**An-Najah National University**
**Faculty of Graduate Studies**

# ENERGY EFFICIENCY IMPROVEMENT AND COST SAVING MEASURES IN SOME DIFFERENT INDUSTRIES IN PALESTINE

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**Dedicated to**

**My parents and family**

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Finally, I dedicate this thesis to my family, more specially my wife and kids for the marvelous support and encouragement they gave me during my preparation of this thesis.

All my friends and fellow graduate students, thank you.

## Abbreviations

| | |
|---|---|
| APR | Annual Percentage Rate |
| Bcf | Billion cubic feet |
| BG | British Gas |
| CDM | Clean Development Mechanism |
| CFL | Compact Fluorescent Lamp |
| EC | Energy Conservation |
| ECO | Energy Conservation Opportunity |
| EEO | Energy Efficiency Opportunity |
| EPC | Energy Performance Contract |
| ESCO | Energy Service Company |
| FAD | Free Air Delivery |
| GCV | Gas Calorific Value |
| GDP | Gross Domestic Product |
| GFCF | Gross Fixed Capital Formation |
| GHG | Greenhouse Gases |
| GS | Gaza Strip |
| HID | High-Intensity Discharge |
| FHV | Fuel Heating Value |
| IEC | Israeli Electric Corporation |
| ISIC | International Standard Industrial Classification |
| IRR | Internal Rate of Return |
| JD | Jordanian Dinar |
| JDECO | Jerusalem Distribution Electric Company |
| KV | Kilovolt |
| KVA | Kilovolt Ampere |
| KWh | Kilowatt hour |
| LPG | Liquefied Petroleum Gas |
| MARR | Minimum Attractive Rate of Return |
| Mtep | 1000 tonne oil equivalent |
| MVA | Megavolt Ampere |
| NPV | Net Present Value |
| O&M | Operation and Maintenance |
| PA | Palestinian Authority |
| PCBS | Palestinian Central Bureau of Statistics |
| PEA | Palestinian Energy Authority |
| PNA | Palestinian National Authority |
| PT | Palestinian Territories |
| SELCO | Southern Electric Company |
| SPBP | Simple Pay Back Period |
| SWH | Solar Water Heater |

| | |
|---|---|
| Tcf | Trillion cubic feet |
| Tep | Tonne of equivalent petrol = Toe (Tonne of oil equivalent) |
| TJ | Terra Joule |
| TPF | Third Party Financing |
| WB | West Bank |

## Values used

**Cost of one kWh = 0.12 JD**

**Cost of one liter of diesel #2 =0.75 JD**

**Cost of one liter of oil #6 = 0.46 JD**

**GCV for oil #2 = 42000 KJ/kg**

**GCV for oil #6 = 40000 KJ/kg**

# إقـــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

**تحسين كفاءة الطاقة ووسائل تقليل التكلفه لبعض الصناعات المختلفه في فلسطين**

**ENERGY EFFICIENCY IMPROVEMENT AND COST SAVING MEASURES IN SOME DIFFERENT INDUSTRIES IN PALESTINE**

اقر بأن ما اشتملت عليه هذه الرسالة إنما هي نتاج جهدي الخاص، باستثناء مـــا تمـــت الإشارة إليه حيثما ورد، وان هذه الرسالة ككل، أو أي جزء منها لم يقدم من قبل لنيل أية درجة علمية أو بحث علمي أو بحثي لدى أية مؤسسة تعليمية أو بحثية أخرى.

# Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

**Student's name:** **اسم الطالب:**

**Signuter:** **التوقيع:**

**Date:** **التاريخ:**

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**ENERGY EFFICIENCY IMPROVEMENT AND COST SAVING MEASURES IN SOME DIFFERENT INDUSTRIES IN PALESTINE**

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## Abstract

In the thirty-three years since the first oil crises in 1973, there have been a number of studies of industrial energy use and the potential for energy conservation in industry of developed countries which have resulted in significant improvement in the efficient use of energy.

The developing countries are still in the process of gaining momentum in this field and are learning from the experiences of the industrialized nations.

The energy situation in Palestine, the efficient use of energy and energy conservation in industry is not in a better condition than most developing countries. In this thesis we tried to establish a start or a beginning step toward the efficient use of energy and energy conservation in industry through conducting energy analysis of industrial consumption in Palestine and through conducting energy audits in some industries in Palestine (Al Safa Dairy Factory, Al Carton Factory, Al Arz Ice –Cream Factory and Al Aqqad Textile Factory) which they considered high energy consumers and allocate the potential for energy savings opportunities.

This research aims to investigate the potential of energy conservation opportunities in some Palestinian industrial facilities. The main objective of

the investigation is to identify the most energy intensive areas of the industries and suggest measures which can be implemented to conserve energy or reduce energy consumption.

It was showed that there is a decent potential for energy savings in the audited industrial facilities. The savings in electric energy was around 277,800 kWh per year and the fuel savings around 66,000 liters per year. On the national level (10 to 20%) savings from the total energy consumption in the industrial sector could be achieved by implementing some energy conservation measures (no and low cost investment) on the most energy consumption equipment in the facility such as boilers, compressors, lighting system and low power factor. Besides decreasing the demand on energy that enhancing the national economy, there is a huge reduction in the environmental emissions such as $CO_2$ (175 tons reduction).

## INTRODUCTION

Energy remains crucial to economic development in any civilized nation and it should be viewed as any other valuable raw material resource required running a business. Energy has costs and environmental impacts. They need to be managed well in order to increase the business' profitability and competitiveness and to mitigate the seriousness of these impacts.

Palestine is one of those nations that are of a great need to all types of energy. The time comes where we don't have to explain any more the need for energy. Most of Palestinian people have access to electricity, whether by general electricity network or by small community diesel generators.

The trickery range to the energy policy makers to improve the energy sector in Palestine within the current complex political and security situation is very limited; Palestine has to import all types of energy from Israelis with high prices and tariff. They also control the quantity and condition of energy, saying nothing that about the arbitrary measures such as continuous threatening to stop pumping fossil fuels and cutting electricity.

The outbreak of Al-Aqsa Intifada in September 2000 froze and terminated all energy planes with Israeli sides and Arab neighboring countries.

The direction towards getting use from renewable energy sources such as solar and photovoltaic energy from sun was a competitive and good option to Palestinians; especially Palestine has been gifted with huge solar radiation. This type of renewable energy was excellently utilized in water heating, but without clear feasibility to use it in utilizing electricity because of the high cost of photovoltaic system per watt.

The proceeding to ward reducing energy consumption in all energy consuming sectors is considered one of the most imperative, factual, quick and feasible measure to bring down and reduce the problem of energy and reduction in environmental emissions in Palestine.

Being the industrial sector is one of the main energy consuming sectors in Palestine that suffers from incredible energy consumption and bad management, this study specialized in energy efficiency improvement and cost saving measures in different industries in Palestine

Energy demands in Palestinian industries account for approximately 6 to 7 % of the national energy demand [1]. Individual industries and businesses have different demands, which are met from various combinations of on-site heat and power generation from delivered fuels, electricity and gas consumption from mains supplies. Fuel and energy consumption rates and energy processes depend on the type of product produced.

This thesis subject comes to highlight the importance and the need for the energy conservation measures in the Palestinian industrial sectors through implementing energy conservation opportunities at different high energy consumed equipment such as boiler, compressed air, lighting and power factor improvement in order to reduce energy consumption as a result of saving money that could be used to expand the investment and in the meanwhile reduce environmental emissions.

The main idea of this work is to examine the energy efficiency opportunities available in the industrial sector in Palestine based on energy audits that will be provided.

The following are the research objectives:

1. To determine the potential of energy consumption in the Palestinian industrial sector
2. To determine the potential of energy savings in different energy consumed equipment through energy audits in four different industries.
3. Data analysis and determination of energy conservation opportunities in the most energy consumption equipments.
4. Establishing economic evaluation and analysis for those energy conservation opportunities.
5. Study and analyze the restricting barriers for the implementation of energy conservation measures in Palestine.

Projects involving adoption energy conservation measures in the industrial sector satisfy general sustainable development goals and energy priorities of the Palestinian National Authority (PNA) which aims at:

1. Energy efficiency improvements,
2. Quality of electricity supply,
3. Reduce imports of electricity and oil,
4. Transfer of clean and efficient technology
5. Reduce the environmental emissions

To assess this contribution to sustainable development, the following positive impacts were identified as below:

- Energy Sector Impacts: On long-term strategy, energy conservation measures by either adoption of efficient industrial technologies, efficient use of energy or utilization of the renewable energy resources will lead to a large saving in conventional energy. This gives opportunity to the un-served communities to have access to electricity as well as better services to served communities. Furthermore, it will lead to reduction of the greenhouse gases emissions.

- Technological Impacts**:** energy efficient and environment friendly technology is a fast developing market, and can allow the transfer of state of the art environmentally sound technology. It can have positive impact on dissemination of technology, especially under the absence of energy labels and lack of awareness.

- Social and Economic Impacts: If research recommendations adopt at national level, this will lead to annual saving to the national economy by reduction in the energy bill of about 10 - 20 % which consequently enhance the standard of living of people through reduction of the production cost.

# CHAPTER ONE

## ANALYSIS OF ENERGY SOURCES IN INDUSTRIAL SECTOR IN PALESTINE

## 1.1 Energy Sources in Palestine

In general, Palestine is considered as one of the poorest countries in terms of energy sources. Energy resources are either dwindling or non-existent.

Indigenous energy resources are quite limited to solar energy for photovoltaic and thermal applications (mainly for water heating), and biomass (wood and agricultural waste) for cooking and heating in rural areas. Potential of wind energy is relatively small but not yet utilized in Palestine. Biogas also not yet utilized

From the perspective of its energy sector, Palestine is an unusual position in at least three respects.

- Firstly, as a small energy market with no developed domestic resources of commercial energy, it is almost entirely dependent on imported energy supplies, specifically electricity and oil products. Palestine imports 100% of its needs of petroleum products and 95% of electricity from Israeli market due to the absence of fossil fuel resources [2].
- A second unusual challenge faced by Palestine is its fragmentation into two distinct geographical zones with divergent economic characteristics, the West Bank and Gaza Strip.
- A third unusual challenge is the constraints imposed by Israeli policies and actions on the ability of the Palestinian Authority (PA) to operate and develop its energy systems.

Natural gas has been discovered lately by British Gas Company (BG) in December 2000 at Gaza shore. BG has signed a 25-year contract to explore for gas and to set up a gas network in the Palestinian Authority [3].

The gas reserves are estimated to be around 1.4 TcF, [4], while the needs for gas by the Gaza power station and other industrial, transport and household consumption was estimated at nearly 14.8 BcF by year [5]. Palestine possesses limited natural resources (minerals and some marine products).

The national independent power system is still under construction and rehabilitation. The Palestinian Energy Authority conducted the construction of an electricity station in Gaza with a generation capacity of 140MW at the first phase. This station is now partially operational producing one third of its full capacity, which is 40 MW. The main source of fuel for this station was supposed to be natural gas, but due to political obstacles which caused the halting of the project for production of natural gas from Gaza sea, the station uses diesel for energy, thus there is no production of natural energy products in Palestine as mentioned above, which results of full dependence on Israel in the import of all energy products.

About 95% of electric power consumed in W.B and G.S is imported from Israel power plants via 22 kV and 33 kV feeders and through three substations of 161 kV/ 33 kV in W.B, while the remaining is generated by decentralized small diesel generators.

However, some 79 localities in the West Bank are not connected to a public electricity network, including 38 in the Hebron district. Of the 531 WBGS localities with connections, 165 received their electricity from the Jerusalem District Electricity Co., 215 from the Israeli Electricity Co., 22 from private generators, 68 from community councils and 61 from other sources [6].

## 1.2 Energy Consumption in Palestine

While energy production and trade is considered as one aspect of the "energy tragedy" in the PT, energy consumption is the other. Total energy consumption (Primary energy supply) did not exceed 944 Mtep in 2000, while this figure was 22,999 Mtep for Israel (nearly 22 times as much). On the other hand, energy consumption for Jordan (with nearly 5 million habitants) was 4,455 Mtep (4 times superior), while for Lebanon (with 4.3 million habitants) this figure was 5,469 (5 times that of west Bank and gaza Strip WBGS) (Fig 1.1)[7,8].

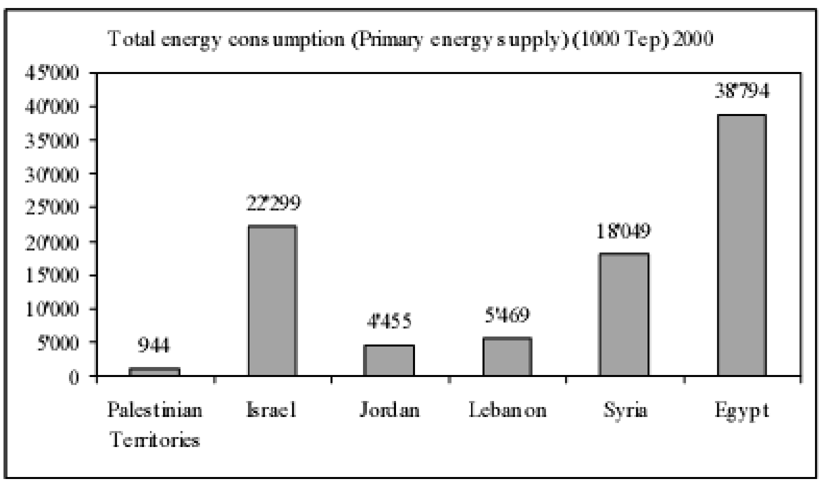


**Figure 1.1**: Total energy consumption (Primary energy supply), 1000 Toe in 2000.

A more comparable indicator, the energy consumption per capita, clearly showed (without confusion) the gravity of the energy problem for the Palestinians. Energy consumption per capita for the Palestinian Territories in 2000 did not exceed 0.3 Toe, which is the lowest in the region. Israel's per capita energy consumption (3.5 Toe) was 10 times greater than the Palestinian consumption level, while that of Jordan and Syria was 3 times superior (0.9 and 1.1 Toe). The American consumption per capita, with 9.7 Toe, is 32 times higher than the Palestinian level (Fig 1.2)[9].

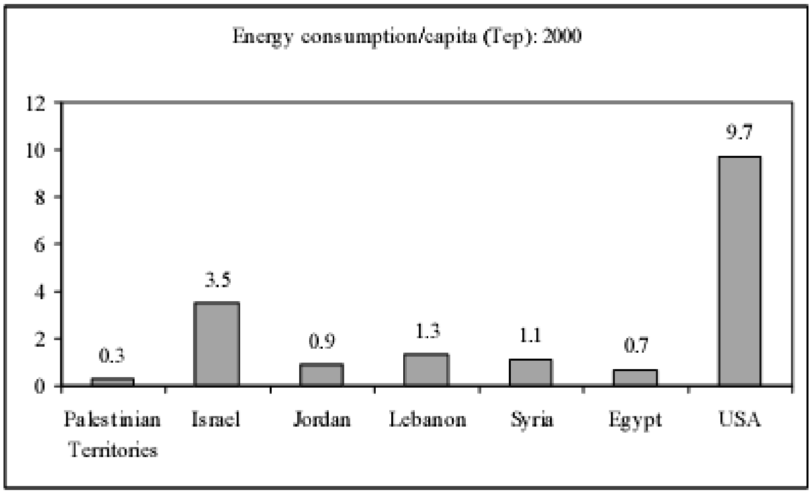


**Figure 1.2**: Energy consumption per capita (Toe) in 2000.

Table 1.1 summarizes the most recent comprehensive energy balance of energy supply and demand for Palestine. It shows that final energy consumption increased by 2% from 2001 to 2002, and by 9% from 2002 to 2003, despite the difficult economic conditions during this period.

**Table 1.1**: Summary of Energy Balance of Palestine 2001, 2002, and 2003 in (TJ) [1].

| Year | 2001 | 2002 | 2003 |
|---|---|---|---|
| Total Energy Requirements[1] | 32,873 | 33,534 | 36,559 |
| Primary production | 6,189 | 8,775 | 10,126 |
| Imports | 26,646 | 24,773 | 26,389 |
| Energy Conversion[2] | -3,111 | -3,835 | -6,486 |
| Final Energy Consumption[3] | 26,853 | 31,052 | 36,365 |
| Industry and construction | 2,138 | 2,043 | 2,266 |
| Transport | 5,414 | 5,969 | 6,914 |
| Household and other sectors | 19,301 | 23,040 | 27,185 |

Notes: (1) Includes exports and stock changes. (2) Includes electricity generation and losses in transport and distribution. (3) Statistical differences account for the difference in data between (Total Energy Requirements less Energy Conversion) and Final Energy Consumption.

The growth in final energy consumption can be partly explained by the fact that energy consumption by the household and other services sectors accounts for about 75% of the total as illustrated in Table 1.2.

This is because energy consumption by these sectors is less responsive than in other sectors to adverse changes in economic conditions. Consumption can be sustained by substantial remittances from abroad that support household incomes and by an increase in non-payments for the supply of commercial energy.

**Table 1.2**: Sectoral composition of final energy consumption.

| **Year** | **2001** | **2002** | **2003** |
|---|---|---|---|
| Industry and construction | 8% | 7% | 6% |
| Transport | 20% | 19% | 19% |
| Household and other sectors | 72% | 74% | 75% |

* Reference: Table 1.1

The breakdown of total final consumption of energy in 2003 is shown in Figure 1.3.

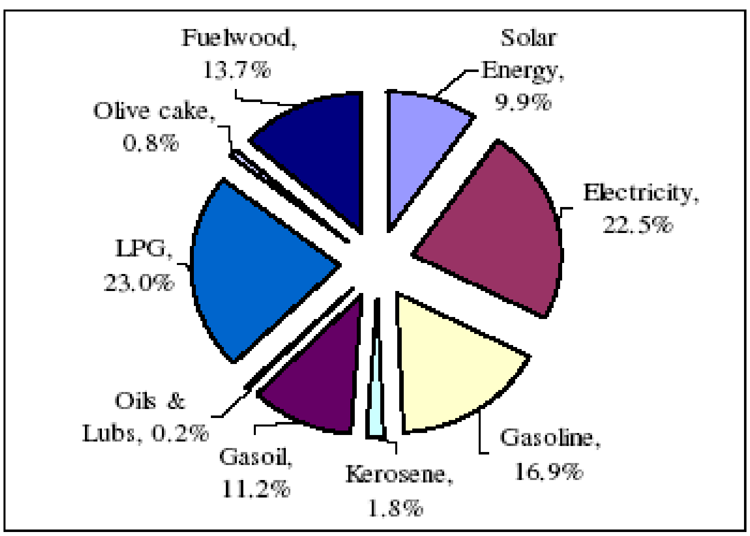


**Figure 1.3**: Breakdown of final consumption of energy in 2003 by source of energy [1].

The dominance of the household and other service sectors in energy consumption means that they accounted for nearly all consumption of solar energy, LPG, olive cake and fuelwood, for about 90% of electricity and kerosene consumption, and for about half of the total consumption of diesel, oils and lubricants in 2003.

LPG accounted for the largest proportion of energy consumption by the household and other services sectors in 2003 (29.5%), followed by electricity (26.6%), fuel wood (17.8%), solar energy (12.8%) and gas oil (9.2%). LPG is the main cooking fuel, but is also used for heating and lighting if electricity is not available. Solar energy is used for water heating [1].

Electricity is used for lighting, refrigeration, entertainment and communications, and fuelwood is used for cooking by households that cannot afford to purchase LPG or when LPG is unavailable.

Imports of petroleum products to West Bank and Gaza have been highly correlated with GDP (see Figure 1.4). Imports of petroleum products declined by between 40% and 50% from the onset of the intifada in 2000 to 2002, and then increased from 2003 onwards.

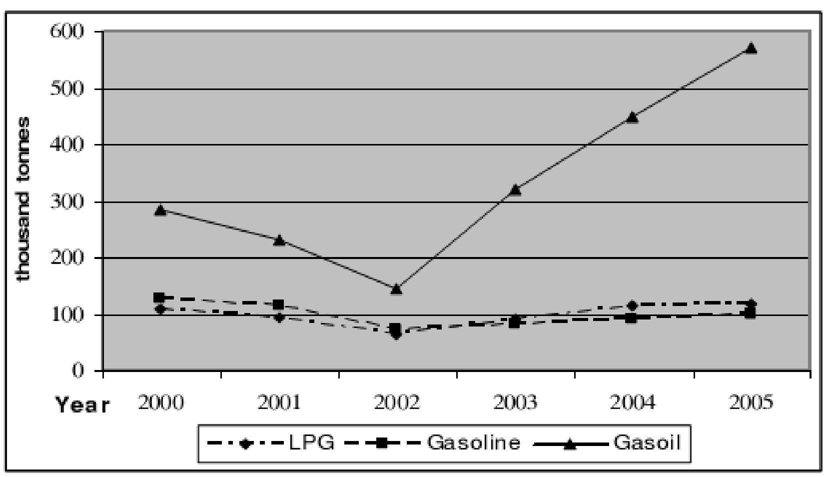


**Figure 1.4**: Trends in imports of petroleum products to West Bank and Gaza Strip 2000 – 2005[10].

The West Bank depends almost entirely on Israeli Electric Company (IEC) for electricity supply. West Bank consumption of electricity – as measured by purchases of bulk power from IEC - increased at an average annual rate of 6.4% between 1999 and 2005, as shown in Figure 1.5.

The pronounced dip in this growth that occurred in 2001 and 2002 is evident due to the eruption of the Intifada, amounting to almost 9% of purchases in 2002.

The maximum capacity of electricity supply to the West Bank is about 550MVA, 30% directly by the Israeli Electric Company (IEC) which supplies electricity in bulk to 215 towns and villages, and 70% indirectly by IEC through Jerusalem distribution electric company (JDECO) which supplies electricity to East Jerusalem and in bulk to 165 towns and villages in the West Bank.

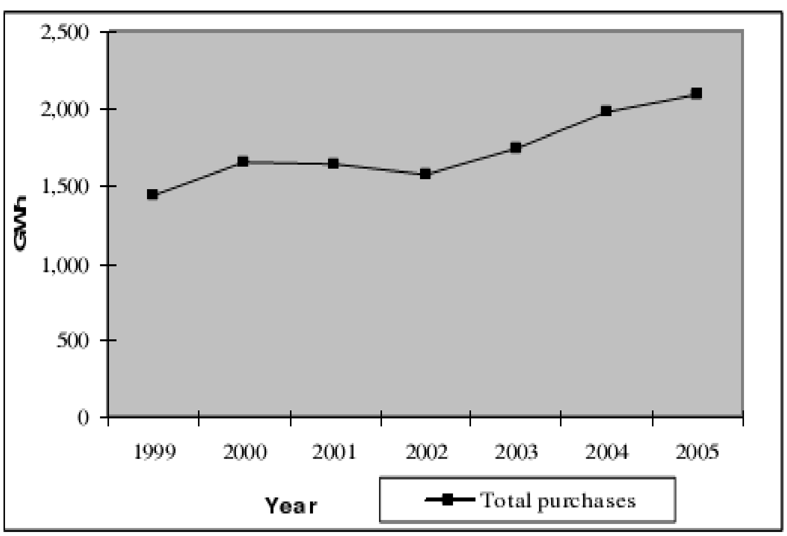


**Figure 1.5**: Power purchased by West Bank utilities 1999-2005[11].

Table 1.3 summarizes the imported energy for the year 2002 for the West Bank and Gaza Strip which accounted to 25,663 TJ of energy, including 2,306,962 MWh of electricity, 104 million litres of gasoline, 207 million litres of diesel, 4 million litres of kerosene and 21 metric tons of oils and lubricants.

**Table 1.3**: Imported energy in the Remaining WB and GS by energy type and region: 2002 [12].

| **Region** | **Energy type** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Electricity (MWh) | Gasoline (1000lt) | Diesel (1000lt) | Kerosene (1000lt) | LPG (Ton) | Oils &Lubricants (Ton) | Wood & Coal (Ton) | Total Energy (TJ) |
| **Palestinian Territories** | **2,306,962** | **103,886** | **207,078** | **4,301** | **95,336** | **21,128** | **3,709** | **25,663** |
| North of West Bank | 403,164 | 21,902 | 38,541 | 1,390 | 27,105 | 2,163 | 891 | **5,100** |
| Middle of West bank | 722,412 | 33,617 | 33,242 | 898 | 9,919 | 2,527 | 125 | **5,844** |
| South of West Bank | 452,668 | 19,747 | 34,529 | 997 | 23,304 | 14,417 | 2,405 | **5,453** |
| Gaza Strip | 728,718 | 28,620 | 100,766 | 1,016 | 35,008 | 2,021 | 288 | **9,266** |

*Remaining West Bank: includes all of the West Bank except for those parts of Jerusalem which were annexed following the 1967 Israeli occupation.

In general the West Bank and Gaza energy sector has a few salient characteristics:

- Total energy consumption in West Bank and Gaza is small by regional standards, let alone international standards, which limits the scope for achieving economies of scale.

- West Bank and Gaza Strip have different energy supply options.

- Most energy demand (75%) is accounted for by the service and household sectors, since there is relatively little activity in manufacturing.

- Nearly all energy is provided by electricity and petroleum products, most of which has been purchased from Israel (some diversification is beginning to develop).

- In general, energy is lightly subsidized in comparison with most countries in the region, and energy prices reflect opportunity costs reasonably well.

- The only substantial domestic energy resource is the Gaza Marine gas field discovered offshore Gaza, which awaits development.

- The most critical institutional constraints arise in the electricity sector, where the development of the distribution companies in West Bank and Gaza is still work-in progress.

- The electricity system in the West Bank consists of numerous isolated distribution systems that are not integrated into a distribution network, and it has no generation capacity or transmission network.

- There is no storage capacity for petroleum products in the West Bank and Gaza (plans for building some storage facilities are under preparation).

## 1.3 Energy Problems

One of the major problems in energy sector is the shortage in supply of conventional energy particularly electricity and petroleum products that are monopolized by the Israeli authority and the lack of a Palestinian infrastructure for close to three decades has impeded any realistic progress on the energy front and created chronic energy problems. The major energy problems could be summarized in:

- Energy resources are either dwindling or non-existent, which makes the supply of conventional energy (electricity and petroleum products) is monopolized by the Israeli authority due to the political situation existed.

- Energy prices are considered one of the main problems for the Palestinian energy sector. Energy prices in Palestine are very high compared to international prices. Table 1.4 shows the prices of different energy sources in the PT.

**Table 1.4**: Consumer energy prices in Palestine 2004 - 2007 [13].

| | |
|---|---|
| Price of Electricity (JD/kWh) | 0.09 – 0.13 |
| Price of Gasoline (JD/liter) | 0.95 |
| Price of Diesel (JD/liter) | 0.75 |
| Residual fuel oil #6 (JD/liter) | 0.46 |
| Price of Kerosene (JD/liter) | 0.75 |
| Price of firewood (JD/ton) | 85 |

- High transmission losses which constitute fundamental problems for the electricity sector.

It is considered the highest compared with other countries in the region. Although the electricity supply is assured by the IEC, which uses the electric transmission and distribution network, no efforts were made to rehabilitate this network. While the electricity transmission loss in the Palestinian Territories was 25% in 2002 of the total energy injected, it was no more than 3% in Israel. Some villages still suffer from either lack of electricity or insufficient services living mostly in rural areas.

Table 1.5 shows the percentage distribution of households by connection to electricity network..

**Table 1.5**: Percent distribution of households in Palestine by connection to Electricity Public Network, by Region and type of Locality ,2004 -2005 [14]

| Region and Type of Locality | Connection to Electrical Public Network | | |
|---|---|---|---|
| | Public Network | Private generator | No electricity |
| **Palestinian Territories** | **96.2** | **2.9** | **0.9** |
| Urban | 99.3 | 0.4 | 0.3 |
| Rural | 88.8 | 8.9 | 2.3 |
| Camps | 99.3 | 0.4 | 0.3 |
| **West Bank** | **94.7** | **4.3** | **1.0** |
| Urban | 99.3 | 0.6 | 0.1 |
| Rural | 88.3 | 9.5 | 2.2 |
| Camps | 98.7 | 1.3 | - |
| **Gaza Strip** | **99.1** | **0.1** | **0.8** |
| Urban | 99.2 | 0.1 | 0.7 |
| Rural | 95.7 | 0.8 | 3.5 |
| Camps | 99.5 | - | 0.5 |

Average consumption per household is about 3,500 kWh per year. There are quite large geographical variations. For example, average consumption for the Southern Electric Company (SELCO) is about 3,000 kWh.

Among Nablus households, the average annual consumption is only about 2,000 kWh. These variations may reflect differences in billing efficiency as well as genuine differences in consumption levels. As the average household size in West Bank and Gaza is about 6 persons, the estimated per capita consumption is about 675 kWh/year. Average consumption is highest in cities, lower in villages and lowest in refugee camps [14].

- Renewable energy has not reached a satisfactory level of utilization, as it was mentioned above.
- Environmental pollution due to conventional energy resources, inefficient use of energy, inefficient and old technology.

- Supply of conventional energy (electricity and petroleum products) is monopolized by the Israeli authority. This creates unrealistic price control, energy shortage and future energy crisis.
- Lack of actual quantitative data on energy needs, demand and supply.

However, huge efforts are needed for the development of energy sector; urgent need for activities at the energy scene that focused on: retrieval of data and/or conducting surveys on energy demand/ consumption, efficient utilization of renewable and local conventional energy resources, and implementation of R&D activities that aimed at alleviating some or all energy problems.

### 1.4 Energy in Industrial Sector.

Palestinian's industrial sector is diverse, characterized by small industries and workshops with little capital and small number of employees. Industrial development is very much linked to political future and stability of the area.

According to the survey conducted by the Palestinian Central Bureau of Statistics (PCBS) in 2004, the industrial enterprises and workshops in Palestine are counted to around 12211, in more than 21 industrial fields. The industrial sector contributes around 12.7% of the GDP, employing around 58242 people (10% of employment). This sector is expected to grow in the coming years with an improved atmosphere for investment and enhanced opportunities for outside trade movements [15].

