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Enhancing Energy Efficiency in The Electrical Processes and Systems of Industrial Facilities: A Case Study for The Petra Glass and Mirror Company in Jericho – Palestine

Tuqa Issa Ismail Abufarah

M.Sc. Thesis

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A thesis submitted in partial fulfillment of requirement for the degree of Master of renewable energy and sustainability

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Jerusalem-Palestine

1445 / 2023

Dedication

With all my heart and longing, I dedicate this work to **my father soul.**

To the five women in my life, my mother **Om Malath**, who raised me on human values, my two sisters **Tham'a** and **Haya**, and to granddaughters **Maryam** and **Sarah.**

To my soul mate, "**my husband Aziz**", and to my brothers.

To my loving friend (**Sumaya**) and friends on the road to success (**Iman, Bayan, Samah, Osama**).

To my first and last homeland, Palestine, "the land of martyrs and heroes."

To the soil of Gaza Hashem, and Al- Ayyash Bank.

Declaration

I certify that this thesis submitted for the degree of the master is the result of my research, except where otherwise acknowledged, and that this thesis, neither in whole nor in part, has been previously submitted for any degree to any other university or institution.

The work was done under the supervision of Dr. Husain Alsamamra from the physics department-Al-Quds University.

Student Name: Tuqa Issa Ismail Abufarah

Signed: Tuqa

Date: 4 /12 / 2023

Acknowledgements

First, I would like to thank Allah, for His mercy on me during all my life, and praise the prophet Mohamad (peace be upon him!). I dedicate this work to my father (Issa Abufarah May ALLH give mercy to his soul), my mother, my brothers, my sisters and all the people who have contributed their precious time and efforts to help me in completing this thesis.

Furthermore, I greatly appreciate the support which I received from my supervisor Dr. Husain Alsamamra for his guides, support, motivation and encouragement throughout the period this work was carried out. I am also grateful to Eng. Ali Al Arouri The main supervisor in the factory, for providing the necessary facilities.

Place of experimental work

The work of this thesis was performed at the Petra Glass and Mirror Company in Jericho - Palestine.

The Petra Glass and Mirror Company one of the biggest glass companies in the Middle East, which is situated on about 10000 m^2 of land in the agricultural and industrial city of Jericho. The factory started manufacturing, performing all connected activities, and exporting its sector to the Palestinian market and the occupied territories in 2018.

The Petra Glass and Mirror Company

Abstract

The need to increase the energy efficiency of manufacturing processes has gained attention due to growing energy prices and more onerous regulations. Governments and corporations from numerous nations are working hard to create technologies for managing energy and creating new energy sources. This research illustrates an integrated design for the Petra Factory in Jericho Industrial City Energy Efficiency Management system (EEM). The goal of this strategy is to reduce energy consumption and thus discount the electricity bill and reduce the percentage of greenhouse gases(GHGs). The photovoltaic system (PV) was expanded, the power factor (PF) was optimized, electrical systems were simulated using the Industrial Internet of Things (IoT), and heavy machinery was scheduled to operate to avoid peak demand. This study demonstrated that there is a clear possibility of achieving the goal. The RET-Screen program was able to determine the optimal economic and environmental feasibility of the PV system expansion strategy. The PV system is expected to generate 426 MWh of electricity per year. The other metric was the 337 ton/year Carbone dioxide (CO_2) decline. Along with decline the factory amount of electricity utilized, increasing the PF from 0.87 to 0.95 yielded, this means saving 18,712.5 kWh/year of electricity consumption. The strategy of replacing old electrical systems with more energy-efficient electrical systems reduced the amount of energy utilized by 140746KWh/year significantly, the adoption of the IoT will clearly have an influence on the electricity bill. The factory will save money on electricity costs by timing the hours that the production lines are work. It is possible to avoid using combustion machines during the peak demand period.

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List Of Abreviations

Abbreviation	Representation
EEM	Energy Efficiency Management
PV	Photovoltaic
GHGs	Greenhouse Gases
PF	Power Factor
CO_2	Carbone dioxide
IoT	Industrial Internet of Things
JDECO	Jerusalem Electricity Company
P	Real power
S	Apparent power
Q	Reactive power
CNC	Computer Numerical Control
PV_{syt}	Photovoltaic system program
KWh	Kilo Watt Hour
KW	Kilo Watt
KVAR	Kilo Volt Ampere Reactive
AC	Alternating Current
DC	Direct Current
K$	Thousand Dollars
MCB	Main Circuit Breaker
Isc	Short circuit current
Voc	Open circuit voltage
MIRR	Modified Internal Rate of Return
IRR	Internal Rate of Return
NPV	Net Present Value
DALI	Digital Addressable Lighting Interface

Chapter One

Introduction

1.1 Background to the Study

In today's culture, issues like climate change, unreliable energy sources, and rising energy costs are becoming more and more significant. The most cost-effective way to address these issues in the short term is through EEM, it is a more efficient way to combat rising energy demands and unstable energy supplies [1] [2-4]. The industrial sector is one of the biggest consumers of energy and one of the biggest producers of CO_2, accounting for 31% of primary energy usage and 28% of CO_2 emissions [5]. In 2020, energy savings of up to 25% made in the manufacturing sector by taking steps such installing energy-efficient motors, fans, and light [6]. Additionally, a study found that adopting technology to intelligently control energy use and investing in energy efficiency solutions can cut energy consumption by 50%, as opposed to operational improvements, which can only lower it by (10 - 20) % [7]. In a thorough literature review assessment, part of it contained a thorough explanation of the idea of EEM and the most significant factories in the world that have implemented its tenets. From the perspectives of the companies, energy efficiency is evolving into a crucial theme in production management as a result of three key factors that manufacturers see as vital for increasing energy efficiency [8]:

Rising energy costs, as a result of the increasing cost of oil, gas, and other fossil fuels like coal, manufacturing enterprises are placing an increasing emphasis on reducing their energy usage [9]. Energy can represent up to 60% of operational expenses (e.g., in the chemical industry) in the energy-intensive manufacturing sectors (such as steel, cement, pulp and paper, and chemicals), making it a significant competitive element [10]. According to Ramirez, A., et al., [11], the cost of energy accounts for around 23% of total operating expenses in non-energy-intensive businesses like mechanical engineering. This figure includes labor costs, raw material and packaging purchases, and energy usage. Due to growing energy prices and the resulting rising production costs for steel, chemicals, etc., resource prices can be anticipated to climb steadily in the upcoming years [12], which will also increase other purchase expenses.

Costs of new environmental restrictions related to CO_2 emissions, countries and decision-makers from all over the world committed to reducing GHGs emissions significantly in the ensuing decades in the Kyoto Protocol from 1997 [13] as well as the Copenhagen Accord from 2009 [14] (see, for example, the target of the EC to reduce at least 20% of GHG by 2020) [2]. A variety of market-oriented regulations and policy initiatives, including taxes, subsidies, tradable emission permits, and green certificates, have been implemented in a number of nations due to the manufacturing sector's approximately one-third contribution to global CO_2 emissions [15-17]. Companies that increase their energy efficiency and, as a result, reduce their carbon footprint can better prepare themselves to deal with the difficulties and expenses brought on by existing and future CO_2 restrictions.

Changing consumer purchasing habits in favor of "green" and energy efficient, goods and services energy efficiency during the use phase of a product is considered by businesses and end users to be a crucial factor in their purchasing decisions [18]. EEM has a significant impact on lowering a product's overall environmental impact, even though consumers may not be aware of it yet. Products that have been produced in an environmentally friendly manner are becoming more and more popular among consumers [19], and manufacturing companies have realized that doing so can give them a reputational and competitive advantage [20-22]. EEM can become a key competitive advantage because it can significantly affect a product's environmental performance.

The aforementioned factors make EEM a crucial pillar supporting each of the three factors (triple bottom line) taken into account in frameworks for sustainable manufacturing, as presented in Figure 1[8].

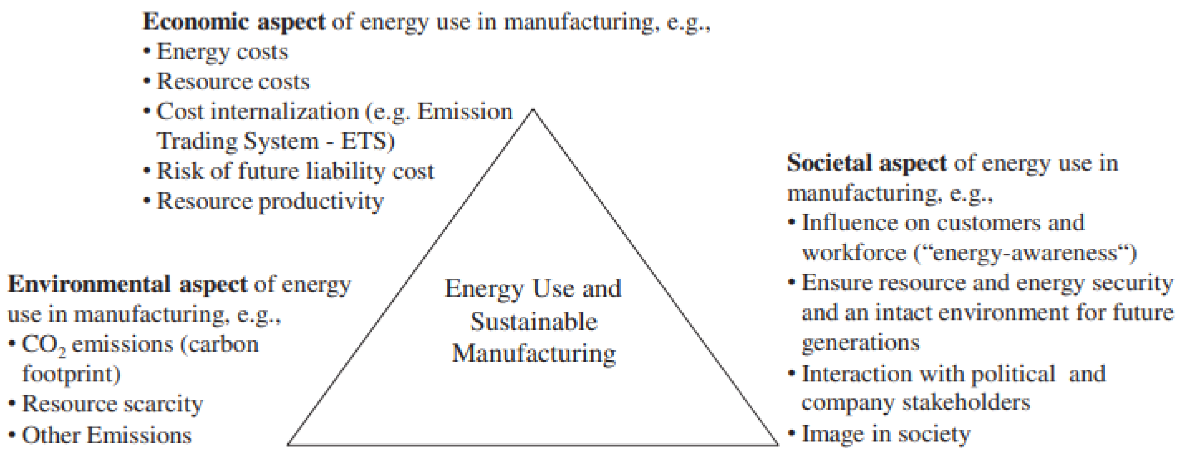

Figure 1: The EEM Contribution to the three main facets of sustainable manufacturing [8].

To sum up, the EEM is a crucial strategy for reducing the negative effects of manufacturing on the environment and is the first step in the adoption of sustainable production [23]. Also, from the perspectives of the companies, EEM is evolving into a crucial theme in production management.

1.2 Problem statement

The Petra Glass and Mirror Company has been taken as a case study in this research. Given that it uses a lot of energy due to the heavy machinery and the numerous loads, so what is the most practical and efficient energy solution?

The purpose of this study is to develop and put into action an energy efficiency management strategy for the case study's energy system. EEM integrates a variety of techniques that can be applied together to manufacturing systems, and it is also possible to conduct economic evaluations and environmental impact assessments, including those related to CO_2 emissions and other GHGs by using the RET Screen program to manage the PV system, one of the most important pillars of EEM. To find the optimal solution, optimization relies on balancing a number of factors. Three different cases will be combined, the basic step, based on expanding the PV system installed on the rooftops of the factory with the lowest CO_2 emissions, the second step, based on improving the PF, and the third step, based on innovating an intelligent system for electrical systems and conserving energy in the factory machinery.

Research Question(s) and Hypothesis

- What are the conditions and variable inputs for each strategy?
- What aspects should be taken into account to determine the greatest performance?
- What is the final total electricity bill after improvement?

1.3 Objectives

Implementing an energy efficiency management strategy in order to improve energy flow and reduce the facility's electricity bill.

1.4 Research significance and relevance

In this work, the topic of EEM been specifically discussed. Since these energy flows are typically directly or indirectly related to the depletion of essential resources, improving resource efficiency is also naturally included in this (such as oil, gas, and coal).

EEM in manufacturing is a problem that is extremely important from both a national and a single company perspective. Industry is a significant energy consumer in the country. From an economic and environmental perspective, taking energy consumption into account is particularly relevant. On the one hand, environmental effects and energy supply are closely related, as an illustration, industry alone accounts for around 28% of CO_2 emissions (plus approximately 9% from direct industrial emissions, as shown in Figure 2) [23].

