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Dedication (Arabic)

بدأنا بأكثر من يّد ، وقاسَيّنا أكثر من هَم, وعانيّنا الكثير من الصعوبات, وها نحن اليوم والحمد لله نطوي سهر الليالي وتعب الأيام وخلاصة مشوارنا بين دفتيّ هذا العمل المتواضع.

إلى منارة العلم والإمام المصطفى, إلى سيد الخلق, إلى رسولنا الكريم سيدنا محمد صلى الله عليه وسلم.

إلى من سعى وشقى لأنعم بالراحة والهناء, إلى من لم يبخل بشيء من أجل دفعي في طريق النجاح, إلى الذي علمني أن أرتقي سلم الحياة بحكمة وصبر, والدي العزيز.

إلى اليَّنبوع الذي لا يَّمل العطاء, إلى من حاكت سعادتي بخيوط منسوجة من قلبها, والدتي العزيزة.

إلى من حبهم يجري في عروقي ويلهج بذكراهم فؤادي زوجتي الغالية و أخوتي وأخواتي .

إلى من علمونا حروفاً من ذهب , وكلمات من درر , وعبارات من أسمى وأجلى عبارات في العلم , إلى من صاغوا لنا علمهم حروفا ومن فكرهم منارة تنير لنا سيرة العلم والنجاح ، إلى أساتذتنا الكرام.

إلى من سرنا سوياً ونحن نشق الطريق معاً نحو النجاح والإبداع , إلى من تكاتفنا يداً بيد ونحن نقطف زهرة تعلمنا , إلى الاصدقاء والزملاء .

Declaration

I certify that this thesis submitted for the degree of master is the result of my own research based on the results found by myself , material of work found by other researchers are mentioned by references , except where otherwise acknowledged , and that this thesis , neither in whole or in part has been previously submitted for any degree to any other university or institution .This work was done under the supervision of Dr .Rushdi Kitaneh and Dr. Husain Alsamamra .

Name : Sanad Kamal Kamel Jaradat

Signed :

Date :

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As it is known, he who does not thank people does not thank Allah. After my great gratitude and thanks to Allah who provided me with the will to complete this work, I would like to express my fully thanks to my persevering supervisor Dr .Rushdi Kitaneh, and co supervisor Dr. Husain Alsamamra who always had a certain good for me in guiding and advising all the way during this work. I also thank my family and friends for standing by me during my work.

ملخص

يعاني قطاع الطاقة في فلسطين من قلة كمية الكهرباء الواردة الينا من قبل الاحتلال الاسرائيلي . حيث يقوم الاحتلال الاسرائيلي بالتحكم بكمية الطاقة الواردة . وهذا يؤثر بشكل سلبي على قطاع الصناعة ايضا .

مدينة طولكرم تعاني بشكل كبير من الطاقة الكهربائية . حيث تم تحديد الطاقة الكهربائية الواصلة للمدينة من قبل الاحتلال الاسرائيلي . لذلك قامت بلدية طولكرم بتعويض النقص في كمية الكهرباء من خلال اضافة مولدات كهربائية تعمل باستخدام الوقود بالقرب من شوارع المدينة .

تعتبر منطقة طولكرم من المناطق كثيرة الرطوبة وذات درجة حرارة عالية . لذلك يتم استهلاك الطاقة بشكل كبير في فترة الصيف (شهر مايو - اوكتوبر) .

تهدف الدراسة لهذا المشروع بالعمل على تقليل استهلاك الطاقة في مصنع الاسلامية الواقع في مدينة طولكرم . حيث تتم الدراسة على وضع خطة استراتيجية تعنى بتخفيض الطاقة المستهلكة في المصنع مع الحفاظ على نفس الكفاءة والجوده الانتاجية .

يتم تخفيض تكلفة استهلاك الطاقة الكهربائية من خلال ايجاد المصادر الاكثر استهلاكا للطاقة الكهربائية في المصنع ومن هذه المصادر : العمل على تحسين معامل القدرة ، تحسين عمل الغلايات ، تحسين عمل الكمبريسور . تحسين الاضاءة في المصنع .. يوجد ايضا مصادر اخرى لكن نكتفي بدراسة اكثر المصادر استهلاكا للطاقة .

تبين من خلال الدراسة ان هناك امكانية لتخفيض تكاليف الطاقة الكهربائية في المصنع من خلال زيادة كفاءة العمل لنظام الاضاءة بمقدار 81090 كيلو واط ساعه . تحسين كفاءة البويلر من خلال تسخين الهواء الداخل للبويلر ليحسن كفاءة البويلر بمقدار ١ % او من خلال التحكم في كمية الهواء الداخل للبويلر ليزيد كفاءة البويلر بمقدار ٠,٦ % او من خلال عمل معالجة كيميائية للبويلر كل ستة اشهر ليزيد الكفاءة بمقدار ٦ % . تحسين عمل مضخة الهواء من خلال تسخين الهواء الداخل حيث ان عملية التسخين الهواء تقلل من مقدار الطاقة بمقدار ٣ .٨ كيلو واط ساعه . تحسين معامل القدرة في المصنع حيث كانت القيمة الاولية له ٠,٧٧ ليتم رفعها بعد اقتراح وضع كاباسيتور لتصل الى ٠,٩٢. وبالتالي لا يتم فرض غرامة على الفاتورة بمعنى تخفيض قيمة الفاتورة السنوية نتيجة الغاء الغرامة المالية المترتبة على انخفاض معامل القدرة .

Abstract

The energy sector in Palestine suffers from the lack of electricity supplied to us by the Israeli occupation. Where the Israeli occupation controls the amount of energy received. So the industrial sector is also suffering.

Tulkarm suffers greatly from electrical power. Where the electrical energy supplied to the city was determined by the Israeli occupation. Therefore, Tulkarm municipality compensated for the shortage in the amount of electricity by adding fuel-powered generators near the city streets.

Tulkarm is one of the regions with great humidity and high temperature. Therefore, energy is consumed greatly during the summer period (May - October).

The study for this project aims to reduce energy consumption in the Islamic plant located in Tulkarm. Where the study is conducted to develop a strategic plan concerned with reducing the energy consumed in the plant while maintaining the same efficiency and production quality.

The cost of electric energy consumption is reduced by finding the most consuming sources of electrical energy in the factory, and from these sources: working to improve the power factor, improving boilers, and improving the compressor's work. Improving lighting in the factory . There are also other sources, but we are content to study the most energy-consuming sources.

It was found through the study that there is a possibility to reduce the electrical energy costs in the plant by increasing the working efficiency of the lighting system by 81,090 kilowatt hours. Improving the efficiency of the boiler by heating the air entering the boiler to improve the efficiency of the boiler by 1%, or by controlling the amount of air entering the boiler to increase the efficiency of the boiler by 0.6%, or by doing a chemical treatment of the boiler every six months to increase the efficiency by 6%. Improving the work of the air pump by heating the incoming air as the air heating process reduces the amount of energy by 3.8 kilowatt hours. Improving the power factor in the factory, where the initial value was 0.77, to be raised after the proposal to put a capacitor to 0.92. Consequently, no penalty is imposed on the bill in the sense of reducing the annual bill value as a result of eliminating the financial penalty resulting from the decrease in the power factor.

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Abbreviation	Representation
GDP	**Gross Domestic Product**
PCBS	**Palestinian Central Bureau Of Statistics**
MWH	**Megawatt Hour**
GHG	**Global House Gases**
VFD	**Variable Frequency Drive**
BTU	**British Thermal Unit**
TBTU	**Trillion British Thermal Units**
HHV	**Higher Heating Value**
LHV	**Lower Heating Value**
LPG	**Liquid Petroleum Gas**
NCV	**Net Calorific Value**
KVAR	**Kilo Volt Amperes**
GCV	**Gross Calorific Value**
TJ	**Tera Joule**
HID	**High Density Discharge**
CFLs	**Compact Fluorescent Lamps**
KWH	**Kilowatt Hour**
MJ	**Mega joule**
Kcal	**Kilo Calorie**
LSHS	**Low Sulphur Heavy Stock (Liquid Fuel)**
FAD	**Free Air Delivery**

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Chapter One
Introduction

1.1 Energy sector in Palestine:

Energy has an important role in improving the life of all citizens. As energy merges into different areas of life mainly the economic field, it is included in all production processes of factories and this in turn works to improve employment opportunities for citizens, and thus provides sufficient electrical energy to protect against unemployment and increase the development of the manufacturing state.

Energy is often one of the biggest variable costs that companies are trying to reduce. Many production companies are trying to pursue an energy efficiency program. The main reason for this is the cost reduction, but this is followed by concerns about the reputation of companies in terms of environmental concern the exhaust gas emissions that significantly affect the environment and climate change.

Energy costs account for more than 10% of total production costs[1] , so the key to reducing costs is how to use that energy in proper manner . To minimize the total cost some companies do not reduce the energy cost but they reduce the so-called operating costs , mainly labor or raw material costs .

The industrial sector occupies the largest energy consumption, consuming 54% of the total energy in the world[2]. The electricity sector in Palestine is characterized by a heavy dependency upon imports (89% - 2013) from Israel, Egypt and Jordan [3]. The yearly energy consumption of the productive sectors represents 3% of the Palestinian gross domestic product (GDP) [4].

As a consequence, all energy efficiency action leading to reduce consumption is an opportunity for making energy available for other usages and thus reducing the need to increase generation capacity.

The table below shows the energy dependence rate for Palestine from 2014 – 2017 (according to Palestinian Central Bureau of Statistics 2018. Energy Balance of Palestine

2017. Ramallah - Palestine. And Palestinian Central Bureau of Statistics, 2018. National Accounts 2017. Ramallah – Palestine)

Table 1.1 : Selected energy Performance Indicators in Palestine, 2014-2017[5]

Indicator	**Year**			
	2017	2016	2015	2014
Renewable energy share in the total final energy consumption (%)	9.7	12.9	13.2	13.3
Energy Dependency Rate (%)	87.3	84.7	84.8	80.3
The Energy Consumption of the Transport Sector to the total energy Consumption (%)	46.6	45.6	43.6	48.7
The Energy Consumption of the Household Sector to the total energy Consumption (%)	38.4	39.7	41.4	38.4
The Energy Consumption of the Service Sector to the total energy Consumption (%)	8.8	8.8	8.5	7.6
The Energy Consumption of the Industry Sector to the total energy Consumption (%)	5.4	4.8	5.2	4.2
Energy Intensity (MJ/USD)	5.7	6.0	5.9	5.8
Annual Electricity Consumption Per Capita (KWh/Capita)	1,138.3	1,141.9	1,151.4	1,048.0

According to these data in table 1.1, the energy dependency rate is increasing annually, which need more energy to import from electric companies, the energy consumption of industry sector else increasing annually which will affect the energy efficiency .

The total energy imported from electricity sources is described in table 1.2 , which shows the energy imported to west bank during year 2017 in MWH .

Table 1.2: Quantity of Electricity Imported in the West Bank by Month and Source in MWH during year 2017 [5]

Month	Total	Source	
		Jordan	Israeli Electricity Company
January	497,726	6,326	491,400
February	451,807	6,187	445,620
March	398,365	47	398,318
April	337,968	-	337,968
May	338,167	123	338,044
June	352,553	-	352,553
July	445,134	11,669	433,465
August	430,201	13,031	417,170
September	390,486	7,536	382,950
October	362,483	274	362,209
November	371,942	-	371,942
December	424,732	9,036	415,696
Total	**4,801,564**	**54,229**	**4,747,335**

The West Bank is totally dependent upon imports (Israel energy company (IEC) for 95% and Jordan for the rest) since there is almost no local generation (however, photo voltage (PV) projects are being prepared for the next future). Globally for Gaza and West Bank, the main part of electricity generation comes from IEC (89%) and to a lesser extend from Egypt and Jordan (4%) [6].

1.2 Industrial situation in Palestine

Industrialization is the backbone of economic development in the modern era, as it is the activity that leads to the development of the state in terms of economic and social terms, as there is no difference on the importance and priority of relying on industrialization in the process of comprehensive civilized development, but the difference lies in the type of industries that must be started, and thus the industrial sector is considered one of the most important productive sectors of any country as it plays a major role with the rest of the production sectors in increasing the gross domestic product and absorbing labor on the one hand, and providing the local product instead of relying on the imported goods on the other hand.

The industrial sector in Palestine has been subjected to many obstacles since 1948 to the present time, in terms of the presence of the Israeli occupation in the first place and even after the establishment of the Palestinian National Authority. During this period, many economic agreements were signed, the most important of which was the Paris Economic Agreement. Although Palestine remained suffering from weak production and profit in the industrial sector, and therefore resorted to relying on Israeli companies to meet the needs of industrial facilities. This, in turn, has contributed to the process of controlling the Palestinian industrial and economic sector by these companies, and thus weak competitiveness, and preventing them from keeping pace with economic and industrial development[7].

The operating costs in industrial plants are divided between the cost of raw materials and the cost of manpower, energy sources such as electricity and fuel, in addition other expenses such as water, maintenance, transportation, and marketing expenses, among others. The distribution of costs differs based on several factors, including the nature of the manufactured product, the size of the facility, the amount of production, sources of raw materials, sale in the local or external market, and others.

An analysis of the cost structure of food industry facilities based on a study obtained at the Palestinian Economic Policy Research Institute in 2019 indicates that raw materials have the largest share of operating costs. In 2017, establishments was about 4.63%. The raw materials followed workers compensation by 15%. Then oil and fuel accounted for 8.6%. The cost of electricity and water occupied the lowest percentage of the total costs at a rate of 2.5%. 0.63%, respectively, during the same year[8].