Table 1.6 summarizes the results of the industry survey by economic activity and according to the International Standard Industrial Classification of all economic activities (SIC). It represents the ISIC code, number of establishments, number of workers, gross value added and the gross fixed capital formation (GFCF).

**Table 1.6**: Industry by economic activity in the Palestinian Territories, PCBS, 2004.

| ISIC | Economic Activity | No. of Companies | No. of Workers | Gross Added Value | G.F.C.F. |
|---|---|---|---|---|---|
| 14 | Mining & quarrying | 163 | 1438 | 21175.8 | 192.1 |
| 15 | Food & Beverages | 1704 | 8561 | 89466.0 | 4245.4 |
| 16 | Tobacco | 19 | 217 | 43235.9 | 340.8 |
| 17 | Textile | 215 | 1099 | 7714.6 | 149.4 |
| 18 | Wearing Apparel | 1140 | 11640 | 49684.9 | 353.8 |
| 19 | Leather Tanning | 279 | 2027 | 24158.0 | 93.8 |
| 20 | Wood & Wood Products | 515 | 1566 | 9368.3 | 85.6 |
| 21 | Paper | 41 | 417 | 7206.2 | 167.5 |
| 22 | Publishing & Printing | 219 | 966 | 15788.2 | 2620.0 |
| 24 | Chemicals | 140 | 1622 | 31329.3 | 659.8 |
| 25 | Rubber & Plastics | 132 | 1024 | 18581.7 | 22.4 |
| 26 | Non Metallic Product | 1772 | 11599 | 129388.0 | 1937.9 |
| 27 | Basic Metals | 25 | 99 | 1093.6 | 1.6 |
| 28 | Metal Products (ex.m/c) | 3077 | 6575 | 33089.0 | 2653.1 |
| 29 | Machinery & Equipment | 195 | 551 | 3293.2 | 12.8 |
| 31+32 | Manufacture of Elec. m/c | 62 | 307 | 1724.5 | 14.3 |
| 33 | Medical & Optical equip. | 43 | 93 | 771.3 | 12.8 |
| 34 | Vehicle Bodies | 17 | 65 | 191.7 | 0.0 |
| 35 | Other Transport equip. | N/A | N/A | N/A | N/A |
| 36 | Furniture | 2005 | 6459 | 49801.0 | 199.9 |
| 37 | Recycling | 10 | 47 | 799.3 | 19.4 |
| 40 | Electricity Supply | 12 | 673 | 51329.6 | 1881.9 |
| 41 | Water Collection & Dist. | 426 | 1197 | 16638.8 | 2384.1 |
| | **Total** | **12211** | **58242** | **605828.9** | **18048.4** |

**Currency: Thousand USD)**

Statistics for energy consumption by sector show the role of the residential sector and other service sectors as the main energy consumer, with 71.3% of the total consumption in 2003, the highest in the region.

The transportation sector is the second greatest consumer of energy with 21.7, while the industrial sector comes in the third place with 7%. These results coincide with the Palestinian political situation and the fact that Palestine is not an industrial country as shown in Figure 1.6[1].

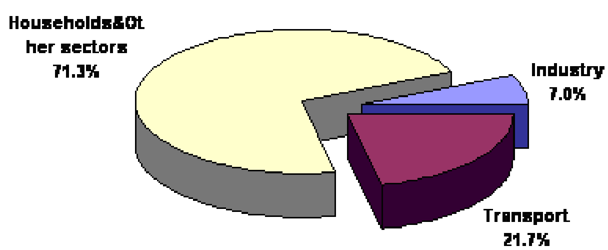


**Figure 1.6**: Total final consumption by sector in Palestine for the year 2003

Table 1.7 and Table 1.8 illustrate the breakdown of final consumption of energy in 2003 by source of energy and the breakdown of source of energy in 2003 by consumption sector.

**Table 1.7**: Breakdown of final consumption of energy in 2003 by source of energy [1].

| Production and Utilization | Total | Energy sources and products in 2003 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Solar Energy | Elect ricity | Gasoline | Kerosene | Gasoil | Oils& Lubs | LPG | Olive cake | Fuel wood |
| Final Consumption (TJ) | 35,413 | 3,491 | 7,491 | 5,976 | 653 | 3,960 | 74 | 8,145 | 278 | 4,852 |
| Proportion of final consumption | 100% | 9.9% | 22.5% | 16.9% | 1.8% | 11.2% | 0.2% | 23.0% | 0.8% | 13.7% |
| Industry and construction (TJ) | 2,266 | - | 670 | 107 | 43 | 1,279 | 39 | 123 | - | 4 |
| Proportion of industrial etc. | 100% | 0.0% | 29.6% | 4.7% | 1.9% | 56.5% | 1.7% | 5.4% | 0.0% | 0.2% |
| Transport (TJ) | 6,914 | - | 72 | 5,707 | 7 | 1,122 | 5 | 2 | - | 0 |
| Proportion of transport | 100% | 0.0% | 1.0% | 82.5% | 0.1% | 16.2% | 0.1% | 0.0% | 0.0% | 0.0% |
| Household and other sectors (TJ) | 27,185 | 3,491 | 7,242 | 162 | 603 | 2,511 | 30 | 8,020 | 278 | 4,848 |
| Proportion of household etc. | 100% | 12.8% | 26.6% | 0.6% | 2.2% | 9.2% | 0.1% | 29.5% | 1.0% | 17.8% |

**Table 1.8**: Breakdown of source of energy in 2003 by consumption sector [1].

| Production and Utilization | **Total** | **Energy sources and products in 2003** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Solar Energy | Elect. | Gasol. | Kerose. | Gasoil | Oils& Lubs. | LPG | Olive cake | Fuel wood |
| Industry and construction | 6.2% | 0.0% | 8.4% | 1.8% | 6.6% | 26.0% | 52.8% | 1.5% | 0.0% | 0.1% |
| Transport | 19% | 0.0% | 0.9% | 95.5% | 1.0% | 22.8% | 6.4% | 0.0% | 0.0% | 0.0% |
| Household and other sectors | 74.8% | 100% | 90.7% | 2.7% | 92.3% | 51.1% | 40.7% | 98.5% | 100% | 99.9% |

Palestine faces continuing growth in energy demands, especially electricity, across all sectors and by necessity future generation expansion will rely substantially upon fossil fuels. These factors create strong economic and environmental incentives to curb energy consumption through efficiency gains in its generation, transmission and end-use.

The major opportunities for energy saving exist within the industrial and residential sectors and international experience has shown that these sectors are responsive to the activities of sustained and well focused information programs. Significant savings can be achieved not through a relatively small number of direct projects but through the stimulation of widespread replication activities across the country.

Figure 1.7 illustrates the increasing demand of electricity in the industrial sector between 1996 and 2004.

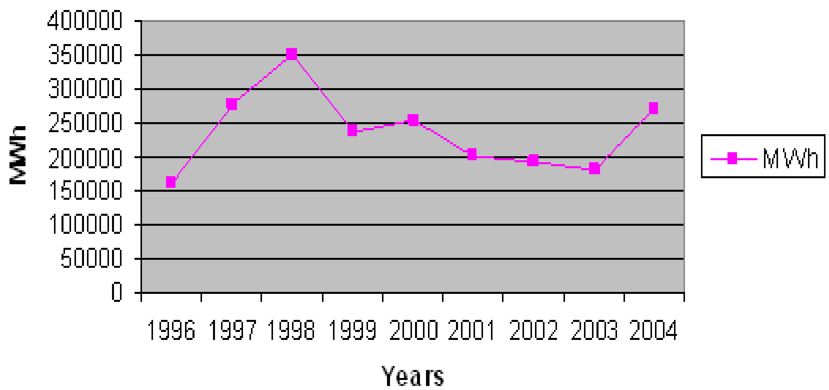


**Figure 1.7**: Electric energy consumed in the industrial sector between 1996 -2004[15].

It is obvious also that there is an urgent need for development of the national industry. Also, drawing up national programs for energy conservation in industry and raising up the share of investment in efficient energy technologies are important steps toward construction and sustainable development.

The efficient use of energy in the industrial sector will slow down the increase in energy demands and reduces waste, leading to cost savings to individual site and reduce cost at the national level.

It is envisaged that energy conservation will be the core of energy planning and can be considered as a new source of energy aiming at reduction of specific energy consumption, mobilization the use of renewable energy resources and use of efficient/ clean technologies, taking into consideration the way and means of goods production as well as the emission control.

**Summery**

As a result of several years of Israeli military occupation of the Palestinian Territories, the Palestinian Energy sector suffers from major distortions and underdevelopment. During the Israeli occupation, the infrastructures of the West Bank and Gaza Strip were largely neglected, if not destroyed by the occupation. This creates chronic energy problems: there is a high unit price of energy, energy shortages and the potential for future energy crises as Israel is the only source of energy importation.

Renewable energy has not reached a satisfactory level of utilization and pollution from conventional resources is a potential environmental threat.

Palestinian's industrial sector is diverse, characterized by small industries and workshops with little capital and small number of employees, but considered from the main consumers of energy sectors.

Energy priorities require the rehabilitation and development of the electricity system, rural electrification, and utilization of renewable energy and energy conservation, particularly in the residential, transport and industrial sector.
It is important to note that an increase in efficiency and dissemination the awareness toward energy conservation through workshops and capacity building for the involved staff must be a priority for the Palestinian Territories in view of the fact that energy resources are so scarce.

# CHAPTER TWO

# IMPORTANCE OF ENERGY CONSERVATION IN INDUSTRIAL SECTOR IN PALESTINE

## 2.1 The Need for Energy Conservation in the Industrial Sector

Few countries have all the energy resources they need within their own borders. Most countries have to rely on imports, as the case of Palestine which imports almost all its needs of energy (Electric and Petroleum) from Israel. Palestine faces continuing growth in energy demands, especially electricity, across all sectors and by necessity future generation expansion will rely substantially upon fossil fuels. These factors create strong economic and environmental incentives to curb electricity consumption through efficiency gains in its generation, transmission and end-use.

The Palestinian industrial sector is however subject to a number of restrictions and at the same time motivations that can affect the energy technologies and necessitate or facilitate implementing energy conservation strategies:

- The need to rehabilitate the existing industries and build up new national industries based on clean and efficient technologies and modern industrial processing.
- The high cost of energy and limited indigenous fossil fuel resources are stimulus for local renewable energy sources and rational use of energy technologies.
- The high losses in the distribution network and low power factor.
- The rising health problems related to pollution forces Palestinians to respect standard environmental regulations and use clean technologies.
- The private firms are now trying to maximize the return on their investments by using technologies that can provide multiple benefits

(higher energy efficiency, heat recovery, etc).

- The high consumption rate of energy which is due to the irrational use of energy, use of inefficient equipment, lack of awareness and knowledge of energy conservation.

- The high demand for energy particularly electricity in order to meet the unusual increment in residential and industrial sectors.

- The efficiency of most industrial equipment and processing is lower than expected. This is due to lack of proper maintenance and control, poor design, improper installation, poor equipment matching, and bad management.

- The lack of national programs, legislative measures and of know- how in the field of rational use of energy, in addition to the limited financial resources for these activities.

- Although the main energy consumers are the large industries, the medium and small industries, need the most help in implementing energy conservation measures, resulting in lower specific energy consumption, improved quality and decreased environmental pollution.

From different visits and contacts to the Palestinian Industry, it became apparent that a big gab in awareness and information exists at the management level.

The major opportunities for energy saving exist within the industrial and residential sectors and international experience has shown that these sectors are responsive to the activities of sustained and well focused information programs. Significant savings can be achieved not through a relatively small number of direct projects but through the stimulation of widespread replication activities across the country.

The efficient use of energy in these sectors will slow down the increase in energy demands and reduces waste, leading to cost savings to individual site and reduce cost at the national level.

Drawing up national programs for energy conservation in industry and raising up the share of investment in new efficient energy technologies are important steps toward construction and sustainable development.

It is envisaged that the energy conservation will be the core of energy planning and can be considered as a new source of energy aiming at reduction of specific energy consumption, mobilization the use of renewable energy resources and use of efficient/ clean technologies, taking into consideration the way and means of goods production as well as the emission control.

Hence, energy conservation coupled with greater use of indigenous fuels can reduce dependence on imports. In some cases energy conservation can free up domestic energy supplies allowing greater availability of indigenous fuels for export. These are key issues for developing countries with high levels of international debts.

Nevertheless, some countries especially in the developing world are successfully improving efficiency in order to raise productivity and ultimately improve upon their economic performances. Conservation of energy is needed to eliminate waste due to current high-energy consumption levels and in some cases to reduce the steeply rising demand for energy associated with rapid growth.

Saving in energy consumption through energy conservation reduces the atmospheric emissions from fossil fuel electric power plants and industrial facilities. The industrial sector accounts for some 41% of global primary energy demand and approximately the same share of $CO_2$ emissions [16].

I. Ibrik and M. Mahmoud have identified that implementing of a national project in Palestine aiming at energy efficiency improvement in residential and industrial sectors as well as in public utilities, which include wide range of diversified audits and power measurements, had led to a high potential of energy saving. Measurement and audit results had shown that the total conservation potential in these sectors is around 15% of the total energy consumption [17].

In the United Kingdom, while fuel use in the industrial sector has dropped dramatically since 1970, industrial output has increased by 46% between 1970 and 1996, resulting in a considerable reduction in the energy intensity of the industry. In 1996 it required almost 60% less energy to produce each unit of output than in 1970. This has been brought about by changes in the structure of the industry, with a decline in the most energy intensive industries, and an increase in the efficiency of energy use. Fuel switching will also have had an impact. It is estimated that 15% of the fall is accounted for by structural change (i.e. the effect on energy consumption of changes in the relative importance of different industrial sectors), and the remainder (85%) by higher efficiency [18].

While the energy to be saved through increased energy conservation and fuel substitution is greatest in developed economies due to their high levels of energy consumption, the energy importing developing countries can also benefit significantly since increased efficiency of energy use would lower their overall energy requirements and thus reduce their energy bills.

Not only does energy conservation reduce energy bills but also it helps improve countries economic performances and also provides environmental benefits such as the reduction of carbon dioxide and sulphur emissions, thus contributing to the global environmental concerns.

Energy is the driving force behind all industrial operations because as industrialization grows, energy consumption levels are growing exponentially, placing tremendous pressure on natural resources and the environment [19].

Energy Conservation in industry is of a critical priority; both in terms of conserving the scarce resources, and also in terms of the consequent financial savings generated and consequently reduce the polluting effects of fossil energy consumption.

Conservation of energy is needed to eliminate waste due to current high-energy consumption levels and in some cases to reduce the steeply rising demand for energy associated with rapid growth.

Energy conservation and efficiency reduces energy production requirements, which mitigates the associated negative environmental impacts of energy resources exploration, development and production.

Energy conservation promotes sustainable and environmentally sound economic growth and development because greenhouse gases emissions (GHG) can be substantially cut in industrial sector.

## 2.2 Classification of Energy Conservation Measures

Based on energy audit and analyses of the plant, a number of potential energy saving projects may be identified. These may be classified into three categories:

1. Low cost - high return;

2. Medium cost - medium return;

3. High cost - high return;

Normally the low cost - high return projects receive priority. Other projects have to be analyzed, engineered and budgeted for implementation in a phased manner. Projects relating to energy cascading and process changes almost always involve high costs coupled with high returns, and may require careful scrutiny before funds can be committed. These projects are generally complex and may require long lead times before they can be implemented. Refer Table 2.1 for project priority guidelines [20].

**Table 2.1**: Priority guideline for energy conservation measure selection

| **Priority** | **Economical feasibility** | **Technical feasibility** | **Risk/feasibility** |
|---|---|---|---|
| A- GOOD | Well defined and attractive | Existing technology adequate | No risk/ highly feasible |
| B- MAYBE | Well defined and only marginally acceptable | Existing technology may be updated, lack of confirmation | Minor operating risk/ maybe feasible |
| C- HELD | Poorly defined and marginally unacceptable | Existing technology is inadequate | Doubtful |
| D- NO | Clearly not attractive | Need major breakthrough | Not feasible |

## 2.3 Strategies for Energy Savings in Industry

The strategies for achieving energy savings in industry are quite different to those for most other sectors. Industry is generally receptive efforts to cut its energy costs but it is less likely to be attracted to regulatory measures that increase its operating costs.

The technical options available for energy savings in the industrial sector are as diverse as the industries themselves. However, they principally revolve around the saving of energy in areas such as:

- Steam distribution and combustion
- Compressed air system
- Lighting system
- Power factor improvement
- Heat recovery

Each system will be analyzed and discussed separately from the energy conservation potential opportunity point of view.

## 2.4 Energy Conservation Systems in Industry

### 2.4.1 Boiler - steam generation

A large fraction of a facility's total energy usage begins in the boiler plant. The cost of boiler fuel is typically the largest energy cost of a facility, or the second largest. For this reason, a relatively small efficiency improvement in the boiler plant may produce greater overall savings than much larger efficiency improvements in individual end users of energy. Also, most boiler plants offer significant opportunities for improving efficiency [21].

The main efficiency measures are listed below.

- **Boiler - reduce excess air:** Excess air is the extra air supplied to the burner beyond the air required for complete combustion. excess air is supplied to the burner because a boiler firing without sufficient air or "fuel rich" is operating in a potentially dangerous condition. Therefore, excess air is supplied to the burner to provide a safety factor above the actual air required for combustion.

  The more air is used to burn the fuel, the more heat is wasted in heating this air rather than in producing steam. Air slightly in excess of the ideal stochiometric fuel/air ratio is required for safety, and to reduce NOx emissions, but approximately 15% is adequate [21]. Poorly maintained boilers can have up to 140% excess air, but this is rare. Reducing this boiler back down to 15% even without continuous automatic monitoring would save 8% of total fuel use. A rule of thumb often used is that boiler efficiency can be increased by 1% for each 15% reduction in excess air or 40°F (22°C) reduction in stack gas temperature [21].

In other words, the stack temperature will also drop after adjustment of the air/fuel mixture, leading to an additional increase in efficiency. Therefore, reducing the oxygen level in the flue gas will reduce the heat loss and reduce fuel consumption as illustrated in figure 2.1.

Controlling excess air is the most important tool for managing the energy efficiency and atmospheric emissions of a boiler system [22].

Table 2.2 illustrates the optimal percentages of $O_2$, $CO_2$ and excess air in the exhaust gases for different types of fuel.

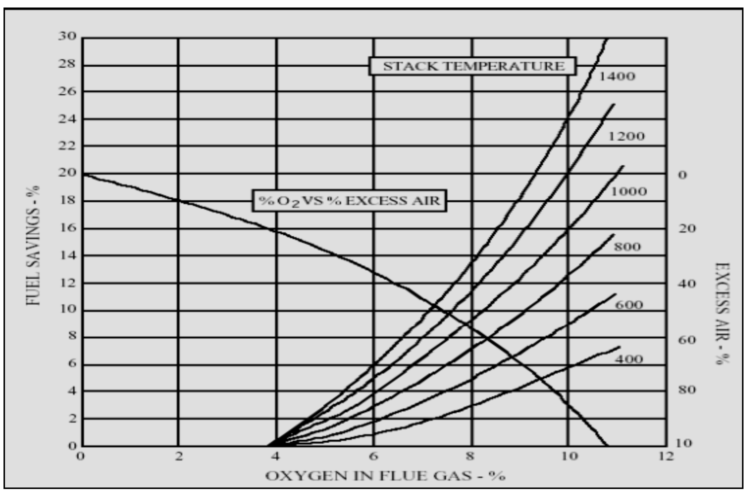


**Figure 2.1**: Liquid petroleum fuel savings available by reducing excess air [23].

**Table 2.2**: Optimal percentages of $O_2$, $CO_2$ and excess air in the exhaust gases [24].

| Fuel Type | **$O_2$** (%) | **$CO_2$** (%) | Excess Air (%) |
|---|---|---|---|
| Natural Gas | 2.2 | 10.5 | 10 |
| Liquid Petroleum Fuel | 4.0 | 13.0 | 22.2 |
| Coal | 4.5 | 14.5 | 25 |
| Wood | 5.0 | 15.5 | 30 |

- **Boiler – maintenance:** A simple maintenance program to ensure that all components of the boiler are operating at peak performance can result in substantial savings. In the absence of a good maintenance system, the burners and condensate return systems can wear or get out of adjustment. These factors can end up costing a steam system up to 20-30% of initial efficiency over 2-3 years. We estimate a 10% possible energy savings on average [21]. Improved maintenance may also reduce the emission of criteria air pollutants.

- **Boiler - recover heat from flue gas:** Heat from flue gasses can be used to preheat boiler feed water in an economizer. The limiting factor for flue gas heat recovery is that one must ensure that the economizer wall temperature does not drop below the dew point of acids in the flue gas (such as sulfuric acid in sulfur containing fossil fuels). 1% of fuel use is saved for every 45°F (25°C) reduction in exhaust gas temperature [25].

- **Boiler - return condensate:** Reusing the hot condensate in the boiler saves energy, reduces the need for treated boiler feed water and reclaims water at 100°C (212°F) sensible heat savings.

  Usually fresh water must be treated to remove solids that might accumulate in the boiler, and returning condensate can substantially reduce the amount of purchased chemical required to accomplish this treatment. The fact that this measure can save substantial energy costs and purchased chemicals costs makes building a return piping system attractive, a 10% energy savings is assumed [21].

### 2.4.2 Compressed air systems

Compressed air is probably the most expensive form of energy used in an industrial plant because of its poor efficiency. Typically, efficiency from start to end use is around 10% for compressed air systems [26]. Because of this inefficiency, if compressed air is used, it should be of minimum quantity for the shortest possible time.

Many opportunities to reduce energy in the compressed air systems are not prohibitively expensive. Following are some of those opportunities.

- **Reduce leaks in pipes:** Leaks can be a significant source of wasted energy. A typical plant that has not been well maintained could have a leak rate between 20 to 50% of total compressed air production capacity [27; 28]. Leak repair and maintenance can reduce this number to less than 10%. Overall, a 20% reduction of annual energy consumption in compressed air systems is projected for fixing leaks [29].

  In addition to increased energy consumption, leaks can make air tools less efficient and adversely affect production, shorten the life of equipment, lead to additional maintenance requirements and increased unscheduled downtime. Leaks cause an increase in compressor energy and maintenance costs.

- **Cold air intake:** It is possible to reduce inlet air temperature to the compressor by taking suction from outside the building. As a rule of thumb, each 5°F (3°C) lower air temperature will save 1% compressor energy [30; 31]. In addition to energy savings, compressor capacity is increased when cold air from outside is used.

- **Heat recovery for water preheating:** As much as 80 to 93% of the electrical energy used by an industrial air compressor is converted into heat. In many cases, a heat recovery unit can recover 50 to 90% of the available thermal energy for space heating, industrial process heating, water heating, makeup air heating, boiler makeup water preheating, industrial drying, industrial cleaning processes, heat pumps, laundries or preheating aspirated air for oil burners [31]. Implementing this measure recovers up to 20% of the energy used in compressed air systems annually for space heating [29].

### 2.4.3 Lighting systems

Lighting is used either to provide overall ambient light throughout the manufacturing storage and office spaces or to provide low bay and task lighting to specific areas. High-intensity discharge (HID) sources are used for manufacturing and storage areas, including metal halide, high pressure sodium and mercury vapor lamps. Fluorescent lamps, compact fluorescent lamps (CFL) and incandescent lights are typically used for task lighting and offices.

Reducing energy in the lighting systems is not prohibitively expensive. Following are some of those opportunities.

- **Reducing the number of lighting lamps:** this can be arranged by measuring the illumination level at the specific area and comparing it with the international standards for illumination, this measure saves a good percentage of energy especially that when you remove a lamp you remove also its ballast that consumes energy.

- **Install high efficiency lighting lamps**: The efficient fluorescent lamp lasts roughly ten times longer than an incandescent light and is three times more effective and consumes less [32].

- **Install reflectors in light fixtures:** Reflectors are highly polished "mirror-like" components that direct light downward, reducing light loss within a fixture. Reflectors can minimize required wattage by using less more effectively [33].

### 2.4.4 Power factor improvement

Power factor is a measure of how effectively you are using electricity at your workplace. Low power factor is expensive and inefficient. Many utility companies charge large commercial and industrial customers an additional fee when power factor is less than a certain value which determined by the electric company, 0.92 in Palestine. Low power factor also reduces an electrical system's distribution capacity by increasing current flow and causing voltage drops [34].

Power factor correction is achieved by the addition of capacitors in parallel with the connected motor or lighting circuits and can be applied at the equipment, distribution board or at the origin of the installation.

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

- Reduction of electricity bills
- Extra kVA available from the existing supply
- Reduction of $I^2R$ losses in transformers and distribution equipment

- Reduction of voltage drop in long cables.
- Environmental benefit. Reduction of power consumption due to improved energy efficiency. Reduced power consumption means less greenhouse gas emissions and fossil fuel depletion by power stations.
- Extended equipment life – Reduced electrical burden on cables and electrical components.

## 2.5 Barriers to Energy Efficiency and Conservation

From our visits to the facilities through energy conservation and interviews with the top management and engineers that have the responsibility on maintenance and production, four categories of barriers to energy conservation and efficiency in the Palestinian industrial sector were identified:

- Management
- Knowledge /information
- Financing
- Policy

### 1. Lack of management awareness

The lack of awareness of energy efficiency and conservation by top management of companies is an important barrier because without management commitment it is an uphill battle to improve energy efficiency. This appears to be the root cause of other barriers, such as the priority for production, lack of investment capital and limited policies.

The most important barrier is that management is focused more on maximizing the production output and turnover rather than on producing safely, more efficiently and reducing production costs. “I think the problem is that they are totally focused on producing their main products in as much volume as technically possible.

Lack of awareness about resource and energy efficiency of top management is also caused by the immature systems to manage energy, from the governmental side as is the situation in Palestine, such as policies, environmental management systems, and an energy or environment manager. This way management is not sufficiently informed about energy and consequently cannot be pro-active towards energy management.

**2. Limited knowledge and information**

A second barrier is about knowledge and information. It covers limited information and (technical) knowledge at company level in general in Palestine, but also a limited access to and availability of knowledge and information.

Company information on energy and resources is crucial because only then the improvements after implementation of options can be measured, and management is more likely to continue with resource and energy efficiency if quantitative data on savings are available.

Also poor information systems were the main cause of lack of electricity and resource consumption data. The reason for poor monitoring is often that energy is considered as a fixed cost and therefore not actively monitored or managed. This is despite the fact that energy costs can be as high as 50 percent in certain plants.

Limited internal knowledge and expertise was also a common problem. A minimum technical knowledge of energy, production processes and equipment is required to be able to identify, investigate and implement options to improve resource and energy efficiency.

**3. Lack of financing**

Almost all companies visited mentioned the financial limitations of implementing energy efficiency and conservation options.

The most common barrier mentioned was the lack of money to invest in options and opportunities. Options with a payback period of more than two or three years were rarely accepted even for discussion. Some options provide huge savings and a short payback period of often less than one year, but the option requires a high investment and the company simply does not have the money at hand, such as purchasing an economizer for waste heat recovery in boilers. One option is to take out a loan, but interest rates can be high, and banks often do not have confidence in the creditworthiness of companies to give them a loan, especially small and medium sized companies.

On the other hand, lack of financing can also be a perceived barrier that stops companies from taking action. Often there is a gap between what management would like to do and how much they are willing to spend.

Fortunately, financing mechanisms are increasingly developed in many countries, most notably the establishment of Energy Service Companies (ESCOs), which will be discussed later in details, that provide (part of) the investment capital for energy efficiency projects in return for a share of the financial savings over a certain number of years.

A relatively new means to finance options is the Clean Development Mechanism (CDM). In short, CDM involves the investment by industrialized countries that have ratified the Kyoto Protocol in projects in developing countries and receive emission reduction units in return.

**4. Lack of policies and legislation and enforcement**

While companies hold the key to reducing their energy consumption, government policy certainly has a big influence. Not existing policies, as is the case in Palestine or Limited policies, poor enforcement and conflicting economic and environmental policies were identified as the fourth group of barriers.

Lack of effective policies is a key issue, such as Energy Conservation Acts that require appointing an energy manager and carry out regular energy audits, promotion of Cleaner Production, limiting environmental pollution levels by using sources efficiently and funding the Energy Conservation Promotion Programs.

Weak enforcement of environmental policies and legislation due that government allocate insufficient funds for policy implementation and enforcement [35, 36].

The only way to energy security is to support and subsidize energy efficiency and conservation and the development of alternative energy sources, not to continue subsidizing imported oil products as is the case in most countries.

This chapter was mainly based on a theoretical analysis of major energy consumption equipment at the industry. Hence a detailed energy audit would have to be undertaken in order to establish more accurate energy consumption data. A detailed energy audit goes beyond the quantitative estimates of cost and savings. System efficiencies are evaluated and measures are identified for improving the end use energy efficiency.

## Summary

Energy efficiency and conservation is increasingly becoming an important factor in long term planning and investment decisions. In each industrial sector there is a large and cost effective energy savings potential.

Within an energy management strategy, or because of recognised poor performance, individual technologies and equipment may need isolated investigations so that their performance can be assessed. This will first require an investigation of the manufacturing process to determine where and how much energy is needed, and then assess the actual energy consumption against the requirements.

With a little adjustment in the operation process of different equipment, a decent amount of saving could be achieved. Energy efficiency improvements can provide a means to reduce costs without negatively affecting the yield or the quality of the product. Where available, we provided specific primary energy savings for each energy conservation measure based on case studies, as well as references to technical literature.

The conservation measures were focused on the most energy consumed equipment such as boiler system, compressed air system, lighting system and power factor improvement.

Above of that, and even there is a huge potential for energy conservation opportunities, still many barriers are facing the implementation of those measures in the level of management, information, financing and policy.

