



EVALUATING THE EFFICIENCY OF A FACILITY THROUGH A DETAILED ENERGY AUDIT

Sinan KAPAN 

Firat University, Mechanical Engineering Department, Elazig, Türkiye, skapan@firat.edu.tr

Article Info

Received: November 28, 2025

Revised: January 30, 2026

Accepted: February 9, 2026

Keywords

Energy Analysis,

Efficiency,

Audit,

CO₂ emissions.

ABSTRACT

Global climate change, triggered by rising greenhouse gas emissions, continues to threaten our planet. One of the most effective ways to reduce greenhouse gas emissions is through energy efficiency practices in industrial facilities.

According to the Energy Efficiency Law enacted in Türkiye, factories with an energy capacity exceeding 1,000 Tonne of oil equivalent (TOE) are required to undergo an energy audit every four years. This study, based on the data gathered from a detailed energy audit conducted at a manufacturing facility, proposed energy efficiency projects. Six areas with energy savings potential were identified. These projects include the installation of an energy monitoring and automation system in the facility, elimination of compressed air leakage, lighting conversion, insulation, solar power plant installation, and replacing inefficient pump motors with more efficient motors.

Implementation of the proposed projects will result in annual savings of \$64,476.5, equivalent to the monetary equivalent of 90.06 TOE of energy. Environmental impact analysis revealed a reduction in greenhouse gas emissions of 418 tons. The total initial investment cost of the 6 proposed projects is \$238,060.6, and the average payback period is calculated as 3.7 years.

1. INTRODUCTION

Global warming is the primary threat to life and nature on our planet in the coming years. Record-breaking temperatures in some regions of the world, increasing glacier melting rates, and droughts in some regions and floods in others are the most fundamental symptoms of climate change. To leave a livable world for future generations, urgent action and concrete steps must be taken to combat global climate change [1]. According to a report published by the International Energy Agency (IEA) in 2013, if measures are not taken to reduce greenhouse gases, the global temperature is predicted to increase by 3.5 °C by the end of the current century. Continuing greenhouse gas emissions at the same rate or increasing will cause further warming of the Earth and lead to climate change [2]. The IEA has recommended that the energy consumed in industry and buildings globally be used efficiently and that investments in clean technologies be made to reduce greenhouse gas emissions from human activities [3], [4]. Currently, the majority of the energy consumed in the world comes from fossil sources with high greenhouse gas emissions [5]. The industrial sector, which accounts for 30-70% of total global energy consumption, is largely responsible for global greenhouse gas emissions [6], [7]. Türkiye has begun taking significant steps toward these goals. According to the Energy Efficiency Law in Türkiye, industrial facilities with a total annual energy consumption of 1,000 TOE or more are required to conduct an audit every four years. While energy audits of facilities are relatively new in the literature, a recent increase has been observed. The common goal of these studies is to demonstrate the potential for reducing greenhouse gas emissions through efficient energy use through direct field studies [8], [9], [10], [11]. Energy audits in industrial facilities are the most effective method for assessing energy savings potential and achieving a clean and sustainable industrial production process.

Boharb et al. [12] conducted an energy audit, in accordance with ASHRAE classification, for an industrial facility in Fez, Morocco, specializing in cattle feed production and trade. In this context, this article presents a detailed analysis of energy use characteristics, revealing poor management of electrical energy. It has been shown that increasing the displacement power factor to 0.98 could save the plant \$52,758 annually. The potential for a 13.6% reduction in annual energy consumption of approximately 27,533 kWh was identified through lighting energy efficiency. Additionally, harmonic reduction by installing passive filters on variable speed drives revealed an energy saving potential of approximately 27,000 kWh per year.

Engin and Ari [13] conducted an energy audit of a rotary kiln system operating in a cement plant. They found that approximately 40% of the total energy input into the system was released into the environment via flue gas, and that approximately 15.6% of this energy could be recovered.

Worrell et al. [14] provide a baseline for energy use and CO₂ emissions by steelmaking processes and evaluate 47 energy efficiency technologies and measures; these measures could reduce energy consumption by 3.8 GJ/tonne and CO₂ emissions by approximately 19%, with payback periods of three years or less, highlighting significant opportunities for cost-effective improvements.