There are legislations and incentives in support of the industry, as government policy has passed laws aimed at providing many incentives in support of industrial establishments in general, and the food industries in particular. For example, a decision was approved by Law No. (10) for the year 2011 regarding the industry in several materials that would positively affect the market share of local food products, the most important of which is working to define special incentives for food processing facilities (in implementation of the decision of Industry Law No. (10) for the year 2011 in its seventeenth article), especially with regard to reducing electricity and fuel prices[9].

1.3 Gross Domestic Product (GDP) Per Capita

According to PCBS, a report was prepared in September of 2019, showing the average per capita production in Palestine during the period 2015-2019. It showed an increase of 2.5% in GDP in Palestine during the second quarter 2019 compared to the second quarter 2018 which excludes the seasonal effect. GDP for the second quarter 2019 at constant prices was 2,754 $ million for the West Bank* and 681 $ million for Gaza Strip as show in figure 1.1.

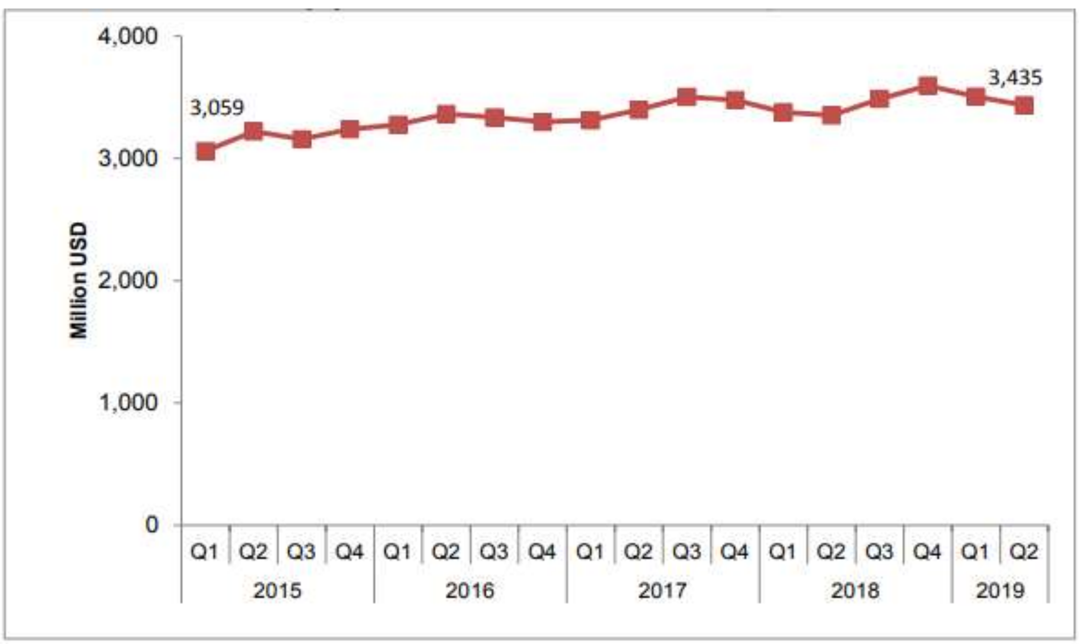


Figure 1.1: The average per capita contribution to the GDP during 2015-2019[3]

1.4 Electric power consumption and demand

Electricity is the backbone of life, industry and development, it has become one of the requirements for production and what the current scientific revolution has reached is through the presence of electricity, its technologies and their preservation, rationalization of them as a social responsibility.[10]

Rationalization **is** optimal use of electrical energy resources, which is a set of procedures or technologies that lead to a reduction in energy consumption without compromising the comfort or productivity of individuals and the use of energy when the real need for it, as improving energy efficiency and rationalizing its consumption does not mean preventing energy consumption as much as it means using this energy in a way that is more Efficient, and low energy waste.

The rationalization of the use of electric energy provides many benefits, including:

- Reducing the value of the electricity bill for the subscriber.
- Avoid separating loads at peak time and in the period when demand for energy increases
- Supporting the energy-saving equipment industry, especially from local production, in a way that helps in developing the national economy as a whole.
- Reducing the investments needed to establish new projects and directing them to improve the quality of service.

Table 1.3 shows the rate of energy consumption for a number of consumers during the period 2003-2009, as it is clear from the table that the highest consumption rates during this period is the household sector at a rate of 75%, followed by the services sector, which grew rapidly from 3% to 18% Then the industrial sector is 7%.

Table 1.3 : Electricity consumption for different consumers in MWh [11]

Year	2003	2004	2005	2006	2007	2008	2009
Industry	648	980.48	643.55	646	739	1032	878
Construction	22	120	41	87	3	31	99
Household	6561.8	6802.73	6685.35	6585	7545	7893.81	8373.84
Services	209	643	633	567	1493.81	1744.68	2325
Total Electrical imports	8336	9355.54	10306	11147	11478	13913	14338.58
Electricity Production	1233	1423	1802	1243	1501	1536	1802
Final Electrical Consumption	7984	9328	8604.41	8497.56	10642.95	10985	12657
Final Energy Consumption	35653	36168.4 2	35647.49	33550.91	35900	33983.36	41098.5
Electrical Consumption/Total Energy Consumption	22.39%	25.79%	24.14%	25.33%	29.65%	32.32%	30.80%
Production/Consumption	14.79%	15.21%	17.48%	11.15%	13.08%	11.04%	12.57%
Industry/Electricity consumption	8.12%	10.51%	7.48%	7.60%	6.94%	9.39%	6.94%
Household /Electricity Consumption	82.19%	72.93%	77.70%	77.49%	70.89%	71.86%	66.16%

According to the data optimized from Palestinian Central Bureau of Statistics showing in table 1.4, it shows the quantity of electricity imported in the west bank by month and source, the highest range of electricity is imported from (IEC) with 4664.56 GWH and from Jordan with 88.099 GWH.

The highest range of imported electricity was in January with rate of 464.899 GWH, This high value is due to the increased consumption of electricity in this month, as this month is one of the coldest months in winter and consumption is high in all sectors (domestic and industrial ,,,,)

Table 1.4: Quantity of electricity imported in the West Bank by month and source according to PCBS

كمية الطاقة الكهربائية المستوردة في الضفة الغربية حسب الشهر والمصدر، 2018				
Quantity of Electricity Imported in the West Bank by Month and Source, 2018				
Unit: MWh				الوحدة: ميجاواط ساعة
Month	المجموع Total	Source	المصدر	الشهر
		الأردن Jordan	شركة الكهرباء الاسرائيلية Israeli Electricity Company	
January	464,899	10,291	454,608	كانون ثاني
February	380,486	8,702	371,784	شباط
March	390,025	10,492	379,533	آذار
April	323,544	11,497	312,047	نيسان
May	389,938	7,662	382,276	أيار
June	386,038	3,424	382,614	حزيران
July	439,159	7,139	432,020	تموز
August	441,671	7,529	434,142	آب
September	416,223	7,009	409,214	أيلول
October	423,629	6,446	417,183	تشرين أول
November	352,439	1,021	351,418	تشرين ثاني
December	456,559	6,887	449,672	كانون أول
Total	4,864,610	88,099	4,776,511	المجموع

Figure 1.2 Shows the imported energy and produced in 2010, where it appears that the majority of the energy is imported by 80% from various sources. The imported part consists of electricity, fuel and other sources of energy.

The rest, which is produced locally with 20 %, consists of solar energy and other types such as coal and wood.

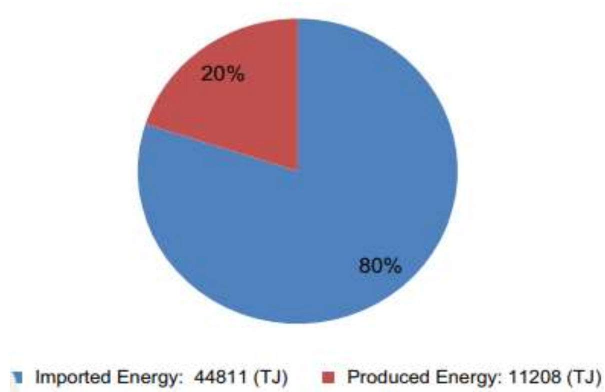


Figure 1.2: Amount of energy imported and produced in 2010 in Palestine [9]

Table 1.5 shows the details of the energy produced and imported during the year 2010, where the amount of energy produced from petroleum derivatives represents about 53.2% of the domestic energy market needs.[12]

Table 1.5 : Energy balance of Palestinian territories in Tera Joul (TJ) . 2010 [9]

Energy flows	Energy products						total
	Solar energy	electricity	Petrolum derivatives	LPG	Olive	Wood and coal	
Primary production	4826	-	-	-	684	5697	11207
Imports	-	14972	23950	5754	-	135	44811
exports	-	-	-	-	-	-155	-155
Total	4826	14972	23950	5754	684	5677	55863

In 2010, the industrial sector occupied a relatively low value of energy consumption by 10.6%. As for the household sector, it obtained the highest rate of energy consumption by 63.3%. As for the rest of the sectors, it got consumption by 26.1%, and the last one was (the agriculture and services sector ...) as shown in figure 1.3 [12].

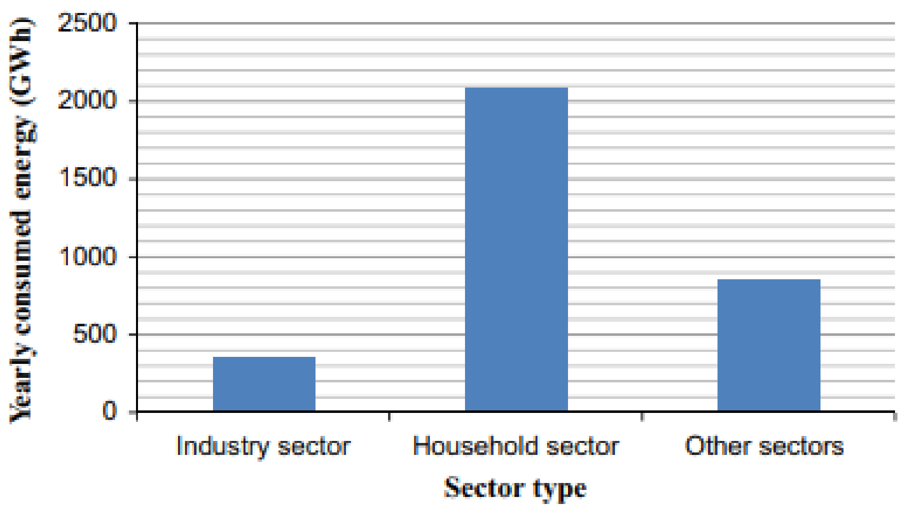


Figure 1.3 : Amount of electricity used by different sectors in Palestine in 2010 [9]

1.5 Literature review

A scientific research was done in Al-Safa Dairy Factory in Palestine and it contained the same specifications of the boiler used in the Islamic factory, where the process of controlling the amount of air to fuel manually, and the combustion efficiency before adjusting the amount of air was 80.5%, but after manually adjusting the amount of air, the result was increasing combustion efficiency to 81.2%, which means an increase in efficiency of 0.7%. As the previous amount of oxygen was 5.5% and the manually adjusted amount was 4.3%, so a decrease in the amount of oxygen required for combustion[36] .

A glass factory study was conducted in the United States of America in 2008, where they discussed energy efficiency practices and energy-saving technologies that can be implemented at the component, process, system and organizational levels. By presenting a discussion of the trends, structure and characteristics of energy consumption in the glass industry in the USA, and with a description of the main process steps in the glass industry. Ernst, et.al obtained results from them, providing projected energy savings and associated costs for many energy efficiency measures, based on case study data from real-world industrial applications. In addition, typical payback periods are provided[10].

To improve energy efficiency in the pharmaceutical sector, the researcher Vittorio and colleagues conducted a study in 2010 to introduce a system to control energy consumption and how this system can improve energy efficiency in the pharmaceutical sector by identifying inexpensive measures to improve energy. Their trend in this study, is a measure based on discounting system behavior by analyzing historical data on energy consumption and related factors through regression analysis in the sector, which is exactly the control in the working time factor for energy consumption in factories. The energy saving methodology is estimated between 5-20% depending on the energy management in this sector. This methodology can be applied in factories at a cost of energy exceeding 150,000 Euro / year [11].

At the University of Petra's in Greece, a study on energy consumption in automobile assembly line was conducted in 2012 by Fysikopoulos and his colleagues, using simulations of the automobile assembly line. The production line is checked for energy consumption of machine level and output cells. By pre-modeling the assembly line and before incorporating energy considerations, the company can save energy and cost. The procedure was to create a model to assemble the body structure inside the body and verify in terms of energy consumption to be calculated. The model developed can provide easy and fast power consumption prediction for a particular input, and this model can be applied to other assembly lines [12].

Koç, Çinçik made analysis for energy consumption in woven fabric production at 2010. They assembled general information about the energy types and levels that are used during woven fabric production, and an energy analyzed in this sector. They developed a theoretical approach to determine energy consumption. The energy consumption of a particular woven fabric produced in the chosen weaving mill has been calculated and the results obtained have been compared with data given in literature . It has been shown that weaving machines consume 29.2% of the total monthly energy consumption (262368.2 KWh/month),while compressors comprise 29.1% of the total energy consumption in the spinning mill chosen. Additionally, the specific electrical energy consumed for each month over a one year period has been calculated, and it has been determined that the values calculated change between 0.94 KWh/m and 1.48 KWh/month. As result, the energy cost was calculated as 0.094$/month . The data for specific energy cost given in literature change between 0.057 - 0.119 $/m, the data for Turkey being 0.082 $/month. It has been shown that there is good agreement between the data calculated and those given in literature [13].