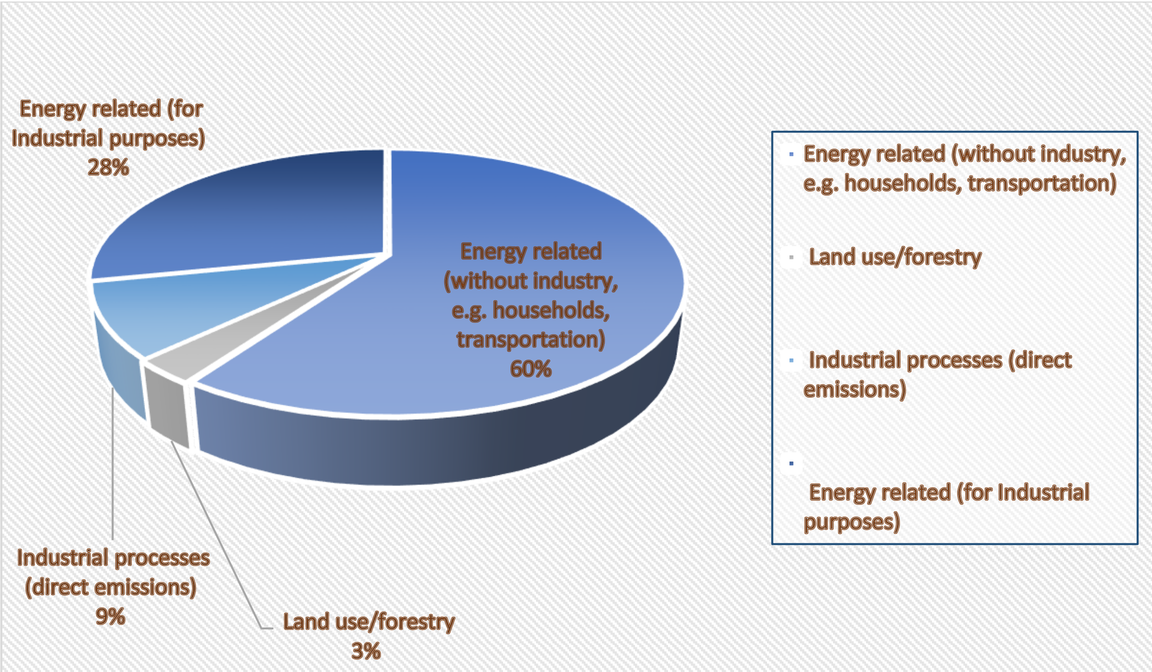

Figure 2: Composition of CO_2 emission in the world [23].

On the other side, there is a significant economic component to energy usage as well. Energy costs for electricity, gas, and oil have been gradually and disproportionately rising in recent years, as shown in Figure 3[23]. Therefore, energy prices nowadays can account for a sizable portion of the total costs of industrial firms. According to studies, energy expenses can account for up to 20% of overall costs in some industries in 2013 [24,25]. Recent studies that are the result of both industry practice and research emphasize the value of energy efficiency in manufacturing. Approximately 70% of small and medium-sized companies' respondents to an industry survey identified energy efficiency as a key issue. While lowering energy costs is undoubtedly the key driver, contributing to environmental conservation is also a significant factor [24]. Studies also highlight the potential that is currently untapped for EEM in industrial, as well as the challenges that prevent the discovery and widespread implementation of improvement strategies in practice [26]. Clearly, there is a great demand for proper techniques and equipment to assist in promoting energy efficiency in industrial businesses.

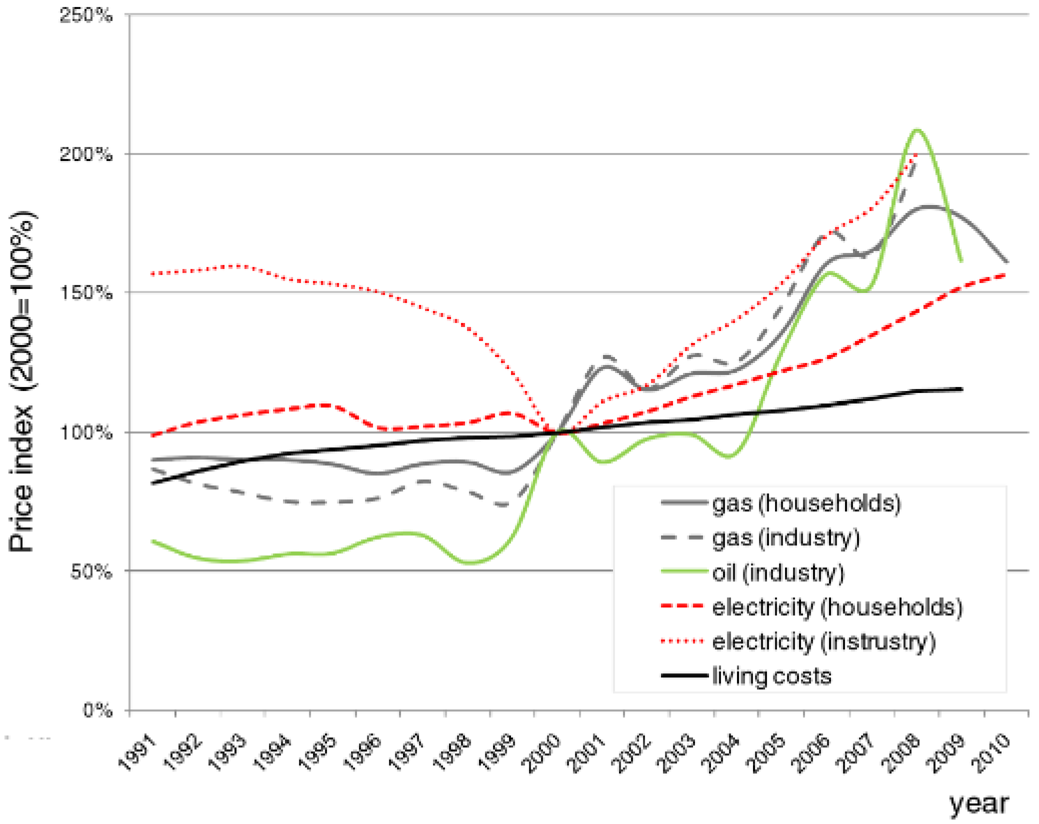

Figure 3: Development of energy prices globally [23].

1.5 Thesis Structure

The thesis contains five chapter as follows:

- Chapter One: Introduction.
  It provides the researcher a succinct overview of the research's problem statement. The purpose and inspiration for this thesis are then outlined.

- Chapter Two: Literature review.
  An explanation of the case study's electrical situation, the EEM concept, a list of the most significant factories in the world that have implemented its tenets.
- Chapter Three: Energy Efficiency Management Opportunities and Optimization Methodology
  It Provides the most recent context for the power currently applied in this study and the data required to obtain optimization methods that applicable to the system.

- Chapter Four: Analysis and Discussion of Results

Energy Audit in the Definite Facility

This chapter offers outputs from AutoCAD and RET screen as well as optimization outcomes from calculations and equations. Additionally, it provides a comparison and discussion of the findings.

- Chapter Five: Concluding Remarks

  This chapter includes a summary of the study's findings and some recommendations for the future.

Chapter Two

Literature review

2.1 Introduction

The analysis of literature review was done in this research, in order to determine what is already known about EEM and the most significant practical applications. On the other hand, the industrial, electrical and situation of Jericho city will be described as well as our case study.

2.2 History and applications on EEM

Although the industrial sector has continuously improved its energy efficiency, examples from the literature and real-world applications demonstrate that the full economic potential of energy efficiency is still untapped [2,3] [27-29]. The "energy efficiency gap" discussion centers on the factors that prevent organizations from realizing financial rewards from expenditures that would reduce their energy use [29-33]. The implementation of energy efficiency improvement measures in businesses has been hampered for a number of reasons, some of which include: decisions based on payback periods rather than interest rate calculations, a lack of capital, the management giving energy efficiency a low priority [29], a lack of information [34], or "difficult-to-measure components" of energy investments (such as transaction or monitoring costs). Low energy management status has also been noted as a barrier to energy efficiency in several research [35-37]. For reasons related to the economy, the environment, or society as a whole, industrial enterprises may benefit from energy management [38,39]. Putting in place an energy management system may be a strategy to cut back on energy use and the associated CO_2 emissions. The scientific community's interest in energy management has significantly increased over the past ten years, and various publications have been published as a result [40]. These studies cover a variety of angles and production domains when addressing energy efficiency. Multidisciplinary strategy comprising various departments, including management, quality, IT, production, and the technical office is necessary for proper energy management to take place [41]. Thus, major current research areas include methods and technologies that promote energy assessment and stakeholder collaboration to assist managers in increasing energy efficiency in production [42]. The modeling and analysis of energy-efficient practices is a major focus of these new approaches and tools, which generally enhance energy-related analysis and decision-making in manufacturing environments. Methods and tools for measuring energy consumption are crucial for energy management activities because they help decision-makers spot chances for improvement and monitor how their choices affect energy use [40]. These commercial solutions can assist businesses in overcoming organizational and cognitive obstacles to the adoption of energy-saving strategies [43]. The first step in improving energy efficiency is monitoring and analyzing the factory's energy usage and its manufacturing procedures [44]. Many studies have provided insight into how to approach the use of these techniques and instruments, which have been shown to be very energy efficient and cost-effective [45,46]. Energy evaluation techniques and tools also raise energy awareness and boost the transparency of a system's real-time energy consumption. They enable for the analysis of various production factors and the evaluation of their effects on energy efficiency (e.g., technologies, raw materials, time, etc) [47]. Additionally, the assessment techniques and technologies offer industrial businesses a thorough, practical means of determining, managing, and enhancing production systems' energy efficiency [44].

There are many applications on the implementation of energy management around the world, in 2008, researchers in the USA conducted a glass factory study in which they addressed energy efficiency techniques and technologies that may be applied at the component, process, system, and organizational levels. By outlining the main process steps in the glass industry and discussing the trends, structure, and characteristics of energy use in the glass industry. Based on case study data from actual industrial applications, Ernst et al., [48], produced conclusions from them that provided estimated energy savings and associated costs for several energy efficiency methods. Additionally, typical payback intervals were given.

A study conducted be Vittorio at el., in 2010 [49], to introduce a system to control energy consumption and how this system can improve energy efficiency in the pharmaceutical sector by identifying low-cost ways to improve energy in order to improve energy efficiency in the pharmaceutical sector. Their trend in this study is a measure based on system behavior discounted by examining historical data on energy consumption and associated components through regression analysis in the industry, which is precisely the control in the working time factor for energy consumption in factories. Depending on how energy is managed in this industry, the anticipated energy saving methods ranges from 2 to 20%. This methodology can be used in industries for an annual energy cost of above €150,000.

Erdem Koç and Emel Çinçik performed an analysis in 2010 [50], of the woven fabric industry's energy use. They gathered broad data on the different kinds and quantities of energy used in the manufacture of woven fabrics, as well as an analysis of energy use in this industry. For the purpose of calculating energy usage, they created a theoretical strategy. Calculating the energy consumption of a specific woven cloth made at the selected weaving mill, the findings were compared to information from the literature. It has been established that compressors make up 29.1% of the overall energy consumption in the selected spinning mill, while weaving machines use 29.2% of the entire monthly energy consumption (262368.2 KWh/month). Additionally, it has been computed how much particular electrical energy is used each month over a year, and it has been shown that the results vary between 0.94 KWh/month and 1.48 KWh/month. As a result, the monthly cost of electricity was determined to be $ 0.094. The literature's data on individual energy costs ranges from 0.057 to 0.119 $/month, with Turkey's figure being 0.082 $/month. The estimated data and those provided in the literature have been proven to be in good agreement.

Fysikopoulos and his colleagues at the University of Petra in Greece [51], did a study on the energy consumption in vehicle assembly lines in 2012 using simulations of the actual auto assembly lines. Energy usage at the machine level and in the output, cells is monitored on the manufacturing line. The business can save money and energy by simulating the assembly line beforehand and before taking energy factors into account. The process involved building a model to construct the body's structure inside the body and confirm the estimated energy use. The created model can quickly and easily anticipate how much power will be used for a specific input, and it may be used on different manufacturing lines.

Nasry et al., in 2015 cared to use the pharmaceutical industry's energy utilization. In their study, they placed a high importance on energy efficiency planning because it might reduce energy consumption in the manufacturing area by around 35% and monthly electricity costs by about 20% [52]. According to their research, they used work flow analysis to analyze energy efficiency based on the company's total weekly energy use in their study in order to make handling of goods easier and efficient energy use depends on the materials used and the energy planning.

