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The use of energy management ISO 50001 to increase the effectiveness of water treatment plants: An application study on the Zai water treatment plant

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ABSTRACT

This study sought to determine the impact of implementing the energy management system ISO 50001 on the Zai Water Treatment Plant's energy efficiency performance and demonstrate how this implementation affected the cost and rate of energy consumption. The proposed study model contained three dependent variables—energy consumption, energy efficiency, and the cost of energy consumption. It also contained an independent variable—the energy management system ISO 50001. All these variables were used to develop various questions to help accomplish the study's goals. Planning was done by selecting pumping stations, selecting the most energy-consuming type of pump, and finally, choosing a pump maintenance project to improve energy performance. The researcher used the case of the Zai water pumping station as an example where the ISO 50001 energy management system was applied along with the stages of the Deming Cycle of management. Four pumping units from the Zai water pumping station served as the research sample for the study.

- Find the impact of implementing the ISO 50001 energy management system on the energy efficiency performance of the Zai water treatment plant.
- The effects of implementing ISO 50001 energy management system on cost and energy consumption at the Zai water treatment plant.
- What effect does the ISO 50001 energy management system affect the Zai Water Treatment Plant's energy efficiency?

After applying the ISO 50001 energy management system, several conclusions were drawn. Energy costs and consumption rates in the pumping units dropped while the energy efficiency in the chosen pumping units increased.

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Review question:	- Find the impact of implementing the ISO 50001 energy management system on plant energy efficiency performance and its effects on cost and energy consumption. - What effect does the ISO 50001 energy management system affect the Zai Water Treatment Plant's energy efficiency?

Method details

Introduction

Nations worldwide have mobilized their resources and efforts to implement extensive energy-saving strategies by switching to clean, renewable energy sources and implementing administrative practices. The energy management system ISO 50001 is one method used to lower energy consumption and increase its efficiency, enhance energy performance and efficiency, and lower energy consumption without incurring additional costs for its implementation [7].

Like other nations worldwide, Jordan, unfortunately, still requires non-renewable energy sources such as oil and natural gas. However, recent increases in the already high import costs have presented a challenge to Jordanian decision-makers. According to a UNICEF assessment (2021), Jordan has the second-poorest water resources in the world [6]. Since Jordan's water industry is one of the highest energy-consuming industries in the kingdom, an administrative system that strives to lower energy costs, improve the efficiency of its usage, and lower water loss is required. Since the Zai Treatment Plant is one of Jordan's most significant treatment plants and the water sector is one of the most energy-intensive sectors, it was imperative to seriously consider working on implementing the ISO 50001 energy management system at this plant which has the benefit of being very cost-effective system to use.

Study problem

The scarcity and the high costs of obtaining energy resources, in addition to the negative environmental impact resulting from their generation and access, created the need to manage energy efficiently, reduce its costs and consumption, and, as a result, reduce its negative environmental impact. The researcher noticed the high energy costs and energy consumption at the Zai Treatment Plant, noting that approximately 90% of the cost of a cubic meter of water comes from the Zai Treatment Plant. As a result, the water treatment station in Zai must implement the ISO 50001 energy management system, which has several economic and environmental benefits.

Energy use is frequently one of the most significant operational costs in the water management industry. As a result, implementing an ISO 50001 system can help organizations in this sector manage costs more effectively by promoting more energy-efficient practices in water purification, distribution, and wastewater treatment. Water management and environmental sustainability are closely related; lowering energy use can help lessen the environmental impact of water distribution and purification processes, which helps save the environment and meet sustainability targets. The ISO 50001 system standards may have been chosen for the Zai water treatment plant to guarantee compliance and quality in the water management industry [30].

Study questions

The primary question that resulted is: "What effect does the ISO 50001 energy management system have on the Zai Water Treatment Plant's energy efficiency? Several sub-questions evolved from it to evaluate the system's utility for water treatment and desalination plants considering the current issue, resulting from the impacts of implementing the ISO 50001 energy management system on cost and energy consumption, energy efficiency, and energy performance.

Practical importance

The study's significance stems from the need for more studies like these to be conducted nationally in Jordan. It helps decision-makers at the ministerial, institutional, governmental, and private sector levels understand the significance of applying the ISO 50001 energy management system to numerous sectors. Moreover, it also assists ministerial decision-makers in developing long-term plans and policies. Although one of the industrial sectors that uses the most energy nationally is the water industry, sectors like the electric industry could also benefit from using the ISO 50001 energy management system.

Objectives of the study

The current study's primary goal is to assess the application of the ISO 50001 energy management system in water treatment facilities and establish its worth by describing how energy costs can be reduced by utilizing it. The study will highlight how the

Fig. 1. Study model.

system's adoption will enhance the study station's energy efficiency and describe how the technology will improve the investigation station's energy efficiency.

Study model

The study model was developed based on the [7] study. It includes an independent variable represented by the ISO 50001 energy management system and its dimensions (commitment of senior management, energy planning, application and operation, audit, verification, and review). Three dependent variables - energy consumption, efficiency, and the cost of its consumption - were also developed based on the literature. A model is shown in Fig. 1 below:

Study hypotheses

Based on the study problem, three main hypotheses were formulated as follows:
H1: Using the ISO 50001 energy management system lowers energy consumption.
H2: Energy efficiency rises when the ISO 50001 energy management system is used.
H3: Using an ISO 50001 energy management system lowers energy expenses.

Research methodology

By gathering the necessary energy data from the Zai treatment plant, the researchers used a case study approach in the Zai water treatment plant while performing the current study. This included setting the energy management plan and the baseline from which the research will start, implementing corrective measures, taking the data after verification and auditing, continuously reviewing, and presenting results.

Research plan

Theoretically, the researcher reviewed the requirements of the ISO 50001 energy management system [9]. On the practical side, the researcher worked on implementing the ISO 50001 energy management system at the Zai Water Treatment Plant, collecting data, and comparing it to the data collected before application.

Increasing energy use efficiency in all activities requires all countries to employ their resources, knowledge, and efforts. Increasing energy consumption efficiency should be done at all levels, beginning at the state level, to eliminate waste produced by this energy and increase energy consumption efficiency. The idea of energy efficiency must strive to create awareness on a global scale, from individuals and citizens to governments, to result in energy consumption and, consequently, financial savings and a reduction in environmental pollution [19].

Since the energy and water sectors have a fundamental relationship with one another [2], the terms "water in energy" and "energy in water" echo that this most crucial of sectors, and the energy use of this sector must be carefully examined by all countries of the world. Since water is used in numerous energy production activities (including fuel extraction, cooling power plants, and power generation by water), the water sector uses much water for things like irrigation operations where water is pumped from wells to treatment plants as part of the water treatment operations [23]. Even in nations with abundant fresh water, these same procedures are used to move and pump water; thus, they require much energy to complete [15].

The water sector is one of the sectors that must be worked on to reduce energy consumption and increase its efficiency [27]. Putting corrective actions in place to lower energy use and increase energy usage efficiency and reviewing and assessing these processes will help achieve the desired results. Creating plans and programs that manage energy effectively and creating short- and long-term plans to track energy consumption is necessary.