Nasry, et.al (2015) focused on energy consumption in a pharmaceutical industry . In their study, they relied on the calculation of energy efficiency on the total weekly energy use in the company, where they carried out work flow analysis to facilitate the handling of materials . Effective energy consumption depends on the energy planning and materials involved based on their study . In their study, they relied on energy efficiency planning as a priority that could save about 35% of energy consumption in the production area and save about 20% on monthly electricity bills [14].

A study was conducted to reduce the electricity consumption of the compressed air system of the steel industry in Brazil in 2017, by Washington and a group of researchers, who based their study on reducing energy consumption by testing the compressed air, where they conducted an ultrasound test in the compressed air line To identify and measure leaks in flow.Once the leak site was identified, it was eliminated through maintenance and corrective improvements, and then energy consumption scenarios were compared before and after improvements. As a result, the average monthly electricity consumption in the reporting period decreased by 57.2%. In addition, one compressor was placed side by side in standby mode[15].

Chapter two
Problem formula

2.1 Industrial sector in Tulkarm city:

There are few industries in Palestine and most of this industrial activity comes from small companies, stores and warehouses. None of these industries can be defined as energy-intensive, or emitters high. But by referring to all of this, the Islamic company is heavily involved in mass production operations in the field of meat and vegetable production. Therefore, compared to other companies, this company can be considered a large company in Tulkarm.

Islamic company is concerned with the manufacture of meat products as primitive production lines where it was initially established on an area of 500 square meters until now reached the area of its buildings to squeeze on a land area of 15,000 square meters.

Where the initial production stages begin to attract meat from companies, local farms and international, once they reach the company is examined by the Department of Quality to be produced after that, as the production department is equipped with the latest technology and modern equipment and refrigeration departments.

Then start the process of cutting meat, which reaches a temperature of minus 25 Celsius degrees and then chop material with it, then these materials are transported by dedicated vehicles to start the process of mixing with special machinery equipment to reach the process of packing products based on size and quality, then transferred materials as packaged on special carriers to the oven section and the cooking process is done by steam at 72 ° C, then the process of rapid cooling under water then the temperature reaches 40 ° C and left to cool slowly before entering the storage refrigerators. And then to the packaging department as showing in figure 2.1.

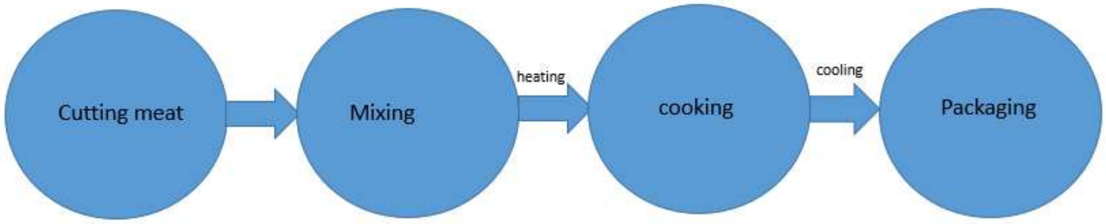


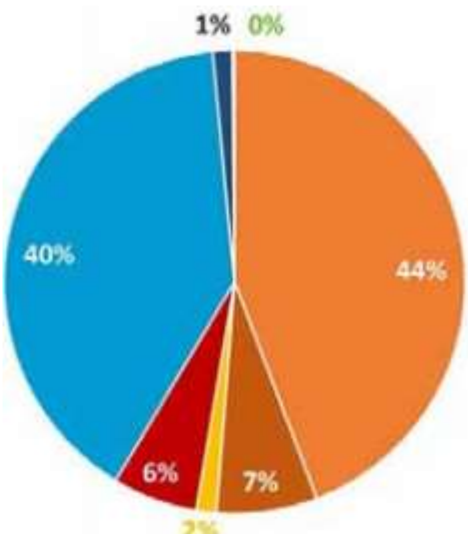
Figure 2.1: the process of product line in factory

The divisions of the company provided the opportunity to produce more than one hundred varieties of different types, flavors and shapes.

All production lines in this factory operate on electrical energy that is purchased from electrical companies. As it consumes energy at high rates, this plant can be considered one of the largest factories in comparison to other factories in Palestine.

2.1.1 Energy consumption in Tulkarm :

Total energy consumption (final energy) in Tulkarm and its surrounding is estimated at 314 GWh in 2014, which equates to approximately 3.11 MWh per person per year (equivalent to 1.9 barrels of oil per person per year). Figure (2.2) shows the pie chart and the table for distribution between sectors [19].



	GWh/y
Residential buildings	139
Tertiary buildings	22
Public lighting	4
Industry	19
Transport	125
Water management	4
Waste treatment	0
Agriculture	0

Figure 2.2 : energy consumption in Tulkarm city[19]

The following figure and table show the Energy consumption per sector and per energy in Tulkarm during year (2014). It shows that the energy in this city is from electricity with approximating range 78 MWH/year for household's. Else energy is from liquid petroleum gas (LPG) and solar for this sector, but for industry it seems not high energy consumption. It shares from electricity consumption with 12000 MWH/year and from diesel and LPG.

Figure 2.3 : Energy consumption per sector and per energy in Tulkarm (2014) [19]

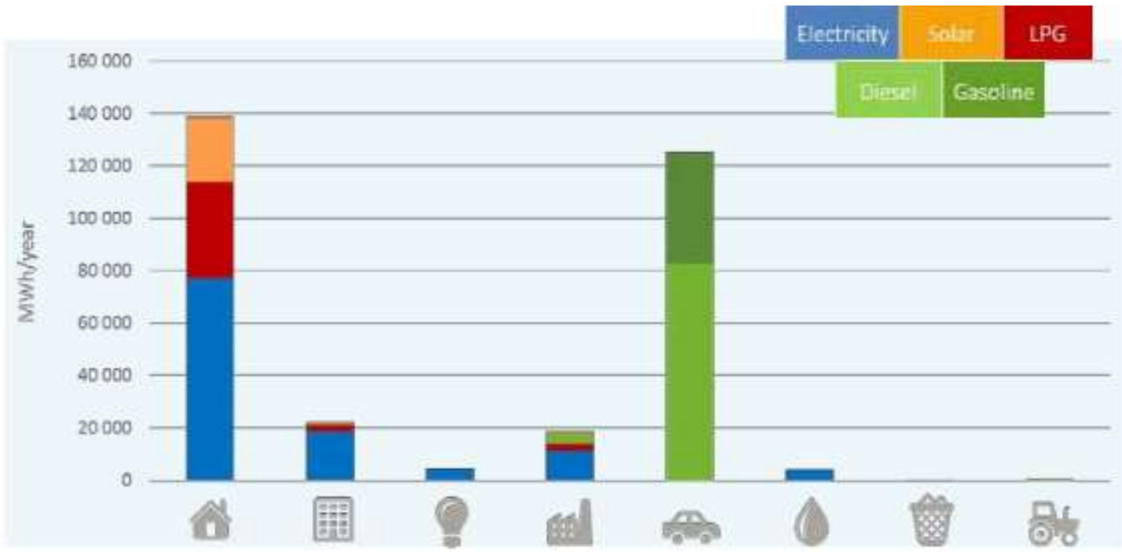


Table 2.1 : Energy consumption per sector and per energy in Tulkarm (2014) [19]

GWh FE/year	Electricity	Solar	LPG	Fuels	Other	Total
Residential buildings	77,5	23,9	36,5	0,4	0,7	**139,0**
Tertiary buildings	18,9	0,0	2,8	0,4	0,1	**22,2**
Public lighting	4,5	0,0	0,0	0,0	0,0	**4,5**
Industry	11,4	0,0	2,7	4,3	0,3	**18,7**
Transport	0,0	0,0	0,0	125,4	0,0	**125,4**
Water management	4,2	0,0	0,0	0,0	0,0	**4,2**
Waste	0,0	0,0	0,0	0,1	0,0	**0,1**
Agriculture	0,1	0,0	0,0	0,2	0,0	**0,4**
Total	**116,6**	**23,9**	**42,0**	**130,9**	**1,1**	**314,5**

2.1.2 Population statistics:

Table 2.2 shows the distribution of population in Tulkarm city, according to this table, the annual population schedule during the period 2007-2014 . The population in Tulkarm and its environs reached 101,000 people. This value is estimated by the Palestinian Statistics Authority, where 44.3% of the population is concentrated in the vicinity of Tulkarm.

Table 2.2: Population distribution in Tulkarm during 2007-2014[19]

	2007	2008	2009	2010	2011	2012	2013	2014
Tulkarem All								
PCBS Estimation	69 386	70 727	72 091	73 475	74 884	76 324	77 774	79 228
Municipality data	69 386	-	-	-	-	-	-	101 000
Tulkarem District	156 566	159 594	162 668	165 791	168 973	172 224	175 494	178 774
Palestine	3 719 189	3 825 512	3 935 249	4 048 403	4 168 860	4 293 313	4 420 549	4 550 368
West Bank	2 323 469	2 385 180	2 448 433	2 513 283	2 580 168	2 649 020	2 719 112	2 790 331

2.1.3 Greenhouse gases (GHG) in Tulkarm:

The process of producing energy produces side effects. One of these effects is greenhouse which cause global warming, that is a source of danger to public health and also a threat to the climate in general.

Greenhouse gases consist of:

1- Carbon dioxide from fuel combustion and smoke emission sources such as car and factory exhaust and forest fires ...

2- The water vapor produced by the evaporation process

3- Nitrogen oxide

4- Ozone

5- Methane gas produced from livestock

Global greenhouse gas emissions in Tulkarm are estimated at 192 kilotons of carbon dioxide per year in 2014, equivalent to 1.9 tons per person per year. This is generally two times higher than the average emissions per person in Palestine, including the Gaza Strip.

The pie chart and the following table show the amount of gases emitted in Tulkarm . Figure 2.4 shows the highest CO_2 emission in residential buildings with 67 $ktCO_2eq$/year, where the industry sector contribute with 11 $ktCO_2eq$/year.

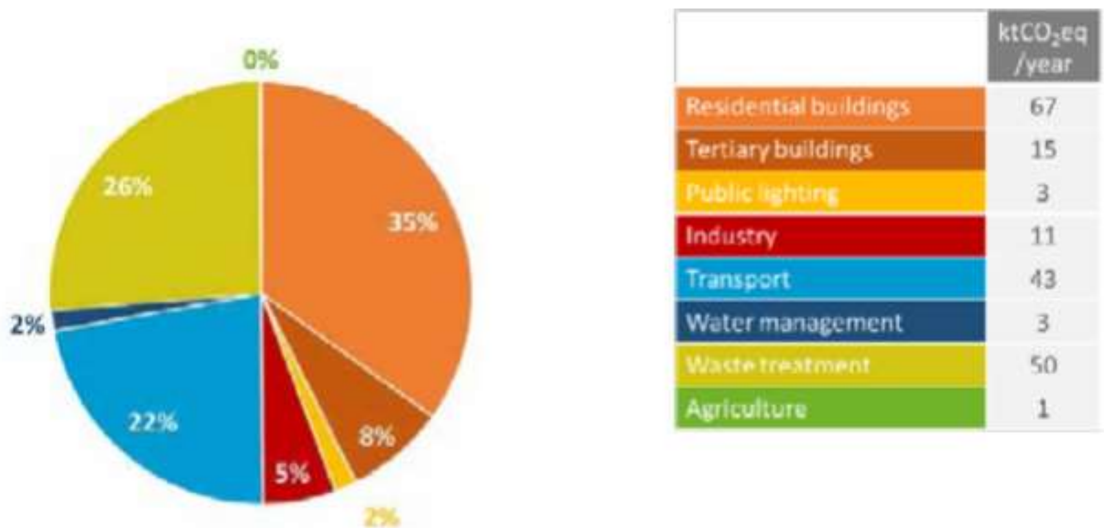


Figure 2.4 : GHG In Tulkarm city [19]

2.2 Electricity conditions in Tulkarm : consumption, supply and prices in industrial sector.

Tulkarm City is located north of the West Bank and has a population of approximately 44,169 , In Tulkarm there is a municipality responsible for supplying seven small suburbs with electricity. Due to its hot summer weather, growing population, increasing number of industrial facilities , and reliance on a single municipality, the city suffers from a shortage of electricity supplies, and residents suffer frequent power outages during the summer[20].

2.2.1 Electric consumption

The industrial sector in Tulkarm is supplied approximately 80 gigawatt / year, but by comparison the city consumes 103 gigawatt / year of electricity, as 80 gigawatt / year will equal 28% of the energy demand in Palestine in 2008. Table 2.3 Shows the amount of electricity supplied to the industrial sector in Tulkarm[19].

Table 2.3 : The amount of electricity provided to industry sector in 2008[19]

	Value provided	Method	Final value
Electricity	80 000 MWh/y	Not consistent	11 400 MWh/y
Liquid gas	Not provided	National Ratio per capita	2 700 MWh/y
Diesel and gasoline	Not provided		4 300 MWh/y
Other	Not provided		290 MWh/y

2.2.2 Electric price in Tulkarm

Table 2.4 shows the average price of electricity in Tulkarm city during year 2019. The average price for many sector is shown in this table.

Table 2.4 : Average price (NIS) of electricity in Tulkarm city during year 2019[21]

Home						Other consumer categories				
The amount of consumption kWh per month	1-160	161-250	251-400	401-600	more than 600	Commercial	Industrial low pressure	Industrial Medium pressure	agricultural	Temporary Service
The cost of consumption KW/h/ per/ month	0.46	0.49	0.57	0.61	0.67	0.63	0.51	0.43	0.46	0.79

2.3 Problem of study:

Due to the large volume of production in the Islamic company, the rate of energy consumption will be increasing continuously by increasing production lines and thus reflected on the size of the production cost, which in turn raises the price of the product to the consumer knowing that the volume of monthly consumption is estimated at 40.000 $ yearly.