In 2017, Washington and a team of researchers [53], conducted a study to lower the electricity consumption of the compressed air system of the steel industry in Brazil. The result was a decrease in the average monthly consumption of electricity by 57.2%. Their study was based on lowering energy consumption by testing the compressed air, where they performed an ultrasound test in the compressed air line to find and quantify flow leaks. Energy consumption scenarios were compared before and after changes once the leak site was located, eradicated through maintenance, and corrective upgrades.

2.3 Overview of the current scenarios

2.3.1 Power sector scenarios in Palestine

In Palestine, the power sector is out-of-date and has been ignored for a while. However, it is ineffective, and unreliable. Critical energy shortages and outages are common due to the system's frequent overload. 92% of the generator's supply comes from Israeli sources, with the remaining coming via interconnection points with surrounding nations including Jordan and Egypt [54].

Due to its strategic location near the Jordanian border and plenty of land resources offered at reasonably affordable prices, the Jericho district has experienced rapid economic expansion and heightened investor rivalry [55]. Jericho is considered one of the most important areas of concession for the Jerusalem Electricity Company (JDECO). The JDECO has been forced to explore for alternatives due to the enormous demand for energy supplies, particularly in the industrial sector. Due to its concession areas, which encompass a sizable portion of the region and several West Bank communities, JDECO is one of the most significant Palestinian economic facilities as well as one of the largest and deepest. Also, it is the only economic artery connecting Jerusalem, the company's primary hub, with the rest of the company's branches Figure 4 shown the current capacity of electricity distribution companies in the West Bank [56].

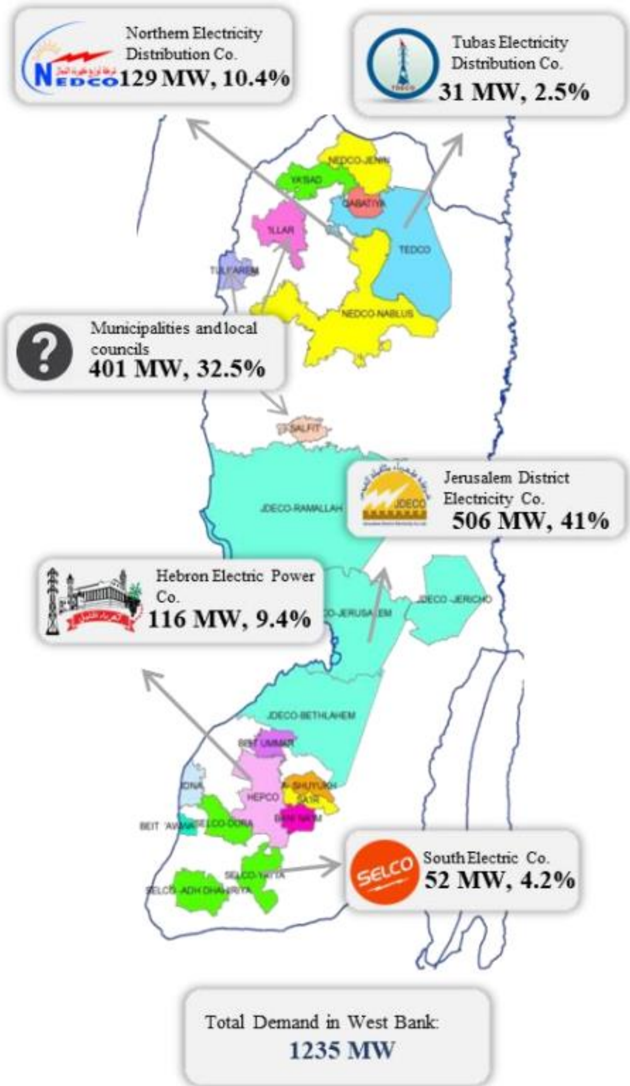

Figure 4: Palestinian electricity distribution companies in the West Bank in 2016 [56].

Energy conservation is a procedure that uses the least amount of energy possible to offer services in government and non-government owned and controlled assets while maintaining the necessary level of service. One of the biggest issues of today is the lack of energy. The human species must contend with the finiteness of the fossil fuel resources on which it has come to rely, even while their usage results in significant environmental degradation [57]. This study, which is focused on energy management in the Industrials' sector in Palestine, is important by the fact that the industrial sector is one of Palestine's major consumers of energy and suffers from extreme energy consumption and poor energy management. According to the Palestinian Central Bureau of Statistics in 2018, the energy consumption in Palestinian industrial sectors represents about 13% of the country's total energy demand, also Table 1 shown the amount of energy consumption in the industry sector, the energy form and the year, 2013-2020 [55].

Table 1: Energy consumption in the industrial sector, the energy form and year, 2013-2020[55].

Energy form	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Electricity (GWh)	405	515	563	570	633	715	686	544
Petroleum products (Kilo tons)	28	16	28	24	25	29	27	22
Renewable energy (Kilo tons)	5	6	6	5	6	7	13	10

Table 1 identified the turbulent growth from 2013 - 2018 and the quantity fall from 2019 – 2020. This is because Covid-19 caused disruptions in many spheres of life, including the industrial field.

2.3.2 Electrical power sector scenarios in Jericho

Jericho is one of the sixteen governorates of the Palestinian National Authority within the Palestinian Territories, located along the eastern regions of the West Bank. The estimated population of Jericho is 31,501, who live in the agglomerations of the Jericho. Due to the population increase, the number of industrial establishments in the region is increasing, and as a result, the demand for electric power has increased, with the maximum load reaching 45.98 MW in 2021[55]. Table 2 shown the average price of electricity in Jericho city for many sectors during year 2022[58].

Table 2: The cost of consumption of electricity in Jericho city during year 2022[58]

Consumer Categories	Price (NIS)
Commercial	0.64
Industrial low pressure	0.52

Industrial medium pressure	0.44
Agricultural	0.47

Based on the Japanese "Corridor for Peace and Prosperity" initiative for regional cooperation, which was launched in 2006, and in accordance with the Palestinian National Development Plan and the industrial cities program, which promotes sustainable development and the investment process, particularly in the city of Jericho and the Jordan Valley, the Commission, with the assistance of the Japanese government, started implementing the city's external infrastructure for Jericho Agricultural Industrial in 2010. The agricultural and industrial city of Jericho is located 4 km from the city center, in the northeast of the city of Jericho. The first phase developed area, which made up roughly 115,000 m^2 of the total estimated area of 615,000 m^2, as shown in Figure 5[59].

Figure 5: Jericho Agricultural Industrial City [59].

In addition to being close to the source of raw materials, its closeness to the Jordanian borders makes it eligible to serve as a gateway to the Arab markets. Petra factory (case study) is one of the Jericho agricultural industrial factories out of 15 factories. It is equipped with heavy machinery, which results in the need for a large electrical capacity and electricity bill, this is explained in Table 3 Which constitutes a large burden on the factory, and this requires the application of EEM measures to reduce as much as possible the percentage of the bill.

Table 3: The amount of electricity consumption and bill for the Petra factory in the year 2022.

Month	Energy consumption (kWh)	Price (NIS)
January	140587	88570
February	146714	92430
March	137396	86560
April	126555	79730
May	127085	80064
June	145788	91847
July	145306	91543
August	143873	90640
September	140382	88441
October	130646	82307
November	120136	75686
December	119325	75175
Total	1497238	1022993

Chapter Three

Energy Efficiency Management Opportunities and Optimization Methodology

3.1 Energy Efficiency Management Opportunities

Energy efficiency in the industrial sector is frequently interpreted and researched as specific energy consumption of processes, machines, and factories [60-64], referring to its thermodynamic meaning and highlighting the idea of "using less energy to provide the same number of services or useful output" [65], as well as its connection to environmental and ecological issues and in particular, CO_2 emissions [66-70]. Such strategies, however, have the flaw of ignoring a crucial component, which is perhaps the most significant for businesses (whose core goal is to enhance their business), namely the decrease of energy expenses. Although it is clear that energy costs and consumption are closely related, it would be a serious conceptual error to try to decrease them while ignoring the energy market's flows, tariffs, and alternatives, which would increase the specific cost of energy's fluctuation.

Each factory has a distinct layout and size. Their technical infrastructure must be planned and tailored to each environment's specific requirements and needs. Most Factories lack laws that specify how these standards might be met, including how the facility itself and its technical systems should be designed and operated.

An ongoing, systematic technique for regulating a building's energy usage pattern is called EEM. Its goal is to keep energy and financial to a minimum that is still allowed by the building's operations, the climate where it is located, and other criteria. It creates and sustains an effective balance between a building's yearly functional energy needs and its yearly actual energy usage [71].

In a broader sense, the importance of EEM in factories can be defined as a method of increasing the energy efficiency of an existing structure by persistently working to reduce energy use. This includes managing the building's operations and upkeep in a way that preserves the energy efficiency improvements made. There are numerous chances for EEM in Palestinian factories.

In the industrial sector, there are as many different technical possibilities for energy reductions. However, they mostly center on preserving energy in places such as:

- Onsite energy production, such as the PV system technology
- PF improvement
- Energy Conservation in Lighting and Air-conditioning system
- Energy saving heavy machines

From the perspective of the potential opportunity for EEM, each system will be analyzed and described independently in the case study.

3.1.1 The PV system for the case study

a sustainable option to reduce energy costs is the self-supply of on-site power generation. This requires significant initial investment and advanced management skills to get the system working properly, and it can certainly be cost effective and bring additional benefits, such as improved supply quality, security, and support to manage demand response [72]. On the other hand, since most cities and villages are now wired into the electrical grid, solar PV energy is cannot compete with electricity generated using more conventional means. But in Palestine, the PV system is among the best solutions for solving the country's severe electricity shortage. In 2023, the PV system with a 380kW capacity was installed at the Petra factory, as shown in Figure 6.

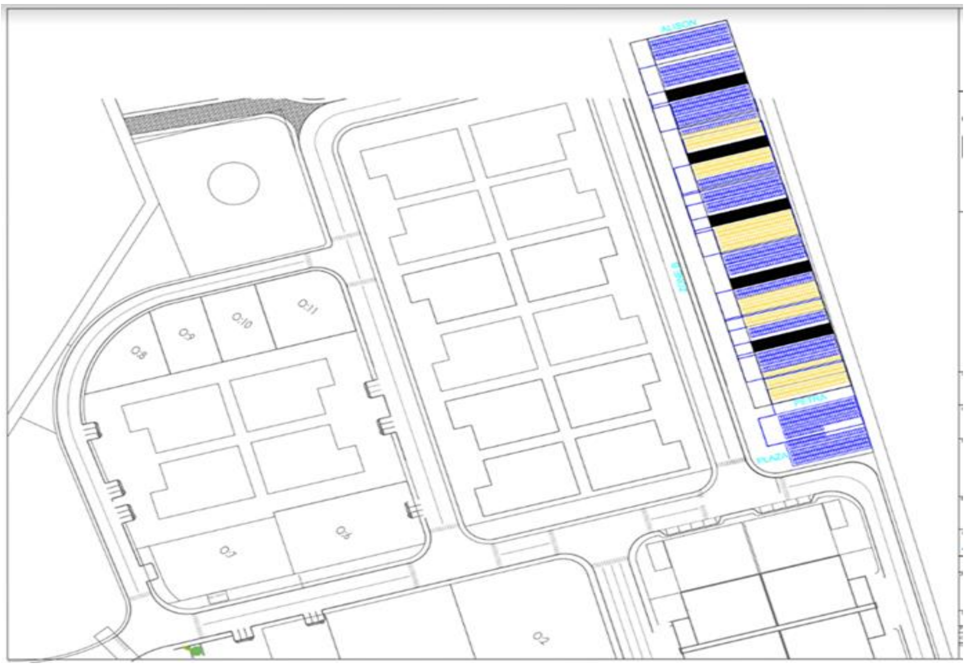

Figure 6: Schematic design of the PV Project on the rooftop of the Petra factory.

The project's objective was to reduce the electricity cost. In Table 4, the cost of the factory's electricity was compared before and after implementing PV technology. Since the size of the factories machinery and operations and the fact that the current PV system's capacity is insufficient, this procedure entails expanding the system's capacity in the dead spaces, this solution has been done in the next chapter.