Oz and Sogut [15] examine an analytical assessment method for energy consumption processes developed for application in hotel energy management systems using an exergetic approach. They examined energy efficiency and environmental impact analyses using energy and exergy analysis using data obtained from energy audits. Energy efficiency was investigated by examining hotel consumption data in both insulated and uninsulated conditions. Consequently, they emphasized that energy losses are not only dependent on the building's structural components but are also directly affected by the hotel's energy management awareness within the facility. They also determined that energy consumption in the uninsulated condition is approximately 43% higher than in the insulated condition. Exergy efficiencies for both conditions are approximately 27% and 16%, respectively. Finally, they offer some recommendations for conscious energy management in hotel applications.

Sait [16] analyzes the electrical energy consumption of an educational building in Rabigh, Saudi Arabia, through a comprehensive audit. Construction materials, cooling load, lighting, and indoor conditions were evaluated, and heat and air leaks were identified using temperature and relative humidity measurements and thermal images. The analysis results show that electricity consumption can be reduced by up to 35.3% and the efficiency of air conditioning units can be increased by 31%. The findings are important for energy management and.

2. MATERIAL AND METHOD

The aim of this study was to analyze the efficiency of existing equipment in a manufacturing facility, identify areas where energy is used intensively, and identify opportunities for improving energy efficiency. This fieldwork consisted of data collection, measurement, evaluation, and conclusion phases. The methodology used for measurements conducted at the facility is described below. In the preliminary data collection phase, comprehensive data collection was conducted using various methods, including observation, interviews with key individuals, and measurements. The following steps were followed for data collection: Each workshop, laboratory, office, and other units within the organization were visited. Information on general electrical appliances was collected through observation and interviews. Site drawings of the existing building layout and electrical distribution were collected. Electricity bills were collected from responsible personnel. In some cases, power consumption of appliances (such as fans) was measured using a power analyzer, while in others, nominal power was used. Information was also collected on redundant/non-functional energy systems. Details of appliance usage were collected through interviews with key individuals, such as electricians and janitors (in the case of departments), and where information was lacking, approximate values and generalizations were made [17]. The devices used in the measurements are given in Table 1, and their photos are given in Figure 1.

Table 1. Devices Used in Measurements

Type of Device	Purpose of Use
Energy Analyzer	Active Power Measurement
Thermal Camera	Temperature Measurement
Surface Temperature Meter	Surface Heat Loss Detection
Pitot Tube	Fan Pressure Measurement
Flue Gas Analyzer	Flue Gas Analysis
Flue Gas Temperature Probe	Flue Gas Temperature Measurement
Ultrasonic Liquid Flow Meter	Fluid Flow Measurement
Conductivity Meter	Feed Water Conductivity Measurement

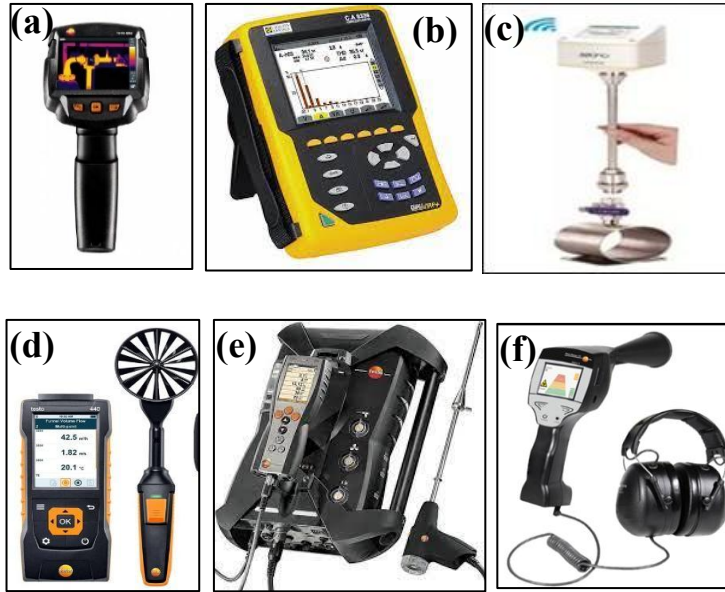


Figure 1. (a) Thermal camera; (b) energy analyzer; (c) multifunctional measuring device; (d) pitot tube; (e) flue gas analyzer; (f) compressed air leak detector.