# CHAPTER THREE

# DESCRIPTION OF THE AUDITED FACILITIES

Four industries were evaluated, audited and analyzed in this study. The nature of manufacturing activities were quite various from each other. They included production systems pertaining to varied products such as dairy products, food, carton and textile.

During the initial part of the site visit, discussions were held with the plants personnel regarding overall annual energy utilization, the manufacturing process, major energy consuming equipment, and specific and unique energy efficiency opportunities (EEO) that may not have been explored.

A general insight into the overall manufacturing system and energy related aspects was given and focusing on priority areas that offer the greatest potential for energy reduction within the plant.

The data were collected using measurement instrumentation and through effective estimation based on sound engineering judgment.

Each facility description will be separately presented throughout this chapter.

The audited facilities are:

- Al Safa Dairy Factory,
- National Carton Factory,
- Al Arz Ice Cream  Factory,
- Al Aqqad Textile Factory,

## 3.1 Al –Safa Dairy Factory

### Facility description

Al Safa factory consists of a single building of two floors with a total area of approximately 1000 square meter each floor. The factory was built in 2001 to produce treated milk with no conservative materials. A layout of the facility is giving in Figure 3.1.

With a lot of hard work, this factory was built on a piece of land with area around 7000 square meter and with production capacity of 60 tones daily of raw milk. The technology used for this purpose is new regarding the dairy products manufacturing. Some of products of Al Safa factory are, treated milk, yogurt, cheese, treated milk with different flavors.

The factory employ 76 local people, the operation hours are 3600 hours per year between 10 -12 hours a day. It comprises various departments

- raw milk receiving department,
- treatment department,
- main production hall , and
- filling and backing departments.

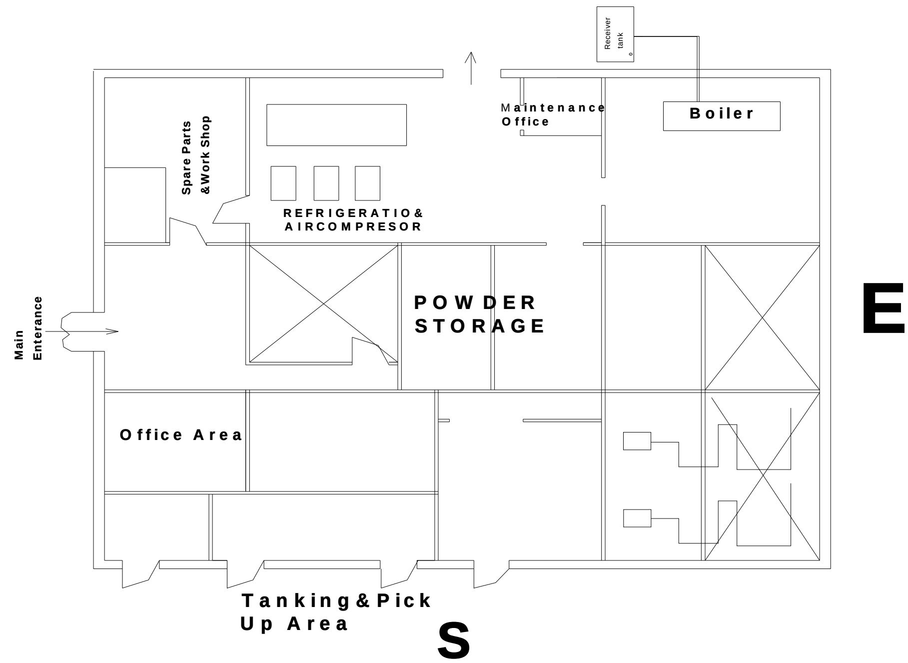


**Figure 3.1**: Al Safa Dairy Factory layout

## Production process

It includes receiving the milk from the farmers and makes the acceptance test on it. Transfer approved milk to the treatment department in order to heat it to the boiling point, and then the cooling process starts in order to bring the milk back to its original temperature in order to send it to different lines production.

The filling process starts for every department, and after few laboratory tests the backing process proceed for delivery or storing in the refrigerator.

The production process is an energy intensive process that requires a huge amount of electrical and thermal energy.

**Energy bill analysis**

Energy management tasks will be simplified if records of data and any information are kept up to date. It's also important to know how much the factory is paying to run and how the energy costs are calculated.

Table 3.1 shows annual energy, electric and fuel consumption in the factory for the period of one year.

**Table 3.1**: Energy consumption and Cost for the period of one year (Alsafa factory).

| **Month** | **Electrical (kWh)** | **Electrical Cost (JD)** | **Fuel cons.[1] (lt)** | **Fuel cost (JD)** |
|---|---|---|---|---|
| September | 50560 | 6067 | 9100 | 5915 |
| October | 48480 | 5818 | 9100 | 5915 |
| November | 60160 | 7219 | 9100 | 5915 |
| December | 49920 | 5990 | 9100 | 5915 |
| January | 48160 | 5779 | 9100 | 5915 |
| February | 56960 | 6835 | 9100 | 5915 |
| March | 56100 | 6732 | 9100 | 5915 |
| April | 49760 | 5971 | 9100 | 5915 |
| May | 56960 | 6835 | 9100 | 5915 |
| June | 55200 | 6624 | 9100 | 5915 |
| July | 44640 | 5357 | 9100 | 5915 |
| August | 49440 | 5933 | 9100 | 5915 |
| **Total** | **626340** | **75160** | **109200** | **70980** |

Figure 3.2 Illustrates the percentage of energy cost distribution for electricity and fuel as a source of energy.

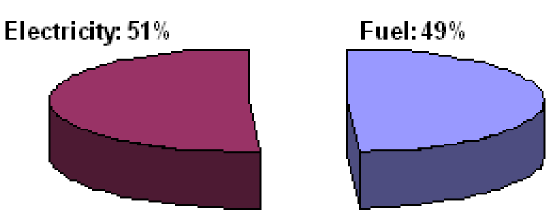


**Figure 3.2**: Energy cost distribution (elect. Vs. fuel)-al Safa factory

[1] This value was given as a monthly average of fuel consumption.

Figures 3.3 and 3.4 illustrate the monthly electrical consumption and the monthly costs respectively.

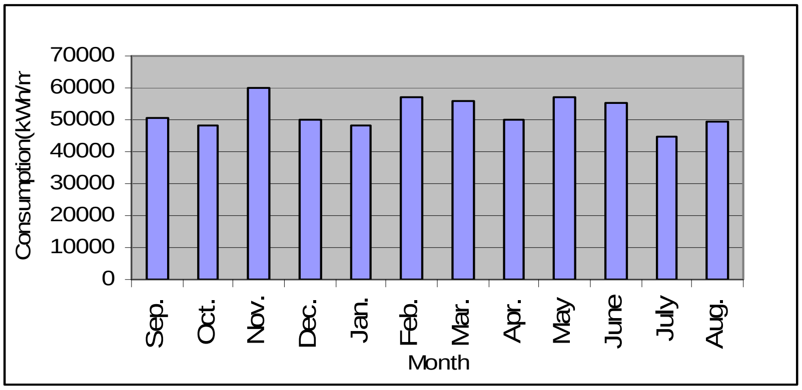


**Figure 3.3**: Monthly elec. energy consumption at al Safa Factory

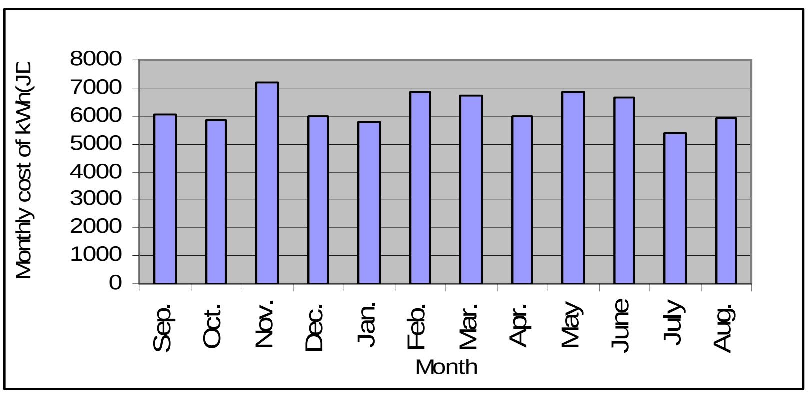


**Figure 3.4**: Total monthly electrical cost at al Safa Factory

From Table 3.1 and Figures 3.3 and 3.4 it is obvious that the factory consumes high electrical and thermal energy which is around 145 000 JD/year. The energy audit examined whether this consumption is within the factory normal energy requirements or if there is a high energy waste and bad energy management.

## 3.2 The National Company for Carton Manufacturing

### Facility description

The national company for carton manufacturing was established at 1992 for producing of different types of carton boards, in addition to production of carton boxes with printing.

The company has two main production lines

1. Carton boards production
2. Printing machine.

The company employs 50 local people; the operation hours are 2400 hours per year an average of 8 hours per day, six days a week. A layout of the facility is given in Figure 3.5.

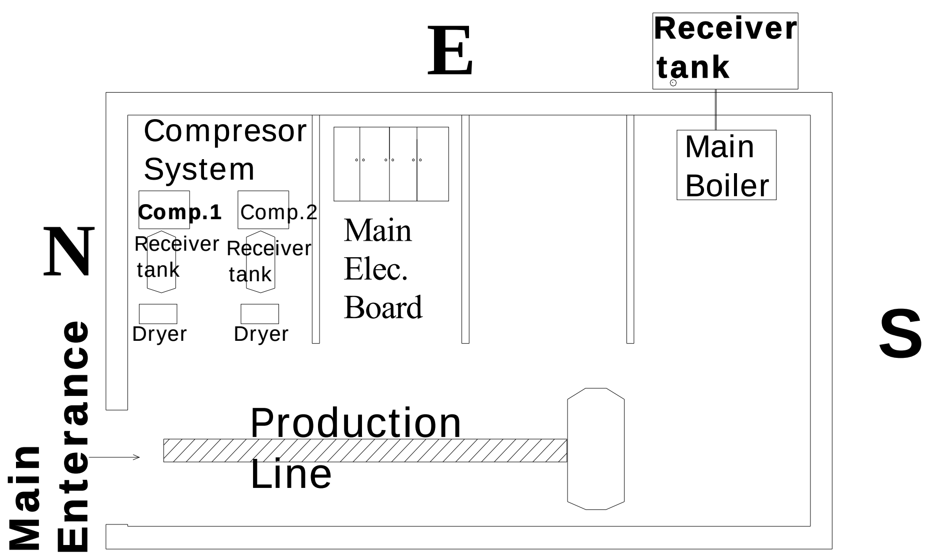


**Figure 3.5**: Al Carton Factory layout

**Production process**

Pulp is mixed with water to create a dilute mixture. This is fed into the cartonboard machine, which drains the water from the mixture to form a sheet. Various other processes are used to extract further moisture such as pressing and steaming. The sheet is then coated up to four times and put onto large reels where it is then cut into the desired form for distribution and sale.

The Cartonboard in either sheets or reels, is loaded then into the Printing machine and printed in one pass with each colour being added in turn. As well as the colours, a varnish is also usually printed after the colours.

The sheets are then taken to a machine that cuts the cartons and also puts in the creases that enable it to be folded in a later operation. When the cartons have been cut and creased, they are moved through to the gluing line where the cartons are folded and glued. The cartons are then packed for shipment.

The production process is an energy intensive process that requires a huge amount of electrical and thermal energy; the main consumers of electrical and thermal energy are:

- Compressed air system which consists of main air compressor, receiver and air dryer.
- Steam generation system which is the diesel boiler in this factory

**Energy bill analysis**

Energy management tasks will be simplified if records of data and any information are kept up to date. It's also important to know how much the factory is paying to run and how the energy costs are calculated.

Table 3.2 shows the annual energy, electric and fuel, consumption in the Carton Factory for the year 2006.

**Table 3.2**: Energy consumption and cost for 2006, (Al Carton factory).

| **Month** | | | | |
|---|---|---|---|---|
| | **Electrical (kWh)** | **Electrical cost (JD)** | **Fuel cons. (lt)** | **Fuel cost (JD)** |
| January | 18024 | 2163 | 10300 | 3440 |
| February | 32192 | 3863 | 17100 | 5711 |
| March | 25333 | 3040 | 15600 | 5210 |
| April | 17695 | 2123 | 9800 | 3273 |
| May | 21125 | 2535 | 14810 | 4947 |
| June | 21760 | 2611 | 15100 | 5043 |
| July | 19132 | 2296 | 12500 | 4175 |
| August | 25580 | 3070 | 16100 | 5377 |
| September | 25444 | 3053 | 16300 | 5444 |
| October | 16655 | 1999 | 8800 | 2939 |
| November | 20798 | 2496 | 13700 | 4576 |
| December | 19330 | 2320 | 14300 | 4776 |
| **Total** | **263068** | **31570** | **164410** | **54911** |

Figure 3.5 illustrates the percentage of energy cost distribution for electricity and fuel as a source of energy**.**

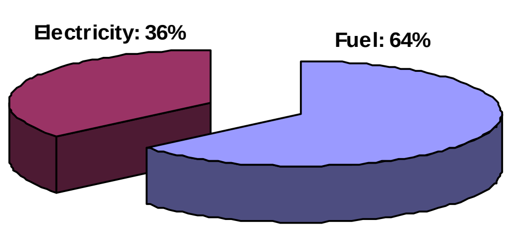


**Figure 3.6**: Energy cost distribution (elect. Vs. fuel)- al Carton Factory

Figures 3.7 and 3.8 illustrate the monthly electric consumption the monthly fuel consumption respectively.

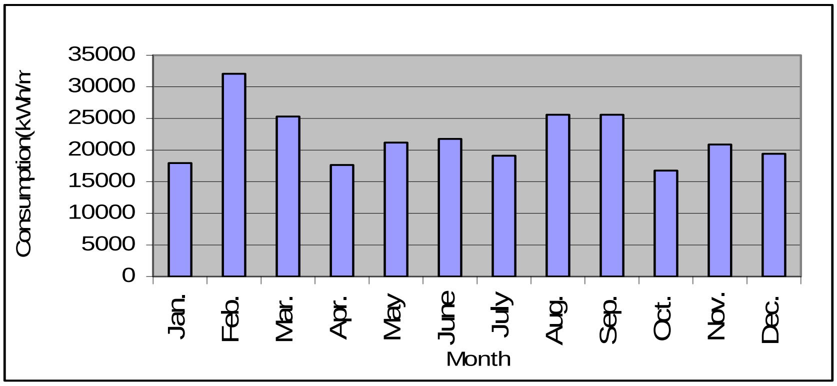


**Figure 3.7**: Monthly elect. Energy consumption at al Carton factory

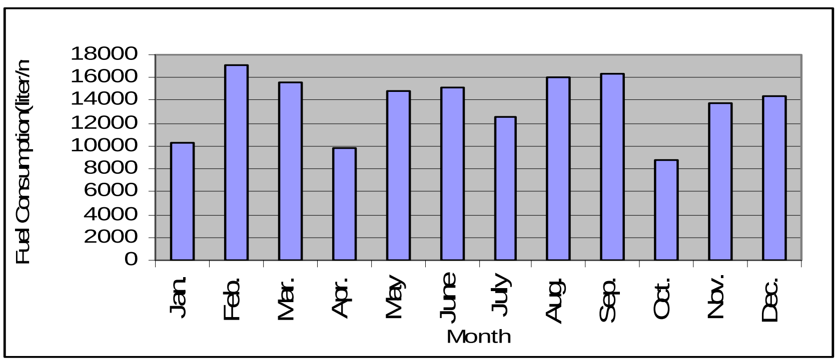


**Figure 3.8**: Monthly fuel consumption at al Carton factory.

From the above Table 3.2 and Figures 3.7 and 3.8, it is obvious that the factory consumes high electrical and thermal energy (around 86500 JD/year). Our mission in this study is to examine whether this consumption is within the factory normal energy requirements or if there is a high energy waste and bad energy management.

## 3.3 Al – Arz Ice Cream Factory

### Facility description

Al Arz factory consists of a single building of three floors with a total area of approximately 1500 square meter. The factory was established since 1950 as an ice making factory till 1959 it started to ice with flavors or what so called in Arabic ASKIMO, while at 1967 the factory began the production of ice cream made of milk and cacao in order to satisfy the requirements of the Palestinian market.

The factory employ 150 local people, 40 of them are permanent and the rest are seasonal, the annual operation hours are 4000 hours per year as the factory works two shifts. A layout of the facility is given in Figure 3.9.

The management of the factory kept improving itself in developing techniques of production the ice cream, the factory produces by now more than 50 kinds of ice cream which satisfies all ages and consumers tastes.

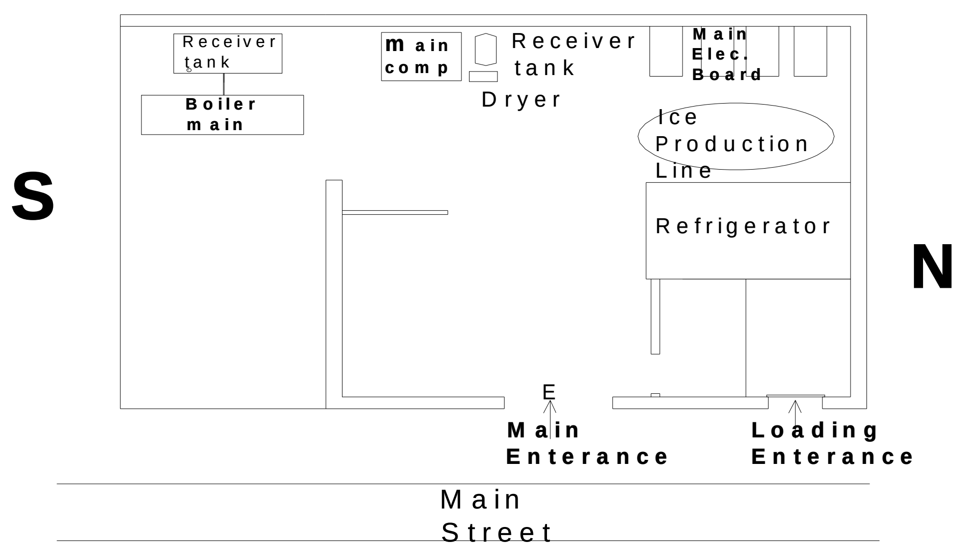


**Figure 3.9**: Al Arz Ice Cream Factory layout

**Production process**

The production process at the factory starts in the kitchen by preparation of the mixture of all kinds including cooking, color and flavor addition.

The quantities then placed in pots in order for the mixing and homogeneous process to start , then transferred to pasteurization department at 80 degrees for 16 seconds and then to storage tanks.

The mixture now is ready to transfer to production lines according to the type needed through pipes then to backing machines and refrigerators.

**Energy bill analysis**

Table 3.3 shows annual energy, electric and fuel consumption in the factory for the year 2006.

**Table 3.3**: Energy consumption and cost for the year 2006 - Al Arz Factory

| Month | Electrical (kWh) | Electrical cost (JD) | Fuel cons. (lt) | Fuel cost (JD) |
|---|---|---|---|---|
| January | 18000 | 2160 | 4000 | 2600 |
| February | 75000 | 9000 | 4000 | 2600 |
| March | 117720 | 14126 | 13000 | 8450 |
| April | 107880 | 12946 | 8000 | 5200 |
| May | 114120 | 13694 | 17050 | 11083 |
| June | 123000 | 14760 | 6000 | 3900 |
| July | 127540 | 15305 | 10500 | 6825 |
| August | 135600 | 16272 | 5330 | 3465 |
| September | 132000 | 15840 | 3670 | 2386 |
| October | 112680 | 13522 | 4750 | 3088 |
| November | 15240 | 1829 | 7750 | 5038 |
| December | 15000 | 1800 | 7140 | 4641 |
| **Total** | **1093780** | **131254** | **91190** | **59276** |

Figure 3.10 illustrates the percentage of energy cost distribution for electricity and fuel as a source of energy.

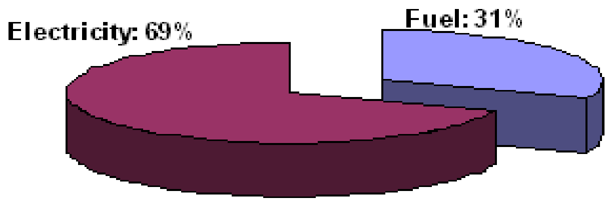


**Figure 3.10**: Energy cost distribution (elect. vs. fuel) -Al Arz Factory

Figures 3.10 and 3.11 illustrate the monthly electricity consumption and the fuel consumption of Al-Arz Ice Cream Factory.

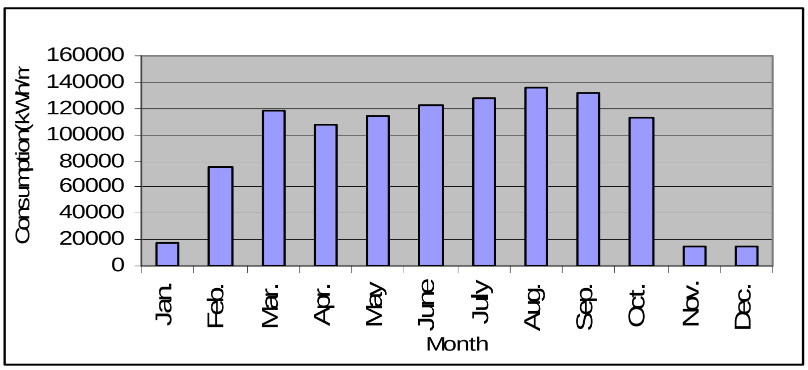


**Figure 3.11**: Monthly electricity energy consumption at Al-Arz Factory.

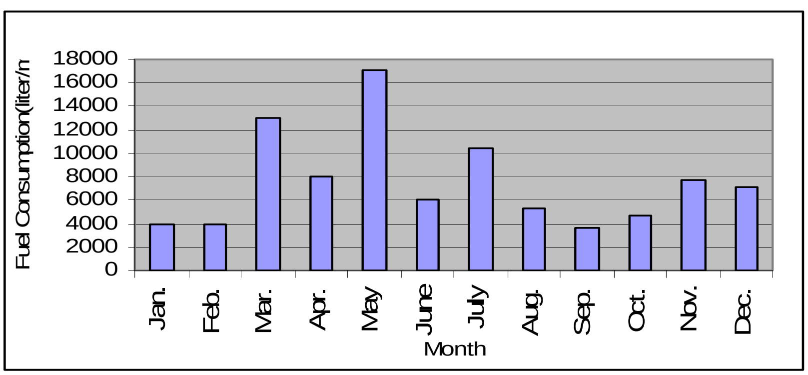


**Figure 3.12**: Monthly fuel consumption at Al-Arz Factory.

From Table 3.3 and Figures 3.11 and 3.12, it obvious that the factory consumes high electrical and thermal energy (around 190530 JD/year). The big deviation in energy consumption between months as seen in graphs is due to seasonal production of ice-cream.

## 3.4 Al Aqqad Textile Factory

# Facility description

Al Aqqad textile industry consists of two buildings, one has all the machinery equipments (boiler, compressor, generators, etc) and the other which consists from 4 stores includes management offices, washing machines and the working halls.

The number of employees is 133 and the operating hours are 10 hours a day.

A layout of the facility is given in Figure 3.13.

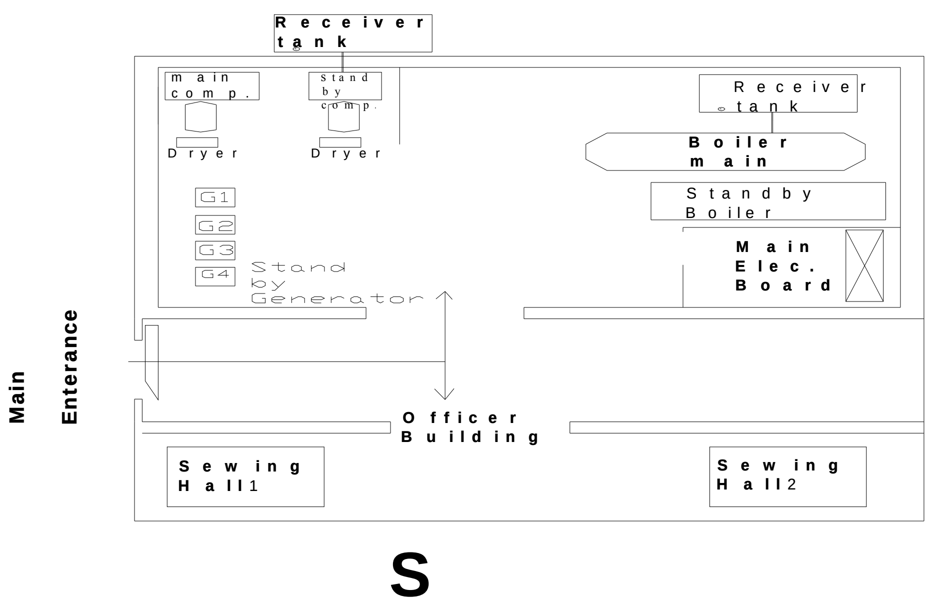


**Figure 3.13**: Al Aqqad Textile Factory layout

**Production process**

A brief description of the production process is described as following: The main product is pants, and the raw materials used to produce these pants include, 50 to 150 meters of uncut rolls of pant material, Zippers, Thread and Buttons.

Steps of manufacturing:

- cut the rolls into different sizes,
- sizes separation,
- sewing and checking the product for quality,
- pressing, folding and packing.

Once an order has been placed with the company specifying the sizes of pants, the first job is to design a pattern that will minimize material waste. The pattern is then used to the receiving dock where it is matched to the material that will be used in filling that order. The material is received on rolls of 50 to 150 meters and then cut to a length in accordance to the pattern generated.

The production of pants follows a specified circular path, including front and back pocket attachment, the pants then washed and steam dried. As a final assembly, the pants are then pressed and packed to be ready for the market.

**Energy bill analysis**

Table 3.4 illustrates the total yearly consumption of fuel types used as a source of energy in the facility for the year 2006. Al Aqqad Factory uses diesel generators for producing electrical energy for the electric operating equipment.

**Table 3.4**: Total energy consumption with corresponding costs-2006 (Al Aqqad)

| Fuel Type | Quantity (liters) | Cost (JD) |
|---|---|---|
| Fuel # 2 | 223000 | 152370 |
| Fuel # 6 | 212000 | 84910 |

Figure 3.14 illustrates the percentage of energy cost distribution for fuel type.

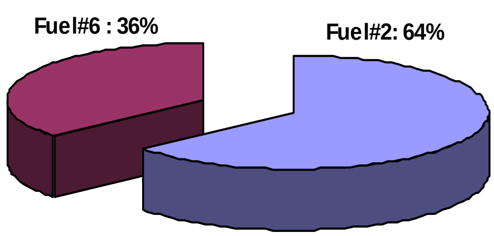


**Figure 3.14**: Percentage of energy cost distribution for fuel type at al Aqqad Factory

The facility is electrified from private owned diesel generators. In order to calculate the cost of 1 kWh using the diesel generators at al Aqqad factory we work as follows:

From the data measured by the energy analyzer which was installed on the electric board of the factory and from Annex (5), it was found that the average energy consumption per hour 230 kWh. And the following data was given from the maintenance department:

Annual diesel consumption for generators: 223000 liters, oil consumption: 2400 liter per year, annual maintenance cost: 3500 JD, annual filters cost: 4000 JD.

Annual operating cost (salary):3000JD, diesel cost per liter: 0.75 JD, operating hours: 3600 hours per year.

Diesel generators cost: 100000 JD (3 generators, two of 230 kW and one 400 kW) and depreciation factor assumed: 10%.

The total cost of energy = (diesel consump. x cost of diesel + oil consump. x oil cost + maint.cost + cost of filters + oper.cost)

= 182550 JD per year

Running cost = energy cost/ (average energy consumed x operating hours)

= 0.22 JD/kWh

Fixed cost = (gener. cost x depr. factor)/ (energy cons. x oper. hours)

= 0.012 JD /kWh

Total cost of kWh = 0.23 JD/kWh

From the above data and Figures, it is obvious that the factory consumes a lot of fuel as an energy source; this due for the factory uses local diesel generators as a power source. Our mission is to find out if this consumption is in the suitable range, in the meanwhile track the saving opportunities.

Next two chapters will present technical analysis through audits for each facility described above followed by economic and financial analysis in order for the energy conservation opportunity to be feasible for implementation from economic point of view.

# CHAPTER FOUR

# ENERGY AUDIT IN DIFFERENT INDUSTRIES IN WEST BANK - PALESTINE

The data for the four tested facilities were collected using measurement instrumentation and through effective estimation based on sound engineering judgment.

The measurements instruments used for measuring and collecting data were:

- The energy analyzer equipment: It was installed on each electrical board of the industry for power measurements and energy consumed and for determination of the power factor.
- Combustion analyzer equipment: It was used on the boiler's chimney for determination of the combustion efficiency, excess air percentage, flue gas temperature, $O_2$ and $CO_2$.
- Clamp meter equipment for power measurement
- Anemometer: For flue gas velocity measurements in the boiler chimney.
- Thermometer: For temperatures measurement
- Lux meter: For lighting illumination measurements
- Timer : For time running determination

Each facility will be separately presented; the potential for saving will be studied from the technical point of view in addition to the calculated method followed in a pointing this potential: The audited facilities were:

- Al Safa Dairy Factory,
- National Carton Factory,
- Al Arz Ice Cream Factory,
- Al Aqqad Textile Factory,

The auditing mission was focused on the most energy consumed equipment in the factories as mentioned before in the field of;

- Boiler efficiency improvement and energy savings
- Improvement of compressed air conditions,
- Conservation in lighting systems,
- Power factor improvement
- Waste heat recovery

The energy conservation scenarios for every opportunity were presented.

## 4.1 The Case of Al Safa Dairy Factory

The energy conservation opportunities (ECO) for this factory will be focused on the boiler system, compressed air system, lighting and power factor improvement; every ECO will be analyzed and presented separately.