Table 4: The Petra factory electricity bill for 2022-2023

Month	Price (NIS) 2022	Price (NIS) 2023
January	88570	51499
February	92430	68567
March	86560	54960
April	79730	59337
May	80064	50863
June	91847	58471

3.1.2 Power Factor correction

The control and correction of the network's PF are practically standard practices in production systems. They are conducted to reduce losses within the industrial plant and to avoid paying penalties and fines imposed by suppliers [73]. According to the characteristics of the load and the quality of the transmission, various techniques for measuring and controlling PF values have been developed [74]. Various methodologies have also been proposed to optimize the number and distribution of capacitors for industrial users using a wide range of simulative algorithms [75]. These methodologies have been thoroughly examined, including life cycle cost assessments, to support the installation of a specific number of capacitors, evaluate the potential use of these devices to deal with line disturbances or mitigate harmonics [76], and thus to gain more benefits from their use, as well as accounting for changes in external factors, such as air temperature, that may affect their efficiency.

The low PF can be costly throughout the course of an electrical system's life in addition to being inefficient. The distribution system's efficiency will rise as a result of an improved power factor, and low power factor penalties' associated energy costs will be decreased.

PF, which is defined as the ratio of real power in kW to apparent power in KVA, as given in the equations from (3.1)- (3.4) [76].

$$PF = \frac{\text{Real Power (P)}}{\text{Apparent Power (S)}} \quad (3.1)$$

Inductive loads, which account for a sizable amount of the power utilized in factories and include transformers, electric motors, and high-intensity discharge lighting, are the main source of low PF. Inductive loads need current to create a magnetic field, and the magnetic field then does the needed work, as opposed to resistive loads, which generate heat by consuming kilowatts. The total or apparent power required by an inductive device is made up of the following components:

- Real power (measured in kW)

  $$P = \sqrt{3} \text{ x Vx I x Cos}\theta \quad (3.2)$$

- Reactive power, the power caused by the magnetizing current (measured in kVAR).

  $$Q = \sqrt{3} \text{ V I Sin}\theta \quad (3.3)$$

Then , $S = \sqrt{(P\char`^2 + Q\char`^2)}$ (3.4)

The apparent power (expressed in kVA) in distribution system increases as a result of the reactive power needed by inductive loads. The PF declines when reactive and apparent power both rise.

3.1.3 Energy Conservation in Lighting and Air-conditioning systems

Factory managers are looking for solutions or strategies to lower energy costs and environmental effect. Lighting retrofits are relatively prevalent and typically give an appealing return on investment because almost all buildings have lighting. The amount of electricity used to run lighting systems makes up a sizeable fraction of the overall electricity used in factories.The facility uses a lot of lighting, and the lighting units are either segregated into offices and buildings or into the manufacturing area and the production equipment. Thus, the following uses two different kinds of discharge sources:

1) In manufacturing, production, and storage facilities, use high density discharge sources, metal halide lamps, high pressure sodium, and mercury vapor lamps.

2) Lighting for tasks and workplaces is typically provided by fluorescent lamps, compact fluorescent lamps and incandescent lighting.

Energy conservation in lighting systems doesn't cost much. Here are a few of those possibilities.

- **Reducing the number of lighting lamps**: This can be done by measuring the illumination level at the designated area and comparing it to the international illumination standards. This measure saves a significant amount of energy, especially because removing a lamp also means removing the ballast, which uses energy.
- **Install high-efficiency lighting fixtures**: These fluorescent lamps are three times more effective, consume less energy, and last about ten times longer than incandescent lights [77].
- **Install reflectors in lighting fixtures**: Reflectors are highly polished, "mirror-like" parts that direct light downward to minimize light loss inside a fixture. By utilizing fewer, more efficient ones, reflectors can reduce the amount of wattage needed [77].
- **Smart lighting system**: The IoT technology brings together hardware, cloud computing, analytics, and people to improve performance and productivity in industrial processes. By using IoT for the industrial sector, industrial companies can digitize processes, develop business models, and improve performance and productivity.

In the air conditioning system, the usage of this systemin the factories creates a number of issues that are not present in less demanding building types. About half of the entire volume is covered by the electrically powered space conditioning system in the factories. Savings can be made in conditioning systems by some method.

- **Use modern energy-saving devices:** This inverter air conditioner is more efficient and consumes less energy than other types of air conditioners.
- **Implementing smart systems using IoT technology:** Air conditioner settings are monitored and adjusted from anywhere with an Internet connection. It is possible to take advantage of this feature in particular to adjust the temperature of the place and control the start and stop based on the presence of people in the place.

3.1.4 Energy Conservation in heavy machines

The optimal management of a system is as important to energy saving goals as the efficiency of its components [78], and energy consumption control can support maintenance and operations planning and practices. Operation and maintenance and energy efficiency measures have a positive reciprocal relationship. Best operating and maintenance techniques have been identified, gathered (primarily through clustering, benchmarking tools and databases), as well as methodologies to choose the ones to be applied by evaluating energy savings potentials in various fields. These have also been published by national and international research organizations per industrial sector or specific system (i.e. International Energy Agency and US Department of Energy). The most widespread and economical best practices are related to choosing the appropriate control points, streamlining processes, scheduling machines efficiently, and planning preventative maintenance [79]. Due to the Petra factory's reliance on a variety of heavy gear, improving performance, such as scheduling machines effectively, is necessary for both economic and environmental reasons. The most well-known of these devices include:

- Glass cutting machines, it is a machine that use the AutoCAD software to optimization the glass sheet. It comes in a variety of sizes to produce fewer scrap, and it employs a diamond stone for cutting. There are three cutting machines at the Petra factory:
    1. Jumbo cutting machine, with the rated power 60 kw.
    2. Standard cutting machine, with rated power 40 kw.
    3. Laminating cutting machine, this machine uses two diamond stones to cut a two-layer glass sheet and the rated power 60 kw.
- Computer numerical control (CNC) machines, this machine is dedicated to sawing, grinding, detailing and polishing all kinds of glass. It has two patterns:
    1. Horizontal CNC machines with the rated power 50 kw.
    2. Vertical CNC machines with the rated power 80 kw.
- Double edging machine with washing machine, this machine edges the four sides of the glass sheet in one process and the rated power 400 kw.
- Seaming machine with washing machine, it is a machine to make edges without polishing and smoothing, such as window glass and the rated power 150 kw.
- Straight edging machine, it is a machine that makes edges for one side of the panel in one operation. There are two machines of this type in the factory, and the rated power is 25 kw for each machine.
- Double line, the aim of this line of machines is to make insulating glass with aluminum material surrounded by silicone and the rated power 200 kw.

- Laminating line, this line consists of a press, a furnace and a press furnace for laminating glass such as balcony glass and the rated power 250 kw.
- Autoclaves machine, the oven operates at a temperature of 130 ℃ and 12 bar for 3 hours, then a slow cooling process, and then a pressure release. There are two machines of this type in the factory and the rated power is 300 kw for each machine.
- Single champers tempering line, the most important line in the factory, because all the glass must pass through this line in order to strengthen the glass, and each type of glass has a different degree of heating and cooling and the rated power is 1200 kw.

Chapter Four

Analysis and Discussion of Results

Energy Audit in The Definite Facility

4.1 Overview

The study's findings are given and analyzed in this chapter with reference to the goal of the study, which was to reduce energy usage and, as a result, lower the power bill. This is achieved by focusing on EEM opportunities. In order to get the best effective model and to better comprehend the results, the results of this study were based on an analysis of RET-Screen, AutoCAD, and PV_{syt} programs. Figure 7 depicts the research's structural design.

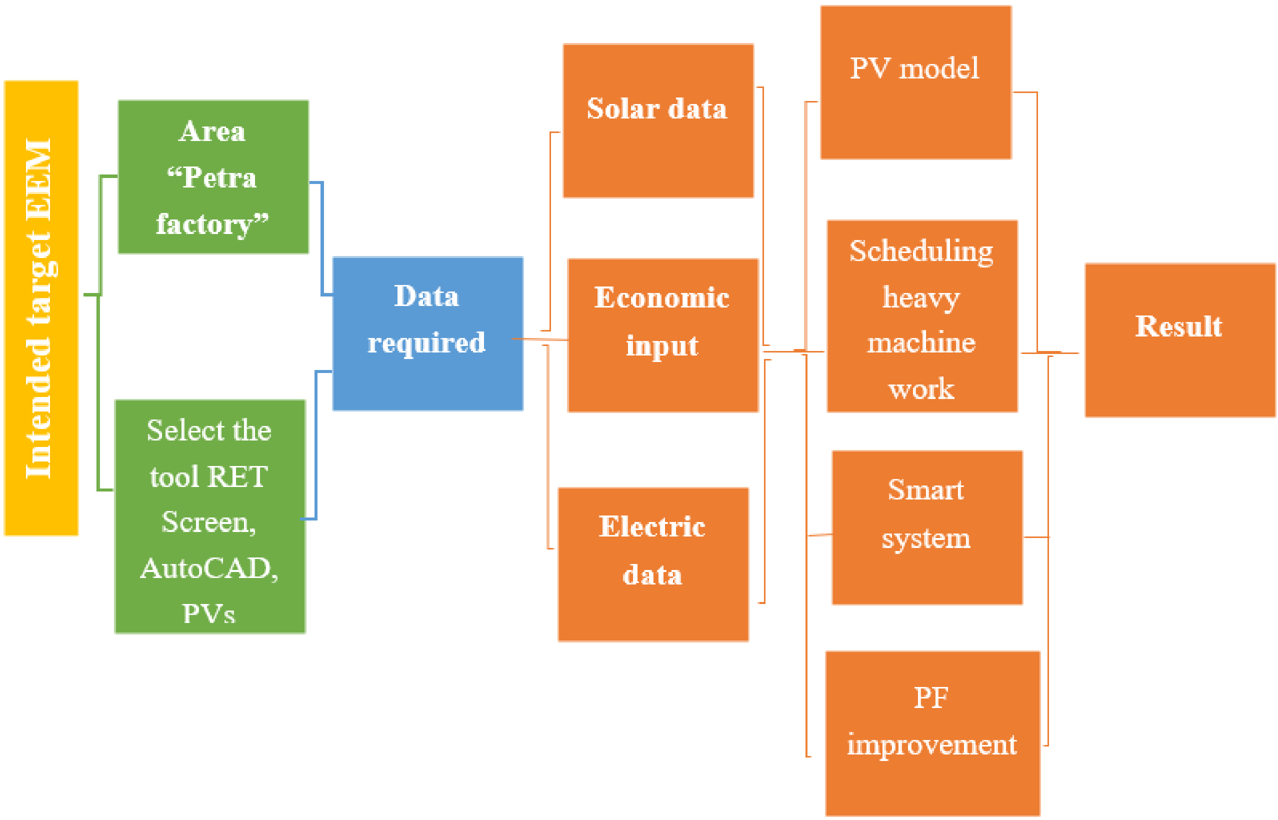

Figure 7: The research's organizational structure

4.2 On-site PV system production expansion opportunity

4.2.1 Design of PV system

Palestine has a great chance of using solar energy successfully because it receives more solar radiation annually than its neighbors. In Jericho, the average solar radiation was about 5.31 kWh/m^2/day [80]. In design we consider the dead land as a starting point. It is described as the area formed from the merging of the five rooftops of the factory, as depicted in Figure 8 in yellow color. For the other dead space, beside the factory buildings, as shown in Figure 9.