2.1. Energy Saving Projects

2.1.1. Energy monitoring system

The energy monitoring system monitors critical and energy-consuming equipment within the facility. The status of critical energy-consuming equipment is monitored both instantly and periodically, allowing for rapid response in case of any issues. Energy analyzers with communication capabilities should be installed in the energy monitoring system.

2.1.2. Compressors

Compressors, due to their low efficiency, account for the vast majority of energy consumption in industrial facilities. Compressed air is a fundamental requirement for most production processes. Therefore, increasing compressor efficiency is essential for ensuring more reliable product quality, increasing productivity, and reducing energy consumption in today's industry. The compressor's specific power was divided by the unit cost of energy to obtain the cost of 1 m³ of air produced by the compressor. Examining business invoices allowed for the determination of the electrical unit price. Eq. (1) determines how much energy is lost in the compressed air systems as a result of air leaks:

$$ES_{L,CAS} = \frac{P_i V \left[\frac{k}{(k-1)} \right] N \left[\left(\frac{P_0}{P_i} \right)^{\frac{(k-1)}{kN}} - 1 \right]}{(E_a E_m)} \quad (1)$$

where N is the number of compressor stages, V stands for air leakage flow rate (m^3/s), P_1 is the atmospheric pressure (Pa), P_0 is the air pressure in the system (Pa), E_a is the adiabatic efficiency of the compressor, and E_m is the compressor motor efficiency [18].

2.1.3. Lighting

It is recommended that more efficient LED fixtures be used instead of older lamps in the facility. The annual energy savings achieved through this process are calculated as follows:

$$E_{s,l} = (P_2 - P_1)t_l \quad (2)$$

where $E_{s,l}$ represents the amount of energy to be saved annually, P_2 represents the power of LED fixtures (kW), P_1 represents the power of old type lamps (kW) and t_l represents the annual usage time (h).

2.1.4. Insulation

Energy leaks in the processes were measured with a thermal camera and a surface temperature probe. Heat losses were calculated using the following basic equations of heat transfer. The target surface temperature after insulation was 50°C . Based on the calculations, several insulation practices were recommended for valves, hot lines, and surfaces to prevent heat loss.

$$Q_c = U_c A (T_s - T_a) \quad (3)$$

$$Q_R = \varepsilon \sigma (T_s^4 - T_a^4) \quad (4)$$

where Q is the total heat transfer amount (W/m^2), U_c is the convection heat transfer coefficient ($\text{W}/\text{m}^2\text{K}$), U_r is the radiation heat transfer coefficient, σ is the Boltzmann constant, ε is the emission coefficient, T_s is the surface temperature, T_a is the ambient temperature.

2.1.5. Renewable Energy

Factors affecting the energy efficiency of photovoltaic panels include irradiance, ambient temperature, and panel area. To calculate the system's total electricity production and efficiency, the temperature of the photovoltaic modules is first determined as follows:

$$T_{mod} = T_{amb} + (NOCT - 20) \times \frac{G}{800} \quad (5)$$

T_{mod} represents the module temperature in $^\circ\text{C}$, T_{amb} represents the ambient temperature, NOCT represents the nominal operating cell temperature and G represents the radiation value. The PV module temperature obtained from Eq. (5) represents the operating temperature of the photovoltaic panels under actual environmental conditions. Since PV efficiency decreases with increasing module temperature, this value is used to assess the realistic electrical performance of the system and is implicitly reflected in the efficiency calculation presented in Eq. (6). Energy efficiency of a photovoltaic system is expressed as the ratio of the energy obtained from the system to the amount of energy reaching the panels:

$$\eta_l = \frac{V_{mp} \times I_{mp}}{G \times A} \quad (6)$$

where, V_{mp} represents the maximum power voltage, I_{mp} represents the maximum power current, A represents the total panel area, and G represents the irradiance value.

2.1.6. Pumps and Electric Motor

The water flow rate used, the pressure the pump must produce to overcome system losses, and the type of pump chosen which establishes the pump's mechanical performance efficiency all affect the total power and energy consumption of the pump motor. The efficiency of the motor powering the pump has a comparable effect on total pump motor power.

$$P_{pump} = \frac{\rho g Q H_m}{1000 \eta_p} \quad (7)$$

where, P_m represents the total pump motor power in kW, ρ represents the fluid density (kg/m^3), g represents the gravitational acceleration (9.81 m/s^2), Q represents the pump volumetric flow rate (m^3/s), H_m represents the pump manometric head (mSS), and η_p represents the pump's overall (total) efficiency.