Jordan is one of the nations that imports energy, and its costs are constantly rising. According to Minister of Energy and Mineral Resources Hala Zawati at a 2021 press conference, electricity consumption in Jordan had reached approximately 10,315 megawatts [25]. Moreover, Jordan is also regarded as one of the countries with the poorest water resources. With a per capita share of 90 m^3 annually, Jordan is one of the three poorest countries in terms of water. The Disi aquifer is regarded as the most significant basin providing groundwater for Jordan, and additional groundwater wells are dispersed throughout the governorates of Jordan [29]. As a result, most of Jordan depends on groundwater for its water supply. The second source is surface water, which Jordanian dams capture. Either way, the water is processed before being pumped into Jordan's water networks, and one of the country's most significant water treatment facilities is the Zai Treatment Plant, which delivers about 85 million cubic meters of water yearly.

The station draws its water from the King Abdullah Canal in the Jordan Valley. It has five lifting stations that raise the water from the Jordan Valley to the Zai Treatment Plant by around 1000 m before pumping it only 200 m higher to Amman. According to data from the station's reports, it must be noted that 90% of the cost of one meter of water comes from the Zai Treatment Plant, meaning that, in addition to Jordan's lack of water resources, overcoming these costs is Jordan's biggest challenge. This is because water treatment uses much electricity to raise the water, resulting in high electricity consumption. Consequently, a system like the ISO 50001 energy management system is urgently needed, which lowers consumption and consumption costs yet boosts energy efficiency.

Through the establishment of a process system, the energy management system aids in improving energy management, which includes energy consumption, use, and efficiency. Every organization must adhere to the requirements in the processing system to optimize its energy performance. Creating and implementing an energy management system includes an energy strategy and its goals for consumption and efficiency within the bounds of the law [28]. As we already stated, Jordan is one of the countries with inadequate water resources, and its resources use a significant amount of energy. As a result, it was essential to use the ISO 50001 energy management system in this situation to transfer the energy, treat it, and take advantage of its many benefits, including improving energy management and lowering energy expenditures.

Previous studies

In the research of Wilson et al. [19] titled Water Utilities' Improvement: The Need for Water and Energy Management Techniques and Skills, the researchers emphasized the significance of implementing an energy management system in the water systems of Tanzania. The study found that the water systems in Tanzania consume the most energy and highlighted the most significant factors affecting energy consumption, including poor maintenance and outdated pumping equipment, in addition to the human factor and its impact on consumption. Additionally, Wilson et al. [19] emphasized the significance of raising workers' understanding of the value of energy and the corrective and preventative actions that can be taken to reduce energy use. The researchers used the descriptive analytical approach to get the necessary results by creating a questionnaire and holding interviews. The most significant findings indicated a need for a broader knowledge of management methods at all levels. The researchers also discovered that there was a lack of proficiency in energy management.

The recommendations of Wilson et al. [19] included **ra**ising awareness of the value of energy, transferring energy management expertise between facilities through training, supplying energy to formalize energy management, requiring energy workers to share experiences, targeting credit agencies and associations in order to obtain the funds required to implement the energy management system, and the requiring training.

In their 2020 study, A Simplified Model of Energy Performance Indicators for Sustainable Energy Management, Nakthong & Kubaha intended to shed light on how the energy management system affects energy efficiency and sustainability. The researchers used a case study technique to study buildings and developed a model that assesses energy indicators under the impact statement and the energy management system. To demonstrate the effects of the system's application, the researchers applied the model to a building and assessed the dimensions. The most significant outcomes included developing a method for tracking and assessing energy in these buildings and discovering an improvement in the energy level in every building that used the ISO 50001 energy management system. The two researchers' most crucial recommendation is to conduct more research to identify more performance metrics for the energy management system.

Muhammad [17] conducted a study in 2016 titled Energy Consumption in Urban Water Cycle**.** Since energy is used in every aspect of the water sector's activities, including pumping and purifying water, this study clarified how the two industries relate in Pakistan. The researchers used a quantitative strategy and data analysis to arrive at their findings, revealing that obtaining water from the ground requires around 0.62 kWh/m3 more energy than obtaining water from the surface. In addition, 5.7 kWh/m3 of energy per kilometer is used to distribute water within Lahore. Their most crucial recommendation was to use solar energy and other renewable energy sources and implement management systems and policies to reduce energy usage.

Another study conducted in 2019 compared the Environmental and Economic Impacts of On- or Off-Grid Solar Photovoltaic with Traditional Energy Sources for Rural Irrigation System**s** [5]. As the title suggests, the study used a case study approach to compare the economic, financial, and environmental costs of using renewable and non-renewable energy sources for pumping and irrigation systems in Spain. Photovoltaic panels were used to represent renewable energy sources, and diesel generators were used to represent non-renewable energy sources. Moreover, on- and off-grid photovoltaic panel connections were compared. The study's most significant findings found that solar energy is the most commercially, financially, and environmentally viable source, and it also has a lower environmental impact than photovoltaic energy that is not connected to the grid. Additionally, [16] conducted a study in 2022 titled Optimization of Energy Consumption in the Pumping Station Supplying Two Zones of the Water Supply System. Since pumping stations are the most energy-intensive process in the water industry, this study focused on energy management for water pumping units using the Digital Markets Act (DMA) regulating system. The study's most significant findings were that some simulation systems used by the two researchers were less energy-consuming and more energy-efficient than others.

Planning

Planning is one of the primary management processes in the energy management system as it creates the energy work team. The company adopts the approach to improve energy performance, and the system becomes linked to the company's vision and strategies

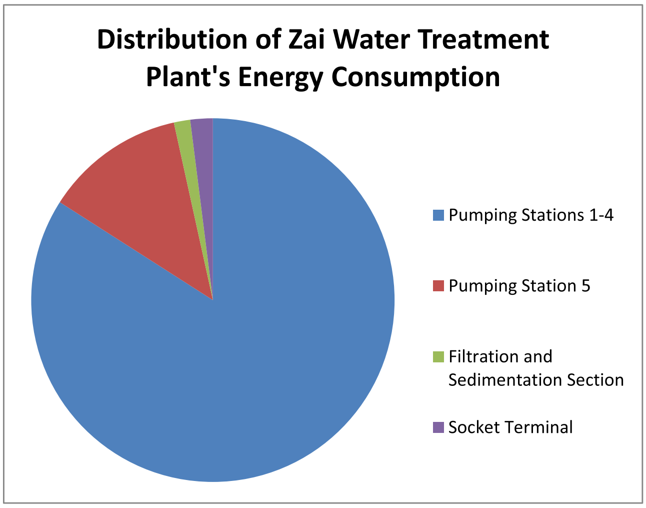

Fig. 2. The study includes the energy usage of five Zai water treatment plant pumping stations.

[21]. It also identifies the opportunities and threats the company faces concerning energy and thoroughly reviews all parts of the company or station by:

1. Defining the system's goals and objectives and defining a clear strategy for the necessary corrective steps to improve the company's energy performance and enable comparisons between the ISO 50001 energy performance improvements.
2. This includes steps such as conducting a thorough analysis of all the station's components and operations in the energy management system planning processes, much like the Zai Water Treatment Plant.
3. Conduct a more thorough analysis to identify the processes that use energy most and create improvement methods.
4. Diagnosing the current situation and determining which equipment uses energy most.
5. Establishing an energy baseline so that future improvements can be compared.
6. Establishing performance standards for the energy evaluation of energy-hungry equipment.
7. Finding energy-saving solutions with a reasonable return on investment.
8. Choosing corrective actions for initiatives that will lower our energy usage.