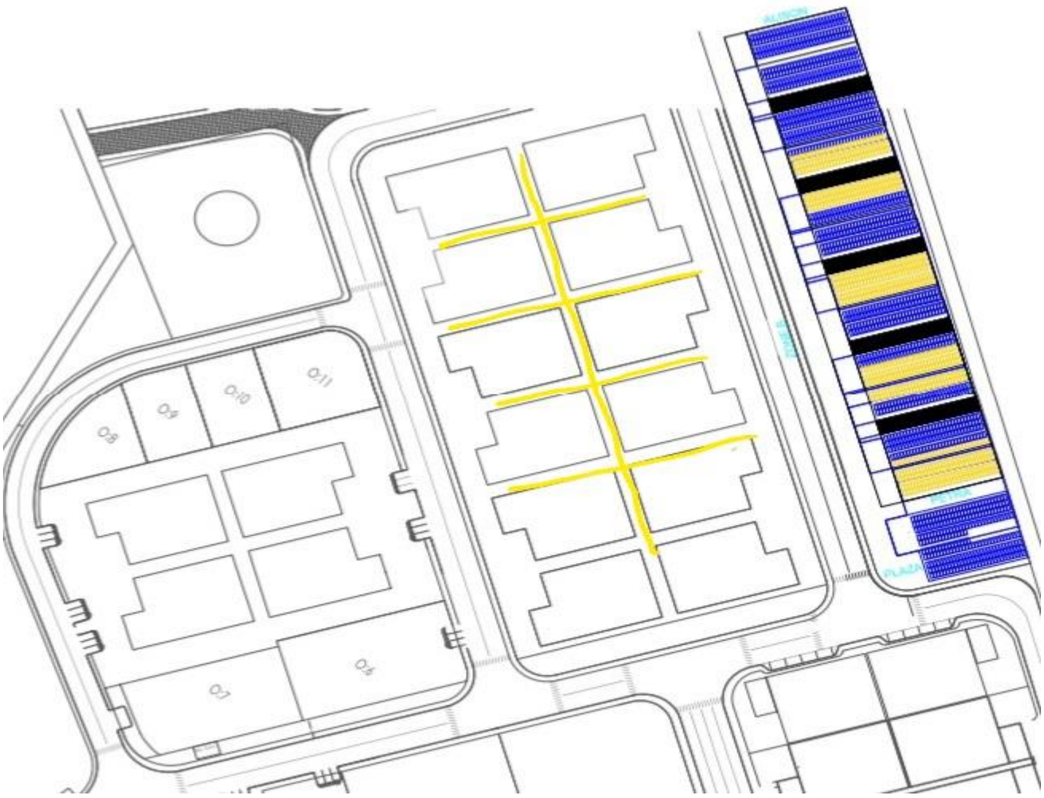

Figure 8: The dead space on the rooftops of the five factory buildings

Figure 9: The dead space on the side of factory buildings

With practical measurements, the total dead land was about 1723 m^2, this area is suitable for the current PV system expansion project. The following step in the design is to determine the overall power consumption of all loads, so based on the factory's electricity bills, which amounted to 1497 MWh/yr. Based on [81], from equation (4.1) DC power equal 293 kw. From equation (4.2) AC power equal 220 kw. From equation (4.3) PV module size equal 900, also the number of inverters was 10 and the number of strings was 30, as shown in Table 5.

Table 5: PV system units' design.

Units	Numbers
Modules	900
Strings	30
Inverters	10

$$P_{dc\ (kw)} = \text{Area } (m^2) * 1\ kW/m^2 * \text{Efficiency of panel} \quad (4.1)$$

$$P_{ac\ (kw)} = P_{dc} * \text{Conversion efficiency} \quad (4.2)$$

Number of PV module = P_{dc}(W) / Rated Power of the module (W)   (4.3)

The technical part includes the details of the equipment and gadgets utilized in the design as well as the installation process to produce successful outcomes. In a grid-based PV system, the technical specification of the PV module must be suitable for the region and the distribution of PV modules among the inverters. As shown in Figure 10, the PV_{syt} program indicated that the proper tilt angle for the solar panel was 45^o in the direction of the south and a 0^o azimuth angle. The RET-Screen program determines the technical details of the solar panel and inverter used in the project under standard test circumstances, which comprise radiation of 1 kW/m^2, a cell temperature of 25 C^o, and normal operating temperature, as shown in Tables 6 and 7, respectively.

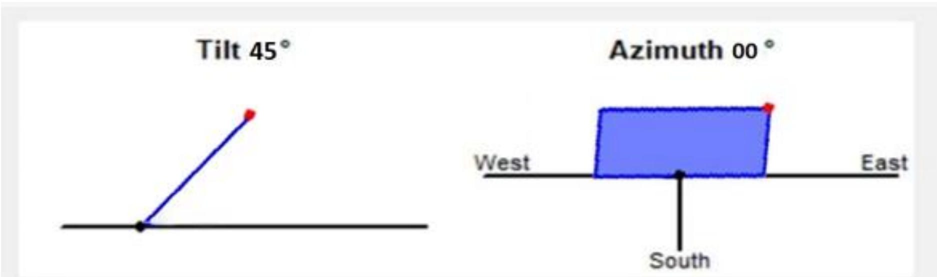

Figure 10: PVsyst analysis (Tilt angle, azimuth angle of the solar panel)

Table 6: Data sheet _Technical parameters of specific panel

Item	Technical specification
Panel Name	Hanwha
Rated Power	325 (W)
Open circuit voltage Voc	46 (V)
Short circuit current Isc	9.20 (A)
Efficiency	17.5%

Table 7**:** Data sheet _Technical parameters of specific inverter.

Item	Technical specification
Inverter Name	KACO
Max DC power	24000 (W)
Voltage Input Range	515-800 (V)
Max input current	22 (A)
Efficiency	98.4%

Also,the RET Screen showed that the solar panel's capacity utilization factor, which measures the electrical energy extracted from the solar plant in relation to the estimated annual energy production, was found to be 18%. The solar radiation and the solar panel's proper location are two factors that affect the capacity utilization factor.

Solar power load isolation, ground-fault detection, and interruption prevention are all achieved by shutting down the inverter. This method is still undergoing development, and it is anticipated that it will eventually become a requirement in all installations. To achieve this, we use the main AC and DC breaker, disconnected. Combiner fuse (MCB DC)/string in a PV system. When a conductor is said to be grounded, it signifies that it is connected to the metallic frame of an electrical equipment. further using grounded conductor to purposefully grounded conductor. In PV systems, it is typically the center-tapped conductor of an older bipolar solar power array technology, as shown in Figure 11, or the negative of the dc output for a two-wire system [81].The typical equipment grounding conductor is a bare copper wire that may also contain a green insulator, another crucial form of safety. Lightning protection in geographical areas, for locations where lightning is a frequent occurrence, the PV system and outdoor devices must be protected with suitable lightning arrestor devices and a special grounding that could provide a workable mitigation and a measure of protection from equipment damage and burn out.Therefore, the risk has been avoided by using a surge arrestor. Every significant calculation required on the protection side for a PV system is listed in equations (4.4), (4.5) and (4.6) [81].

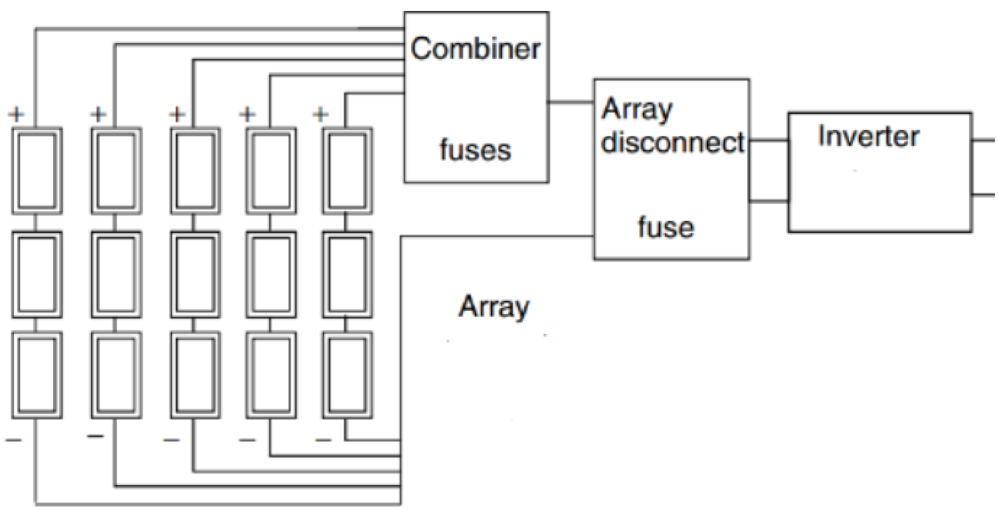

Figure 11: PV system protection design layout [81].

Combiner fuses > 1.25*1.25*Isc (4.4)

Array disconnect or fuse > Number of string * MCB rating / string (4.5)

Inverter fuse > 1.25 *(inverter output power/ output voltage) (4.6)

4.2.2 Economic results of the PV project

The purpose of the financial analysis is to ascertain and evaluate the financial viability of building the PV system in Jericho.The PV systems financial analysis provides an assessment of potential new or increasing revenue and costs. Table 8 shows the analysis for constant costs and total operation costs .

Table 8 : Investment and operation cost

Description	Quantity	Unit price ($)	Total price ($)
Total cost of PV modules	900	160	144000
Total cost of inverters	10	2800	28000
Design and engineering	1	10000	10000
Installation labor cost	1	2000	2000
Switchgear	1	30000	30000
Cables cost	1	2000	2000
Total Operation Cost	1	5000	5000
			221000

The main of the project's income comes from selling the generated electricity to the distribution company. The PV system is expected to generate 426 MWh of electricity per year and the cost of energy production per kWh is anticipated to be around $0.16. According to Table 9, it is anticipated that the project will generate a total of $66070 annually(231245 NIS/yr), through the estimated payback period is 3.7 years ,the project's Internal Rate of Return (IRR) during a 20 year lifespan is approximately 23% and the net present value(NPV) was 0. 589244 K$ which is a solid sign for the investor.

Table 9: Financial output from RET-Screen

parameters	Value
IRR	23.1%
MIRR	13.7%
NPV	0. 589244 (K$)
Payback Period	3.7 year
Revenue	66070($/y)

4.2.3 Emission results of The PV project

The GHG are gases in the atmosphere that raise the surface temperature of planets such as Earth, they consist of water vapor (H_2O), CO_2, methane (CH4), nitrous oxide (N_2O), and ozone (O_3). The amount of GHG that could be avoided by using renewable energy sources can be calculated by the RET-Screen. Data has been entered about the fuel types utilized in the country under consideration, which is set to "all fuel types," as well as the transportation losses, which are estimated to be 15% for Palestine as a developing nation. Constructing PV power plants or switching from conventional generation to solar electricity has a considerable impact on reducing GHG emissions. Table 10 demonstrates the earnings from investing in carbon in order to reduce gas emissions as another method of inspiring investors. The revenue from lowering GHG emissions is estimated to be 3370 ($/year), since it is anticipated that the net reduction in GHG will reach 337 tons annually.

Table10: Annual GHG emission revenue.

GHG reduction in revenue	Value
Net GHG reduction	337 (ton/yr)
Net GHG reduction for 25yr	8425 (ton)
GHG reduction credit rate	10 ($/ton)
GHG reduction revenue	3370 ($/yr)

Therefore, Petra factory site offers the best environment from the point of view of techno-economic feasibility, and GHG reduction by expanding 220 kw to the PV system.

4.3 Power Factor correction opportunities

The JDECO serves as the Patra factory primary electricity source through three feeders with maximum capacity of 1000 KVA for each one. The energy analyzer's 24-hour average PF reading was 0.87, as shown in Figure12. This PF is seen as being extremely low and a source of significant financial strain for the business, particularly if the JDECO begins to enforce financial fines for the low PF. This factor encapsulates the idea of lowering the electricity cost by raising the PF to a value of 0.92 or higher in order to avoid penalties from the electricity provider, which are imposed by the electricity companies according to Table 11 [82].