3. RESULTS AND DISCUSSION

This study conducted a detailed study to evaluate the efficient use of energy consumed during the operations of a manufacturing facility, assess changes in CO_2 emissions, report the facility's current energy consumption, and determine the amount of energy that could be saved.

In this context, the facility's energy consumption analysis from previous years was examined in terms of energy efficiency for the energy-consuming equipment in the production line: the compressor and compressed air system, thermal losses in the plumbing system, pumps, electric motors, and lighting systems. The facility's energy consumption data for 2022 is shown in Figure 2, showing primary energy sources and percentages. Coal accounted for the highest share of the facility's total energy consumption in 2022, at 74%, followed by electricity at 26% and diesel fuel at 1%.

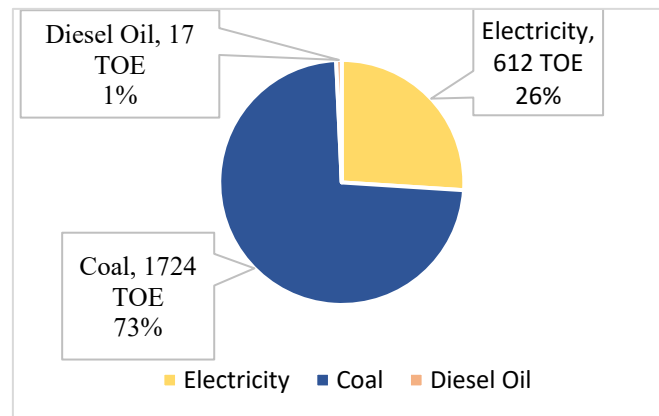


Figure 2. Energy consumption data of the facility

When the regression analysis values in Figure 3 are examined, the R^2 value is 0.0771. In the regression analysis, the R^2 value being close to 1 shows that the connection between production and consumption is proportional. R^2 values should be brought as close to 1 as possible by minimizing consumption not related to production. This is possible through efficiency-enhancing efforts.

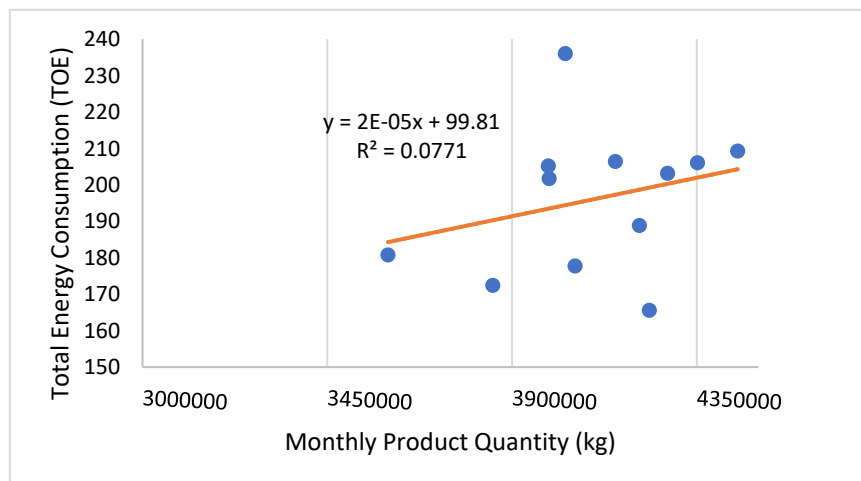


Figure 3. Total Energy Consumption and Product Trend Graph

Table 2. Specific Energy Consumption

Months	Product Quantity (kg)	Total Energy Consumption (TOE)	Specific Energy Consumption (TOE/kg)
January	4279273.95	203.14	0.000047
February	3853709.8	172.39	0.000045
March	4449935.65	209.27	0.000047
April	4152091.11	206.39	0.00005
May	4234641.46	165.54	0.000039
June	4352196.53	206.04	0.000047
July	3598295.65	180.75	0.00005
August	4210795.86	188.81	0.000045
September	4053875.36	177.73	0.000044
October	3990895.77	201.7	0.000051
November	3988909.34	205.18	0.000051
December	4030066	235.98	0.000059

Basic energy loads such as lighting, compressed air systems, pumps, auxiliary equipment, and standby losses operate continuously, independent of production fluctuations. In addition, variations in operating schedules, equipment operating at partial load, and process-related inefficiencies weaken the direct relationship between production output and total energy consumption.