### 4.1.1 Improving boiler system operation

The boiler at Al Safa Dairy Factory is a 5 ton/hour capacity of steam production, it operates 3600 hours per year, the steam is used for the milk boiling and treatment process, the condensate is returning to the receiver tank while the make – up water is submitted from the municipality after the softening process, Table 4.1 illustrates the boiler and combustion measured operating data:

**Table 4.1**: Al Safa boiler and combustion measured operating data

| | |
|---|---|
| **Data measured by thermometer** | |
| Receiver tank temperature (condensate water) | 48 C° |
| Output pressure | 8 bar |
| Inlet air temperature ( combustor) | 26 C° |
| Ambient temperature (boiler room) | 30 C° |
| **Combustion analyzer measured data** | |
| Combustion exhaust air temperature | 205 C° |
| $O_2$ | 5.5 % |
| $CO_2$ | 11.8 % |
| Losses | 19.6% |
| Excess air | 33.5 % |
| Combustion efficiency | 80.5 % |
| Chimney's diameter | 0.4 m |
| Average flue gas velocity | 3m/sec |

**Boiler efficiency calculation**

The boiler efficiency is an indication that shows how efficient the boiler is working and the amount of wasted energy due to low efficiency, equation 4.1 could be used for calculation of the boiler efficiency [46]:

$$\eta_{boiler} = [Q \times (h_g - h_f) / q \times GCV] \times 100\,\% \qquad 4.1$$

where:

$\eta_{boiler}$ : Boiler efficiency
Q : The amount of steam production (kg/h),
$h_g$ : Steam enthalpy (kJ/kg)
$h_f$ : Inlet water enthalpy (kJ/kg)
q : The amount of fuel used (kg/h)
GCV : Heating value of fuel (kJ/kg)

To apply equation 4.1, the fuel consumption and the steam flow rate were monitored every half hour, and the following procedures present the determination method.

**Determination of fuel consumption**

Table 4.2 illustrates the recorded parameters for Al Safa boiler regarding the fuel consumption for a period of half hour.

**Table 4.2:** Recorded parameters of Al Safa fuel consumption

| **Time** | **Steam Pressure (Bar)** | **Flue Gas Temperature (°C)** | **Feed Water Temperature (°C)** | **Oil Tank Level (litre)** |
|---|---|---|---|---|
| 9:10 | 8.2 | 316 | 49 | 670 |
| 9:40 | 8.0 | 310 | 48 | 649 |
| 10:10 | 7.4 | 308 | 47 | 632 |
| 10:40 | 7.8 | 306 | 48 | 616 |
| 11:10 | 8.1 | 311 | 48 | 601 |
| 11:40 | 8.6 | 307 | 47 | 582 |
| **Average** | 8.0 | 310 | 48 | |

From Table 4.2, the fuel consumption per hour could be calculated as follows:

Fuel consumption = (oil level$_{before}$ – oil level$_{after}$ ) ÷ (test period)

Fuel consumption (lt/hr) = (670-582) lt ÷ 2.5 hr = 35.2 liters / hr

Fuel consumption (kg/hr) = 35.2 lt/h × 0.943 kg/lt

= 33.2 kg/hr.

Where 0.943 Kg/lt is the specific gravity of fuel used.

### Determination of steam flow rate

The steam flow rate could be found by determining the amount of water consumed by the boiler in period of time; Table 4.3 shows the steam rate measurement for every half an hour of Al Safa boiler operation:

**Table 4.3**: Steam flow rate measurement for Al Safa boiler

| Sample No. | Time for which sample was collected (sec) | Quantity pumped in 30 sec(litre) |
|---|---|---|
| 1 | 30 | 5.1 |
| 2 | 30 | 4.7 |
| 3 | 30 | 4.8 |
| 4 | 30 | 4.4 |
| 5 | 30 | 4.7 |
| 6 | 30 | 4.5 |
| **Average** | **30** | **4.7** |

Average water pumped in 30 sec = 4.7 liters.

Water pumped in 60 sec (1 min) = 9.4 liters

Water pumped in 1 hour = 564 liters.

Operating time of pump per hour = 44 min = 0.73 hr

Water cons./hr = (Total oper. time of pump/hr x actual pumping. capacity)

= 412 lt/hour

Steam flow rate = Water consumption = 412 Kg/hr

Applying equation 4.1:

$\eta_{boiler} = [Q \times (h_g @ 800 \text{ Kpa} - h_f @48°C) / q \times GCV ] \times 100\%$

$=75.8\%$

This efficiency considered low comparing to the normal range of the boiler efficiency (80 – 85%).

So, this considers a good indication for improving the boiler efficiency and conserving energy in the factory.

The scenarios of increasing boiler efficiency and saving energy are discussed below:

# 1. Adjusting boiler air – fuel ratio

This adjustment is to improve the combustion efficiency of the boiler. Referring to the combustion analyzer data shown in Table 4.1, the percentage of $O_2$ was 5.5 % and the stack temperature around 401 ºF. So, using Figure 2.1, the possible fuel saving is about 0.8 % of total fuel used [21].

Or this saving could be achieved by manual adjustment the air- fuel ratio as close as to the optimum values (Table 2.2). Table 4.4 shows the after improvement values:

**Table 4.4**: Combustion data values after improvement

| Combustion Analyzer values after improvement | |
|---|---|
| Combustion exhaust air | 184 C° |
| $O_2$ | 4.3 % |
| $CO_2$ | 11.2 % |
| Losses | 17.8 % |
| Excess air | 26.3 % |
| Combustion Efficiency | 81.2 % |

The annual fuel savings, to be realized by increasing the combustion efficiency to a value of 81.2 %, can be estimated also from equation 4.2 [47].

$$\text{Fuel saving} = U \times [1- (\eta_{before}/\eta_{after})] \qquad 4.2$$

where:

U: annual fuel usage by boiler, liters/yr
$\eta_{before}$: combustion efficiency before improvement
$\eta_{after}$: combustion efficiency after improvement

**2. Increasing the feed water temperature using heat from stack temperature.**

During the detailed energy audit, it was noticed that the boiler feed water temperature is not preheated well (48 degrees, Table 4.1) which makes this system inefficient toward energy use. It is well known that preheating boiler feed water will save a considerable amount of fuel energy, since this additional heat energy added to the water before entering the boiler will reduce the amount of energy needed to heat the water up to the working temperature [25] .

Based on this fact, it is suggested herein to make use of the waste heat exiting from the chimney of the boiler in preheating the boiler feed water by installing an economizer at the boiler chimney.

Boiler stack economizers are simply heat exchangers with hot flue gas on one side and water on the other (Figure 4.1). Economizers must be sized for the volume of flue gas, its temperature, the maximum pressure drop allowed through the stack, and how much energy needs to be recovered. Some units are designed to keep the flue gases above condensation temperature, and others are made of materials that resist the corrosive effect of condensed flue gases.

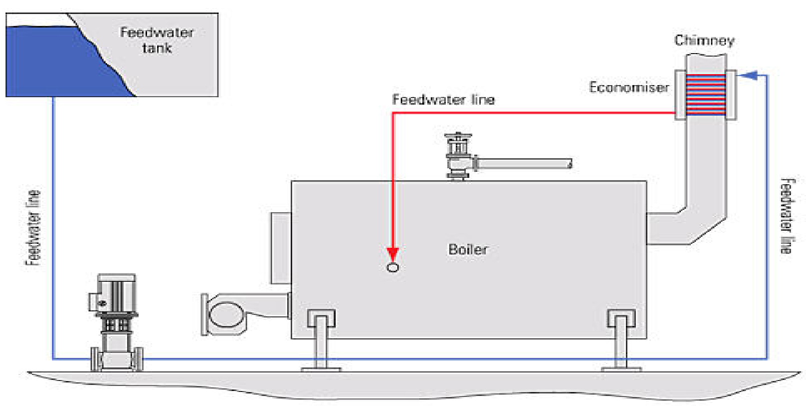


**Figure 4.1**: Heat recovery from stack boiler temperature

The real energy savings from a boiler stack economizer come from the drop in temperature of the flue gases flowing through the economizer, multiplied by the mass flow rate of the flue gases. A typical non-condensing boiler has a flue gas temperature of 135°C (275°F) [47].

The parameters needed in quantifying the available energy in the flue gas were measured using the flue gas analyzer as shown in Table 4.1.

In order to calculate the available heat in the flue gas we use equation 4.3:

Available heat = flue gas mass flow rate × specific heat × temp. drop

$$Q = m \times C_p \times \Delta T \qquad 4.3$$

Mass flow rate (m) = density × area × velocity

where:

Q: The available heat (kJ/kg)
m: flue gas mass flow rate (kg/sec)
$C_p$: gas specific heat (kJ/kg. ˚C)
$\Delta T$: the temperature differential (˚C)

### 3. Increasing the make-up water temperature using solar water heater (SWH)

The amount of make–up water needed per day for the boiler at Al Safa factory is approximated to be 1.5 $m^3$.

The SWH could increase the water temperature coming from the source (municipality) up to 70˚C.

The amount of energy required for increasing 1.5 $m^3$ water from 15˚C to 70˚C is calculated from equation 4.3, which was found equal to 95.8 kWh/ day.

This amount of energy could be saved by using SWH instead of the boiler which will depend on the boiler efficiency used.

The area of the collectors needed to attain this energy is calculated as follows:

Area of collectors = kWh produced/ (average solar radiation × $\eta_{collector}$ )

= 46 m²

Number of collectors required = total area/area of one collector

= 27 collectors required

Figure 4.2 illustrates the collectors' distribution of the SWH for Al Safa Dairy Factory.

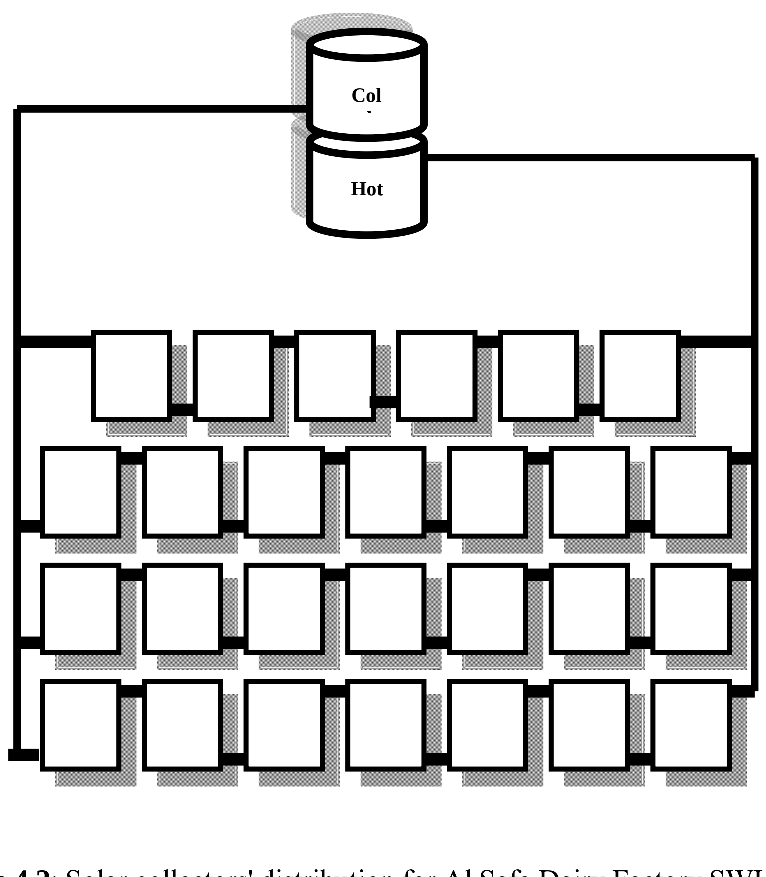


**Figure 4.2**: Solar collectors' distribution for Al Safa Dairy Factory SWH

### 4.1.2 Improving the operating condition of the compressed air system

Compressed air system at Al Safa factory consists from one main compressor, air receiver and air dryer. Table 4.5 below shows the compressor's data for Al Safa factory.

**Table 4.5**: Al Safa dairy factory compressor's data

| | |
|---|---|
| Compressor type | Displacement rotary screw type-model cyclon 222-1999 |
| Rated power | 26.1 kW |
| Capacity | 3.49 $m^3$/min |
| RPM | 2960 |
| Max pressure | 8.2 bar |
| Operating pressure | 6-6.2 bar |

**Free air delivery (FAD) calculation for the compressor at Al Safa factory**

Calculation of the FAD is used as an indicator about the presence of a problem in the compressor, in order to fix this problem as soon as possible to avoid unnecessary additional cost when the compressed air system is operated inefficiently comparing it with the rated FAD written on the name plate of the compressor.

Equation 4.4 is used to calculate the FAD [48].

FAD = receiver vol. × (starting pres. - final (cut-off) pres.)/ fill receiver time

$$FAD = V_R \times (P2-P1)/T \qquad 4.4$$

The measured parameter at Al Safa dairy factory was as follows:

$V_R = 1\ m^3$, $P1 = 0.5\ bar_g$, $P1 = 6.0 bar_g$, $T\ =2.05$ minutes.

Applying equation 4.4.

FAD = 2.7$m^3$/min.

Table 4.6 illustrates the compressor rated and measured FAD, and the specific power consumption.

**Table 4.6**: FAD and specific power consumption for Al Safa compressor

| **Particulars** | **Unit** | **Compressor cyclon 222-1999** |
|---|---|---|
| Manufacturer | - | Kaeser BS61 |
| Comp. type | - | Screw |
| Motor rating | kW | 26.1 |
| Measured power during loading | kW | 15 |
| Rated FAD | $m^3$/min | 3.49 |
| Calculated FAD | $m^3$/min | 2.7 |
| Specific Power consumption | (kW/m3/min) | 5.55 |

The specific power consumption (SPC) is calculated as follows:

SPC = Measured power during loading (kW)/ calculated FAD ($m^3$/min).

From table 4.6 it seems that the specific power consumption for the compressor at Al Safa is relatively high 5.55 kW/$m^3$/min comparing to 4.3 kW/$m^3$/min in case the compressor was working with the rated FAD, and this is an indication that the compressor is not working efficiently.

**1. Arresting the air leakage for the compressor (Load/No load test)**

This test is done on the compressor in order to determine any leakages of air in the air distribution pipes which consider waste of energy because it forces the compressor to work continually and consumes more energy to replace the wasted air.

The test procedure illustrated by accounting the time of loading and unloading and then calculation of wasted energy. Table 4.7 illustrates the air leakage test conducted on the air compressor of Al Safa dairy factory.

**Table 4.7**: Air leakage test for al Safa compressor

| | **On – line (Sec)** | **Off- line (sec)** |
|---|---|---|
| Cycle 1 | 4.9 | 19.1 |
| Cycle 2 | 5.18 | 22.21 |
| Cycle 3 | 6.14 | 18.66 |
| Cycle 4 | 6.58 | 23.4 |
| **Average time** | **5.7** | **20.84** |
| **W loaded** | **15 kW** | |
| **W unloaded** | **2.4 kW** | |

Calculation of the additional power demand for the coverage of the wasted energy is done by applying equation 4.5 [29].

$$\text{Additional power (kW)} = (W_{loaded} - W_{unloaded}) \times (T/T+t) \qquad 4.5$$

where:

$W_{loaded}$: Power requirement during "loaded" mode (kW)
$W_{unloaded}$: Power requirement during "unloaded" mode (kW)
T = Time running "loaded" (sec)
t = Time running "unloaded" (sec)

From Table 4.7:

Additional demand (kW) = 2.706 kW wasted power per hour.

**2. Improving the inlet air temperature conditions**

The average inlet air temperature of the compressor unit at Al Safa factory was measured and found 31 C° and the average outdoor temperature was 20 C°. This means a good opportunity to save energy if the inlet air temperature reduces to 20 C° simply by installing an air intake duct from outside the building instead of drawing air from the warmer plant environment or by changing the location of the compressor to be able to get its intake air from the surrounding.

The reduced power requirement can be calculated from equation 4.6 which is derived from the ideal compression power equation [30, 31]:

$$W_2 = W_1 \times \{1 + [0.00341 \times (T_2 - T_1)]\} \qquad 4.6$$

$W_1$, $W_2$ = initial and final ideal compression powers (kW)
$T_1$, $T_2$ = initial and final inlet air temperatures (°K)

It was found that $W_2$ = 14 kW and this means 1 kW power reduction per hour.

### 4.1.3 Lighting system improvement

Lighting at Al Safa factory according to the measurements taken by the Lux meter and comparing them with the standards are very excessive in many areas. Table 4.8 illustrates the existing lights and their power capacity at Al Safa factory.

**Table 4.8**: Number and capacity of existing lighting luminaries at Al Safa dairy factory

| Type of fixture | Wattage | No. units | Total kW* |
|---|---|---|---|
| Fluorescent lamps 2 ×36 with conventional ballasts | 36 | 191×2 | 16.5 |
| Fluorescent lamps 4×18 with conventional ballasts | 18 | 12×4 | 1.04 |
| CFL' | 9 | 18×2 | 0.39 |
| Fluorescent lamps 1×13 with conventional ballasts | 13 | 12×1 | 0.19 |
| Floodlights Mercury | 400 | 4×1 | 1.92 |
| Floodlights sodium | 150 | 10×1 | 1.8 |
| **Total** | | | **21.84** |

* Including 20% additional wattage for ballasts

Total energy consumed by lighting system at Al Safa dairy factory is accounted to 78624 kWh/year (12.5 % of total electric energy consumption) at a cost of 9435 JD per year.

Three energy conservation opportunities (ECOs) could be implemented in this factory in some areas were the lighting found to be very excessive comparing to the standards.

### 1. Reducing the number of lighting Lamps

In certain areas of the factory, the lux meter was used in order to measure the illumination, it was found that the illuminations were above the standard illuminations required for the certain areas or places, Annex (1).

In order to calculate the optimum number of fixtures and reducing the number of excessive lamps equation 4.7 was used [32]:

$$N = (E \times A) / (n \times \Phi \times K_u \times K_m) \qquad 4.7$$

where:

N**:** number of units, E: illumination lm/m² (lux), A: area in m², n: number of lamps in the unit, Φ: luminous flux in lumen, $K_u$: reflectance factor (it depends on the color of walls, 0.6-0.8), $K_m$: maintenance factor (it depends on the condition of the lamp, clean or not, 0.6- 0.8).

Applying equation 4.7 using the standard luminance for the certain areas and comparing it with the measured ones using the Lux meter, we have the proposed lights illustrated in Table 4.9.

As an example if we apply equation 4.7 in the offices with area 65 m² (Table 4.9), we could find the number of units required is 12 units instead of 17 units. Therefore 5 units could be removed as illustrated in Table 4.9, and this procedure is followed for the rest of areas.

**Table 4.9**: Existed and proposed lighting system at Al Safa dairy factory

| **Existing System of lighting** | | | | | | **Proposed System of Lighting** | | | |
|---|---|---|---|---|---|---|---|---|---|
| Area Name. | Lamp Type | Lamp Wattage | No. of units | Usage Time | Energy * Used (kWh/Yr) | No. of units | Energy Used (kW/yr) | Energy Savings (kWh/yr) | Cost Savings (JD/yr) |
| Offices 65 m² | FL | 36 | 17 | 3600 | 5288 | 12 | 3732 | 1556 | 186 |
| Main Prod. Area 170 m² | FL | 36 | 50 | 3600 | 15552 | 34 | 10576 | 4976 | 596 |
| Boiler and equipment room | FL | 36 | 30 | 3600 | 9332 | 20 | 6220 | 3112 | 374 |
| Filling Room | FL | 36 | 54 | 3600 | 16796 | 36 | 11198 | 5598 | 672 |
| Receiving and Sterilized room | FL | 36 | 26 | 3600 | 8086 | 17 | 5288 | 2798 | 336 |
| Ref. | FL | 36 | 14 | 3600 | 4354 | 7 | 2178 | 2176 | 260 |
| **Totals** | | | | | | | | **20216** | **2424** |

- Including 20% additional wattage for ballasts

## 2. Install high efficiency lighting lamps

Many of the work areas at Al Safa dairy factory are lighted by standard efficiency fluorescent lights. If the factory management starts to phase out inefficient lighting now by replacing the lights that burn out with high – efficiency (low voltage) lights, it will be able to implement this Energy Conservation Opportunity (ECO) without noticing an appreciable implementation cost. This is because it will have no additional labor cost when you replace lights on an as-needed basis, and the management will begin to see savings in its electric bills that will repay your additional cost of implementation [33].

Table 4.10 provides the existing lighting and the proposed changes. These calculations assume that you have already implemented the first ECO mentioned above. If you decided not to implement that ECO, then the savings from this ECO would be greater because the number of lamps as well wattages would be greater.

The values calculated in the proposed lighting section were based on replacement of existing lamps (low efficient FL 36 w) with the recommended lamps (High efficient T8 FL, 32 w).

**Table 4.10**: Existed and proposed changes conditions at Al Safa after reducing lamps and using high efficient lamps

| **Existing Conditions** | | | | | | **Proposed Conditions** | | | **Savings** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Lamp type | Rating W | # of units | Annual operating hours | kW* | kWh | Replacing lamps | kW | kWh | kW | kWh |
| Conv. Fluor. | 36 | 126 | 3600 | 10.88 | 39190 | HF/32W | 9.67 | 34836 | 1.21 | 4354 |
| Total | | | | 10.88 | 39190 | | 9.67 | 34836 | 1.21 | 4354 |

* Including 20% additional wattage for ballasts

### 3. Install reflectors in lighting fixtures

Special reflectors are available for fluorescent lamp fixtures. These reflectors approximately double the light output of the light fixture. Once the reflectors installed in the fixtures, one lamp could be disconnected in every two-lamp fixture. When the lamp disconnected, the ballast also should be disconnected for that lamp because ballasts draw energy whether the lamp is working or not. Reducing the number of lights in this situation will not appreciably decrease the light levels in the facility [32].

Tables 4.11 and 4.12 show the existed and the proposed energy demand and the proposed energy usage of Al Safa dairy factory for this energy conservation opportunity. These calculations assume that you have already implemented the two previous ECOs. If you decided not to implement those ECOs, then the savings from this ECO would be greater because the lamp wattages would be greater.

**Table 4.11**: Existed and proposed lighting at Al Safa dairy factory by using reflectors

| **Existing Lighting** | | | | | |
|---|---|---|---|---|---|
| Lamp Type | No. of units | Lamp Wattage (W) | Total Wattage (kW) | Usage Time | Total Energy Used (kWh/yr) |
| HF | 126 | 32 | 9.67 | 3600 | 34836 |
| Total | | | | | **34836** |
| **Proposed Lighting** | | | | | |
| Lamp Type | Lamp Wattage (W) | Present No. of lamps | Recomm. No. of lamps | Present No. of Ballasts | Recomm. No. of Ballasts |
| HF | 32 | 252 | 126 | 252 | 126 |

**Table 4.12**: Proposed energy usage with reflectors installation at Al Safa factory

| **Proposed Energy Usage** | | | | |
|---|---|---|---|---|
| Lamp Type | Lamp Wattage (W) | Recommended No. of Lamps | Usage Time (hr) | Proposed Energy Usage (kWh/yr) |
| HF | 32 | 126 | 3600 | 17418 |
| Total | | | | **17418** |

### 4.1.4 Power factor improvement

The main electrical source for the Al Safa factory is Nablus municipality via three feeders of 200 kVA maximum capacities. The average power factor measured by energy analyzer for 24 hours was 0.7 (Annex2).

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.

- **Power factor saving opportunities**

  The saving opportunity is summarized by installing capacitors bank parallel to the loads to correct the phase angle between the voltage and current as a result of raising the power factor to 0.92 as the acceptable value for the electricity suppliers (required from the IEC) in order to avoid the low power factor penalties, which they are suppose to be imposed by the municipality soon according to Table 4.13 [34].

**Table 4.13**: Power factor proposed penalties in Palestine [34].

| Power Factor value | Penalty |
|---|---|
| 92% or more | None |
| Less than 92% to 80% | 1% of the total bill for every 0.01 of power factor less than 92% |
| Less than 80% to 70% | 1.25% of the total bill for every 0.01 0f power factor less than 92% |
| Less than 70% | 1.5% of the total bill for every 0.01 of power factor less than 92% |

- **Methodology used on correcting power factor.**

Measuring the average power factor of the factory for a sufficient period of time using the energy analyzer device.

Figure (4.3) illustrates the existed average power factor and average real, apparent and reactive power for 24 hours at Al Safa dairy factory (Annex2).

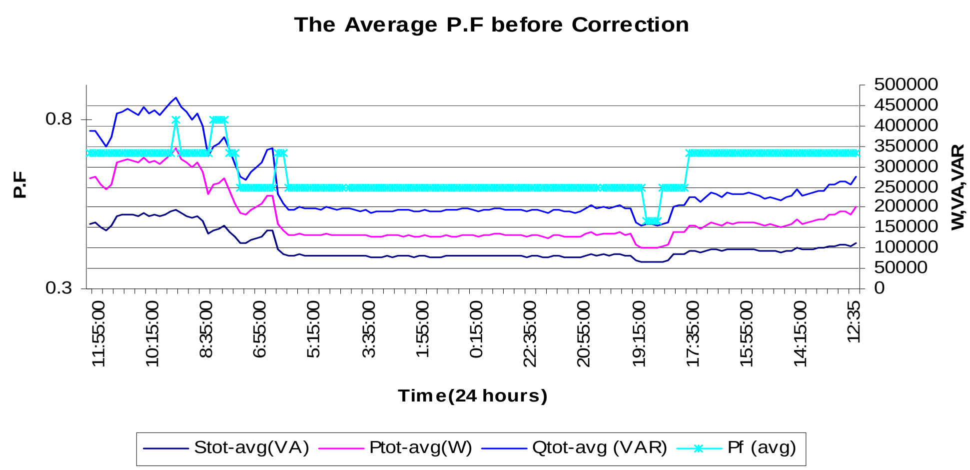


**Figure 4.3**: Average power factor measured at Al Safa (before improvement).

Installing fixed capacitor bank where $Q_c$ (fixed) < $Q_c$ min, figure below illustrates the average power factor after installing 40 kVAr fixed capacitor bank. The reactive power of the capacitor $Q_c$ required for improvement the PF is calculated from equation 4.8.

$$Q_c = P[\tan \Phi_1 - \tan \Phi_2] \qquad 4.8$$

Where $Q_c$ the reactive power of the capacitor in (kVAr), P the active power (kW); $\Phi_1$ and $\Phi_2$ the angles between voltage and current before and after power factor correction respectively.

Figure 4.4 illustrates the average power factor after installing 40 kVAr calculated using equation 4.8 and (Annex2).

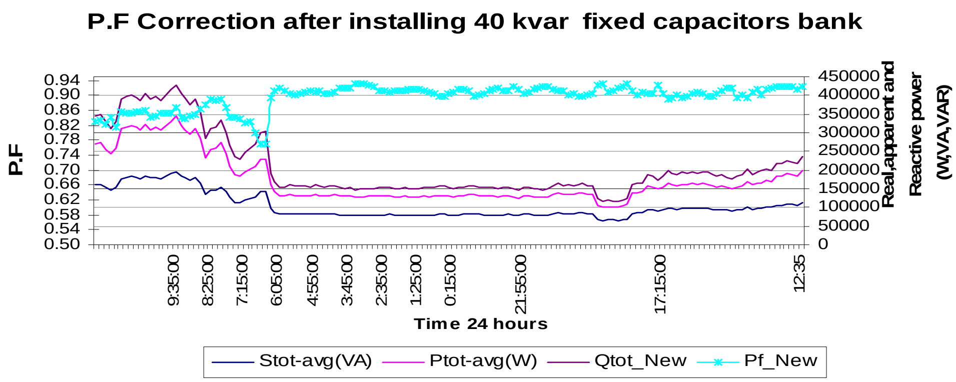


**Figure 4.4**: Improving power factor after installing fixed capacitor of 40 kVAr -Al Safa

As shown in Figure 4.4, the power factor has been improved, but still low and less than the permissible for a specific period from 6:35 Am to 12:15 PM.

After studying the load at Annex 2-, a 25 kVAr capacitors bank is proposed to be installed in this period and controlled by a timer circuit.

Figure 4.5 illustrates the average power factor after entering the controlled capacitors bank to the feeders and it has been fully corrected.

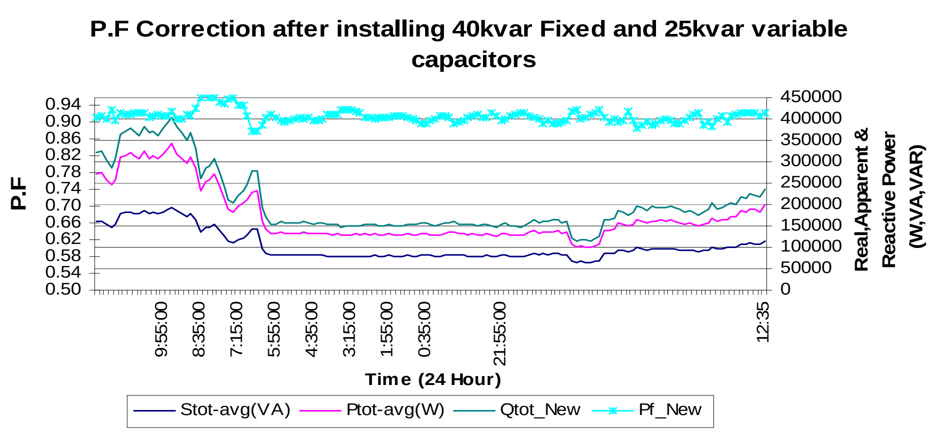


**Figure 4.5**: Improved power factor using 40 kVAr fixed and 25 kVAr variable capacitor-Al Safa Factory.

## 4.2 The Case of the National Carton Company

### 4.2.1 Improving boiler system operation

**Table 4.14**: Al Carton boiler and combustion measured operating data

| | |
|---|---|
| **Data measured by thermometer** | |
| Receiver tank temperature (condensate water) | 40C° |
| Pressure output (it is distributed into branches) | 8.8 bar |
| Inlet air temperature ( combustor) | 18 C° |
| Ambient temperature (Boiler room) | 20 C° |
| | |
| **Combustion analyzer** | |
| Combustion exhaust air | 203 C° |
| O2 | 9.5 % |
| CO2 | 9.4 % |
| Losses | 15.1 % |
| Excess air | 45% |
| Combustion Efficiency | 80.7 % |
| Chimney's diameter | 0.45 m |
| Average flue gas velocity | 3.8 m/sec |

Using equation 4.1 and the procedure followed in the calculation of of Al Safa boiler efficiency, and oil No. 6 used as fuel source; it was found that the water flow rate 679 kg/h and rate of fuel consumption 47.5 kg/h, therefore the efficiency of the boiler at Al Carton factory was 76.5%.