The components of the planning process

- Comprehensive review.
- Detailed review to determine the most consuming processes.
- Determine the most energy-consuming equipment.
- Set an energy baseline.
- Define performance criteria for evaluation.
- Identify proposed projects to improve energy performance.
- Set appropriate corrective actions.

Accordingly, the planning section of the energy management system has several parts and processes. These processes were used in the Zai Water Treatment Plant, allowing the researcher to identify the most energy-consuming processes and delve further into each until the most energy-consuming equipment was found. The evaluation criteria were developed from there, and a corrective plan was created to reduce energy consumption (Yung [3]).

Planning components and processes in the energy management system

Identifying the present state (initial review of energy) is the phase that thoroughly evaluates the energy in every station area. For this purpose, the electricity bills must be reviewed, after which each station operation's energy consumption percentage must be specified. These percentages will be the target basis for energy savings. The water treatment facility's energy usage at the Zai Water Treatment is depicted in Fig. 2 [8], which shows the distribution of energy consumption within the water treatment plant.

Creating processes for improvement

This stage attempts to implement corrective measures for energy usage, considering three factors: creative, financial, and environmental. However, following the steps for technical and budgetary issues in this investigation, the researcher did not touch upon the environmental issues in this study [8].

Identification of the current state

This audit portion focused on the Zai Water Treatment Plant's pumping stations, consisting of four homogenous stations and four identical pumping units per station, totaling sixteen identical pumping units with the exact specifications [8]. Due to the high energy consumption of the pumping stations—approximately 358,266 megawatts per year (or 84% of the total energy consumption of the Zai Treatment Plant) —any improvement in the consumption efficiency of any pumping station will have a positive impact on the energy consumption commissioned and carried out at the Zai Water Treatment Plant. Several axes are used to diagnose the current state of affairs; however, the researcher will only focus on the distribution of energy consumption.

In researching the distribution of energy consumption in pumping stations and identifying the most energy-consuming equipment (SEUs), the researcher found that the pumping units (pump–motor) consume the most energy-consuming as their consumption constitutes (99.25%) of the total energy consumption in the pumping stations. Thus, the researcher applied the ISO 50001 energy management system to pumping units (pump + motor), choosing them because they consume the most energy. As a result, the researcher applied the ISO 50001 energy management system phases to four of the sixteen pumping units.

The equipment with the highest energy consumption should have specific energy evaluation performance requirements. This is one of the most crucial stages of the planning procedure within the ISO 50001 energy management system, and it must be based on specific criteria for comparison before and after the application processes. The researcher has identified several criteria to indicate the impact of the application on the study's variables by providing answers to the study's questions. The criteria were divided into five categories by the researcher:

A. Hydraulic measurements:
    - Pump discharge flow.
    - Pump suction and discharge pressure.

B. Electrical measurements:
    - Electric current.
    - Voltage.

C. Power factor.
    - Pumping unit efficiency (pump-motor):

Calculating the pump's efficiency requires first dividing the hydraulic power by the mechanical power and then multiplying the result by 100%:

$$\text{Pump } efficiency = \text{Ph}/\text{Pm} * 100\%$$

The researcher used the idea of overall efficiency, which is the hydraulic power divided by the electrical power multiplied by (100%) because it was impossible to calculate the mechanical power alone:

$$= \text{Ph}/\text{Pe} * 100\% \text{ Overall } Efficiency$$

However, the electrical power for each pumping unit in the pumping stations was determined by the researcher using the electric power calculator, which may also be calculated using the equation below:
Electrical Power (Pe) = V *I *COSα *1.732 [14]
Where:

V: the voltage measured inside the station.
I: Electric current measured inside the station.
COSα: power factor measured inside the station.

As for the hydraulic power of the pump, it can be calculated based on the following equation:

Ph= Q * H *1000 *9.81 / 3.6 *106 [11].

Where:

How much water the pump produces every hour (m3/h)
H: The amount, in meters, of pressure between the pump's suction and pump.

The pumping stations have all the readings required to calculate the electrical and hydraulic power since each station has measurement equipment for the parameters required for each pumping unit. This equipment is highly accurate and reliable. Pumping stations 2 and 3 do not have water flow calculators. As mentioned earlier, the calculation process is subsequently reduced to being calculated scientifically by calculating the volume of extra water in the next tank during a given period (Calculation of Pump Efficiency: Formula & Equation | [31]

Specific consumption

This refers to the ratio of electrical consumption (kilowatts) to water flow (m3/hour). This measurement is precise. This provides a more accurate estimate when assessing electrical consumption since it considers the volume of water pushed using a particular electrical capability [4].

Specific consumption = electric power/water flow.

It is important to note that the evaluation will be better if the proportion of electrical energy utilized is smaller.

Establish an energy baseline to assess future improvements

The energy baseline, which may be defined for any variable, serves as the foundation for comparing performance before and after the implementation of the energy management system. It serves as a benchmark from which we can deduce performance improvement or non-improvement. Table 1 demonstrates the foundation for energy efficiency and the volume of energy consumption [18]. Table 1 shows the energy efficiency and the amount of energy consumed by the pumping units before implementing the ISO 50001 energy management system for the year (2022).

As stated in the table above, after establishing the baseline, the researcher chose four pumping units to apply the corrective measures to address the study's issues. These units are displayed in Table 2 below.

Identify energy-saving projects with a reasonable rate of return

It was necessary to research suitable projects to minimize energy usage after finishing the earlier planning stages in the ISO 50001 energy management system. The study's intended outcomes, which were also the most crucial of these efforts, were:

A. **Setting up a Solar Energy Production System**

One of the contemporary methods for producing energy thought to be ecologically benign is the system that uses the sun. When investigating this option, the researcher discovered that it would be challenging to put it into practice due to the high cost of the system. Moreover, the Zai Treatment Plant's high energy requirements make it challenging to rely on solar energy in pumping stations and connect it to Jordan's electricity grid.

B. **The Process of Replacing Existing Pumps with New Ones**

Because the replacement project requires a significant amount of money, the researcher studied this option and concluded that it is feasible only several years after the start of the system application within a long-term strategic plan. As a result, it can be studied after implementing the system's application, and savings can be realized. Since the ISO 50001 energy management system is a continuous management process aiming at continuous improvement, we can consider additional development and look for more expansive areas of improvement by investing in the acquired savings [24].

C. **Choosing Correctional Project Methods**

The researcher chose the current pumps' maintenance projects and decided on their maintenance and treatment techniques to get their results. The researcher investigated this option and showed that it was feasible and had the potential to improve the study's variables by decreasing the mechanical losses of the pumps, increasing the hydraulic power (beneficiary), and increasing the pumping unit's energy efficiency while decreasing electricity use and increasing financial savings [24].