Energy performance indicators have been determined to monitor the facility's energy consumption and assess its performance within the scope of energy management efforts. The energy performance indicator can be expressed as the total energy consumption per unit of production for the facility. Table 2 shows the total energy consumption per kilogram. Specific energy consumption was calculated as 0.000048.

3.1. Energy Saving Projects

Based on the measurement data obtained from a detailed energy audit within the scope of this study, six main projects were proposed to facility officials and are presented in Table 3. These recommendations include the installation of an energy monitoring and automation system in the facility, elimination of compressed air leakage, LED lighting conversion, insulation, solar power plant installation, and replacing inefficient pump motors with more efficient motors. It was determined that the implementation of these six efficiency-enhancing projects would result in a total annual savings of 52.3 TOE of electricity and 37.7 TOE of coal. The savings from these efficiency-enhancing projects would amount to \$64,476.50 annually, with a total investment of \$238,060.60. The simple payback period for this investment is 3.7 years. Implementing these measures would result in a total emission reduction of 418 tons of CO₂/year.

Table 3. Energy Efficiency Measures

Energy Efficiency Measure	Energy Type	Savings Amount		CO ₂ Reduction (CO ₂ -ton/year)	Investment Cost (\$)	Payback Period (year)
		TOE/Year	\$/Year			
Installation of Energy Monitoring and Automation System in the Facility	Coal	15.9	5144.6	53.3	4019.5	0.37
	Electricity	6.1	5858.8	34		
Elimination of Compressed Air Leakage	Electricity	2.63	1898.5	11	479.3	0.25
LED Lighting Conversion	Electricity	3.6	3430.8	19.9	16183.5	4.72
Insulation	Coal	21.13	8304.3	73.9	3157.4	0.38
Solar Power Plant Installation	Electricity	38.3	36656.2	212.8	202263.3	5.52
Replacing Inefficient Pump Motors with More Efficient Motors	Electricity	2.4	3183.3	13.1	11957.6	3.76
Total		90.06	64476.5	418	238060.6	3.70

3.1.1. Energy Monitoring System

Energy consumption at the facility is monitored locally using meters. The facility does not have an energy monitoring system. It is recommended that an energy monitoring system be installed to monitor all energy consumed at the facility and ensure energy consumption control. Eleven locations have been designated to monitor the quality of the boiler, compressed air, and other equipment at the facility. It is anticipated that the installation and active use of the energy monitoring system could result in savings of 1% in electricity and natural gas. This would result in an improvement of 15.9 TOE of coal and 6.1 TOE of electrical energy consumption.

3.1.2. Compressed Air System

The facility has three compressed air compressors to supply compressed air to all production lines and production points. These compressors operate at 5.5 bar. Pressure, power, and flow data for these compressors are shown in Table 4.

Table 4. Compressor Inventory Information

Number of Compressors	Power (kW)	Pressure (bar)	Free Air Delivery (m ³ /min)
1	22 kW	12.75	4.51
2	22 kW	7.20	4.09
3	3 kW	7.30	-

Compressed air generated by the compressors, combines with the collector line and flows into compressed air tanks. It then exits the dryer, passes through a filter, and then passes into the plant. Compressed air leaks are frequently encountered in moving parts such as pneumatic hoses, air guns, and jack connections due to twisting, stretching, and tearing. Therefore, the constant occurrence of air leaks is quite natural. Periodic scanning and repairs are crucial to minimize air leaks. Compressed air leakage measurements were carried out using an ultrasonic detector. A total of 17 leakage points were identified in different sections of the facility. Based on the measured sound levels, the leaks were classified as small, medium, and large. The annual energy losses associated with each leakage category are summarized in Table 5.

The annual energy loss caused by these compressed air leaks at the plant is 2,63 TOE, resulting in an annual financial loss of \$1,898.5. Preventing air leaks can reduce CO₂ emissions by 11 tons/year. The annual operating time of the compressors is calculated as 6840 hours/year and electricity is 0.154 \$/kWh.