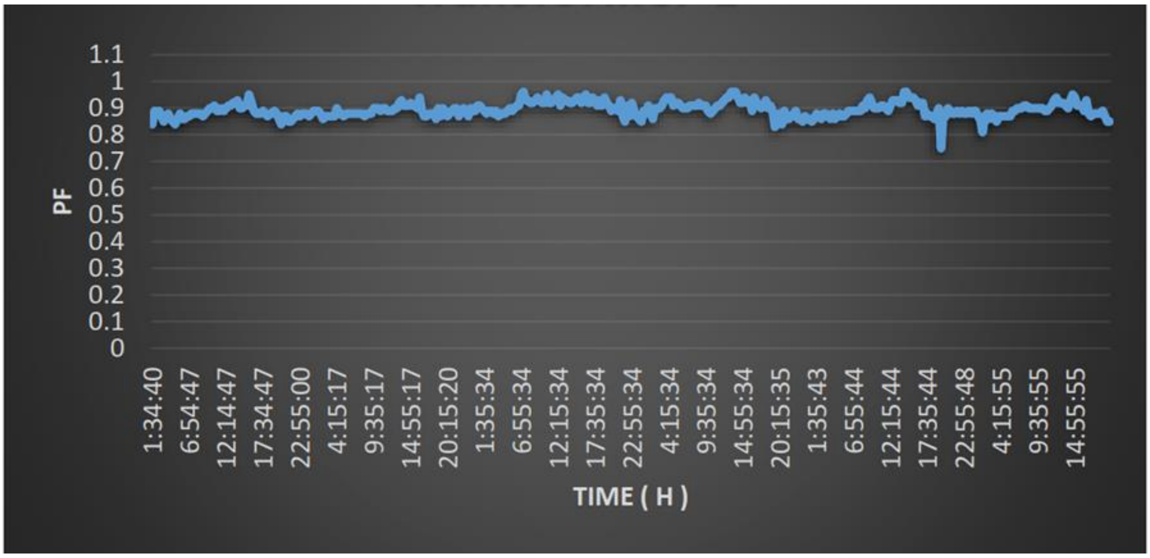

Figure 12: Average PF measured at Patra factory (before improvement).

Table 11: PF proposed penalties in Palestine [82].

PF value	**Penalty** (of the total bill for every 0.01 of PF less than 92%)
PF ≥ 0.92	None
0.92 ≥ PF ≥ 0.80	1%
0.80 ≥ PF ≥ 0.70	1.25%
PF < 0.70	1.5%

The equation (4.7) [76] can be used to determine the capacitor banks required to increase PF.

$$Qc = P (\tan \theta_1 - \tan \theta_2) \qquad (4.7)$$

Where:

Qc: Capacity of the capacitor bank is required to increase PF in kVAR.

P: maximum power kW

θ_2: $\cos^{-1}\theta_2$ (suggested PF)

θ_1: $\cos^{-1}\theta_1$ (actual average PF)

The average PF of all factory transformers can now be considered to be 0.87. Then, equation (4.7) can be used to determine how many capacitor banks are required; the maximum power is 171 kW.

$QC = 171 \times [\tan(\cos 0.87^{-1}) - \tan(\cos 0.95^{-1})]$

$QC = 171 \times (0.56669 - 0.3285) = 41$ kVAR

This number, 41 kVAR, represents the total number of capacitors needed to improve the factory's PF. Using device known as a capacitor power controller, it is separated into capacitors starting from, for example, (15 - 100) KVAR. This device has a number of stages (6, 8, 10, etc.), after which it starts reading the required PF and starting to enter the capacitance value to get to that required PF. The employment of a control device is required because, if capacitors are added without adjustment or control, 41 kVAR will turn into P (kw) in the absence of the factory's demand for other P (kw), costing extra money. In contrast, 41 kVAR is counted as Q (kVAR) and exposes the company to a financial fine if the PF is not rectified. In detail the flowchart in Figure13 illustrates how penalties for poor PF can be calculated. According to the company's bills, the total energy consumption amounted to 1497 MWh. Because the electrical panel's PF has increased, as a result of this, the value of the total bills has decreased, which translates to 1.25% less electricity being used overall.

1497MWh * 1.25% = 18712.5 KWh

By multiplying with kWh price, the saving money is:

18712.5 * 0.64 NIS = 12000 NIS / year.

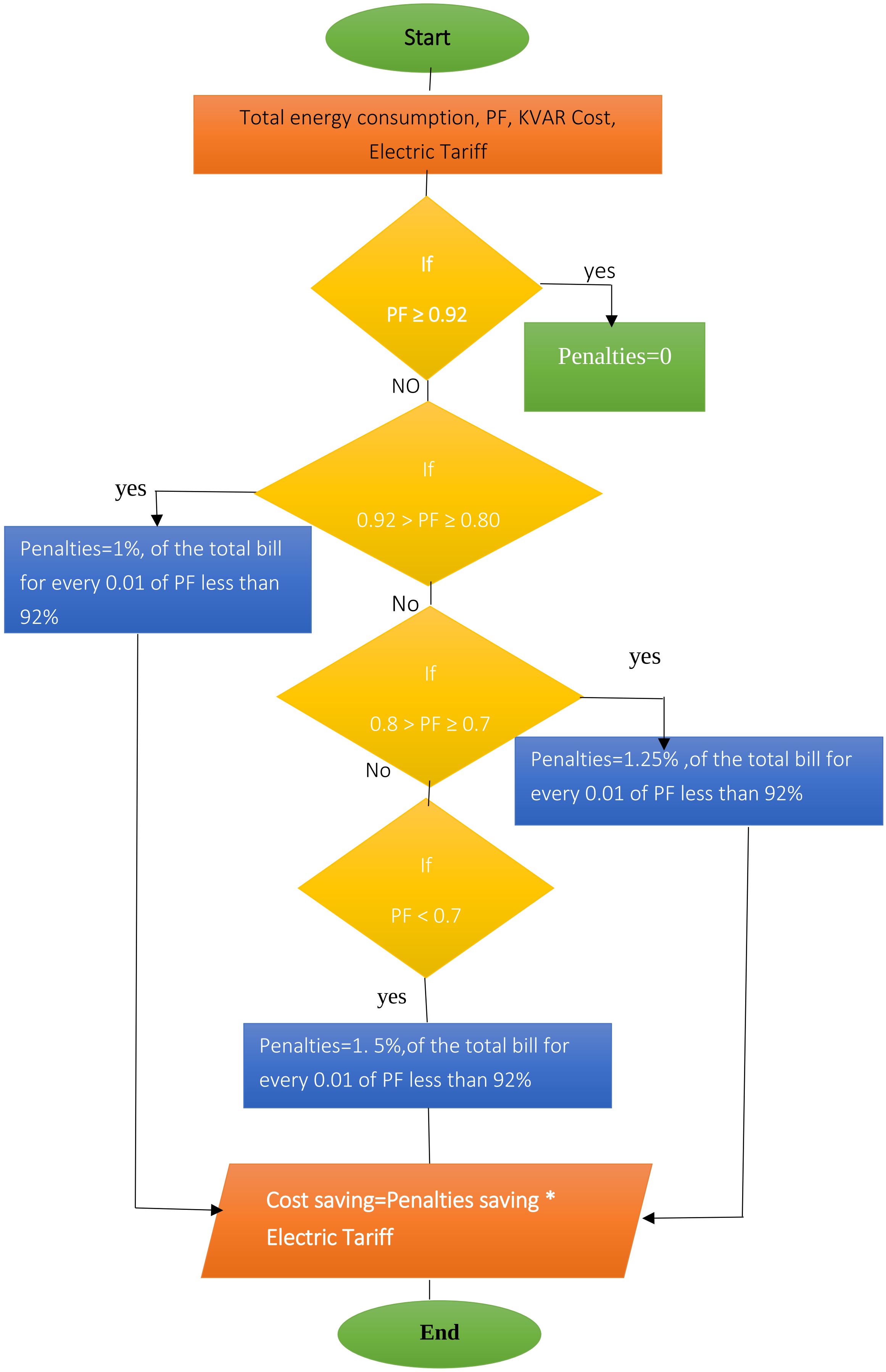

Figure 13: Flowchart for PF correction

4.4 The Lighting and Air conditioning systems improvement opportunities

Utilizing a smart system to control lighting and air conditioners is one of the contemporary methods to lower energy consumption in electrical systems [83]. In this work, the smart system was applied to the air conditioning system in employee offices, while it was applied to the lighting system in employee offices and the entire factory. The lighting and air conditioners already present in the factory must first be categorized and the suggested substitute, as indicated in Tables 12 and 13.

Table 12: Available Petra factory electrical systems.

Available services	No of unite	Annual operating hour	Electrical Power (kw)	Electricity consumption (kWh)
LG 1.5 Ton LSA5VF2D Star Split A	9	3600	14	50706
Compact fluorescent	80	4500	2	9000
Hubbell Lighting	100	4500	40	180000
Total			56	239706

Table 13: Alternative Petra factory electrical systems.

Replacing service	No of unite	Annual operating hour	Electrical Power (kw)	Electricity consumption (kWh)
SAMSUNG AR18JV5D AWK 1.5 TON INVERTER SPLIT AC SPECIFICATIONS	9	3600	8.1	29160
LED light bulb	80	4500	0.5	2250

150W UFO LED	100	4500	15	67500
Total			23.6	98910

According to the preceding Tables (12,13), the total energy used for lighting and services that were already in place was 239706 kWh. While the value of the proposed alternative decreased to 98910 kWh. Thus, the overall amount of energy saved is 140796 kWh and the money saved is 90,000 NIS/yr.

The smart system was implemented utilizing system-specific tools to manage the electrical systems. Digital Addressable Lighting Interface (DALI) Protocol is described as a specific protocol for digital lighting control that makes it simple to construct scalable, reliable, and adaptable lighting networks [84]. Due to its straightforward design, the DALI system was chosen for this project, as shown in Figures 14 and 15. The lighting system in the area will automatically turn on if the occupancy sensor sends a signal indicating that individuals have entered the area, while the converse occurs if no one is present.