## 1. Adjusting boiler air – fuel ratio

From Table 4.14 and using Figure 2.1, the amount of fuel that could be saved is about 5% of the total fuel consumption.

Or by adjusting the air –fuel ratio to the optimum values, so the combustion efficiency increased from 80.7% to 84.3% (measured), then using equation 4.2 the amount of fuel saving could be calculated.

**2. Increasing the feed water temperature using heat from stack temperature.**

Applying equation 4.3, the amount of available heat in the flue gas could be found and the fuel saving could be calculated based on parameters in Table 4.14.

**3. Increasing the make-up water temperature using solar water heater (SWH)**

Using equation 4.3, it was found that 80 kWh per day is needed to heat up 1.25 m³ of make – up water from 15 to 70˚C. This amount of energy could be saved using SWH system instead of boiler with efficiency 76.5% as the case at Al Carton. The SWH system required is consists of 24flat plate collectors.

### 4.2.2 Improving the operating condition of the compressed air system

**Table 4.15**: FAD and specific power consumption for Al Carton compressor

| **Particulars** | **Unit** | **Compressor cyclon 222-1999** |
|---|---|---|
| Manufacturer | - | Kaeser BS61 |
| Comp. type | - | Screw |
| Motor rating | kW | 37 |
| Measured power during loading | kW | 28.7 |
| Rated FAD | $m^3$/min | 5.4 |
| Calculated FAD | $m^3$/min | 3.8 |
| Specific Power consumption | (kW/m3/min) | 7.55 |

Using equation 4.4, the FAD for Al Carton factory compressor was calculated, where the measured parameters were as follows:

$V_R = 1.25\ m^3$, $P1 = 0.3\ bar_g$, $P2 = 5.8\ bar_g$, $T = 1.8$ minutes.

Scenarios of improving working conditions for the compressed air system at Al Carton factory are as follows:

**1. Arresting the air leakage for the compressor (Load/No load test):**

**Table 4.16**: Air leakage test for al Carton compressor

| | **On – line (Sec)** | **Off- line (sec)** |
|---|---|---|
| Cycle 1 | 5.4 | 20.3 |
| Cycle 2 | 5.7 | 22.3 |
| Cycle 3 | 6.35 | 23.15 |
| Cycle 4 | 6.83 | 24.7 |
| **Average time** | **6.07** | **22.61** |
| **W loaded** | **28.7 kW** | |
| **W unloaded** | **3.6 kW** | |

The additional wasted power for air leakage is calculated using equation 4.5 and it was found 5.3 kW per hour.

**2. By improving the inlet air temperature conditions:**

The reduced power requirement can be calculated from equation 4.6 by decreasing the inlet air temperature of the compressor from **19 to 11 C°** by simply drawing air from the surrounding.

It was found that $W_2 = 27.3$ kW which means 1.4 kW power reduction per hour.

### 4.2.3 Power factor improvement

The average power factor measured by energy analyzer for 24 hours was 0.72 (Annx.3).

The required action for power factor improvement is installing capacitors banks parallel to the loads to correct the phase angle between the voltage and current as a result of raising the power factor to 0.92. The capacitors banks needed are one is 0.8 kVAr fixed capacitor and one is 170 kVAr as a variable capacitor controlled by a timer circuit from 7:35 to 21:02 using equation 4.8 (Annex3).

## 4.3 The Case of Al – Arz Ice Cream Factory

The audited systems at Al Arz ice cream factory were the boiler system, the compressed air system and lighting system. For the issue of power factor improvement, using the energy analyzer equipment, it was found that the power factor is above the minimum value required 92% due to that the factory's management had already installed capacitors bank for the improvement (Annex4).

### 4.3.1 Improving boiler system operation

**Table 4.17**: AL Arz boiler and combustion measured operating data

| | |
|---|---|
| **Data measured by thermometer** | |
| Receiver tank temperature (condensate water) | 47C° |
| Pressure output (it is distributed into branches) | 8 bar |
| Inlet air temperature ( combustor) | 14 C° |
| Ambient temperature (Boiler room) | 18 C° |
| Boiler operating hours | 2500 h |
| **Combustion analyzer** | |
| Combustion exhaust air temperature | 261 C° |
| O2 | 7.7 % |
| CO2 | 9.8 % |
| Losses | 27.3 % |
| Excess air | 53 % |
| Combustion Efficiency | 72.7 % |
| Chimney's diameter | 0.32m |
| Average flue gas velocity | 3.3 m/sec |

Using equation 4.1 and the procedure followed in the calculation of Al Safa boiler efficiency, and oil No. 2 used as fuel source; it was found that the water flow rate 294 kg/h and rate fuel consumption 24.5 kg/h, therefore the efficiency of the boiler at Al Arz factory was 69.1%.

## 1. Adjusting boiler air – fuel ratio

From Table 4.17 and using figure 2.1, the amount of fuel that could be saved is about 3.8% of the total fuel consumption.

Or by adjusting the air –fuel ratio to the optimum values, so the combustion efficiency increased from 72.7 to 75.5% by reducing the excess air (tested and measured), then using equation 4.2 the amount of fuel saving could be calculated.

**2. Increasing the feed water temperature using heat from stack temperature.**

Applying equation 4.3, the amount of available heat in the flue gas could be found and the fuel saving could be calculated based on parameters in Table 4.17.

**3. Increasing the make-up water temperature using solar water heater (SWH)**

Using equation 4.3, it was found that 95.8 kWh per day is needed to heat up 1.5 $m^3$ of make – up water from 15 to 70˚C. This amount of energy could be saved using SWH system instead of boiler with efficiency 69.1% as the case at Al Arz factory. The SWH system required is consists of 27 flat plate collectors.

### 4.3.2 Improving the operating condition of the compressed air system

**Table 4.18**: FAD and specific power consumption for the two compressors at Al Arz Ice-Cream Factory.

| **Particulars** | **Unit** | **Comp # 1** | **Comp # 2** |
|---|---|---|---|
| Comp. type | - | Screw | Screw |
| Rated Motors | kW | 75 | 55 |
| Rated FAD | $m^3/min$ | 12.72 | 9.1 |
| Calculated FAD | $m^3/min$ | 8.36 | 6.73 |
| Measured power during loading | kW | 46.8 | 28.6 |
| Specific power consumption | (kW/m3/min) | 5.6 | 4.25 |

Using equation 4.4, the FAD of the two compressors at Al Arz factory were calculated as the measured parameters were as follows:

For compressor #1:
$V_R = 2\ m^3$, P1 = 0.3 $bar_g$, P2 = 7.2 $bar_g$ ,T =1.65 minutes.
For compressor #2:
$V_R = 1.25\ m^3$, P1 = 0.0 $bar_g$, P2 = 7.0 $bar_g$ ,T =1.3 minutes.

**1. Arresting the Air leakage for the compressor #1 (Load/No load test)**

Compressor #1 is the main and more operating in the factory, so our audit was taking only on this compressor.

**Table 4.19**: Air leakage test taking on main compressor at Al Arz factory

| | **On - line (Sec)** | **Off- line (sec)** |
|---|---|---|
| Cycle 1 | 5.6 | 24.2 |
| Cycle 2 | 5.2 | 22 |
| Cycle 3 | 5.5 | 24 |
| Cycle 4 | 5.8 | 25 |
| **Average time** | **5.525** | **23.8** |
| **W loaded** | **46.8 kW** | |
| **W unloaded** | **7.48kW** | |

The additional wasted power for air leakage is calculated using equation 4.5 and it was found 7.4 kW per hour.

**2. Improving the inlet air temperature conditions**

Both of the compressors are located outdoor, so the intake air temperature is the outdoor temperature which is the optimum operating conditions, except for the compressor number 1 is located next to the boiler (outdoor) as a result of heating up the surrounding air.

The intake air temperature for this compressor was measured at 31° C, while the outdoor temperature was 18 ° C, so it is an opportunity for saving by changing the location of the compressor.

The reduced power requirement can be calculated from equation 4.6 and it was found that:

$W_2$ = 43 kW, which means 3.8 kW power reduction per hour.

### 4.3.3 Improving the lighting system

In general lighting at Al Arz facility is within the optimum range according to the measurements taken using the lux meter in different areas of the facility, so Energy Conservation Opportunities are limited in two directions:

## 1. Install high efficiency lighting lamps

**Table 4.20**: Existed and proposed changes conditions at Al Arz after installing efficient Lamps.

| Existing Conditions | | | | | | Proposed Conditions | | | Savings | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lamp type** | Rating (W) | # of lamps | Annual operating hours | kW* | kWh | Replacing lamps | kW | kWh | kW | kWh |
| Conv. Fluor. | 40 | 122 | 4000 | 5.86 | 23424 | HF/32W | 4.68 | 18739 | 1.18 | 4685 |
| Conv. Fluor. | 36 | 130 | 4000 | 5.62 | 22464 | HF/32W | 5.0 | 19968 | 0.62 | 2496 |
| Incan. | 40 | 9 | 4000 | 0.432 | 1728 | CFL/9W | 0.097 | 389 | 0.335 | 1339 |
| Incan. | 75 | 4 | 4000 | 0.36 | 1440 | CFL/9W | 0.043 | 172 | 0.317 | 1268 |
| **Total** | | | | **12.27** | **49056** | | **9.82** | **39268** | **2.452** | **9788** |

- Including 20% additional wattage for ballasts

## 2. Install reflectors in lighting fixtures

**Table 4.21**: Existed and proposed lighting at Al Arz factory after installing reflectors

| **Existing Lighting** | | | | | |
|---|---|---|---|---|---|
| Lamp Type | No. of lamps | Lamp Wattage (W) | Total Wattage (kW) | Usage Time | Total Energy Used (kWh/yr) |
| HF | 252 | 32 | 9.67 | 4000 | 38680 |
| Total | | | | | **38680** |
| **Proposed Lighting** | | | | | |
| Lamp Type | Lamp Wattage (W) | Present No. of lamps | Recomm. No. of lamps | Present No. of Ballasts | Recomm. No. of Ballasts |
| HF | 32 | 252 | 126 | 252 | 126 |

**Table 4.22**: Proposed energy usage with reflectors installation at Al Arz factory

| **Proposed Energy Usage** | | | | |
|---|---|---|---|---|
| Lamp Type | Lamp Wattage (W) | Recommended No. of Lamps | Usage Time (hr) | Proposed Energy Usage (kWh/yr) |
| HF | 32 | 126 | 4000 | 19353 |
| Total | | | | **19353** |

## 4.4 The Case of Al Aqqad Textile Factory

The audited systems at Al Aqqad factory were the boiler, compressed air, lighting and power factor improvement.

### 4.4.1 Improving boiler system operation

**Table 4.23**: AL Aqqad boiler and combustion measured operating data

| **Data measured by thermometer** | |
|---|---|
| Receiver tank temperature (condensate water) | 40C° |
| Pressure output | 6 bar |
| Inlet air temperature ( combustor) | 18 C° |
| Ambient temperature (Boiler room) | 20 C° |
| **Combustion analyzer measured data** | |
| Combustion exhaust air temperature | 192 C° |
| $O_2$ | 9.5 % |
| $CO_2$ | 9.4 % |
| Losses | 15.1 % |
| Excess air | 75 % |
| Combustion Efficiency | 80 % |
| Chimney's diameter | 0.40 m |
| Average flue gas velocity | 3.4 m/sec |

Using equation 4.1 and the procedure followed in the calculation of of Al Safa boiler efficiency, and oil No. 6 used as fuel source; it was found that the water flow rate 370 kg/h and the rate fuel consumption 25.27 kg/h, therefore the efficiency of the boiler at Al Aqqad factory was 78.3 %.

### 1. Adjusting boiler air – fuel ratio

From Table 4.23 and using figure 3.1, the amount of fuel that could be saved is about 4.4%. of the total fuel consumption.

Or by adjusting the air –fuel ratio to the optimum values, so the combustion efficiency increased from 80% to 83.5 % (adjusted and measured), then using equation 4.2 the amount of fuel saving could be calculated.

### 2. Increasing the feed water temperature using heat from stack temperature.

Applying equation 4.3, the amount of available heat in the flue gas could be found and the fuel saving could be calculated based on parameters in Table 4.23.

### 3. Increasing the make-up water temperature using solar water heater (SWH)

Using equation 4.3, it was found that 127.7 kWh per day is needed to heat up 2 $m^3$ of make – up water from 15 to 70˚C. This amount of energy could be saved using SWH system instead of boiler with efficiency 78.3% as the case at Al Aqqad. The SWH system required is consists of 36 flat plate collectors.

### 4.4.2 Improving the operating condition of the compressed air system

Compressed air system at Al Aqaad factory consists from one main compressor CS 121 and one standby compressor BS61 in addition to air receiver and air dryer.

**Table 4.24**: FAD and SPC for compressors at Al Aqqad ice-cream factory.

| Particulars | Unit | Comp # 1 | Comp # 2 |
|---|---|---|---|
| Comp. type | - | Screw - Kaeser CS 121 | Screw- Kaeser BS61 |
| Motor rating | kW | 37 | 30 |
| Rated FAD | $m^3$/min | 5.4 | 4.4 |
| Calculated FAD | $m^3$/min | 3.7 | 2.2 |
| Measured power during loading | kW | 31.1 | 2.4 |
| Specific power consumption (SPC) | (kW/m3/min) | 8.4 | 10.18 |

Using equation 4.4, the FAD of the two compressors at Al Aqqad factory was calculated as shown in Table 4.24.

## 1. Arresting the air leakage (Load/No load test)

- **The main compressor CS 121**

**Table 4.25**: Air leakage test taking on main compressor at Al Aqqad factor

| | **On – line (Sec)** | **Off- line (sec)** |
|---|---|---|
| Cycle 1 | 11 | 28.5 |
| Cycle 2 | 10.3 | 28 |
| Cycle 3 | 9.7 | 25.8 |
| Cycle 4 | 9.8 | 26.1 |
| **Average time** | **10.2** | **27.1** |
| **W loaded** | **31.1 kW** | |
| **W unloaded** | **3.1 kW** | |

The additional wasted power for air leakage is calculated using equation 4.5 and it was found 7.65 kW per hour which is about 24.5% of overall demand, the operating hours for the main compressor are 3600 hours per year.

- **The standby compressor BS61**

**Table 4.26**: Air leakage test taking on the standby compressor at Al Aqqad

| | **On – line (Sec)** | **Off- line (sec)** |
|---|---|---|
| Cycle 1 | 6.2 | 23.8 |
| Cycle 2 | 6.4 | 24 |
| Cycle 3 | 5.9 | 22.6 |
| Cycle 4 | 6.2 | 23.2 |
| **Average time** | **6.175** | **23.4** |
| **W loaded** | **22.4 kW** | |
| **W unloaded** | **2.8 kW** | |

The additional wasted power for air leakage is calculated using equation 4.5 and it was found 4.1 kW per hour which is about 18.2 % of overall demand of the compressor, and the operating hours for the standby compressor are 1200 hours per year.

**2. Improving the inlet air temperature conditions**

It was noticed that the intake temperature of the BS 61 Kaeser compressor is directly located at the outlet of the CS 161 compressor.This configuration is illustrated in Figure 4.6.

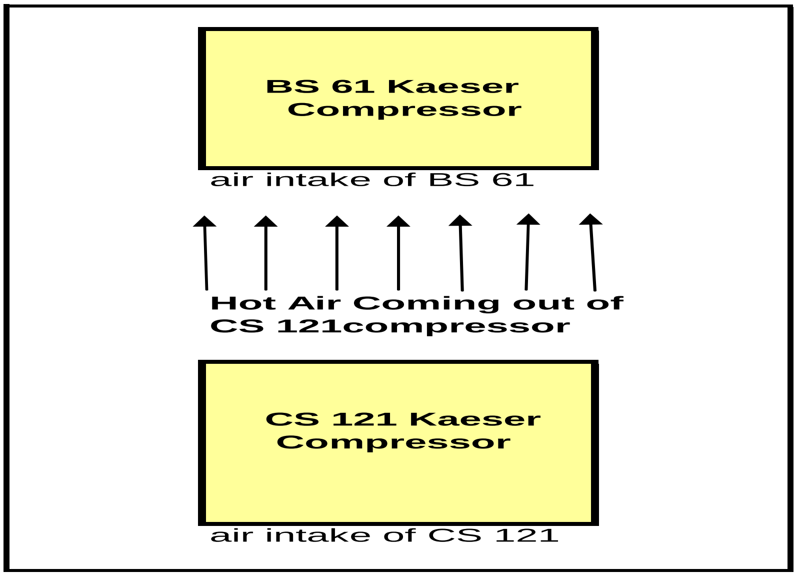


**Figure 4.6**: Present configuration for Kaeser compressors at al Aqqad

This configuration increases the intake temperature of the BS 61 compressor to a great extent, which will consequently increase the energy consumption in this compressor. It is known that every 4C° rise in inlet air temperature will result in about 1 % increase in energy consumption to achieve output.

Therefore, it is recommended to change the orientation of these two compressors to let the BS 61 compressor suck as cold air as possible. This proposed configuration is shown in Figure 4.7.

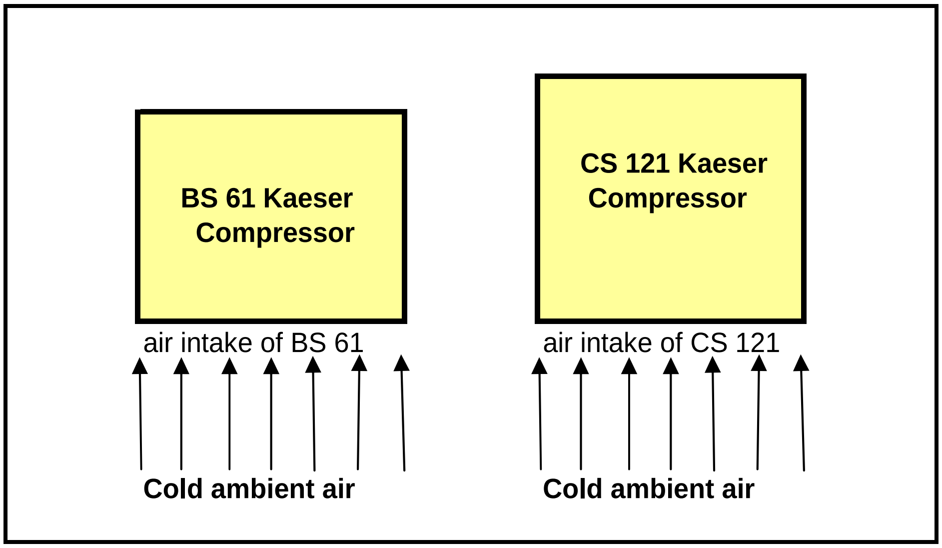


**Figure 4.7**: Proposed configuration for Kaeser compressors at al Aqqad

Therefore, it is recommended to change the present location of the compressors to provide a cooler intake temperature for theses compressors.

Saving resulting from this measure can be simply calculated from equation 4.6.

The temperature of air exiting CS 121 compressor and entering into the BS 61 compressor is 56°C and the outdoor temperature was 17° C.

It was found that the power requirement was reduced from 22.4 kW to 17 kW.

This means 5.4 kW reductions per hour in overall demand of the compressor.

### 4.4.3 Improving the lighting system

Lighting at Al Aqqad factory according to the measurements taken by the Lux meter and comparing them with the standards are very excessive in many areas, especially in cutting, sewing and in the laundry hall. Three ECOs could be implemented in this factory.

### 1. Reducing the number of lighting lamps

Using equation 4.7 on the existed lights at the factory, the proposed system of lighting is presented in Table 4.27.

**Table 4.27**: Existed and proposed lighting system at ALAqqad Textile Factory

| **Existing System of lighting** | | | | | | **Proposed System of Lighting** | | | |
|---|---|---|---|---|---|---|---|---|---|
| Area Nane. | Lamp Type | Lamp ( W) | No. of Lamps | Usage Time | Energy Used (kWh/Yr)* | No. of Lamps | Energy Used (kWh/yr) | Energy Savings (kWh/yr) | Cost Savings (JD/yr) |
| Production Halls | CFL | 36 | 1440 | 2000[2] | 124416 | 960 | 82944 | 41472 | 9538 |
| Washing and Drying | CF | 36 | 204 | 2000 | 17625 | 136 | 11750 | 5875 | 1351 |
| Corridor | CF | 36 | 8 | 2000 | 691 | 4 | 346 | 345 | 79 |
| Corridor | Halogen | 35 | 12 | 2000 | 1008 | 9 | 756 | 252 | 58 |
| Office | CFL | 36 | 18 | 2000 | 1555 | 10 | 864 | 691 | 159 |
| Office | CFL | 18 | 8 | 2000 | 345 | 6 | 259 | 86 | 20 |
| **Totals** | | | | | | | | **48721** | **11205** |

- 0.229 JD/kWh

### 2. Install high efficiency lighting lamps

**Table 4.28**: Existed and proposed changes at Al Aqqad after using high efficient lamps

| **Existing Conditions** | | | | | | **Proposed Conditions** | | | **Savings** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lamp type** | Rating (W) | # of lamps | Annual oper. hours | kW* | kWh | Replacing lamps | kW | kWh | kW | kWh |
| Conv. Fluor. | 36 | 1110 | 2000 | 47.95 | 95904 | HF/32W | 42.62 | 85248 | 5.33 | 10660 |
| **Total** | | | | **47.95** | **95904** | | **42.62** | **85248** | **5.33** | **10660** |

[2] Based on the average lighting hours

### 3. Install reflectors in light fixtures

**Table 4.29**: Existed and proposed lighting at Al Aqqad factory for using reflectors

| **Existing Lighting** | | | | | |
|---|---|---|---|---|---|
| Lamp Type | No. of Lamps | Lamp Wattage (W) | Total Wattage (kW) | Usage Time | Total Energy Used (kWh/yr) |
| HF | 1110 | 32 | 42.62 | - | 85240 |
| Total | | | | | 85240 |
| Proposed Lighting | | | | | |
| Lamp Type | Lamp Wattage (W) | Present No. of Lamps | Recomm. No. of Lamps | Present No. of Ballasts | Recomm. No. of Ballasts |
| HF | 32 | 1110 | 555 | 1110 | 555 |

**Table 4.30**: Proposed energy usage with reflectors installation at Al Aqqad factory

| **Proposed Energy Usage** | | | | |
|---|---|---|---|---|
| Lamp Type | Lamp Wattage (W) | Recommended No. of Lamps | Usage Time (hr) | Proposed Energy Usage (kWh/yr) |
| HF | 32 | 555 | - | 42620 |
| **Total** | | | | **42620** |

### 4.4.4 Power factor improvement

The average power factor measured by energy analyzer for 24 hours was 0.78. The required action for power factor improvement is installing capacitors banks parallel to the loads to correct the phase angle between the voltage and current as a result of raising the power factor to 0.92. The capacitors banks needed are one is 20 kVAr fixed capacitor , 50 kVAr and 20 kVAr as a variable capacitors controlled by a timer circuit from 8.32 to 17:02 and 17:02 to 18:12 respectively using equation 4.8 and as is showed in Annex (5).

For Al Aqqad factory and implementing the previous energy conservation opportunities, the saving could be doubled or even more if the factory replace its power supply from local diesel generators as it is right now to be connected with the electrical grid which considered cheaper if we compare the cost of one kWh produced by the diesel generator to the cost of one kWh supplied by the electrical grid. In chapter five this comparison will be presented.

# CHAPTER FIVE

# ECONOMICAL EVALUATION OF ENERGY AUDITS IN INDUSTRIAL SECTOR IN PALESTINE

In the previous chapter the technical analysis for each energy conservation opportunity on different systems was produced and analyzed. This chapter will be focused on the calculation of the savings in each ECO, the amount of energy saved (electric and fuel) and the equal amount of money, the investment cost required to implement this opportunity in order to achieve this saving and the simple payback period will be the judgment on this investment in order to be feasible.

## 5.1 Economical Evaluation of Energy Conservation Opportunities at Al Safa Dairy Factory.

Four systems were examined and audited at Al Safa factory, boiler system, compressed air system, lighting system and power factor improvement. The energy saving for each opportunity was determined and the feasibility of implementing this opportunity was analyzed.

### 1. Energy saving for the boiler system:

- **Adjusting boiler air – fuel ratio**

  If it is assumed that the boiler consumes all of the fuel oil consumed in the factory during the year, then the 0.8% fuel savings using Figure 2.1 are equal to:

  Fuel Saving = annual fuel consumption × fuel percentage savings

  Saving = 109200 (lt/year) × 0.008 = 874 lt/year

  Cost savings = Savings (lt/year) × Fuel Price (JD/lt)

  = 655.5 JD/year

The implementation cost to do this scenario is the purchasing of combustion analyzer equipment kit which its price in the range of 1500 JD. The combustion efficiency should be checked bi-monthly basis. This is a simple procedure, requiring about 30 minutes.

Simple payback period (SPBP) = Implementation cost / Annual cost savings

= 2.3 years

The annual fuel savings could be realized also by increasing the combustion efficiency to a value of 81.2 % instead of 80.5% (Table 4.1) by adjusting the air –fuel ratio, as in our case, this saving is calculated using equation 4.2.

Fuel saving = U × [1- ($\eta_{before/}$ $\eta_{after}$)]

= 941 lt/year

Annual money saving = Fuel saving/y × Fuel price (JD/lt)

= 706 JD/yr

- **Increasing the feed water temperature using heat from stack temperature.**

Applying equation 4.3:

In order to calculate the heat available in the flue gas we proceed as follows:

Diameter of the boiler chimney = 0.4m
Measured average flue gas velocity = 3 m/sec.
Measured average flue gas temperature = 205 °C.

Temperature drop = 55 °C, (205 – 150) °C. Where the 150°C is a temperature above the dew point temperature which is around 135 to 140°C for security reasons.

Mass flow rate = velocity × area × air density

= 0.37 kg/sec

Available heat = air mass flow rate × air specific heat × temperature drop.

= 21.4 kW

Now assuming a heat transfer efficiency of 90%, the available heat will be about 19.2 kW. Therefore, the resulting rise in the temperature of the boiler feed water will be:

Temperature rise = heat available /( water flow rate × water specific heat)

= 40 °C

Therefore, if the average boiler feed water temperature in the receiver tank is 48°C (Table 4.1) then the boiler feed water temperature will be approximately 88°C.

Therefore, energy saved = water flow rate × difference in water enthalpy.

Therefore, energy saved= 69064 kJ/h

This amount of energy costs the present boiler the following amount of fuel:

Fuel saved = Energy saved in kJ/ (boiler efficiency × heating value of fuel)

= 2.17 kg/h

Now based on a total number of 3600 operating hours annually, this is equal to 7812 kg are saved annually, which is equal to **8281 liters** which cost **6210 JD** annually.

To calculate the pay back period of this system, the approximate cost of the economizer and the additional piping and insulation is about **10,200 JD**. Therefore the pay back period is about **1.6 years** which is very reasonable.

- **Increasing the make-up water temperature using solar water heater (SWH)**

  Using the SWH for heating 1.5 $m^3$ from 15 to 70˚C required 95.8 kWh per day, if the boiler at Al Safa with 75.8% efficiency was used, the amount of savings is calculated as:

Annual fuel saving = (kWh required × sunny days/y)/(fuel HV × boiler eff.)

= 2297 Kg/year of fuel

The total cost for the whole SWH system is around 1700 JD.

SPBP = 0.93 year

- **Energy saving summary for the boiler system at Al Safa Dairy Factory**

  Table 5.1 summarizes the saving measure opportunities implemented on the boiler system with the amount of savings that accounted to 10.7 % from the total diesel consumption at the factory for one year; the investment cost and the simple pay back period are also presented.

**Table 5.1**: Energy saving summary from improvement of boiler operation at Al Safa factory

| Energy saving measures | Savings (JD) | Investment (JD) | Pay Back Period (Year) |
|---|---|---|---|
| Adjusting the Air – Fuel Ratio | 706 | 1500 | 2.12 years |
| Increasing the feed water temperature using heat from stack temperature. | 6210 | 10200 | 1.6 year |
| Increasing the Make-up water temperature using SWH | 1826 | 1700 | 0.93 year |
| **Total** | **8742** | **15700** | **1.8 year** |

## 2. Energy saving for the compressed air system

- **Arresting the air leakage for the compressor (Load/No load test)**

  Using Table 4.7 and applying equation 4.5:

$$\text{Additional power (kW)} = (W_{loaded} - W_{unloaded}) \times (T/T+t)$$

Additional demand (kW) =2.706 kW

Air leakage cost = additional power × annual operating hours × price of kWh

= 1170 JD/y

If we assume that 90 % of the leaks can be arrested, so the annual saving will be about 1053 JD.

The investment cost summarizes on improving the maintenance procedure, retrofitting control valves and fittings. The estimation cost, according to the maintenance manager, around 150 JD.

SPBP =0.14 year

- **Improving the inlet air temperature conditions**

  Applying equation 4.6:

  $W_2 = W_1 \times \{1 + [0.00341 \times (T_2 - T_1)]\}$

  W2 = 14kW

From the above calculation, it is noticed that the power is reduced from 15 kW to 14 kW by drawing colder air from surrounding, which means 1 kW reductions per hour.