Table 5. Summary of Compressed Air Leakage Measurements

Leak Category	Number of Leaks	Typical Sound Level (dB)	Line Pressure (bar)
Small leaks	6	43–47	5.5
Medium leaks	8	48–54	5.5
Large leaks	3	55–60	5.5
Total	17	-	-

3.1.3. Lighting

Inspections of the facility revealed that the lighting fixtures are predominantly LED, some fluorescent, and some floodlights. The facility primarily uses LED, with a very low percentage of fluorescent and floodlight fixtures. Replacing these floodlights with more efficient LED lighting would result in energy and cost savings. Calculations indicate an annual electricity savings of 3.6 TOE. This also translates to an annual financial savings of \$ 3,430.80, with a simple payback period of 4.72 years, based on the project's cost. The lighting energy consumption analysis was conducted based on the power ratings of the existing luminaires, the total number of installed fixtures, and their annual operating hours. The facility includes fluorescent, high-bay projector, outdoor, and administrative lighting systems, which

operate between 3,744 and 7,488 hours per year, depending on the production schedule. The key parameters used in the LED lighting conversion calculations are summarized in Table 6, and the annual energy savings were calculated using Eq. (2).

Table 6. Summary of Lighting System Parameters Used in LED Conversion Analysis

Existing Fixture Type	Power per Fixture (W)	Number of Fixtures	Annual Operating Time (h/year)
Fluorescent/linear lighting	36	429	3,744 – 7,488
High-bay / projector lighting	110	116	3,744 – 7,488
Medium power lighting	60	20	3,744
Outdoor projector lighting	150	6	3,744
Administrative building lighting	18	47	3,744
Total	-	618	-

3.1.4. Insulation

The mechanical installation examined within the scope of the study included elements such as valves, strainers, flanges, pipes, collectors, and pump housings. While the lines were generally insulated, some valves and lines were found to be uninsulated. A study was conducted to determine the efficiency achieved by isolating uninsulated installation elements. Examples of thermal images taken with the Testo 868 thermal camera of the installation lacking insulation are provided on the next page. Insulating uninsulated mechanical installation elements will ensure energy efficiency. Thermal camera images of the facility are given in Figure 4.

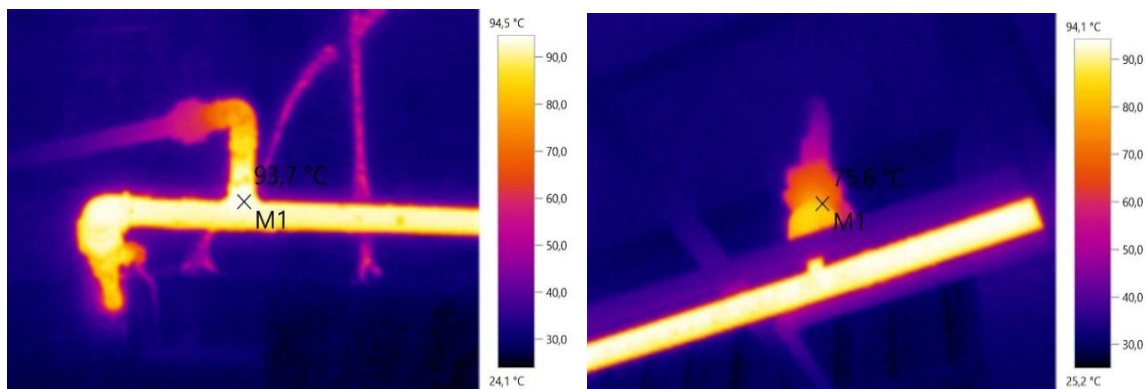


Figure 4. Thermal Camera Images of the Installation

In the heat loss analysis, surface temperatures of uninsulated components ranged between 60°C and 160°C, while ambient temperature was taken as 30°C based on on-site measurements. Pipe outer diameters were determined from nominal diameters, and insulation thicknesses were selected according to standard industrial insulation practices, resulting in insulated outer diameters ranging between 0.12 m and 0.27 m. Heat loss calculations were performed for both uninsulated and insulated conditions using linear heat loss models (W/m), and total heat losses were obtained by multiplying unit heat loss values by the equivalent pipe lengths.