Implementation

The researcher applied the station's ISO 50001 energy management system based on a Zai Water Treatment Plant case study. ISO 50001 energy management system is based on the Deming Cycle Plan Do Check Act (PDCA); this scientific method suggests a change in a process, carrying it out, evaluating the outcomes, and then taking necessary action is the foundation of the PDCA improvement cycle. Looping system for continuous improvement [26]. It is explained in Fig. 3 below:

The planning phase is followed by the implementation process, which transfers what has been prepared as one of the critical administrative processes. The application of corrective plans from maintenance operations and procedures to operations is made to make a reality that has been applied. The ISO 50001 energy management system looks at energy efficiency in all stages. After determining the most frequently used equipment and the significant energy uses (SEUs), the following steps are specifying performance standards, creating a baseline on which to base the comparison process, and specifying maintenance tasks by the researcher to access the study's findings. Moreover, identifying the necessary corrective measures and implementing these procedures is necessary to reach the study results. The four pumping units were selected so that the corrective procedures could be implemented on them. Additionally, the researcher carried out the following corrective procedures and maintenance on the pumps at the cost of 522,000 Jordanian dinars (JOD), which was distributed as follows:

1. Carrying out maintenance operations on parts of the pump shaft, filling and rebuilding the pump case of Pumping Unit 1 in Pumping Station 4, which costs 15,500 JOD in maintenance costs.
2. Carrying out maintenance operations for parts of the pump shaft, filling and rebuilding the pump case of Pumping Unit 4 in Pumping Station 4 for 15,500 JOD.
3. Carrying out maintenance operations for the parts of the pump shaft while preserving what it was pouring without performing any maintenance operations for it at a maintenance cost of 10,600 JOD.

Table 1

Energy efficiency and amount of energy consumed by the pumping units before the implementation of the ISO 50001 energy management system for the year (2022).

			Time	Input power before	Input power after	Power cosumpit on	COS	MW	Amp	KV	Tank elivation before	Tank elivation after	Water flow	water flow	Suction head	discharg e head	Pump head	Rated Power
satation	Pump	Data	Min.	KW	KW	KWH					m	m	m3/min	m3/hr	m	m	m	KW
PS1	1	5-01-2022	10	2481,097	2481,597	3000	0.985	2.8	280	6.95	1.22	1.92	49.46	2967.30	18	300	282	3200
	2	05-01-2022	10	4925,784	4926,271	2922	0.985	2.8	275	7	0.98	1.63	45.92	2755.40	18	300	282	3200
	3	10-01-2022	10	5733,219	5733,703	2907	0.95	2.8	280	6.8	0.8	1.47	47.34	2840.10	18	300	282	3200
	4	10-01-2022	10	8410,445	8410,930	2910	0.95	2.8	278	6.8	1.07	1.73	46.63	2797.70	18	300.3	282	3200
PS2	1	13-01-2022	10	1207,469	1207,986	2940	0.995	2.9	290	7	1.12	1.82	49.46	2967.30	19.4	302.9	283.54	3200
	2	13-01-2022	10	9102,995	9103,483	2928	0.995	2.9	290	7	1.28	1.95	47.34	2840.10	19.4	302.9	283.3	3200
	3	17-01-2022	10	7119,329	7119,815	2916	0.95	2.85	275	6.9	0.99	1.66	47.37	2840.10	19.38	303.98	284.6	3200
	4	17-01-2022	10	8957,859	8958,358	2994	0.95	2.9	280	9.9	1.03	1.73	49.46	2967.30	19.38	304.98	285.6	3200*
PS3	1	20-01-2022	10	8229,634	8230,171	3222	0.99	3.1	320	6.75	1.93	2.69	53.69	3221.64	19.4	297.84	2780.4	3300
	2	20-01-2022	10	2227,361	2227,877	3096	0.99	3	295	6.8	1.18	1.89	50.16	3010	19.4	296.82	277.42	3500
	3	20-01-2022	10	6947,069	6947,582	3078	0.95	3	280	6.9	2.01	2.67	46.63	2798	19.4	297.84	278.44	3300
	4	20-01-2022	10	8792,167	8792,698	3186	0.95	3	300	6.8	1	1.73	51.57	3094	19.4	298.86	279.46	3500*
PS4	1	05-01-2022	10	7216,431	7216,996	3390	0.985	3.3	330	6.9			47	2820	19.4	312.12	292.72	3500
	2	22-01-2022	10	314,431	314,995	3384	0.985	3.25	320	6.9			53	3180	19.4	312.12	292.72	3500
	3	22-01-2022	10	6867,662	6868,202	3240	0.965	3.2	300	7			50.5	3030	19.4	312.12	292.72	3500*
	4	22-01-2022	10	542,717	543,278	3366	0.97		300	7			47.2	2832	19.4	312.12	292.72	3500*

Table 2
Four pumping units to which corrective measures were applied to address the study's issues after establishing the baseline.

Tank elivation before	Tank Elivation after	Water flow	Water flow	Suction head	Pump head	Rated Power	
M	m	m3/min	m3/hr	m	m	m	KW
0.98	1.63	45.92	2755.40	18.00	300.00	282.00	3200.00
2.01	2.67	46.63	2798.00	19.40	297.84	278.44	3300.00
0.00	0.00	47.00	2820.00	19.40	312.12	292.72	3500.00
0.00	0.00	47.00	2832.00	19.40	312.12	292.72	3500*

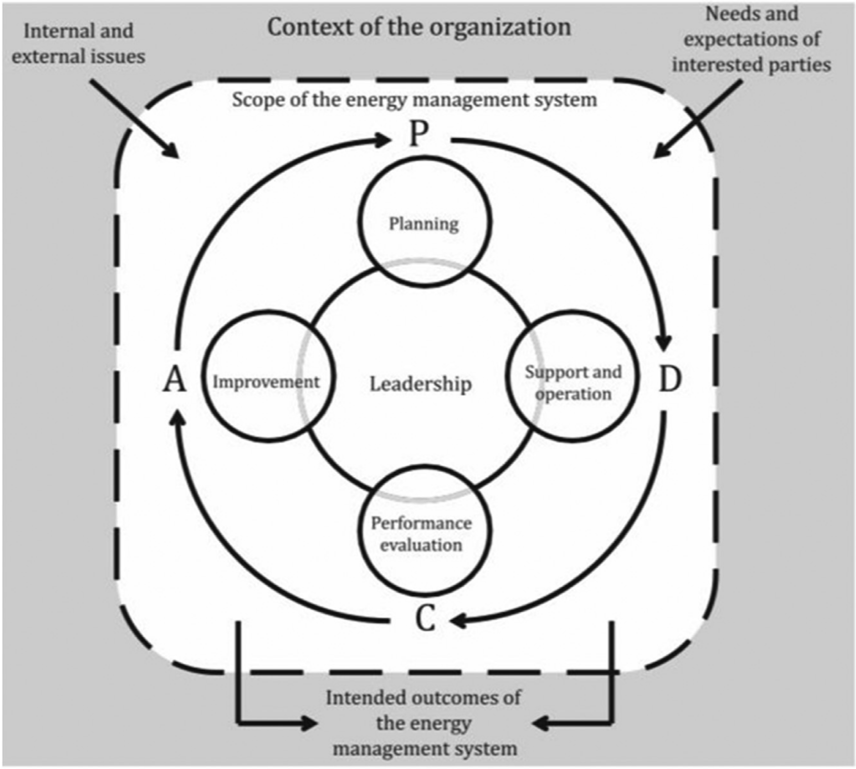

Fig. 3. Plan-do-study-act (PDSA) cycle which know as Deming Cycle of management is a four-step modification process model, used as a technique for project planning.