In this work, appropriate solutions will be found to reduce energy consumption in this plant without affecting the performance and production efficiency factors. Therefore, we will consider a set of solutions, including two objective :

1) Main objective :

Study the energy consumption of the plant by calculating the amount of annual energy cost and the amount of consumed loads and then work to reduce the cost while maintaining the stability of production .

2) Secondary objective

Following an operational program aimed at reducing the cost of consumption according to the kilowatt-hour price system in Palestine

1. Work to create a synchronization system for the operation of boiler and compressed air system
2. Test the power factor and work to improve it
3. Adjustment of lighting systems and other services by controlling lighting quality and quantity. To find the best alternative that less consumed energy.
4. Examine the possibility of installing a heat exchanger on the boiler

2.4 Energy conservation fields in industries

2.4.1 Steam distribution:

Steam is largely used in industrial facilities, where it can be generated through waste heat, or it can be generated using boilers, but the volume of steam used in the facility has a specific mechanism as shown in Figure 2.5.

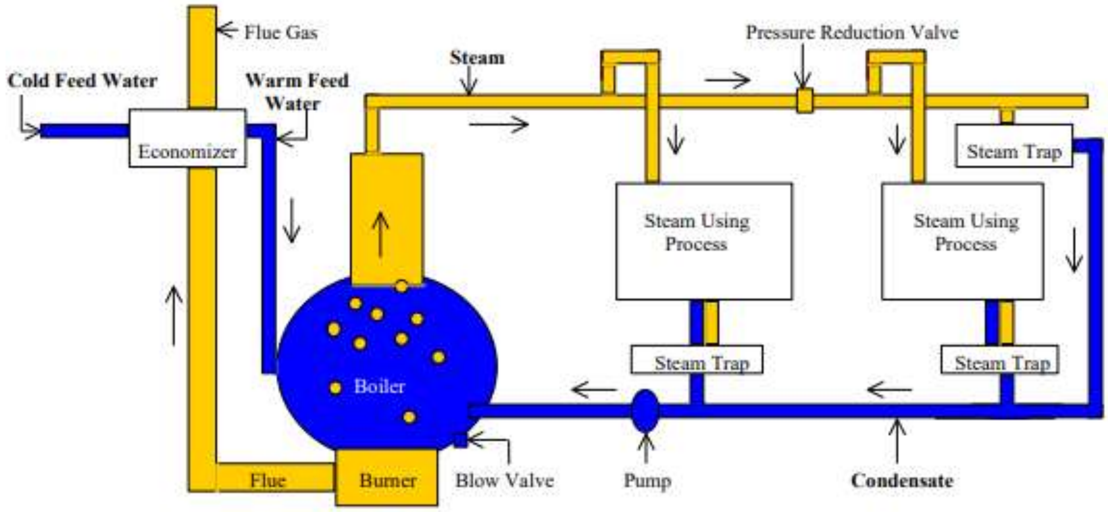


Figure 2.5: Schematic presentation of a steam production and distribution system[22]

An article was published in united states of America on energy consumption in the industrial sector in 2002 , where the results as follows: The industrial sector consumes more than 39% of the energy used in the United States. In 1994, industrial consumption was composed of 5,676 trillion Btu (TBtu) of steam (34%); 7,708 TBtu of fuel (47%); and 3,127 TBtu of electricity (19%)[23].

2.4.2 Combustion Efficiency

Combustion efficiency is an indication of the burner's ability to burn fuel and the ability of the boiler to absorb the heat generated. The amount of unburned fuel and excess air in the exhaust are used to assess a burner's combustion efficiency.

Insufficient combustion air lead to reduce fuel efficiency, creates highly toxic carbon monoxide and produces soot. To ensure there is sufficient oxygen to fully react with the fuel, additional combustion air is usually provided. This additional air, called "excess air", is expressed as the percentage of air above the amount theoretically required for complete combustion[24].

Excess air to achieve highest possible efficiency for some common fuels:

- *5 - 10%* for natural gas
- *5 - 20%* for fuel oil
- *15 - 60%* for coal

Carbon dioxide - CO_2 - is a combustion product and the content of CO_2 in a flue gas is an important indication of the combustion efficiency. Figure 2.6 shows the relationship between O_2 , CO_2 , and excess air.

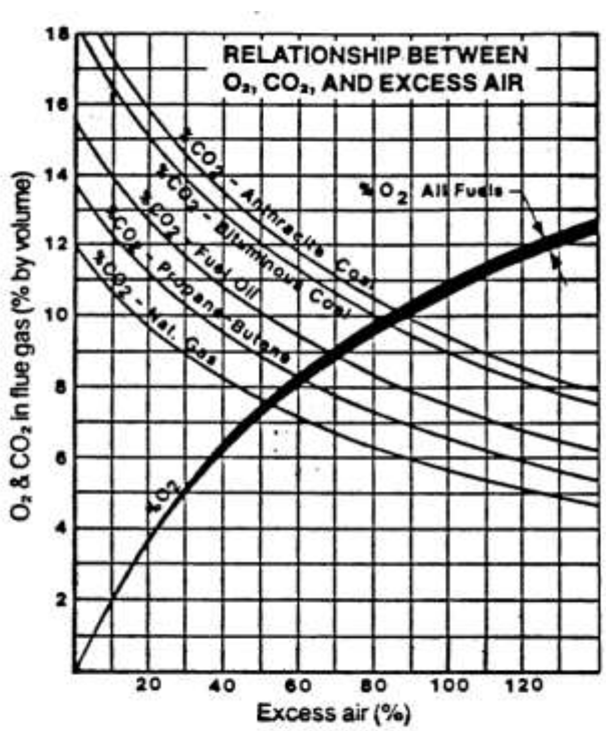


Figure 2.6: Relationship between O_2 , CO_2 , and excess air [25].

The combustion efficiency increases with increasing excess air - until the heat loss in the excess air is larger than the heat provided by more efficient combustion as shown in figure 2.7 .

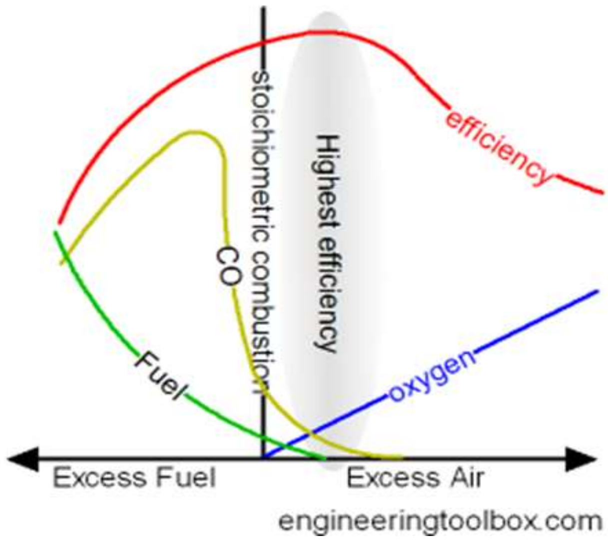


Figure 2.7 : Combustion efficiency and excess air[26]

2.4.3 Boiler Efficiency

Optimizing boilers efficiency is important to minimize fuel consumption and unwanted excess to the environment.

Boilers are supplied based on several data, for example : thermal efficiency of 85%, combustion efficiency of 87%, a boiler efficiency of 80%, and a fuel to-steam efficiency of 83%[27] .

Typically,

1. Thermal efficiency reflects how well the boiler vessel transfers heat.
2. Combustion efficiency typically indicates the ability of the burner to use fuel completely without generating carbon monoxide or leaving hydrocarbons unburned.
3. Boiler efficiency could mean almost anything. Any fuel-use must compare energy put into the boiler with energy coming out.
4. "Fuel to steam efficiency" is accepted as a true input/output value.

Each of these terms represents something different from the other. Any boiler can use less fuel than the other in the same application. As there are several criteria by which proficiency is determined, and this is determined by tests. Therefore, an easier and more cost-effective method is represented by reviewing the design detaNIS of the boiler, and estimating the value of efficiency in five broad elements, as follows:

1- Boiler stack temperature**:** The stack temperature is a measure of the temperature that the dry flue gases will transfer and the moisture loss. This generally indicates improved boiler efficiency. Whereas, the chimney temperature is the temperature of combustion that leaves the boiler and reflects the amount of energy that has not transferred from the fuel to the steam. The lower the temperature in the chimney, the more efficient in design of the heat exchanger and the greater fuel economy and fuel efficiency to steam. So that for the boiler to operate at an efficiency of 84%, the chimney temperature must be less than 350 degrees Fahrenheit[28].

2- Heat content of fuel **:** Calculating efficiency requires knowledge of the calorific value of the fuel, the ratio of carbon to hydrogen, whether the water produced is lost as vapor or condensed, and whether the latent heat (the heat needed to convert water into vapor) is recovered.

Any fuel has two widely published energy contents. They are:

1. The Higher Heating Value (HHV), also called Gross Calorific Value (GCV)
2. The Lower Heating Value (LHV), also called the Net Calorific Value (NCV)

3- Fuel specification**:** The type of fuel has a major impact on efficiency. With a gaseous fuel containing a higher percentage of hydrogen. Where more water vapor is formed during combustion. The result is energy loss as the resulting steam absorbs the energy in the boiler and reduces the efficiency of the device

The specification used to calculate efficiency must be based on the fuel to be used at the installation. As a rule, typical natural gas has a hydrogen/-carbon (H/C) ratio of 0.31. If an H/C ratio of 0.25 is used for calculating efficiency, the value increases from 82.5% to 83.8% [27].

4- Excess air levels **:** Excess air is supplied to the boiler beyond what is required for complete combustion primarily to ensure complete combustion and to allow for normal variations in combustion. A certain amount of excess air is provided to the burner as a safety factor for sufficient combustion air.

2.4.4 Compressed air systems

The compressed air is the important factor can be improved to reduce energy consumption in company. Many industrial facilities require some form of compressed air, in order to operate a simple air device or for more complex tasks such as operating pneumatic control tools.

A recent study carried out by the US Department of Energy showed that the industrial facility's consumption of compressed air is 10% of the facility's electricity consumption[29].

There are more than a dozen measures that can be considered to reduce energy use for compressed air plant, here are three major ones:

1- Reduce leaks

- Typical plants that are poorly maintained have 20-50% leak rates
- Leak repair and maintenance can reduce the leak rate to 10%
- Overall, leak repair could reduce annual consumption by as much as 20% [30].

The most common areas for leaks are couplings, hoses, fittings, regulators, traps, valves, and disconnects. Quick disconnects are notorious for leaking and should be avoided. Detecting methods include manual inspection as well as ultrasonic acoustic detection. Leaks will continue to occur, so detection and correction programs need to be ongoing efforts.

2- Use alternate sources for specific applications:

Table 2.5 shows the alternate source for some of applications used in compressed air system.

Table 2.5 : Alternate source for some component in compressed air systems[30]

Application	Alternative
Air motors	Compressed air should only be used for positive displacement
Cooling electrical cabinets	Air conditioning fans should be used instead of compressed air vortex tubes
Flowing high-pressure air past an orifice to create a vacuum	A vacuum pump system should be applied instead of compressed air venturi methods
Cooling, aspirating, agitating, mixing, or package inflating	Blowers
Cleaning parts or removing debris	Brushes, blowers, or vacuum pump systems or nozzles that are more efficient
Moving parts	Blowers, electric actuators, or hydraulics
Blowguns, air lances, and agitation	Low-pressure air
Tools or actuators	Consider efficient electric motors

Source: ENERGY STAR

3- Reduce inlet air temperature:

1. Each 15-celeius degree will save 1% of compressor energy
2. There is usually a quick payback of 1-5 years
3. Approaches to reduce air inlet temperature include:

- Duct inlet from outside
- Duct exhaust air (cooling air) to outside
- Ventilate room
- Heat recovery

2.4.5 Pumps:

In order to reduce energy consumption by the pump, the bypass loops must be eliminated, which can reduce 10-20%. In most modern systems these loops are dispensed. Figure 2.8. illustrates the mechanism of work of the pump and its connected parts.

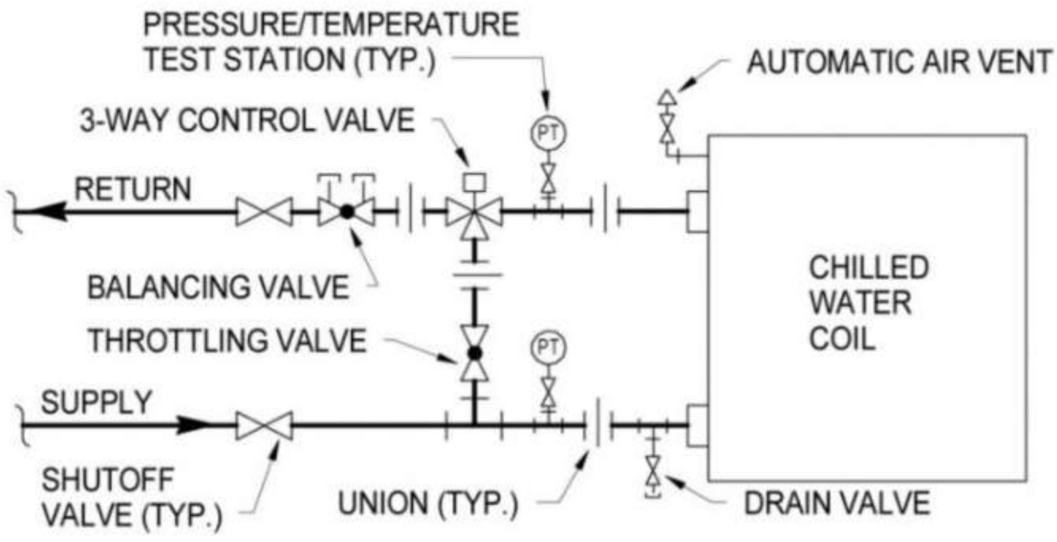


Figure 2.8 : The principle work of pump and its connected parts[30]

Bypass loops are devices that maintain a continuous flow in the main circuit, for example, a three-way valve that serves cooled water coNIS allows variable flow across the coil. But it maintains the continuous flow in the main loop. So by eliminating these devices. We allow pumps to work closer to actual demand and with less braking force, and this is definitely a positive step to reduce energy consumption.