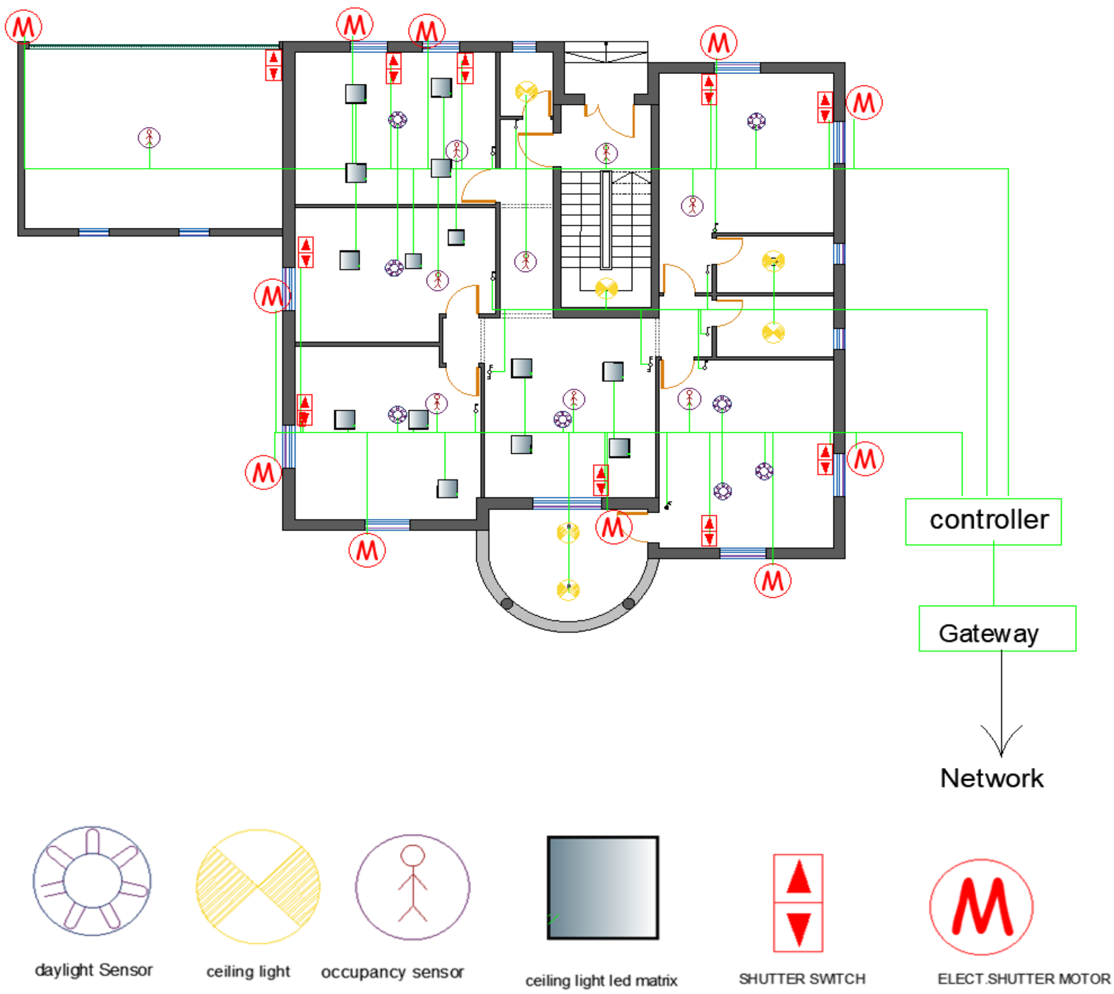

Figure 14: Smart lighting system for engineers' and workers' offices

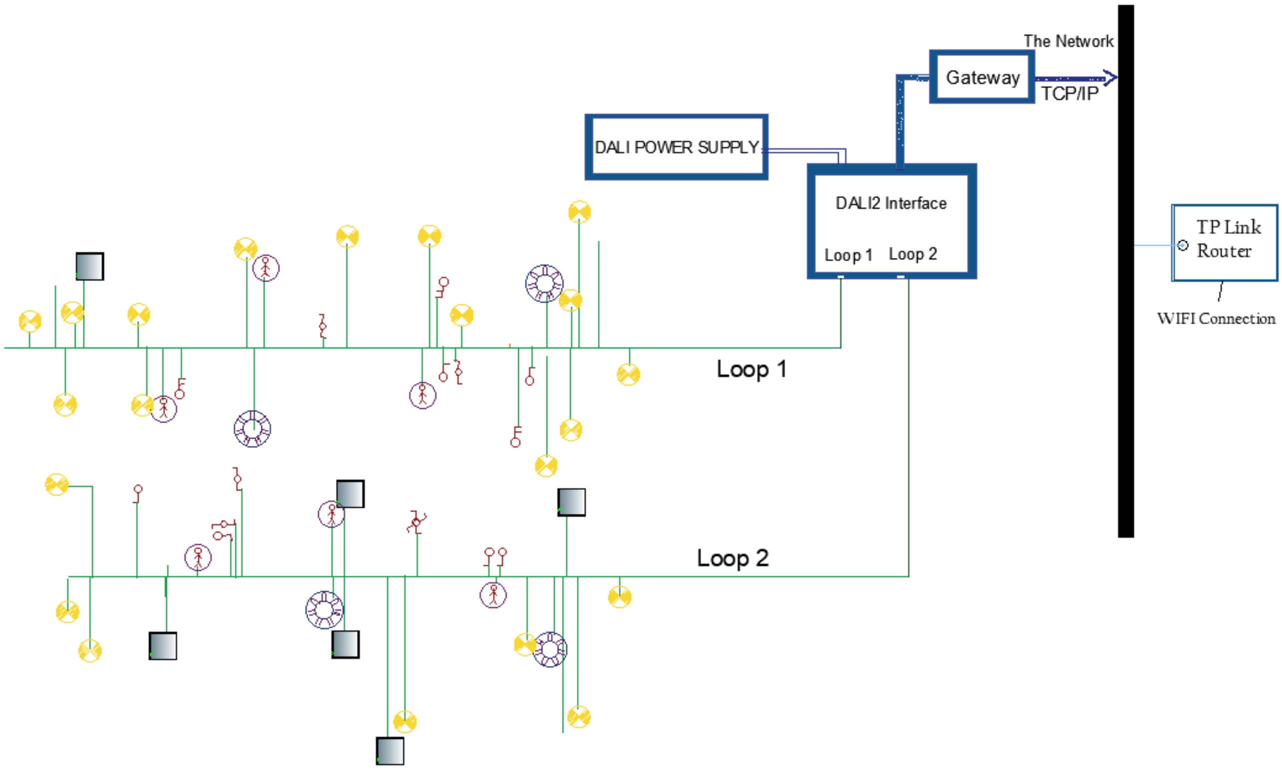

Figure 15: Smart lighting system for the working area (inside the factory)

For the air conditioning system, as shown in Figure 16, the building's fixed-point temperature is set for heating and cooling, respectively, at 21 C^{o} and 24 C^{o} (as an example). During unoccupied hours, the set-back and set-up temperatures are set to 15.5 C^{o} and -1 C^{o}, respectively. The system will be activated to maintain the temperature within the designated range in heating for winter and cooling for summer if the occupancy sensor sends a signal indicating the presence of people in the rooms. If the system's acceptable temperature falls below the minimum during the summer, the cooling power will progressively be reduced to save energy. In the winter, the heating temperature will be lowered if the system temperature exceeds the permitted limit.

In the event that the occupancy sensor occurs a signal indicating that there were no people in the area and at the same time the window sensor signaled that the window was open (the sensor outputs were programmed to the logic gate or), the system waits a few minutes to reduce the system work by half and after additional minutes and the outputs remain sensor as before, the system will turn off completely.

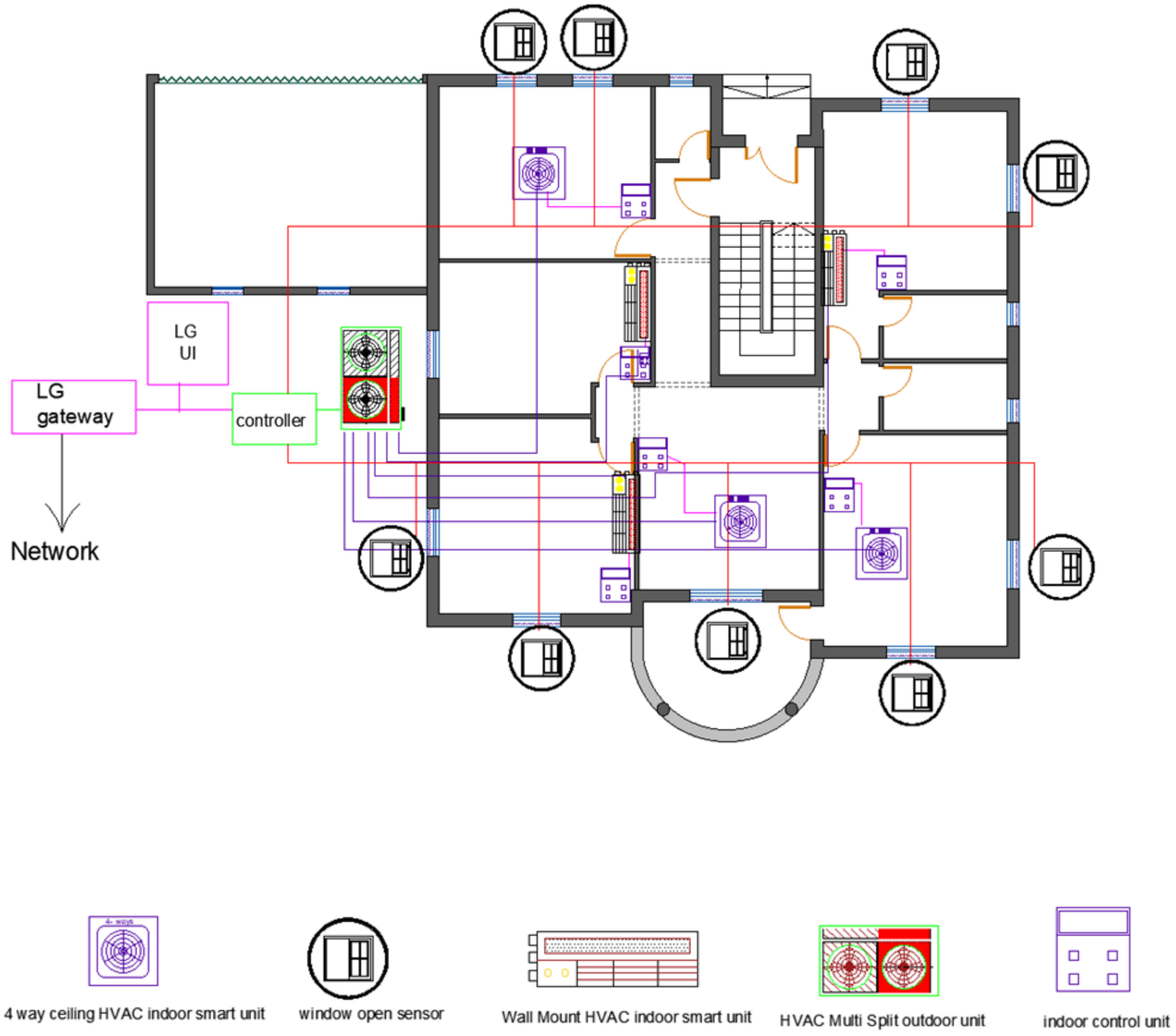

Figure 16: Smart air conditioning system for engineers' and workers' offices

An integrated network must be built as the final stage in the smart system, in order to connect all electrical systems, in addition to the factory's existing fire system, to the electrical panel, as shown in Figure 17.

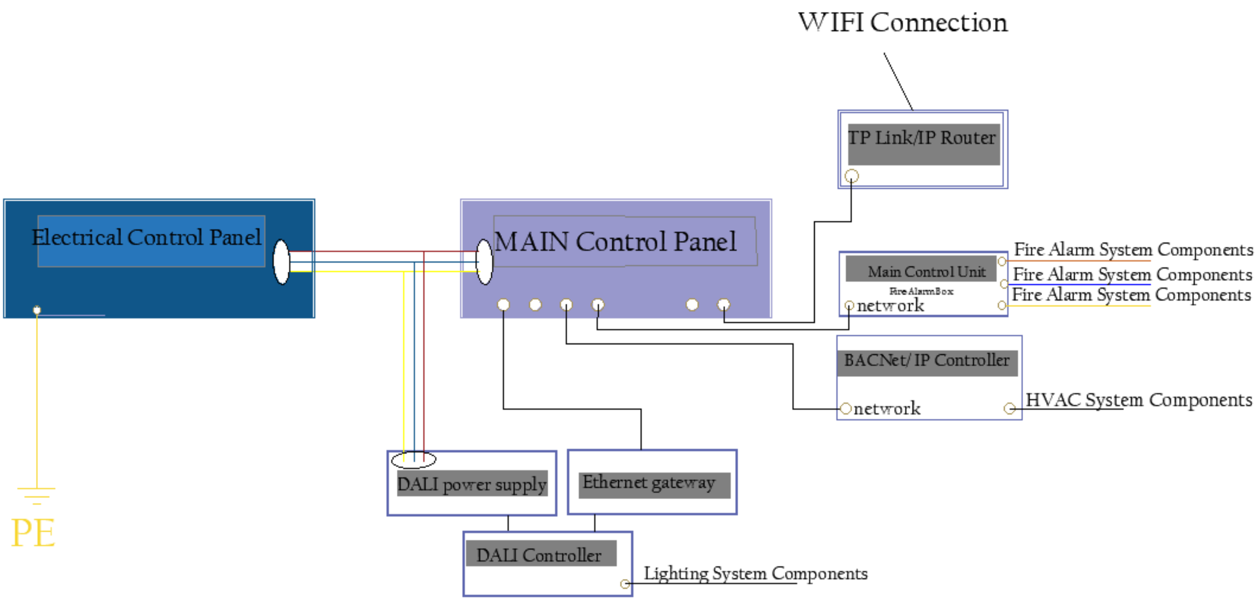

Figure 17: Connection of the integrated smart system to the electrical network

By following this procedure, the factory has avoided having to pay exorbitant electricity expenses as a result of ignoring lighting issues. A decrement in electricity bills will appear after applied this system in the factory.

4.5 Scheduling heavy machinery work times

The highest average demand ever is a peak demand. This happens during the summer, when demand on the electrical system is typically at its maximum. One of the best ways to find hidden expenses, safeguard equipment from hazardous situations, and minimize unscheduled downtime is through peak demand management.

Once peak demand is realized, an attempt is made to reduce it in order to save money. Because the infrastructure required to meet demand will be more advanced as peak demand increases. Energy costs could decrease significantly if the factory was able to shift power loads during peak hours.