Energy reduced = power reduction× operating hours

= 3600 kWh per year

Money saving = energy reduced × cost of kWh

= 432 JD per year

The investment cost required for this saving is the price and the installation cost of the duct which estimated at 160 JD.

SPBP = 0.4 year.

- **Energy Saving Summary for the compressed air system at Al Safa Dairy Factory**

Table 5.2 summarizes the saving measure opportunities implemented on the compressed air system with the amount of savings which accounts to 2 % of total electric energy in the factory, the investment cost and the simple pay back period are also illustrated.

**Table 5.2**: Energy saving summary from improvement of compressed air system conditions at Al Safa factory.

| **Energy saving measures** | **Savings (JD)** | **Investment (JD)** | **Pay back period (Year)** |
|---|---|---|---|
| Arresting Air leakage | 1053 | 150 | 0.14 year |
| Improving the inlet air temperature conditions | 432 | 160 | 0.4 year |
| **Total** | **1485** | **310** | **0.2 year** |

**3. Energy saving for the lighting system**

- **Reducing the number of lighting lamps**

From Table 4.9, the amount of saving by implementing the energy conservation opportunity by reducing the number of lamps used according to equation 4.7 is 2424 JD per year, and the implementation cost is Zero (0 JD), so the simple pay back period is immediate.

- **Install high efficiency lighting lamps**

Referring to Table 4.10:

Money saving = energy saving in kWh × cost of kWh

= 522 JD

The total implementation cost is approximately 260 JD. This cost is based on the cost of replacing existing lamps with high – efficiency lamps as old lamps burn out. This cost is simply the price difference (or cost premium) between the regular (1 JD) and high – efficiency FL lamps (2 JD), since no additional labor cost will be necessary.

SPBP = (implementation cost in JD)/ (Total cost saving JD/yr)

= 0.5 year

- **Install reflectors in lighting fixtures**

Referring to Tables 4.11 and 4.12:

Energy Savings (kWh/yr) = existed energy usage – proposed energy usage

= 17418 kWh/year

Money savings (JD/y) = Energy savings (kWh/y) × cost of kWh

= 2090 JD/y

The investment cost for this opportunity illustrated in the cost of the reflector and the installation cost. The price of the reflector for each unit and the installation cost is around 25 JD.

SPBP = 1.5 year

- **Energy saving summary for the lighting system at Al Safa Dairy Factory.**

Table 5.3 summarizes the saving measure opportunities implemented on the lighting system with the amount of savings that reached to about of 6.7% of the total electric energy consumed in the factory; the investment cost and the simple pay back period are illustrated also.

**Table 5.3**: Energy saving summary from improvement of lighting system at Al Safa factory.

| **Energy saving measures** | **Savings (JD)** | **Investment (JD)** | **Pay Back Period (Year)** |
|---|---|---|---|
| Reducing the number of lighting lamps | 2424 | 0 | immediate |
| Install high efficiency lighting lamps | 522 | 260 | 0.5 year |
| Install reflectors in light fixtures | 2090 | 3150 | 1.5 year |
| **Total** | **5036** | **3410** | **0.68 year** |

### 4. Energy saving from power factor improvement

The avoided penalties which considered as savings in case of imposing the penalty law are calculated according to Table 4.13 as follows:

Avoided penalties = 1.25 × (Improved power factor – Old power factor) × Electricity consumption (kWh/year) × cost of kWh

= 20670 JD/year

The cost of investment for the power factor improvement is the prcie of the capacitors banks and the timer circuit controller which is about 1900 JD.

Table 5.4 summarizes the saving measure opportunities achieved by improving the power factor including the amount of savings which reaches amount of 21.5% from total electric consumption in case imposing the low power factor penalties from municipalities , the investment cost which is the price of the capacitors bank and the timer circuit controller and the simple pay back period.

**Table 5.4**: Energy saving summary from improvement of power factor at Al Safa factory.

| **Energy saving measures** | **Savings (JD)** | **Investment (JD)** | **Pay Back Period (Year)** |
|---|---|---|---|
| Power factor improvement | 20670 | 1900 | 1 month |
| **Total** | **20670** | **1900** | **1 month** |

The total amount of saving achieved by implementing the four previous energy conservation opportunities is accounted to 20% of the total annual energy consumed at the factory, but as we mentioned in this thesis that the penalties for the low power factor did not imposed yet, so the amount of savings not including the low power factor penalties are equal to 9.7% of the total annual energy consumed in the factory.

## 5.2 Economical Evaluation of Energy Conservation Opportunity at Al Carton National Factory.

Energy conservation opportunities at this factory were focused on three energy consumed systems, boiler system, compressed air system and power factor improvement. At Al Carton factory we didn't deal with the lighting system as it does not consider a major electric consumer as it was seen from our auditing. The energy saving for each opportunity was determined and the feasibility of implementing this opportunity was analyzed.

## 1. Energy saving for the boiler system:

- **Adjusting boiler air – fuel ratio**

Savings of 5% from the total fuel consumption could be achieved according to the data in Table 4.14 and Figure 2.1

The annual fuel savings could be realized also by increasing the combustion efficiency from 80.7 % to a value of 84.3 % by adjusting the Air –Fuel ratio, as in our case, this saving is calculated using equation 4.2. It was found that the savings are equal to 3230 JD per year and the SPBP is 0.46 year.

- **By increasing the feed water temperature using heat from stack temperature.**

Applying equation 4.3 and using Table 4.14 where:

Diameter of the boiler chimney = 0.45 m
Measured average flue gas velocity = 3.8 m/sec.
Measured average flue gas temperature = 203°C.
Temperature drop =53°C.
Water flow rate = 679 kg/h , it was found that:
Air mass flow rate = 0.6 kg/sec

Therefore, available heat = 30 kW with a heat transfer efficiency 90%.

Temperature rise = 38°C and Energy saved = 108025kJ/h.

Fuel saved with a boiler of efficiency equal to 76.5% = 3.53 kg/h.

Based on a total number of 2400 operating hours annually, this is equal to 8472kg of fuel are saved annually, which is equal to 8980 liters of fuel oil #6 with a cost **4131 JD** annually.

The approximate cost of the economizer and the additional piping and insulation is about **9000 JD**. Therefore the pay back period is about **2.2 years** which is very reasonable.

It is very obvious that this investment is considered feasible to implement from the short Simple payback period if investment returned .This energy conservation opportunity comes under the low cost investment, and in order to be more sure and accurate toward this ECO, we could use the internal rate of return (IRR) and the net present value (NPV) methods which they are more trusted ways for securing an investment.

In our case the investment cost is 9000JD which is the price and the installation cost of the economizer.

If we assume that the MARR is equal to 15% which is the most usable one and the economizer will last 5 years and will have a salvage value of 500 JD at the end of the 5 years.

Applying those values on the equations of determining the IRR and NPV, it was found that this investment is highly recommended were the IRR found to be greater than the MARR 19.74%.

Whole method and calculation procedure is presented in Annex 6 as an excel sheet with the required diagram, this could be repeated for the four factories in this thesis where the investment security checking is needed.

- **Increasing the make-up water temperature using solar water heater (SWH)**

  Using the SWH for heating 1.25m³ from 15 to 70˚C required 80kWh per day, if the boiler at Al Carton with 76.5 % efficiency was used, the amount of savings is 918 JD per year and the SPBP is equal to 2 years.

- **Energy saving summary for the boiler system at Al Carton factory**

  Table 5.5 summarizes the saving measure opportunities implemented on the boiler system with the amount of savings 10.9 %, the investment cost and the simple pay back period.

**Table 5.5**: Energy saving summary from improvement of boiler operation at Al Carton factory

| **Energy saving measures** | **Savings (JD)** | **Investment (JD)** | **Pay Back Period (Year)** |
|---|---|---|---|
| Adjusting the Air – Fuel Ratio | 3230 | 1500 | 0.46 year |
| Increasing the feed water temperature using heat from stack temperature. | 4131 | 9000 | 2.2 years |
| Increasing the Make-up water temperature using SWH | 918 | 1400 | 1.5 year |
| **Total** | **8279** | **13400** | **1.62 year** |

## 2. Energy saving for the compressed air system

- **Arresting air leakage for the compressor (Load/No load test)**

  Using Table 4.16 and applying equation 4.5:

  The additional power is found 5.3 kW per hour, the amount of savings is 1374 JD and the SBPB equal to 0.2 year as the investment cost is 250 JD.

- **By improving the inlet air temperature conditions**

Using equation 4.6, it was found that the reduced power by decreasing the inlet air temperature from 19 to 11 C° is 1.4 kW per hour which is equal to a savings of 403 JD per year and with a SPBP of 0.5 year with 200 JD investment cost.

- **Energy saving summary for the compressed air system at Al Carton Factory**

Table 5.6 summarizes the saving measure opportunities implemented on the compressed air system with the amount of savings 5.6 %, the investment cost and the simple pay back period.

**Table 5.6**: Energy saving summary from improvement of compressed air system conditions at Al Carton factory.

| **Energy saving measures** | **Savings (JD)** | **Investment (JD)** | **Pay Back Period (Year)** |
|---|---|---|---|
| Arresting Air leakage | 1374 | 250 | 0.2year |
| Improving the inlet air temperature conditions | 403 | 200 | 0.5 year |
| **Total** | **1777** | **450** | **0.25 year** |

### 3. Energy saving from power factor improvement

The avoided penalties by improvement the power factor from 0.72 to 0.92 (Annex 2) as required is found according to Table 4.13 to 7892 JD per year with SPBP equal to 0.4 year as the investment cost is 3000 JD .

Table 5.7 summarizes the saving measure opportunities achieved by improving the power factor including the amount of savings 20%, the investment cost which is the price of the capacitors bank and the timer circuit controller and the simple pay back period.

**Table 5.7**: Energy saving summary from improvement of power factor conditions at Al Carton factory.

| Energy saving measures | Savings (JD) | Investment (JD) | Pay Back Period (Year) |
|---|---|---|---|
| Power factor improvement | 7892 | 3000 | 0.4 year |
| **Total** | **7892** | **3000** | **0.4 year** |

Total amount of saving at Al Carton factory excluding the power factor penalties is equal to 9.4 % of the total annual energy consumed at the factory.

### 5.3 Economical Evaluation of Energy Conservation Opportunity at Al Arz Ice Cream Factory.

Energy conservation opportunities in this factory were focused on three energy consumed systems, boiler system, compressed air system and lighting system. At Al Arz factory we didn't deal with the power factor improvement as the factory had already installed capacitor banks and the power factor was found above the required value as it was measured by the energy analyzer equipment installed (Annex 4). The energy saving for each opportunity was determined and the feasibility of implementing this opportunity was analyzed.

## 1. Energy saving for the boiler system:

Table 5.8 summarizes the saving measure opportunities implemented on the boiler system with the amount of savings (16.6 %), the investment cost and the simple pay back period.

**Table 5.8**: Energy saving summary from improvement of boiler operation at Al Arz factory

| **Energy saving measures** | **Savings (JD)** | **Investment (JD)** | **Pay Back Period (Year)** |
|---|---|---|---|
| Adjusting the Air – Fuel Ratio | 2536 | 1500 | 0.60 year |
| Increasing the Make –up water temperature using heat from stack temperature. | 6867 | 11000 | 1.6 year |
| Increasing the Make-up water temperature using SWH | 2003 | 1700 | 0.85 year |
| **Total** | **11406** | **14200** | **1.2 year** |

## 2. Energy saving for the compressed air system

Table 5.9 summarizes the saving measure opportunities implemented on the compressed air system with the amount of savings 3.8%, the investment cost and the simple pay back period.

**Table 5.9**: Energy saving summary from improvement of compressed air system conditions at Al Arz factory.

| **Energy saving measures** | **Savings (JD)** | **Investment (JD)** | **Pay Back Period (Year)** |
|---|---|---|---|
| Arresting Air leakage | 3197 | 400 | 0.12 year |
| Improving the inlet air temperature conditions | 1824 | 450 | 0.25 year |
| **Total** | **5021** | **850** | **0.17 year** |

## 3. Energy saving for the lighting system

Table 5.10 summarizes the saving measure opportunities implemented on the lighting system with the amount of savings 2.7%, the investment cost and the simple pay back period.

**Table 5.10**: Energy saving summary from improvement of lighting system at Al Arz factory

| **Energy saving measures** | **Savings (JD)** | **Investment (JD)** | **Pay Back Period (Year)** |
|---|---|---|---|
| Install high efficiency lighting lamps | 1175 | 300 | 0.25 year |
| Install reflectors in light fixtures | 2319 | 3150 | 1.36 year |
| **Total** | **3494** | **3450** | **1 year** |

Total amount of saving from implementing the three previous ECO's is equal to 10 % of the total annual energy consumed at the factory.

## 5.4 Economical Evaluation of Energy Conservation Opportunity at Al Aqqad Textile Factory.

Energy conservation opportunities were focused on four energy consumed systems, boiler system, compressed air system, lighting system and power factor improvement. The energy saving for each opportunity was determined and the feasibility of implementing this opportunity was analyzed.

### 1. Energy saving for the boiler system:

Table 5.11 summarizes the saving measure opportunities implemented on the boiler system with the amount of savings 9.5 %, the investment cost and the simple pay back period.

**Table 5.11**: Energy saving summary from improvement of boiler operation at Al Aqqad factory

| **Energy saving measures** | **Savings (JD)** | **Investment (JD)** | **Pay Back Period (Year)** |
|---|---|---|---|
| Adjusting the Air – Fuel Ratio | 4300 | 1500 | 0.35 year |
| Increasing the Make –up water temperature using heat from stack temperature. | 3510 | 9000 | 2.5 years |
| Increasing the Make-up water temperature using SWH | 1517 | 2200 | 1.45 year |
| **Total** | **9327** | **12700** | **1.36 year** |

### 2. Energy saving for the compressed air system

Table 5.12 summarizes the saving measure opportunities implemented on the compressed air system with the amount of savings 5.4%, the investment cost and the simple pay back period. Let's mention here that the cost of one kWh is 0.23 JD due to utilization of diesel generators as the power supply source as it was calculated in chapter three, so the saving could be more if they switched to the electric grid.

**Table 5.12**: Energy saving summary from improvement of compressed air system conditions at Al Aqqad factory.

| Energy saving measures | Savings (JD) | Investment (JD) | Pay Back Period (Year) |
|---|---|---|---|
| Arresting Air leakage | 6719 | 750 | 0.11 year |
| Improving the inlet air temperature conditions | 1490 | 500 | 0.33 year |
| **Total** | **8209** | **1250** | **0.15 year** |

The factory could save up to 3926 JD in energy conservation in compressed air system just by switching to the electric grid to be as its power supply instead of the diesel generators.

### 3. Energy saving for the lighting system

Table 5.13 summarizes the saving measure opportunities implemented on the lighting system with the amount of savings that accounted to around 15.4% of the total electric energy consumed for the factory, the investment cost and the simple pay back period.

**Table 5.13**: Energy saving summary from improvement of lighting system at Al Aqqad factory

| Energy saving measures | Savings (JD) | Investment (JD) | Pay Back Period (Year) |
|---|---|---|---|
| Reducing the number of lighting lamps | 11205 | 0 | immediate |
| Install high efficiency lighting lamps | 2452 | 1110 | 0.45 year |
| Install reflectors in light fixtures | 9803 | 13875 | 1.4 year |
| **Total** | **23460** | **14985** | **0.64 year** |

The factory could save up to 11220 JD in energy conservation in lighting system just by switching to the electric grid connection to be as its power supply instead of the diesel generators.

**4. Energy saving from power factor improvement**

The avoided penalties, in case the supply for electric energy was the public grid, by improvement the average power factor from 0.78 to 0.92 (Annex 5) as required is found according to Table 4.13 up to 16361 JD[3] per year with SPBP equal to 40 days as the investment cost is 1750 JD.

In case the factory was connected to the public grid instead of the private diesel generators, the cost of electric energy would be lower 0.12 JD/kWh instead of 0.23 JD/kWh, as calculated in chapter three, for which is paying now, so the amount of savings could be doubled.

The total amount of saving could reach up to 15.5 % of the total annual energy consumed at the factory due to the high energy consumed for lighting which was a very good potential for saving.

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[3] based on annual diesel consumption for the generators is 212000 liters and each liter of diesel produce 10.5 kWh, the efficiency of the generator is 35%.

## 5.5 Evaluation of Energy Conservation in Industrial Sector in Palestine

It seems from the previous economical analysis that a huge amount of savings in the industrial facilities could be achieved by implementing no cost and low cost energy conservation measures. It means that we could save a good percentage in energy consumption by just a simple changing in the behavior of energy utilization (no cost) or by a small amount of investment in order to achieve the required goal (low cost).

Table 5.14 summarizes the potential savings in electric and fuel energy in each of the four studied factories, the equal amount of money and the reduction in $CO_2$ emissions:

**Table 5.14**: Summary of the total energy savings and $CO_2$ reduction in the four studied factories.

| Factory name | Electric Energy consumption (kWh/y) | Fuel energy consumption (liter) | Savings in kWh | | Savings in fuel | | Money savings JD/y | CO2 reductions Tons/y |
|---|---|---|---|---|---|---|---|---|
| | | | kWh/y | % | Liter/y | % | | |
| **Al Safa Dairy Factory** | 626340 | 109200 | 54342 | 8.7 | 11656 | 10.7 | 15263 | 34 |
| **Al Carton Factory** | 263068 | 164410 | 14808 | 5.6 | 17998 | 10.9 | 10056 | 24.8 |
| **Al Arz Ice Cream Factory** | 1093780 | 91190 | 70959 | 6.5 | 15208 | 16.6 | 19921 | 44.35 |
| **Al Aqqad Textile Factory** | | 223000 | | | 42147 | 18.9 | 31669 | 71.9 |
| | | 212000 | | | 20276 | 10.9 | 9327 | |
| **Total** | | | | | | | **86236** | **175** |

From Table 5.14, the percentage of energy savings for the four studied factories was as follows: Al Safa dairy factory 9.7%, Al Carton factory 9.4%, Al Arz ice cream factory 10% and Al Aqqad textile factory 15.5 % which considered very high percentage comparing to other factories due that the factory uses diesel generators as its supply for power were the cost of kWh come to 0.23 JD instead of 0.12 using the grid as a power supply (chapter 3). Those amount of savings mentioned here are not including the amount of savings achieved by avoiding the low power factor penalties, due to that the municipalities did not start yet to impose these penalties ,otherwise the saving percentage would be much greater.

From the above analyses we could come to a result that the saving percentage by implementing the previous energy conservation measures on the most energy consumed equipment in the four audited facilities could reach up to 2.5 ktoe of electric energy and 7.7 ktoe of fuel energy annual savings. On the national level, 10 -20 % (226.6 - 453.2 TJ[4] per year) of the total energy consumed in the industrial sector could be saved depending on the equipment and system which the energy conservation measures were implemented on and the type of the manufacturing. .

Therefore saving one barrel of petroleum is better than discovering a new one economically and environmentally.

The reduction in the environmental emissions achieved from the four audited facilities is accounted to 175 tons[5] of CO2 per year (Table 5.14), and this rate of reduced emissions could be achieved for the rest of the facilities, so saving energy means less emissions and cleaner environment.

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[4] Based on 1 TJ = 277777.8 kWh
[5] based on 1 kWh produce 700g of CO2, and 1 liter of fuel produce 1.05 kg CO2.

This is a very good indication that if we implement a national energy conservation program on all the industrial facilities existed, a huge amount of energy savings could be a achieved (about 10 to 20%) which will enhance the national economy and lower the dependence on imported energy by decreasing the demand through following the energy conservation measures, in addition to the reduction in the environmental emissions produced by utilization of the conventional types of energy.

# CHAPTER SIX

# FINANCING ENERGY MANAGEMENT AND CONSERVATION PROJECTS

Since soaring energy prices and the growing need for energy efficiency hit the center of our radar screen in the 1970s, there has been growing recognition that using energy more efficiently is good for the economy and the environment. Yet survey after survey revealed that many organizations put off energy – efficiency and conservation work for one major reason: **Money.**

Organization either lacked the money, or those that had the funds were inclined to spend their money elsewhere. The reasons are legitimate "We must use the money to invest in new production equipment. The payback is not short enough," etc., etc.

The horrible truth is that top management is not interested in ENERGY!. The only time it seems to reach their consciousness is when there is a shortage or a sudden power outage.

Although investments to improve energy efficiency and conservation are often cost effective and offer attractive rates of return, many profitable investment opportunities are being lost due to broad national, economic and institutional factors which restrict investments in energy efficiency. But the problem of financing may be the major factor causing the slow rate of progress in developing countries in achieving modern standards of energy efficiency. The lack of credit and the inability to obtain financing for projects are strong deterrents to investments in energy efficiency in many countries around the world.

Alternative financing mechanisms have developed because they can overcome the barriers that have inhibited profitable energy efficiency and conservation investments. Competition for limited investment capital, uncertainty regarding the types of efficiency technologies and practices most worth adopting, risk aversion, and lack of motivation on the part of facility owners are all addressed in one fashion or another by the alternative financing techniques.

These three terms -- energy services companies, performance contracting, and third party financing -- are the central concepts of innovative financing for energy efficiency and conservation projects and so are introduced here:

- Energy Services Companies (ESCOs) are most often private companies that provide comprehensive energy efficiency or load reduction services to customers that own or operate facilities such as factories and buildings.

- Performance contracting most often refers to the practice of providing energy savings to a customer for a fee, the level of which depends on the amount of energy saved.

- Third party financing (TPF) is the funding of energy savings investments by an outside company, using energy savings to pay for the investment.

In Palestine were the price of energy is very high comparing with the prices in the region or globally, we are in such a need for energy conservation measures and energy efficiency technologies. One of the major barriers in implementing energy conservation programs is the identification and securing of appropriate financing. Self-financing cannot provide the necessary means for overriding those barriers, as from our field visits and meeting with the management of the factories, we always had the same more answer when we asked for the availability and if they were ready to implement such programs was yes in case of finding a fund to cover the investment cost. Therefore, establishing an ESCOs in the Palestinian Territories could be the solution for this matter and a good business as the potential for energy conservation measures and energy efficiency is very high which has been discussed and proved in our case studies, two things had been highlighted, the energy is not used efficiently and the technology used is not as efficient as it should be and this is a major enhancement for starting an ESCO business.

## 6.1 Energy Service Company Field of Work

The basic role of the Energy Service Company (ESCO) is to provide comprehensive energy efficiency services to consumers including project finance, engineering, project management, equipment maintenance monitoring and evaluation, usually through Energy Performance Contracts (EPC). ESCOs can package their services using a variety of finance schemes whereby they finance up-front capital improvements in the client's premises in exchange for a portion (or the total, depending on the EPC) of the savings generated.

The ESCOs are in effect able to turn the cost savings from efficiency measures into a revenue stream which can be used to repay debt and provide a profit. That's why performance contracts are sometimes referred as "paid from savings" contracts.

Through the years, ESCO services have become more varied. It has become a customer –driven industry and the customer typically has a selection of ESCO services from which to choose. Services offered by an ESCO usually include:

- An investment grade energy audit to identify energy and operational savings opportunities, assess risks, determine risk management /mitigating strategies, and calculate cost-effectiveness of proposed measures over time;

- Financing from its own resources or through arrangements with banks or other financing sources without the firm compromising its own capital, thus leaving capital available for other priorities;

- The purchase, installation and maintenance of the installed energy-efficient equipment; possibly maintenance on all energy-consuming equipment;

- New equipment training of operations and maintenance (O&M) personnel;

- Training of O&M personnel in energy-efficient practices;

- Monitoring of the operations and energy savings, so reduced energy consumption and operation costs persist and, in many cases, additional production advantages;

- Measurement and savings verifications;

- A guarantee of the energy savings to be achieved [38].

## 6.2 Performance Contracting and Financing

Performance contracting is defined by the following key attributes:

- Performance contracting offers turnkey services, including feasibility analysis, design, engineering, construction management, installation, operation, maintenance, and financing;
- Performance contractors are compensated based on measured results;
- Most of the technical, financial, and operational risks are borne by the performance contractor.

While all performance contractors are energy service companies (ESCOs), not all ESCOs are performance contractors. A number of ESCOs work for utilities on a subcontractor basis, installing demand-management and energy efficiency measures prescribed or designed by the utility company.

Such companies incur minimal risk or responsibility for the longer-term use and reliability of the energy savings generated by the measures they install. Nevertheless, fairly common practice in the industry is to use the term ESCO and performance contractor interchangeably [39].

The popularity of performance contracting rests on the many benefits it delivers. The highlights of the benefits it offers the customer which offers ESCO services are:

- An immediate upgrade of facilities and reduced operating costs-without any initial capital investment;
- Access to the ESCO's energy efficiency expertise;

- Positive cash flow-most projects generate savings that exceed the guarantee;
- The opportunity to use the money, which would have been used for required upgrades or replacements to meet other needs;
- Improved more energy –efficient operations and maintenance;
- The guaranteed performance of the new equipment for the life of the contract (not just through a warranty period);
- A more comfortable, productive environment; and
- Services paid for with the money which the customer would otherwise have paid to the utilities for wasted energy [37].

### 6.3 The Role of the Third Party Financing Projects

An investment in an energy efficiency and conservation project is like any other capital investment. Consequently, a customer or firm will follow its normal capital investment evaluation process when considering an investment in energy efficiency. In a normal project cycle, the company will go through a number of typical activities. The company will first assess the relative importance and costs of energy as a share of its total costs, and its impact on profitability. Then, an assessment of potential efficiency activities will be made. Energy audits are very important at this stage and, before a final decision is made, the assessment will include an "investment grade" audit to better identify energy efficiency measures to be implemented.

These measures will be costed out, their rates of return estimated, and, if an investment meets the company's investment criteria, a decision will be made as to how to finance and implement the investment.

Third party financing (TPF) is the funding of energy saving investments by an outside company, using energy savings to pay for the investment. The main actor in third party financing is an energy service company. However, the ESCO usually will not finance the project out of its own equity. Rather, the ESCO will obtain funding for the investment from a third party, such as a bank or leasing company [40].

Third party financing was developed to help companies (the customer) to finance efficiency investments.

The advantage is that the customer does not have to put any cash out to finance the initial investment. It merely has to make payments to the performance contractor. The concept of third party financing always includes technical advice. Therefore, the customer does not have to be concerned about technical matters, because it relies on the ESCO for this expertise.

A company may finance a project in one of three fundamental ways: self-financing, debt-financing, or third party financing. An ESCO may use its own funds to finance the investment, which should ultimately be self-financing. Debt financing involves the company's taking out loans to finance the project, in which case they must make interest payments. In third party financing, the customer makes payments to the performance contractor, based on the savings from the project. In principle, it should be off-balance sheet financing. In practice, the customer usually has to sign the lease or loan agreement. Payments on the loan are made out of the energy savings [41].

## 6.4 Different Types of ESCO Projects

1. In a guaranteed savings project, the customer finances the design and installation of the efficiency measures by borrowing the funds from a third party (usually a commercial bank) or by leasing the equipment. Financing is typically arranged by the ESCO. Let us be clear: in a project structured around guaranteed savings the customer borrows the money—not the ESCO. The ESCO has no contractual relationship with the bank financing the project. It is the customer who has duty of repayment on the loan [42].

The ESCO assumes project performance risk under this project structure. It guarantees that energy savings will meet agreed- upon minimums, usually enough to cover debt service. If minimums are not met, the ESCO pays the customer the difference. If minimums are exceeded, the customer agrees to pay the ESCO an agreed upon percentage of the savings. Thus, the ESCO is providing a guarantee of performance to the customer. The customer is willing to assume the debt, or lease payment, because of the guarantee that the savings will exceed the debt payments.

The advantage of the guaranteed savings approach is that a third party financier assesses and bears the customer's credit risk. Financial institutions, such as banks, are better equipped to handle this risk than the ESCO. This approach also keeps the ESCO's balance sheet free of project debt (which has advantages for the ESCO).

2. Shared savings contracts are those in which the ESCO finances the project, either from its own funds or by borrowing from a third party. Thus the ESCO takes on not only the performance risk, but also the risk associated with the customer's creditworthiness. Savings percentages paid to the ESCO are

higher than in guaranteed savings contracts, in which the ESCO assumes only the performance risk.

Shared savings contracts are useful when the customer does not want to, or cannot, use borrowing capacity. For example, many subsidiaries of large companies do not generally secure debt independently.

For them, shared savings is a useful approach, because the transaction structure ensures that the customer will never pay more than the savings and that the obligation will likely be off the balance sheet.

Shared savings contracts are also useful for the customer, because they are regarded as new equity, and often are not required to meet internal investment criteria. For example, if the internal hurdle rate of the target company is 25 percent and the expected annual percentage rate (APR) of a shared savings contract is 15 percent, the shared savings contract may be viewed as a bargain since it is much less expensive than internal funds. By contrast, a guaranteed savings approach would likely not be acceptable for this project. Shared savings contacts generally provide the user with the operations and maintenance responsibilities if he wishes.

3. Pay from savings contracts are a subcategory of guaranteed savings contracts, but instead of fixed payments for the customer to repay the loan, the payment schedule depends on the level of savings. The more the savings the quicker the re-payment [43].

Pay from savings contracts is generally less risky than guaranteed savings projects. (They have roughly the same risk profile for the customer as shared savings contracts). An attractive feature of this structure is its "open book" approach.

## 6.5 Financing Tools

Debt and lease financing are the most common instruments used to finance performance-based efficiency projects in the world. It may surprise some readers, but ESCO equity is not typically used to finance projects. Furthermore, the debt is usually assumed by the customer. Debt financing is used because of a number of significant advantages -- both to the customer and the ESCO -- over equity investments in projects.