Pump sizing is done by reducing pump thrust and reducing throttle valves, which in turn saves energy by 15-20%. The pump is designed based on (flow and head), so the pump must be chosen based on these specifications in order to work with the best operating characteristics[31].

2.4.6 Lighting system:

Lighting is widely used in the facility, where lighting units are divided either into offices and buildings or in the manufacturing area and production equipment. Therefore, two types of discharging sources are used as follows:

1- High density discharge (HID) sources, metal halide lamps, high pressure sodium and mercury vapor lamps in manufacturing, production and storage areas.

2- Fluorescent lamps, compact fluorescent lamps (CFLs), and incandescent lamps are usually used to illuminate tasks and offices.

To reduce the process of energy consumption through lighting, the following can be done:

1- Reducing the number of lighting lamps.

2- Install high efficiency lighting lamps like florescent.

3- Install reflectors in light fixtures like using mirrors.

2.4.7 Power factor improvement:

Low power is not only inefficient, but can also be expensive over the life of an electrical system. Improving the power factor will increase the distribution system's efficiency and reduce energy costs associated with low power factor penalties.

What is Power Factor (PF)?

Power factor is a dimensionless number between 0 and 1 that is defined as the ratio of real power (kW) to apparent power (kVA). Real power is considered to be the work producing component. Apparent power is the product of the total current and voltage used by the load, which includes power used for electromagnetic fields. In other words, real power is the amount of power needed to perform the work in a perfect world while apparent power is the power needed to perform the work in real world conditions. This relationship is shown in figure 2.9[32].

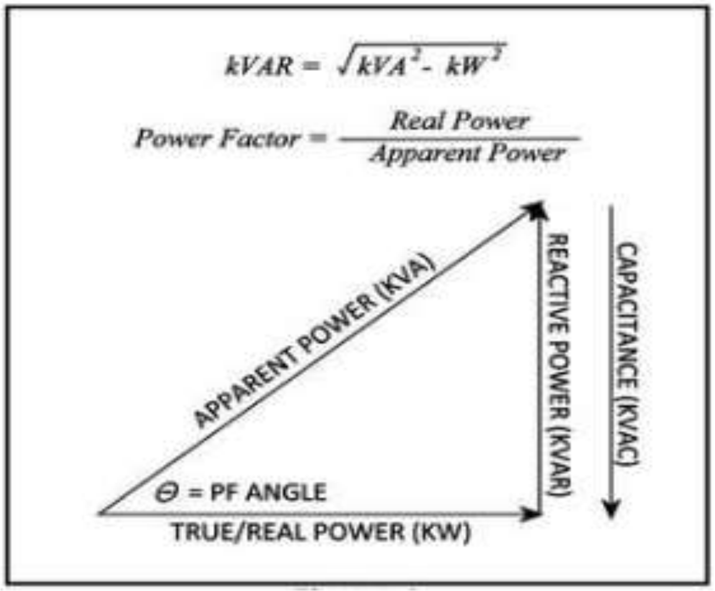


Figure 2.9: The relationship between real power and apparent power[33]

Power factor correction:

There are many different strategies that can be used individually or in combination to correct low power factor. A few of these strategies are:

- Install capacitors in the distribution system
- Minimize operation of idling or lightly loaded motors
- Install variable frequency drive (VFD) systems to lightly loaded induction motors
- Install new motors that will be operated near their rated capacity
- Replace lightly loaded motors with motors sized to be operated near their rated capacity
- Avoid operation of equipment above its rated voltage.

the benefits that can be achieved by applying the correct power factor correction are:

- Reduced demand charges
- Increased load carrying capabilities in existing circuits
- Improved voltage
- Reduced power system losses
- Reduced carbon footprint
- Reduction of electric bills.

Chapter Three

Results and discussion (modeling and simulation)

3.1 Introduction:

It is very important to know the amount of electricity consumed by the facility and the amount of utility bills generated during the temporal reality. This is so that we can analyze these bills in order to develop a specific plan to reduce the amount of electrical consumption during these years. Where a clear plan must be made for a mechanism to reduce the annual electrical consumption rate. Therefore, monthly and yearly consumption will be taken into consideration over three years, which will be detailed during this research.

Various tools and methods have been developed in recent years to support systematic analysis and optimum utilization of companies and industrial institutions in order to reduce their energy consumption. However, the current methods focus on the manufacturing processes and systems that exist in the organization. It does not generally take the resources of the company. Therefore, it is imperative to reconsider the interrelationships between products, processes and resources in the factory in order to fully integrate the energy efficiency in the enterprise.

3.2 Electric bills analysis in the factory:

All these data were taken by the Electricity Department of Tulkarm municipality .In this project the bills will be analyzed over a period three years (2016-2018). A comprehensive comparison between these years is done in terms of the price of kilowatts, and the monthly, annual consumption of electricity in the facility.

The factory contains three subscriptions with the names of different people, according to what is registered in the electricity department. The data was obtained by the municipality with these three contributions. Then, it was collected each year separately to know the amount of annual electricity consumption in the facility and the amount of electricity bills.

The operator's data will be simplified in terms of cost of energy consumption. It was also obtained by the electricity department in the municipality of Tulkarm for the year 2016 , 2017 , 2018 as follows.

The following table 3.1 shows the monthly factory consumption for the year 2016 as well as the kilowatt hour price during this year.

Table 3.1 : the total consumption of energy in 2016 for Islamic company

Month	Energy consumption (KWh)	Total price (NIS)
January	132450	79123
February	139300	82707
March	141070	83580
April	143870	85148
May	187900	112301
Jun	172750	103794
July	172470	102750
August	219700	130472
September	200640	120865
October	208640	124721
November	186920	111494
December	159290	96021
Total	**2065000**	**1232976**

The electric price for KWH in this year was 0.20 $ which’s equal in shekel 0.69 NIS.

Through the data listed in the previous table 3.1. The following figure 3.1 was made to show the highest monthly electricity consumption in 2016.

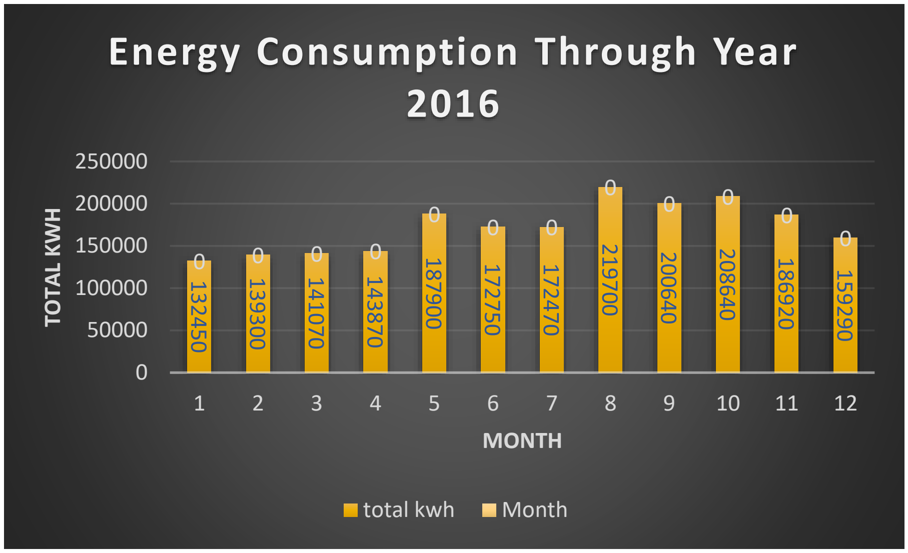


Figure 3.1: The histogram distribution for energy consumption in 2016

From figure 3.1 the highest electric consumption is during August month with 219700 KWH, and the lowest electric consumption was in January with 132450 KWH.

Table 3.2 shown the data for the year 2017 , its classified the electric consumption during this period in KWH :

Table 3.2 : The total consumption of energy in 2017 for Islamic company

Month	Energy consumption (KWh)	Total price (NIS)
January	165440	109421
February	173880	111473.3
March	155820	100146
April	188240	121114.1
May	183790	117892
Jun	160360	100396.9
July	236330	154939.1
August	235690	150926.1
September	219900	142085.6
October	229350	147298.2
November	197700	128142.5
December	208670	136357.3
Total	**2355170**	**1520192**

Through the data listed in the previous table, the following chart was made to show the highest monthly electric consumption in 2017.

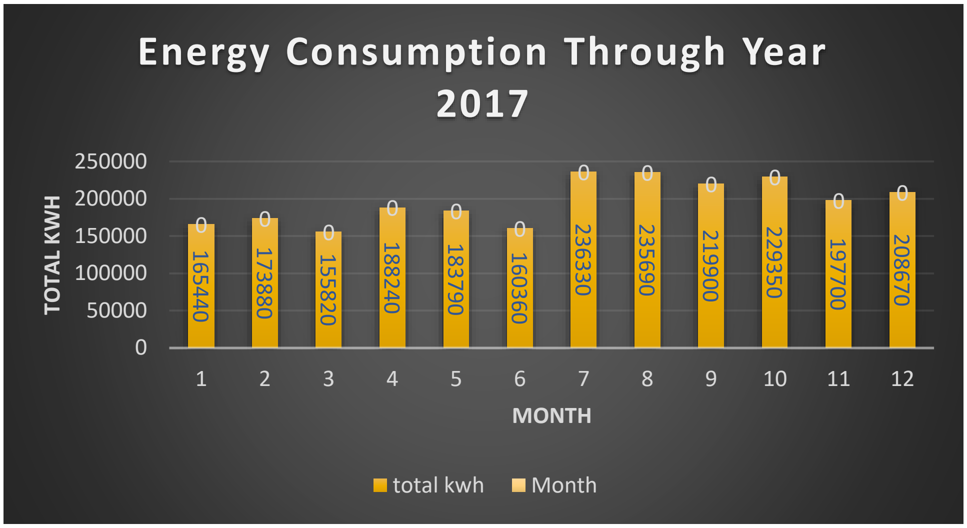


Figure 3.2: The histogram distribution for energy consumption in 2017

According to figure 3.2 , we can see that the highest energy consumption was in July with 236330 KWH, and the lowest energy consumption was in march with 155820 KWH .

The data for 2018 was obtained as shown in table 3.3 :

Table 3.3 : The total consumption of energy in 2018 for Islamic company

Month	Energy consumption (KWh)	Total price (NIS)
January	197740	128220
February	205640	133221
March	196220	126746
April	220430	142596
May	215340	139050
Jun	191570	131125
July	232700	149520
August	241580	156408
September	243320	157311
October	247380	160729
November	226727	134294.9
December	230100	136314
Total	**2648747**	**1695535**

Through the data listed in the previous table, the following chart was made to show the highest monthly electricity consumption in 2018:

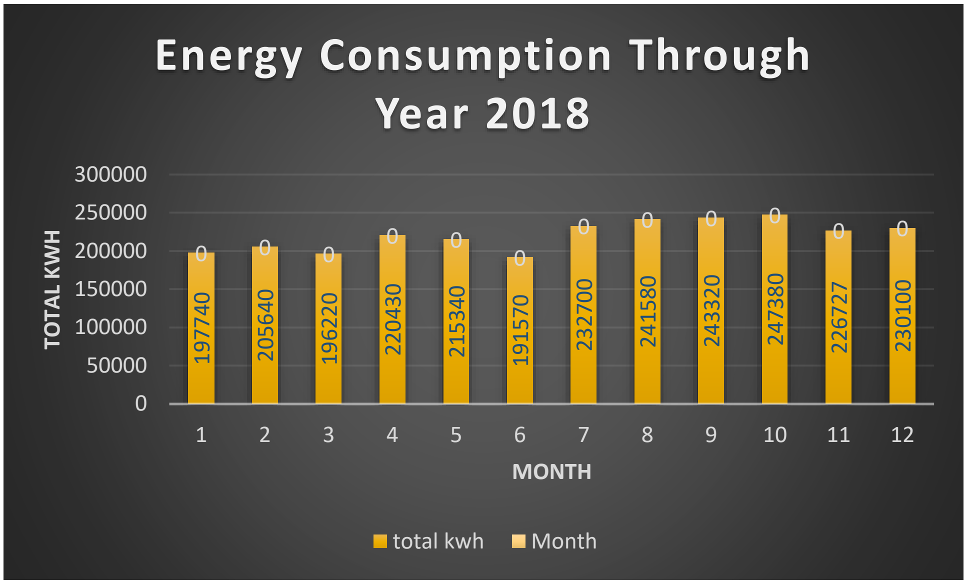


Figure 3.3: The histogram distribution for energy consumption in 2018

Figure 3.3 describes the energy consumption in year 2018. It shows that the highest energy consumption was in October with 247380 KWH, and the lowest energy consumption was in Jun with 191570 KWH .

3.3 The data analyzer by power analyzer:

A power analyzer was used to collect data on the electricity consumption of the plant. As the factory contains two electrical transformers, the device was connected to the first electrical transformer for six days and to the second transformer for four days.

Through this device, the following data was obtained:

- power
- voltage
- current
- frequency
- power factor

The data obtained for first transformer are shown in the figures below where the X axis represents the time in hours and the Y axis represents the power in kilowatts.