There is no one peak demand reduction strategy that works for every firm. Facility managers typically decide to combine two or more programs to increase their savings. Before it appears on a production invoice, a peak demand issue can be found via real-time equipment monitoring. The likelihood of saving money increases with the timing of this discovery. The most frequent cause of high peak demand is concurrent operation of many energy-intensive processes. Simply scheduling these systems to run during off-peak times will solve this issue and prevent them from ever running at the same time. Facility managers have two options for accomplishing this: onboard controls or a building automation system. The idea of peak demand distribution, also known as optimal scheduling, as presented in Figures 18 and 19, and the impact on peak demand charges.

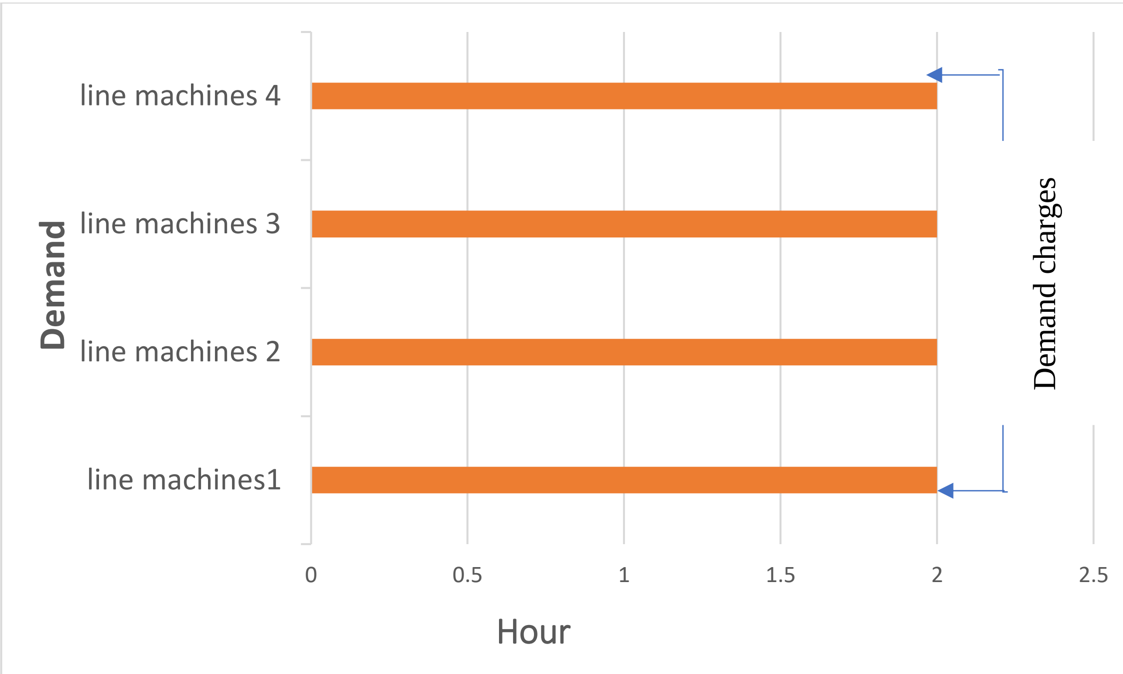

Figure 18 : Machine work during the same period of time (without scheduling)

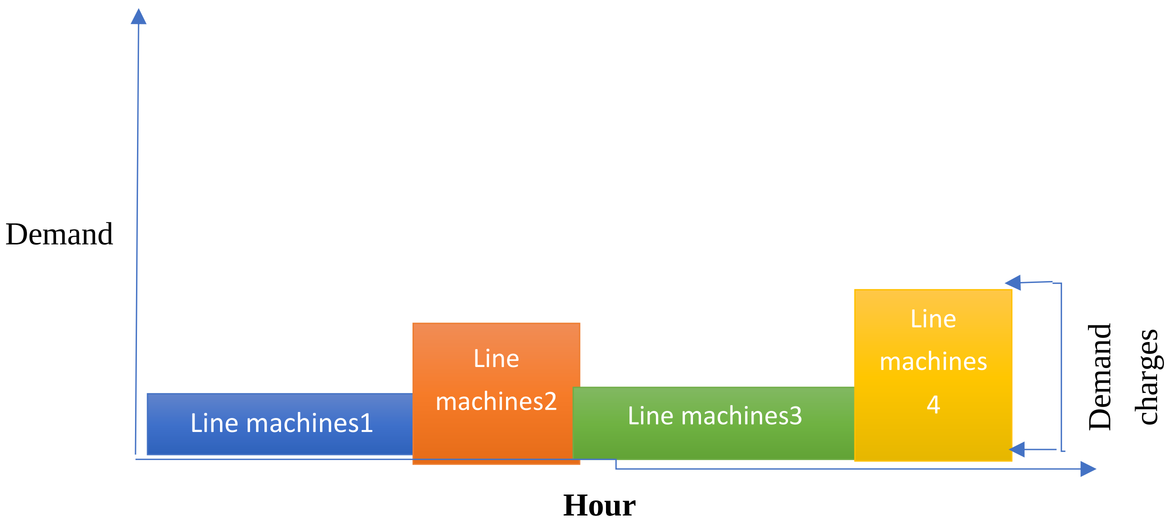

Figure 19: Operating machines during different periods of time (with scheduling)

The JDECo's policies apply to the demand charges. According to the season, the JDECo divides electrification time into four periods. Each time of the day has a cost per KWh of electricity, such as from 10 am to 4 pm in the summer and from 10 pm to 6 pm in the winter, the price of electricity rises to three times its initial level, in order to limit loads and consumption during the period of peak demand. So, a timetable must be created for the loads of the Petra factory, in order to avoid paying twice as much. To do this, low-consumption loads are operated during peak hours, and high-consumption loads are operated during post- or pre-peak hours, as shown in Table 14.

Table 14: Scheduling the working hours of the factory machines

During peak hours	During post- or pre-peak hours
Cutting machines	Autoclaves machine
CNC machine	Single champers tempering line
Edging machines and double line	

To sum up, when there is a lot of electrical demand, dirtier fuels like oil and inefficient natural gas start to be used. By using less of these high-emission facilities, lowering demand during grid-wide peaks displaces relative more emissions than at other times. It's crucial to plan ahead. Part of this is understanding how to efficiently reduce load to gain the best EEM opportunities.

4.6 Summary of results

The Petra factory's annual expenditure for energy in 2022 was 1022993 NIS. There are a variety of EEM strategies that can be used to reduce energy consumption and electricity bills in a factory. The approach taken achieved a set of results shown in Table 15.

Table 15: Financial results after implementing EEM in the Petra factory

Strategies	**Financial return**
Expanding the PV system	230000 NIS/yr
Improving the PF	12000 NIS/yr
The Lighting and Air conditioning systems improvement	90000 NIS/yr
Scheduling heavy machinery work times	Avoid demand charges on electricity bill during peak hours

Chapter Five

Conclusion Remarks

5.1 Summary

Factories stand out among other industries in terms of energy intensity, due to their constant operation. However, the health, safety, and security of the community that industries serve depend on efficient functioning. Energy management measures have become widespread due to the high cost of fuel. In this thesis, the Petra Glass and Mirror factory in the industrial city of Jericho was subjected to the EEM system. First, the load was determined and quantitatively represented on a yearly basis. Second, data was collected on the systems to be improved. Finally, the management approach and optimization methods for energy efficiency are described. Despite their modest size, the strategies mentioned in this thesis clearly had an impact on rationalizing energy consumption. by creating a number of different ideas. These suggestions can lessen the cost of factory energy bills. Given the significant drop in GHGs that will have a detrimental impact on the environment, it is important to consider this factor. An expanded PV system with a capacity of 220 kW was implemented and evaluated using RET-Screen optimization software to achieve the best configuration. In addition to adjusting the PF to avoid financial penalties, then replacing the electrical systems with energy-saving devices to be controlled by the smart system, and finally scheduling the working hours of the factory's machine lines to avoid the period of peak demand. These suggestions can be implemented in the majority of industrial settings, thus the impact on the degree of rationalization of electric energy usage is obvious. Promote understanding and awareness of efficient and responsible energy use in the factory. It is accomplished by working on guidance classes for factory workers and staff. However, by rationalizing electricity use using the techniques mentioned, manufacturing can be achieved at the lowest possible cost while maintaining the same efficiency. Every industrial site must therefore make an effort to designate an electrical engineer to investigate how much electricity is consumed there and how to save costs. Electrical energy conservation extends beyond industrial facilities, due to Palestine's relative paucity of energy resources compared to other nations and total reliance on energy supplies provided by the Israeli occupation.

5.2 Recommendations

There are a number of recommendations that each sector can implement in order to improve the outcomes of the effort to reduce electricity usage, including:

- Finding financial institutions to assist those who have the potential to participate in the process of producing electric energy will help Palestine's energy sector.
- Work on educating and training staff members and workers in institutions about the facility's energy-saving system.
- Supporting research and studies aimed at locating cheaper and more productive alternatives to current energy systems.
- The installation of sensors that react to movement in order to introduce contemporary control methods into electrical systems. Consequently, systems' operating hours are decreased.
- Organize and plan the manufacturing lines' schedule so that the electrical loads are spread, controlling the power factor's value.
- Constructing a thorough action plan based on the industrial sector's power analysis to better understand energy consumption and gas emissions from industry.
- Heighten awareness among the corporate community of the value of producing electricity utilizing renewable energy sources (solar, wind, etc.) rather than relying on fuel.
- Establishing legislation and laws that support the production of electrical energy from renewable energy sources and make these laws easier to follow for those who operate in this sector. and enacting tough legislation to punish those who violate the law.

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تعزيز كفاءة الطاقة في العمليات والأنظمة الكهربائية في المنشآت الصناعية: دراسة حالة لشركة البتراء للزجاج والمرايا في أريحا – فلسطين

ملخص

لقد اكتسبت الحاجة إلى زيادة كفاءة الطاقة في عمليات التصنيع الاهتمام بسبب ارتفاع أسعار الطاقة واللوائح الأكثر صرامة. تعمل الحكومات والشركات من العديد من الدول بجد لإنشاء تقنيات لإدارة الطاقة وإنشاء مصادر جديدة للطاقة. يوضح هذا البحث تصميماً متكاملاً لنظام إدارة كفاءة الطاقة في مصنع البتراء في مدينة أريحا الصناعية. والهدف من هذه الاستراتيجية هو تقليل استهلاك الطاقة وبالتالي خصم فاتورة الكهرباء وتقليل نسبة الغازات الدفيئة. تم توسيع النظام الكهروضوئي، وتم تحسين عامل الطاقة، وتمت محاكاة الأنظمة الكهربائية باستخدام إنترنت الأشياء الصناعي، ومن المقرر أن تعمل الآلات الثقيلة لتجنب ذروة الطلب. وأظهرت هذه الدراسة أن هناك إمكانية واضحة لتحقيق الهدف. تم تحديد الجدوى الاقتصادية والبيئية المثلى لاستراتيجية توسيع النظام الكهروضوئي، ومن المتوقع أن يولد النظام الكهروضوئي 426 ميجاوات ساعة من الكهرباء سنويًا. وكان المقياس الآخر هو انخفاض ثاني أكسيد الكربون بمقدار 337 طنًا سنويًا. جنبا إلى جنب مع انخفاض كمية الكهرباء المستخدمة في المصنع، وزيادة PF من 0.87 إلى 0.95، وهو ما يترجم إلى توفير 18712.5 كيلووات ساعة / سنة في استهلاك الكهرباء. أدت استراتيجية استبدال الأنظمة الكهربائية القديمة بأنظمة كهربائية أكثر كفاءة في استخدام الطاقة إلى تقليل كمية الطاقة المستخدمة بمقدار 140746 كيلووات في الساعة/السنة بشكل كبير، ومن الواضح أن اعتماد إنترنت الأشياء سيكون له تأثير على فاتورة الكهرباء. سيوفر المصنع المال الذي ينفق على تكاليف الكهرباء من خلال توقيت ساعات عمل خطوط الإنتاج. من الممكن تجنب استخدام آلات الاحتراق خلال فترة ذروة الطلب.