4. Carrying out maintenance operations for the parts of the pump shaft while preserving what it was pouring without performing any maintenance operations for it at a maintenance cost of 10,600 JOD.

The procedures and operations the researcher applied to the pumping units are his corrective measures to improve energy efficiency and answer the study questions [10].

Review and analysis

The review process in the ISO 50001 energy management system aims to monitor energy efficiency and consumption after corrective measures are carried out. It also analyzes the results after application, evaluates the analysis, and finds out the extent to which the obtained results match the goals the researcher previously set. Accordingly, the researcher collected the results. After applying and analyzing the corrective procedures, he compared them with the results before the application (baseline).

Results analysis

As mentioned earlier, the researcher collected the readings and performance criteria before and after applying the corrective procedures, as shown above, and analyzed the results: The blue column shows the pre-procedure energy consumption, and the red column shows the post-procedure energy consumption, (Figs. 4 and 5).

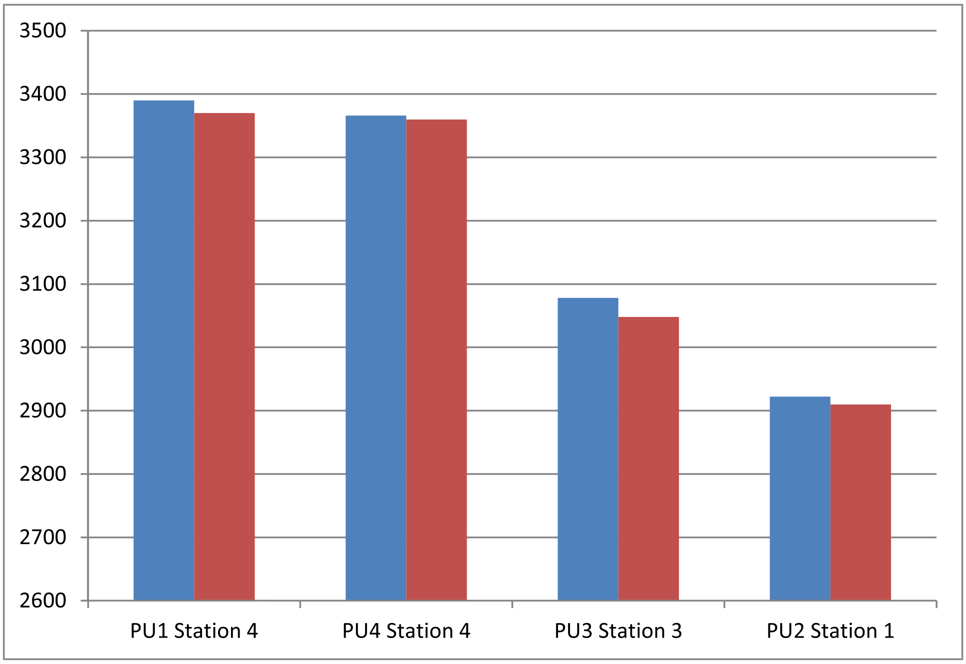

Fig. 4. The electrical capacity (electrical consumption) before and after applying the corrective measures for each operational hour.

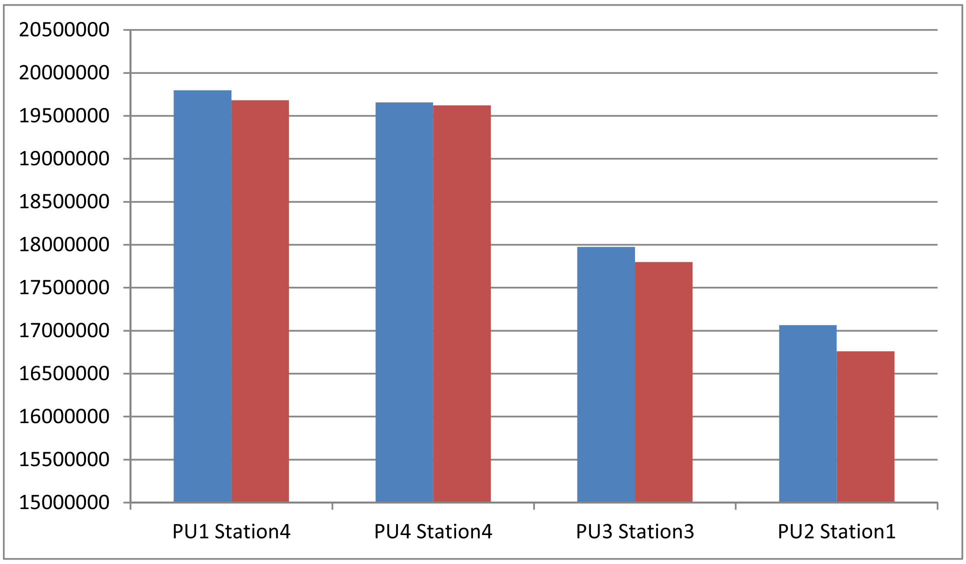

Fig. 5. The electrical capacity (electrical consumption) before and after applying the corrective measures over one operational year.

The figure above represents the electrical consumption over an operating year before and after the application. It was assumed that the pumping unit would operate for 16 h/day for 365 days, and this is the lowest operating rate for the pumping unit in the Zai Water Treatment Plant. Based on the readings, the difference in consumption before and after the procedures was as follows:

Pumping unit 1, station 4

Consumption difference (kWh) = 19,797,600 – 19,680,800 = 116,800 kWh. After applying the application, the electrical consumption decreased by 0.06%, meaning the consumption difference over an entire year is considered significant.

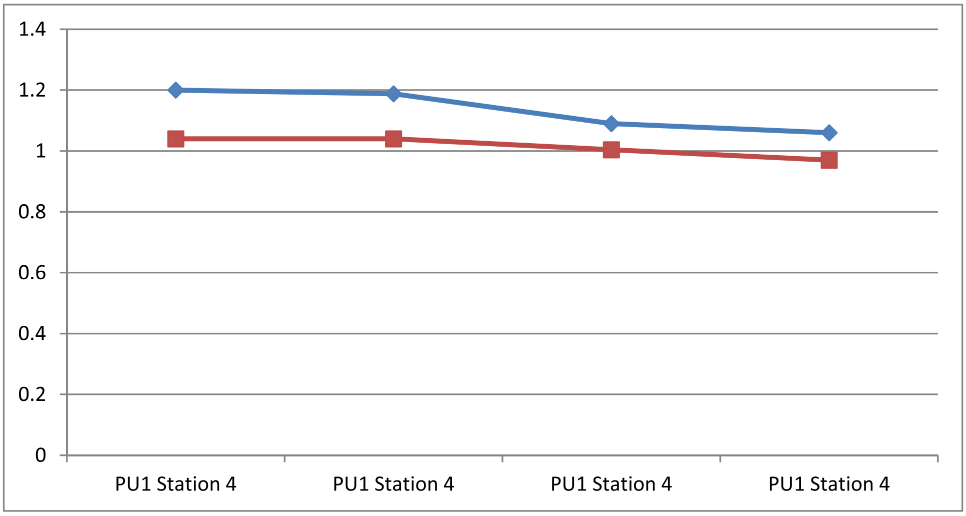

Fig. 6. The specific consumption of the pumping units before and after carrying out the corrective procedures.