Transformer 1 :

<u>15 September 2020</u>

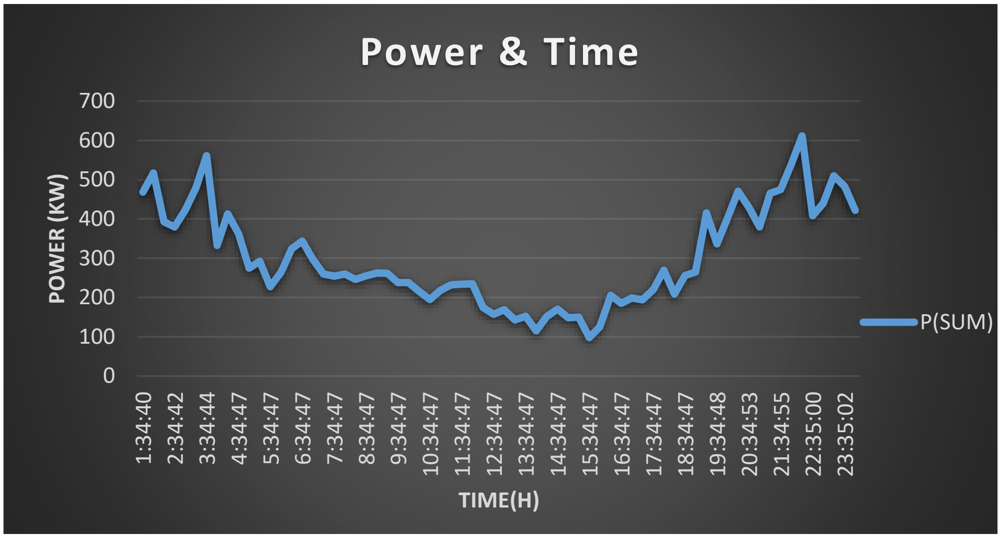


Figure 3.4: Relation between power & time in 15 September 2020

<u>16 September 2020</u>

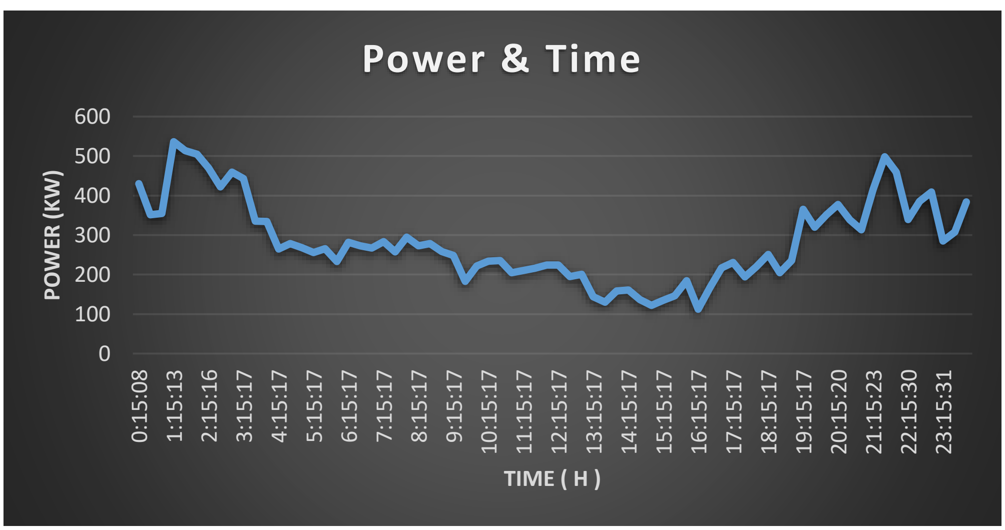


Figure 3.5 : Relation between power & time on 16 September 2020

17 September 2020

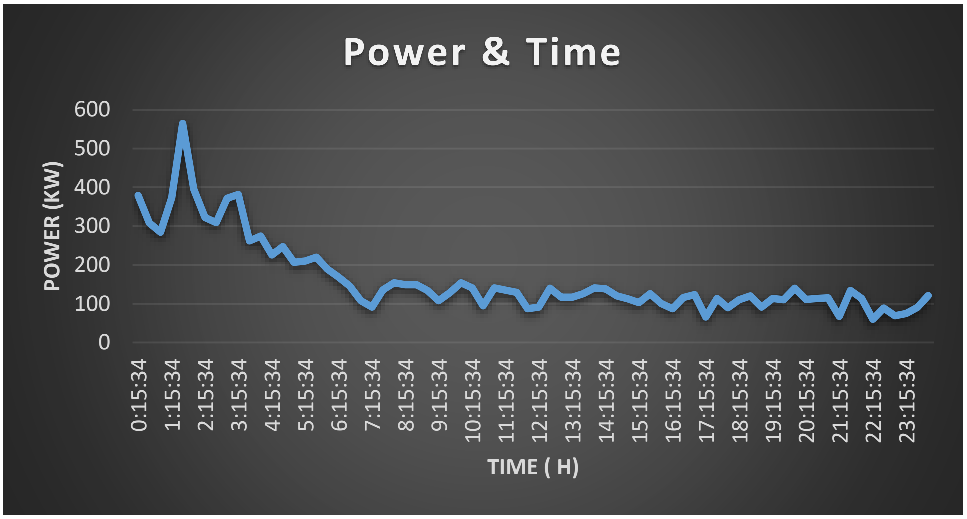


Figure 3.6 : Relation between power & time on 17 September 2020

18 September 2020

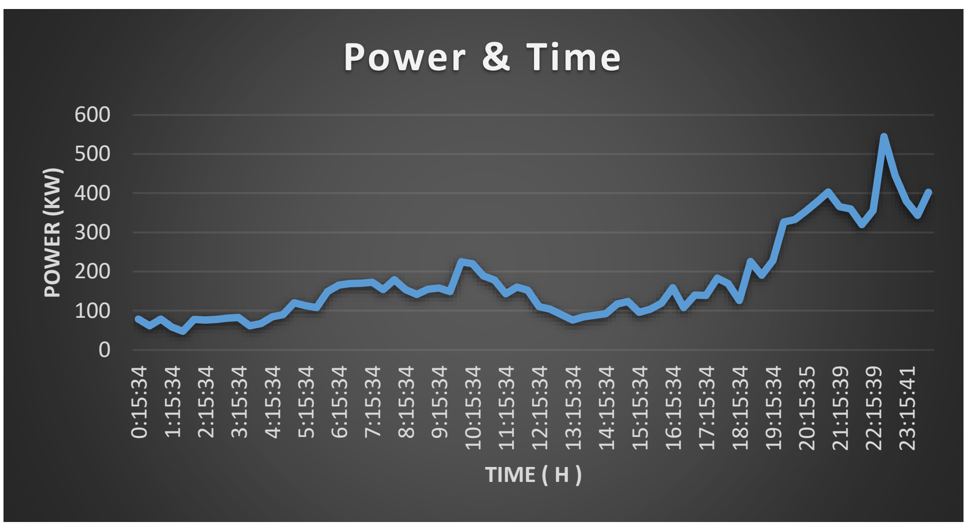


Figure 3.7: Relation between power & time on 18 September 2020

19 September 2020

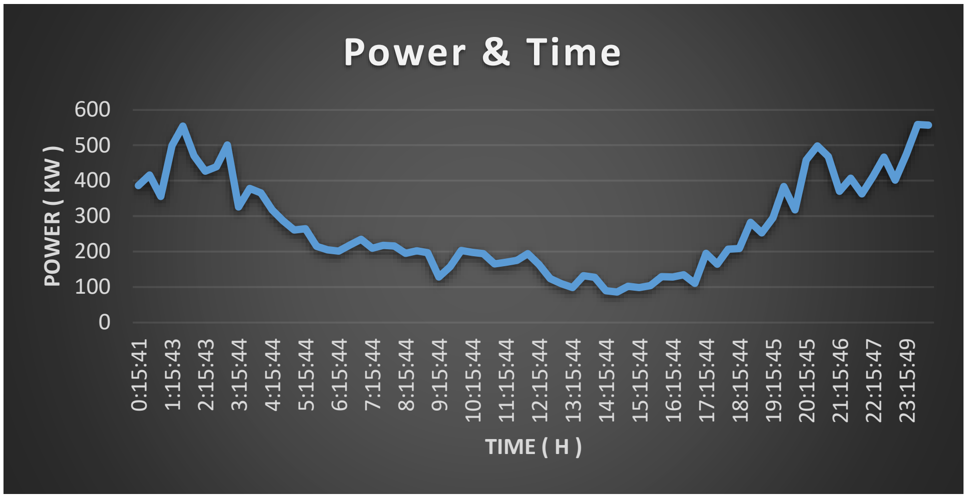


Figure 3.8: Relation between power & time on 19 September 2020

20 September 2020

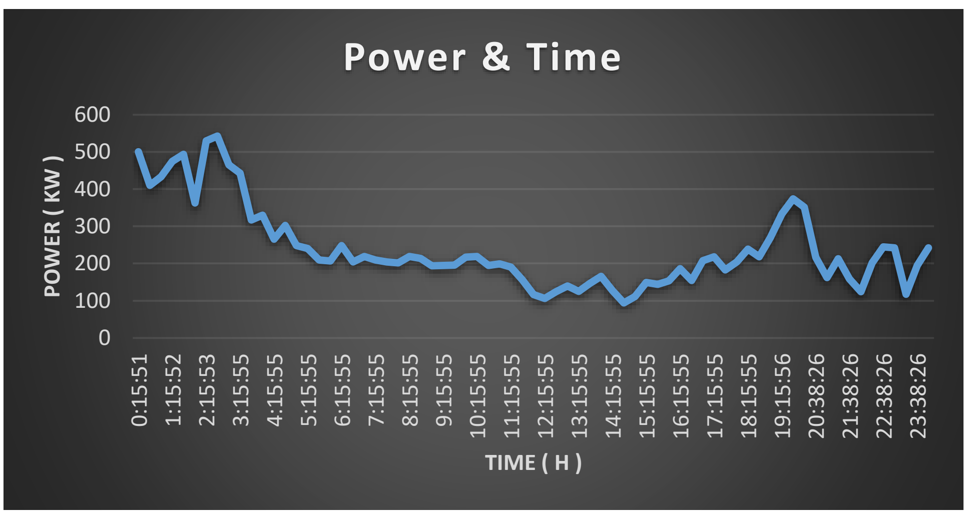


Figure 3.9 : Relation between power & time on 20 September 2020

Through the shown diagram of the first transformer. It can be concluded that the highest rate of electricity consumption starts from 7 pm to 4 am. due to the work of the cooling system (refrigerators and freezers) and lighting system.

Transformer 2 :

