Having identified the production lines where the energy indicator is high, an intervention plan is made, improving the processes and applying policies and good practices regarding performance, use, and consumption efficiently for each production line.

An energy efficiency management system is implemented according to ISO 50001, based on the continuous improvement cycle, which will have a positive impact on the company; the same aims to propose actions to improve energy performance, also allow simultaneously aligns the current range of related disciplines and environmental and economic benefits [28], through the diagnosis of route of all areas of consumption, considering specific demand indicators with which it was possible to identify potential savings and finally actions to improve energy performance, taking into account the information analyzed will be proposed. The continuous improvement cycle, following the P, H, V, A steps procedure, has been institutionalized through the energy policy and good consumption practices; proof that this methodology has been implemented is that the personnel in charge think and do things following the four steps.

Post-Test Implementation Results

With the implementation of energy efficiency management, it is possible to improve the electrical consumption in the company Ladrillera; it is possible to verify the information collection results, as seen in the Post Test.

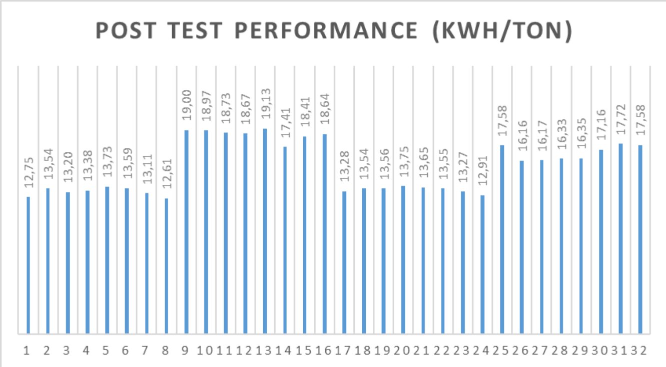

Figure 9. Post Test Energy Performance
Source: Own elaboration.

Figure 9 shows that the trend of the energy performance indicator after implementation shows that the amount of energy consumed is lower; when the indicator decreases, it means that energy use is efficient.

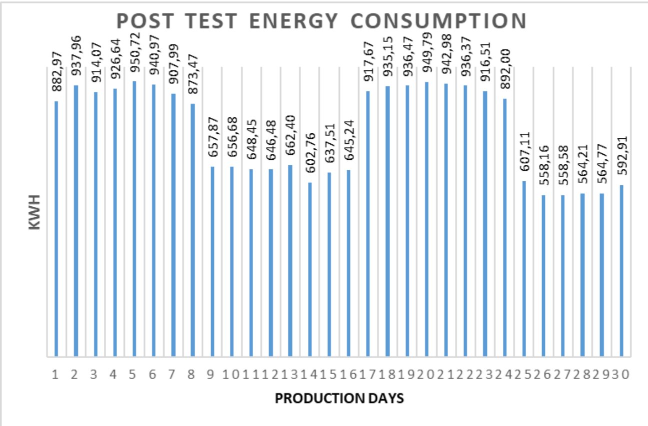

Figure 10. Post Test Energy Consumption
Source: Own elaboration.

The record of electrical energy consumption, called the Post-Test, as shown in Figure 10, records the permissible parameters of the inputs and outputs of the selected processes. The records are important because they show the energy consumption and the indicator's trend.

D. Stage 3: Verification

- Monitoring and measuring the intervened processes are performed to determine the energy performance concerning policies and objectives [29].
- The results achieved are reported.
- Controls and reporting systems are implemented to track energy performance.
- Indicators (KPIs) are considered to verify that the outlined objective is implemented in the proposal; kilowatt hours consumed are verified between tons produced.
- At this stage, the result of the kilowatt hours consumed during one month before and after the improvement can be verified.

The records obtained are verified to corroborate the pre and post-test (Figure 11).

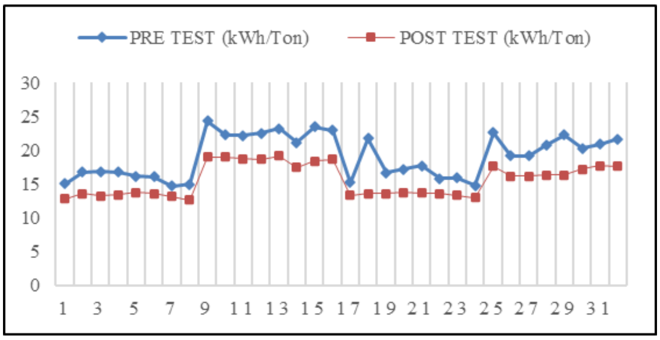

Figure 11. Pre-Test and Post-Test Performance
Source: Own elaboration.

The actions taken during the implementation of energy efficiency management at the plant helped to improve energy performance by improving processes and reducing energy consumption.

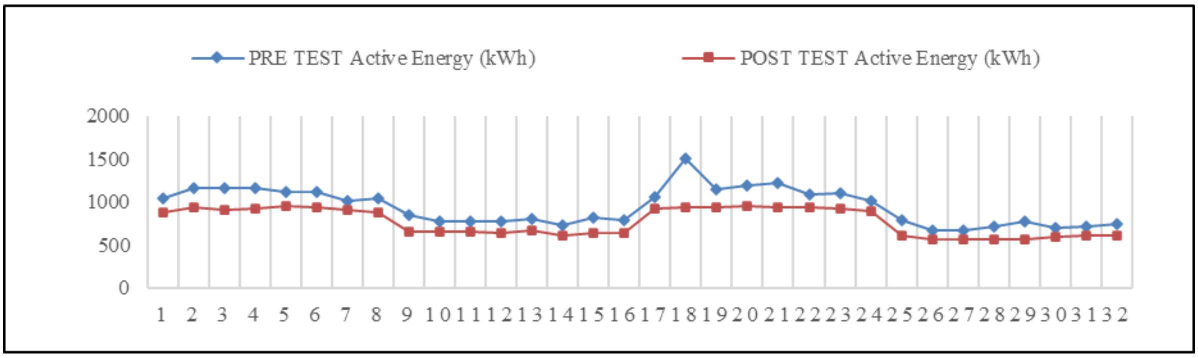

Figure 12. Energy Consumption Pre-Test and Post-Test
Source: Own elaboration.