**Debt**: Debt is the most common financing instrument, primarily because it lowers financing costs. Debt lowers financing costs because the average customer's cost of capital is lower than the average leasing company's or ESCO's. Of course, the cost associated with non-recourse project financing by a third party is highest of all. (Non-recourse means that project loans are secured only by the project's assets. Non- recourse financing entails more risk, and therefore demands higher interest rates). Most ESCO projects are financed by debt which the customer has borrowed from a bank or other lending institution. The principal disadvantage of debt is that it appears on the customer's balance sheet, which affects its ability to borrow for activities directly related to its business.

**Leases**: Leases are similar to debt financing. ESCOs frequently use guaranteed leases, which are analogous to debt-based guaranteed savings projects.

**ESCO Financing**: In ESCO financing, the ESCO typically borrows the money to finance the project. By borrowing directly from the financing institution, the ESCO becomes fully responsible for repayment.

Under this financing scheme, projects have a shared savings structure. The advantage to the customer is that it is free of repayment obligations. In turn, however, the customer has to pay the ESCO a larger share of energy savings.

It is the project revenue stream that permits ESCO financing (which makes it similar to non-recourse project financing). The financing institution may either assume the rights to the energy savings payments as collateral, or they may take a security interest in the project equipment.

ESCO financing is risky, requiring higher returns, because the ESCO assumes not only the project performance risk, but also the underlying customer credit risk. If the customer goes out of business, the revenue stream from the project will stop, putting the ESCO at risk. In addition, an ESCO can only finance a limited number of these types of projects, because every new project causes its debt-to-equity ratio to decline. At some point, financial institutions will cease to lend to the ESCO due to its high debt ratio [44].

ESCO's use their own working capital for identifying and developing projects. All of the activities that ESCOs conduct for a project are bundled into that project's cost. They then use project financing to construct the project. The ESCO will recoup their working capital spent on the project with funds from the project financing--when, and if, it comes. This makes for a fairly risky and costly project development cycle.

Monitoring and verification are extremely important to performance-based projects. Because the ESCO must perform to be remunerated, ESCOs need to measure the energy savings. These savings should be monitored over the project's life in order for the ESCO to prove to the customer that savings are real and ongoing. Measurement involves ongoing verification of energy savings, often by comparing a customer's energy bills against a baseline. Measurement often involves metering, which is the direct tracking of energy savings according to sanctioned engineering protocols. The advantage and appeal of metering is its accuracy. The purpose of monitoring energy savings is to ensure that those savings continue over time. It also serves to ensure the quality and effectiveness of ongoing maintenance, which is featured in almost every ESCO project. In some cases the ESCO will not perform monitoring, which makes the project less expensive, but this would not be performance contracting.

Lenders tend to require a variety of credit enhancements for this type of financing, such as bonding or insurance.

ESCO financing is not only expensive; it is a formidable marketing challenge. These projects require very high shared savings payments to be justified. This makes the savings less attractive to the customer. As a consequence, ESCOs tend to prefer to structure their projects under customer-financed guaranteed savings contracts.

**Conclusions**

The energy situation in Palestine is somewhat unique when compared to other countries in the region. There are virtually no available natural resources, and due to on-going political situation, the Palestinians rely (or have to rely) almost totally on Israel for their energy needs.

Palestine faces continuing growth in energy demands, especially electricity, across all sectors and by necessity future generation expansion will rely substantially upon fossil fuels. These factors create strong economic and environmental incentives to curb energy consumption through efficient use of energy and energy conservation in all sectors and equipments with high energy consumption rate.

However, people have learnt to utilize some of the renewable energy in the past in heating water for instance. The use of solar energy for water heating is wide spread in the Palestinian territories, and offers an opportunity to develop this trend and make it more efficient and sustainable.

Regarding audits and energy conservation measures and despite the fact that the measures were discussed at small-scale levels it is evident that they could actually make substantial energy savings. These savings could reduce the financial burden of the current energy bills at the factories. There would also be environmental benefits derived from implementing energy conservation measures. There would be tremendous reduction of localized gaseous emissions to the environment.

The major opportunities for energy saving exist within the industrial and residential sectors and international experience has shown that these sectors are responsive to the activities of sustained and well focused information programs. Significant savings can be achieved not through a relatively small number of direct projects but through the stimulation of widespread replication activities across the country.

It was presented and approved in this thesis that there is a great potential for energy savings in the Palestinian industrial sector by implementing energy conservation measures of no and low cost investment due to lack of awareness and the know –how toward the efficient and the rational use of energy in the industrial machinery and not wasting energy while there is possibility to produce same amount and same quality of products with less energy consumption through applying energy conservation measures.

Despite the great potential opportunities that exist for energy conservation in the different factories, they need to develop an effective energy management system before implementing any energy conservation measures. It is advised that they should appoint an Energy Manager in the facility who will assist in implementing such an energy policy and also develop a comprehensive system for setting targets, monitoring consumption, quantifying saving and providing budget records. The energy manager would also assume the responsibility of educational awareness campaigns as way of changing the attitudinal behaviors of employees and even the management towards energy conservation.

It is also recommended that an energy conservation fund should be set up to assist with financing future energy conservation related investments.

**Recommendations**

Based on this thesis and related studies, it is recommended to take the following measures in order to decrease the demand on energy and reduce energy waste:

- Develop legal and legislative instruments by the Palestinian legislative council (PLC), and related ministries, and issue legal enforcement of energy codes and manual practices for energy conservation and efficiency.

- Increase awareness of energy issues and energy conservation within the professional, general public and legislators.

- Support and improve utilization of renewable energy sources especially of solar power as sunshine is abundant and clean source of energy.

- Strengthen the role of ESCO,s and encourage industrial development by encouraging investments in energy conservation programs within the sector.

- Support the development of financial instruments such as offering financial support and soft loans in the energy saving sector.

- Support the existing and new energy research and information centers to acquire the potentials in energy sector and to encourage investment and use of new technology and concepts of energy conservation and efficiency.

- Adopt a more efficient structure of pricing policies, based on quality of services provided and taking into consideration standard of living (income levels rates), adopting progressive pricing (categorizing consumption) instead of flat rate on kWh..

- Introduce technical training for energy conservation practices to schools, vocational colleges and universities.

- Introduce and develop training and knowledge of energy saving practices to the private sector, especially industry.

- Support pilot programs and projects in sustainable energy production, saving, and conservation within the existing energy sector.

- Explore the possibilities of heat recovery for multiple uses including pre-heating combustion air and for hot water systems in ablutions. Energy recovery is the beneficial use of heat or cooling energy that would otherwise be lost or needs to be removed from a specific space. Technologies that recover heat and/or cooling energy reduce the cost and consumption of energy in commercial and institutional buildings. The recaptured energy is potentially useful for heating and/or cooling/dehumidifying outdoor air brought into a building for ventilation, space heating, and water heating. Those could be interesting subjects for future thesis of the same field of energy conservation opportunities.

- Investigation into power factor correction.

  Improving power factor of an industrial plant reduces the electrical losses and increases electrical capacity in addition to avoiding of imposing penalties.

- Consider re-scheduling production or other operations to spread out the electrical load and thus improve the load factor.

- Improved house -keeping measures in lighting system such as;
    1. always turning lights off when they are not needed. This can be achieved by using stickers or reminders to make employees more aware.
    2. regular maintenance checks of the lighting especially cleaning of lamps to remove dirt.
- Where possible the use of daylight to maximize the advantage to reduce lighting should be encouraged.
- Establishment of a campaign program to raise awareness of the benefits of energy conservation could happen change the attitudes or ignorance of the employees or any other stakeholder for a better prospect of responsibility.
- Introducing automatic control systems, with light and or proximity sensors and time switches. These devices reduce energy consumption by limiting usage of lamps to those times when lighting is actually required, and available daylight is insufficient.

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# Annexes

**Annex 1**:Illumination standards [45]

| Place | Standard Illumination (lm/m²) or lux |
|---|---|
| Sewing machines | 200 - 500 |
| Offices | 400-600 |
| Mechanical work | 250-500 |
| Boilers room | 150-280 |
| Corridors | 210 |
| Production areas in general | 400-650 |

**Annex 2**: Energy analyzer data for power factor improvement at Al Safa Factory

| Time | S-avg(VA) | P-avg(W) | Q-avg (VAR) | Pf (avg) | Q-_New | Pf_New | Q_New | Pf_New |
|---|---|---|---|---|---|---|---|---|
| 12:35 | 114300 | 85770 | 75670 | 0.7 | 35670 | 0.92 | 35670 | 0.92 |
| 12:45 | 106300 | 76940 | 73420 | 0.7 | 33420 | 0.92 | 33420 | 0.92 |
| 12:55 | 108800 | 80250 | 73550 | 0.7 | 33550 | 0.92 | 33550 | 0.92 |
| 13:05 | 109300 | 80900 | 73550 | 0.7 | 33550 | 0.92 | 33550 | 0.92 |
| 13:15 | 106000 | 77640 | 72200 | 0.7 | 32200 | 0.92 | 32200 | 0.92 |
| 13:25 | 106300 | 77760 | 72500 | 0.7 | 32500 | 0.92 | 32500 | 0.92 |
| 13:35 | 99380 | 70340 | 70200 | 0.7 | 30200 | 0.92 | 30200 | 0.92 |
| 13:45:00 | 100200 | 70690 | 71120 | 0.7 | 31120 | 0.92 | 31120 | 0.92 |
| 13:55:00 | 98720 | 67150 | 72370 | 0.7 | 32370 | 0.90 | 32370 | 0.90 |
| 14:05:00 | 96670 | 67080 | 69600 | 0.7 | 29600 | 0.91 | 29600 | 0.91 |
| 14:15:00 | 95020 | 64620 | 69660 | 0.7 | 29660 | 0.91 | 29660 | 0.91 |
| 14:25:00 | 100900 | 68080 | 74490 | 0.7 | 34490 | 0.89 | 34490 | 0.89 |
| 14:35:00 | 94510 | 63240 | 70230 | 0.7 | 30230 | 0.90 | 30230 | 0.90 |
| 14:45:00 | 92590 | 60520 | 70070 | 0.7 | 30070 | 0.90 | 30070 | 0.90 |
| 14:55:00 | 89680 | 61070 | 65680 | 0.7 | 25680 | 0.92 | 25680 | 0.92 |
| 15:05:00 | 91900 | 63220 | 66690 | 0.7 | 26690 | 0.92 | 26690 | 0.92 |
| 15:15:00 | 93860 | 63820 | 68830 | 0.7 | 28830 | 0.91 | 28830 | 0.91 |
| 15:25:00 | 92340 | 61560 | 68820 | 0.7 | 28820 | 0.91 | 28820 | 0.91 |
| 15:35:00 | 94610 | 62900 | 70660 | 0.7 | 30660 | 0.90 | 30660 | 0.90 |
| 15:45:00 | 96900 | 64770 | 72070 | 0.7 | 32070 | 0.90 | 32070 | 0.90 |
| 15:55:00 | 97750 | 66670 | 71480 | 0.7 | 31480 | 0.90 | 31480 | 0.90 |
| 16:05:00 | 95770 | 65580 | 69790 | 0.7 | 29790 | 0.91 | 29790 | 0.91 |
| 16:15:00 | 97130 | 66310 | 70980 | 0.7 | 30980 | 0.91 | 30980 | 0.91 |
| 16:25:00 | 96250 | 64450 | 71480 | 0.7 | 31480 | 0.90 | 31480 | 0.90 |
| 16:35:00 | 97300 | 65040 | 72370 | 0.7 | 32370 | 0.90 | 32370 | 0.90 |
| 16:45:00 | 93840 | 62680 | 69830 | 0.7 | 29830 | 0.90 | 29830 | 0.90 |
| 16:55:00 | 95940 | 63610 | 71820 | 0.7 | 31820 | 0.89 | 31820 | 0.89 |
| 17:05:00 | 98460 | 65300 | 73690 | 0.7 | 33690 | 0.89 | 33690 | 0.89 |
| 17:15:00 | 92630 | 61810 | 68990 | 0.7 | 28990 | 0.91 | 28990 | 0.91 |
| 17:25:00 | 88350 | 60460 | 64420 | 0.7 | 24420 | 0.93 | 24420 | 0.93 |
| 17:35:00 | 92570 | 61640 | 69060 | 0.7 | 29060 | 0.90 | 29060 | 0.90 |
| 17:45:00 | 93820 | 62700 | 69790 | 0.7 | 29790 | 0.90 | 29790 | 0.90 |
| 17:55:00 | 85790 | 55570 | 65360 | 0.6 | 25360 | 0.91 | 25360 | 0.91 |
| 18:05:00 | 84990 | 53890 | 65720 | 0.6 | 25720 | 0.90 | 25720 | 0.90 |
| 18:15:00 | 84180 | 54190 | 64410 | 0.6 | 24410 | 0.91 | 24410 | 0.91 |
| 18:25:00 | 68440 | 39960 | 55560 | 0.6 | 15560 | 0.93 | 15560 | 0.93 |
| 18:35:00 | 66890 | 37340 | 55500 | 0.6 | 15500 | 0.92 | 15500 | 0.92 |
| 18:45:00 | 65420 | 35170 | 55150 | 0.5 | 15150 | 0.92 | 15150 | 0.92 |
| 18:55:00 | 65980 | 35180 | 55820 | 0.5 | 15820 | 0.91 | 15820 | 0.91 |
| 19:05:00 | 66500 | 35300 | 56360 | 0.5 | 16360 | 0.91 | 16360 | 0.91 |
| 19:15:00 | 64920 | 35770 | 54180 | 0.6 | 14180 | 0.93 | 14180 | 0.93 |
| 19:25:00 | 67980 | 38870 | 55770 | 0.6 | 15770 | 0.93 | 15770 | 0.93 |
| 19:35:00 | 82850 | 51990 | 64500 | 0.6 | 24500 | 0.90 | 24500 | 0.90 |
| 19:45:00 | 82440 | 51090 | 64700 | 0.6 | 24700 | 0.90 | 24700 | 0.90 |
| 19:55:00 | 85370 | 53860 | 66230 | 0.6 | 26230 | 0.90 | 26230 | 0.90 |
| 20:05:00 | 84400 | 52770 | 65870 | 0.6 | 25870 | 0.90 | 25870 | 0.90 |
| 20:15:00 | 82730 | 51770 | 64530 | 0.6 | 24530 | 0.90 | 24530 | 0.90 |
| 20:25:00 | 83960 | 52510 | 65500 | 0.6 | 25500 | 0.90 | 25500 | 0.90 |
| 20:35:00 | 81860 | 51710 | 63460 | 0.6 | 23460 | 0.91 | 23460 | 0.91 |
| 20:45:00 | 84940 | 55200 | 64550 | 0.6 | 24550 | 0.91 | 24550 | 0.91 |
| 20:55:00 | 82480 | 53040 | 63160 | 0.6 | 23160 | 0.92 | 23160 | 0.92 |
| 21:05:00 | 78420 | 49640 | 60700 | 0.6 | 20700 | 0.92 | 20700 | 0.92 |
| 21:15:00 | 77730 | 49140 | 60220 | 0.6 | 20220 | 0.92 | 20220 | 0.92 |
| 21:25:00 | 78580 | 49470 | 61050 | 0.6 | 21050 | 0.92 | 21050 | 0.92 |
| 21:35:00 | 79160 | 49430 | 61830 | 0.6 | 21830 | 0.91 | 21830 | 0.91 |
| 21:45:00 | 81230 | 50750 | 63430 | 0.6 | 23430 | 0.91 | 23430 | 0.91 |
| 21:55:00 | 80800 | 49950 | 63510 | 0.6 | 23510 | 0.90 | 23510 | 0.90 |
| 22:05:00 | 77220 | 47500 | 60880 | 0.6 | 20880 | 0.92 | 20880 | 0.92 |
| 22:15:00 | 78610 | 49750 | 60860 | 0.6 | 20860 | 0.92 | 20860 | 0.92 |
| 22:25:00 | 80970 | 51080 | 62820 | 0.6 | 22820 | 0.91 | 22820 | 0.91 |

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|---|---|---|---|---|---|---|---|---|
| 22:35:00 | 80070 | 49900 | 62620 | 0.6 | 22620 | 0.91 | 22620 | 0.91 |
| 22:45:00 | 79230 | 49910 | 61530 | 0.6 | 21530 | 0.92 | 21530 | 0.92 |
| 22:55:00 | 80250 | 50680 | 62220 | 0.6 | 22220 | 0.92 | 22220 | 0.92 |
| 23:05:00 | 80190 | 50070 | 62630 | 0.6 | 22630 | 0.91 | 22630 | 0.91 |
| 23:15:00 | 80550 | 49830 | 63280 | 0.6 | 23280 | 0.91 | 23280 | 0.91 |
| 23:25:00 | 81000 | 49830 | 63870 | 0.6 | 23870 | 0.90 | 23870 | 0.90 |
| 23:35:00 | 82830 | 51100 | 65190 | 0.6 | 25190 | 0.90 | 25190 | 0.90 |
| 23:45:00 | 82490 | 52790 | 63380 | 0.6 | 23380 | 0.91 | 23380 | 0.91 |
| 23:55:00 | 81140 | 51670 | 62550 | 0.6 | 22550 | 0.92 | 22550 | 0.92 |
| 0:05:00 | 79920 | 50300 | 62110 | 0.6 | 22110 | 0.92 | 22110 | 0.92 |
| 0:15:00 | 79620 | 49400 | 62430 | 0.6 | 22430 | 0.91 | 22430 | 0.91 |
| 0:25:00 | 80390 | 49740 | 63150 | 0.6 | 23150 | 0.91 | 23150 | 0.91 |
| 0:35:00 | 82090 | 50500 | 64710 | 0.6 | 24710 | 0.90 | 24710 | 0.90 |
| 0:45:00 | 81610 | 49870 | 64610 | 0.6 | 24610 | 0.90 | 24610 | 0.90 |
| 0:55:00 | 80290 | 49420 | 63280 | 0.6 | 23280 | 0.90 | 23280 | 0.90 |
| 1:05:00 | 79860 | 49370 | 62760 | 0.6 | 22760 | 0.91 | 22760 | 0.91 |
| 1:15:00 | 80530 | 50660 | 62600 | 0.6 | 22600 | 0.91 | 22600 | 0.91 |
| 1:25:00 | 78680 | 49270 | 61340 | 0.6 | 21340 | 0.92 | 21340 | 0.92 |
| 1:35:00 | 78990 | 49440 | 61600 | 0.6 | 21600 | 0.92 | 21600 | 0.92 |
| 1:45:00 | 78920 | 49170 | 61730 | 0.6 | 21730 | 0.91 | 21730 | 0.91 |
| 1:55:00 | 80550 | 50390 | 62840 | 0.6 | 22840 | 0.91 | 22840 | 0.91 |
| 2:05:00 | 79620 | 49600 | 62280 | 0.6 | 22280 | 0.91 | 22280 | 0.91 |
| 2:15:00 | 79320 | 49250 | 62170 | 0.6 | 22170 | 0.91 | 22170 | 0.91 |
| 2:25:00 | 81030 | 50810 | 63120 | 0.6 | 23120 | 0.91 | 23120 | 0.91 |
| 2:35:00 | 79790 | 49670 | 62440 | 0.6 | 22440 | 0.91 | 22440 | 0.91 |
| 2:45:00 | 80320 | 50300 | 62620 | 0.6 | 22620 | 0.91 | 22620 | 0.91 |
| 2:55:00 | 79300 | 50730 | 60950 | 0.6 | 20950 | 0.92 | 20950 | 0.92 |
| 3:05:00 | 79520 | 51160 | 60870 | 0.6 | 20870 | 0.93 | 20870 | 0.93 |
| 3:15:00 | 78400 | 50670 | 59820 | 0.6 | 19820 | 0.93 | 19820 | 0.93 |
| 3:25:00 | 78230 | 50450 | 59790 | 0.6 | 19790 | 0.93 | 19790 | 0.93 |
| 3:35:00 | 77370 | 49610 | 59370 | 0.6 | 19370 | 0.93 | 19370 | 0.93 |
| 3:45:00 | 80230 | 51150 | 61810 | 0.6 | 21810 | 0.92 | 21810 | 0.92 |
| 3:55:00 | 79670 | 50530 | 61590 | 0.6 | 21590 | 0.92 | 21590 | 0.92 |
| 4:05:00 | 80130 | 51170 | 61660 | 0.6 | 21660 | 0.92 | 21660 | 0.92 |
| 4:15:00 | 82000 | 51570 | 63760 | 0.6 | 23760 | 0.91 | 23760 | 0.91 |
| 4:25:00 | 81690 | 50830 | 63940 | 0.6 | 23940 | 0.90 | 23940 | 0.90 |
| 4:35:00 | 81170 | 50480 | 63560 | 0.6 | 23560 | 0.91 | 23560 | 0.91 |
| 4:45:00 | 81340 | 51200 | 63200 | 0.6 | 23200 | 0.91 | 23200 | 0.91 |
| 4:55:00 | 83220 | 52850 | 64280 | 0.6 | 24280 | 0.91 | 24280 | 0.91 |
| 5:05:00 | 81200 | 51070 | 63140 | 0.6 | 23140 | 0.91 | 23140 | 0.91 |
| 5:15:00 | 81680 | 51120 | 63700 | 0.6 | 23700 | 0.91 | 23700 | 0.91 |
| 5:25:00 | 81750 | 50790 | 64050 | 0.6 | 24050 | 0.90 | 24050 | 0.90 |
| 5:35:00 | 82140 | 50860 | 64490 | 0.6 | 24490 | 0.90 | 24490 | 0.90 |
| 5:45:00 | 83650 | 53020 | 64700 | 0.6 | 24700 | 0.91 | 24700 | 0.91 |
| 5:55:00 | 81130 | 51250 | 62890 | 0.6 | 22890 | 0.91 | 22890 | 0.91 |
| 6:05:00 | 80690 | 51600 | 62030 | 0.6 | 22030 | 0.92 | 22030 | 0.92 |
| 6:15:00 | 87060 | 57110 | 65710 | 0.7 | 25710 | 0.91 | 25710 | 0.91 |
| 6:25:00 | 96390 | 63890 | 72180 | 0.7 | 32180 | 0.89 | 32180 | 0.89 |
| 6:35:00 | 142900 | 87710 | 112800 | 0.6 | 72800 | ***0.77*** | 47800 | 0.88 |
| 6:45:00 | 142200 | 87400 | 112200 | 0.6 | 72200 | ***0.77*** | 47200 | 0.88 |
| 6:55:00 | 129200 | 81180 | 100500 | 0.6 | 60500 | ***0.80*** | 35500 | 0.92 |
| 7:05:00 | 123200 | 80030 | 93720 | 0.6 | 53720 | ***0.83*** | 28720 | 0.94 |
| 7:15:00 | 119300 | 75930 | 92130 | 0.6 | 52130 | ***0.82*** | 27130 | 0.94 |
| 7:25:00 | 111300 | 70800 | 85930 | 0.6 | 45930 | ***0.84*** | 20930 | 0.96 |
| 7:35:00 | 114200 | 73760 | 87180 | 0.6 | 47180 | ***0.84*** | 22180 | 0.96 |
| 7:45:00 | 126500 | 84560 | 94130 | 0.7 | 54130 | ***0.84*** | 29130 | 0.95 |
| 7:55:00 | 140900 | 101100 | 98230 | 0.7 | 58230 | ***0.87*** | 33230 | 0.95 |
| 8:05:00 | 155000 | 118200 | 100200 | 0.8 | 60200 | ***0.89*** | 35200 | 0.96 |
| 8:15:00 | 147500 | 110800 | 97480 | 0.8 | 57480 | ***0.89*** | 32480 | 0.96 |
| 8:25:00 | 145200 | 109300 | 95560 | 0.8 | 55560 | ***0.89*** | 30560 | 0.96 |
| 8:35:00 | 134800 | 97310 | 93400 | 0.7 | 53400 | ***0.88*** | 28400 | 0.96 |
| 8:45:00 | 165000 | 121800 | 111200 | 0.7 | 71200 | ***0.86*** | 46200 | 0.93 |
| 8:55:00 | 178800 | 130900 | 121700 | 0.7 | 81700 | ***0.85*** | 56700 | 0.92 |

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|---|---|---|---|---|---|---|---|---|
| 9:05:00 | 172500 | 125000 | 118900 | 0.7 | 78900 | ***0.85*** | 53900 | 0.92 |
| 9:15:00 | 179200 | 129200 | 124100 | 0.7 | 84100 | ***0.84*** | 59100 | 0.91 |
| 9:25:00 | 184600 | 134400 | 126400 | 0.7 | 86400 | ***0.84*** | 61400 | 0.91 |
| 9:35:00 | 194400 | 148800 | 125100 | 0.8 | 85100 | ***0.87*** | 60100 | 0.93 |
| 9:45:00 | 189800 | 141200 | 126800 | 0.7 | 86800 | ***0.85*** | 61800 | 0.92 |
| 9:55:00 | 183300 | 135400 | 123500 | 0.7 | 83500 | ***0.85*** | 58500 | 0.92 |
| 10:05:00 | 176800 | 129800 | 120000 | 0.7 | 80000 | ***0.85*** | 55000 | 0.92 |
| 10:15:00 | 181500 | 132900 | 123500 | 0.7 | 83500 | ***0.85*** | 58500 | 0.92 |
| 10:25:00 | 178800 | 129700 | 123100 | 0.7 | 83100 | ***0.84*** | 58100 | 0.91 |
| 10:35:00 | 185100 | 138500 | 122800 | 0.7 | 82800 | ***0.86*** | 57800 | 0.92 |
| 10:45:00 | 177200 | 131400 | 118900 | 0.7 | 78900 | ***0.86*** | 53900 | 0.93 |
| 10:55:00 | 180300 | 133500 | 121100 | 0.7 | 81100 | ***0.85*** | 56100 | 0.92 |
| 11:05:00 | 183500 | 136200 | 122900 | 0.7 | 82900 | ***0.85*** | 57900 | 0.92 |
| 11:15:00 | 180700 | 133100 | 122200 | 0.7 | 82200 | ***0.85*** | 57200 | 0.92 |
| 11:25:00 | 177800 | 131900 | 119200 | 0.7 | 79200 | ***0.86*** | 54200 | 0.92 |
| 11:35:00 | 154000 | 103600 | 113900 | 0.7 | 73900 | ***0.81*** | 48900 | 0.90 |
| 11:45:00 | 144900 | 100400 | 104500 | 0.7 | 64500 | ***0.84*** | 39500 | 0.93 |
| 11:55:00 | 152600 | 103600 | 112000 | 0.7 | 72000 | ***0.82*** | 47000 | 0.91 |
| 12:05:00 | 161100 | 113200 | 114600 | 0.7 | 74600 | ***0.83*** | 49600 | 0.92 |
| 12:15:00 | 159800 | 111100 | 114800 | 0.7 | 74800 | ***0.83*** | 49800 | 0.91 |

**Annex 3**: Energy analyzer data for power factor improvement at Al Carton Factory

| Date & Time | St/E+ Avg (VA) | Pt/E+ Avg (W) | Qti/E+ Avg | (VAR) | | Pfti+ Avg. |
|---|---|---|---|---|---|---|
| 05/02/2007 00:00 | 4300 | 3666 | 2247 | 1447 | | 0.93 |
| 05/02/2007 00:12 | 4236 | 3617 | 2205 | 1405 | | 0.93 |
| 05/02/2007 00:22 | 4203 | 3585 | 2193 | 1393 | | 0.93 |
| 05/02/2007 00:32 | 4221 | 3600 | 2204 | 1404 | | 0.93 |
| 05/02/2007 00:42 | 4237 | 3616 | 2209 | 1409 | | 0.93 |
| 05/02/2007 00:52 | 4279 | 3645 | 2240 | 1440 | | 0.93 |
| 05/02/2007 01:02 | 4207 | 3596 | 2184 | 1384 | | 0.93 |
| 05/02/2007 01:12 | 4225 | 3609 | 2196 | 1396 | | 0.93 |
| 05/02/2007 01:22 | 4235 | 3615 | 2206 | 1406 | | 0.93 |
| 05/02/2007 01:32 | 4246 | 3629 | 2205 | 1405 | | 0.93 |
| 05/02/2007 01:42 | 4249 | 3631 | 2208 | 1408 | | 0.93 |
| 05/02/2007 01:52 | 4279 | 3652 | 2229 | 1429 | | 0.93 |
| 05/02/2007 02:02 | 4292 | 3666 | 2231 | 1431 | | 0.93 |
| 05/02/2007 02:12 | 4266 | 3647 | 2211 | 1411 | | 0.93 |
| 05/02/2007 02:22 | 4266 | 3644 | 2217 | 1417 | | 0.93 |
| 05/02/2007 02:32 | 4266 | 3646 | 2215 | 1415 | | 0.93 |
| 05/02/2007 02:42 | 4271 | 3650 | 2217 | 1417 | | 0.93 |
| 05/02/2007 02:52 | 4275 | 3655 | 2218 | 1418 | | 0.93 |
| 05/02/2007 03:02 | 4282 | 3661 | 2221 | 1421 | | 0.93 |
| 05/02/2007 03:12 | 4291 | 3669 | 2225 | 1425 | | 0.93 |
| 05/02/2007 03:22 | 4300 | 3676 | 2230 | 1430 | | 0.93 |
| 05/02/2007 03:32 | 4298 | 3675 | 2228 | 1428 | | 0.93 |
| 05/02/2007 03:42 | 4307 | 3682 | 2235 | 1435 | | 0.93 |
| 05/02/2007 03:52 | 4294 | 3671 | 2227 | 1427 | | 0.93 |
| 05/02/2007 04:02 | 4276 | 3655 | 2219 | 1419 | | 0.93 |
| 05/02/2007 04:12 | 4258 | 3642 | 2206 | 1406 | | 0.93 |
| 05/02/2007 04:22 | 4233 | 3621 | 2192 | 1392 | | 0.93 |
| 05/02/2007 04:32 | 4408 | 3822 | 2195 | 1395 | | 0.94 |
| 05/02/2007 04:42 | 4904 | 4387 | 2192 | 1392 | | 0.95 |
| 05/02/2007 04:52 | 4901 | 4384 | 2192 | 1392 | | 0.95 |
| 05/02/2007 05:02 | 4876 | 4364 | 2175 | 1375 | | 0.95 |
| 05/02/2007 05:12 | 4844 | 4338 | 2155 | 1355 | | 0.95 |
| 05/02/2007 05:22 | 4820 | 4315 | 2147 | 1347 | | 0.95 |
| 05/02/2007 05:32 | 4803 | 4301 | 2138 | 1338 | | 0.95 |
| 05/02/2007 05:42 | 4304 | 3881 | 1860 | 1060 | | 0.96 |
| 05/02/2007 05:52 | 3607 | 3293 | 1471 | 671 | | 0.98 |
| 05/02/2007 06:02 | 3581 | 3277 | 1444 | 644 | | 0.98 |
| 05/02/2007 06:12 | 3541 | 3241 | 1426 | 626 | | 0.98 |
| 05/02/2007 06:22 | 3503 | 3204 | 1416 | 616 | | 0.98 |
| 05/02/2007 06:32 | 3532 | 3232 | 1425 | 625 | | 0.98 |
| 05/02/2007 06:42 | 3207 | 2851 | 1470 | 670 | | 0.97 |
| 05/02/2007 06:52 | 2019 | 1262 | 1576 | 776 | | 0.85 |
| 05/02/2007 07:02 | 15590 | 12570 | 9219 | 8419 | | 0.83 |
| 05/02/2007 07:12 | 83320 | 64940 | 52200 | 51400 | | 0.78 |
| 05/02/2007 07:22 | 165600 | 118700 | 115300 | 114500 | | 0.72 |
| 05/02/2007 07:32 | 211000 | 124800 | 170100 | 100 | | 1.00 |
| 05/02/2007 07:42 | 229600 | 135500 | 185400 | 15400 | | 0.99 |
| 05/02/2007 07:52 | 207100 | 133800 | 158000 | -12000 | | 1.00 |
| 05/02/2007 08:02 | 185000 | 124200 | 137000 | -33000 | | 0.97 |
| 05/02/2007 08:12 | 227200 | 145600 | 174300 | 4300 | | 1.00 |
| 05/02/2007 08:22 | 277200 | 164400 | 223100 | 53100 | | 0.95 |
| 05/02/2007 08:32 | 347200 | 205300 | 280000 | 110000 | | 0.88 |
| 05/02/2007 08:42 | 305000 | 175200 | 249600 | 79600 | | 0.91 |
| 05/02/2007 08:52 | 304600 | 175200 | 249200 | 79200 | | 0.91 |
| 05/02/2007 09:02 | 323100 | 192200 | 259700 | 89700 | | 0.91 |
| 05/02/2007 09:12 | 315300 | 187300 | 253600 | 83600 | | 0.91 |
| 05/02/2007 09:22 | 317900 | 186900 | 257100 | 87100 | | 0.91 |
| 05/02/2007 09:32 | 295000 | 174900 | 237500 | 67500 | | 0.93 |
| 05/02/2007 09:42 | 300900 | 178600 | 242100 | 72100 | | 0.93 |