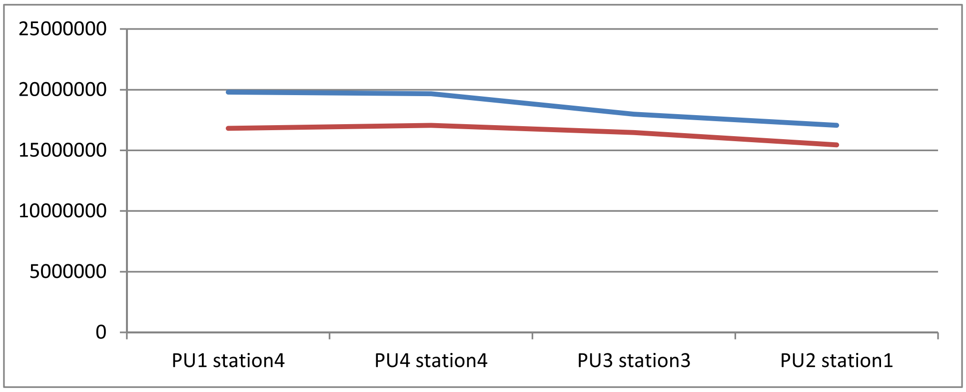

Fig. 7. The electrical consumption of the pumping units before and after carrying out the corrective procedures, considering the specific consumption.

Pumping unit 4, station 4

Consumption difference (kilowatts) = 19,657,440 – 19,622,400 = 35,040 kW, meaning electrical consumption decreased by 0.0018% after the application. In other words, the difference in consumption over an entire year is slight.

Pumping unit 3, station 3

Consumption difference (kWh) = 17,975,520–17,800,320 = 175,200 kWh means that the electrical consumption after the application decreased by 0.0097%, which, in turn, means that the difference in consumption over an entire year is slight.

Pumping unit 2 station 1

Consumption difference (kilowatts) = 16,849,200–16,761,600 = 87,600 kW, meaning that the electrical consumption decreased by 0.52% after the application. In other words, the difference in consumption over an entire year is slight.

Note that the electrical consumption decreased after all corrective measures were applied to the pumping units. However, this decrease is not considered significant because the evaluation based on the electrical consumption in an absolute way needs to be considered an accurate measure. After all, it did not consider the amount of water pumped before and after the application. In addition, the corrective measures were based on one component of the pumping unit, which is the pump itself. In contrast, the other component (the electric motor) was used before and after the corrective measures. Moreover, Fig. 6 shows the specific consumption before and after applying the corrective procedures.

Note from Fig. 7 that the specific consumption decreased significantly after applying the corrective measures, as it considered the amount of energy consumed (energy loss) to the amount of water pumped (energy gain).

The researcher analyzed the readings and performance standards of the pumping units under study before and after the application. The electrical consumption was calculated before and after the application process. Afterwards, a more accurate calculation was made by taking the performance standard - the specific consumption - which calculates kilowatts / m3.

Efficiency of the pumping unit (pump-motor)

The concept of efficiency in the pumping unit means the optimal use of energy; therefore, it is the exploited energy (hydraulic) concerning the wasted electrical energy. Moreover, mathematically, it can be expressed as the ratio between hydraulic and electrical power in pumping units.

- Overall Efficiency = Hydraulic power ÷ Electrical power) *100%

Whereas:

- Hydraulic power (Ph) = Q*h*1000*9.81 /(3.6*10ˆ6). (Kaddari, et al., 2017)
- Electrical power (Pe)= V *I *COSα *1.732

Concerning electrical power, the researcher relied on the instantaneous electrical power calculator, characterized by high accuracy, and the flow and pressure calculator available in the pumping stations to calculate the water flow and pressure difference for each pump.

Cost

After stating the costs incurred, the researcher used the specific consumption before taking corrective measures. The researcher also relied on the water flow before and after the application since the costs are related to the water flow and the specific consumption. Before carrying out the corrective measures, the pumping unit would have significantly increased the cost.

Financial evaluation criteria

To evaluate the financial savings resulting from the project, the researcher used the payback period criterion - the most straightforward financial evaluation criterion. The payback period is the time required for the project to recover the capital invested in the project. The shorter the time, the greater the project's financial feasibility [20]. Moreover, it can be calculated mathematically with the following equation:

Payback period = invested capital / financial savings.

As mentioned, the project is a maintenance project for four pumping units. Its capital cost was 52,200 JOD. The financial savings from applying corrective measures (maintenance) were 829,331.50 JOD.

Payback period = 52,200/829,331.5 = 0.0629 years (or 23 days)

The recovery period for the invested amount is 23 days - a very short period for improving the efficiency of the Zai Water Treatment Plant pumping units. It is an excellent economic feasibility, given that these units consume a lot of energy.

Regression model

After carrying out the corrective procedures and collecting the results before and after applying the energy management system, the results were analyzed and reviewed, and the researcher clarified and analyzed all the readings. Next, the researcher created an applied model using simple regression for each pumping unit [13], in which the flow and electrical consumption readings were taken before corrective actions were taken. In order to compare the results after carrying out the corrective procedures with the prediction equation, the reading was taken every hour, and accordingly, eight readings were taken. The following is an illustration of the model for each pumping unit: (Figs. 8-11)

Station 4, pumping unit 1

The water flow and power consumption of the pumping unit were measured eight times each, and the results were as follows:

Station 4, pumping unit 4

Eight readings were collected for each of the water flow and electrical consumption of the pumping unit, and the readings were as follows:

Station 3, pumping unit 3

Eight readings were collected for each of the water flow and electrical consumption of the pumping unit, and the readings were as follows:

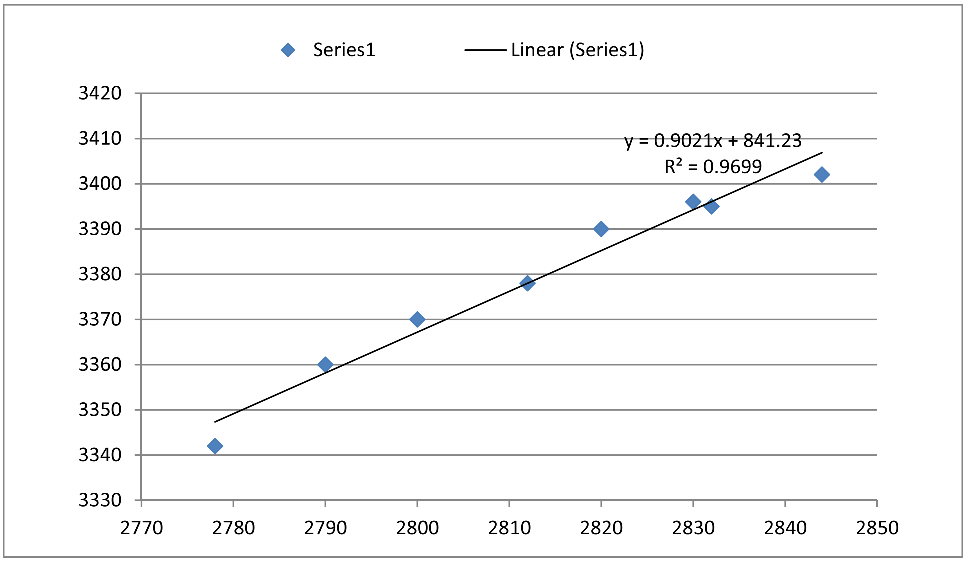

Fig. 8. The distribution of data for pumping unit 1, station 4 electrical consumption, water flow, and the equation for estimating electrical consumption.