<u>21 September 2020</u>

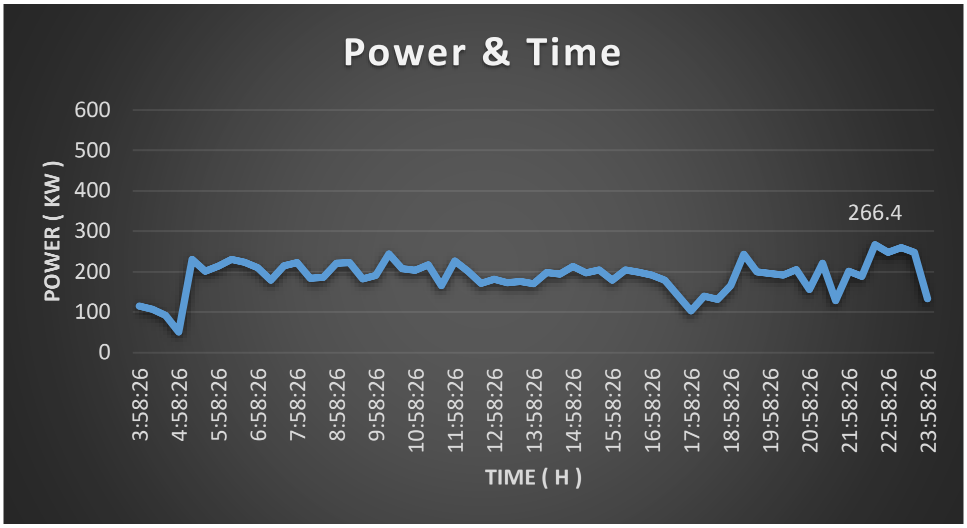


Figure 3.10: Relation between power & time on 21 September 2020

<u>22 September 2020</u>

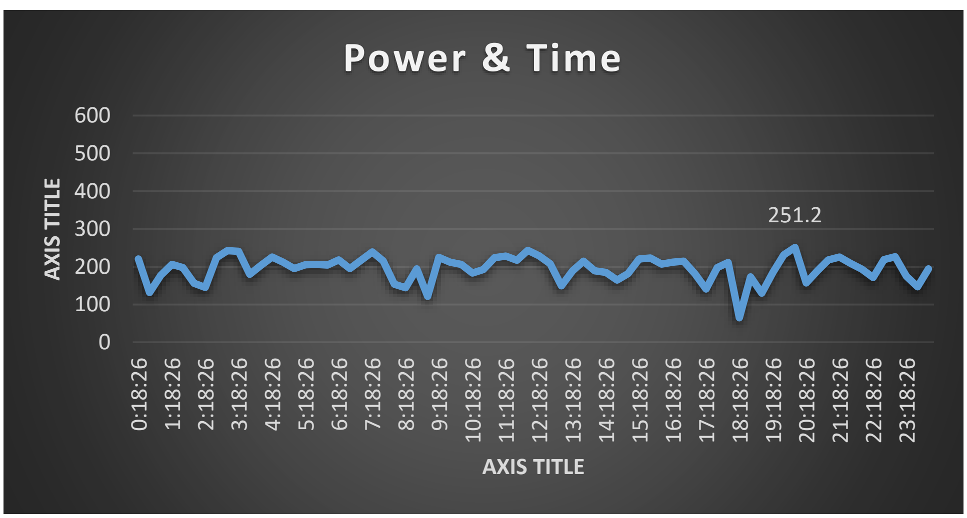


Figure 3.11 : Relation between power & time on 22 September 2020

22 September 2020

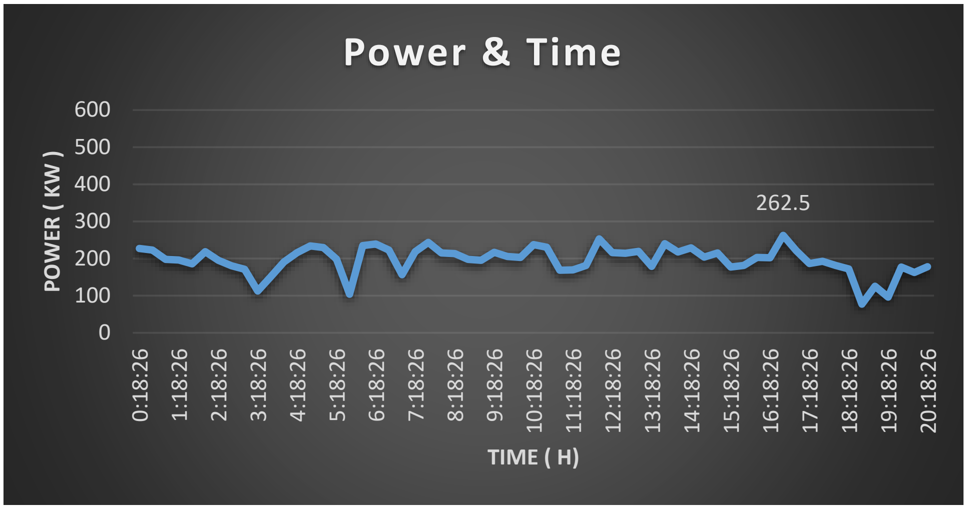


Figure 3.12 : Relation between power & time on 23 September 2020

In Transformer No.2 the amount of electricity consumed is less than the transformer No. 1 because the cooling system is not connected to this electrical transformer. The highest energy consumption rate in 1st transformer is approximately 260 kilowatts, and in the second transformer is 192 kilowatts.

Approximated Average electricity consumption in factory according to the data of power analyzer:

The average consumption of electricity in factory for nine days, was approximated about 290.5 kw/hour.

According to that average, the estimated power consumption for one year is calculated by:

290.5 kw * 24 hour * 365 day = 2,544,780 KWh.

The price of 1 KWh is 0.642 NIS so the total price consumption is calculated to be:

2,544,780 KWh * 0.642 NIS = 1,633,748 NIS.

3.4 Suggested solutions to reduce energy consumption in the plant:

To reduce the amount of energy consumption in the plant, a combination of factors must be controlled ,including: power factor correction, the boiler system, cooling system, compressed air system, lighting and, each one will have discussed separately.

3.4.1 Power factor correction:

The main electrical source for the Islamic factory is Tulkarm municipality via tow feeders of 200 KVA maximum capacities. The average power factor measured by energy analyzer for 24 hours was 0.88 for first transformer, and 0.7 for second transformer. This power factor is considered very low and a source of high money burdens to the company especially if the municipality starts to impose money penalties to the low power factor.

The idea of reducing the electricity bill is summarized in this factor by increasing the value of the power factor to a value of 0.92 or higher, in order to avoid fines by the electricity supplier. The value of the fine is summarized on the power factor in Table 3.4 .

Table 3.4 : Power factor proposed penalties in Palestine [34]

Power Factor value	**Penalty** (of the total bill for every 0.01 of power factor less than 92%)
92% or more	None
Less than 92% to 80%	1%
Less than 80% to 70%	1.25%
Less than 70%	1.5%

3.4.1.1 Power factor correction techniques:

The power factor can be improved by adding two capacitors to the electrical panel, the value of each capacitor is 20 KVAR, in order to obtain an adjustment in the power factor value to be higher than 0.92. Consequently, fines by the municipality will be reduced.

Figures 3.13 and 3.14 show the relationship between time and power factor for the first and second transformers.

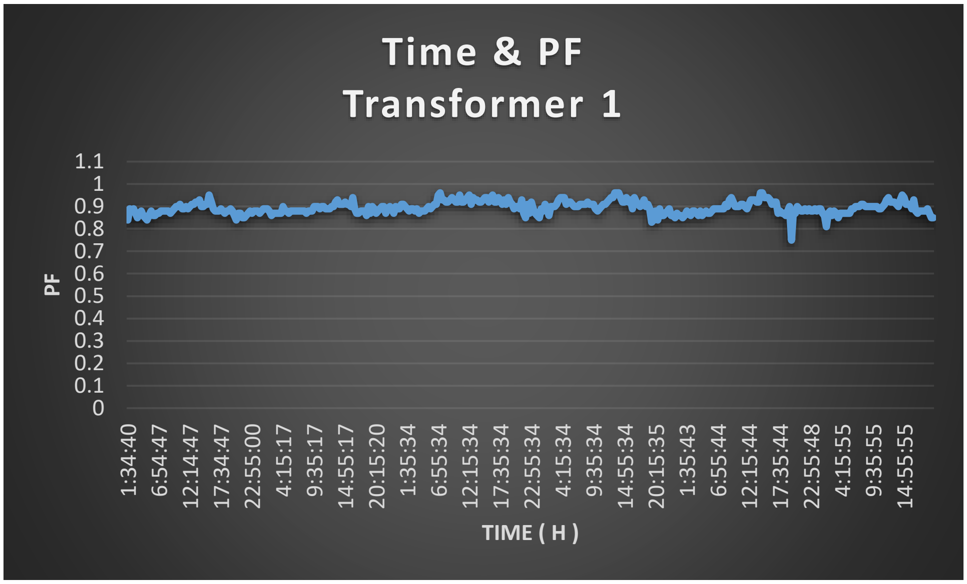


Figure 3.13: Relation between power factor & time in transformer 1

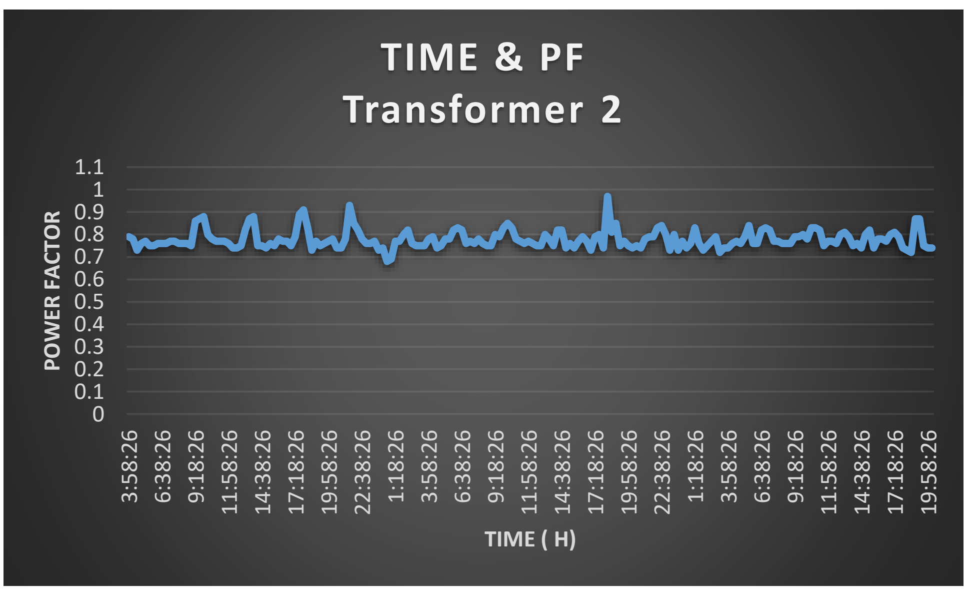


Figure 3.14 : Relation between power factor & time in transformer 2

The equation below can be used to calculate the power factor :

$$Qc = P\ [\tan \emptyset 1 - \tan \emptyset 2\ ] \qquad 3.1\ [35]$$

Where **:**

Qc is the reactive power of the capacitor in (KVAR)

P is the active power (kW)

Φ1 and **Φ2** the angles between voltage and current before and after power factor correction respectively.

A scientific research was conducted in Al Safa Dairy Factory on a mechanism to improve energy consumption in the factory, and among the solutions was to improve the power factor, as the value of the power factor in this plant was 0.77, and to improve the power factor, a fixed capacitor was added with a value of 40 KVAR and a variable capacitor with value of 25 KVAR, because this transformer is similar to that in reference [36].

By suggest to add two capacitors, the power factor will be improved to be higher than 0.92, thus reducing the value of the electric bill due to non-payment of fines.

According to that the ratio 1.25% of the total bill for every 0.01 of power factor less than 92% will be cancelled, because the power factor is corrected to be than 0.92.

3.4.2 Boiler system operation improvement :

The factory has two boilers: The first has a capacity of 3 tons / hour of steam, and the other is 2 tons / hour, they operate 3600 hours per year, and the steam is used in the process of cooking and pasteurization of meat,

In this system, diesel fuel is used, due to the low price of this fuel, but this type of fuel affects the increase in emissions from the exhaust (the environment), so a controller must be installed on it to regulate the ratio of the mixture (fuel and air)

Boiler efficiency can be improved by:

1- Increase the volume of the condensation tank, as the condensed water is used by returning it back to the boiler, thus no need to heat for a long time (short in operating hours).

2- Flushing every six months with an acidic substance, which in turn increases the efficiency of the boiler by 5%[37].

3- Utilizing the exhaust temperature by making a radiator to heat water and use this hot water in a washing process for the factory machines. The exhaust temperature can reach approximately 170-200 C°, and the factory consumes about 100 m^3 of water daily to clean the machines, this amount is heated to reach the temperature of 44 C° as shown in table 3.5. This is the value that water must be heated to be able to clean meat machines. Table 3.6 shows the measured operating data by combustion analyzer.

Despite the difference in capacity between the first and second boilers, the results will be close to each other, but the first boiler calculations have been made as an example. No data were taken for Boiler No. 2.

Table 3.5: The data measured from boiler number 1

Condensate water temperature	44 C°
Output pressure	6 Bar
Boiler room temperature (ambient temperature)	32 C°
Inlet air temperature	27 C°

Table 3.6 : Boiler measured data by combustion analyzer

Exhaust air temperature	198 C°
CO_2	10.3%
O_2	9 %
Excess air	42%
Chimney diameter	0.5 m
Gas velocity	3.8 m/s
Combustion efficiency	79.2 %

3.4.2.1 Boiler efficiency calculation:

The thermal efficiency of the boiler is evaluated as the actual percentage of heat produced by the fire process and used in the generation of steam.

There are two methods of evaluating boiler efficiency:

1- direct

2- indirect.

The direct method is the ratio between the heat gained from boiler water to generate steam (the actual energy utilized from it) to the total energy generated by the fuel combustion process.

The indirect method is to measure all types of wasted energy in the boiler (example: losses through the boiler body, losses to the atmosphere by the chimney, losses through blowdown water), then all losses are subtracted from 100%.

The direct method is the easiest and fastest in calculation, as it is calculated through the following equation:

$$\textbf{Boiler efficiency}\ (\boldsymbol{\eta}) = [\mathbf{Q\ x\ (hg - hf)\ /\ q\ x\ GCV}]\ \mathbf{x\ 100} \qquad \mathbf{3.1}\ [38]$$

Where **:**

Q is the quantity of steam generated per hour in (Kg/hr) .

q is the quantity of fuel used per hour in (Kg/hr) .

hg is the steam enthalpy in (kJ/kg).

hf is the inlet water enthalpy in (kJ/kg).

GCV is the type of fuel and gross calorific value of the fuel in (Kcal/kg of fuel)

As an exsample:

The boiler produces Steam flow rate = Water consumption = 410 Kg / hr

Steam pressure = 6 bar

Steam temperature = 316 ° C

Through the steam tables, knowing the pressure and temperature of the steam, it is possible to obtain the energy of that vapor to be 731 kcal / kg according to thermodynamic table A-6 in reference [39].

Boiler water temperature is 48 Celsius degree .

Through the steam tables, given the water temperature, it is possible to obtain the water energy to be 43 kcal / kg.

It important for us to get the amount of combustion fuel to be 34 Kg / hr.

The minimum calorific value of that diesel fuel is 10,939 kcal / kg.

The boiler efficiency is calculated by the following equation :

$$\textbf{Boiler efficiency } (\boldsymbol{\eta}) = [\mathbf{Q \ x \ (hg - hf) \ / \ q \ x \ GCV}] \ \mathbf{x \ 100}$$

Boiler efficiency $(\boldsymbol{\eta})$ = [410 x$(731 - 43)/10{,}939$ x 34] x 100 = 75.8 %

The results shown that the boiler efficiency is low and therefore it must be raised to 80-85%[40].

3.4.2.2 Mechanism for raising the boiler efficiency:

1- Combustion Air Pre-Heater:

The hot combustion air can increase the efficiency of the boiler by about 1% for every 4.44 Celsius in increase in temperature. The most common way to heat air is to use a heat exchanger on the flue exhaust. The heat exchanger can be either air to air or air to liquid to air[41].

2- Excess Air Control:

Excess air is required in the complete combustion process in all practical situations. The air volume is greatly increased to ensure maximum boiler efficiency and to minimize the heat loss in the gas flue. As this level varies according to the design of the furnace, fuel type, stove and practical variables. Table 3.7 shows the theoretical amount of air required to burn different fuels.