3.1.5. Renewable Energy Resources

An inspection of the facility's roof identified suitable areas for solar panel installation. The approximate dimensions of the areas were determined on a map, and production potential was calculated using simulations using the PVsyst program.

Table 7 shows the amount of electricity delivered to the grid and the financial savings based on the unit cost of electricity obtained from the operating bill, based on the PVsyst simulation results for the

projected solar power plant system. The solar power plant system to be installed at the facility will meet a portion of the facility's electricity needs. Monthly production quantities based on simulation results based on solar power plant system components are presented in Figure 5.

Table 7. Solar Energy System Components

Number of Panels	575
Panel Capacity (Wp)	550
Total DC Power (kWp)	316,25
Number of Inverters	3
Inverter Power (kWac)	300
Total AC Power (kWac)	900

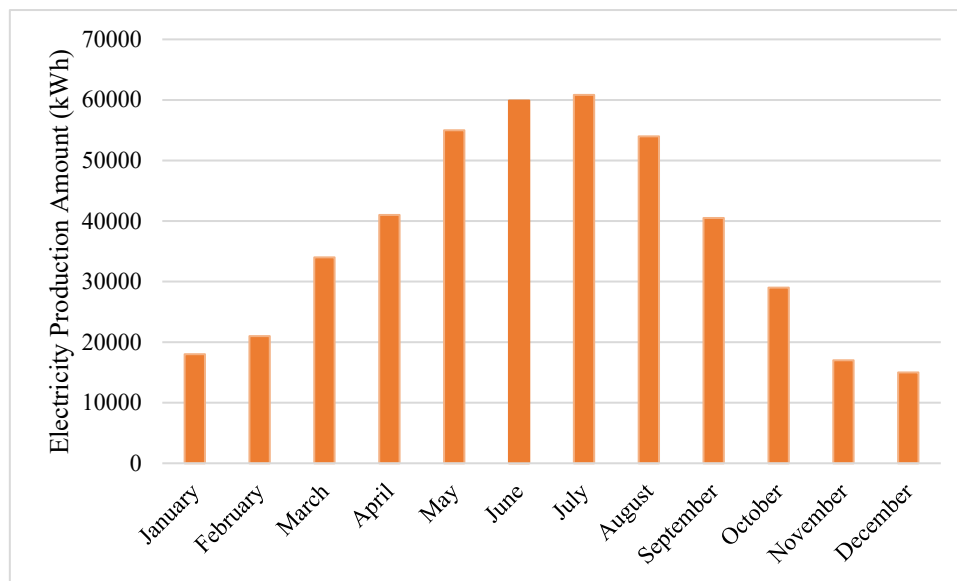


Figure 5. Electricity amounts given to the grid according to PVsyst simulation results

The facility's rooftop solar power plant installation will generate 38.3 TOE of electricity annually. Using the generated electricity within the facility will reduce grid draw, resulting in lower electricity costs. Furthermore, when production exceeds demand, a two-way meter allows for electricity to be fed back into the grid. This will reduce electricity bills through monthly offsetting. The estimated savings are \$36,656.2. The project investment cost is \$202,263.3, and the basic payback period is 5.52 years. As electricity costs increase over time, the payback period will decrease further.

3.1.6. Pumps

This section examines measurements taken from booster pumps and pump groups as part of the facility's energy audit. The pump motors are rated at IE3 premium efficiency and IE2 high efficiency. It is recommended that these pump motors be replaced with IE4 super premium efficiency motors at the end of their lifespan. The project to replace existing pumps with more efficient ones yields annual energy savings of 2.4 TOE, a cost equivalent of \$3,183.3, an initial investment of \$11,957.6, and a payback period of 3.76 years.

4. CONCLUSION AND SUGGESTIONS

In this study, a detailed energy survey of energy-consuming devices at a production facility was conducted to determine annual energy savings. Based on measurements taken at the facility, six energy efficiency measures were identified. These projects include the installation of an energy monitoring and automation system in the facility, elimination of compressed air leakage, LED lighting conversion,

insulation, solar power plant installation, and replacing inefficient pump motors with more efficient motors. Implementing all the proposed projects will result in total annual energy savings of 90.06 TOE, equivalent to \$64,476.5. An environmental impact analysis of energy consumption indicates that 418 tons less CO₂ will be released into the atmosphere annually. The total initial investment cost of the projects was \$238,060.6, and the average payback period was calculated as 3.7 years.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

Artificial Intelligence (AI) Contribution Statement

This manuscript was entirely written, edited, analyzed, and prepared without the assistance of any artificial intelligence (AI) tools. All content, including text, data analysis, and figures, was solely generated by the authors.