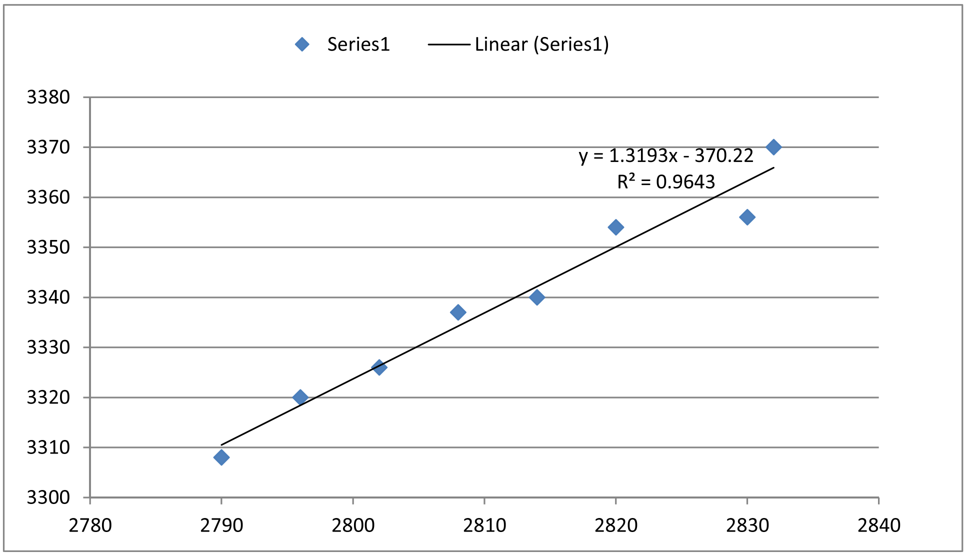

Fig. 9. The Distribution of data for pumping unit 4, station 4 electrical consumption, water flow, and the equation for estimating electrical consumption.

Station 1, pumping unit 2

Eight readings were collected for each of the water flow and electrical consumption of the pumping unit, and the readings were as follows: (Tables 3-8)

Study findings

Electrical consumption results

After implementing the corrective measures for the pumping units, the study demonstrated that the application of the ISO 50001 energy management system was reflected in a reduction in the consumption of electrical energy on each of the four pumping units. The researcher indicated that this reduction was based on specific consumption. In the case of pumping units, the corrective operation

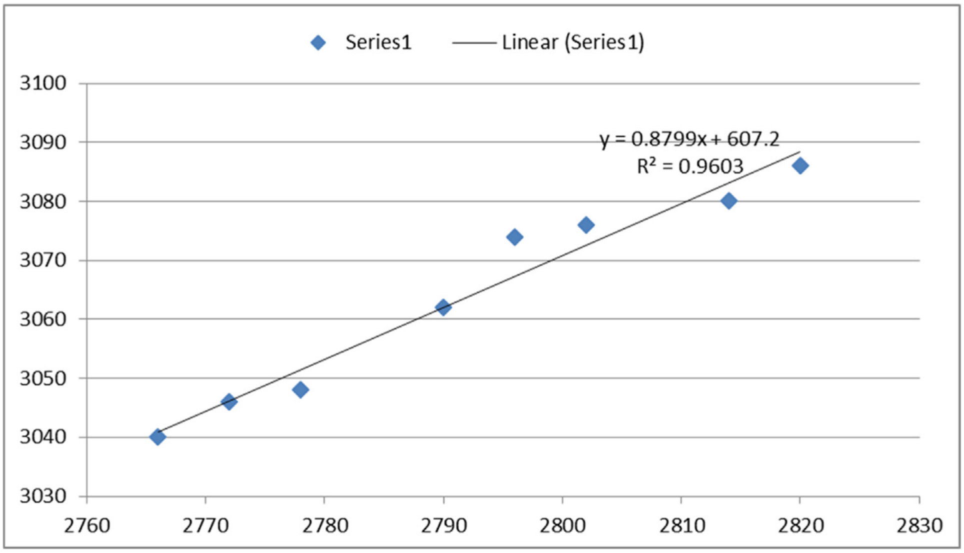

Fig. 10. The data distribution for pumping unit 3, station 3 electrical consumption, water flow, and the equation for estimating electrical consumption.

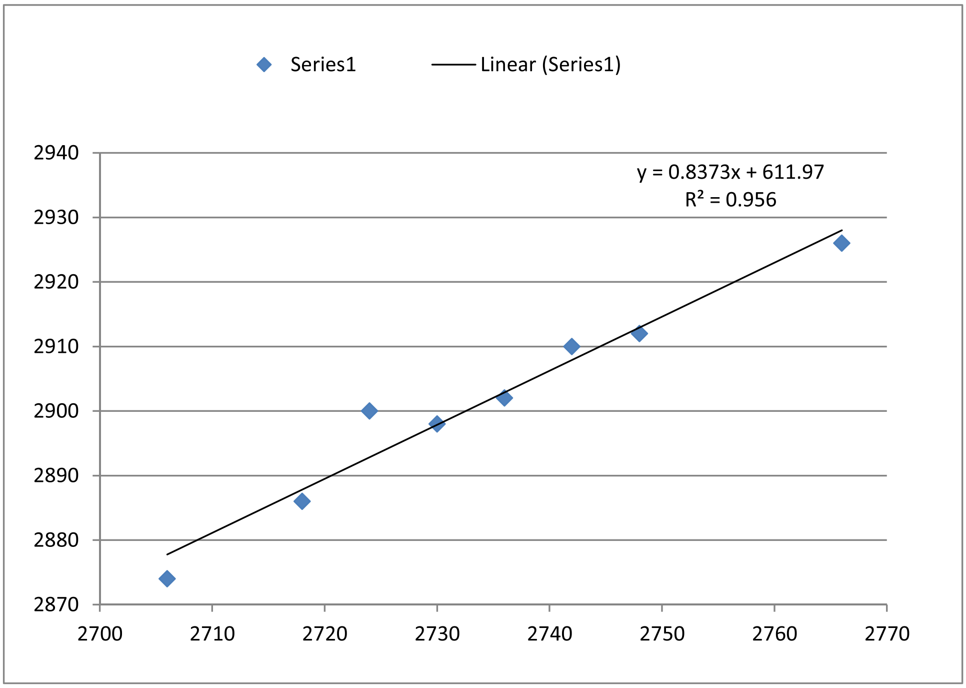

Fig. 11. The distribution of data for pumping unit 2, station 1 electrical consumption, water flow, and the equation for estimating electrical consumption.

increased the rate of water flow produced by the units, indicating that the water flow increased as a result of the treatment. In contrast, the rate of electricity consumption remained nearly constant.