Table 3.7 : Theoretical amount of air required to burn different fuels [42]

THEORETICAL COMBUSTION DATA – COMMON BOILER FUELS					
Fuel	kg of air req./kg of fuel	kg of flue gas/kg of fuel	m3 of flue/kg of fuel	Theoretical CO2% in dry flue gas	CO2% in flue gas achieved in practice
Solid Fuels					
Bagasse	3.2	3.43	2.61	20.65	10-12
Coal	10.8	11.7	9.40	18.70	10-13
(bituminous)	8.4	9.10	6.97	19.40	9-13
Lignite	4.6	5.63	4.58	19.8	14-15
Paddy Husk	5.8	6.4	4.79	20.3	11-13
Liquid Fuels					
Furnace Oil	13.90	14.30	11.50	15	9-14
LSHS	14.04	14.63	10.79	15.5	9-14

Through Table 3.7. The theoretical air volume required to burn diesel fuel in this boiler is 13.90 kg of air req./kg of fuel, but the excess air for the same fuel used in boiler can be rated between 15-20 %. Controlling excess air to an optimum level always results in reduction in flue gas losses; for every 1% reduction in excess air there is approximately 0.6% rise in efficiency[42].

In the Islamic factory the fuel consumption per hour is 36 liter/hour which is equal to 126720 liter/year for the boiler operating 10 hour daily. From equation(3.2) the fuel saving can be calculated by:

$$\text{Fuel saving} = U \times [1 - (\eta\ \text{before} / \eta\ \text{after})] \qquad 3.2\ [35]$$

Where:

U: annual fuel usage by boiler, liters/yr.

η before: combustion efficiency before improvement.

η after: combustion efficiency after improvement.

By substitution in the equation above

$$\text{Fuel saving} = 126720 \times [1 - (79.2/79.7)]$$

Fuel saving = 794.9 liters /year

3- Power flushing boiler:

One of the best ways to increase the efficiency of the boiler is the flushing process, where water is treated chemically, as the boiler efficiency increases by 5% after this process[43] .

Without water treatment, the system will be affected by oxides and lime scale causing further losses in efficiency. There is a study showing that the boiler will reduce its efficiency after use for only 3 weeks. This, in turn, increases fuel consumption and a longer heating period.

3.4.3 Improvement of the operating condition of the compressed air system:

The factory has two compressors, one main and the other is back-up compressor, both have an air dryer and air receiver.

Table 3.8 shows the specifications of the main and secondary compressors used in the factory.

Table 3.8 : Islamic company compressors data

	compressor #1	compressor #2
Comp. type	Rotary screw	Rotary screw
Manufacturer	Ozen OSC 60 B	Ozen OSC 60 D
Revolution (rpm)	2900	2940
Working pressure (bar)	8	10
Rated power (kw)	45	45
Capacity (L/min)	7600	7100

3.4.3.1 Calculation data for the compressor :

1- Measurement of free air delivery (FAD):

The compressor capacity is the full volume of compressed air or gas flow and delivery under the conditions of temperature and pressure in addition to the installations at the inlet of the compressor, which means the actual flow rate and this is called the FAD

FAD can be calculated according by equation (3.3):

$$Q = FAD\left(\frac{m^3}{min}\right) = (P2 - P1) x V / (Pa x t) \qquad 3.3 [29]$$

Where**:**

P2 = Final pressure after filling (kg/cm²).

P1 = Initial absolute pressure (kg/cm²) after bleeding.

Pa = Atmospheric pressure (1.033 kg/cm²).

V = Storage volume in m³, which includes the air receiver and delivery piping.

t = Time needed to achieve pressure to P2, in minutes.

According to this equation the FAD for main compressor can be calculated:

Initial pressure P1 = 0.5 kg/cm².

Final pressure P2 = 8.2 kg/cm².

Atmospheric pressure P0 = 1.033 kg/cm².abs

Total volume = 1 m³

Pump-up time = 2 min;

$$\text{FAD}\left(\frac{\text{m}^3}{\text{min}}\right) = (\text{P2} - \text{P1})\text{x V} / (\text{ Pa x t})$$

The FAD = 3.7 m^3/min = 3700 Liter / min

From table 3.8 the rated FAD for the compressor #1 equal 7600 liter/min but the calculated FAD for this compressor is 3700 liter/min

So, the specific power consumption (SPC) can be calculated according to reference in equation 3.4 during loaded compressor :

$$\text{SPC} = \text{Actual Power consumption, (kw)/FAD, (m3/min)} \qquad 3.4\ [30]$$

Actual power consumption during loading = 25 kw

SPC for calculated FAD = 25/3.7 = 6.75 kw/ m^3/min

SPC for rated FAD = 25 /7.6 = 3.23 kw/ m^3/min

As a result, we can conclude that the compressor was not working efficiently during loading.

3.4.3.2 Compressed air leakage test:

The leakage test can be calculated using the following steps:

1- the compressor is turned on, although air valve is closed.

2- using timer to find how long it is unloaded or stopped (for better result from 4-5 cycles, the compressor should start work)

3- calculating the amount of leak using following formula

$$\% \boldsymbol{leakage} = \boldsymbol{load\ sec} / (\boldsymbol{load}\ \mathbf{sec} + \boldsymbol{unload\ sec}) \qquad 4.4\ [44]$$

For one cycle :

Load test time = 8 sec

Unload test time = 20 sec

Stop time = 0

W loaded = 17 kw

W unloaded = 3.1 kw

Substituting the upper values in equation 4.4 we get **:**

$$\% \, leakage = 8/(8 + 20 + 0)$$

% leakage = 28.5 %

So the wasted power can be calculated by equation 4.5:

$$\boldsymbol{wasted\ power} \ (\boldsymbol{kw}) = (\mathbf{W\ loaded} - \mathbf{W\ unloaded}) * \% \ \mathbf{leakage} \qquad 4.5\ [45]$$

By substitute data from which we get:

$$wasted\ power \ (kw) = (17 - 3.1) * 0.285$$

Wasted power (kw) = 3.96 kw per hour

3.4.3.3 Mechanism to improve compressor efficiency

This can be done by control the temperature of air entering the compressor:

The inlet temperature of the compressor affects the density of air at the inlet of the compressor, and it affect the kinetic energy transferred by the blades to air. Thus, the increased density leads to an increase in the free air delivery as well as an increase in the energy consumption of the compressor.

The average air temperature entering the compressor in the factory was measured and found 34 ° C and the average outdoor air temperature 23 ° C. Thus, energy can be saved if the inlet air temperature is reduced to 23 ° C by installing an external air cooler that can be connected to the external environment of the factory and not from inside the factory.

A study was done in Al – Arz Ice Cream Factory and Almost has the same conditions in Islamic company where its find that decreasing the temperature will reduce power requirement about 3.8 power reduction per hour [36] .

3.4.4 Improving the lighting system and other services :

One method used to reduce energy consumption in the factory is improving the lighting system. Table 3.9 shows the classification of lighting and services in the factory.

Table 3.9 : The available services in the factory and the alternative suggestion

Available services						Alternative suggestions				Saving	
Service type	Rating W	# of unit	Annual operating hour	kw	KWh	Replacing service	Rating w	KW	KWh	kw	KWh
LG 1.5 Ton LSA5VF2D1 2 Star Split Ac	1565	7	3600	10.9	39240	SAMSUNG AR18JV5D AWK 1.5 TON INVERTER SPLIT AC SPECIFICATIONS	900	6.3	22680	4.6	16560
Compact fluorescent	25	180	4500	4.5	20250	LED light bulb	12	2.16	9720	2.34	10530
Industrial light type (Hubbell Lighting)	400	48	4500	19.2	86400	150W UFO LED	150	7.2	32400	12	54000
Total				34.6	145890		1062	15.66	64800	18.94	81090

The total energy consumption by available services and lighting is 86400 KWh , while the total energy consumption for alternative suggestion from services and lighting is decreased to 32400 , so the bill will be reduced .

3.4.5 Summary of results:

According to the bills for Islamic company in the years 2016, 2017, 2018. The total energy consumption was 2065000 KWh for 2016, 2355170 KWh for 2017 and 2648747 KWh for 2018 .

To reduce the energy consumption, there are many mechanisms to be used with the results depicted below:

1- **Power factor correction:**

In order to increase the power factor , two capacitors loaded to electric panel , the result was reducing the value of total bills , because the power factor raise to 0.92 . The approximated electric consumption was 2,544,780 KWh, and increasing the power factor will reduce the electric consumption for 1.25 % of the fine.

2544780 KWh * 1.25% = 31,809.75 KWh

By multiplying with KWh price the saving money is:

31,809.75 * 0.642 NIS = 20421 NIS per year.

2- Increasing boiler efficiency;

The Islamic factory use two boiler with different capacity and after calculation , the boiler efficiency was 75.8 %, but to increase the efficiency many methods used:

- Combustion Air Pre-Heater **:** the efficiency of the boiler by about 1% for every 4.44 ° C in increasing the temperature
- Excess Air Control **:** for every 1% reduction in excess air there is approximately 0.6% rise in efficiency .
- Power flushing boiler**:** The boiler efficiency increases by 5% after this process

3- Improving the operating conditions of the compressed air system:

There are two compressors in the factory , one is main , and the other spare. The calculations for compressor detect that the main compressor has a calculated free air delivered 3700 liter/min, and the rated FAD was 7600 liter/min, which means there's a leakage in the system.

The calculated leakage was 28.5 %, so the wasted power was 3.96 KWh.

To improve the compressor operation and to decrease the wasted power, the following method will be done:

Control the temperature of the air entering the compressor by decreasing the temperature will reduce power requirement about 3.8 power reduction per hour**.**

4- Improving the lighting system and other services:

The process of reducing energy consumption takes place through counting the services in the factory and calculating the amount of energy consumption for each part of it, and then finding the least consuming alternative for electric energy. Where the counting process took place, and the results were as follows:

- Reducing energy consumption by alternative air conditioners by 16560 KWh
- Reducing energy consumption through the use of LED lighting systems by 10530 kilowatt hours
- Reducing energy consumption through the use of LED headlamps by 54,000 KWh

So the total energy saving is 81090 KWh.

Chapter four

Conclusion and Recommendation

4.1 Conclusion

The lack of energy sources in Palestine, in comparison with other countries, it has led to its complete dependence on the energy sources available from the Israeli occupation.

The increase in energy demand, especially electricity, coincides with the increase in the number of industrial facilities, and this is what happening in Palestine. Therefore, it is imperative to find an alternative sources that can be relied upon to supply these facilities and sectors with electricity.

The rationalization of electricity consumption comes through following a rationalization plan that is used in factories and various sectors. Therefore, it is imperative to educate the manpower and the administrative system in the facility about the mechanism for rationalizing energy consumption.

Many people are conserving and setting up methods for reducing electricity consumption. Examples include the use of solar energy to heat water. Thus cutting out electrical energy in the heating process. This method created an opportunity to develop this trend and make it more efficient and sustainable.

The methods discussed in this thesis, despite their smallness, had a clear impact on rationalizing energy consumption. By developing a set of alternative proposals.

These proposals can reduce the financial burden of plant energy bills. It is necessary to look at the environmental aspect, as there will be a massive reduction in the amount of greenhouse gas emissions that negatively affect the environment.

These proposals can be applied in most industrial establishments, and thus the effect is clear on the amount of rationalization of electric energy consumption

Increase awareness and knowledge towards efficient and rational use of energy in the plant. It is done through the work of guidance lessons for workers and employees in the factory. Whereas, there can be production with the same efficiency and lowest costs by rationalizing electricity consumption in the methods discussed.

Therefore, every industrial facility must work to assign an electrical engineer to study the amount of electricity consumption in the plant and the mechanism of reducing the cost.

The process of saving electrical energy is not just about the factory. There will even be a reduction in energy consumption throughout the region. And considering that the city of Tulkarm suffers from a great scarcity of electrical energy, the electrical energy will reach the electrical grid in the city.

4.2 Recommendations

In order to obtain better results in the process of reducing electricity consumption, there are several recommendations that any sector can follow, including:

1. Supporting the energy sector in Palestine by finding financial institutions to support people who have the potential in the process of producing electric energy
2. Work on training employees and workers in institutions on the mechanism of energy conservation in the facility
3. Supporting research and studies concerned with finding alternative solutions for energy systems at the lowest cost and with the same productivity
4. Using the sun's rays in the process of lighting for factories or homes as much as possible.
5. The introduction of modern control systems in lighting systems through the installation of optical sensors that act on the movement or make timing for specific lighting. Thus reducing the working hours of lighting.
6. Work on arranging and scheduling the production lines program so that the electrical loads are distributed and thus control the value of the power factor
7. Utilizing solar energy in the process of producing electricity by placing a group of solar panels over the facility, thus reducing the consumption of electrical energy supplied through the municipality
8. Utilization of the exhaust energy that results from the combustion process during the operation of the boiler in the process of heating water for use in other purposes such as washing the factory machinery.
9. The possibility of producing electricity by exploiting the exhaust energy by installing electrical thermal systems called TIG. They are installed on the exhaust system to produce electrical energy.
10. Issuing legislations and laws that help in the process of producing electrical energy using renewable energy systems and facilitate these laws for people working in this field. and making strict laws and legislations against people in violation (through the theft of electricity) .

11. Obtaining a better understanding of energy consumption and emissions of gases from industries in Tulkarm, by building a comprehensive action plan on the power analysis of the industrial sector .
12. Raising the level of awareness among employers, by making any change that enables them to promote it to reduce energy consumption or by promoting products and services that will help their customers to reduce energy consumption
13. Raise the level of awareness among the business sector about the importance of using renewable energy (solar, wind ...) in producing electricity, instead of relying on fuel to produce energy .

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