REFERENCES

- [1] S. Kaya and M. Yilmaz, "Global climate change and historical trends in climate indicators," *Cukurova University Journal of Engineering and Architecture*, vol. 40, no. 1, pp. 127–140, 2025.
- [2] International Energy Agency, *World Energy Outlook 2013*. Paris, France: IEA, 2013.
- [3] E. Worrell, L. Bernstein, J. Roy, L. Price, and J. Harnisch, "Industrial energy efficiency and climate change mitigation," *Energy Efficiency*, vol. 2, pp. 109–123, 2009.
- [4] S. Kartha, L. Nilsson, N. Sharma, and J. R. Moreira, "Global energy efficiency improvement in the long term: a demand- and supply-side perspective," *Energy Efficiency*, vol. 4, pp. 435–463, 2011.
- [5] S. E. Hosseini, "An overview of global energy scenarios and transition pathways," *Renewable and Sustainable Energy Reviews*, vol. 141, p. 110608, 2021.
- [6] M. Levi, "Climate implications of energy choices in the industrial sector," *Energy Policy*, vol. 39, no. 10, pp. 6155–6164, 2011.
- [7] A. Hasanbeigi, L. Price, and C. Zhang, "Energy efficiency improvement and CO₂ emission reduction in the iron and steel sector," *Energy Policy*, vol. 39, no. 9, pp. 5680–5692, 2011.
- [8] A. Thollander and P. Rohdin, "Energy audits in industry—A systematic review of the literature," *Energy Policy*, vol. 60, pp. 134–144, 2013.
- [9] M. C. P. Ramirez, W. F. Brouwer, K. Blok, and E. Worrell, "Energy efficiency and CO₂ emissions reduction opportunities in the industrial sector: A case study approach," *Energy*, vol. 31, no. 12, pp. 2270–2285, 2006.
- [10] C. Trianni and G. Cagno, "Dealing with barriers to industrial energy efficiency: An innovative approach to support energy audit activities," *Applied Energy*, vol. 104, pp. 653–662, 2013.
- [11] E. Fabrizio, V. Corrado, and A. Filippi, "A methodology for energy audit and monitoring of industrial facilities," *Energy and Buildings*, vol. 43, no. 8, pp. 2140–2147, 2011.
- [12] A. Boharb, A. Allouhi, R. Saidur, T. Kousksou, A. Jamil, Y. Mourad, and A. Benbassou, "Auditing and analysis of energy consumption of an industrial site in Morocco," *Energy*, vol. 101, pp. 332–342, 2016.
- [13] T. Engin and V. Ari, "Energy auditing and recovery for dry type cement rotary kiln system: a case study," *Energy Conversion and Management*, vol. 46, no. 4, pp. 551–562, 2005.
- [14] L. Worrell, J. Roy, K. C. Delhotal, L. Price, and E. Worrell, "Industrial energy efficiency and carbon dioxide mitigation opportunities in the U.S. iron and steel industry," *Energy*, vol. 31, no. 12, pp. 2270–2285, 2006.
- [15] M. E. U. Oz and M. Z. Sogut, "Assessment of energy performance based on energy audit of a hotel using exergy approach," *European Journal of Technique (EJT)*, vol. 9, no. 1, pp. 45–53, 2019.
- [16] H. H. Sait, "Auditing and analysis of energy consumption of an educational building in hot and humid area," *Energy Conversion and Management*, vol. 66, pp. 143–152, 2013.
- [17] O. A. Oyelaran, Y. Y. Twada, and O. M. Sanusi, "Energy audit of an industry: A case study of fabrication company," *Aceh International Journal of Science and Technology*, vol. 5, no. 2, pp. 45–53, 2016.
- [18] S. Çağman, E. Soylu, and U. Unver, "A research on the easy-to-use energy efficiency performance indicators for energy audit and energy monitoring of industrial compressed air systems," *Journal of Cleaner Production*, vol. 365, 132698, 2022.