Furthermore, when comparing electrical consumption to water flow using a ratio known as specific consumption, the researcher created a straightforward model because the ratio decreased after the procedure, indicating that the electrical consumption would increase if the same amount of water were pumped after the procedure with the same pumping unit as before. By creating a straightforward (predictive) linear regression equation before taking corrective action, it links the relationship between electrical consumption (the dependent variable) and water flow (the independent variable), demonstrating that there is a direct correlation between the two variables in the four pumping units. The model also shows that the electrical consumption will undoubtedly increase and is consistent

Table 3
Readings that were collected by the researcher before corrective actions were taken.

Station	Pump #	Date	Time min.	Input power before KW	Input power after KW	Power Consumption KWH	COS	MW	Amp	KV	Tank elivation before m	Tank Elivation after m	Water flow m3/min	Water flow m3/hr	Suction head m	Pump head m	Rated Power m	KW
PS1	2.00	44,682.00	10.00	4,925,784.00	4,926,271.00	2922.00	0.99	2.80	275.00	7.00	0.98	1.63	45.92	2755.40	18.00	300.00	282.00	3200.00
PS3	3.00	20/1/2022	10.00	6,947,069.00	6,947,582.00	3078.00	0.95	3.00	280.00	6.90	2.01	2.67	46.63	2798.00	19.40	297.84	278.44	3300.00
PS4	1.00	44,682.00	10.00	7,216,431.00	7,216,996.00	3390.00	0.99	3.30	330.00	6.90	0.00	0.00	47.00	2820.00	19.40	312.12	292.72	3500.00
PS4	4.00	22/12,022	10.00	542,717.00	543,278.00	3366.00	0.97	0.00	300.00	7.00	0.00	0.00	47.00	2832.00	19.40	312.12	292.72	3500*

Table 4
Cost of consumption before and after applying the management system and the savings achieved as a result of the application over one year.

	Unit Name	Energy Cost After Implementation JOD/Year	Energy Cost Before Implementation JOD/Year	Cost Savings
1	Station 4 Pumping Unit 1	1,897,205.56	2,179,768.32	282,562.76
2	Station 4 Pumping Unit 4	1,886,203.2	2,136,675.37	250,472.17
3	Station 3 Pumping Unit 3	1,709,851.08	1,855,090.65	145,239.57
4	Station 1 Pumping Unit 2	1,637,536	1,788,593	151,057

Table 5
The measurements taken for pumping unit 1 at station 4.

Water flow rate(m^3/hr) X	Electrical Consumption (KWH) Y
2830	3396
2800	3370
2820	3390
2790	3360
2832	3395
2844	3402
2812	3378
2778	3342

Table 6
The measurements taken for pumping unit 4 at station 4.

Water flow rate(m^3/hr) X	Electrical consumption(kWh) Y
2830	3356
2808	3337
2814	3340
2790	3308
2832	3370
2796	3320
2802	3326
2820	3354

Table 7
The measurements taken for pumping unit 3 at station 3.

Water flow rate(m^3/hr) X	Electrical consumption(kWh) Y
2790	3062
2796	3074
2814	3080
2766	3040
2778	3048
2802	3076
2772	3046
2820	3086

Table 8
The measurements taken for pumping unit 2 at station 1.

Water flow rate(m^3/hr) X	Electrical consumption(kWh) Y
2736	2902
2718	2886
2742	2910
2766	2926
2724	2900
2730	2898
2706	2874
2748	2912

with the results reached when depending on specific consumption when estimating the amount of energy required to pump the same water flow obtained after the remedial process. The electricity consumption of the pumping units and the study's findings agreed with those of [7], António et al. [1], and Kaddari et al. [8].

Energy expenses

The study's energy expenses findings, including a significant cost reduction of around 829,331.50 JOD, revealed that energy consumption prices were reduced after implementing the ISO 50001 energy management system [22]. This was achieved because of its application, understanding that localized costs were approximately 52,200 JOD, and the investment recovery period was only 21 days. This result agreed with the studies conducted by Aghajanzadeh et al. (2016), Swietochowska et al. (2021), and Mohamad et al. [12].

Energy efficiency

The study revealed that the effectiveness of energy consumption increased after the implementation of the ISO 50001 energy management system, as it increased in all energy units after the application of the corrective procedure at a rate of (7.65%) for all pumping units considered to be invaluable, mainly since the pumping units are subject to the energy management system. The investigation determined that it had high electrical capabilities, and this improvement and increase in water flow rate (which benefited from the energy) boosted energy efficiency. This finding was in line with Kaddari et al. [8] research.

Validating the research hypotheses

1. Due to the implementation of the ISO 50001 energy management system, consumption dropped by about 8,698,488.76 kWh annually.
2. The efficiency of the pumping units increased by 7.65% across the board when the ISO 50001 energy management system was implemented.
3. With an estimated 829,331.50 JOD in savings, the outcomes demonstrated reduced energy consumption expenditures following the adoption of the ISO 50001 energy management system.

Recommendations

Considering the findings, the study made several recommendations, including keeping the pumping units at Zai Treatment Plant's energy efficiency level at no less than 75% and developing a system to do that. Additionally, staff members in businesses and institutions were recommended to be informed about energy's significance. Finally, the researcher recommended that the energy performance of pumping stations be monitored and assessed regularly to determine how the installation of the ISO 50001 energy management system will affect the plant's energy efficiency performance. What is the impact of putting the ISO 50001 energy management system into practice on expenses and energy usage, and What impact does the Zai Water Treatment Plant's energy efficiency have from the ISO 50001 energy management system?

1. Because energy efficiency is important in reducing energy consumption and costs, the Zai Treatment Plant must concentrate on the energy efficiency of the special pumping units, where an efficiency of at least 75% must be maintained for each unit.
2. A continuous monitoring mechanism to evaluate the energy performance in the pumping stations is needed and plans that include corrective measures to ensure high energy performance must be developed.
3. There is a need to link the energy performance of the pumping stations to the companies' and institutions' strategy, and this strategy must be based on plans to reach the best use of energy.
4. Inter-institutional collaboration is needed to develop a strategy for institutional energy consumption reduction that can be adopted nationally.
5. Applying the research to more pumping facilities and other projects is required.
6. Future research should focus on various businesses and industries to show how utilizing the ISO 50001 standard reduces energy costs.

Ethical statements

The work does not involve animal or human subjects and does not use data from social media platforms.

Credit author statement

Omar S. Arabeyyat: Conceptualization, Methodology, Writing, Reviewing and Editing **Laith A. Ragha:** Validation, Conceptualization, and Software and Writing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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