Figure 12 verifies the results of energy consumption; it is possible to validate the decrease after the implementation of the improvement in the crude oil production lines, decreasing from 30,187.03 kWh to 24,584.32 kWh for each production shift, using the same amount of tons produced. It should also be noted that energy is a resource that allows for many benefits, such as sustainable development in the processes and elimination of energy waste. [30].

E. Stage 4: Act, management review

Actions are taken to continuously improve energy performance based on the results. The committee periodically reviews the energy policy, objectives, goals, targets, and action plans to ensure the expected results.
Actions had to be taken to achieve the research objectives; since the standard itself tells you what to do but does not indicate how to do it, it must be applied since the brick industry has medium-sized machinery, the largest energy consumer.

3. Results

Considering the results obtained during the implementation of a series of actions that improved the energy performance and reduced the energy consumption in the brick kiln company, we had. As a result, of the decrease of electric energy, for the same amount of tons produced (kWh/Ton), in figure 11 of the monthly energy consumption, we can also verify the decrease, registered in the monthly energy invoicing, having as reference the monthly cost between the kilowatts consumed (monthly cost $ /kWh), is another indicator that allows us to verify how variable the consumption is, with the results obtained that allow us to take actions aligned to energy efficiency, identifying the largest consumer of energy, in this case, was the crude oil process line 1 and 2, with which it is possible to obtain better results in the current implementation. The energy management system allows us to optimize productivity, analyzing energy performance by applying the continuous improvement of the energy efficiency cycle, repeating the cycle as many times as necessary to standardize energy efficiency in all processes.

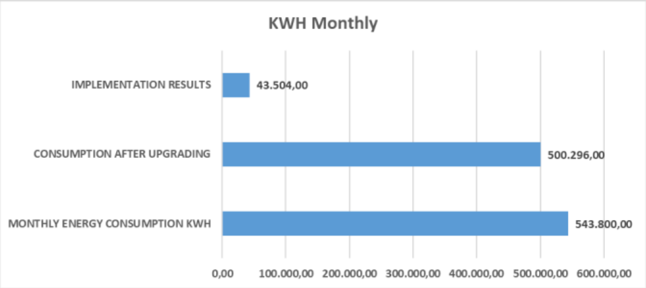

Figure 13. Monthly energy consumption kWh
Source: Own elaboration.

Figure 13 shows the decrease in energy consumption in its two scenarios, before the implementation of the energy management system, it registers parameters of 543,800 kWh during a month of production, after the implementation it registers parameters of 500,296 kWh, with the same amount of tons produced, obtaining an energy saving of 43,504 kWh, that is, an 8% reduction in energy consumption.

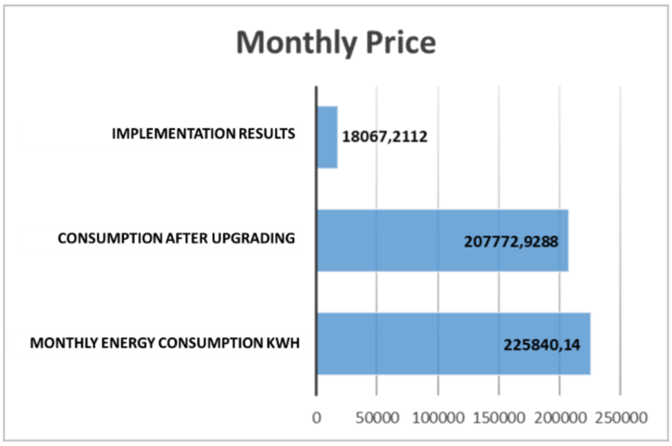

Figure 14. Monthly energy cost
Source: Own elaboration.

To find the cost of monthly energy billing for the consumption of 543,800 kWh, multiply S/ 0.4153 per kilowatt hour, resulting in a monthly cost of S/ 225,840.14 nuevos soles, after the improvement the energy cost is S/207,772.93, obtaining a profit of S/18,067.21, as shown in Figure 14.

4. Conclusions

It was determined that through the application of energy efficiency management according to ISO 50001, it was demonstrated that electricity consumption decreased by 8% of 43,504 kWh monthly, represented in monetary units S/18,067.23, obtaining a decrease in annual electricity consumption of 642,048 kWh, which represents a savings of S/ 216,806.52 (US$ 59,891.30 exchange rate S/3.62). The improvement of electric energy consumption was based on the development of the improvement, radical decisions were made within a system, making structural changes to be able to demonstrate and make the results possible, as well as to indicate that it complies with the guidelines of ISO 50001, in reducing greenhouse gas emissions, when the efficient use of energy is made, it is also contributing to sustainable development without affecting the environment. This research contributes to the proper use of energy, eliminating waste even when companies do not take into account the amount of energy consumed and pay large sums of money, regardless of the fact that, as demand increases, environmental pollution also increases, the ideal would be to have a sustainable and ethical growth before society.

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