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|---|---|---|---|---|---|---|
| 05/02/2007 09:52 | 164700 | 105100 | 126800 | -43200 | | 0.92 |
| 05/02/2007 10:02 | 156400 | 94570 | 124600 | -45400 | | 0.90 |
| 05/02/2007 10:12 | 161100 | 96770 | 128800 | -41200 | | 0.92 |
| 05/02/2007 10:22 | 172100 | 111400 | 131200 | -38800 | | 0.94 |
| 05/02/2007 10:32 | 214400 | 135900 | 165800 | -4200 | | 1.00 |
| 05/02/2007 10:42 | 272800 | 161100 | 220100 | 50100 | | 0.95 |
| 05/02/2007 10:52 | 301000 | 169900 | 248500 | 78500 | | 0.91 |
| 05/02/2007 11:02 | 301800 | 176000 | 245100 | 75100 | | 0.92 |
| 05/02/2007 11:12 | 300600 | 167100 | 249900 | 79900 | | 0.90 |
| 05/02/2007 11:22 | 308300 | 174200 | 254300 | 84300 | | 0.90 |
| 05/02/2007 11:32 | 296200 | 175700 | 238400 | 68400 | | 0.93 |
| 05/02/2007 11:42 | 310500 | 184700 | 249500 | 79500 | | 0.92 |
| 05/02/2007 11:52 | 262400 | 164700 | 204200 | 34200 | | 0.98 |
| 05/02/2007 12:02 | 316200 | 180500 | 259600 | 89600 | | 0.90 |
| 05/02/2007 12:12 | 322700 | 188000 | 262300 | 92300 | | 0.90 |
| 05/02/2007 12:22 | 278300 | 159400 | 228200 | 58200 | | 0.94 |
| 05/02/2007 12:32 | 264000 | 157000 | 212200 | 42200 | | 0.97 |
| 05/02/2007 12:42 | 285700 | 165400 | 233000 | 63000 | | 0.93 |
| 05/02/2007 12:52 | 273100 | 161000 | 220500 | 50500 | | 0.95 |
| 05/02/2007 13:02 | 270600 | 161400 | 217200 | 47200 | | 0.96 |
| 05/02/2007 13:12 | 259700 | 160300 | 204300 | 34300 | | 0.98 |
| 05/02/2007 13:22 | 235100 | 156400 | 175500 | 5500 | | 1.00 |
| 05/02/2007 13:32 | 248100 | 160200 | 189400 | 19400 | | 0.99 |
| 05/02/2007 13:42 | 238800 | 150700 | 185200 | 15200 | | 0.99 |
| 05/02/2007 13:52 | 256400 | 153600 | 205200 | 35200 | | 0.97 |
| 05/02/2007 14:02 | 260100 | 156600 | 207600 | 37600 | | 0.97 |
| 05/02/2007 14:12 | 291200 | 168400 | 237600 | 67600 | | 0.93 |
| 05/02/2007 14:22 | 264700 | 156600 | 213400 | 43400 | | 0.96 |
| 05/02/2007 14:32 | 304200 | 176300 | 247900 | 77900 | | 0.91 |
| 05/02/2007 14:42 | 286400 | 161200 | 236700 | 66700 | | 0.92 |
| 05/02/2007 14:52 | 285200 | 163600 | 233600 | 63600 | | 0.93 |
| 05/02/2007 15:02 | 278300 | 155700 | 230700 | 60700 | | 0.93 |
| 05/02/2007 15:12 | 259400 | 144300 | 215500 | 45500 | | 0.95 |
| 05/02/2007 15:22 | 296600 | 169800 | 243100 | 73100 | | 0.92 |
| 05/02/2007 15:32 | 292400 | 161700 | 243500 | 73500 | | 0.91 |
| 05/02/2007 15:42 | 300900 | 170700 | 247800 | 77800 | | 0.91 |
| 05/02/2007 15:52 | 284600 | 159300 | 235800 | 65800 | | 0.92 |
| 05/02/2007 16:02 | 281600 | 158000 | 233100 | 63100 | | 0.93 |
| 05/02/2007 16:12 | 289900 | 164200 | 238900 | 68900 | | 0.92 |
| 05/02/2007 16:22 | 281700 | 153400 | 236200 | 66200 | | 0.92 |
| 05/02/2007 16:32 | 288200 | 160700 | 239100 | 69100 | | 0.92 |
| 05/02/2007 16:42 | 282900 | 160000 | 233300 | 63300 | | 0.93 |
| 05/02/2007 16:52 | 293800 | 164500 | 243500 | 73500 | | 0.91 |
| 05/02/2007 17:02 | 251200 | 144500 | 205500 | 35500 | | 0.97 |
| 05/02/2007 17:12 | 197500 | 118300 | 158200 | -11800 | | 1.00 |
| 05/02/2007 17:22 | 168400 | 97880 | 137000 | -33000 | | 0.95 |
| 05/02/2007 17:32 | 166700 | 95710 | 136500 | -33500 | | 0.94 |
| 05/02/2007 17:42 | 190100 | 113800 | 152300 | -17700 | | 0.99 |
| 05/02/2007 17:52 | 201100 | 121800 | 160100 | -9900 | | 1.00 |
| 05/02/2007 18:02 | 269700 | 157700 | 218800 | 48800 | | 0.96 |
| 05/02/2007 18:12 | 292100 | 169800 | 237600 | 67600 | | 0.93 |
| 05/02/2007 18:22 | 241600 | 137900 | 198300 | 28300 | | 0.98 |
| 05/02/2007 18:32 | 238000 | 136200 | 195200 | 25200 | | 0.98 |
| 05/02/2007 18:42 | 273000 | 151800 | 226800 | 56800 | | 0.94 |
| 05/02/2007 18:52 | 284500 | 166100 | 231000 | 61000 | | 0.94 |
| 05/02/2007 19:02 | 243600 | 138200 | 200500 | 30500 | | 0.98 |
| 05/02/2007 19:12 | 249700 | 143000 | 204700 | 34700 | | 0.97 |
| 05/02/2007 19:22 | 275400 | 156200 | 226800 | 56800 | | 0.94 |
| 05/02/2007 19:32 | 191300 | 122900 | 146500 | -23500 | | 0.98 |
| 05/02/2007 19:42 | 266000 | 155100 | 216000 | 46000 | | 0.96 |
| 05/02/2007 19:52 | 288600 | 175500 | 229100 | 59100 | | 0.95 |
| 05/02/2007 20:02 | 281600 | 168900 | 225200 | 55200 | | 0.95 |
| 05/02/2007 20:12 | 282600 | 168000 | 227300 | 57300 | | 0.95 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 05/02/2007 20:22 | 270900 | 154800 | 222300 | 52300 | | 0.95 |
| 05/02/2007 20:32 | 235900 | 143500 | 187200 | 17200 | | 0.99 |
| 05/02/2007 20:42 | 262600 | 152000 | 214100 | 44100 | | 0.96 |
| 05/02/2007 20:52 | 242900 | 144600 | 195100 | 25100 | | 0.99 |
| 05/02/2007 21:02 | 259600 | 146500 | 214300 | 44300 | | 0.96 |
| 05/02/2007 21:12 | 174400 | 104500 | 139600 | 138800 | | 85.00 |
| 05/02/2007 21:22 | 72710 | 57300 | 44750 | 43950 | | 87.00 |
| 05/02/2007 21:32 | 10240 | 5973 | 8319 | 6519 | | 0.88 |
| 05/02/2007 21:42 | 3759 | 2912 | 2376 | 1576 | | 0.88 |
| 05/02/2007 21:52 | 3577 | 2782 | 2249 | 1449 | | 0.89 |
| 05/02/2007 22:02 | 4247 | 3094 | 2909 | 2109 | | 0.83 |
| 05/02/2007 22:12 | 4244 | 3096 | 2902 | 2102 | | 0.83 |
| 05/02/2007 22:22 | 4336 | 3456 | 2618 | 1818 | | 0.89 |
| 05/02/2007 22:32 | 5598 | 5052 | 2410 | 1610 | | 0.95 |
| 05/02/2007 22:42 | 5043 | 4520 | 2235 | 1435 | | 0.95 |
| 05/02/2007 22:52 | 5148 | 4551 | 2407 | 1607 | | 0.94 |
| 05/02/2007 23:02 | 4975 | 4449 | 2226 | 1426 | | 0.95 |
| 05/02/2007 23:12 | 5179 | 4594 | 2390 | 1590 | | 0.95 |
| 05/02/2007 23:22 | 4923 | 4410 | 2187 | 1387 | | 0.95 |
| 05/02/2007 23:32 | 5040 | 4458 | 2352 | 1552 | | 0.94 |
| 05/02/2007 23:42 | 4218 | 3604 | 2191 | 1391 | | 0.93 |
| 05/02/2007 23:52 | 4258 | 3645 | 2201 | 1401 | | 0.93 |

**Annex4**: Energy analyzer data for power factor improvement at Al Arz Ice-Cream Factory

| Date & Time | St/E+ Avg (VA) | Pt/E+ Avg (W) | Qti/E+ Avg (VAR) | Pfti+ Avg. |
|---|---|---|---|---|
| 14/03/2007 10:45 | 238600 | 231200 | 58990 | 1 |
| 14/03/2007 11:45 | 247900 | 240600 | 59500 | 1 |
| 14/03/2007 12:45 | 246800 | 239600 | 59150 | 1 |
| 14/03/2007 13:45 | 207800 | 202200 | 48010 | 1 |
| 14/03/2007 14:45 | 153600 | 147900 | 41510 | 1 |
| 14/03/2007 15:45 | 84930 | 81050 | 25360 | 1 |
| 14/03/2007 16:45 | 56930 | 54300 | 17120 | 1 |
| 14/03/2007 17:45 | 46620 | 43260 | 17390 | 0.9 |
| 14/03/2007 18:45 | 52380 | 48270 | 20340 | 0.9 |
| 14/03/2007 19:45 | 54120 | 49460 | 21960 | 0.9 |
| 14/03/2007 20:45 | 54370 | 49540 | 22390 | 0.9 |
| 14/03/2007 21:45 | 54590 | 49720 | 22520 | 0.9 |
| 14/03/2007 22:45 | 53580 | 48950 | 21790 | 0.9 |
| 14/03/2007 23:45 | 54590 | 49600 | 22800 | 0.9 |
| 15/03/2007 00:45 | 53840 | 49060 | 22170 | 0.9 |
| 15/03/2007 01:45 | 57100 | 51770 | 24080 | 0.9 |
| 15/03/2007 02:45 | 61490 | 55760 | 25910 | 0.9 |
| 15/03/2007 03:45 | 54460 | 49600 | 22470 | 0.9 |
| 15/03/2007 04:45 | 51600 | 47580 | 19970 | 0.9 |
| 15/03/2007 05:45 | 42870 | 40300 | 14610 | 0.9 |
| 15/03/2007 06:45 | 65150 | 62990 | 16640 | 1 |
| 15/03/2007 07:45 | 122100 | 118600 | 28940 | 1 |
| 15/03/2007 08:45 | 171300 | 166000 | 42470 | 1 |
| 15/03/2007 09:45 | 184200 | 178500 | 45650 | 1 |
| 15/03/2007 10:45 | 193800 | 187900 | 47490 | 1 |
| 15/03/2007 11:45 | 171100 | 166400 | 39970 | 1 |
| 15/03/2007 12:45 | 160100 | 155000 | 40040 | 1 |
| 15/03/2007 13:45 | 169700 | 162700 | 48030 | 1 |
| 15/03/2007 14:45 | 105900 | 100600 | 33080 | 0.9 |
| 15/03/2007 15:45 | 51450 | 49290 | 14740 | 1 |
| 15/03/2007 16:45 | 38300 | 36700 | 10940 | 1 |
| 15/03/2007 17:45 | 41320 | 38010 | 16210 | 0.9 |
| 15/03/2007 18:45 | 47120 | 42630 | 20070 | 0.9 |
| 15/03/2007 19:45 | 47200 | 42660 | 20200 | 0.9 |
| 15/03/2007 20:45 | 47290 | 42730 | 20270 | 0.9 |
| 15/03/2007 21:45 | 54080 | 48740 | 23430 | 0.9 |
| 15/03/2007 22:45 | 47310 | 42940 | 19850 | 0.9 |
| 15/03/2007 23:45 | 47690 | 43000 | 20610 | 0.9 |
| 16/03/2007 00:45 | 47250 | 42640 | 20360 | 0.9 |
| 16/03/2007 01:45 | 47210 | 42710 | 20130 | 0.9 |
| 16/03/2007 02:45 | 47580 | 43000 | 20370 | 0.9 |
| 16/03/2007 03:45 | 47310 | 42730 | 20290 | 0.9 |
| 16/03/2007 04:45 | 43820 | 40230 | 17370 | 0.9 |
| 16/03/2007 05:45 | 35090 | 33230 | 11280 | 0.9 |
| 16/03/2007 06:45 | 35030 | 33300 | 10870 | 0.9 |
| 16/03/2007 07:45 | 34880 | 33290 | 10400 | 1 |
| 16/03/2007 08:45 | 35330 | 33660 | 10710 | 1 |
| 16/03/2007 09:45 | 34800 | 33200 | 10430 | 1 |
| 16/03/2007 10:45 | 34470 | 33000 | 9964 | 1 |
| 16/03/2007 11:45 | 34150 | 32630 | 10070 | 1 |
| 16/03/2007 12:45 | 35180 | 33420 | 10980 | 0.9 |
| 16/03/2007 13:45 | 35480 | 33710 | 11040 | 0.9 |
| 16/03/2007 14:45 | 34820 | 33250 | 10350 | 1 |
| 16/03/2007 15:45 | 34470 | 32890 | 10300 | 1 |
| 16/03/2007 16:45 | 36920 | 34940 | 11910 | 0.9 |
| 16/03/2007 17:45 | 40520 | 37370 | 15660 | 0.9 |
| 16/03/2007 18:45 | 47230 | 42780 | 20030 | 0.9 |
| 16/03/2007 19:45 | 47150 | 42640 | 20120 | 0.9 |
| 16/03/2007 20:45 | 55020 | 49440 | 24140 | 0.9 |
| 16/03/2007 21:45 | 46760 | 42340 | 19830 | 0.9 |

| | | | | |
|---|---|---|---|---|
| 16/03/2007 22:45 | 46460 | 42070 | 19720 | 0.9 |
| 16/03/2007 23:45 | 47300 | 42620 | 20500 | 0.9 |
| 17/03/2007 00:45 | 47430 | 42790 | 20440 | 0.9 |
| 17/03/2007 01:45 | 47680 | 42850 | 20890 | 0.9 |
| 17/03/2007 02:45 | 47930 | 42960 | 21250 | 0.9 |
| 17/03/2007 03:45 | 48220 | 43320 | 21170 | 0.9 |
| 17/03/2007 04:45 | 44900 | 41010 | 18280 | 0.9 |
| 17/03/2007 05:45 | 34980 | 33270 | 10790 | 1 |
| 17/03/2007 06:45 | 70000 | 67820 | 17330 | 1 |
| 17/03/2007 07:45 | 160600 | 156100 | 37840 | 1 |
| 17/03/2007 08:45 | 193300 | 187800 | 46090 | 1 |
| 17/03/2007 09:45 | 227900 | 220900 | 56060 | 1 |
| 17/03/2007 10:45 | 236600 | 228800 | 60180 | 1 |
| 17/03/2007 11:45 | 260100 | 252100 | 64050 | 1 |
| 17/03/2007 12:45 | 254800 | 247400 | 60960 | 1 |
| 17/03/2007 13:45 | 235300 | 228000 | 58120 | 1 |
| 17/03/2007 14:45 | 177200 | 170200 | 49160 | 1 |
| 17/03/2007 15:45 | 107500 | 102100 | 33610 | 0.9 |
| 17/03/2007 16:45 | 53700 | 51590 | 14880 | 1 |
| 17/03/2007 17:45 | 50760 | 47350 | 18280 | 0.9 |
| 17/03/2007 18:45 | 52760 | 48200 | 21460 | 0.9 |
| 17/03/2007 19:45 | 51620 | 47330 | 20600 | 0.9 |
| 17/03/2007 20:45 | 52480 | 47780 | 21710 | 0.9 |
| 17/03/2007 21:45 | 51440 | 47100 | 20690 | 0.9 |
| 17/03/2007 22:45 | 51190 | 46890 | 20540 | 0.9 |
| 17/03/2007 23:45 | 51190 | 46750 | 20840 | 0.9 |
| 18/03/2007 00:45 | 51040 | 46660 | 20680 | 0.9 |
| 18/03/2007 01:45 | 52150 | 47390 | 21760 | 0.9 |
| 18/03/2007 02:45 | 51860 | 47220 | 21440 | 0.9 |
| 18/03/2007 03:45 | 51640 | 47120 | 21140 | 0.9 |
| 18/03/2007 04:45 | 48610 | 44960 | 18490 | 0.9 |
| 18/03/2007 05:45 | 39550 | 37840 | 11530 | 1 |
| 18/03/2007 06:45 | 71510 | 69410 | 17180 | 1 |
| 18/03/2007 07:45 | 178100 | 171600 | 47860 | 1 |
| 18/03/2007 08:45 | 207400 | 200600 | 52850 | 1 |
| 18/03/2007 09:45 | 222500 | 216100 | 53210 | 1 |

**Annex 5**: Energy analyzer data for power factor improvement at Al Aqqad Textile Factory

| Date & Time | St/E+ Avg (VA) | Pt/E+ Avg (W) | Qti/E+ Avg (VAR) | (VAR) | | pfactor | | |
|---|---|---|---|---|---|---|---|---|
| 07/02/2007 06:12 | 27040 | 16960 | 21050 | 1050 | | 1.00 | | |
| 07/02/2007 06:22 | 32410 | 20000 | 25500 | 5500 | | 0.96 | | |
| 07/02/2007 06:32 | 51050 | 38230 | 33830 | 13830 | | 0.94 | | |
| 07/02/2007 06:42 | 62010 | 49190 | 37760 | 17760 | | 0.94 | | |
| 07/02/2007 06:52 | 47430 | 30720 | 35880 | 15880 | | 0.89 | | |
| 07/02/2007 07:02 | 60410 | 43790 | 41610 | 21610 | | 0.90 | | |
| 07/02/2007 07:12 | 59910 | 40730 | 43930 | 23930 | | 0.86 | | |
| 07/02/2007 07:22 | 65820 | 48160 | 44860 | 24860 | | 0.89 | | |
| 07/02/2007 07:32 | 71810 | 55750 | 45270 | 25270 | | 0.91 | | |
| 07/02/2007 07:42 | 74250 | 56630 | 48010 | 28010 | | 0.90 | | |
| 07/02/2007 07:52 | 78460 | 58550 | 52230 | 32230 | | 0.88 | | |
| 07/02/2007 08:02 | 78110 | 56740 | 53680 | 33680 | | 0.86 | | |
| 07/02/2007 08:12 | 75970 | 55510 | 51860 | 31860 | | 0.87 | | |
| 07/02/2007 08:22 | 83090 | 57860 | 59630 | 39630 | | 0.83 | | |
| 07/02/2007 08:32 | 108000 | 63600 | 87350 | 67350 | 17350 | 0.69 | 0.97 | -50000 |
| 07/02/2007 08:42 | 120300 | 79240 | 90600 | 70600 | 20600 | 0.75 | 0.96 | |
| 07/02/2007 08:52 | 120300 | 79170 | 90640 | 70640 | 20640 | 0.75 | 0.96 | |
| 07/02/2007 09:02 | 137900 | 87420 | 106700 | 86700 | 36700 | 0.71 | 0.92 | |
| 07/02/2007 09:12 | 155400 | 99470 | 119400 | 99400 | 49400 | 0.71 | 0.90 | |
| 07/02/2007 09:22 | 132400 | 82290 | 103800 | 83800 | 33800 | 0.70 | 0.93 | |
| 07/02/2007 09:32 | 154800 | 102200 | 116200 | 96200 | 46200 | 0.73 | 0.90 | |
| 07/02/2007 09:42 | 168000 | 112100 | 125200 | 105200 | 55200 | 0.73 | 0.89 | |
| 07/02/2007 09:52 | 167600 | 107300 | 128800 | 108800 | 58800 | 0.70 | 0.88 | |
| 07/02/2007 10:02 | 162600 | 100800 | 127600 | 107600 | 57600 | 0.68 | 0.88 | |
| 07/02/2007 10:12 | 154900 | 93170 | 123800 | 103800 | 53800 | 0.67 | 0.89 | |
| 07/02/2007 10:22 | 139200 | 87500 | 108200 | 88200 | 38200 | 0.70 | 0.92 | |
| 07/02/2007 10:32 | 139400 | 95270 | 101700 | 81700 | 31700 | 0.76 | 0.93 | |
| 07/02/2007 10:42 | 136900 | 89570 | 103600 | 83600 | 33600 | 0.73 | 0.93 | |
| 07/02/2007 10:52 | 135500 | 88620 | 102500 | 82500 | 32500 | 0.73 | 0.93 | |
| 07/02/2007 11:02 | 142800 | 95460 | 106200 | 86200 | 36200 | 0.74 | 0.92 | |
| 07/02/2007 11:12 | 141800 | 93400 | 106700 | 86700 | 36700 | 0.73 | 0.92 | |
| 07/02/2007 11:22 | 131700 | 88160 | 97840 | 77840 | 27840 | 0.75 | 0.94 | |
| 07/02/2007 11:32 | 137500 | 91760 | 102400 | 82400 | 32400 | 0.74 | 0.93 | |
| 07/02/2007 11:42 | 150000 | 97620 | 113900 | 93900 | 43900 | 0.72 | 0.91 | |
| 07/02/2007 11:52 | 149200 | 95410 | 114700 | 94700 | 44700 | 0.71 | 0.90 | |
| 07/02/2007 12:02 | 119500 | 70100 | 96770 | 76770 | 26770 | 0.67 | 0.94 | |
| 07/02/2007 12:12 | 116500 | 72760 | 91010 | 71010 | 21010 | 0.72 | 0.96 | |
| 07/02/2007 12:22 | 134700 | 86970 | 102900 | 82900 | 32900 | 0.72 | 0.93 | |
| 07/02/2007 12:32 | 125200 | 79300 | 96910 | 76910 | 26910 | 0.72 | 0.94 | |
| 07/02/2007 12:42 | 120100 | 75690 | 93290 | 73290 | 23290 | 0.72 | 0.95 | |
| 07/02/2007 12:52 | 114800 | 75780 | 86320 | 66320 | 16320 | 0.75 | 0.97 | |
| 07/02/2007 13:02 | 111800 | 74190 | 83760 | 63760 | 13760 | 0.76 | 0.98 | |
| 07/02/2007 13:12 | 123600 | 80740 | 93640 | 73640 | 23640 | 0.74 | 0.95 | |
| 07/02/2007 13:22 | 132900 | 85760 | 101600 | 81600 | 31600 | 0.72 | 0.93 | |
| 07/02/2007 13:32 | 132800 | 86370 | 100900 | 80900 | 30900 | 0.73 | 0.93 | |
| 07/02/2007 13:42 | 126900 | 76920 | 100900 | 80900 | 30900 | 0.69 | 0.93 | |
| 07/02/2007 13:52 | 142400 | 98280 | 103100 | 83100 | 33100 | 0.76 | 0.93 | |
| 07/02/2007 14:02 | 137900 | 91980 | 102800 | 82800 | 32800 | 0.74 | 0.93 | |
| 07/02/2007 14:12 | 136200 | 89800 | 102500 | 82500 | 32500 | 0.74 | 0.93 | |
| 07/02/2007 14:22 | 135400 | 92370 | 99050 | 79050 | 29050 | 0.76 | 0.94 | |
| 07/02/2007 14:32 | 127900 | 80360 | 99530 | 79530 | 29530 | 0.71 | 0.94 | |
| 07/02/2007 14:42 | 137000 | 94060 | 99700 | 79700 | 29700 | 0.76 | 0.94 | |
| 07/02/2007 14:52 | 128600 | 84500 | 97050 | 77050 | 27050 | 0.74 | 0.94 | |
| 07/02/2007 15:02 | 120000 | 77100 | 91970 | 71970 | 21970 | 0.73 | 0.96 | |
| 07/02/2007 15:12 | 118600 | 76730 | 90500 | 70500 | 20500 | 0.74 | 0.96 | |
| 07/02/2007 15:22 | 112400 | 69200 | 88640 | 68640 | 18640 | 0.71 | 0.97 | |
| 07/02/2007 15:32 | 110100 | 67280 | 87210 | 67210 | 17210 | 0.71 | 0.97 | |
| 07/02/2007 15:42 | 111700 | 71460 | 85930 | 65930 | 15930 | 0.73 | 0.97 | |

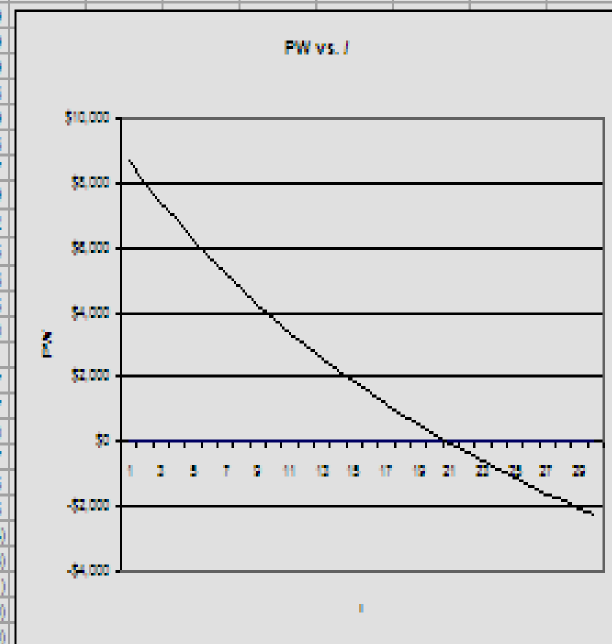
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 07/02/2007 15:52 | 103600 | 69270 | 77110 | 57110 | 7110 | 0.77 | 0.99 | |
| 07/02/2007 16:02 | 105700 | 70290 | 79050 | 59050 | 9050 | 0.77 | 0.99 | |
| 07/02/2007 16:12 | 99870 | 65130 | 75710 | 55710 | 5710 | 0.76 | 0.99 | |
| 07/02/2007 16:22 | 99440 | 64590 | 75600 | 55600 | 5600 | 0.76 | 0.99 | |
| 07/02/2007 16:32 | 110800 | 65880 | 89160 | 69160 | 19160 | 0.69 | 0.96 | |
| 07/02/2007 16:42 | 109900 | 64910 | 88740 | 68740 | 18740 | 0.69 | 0.96 | |
| 07/02/2007 16:52 | 94110 | 59310 | 73070 | 53070 | 3070 | 0.75 | 1.00 | |
| 07/02/2007 17:02 | 69470 | 47190 | 50980 | 30980 | 10980 | 0.84 | 0.94 | -20000 |
| 07/02/2007 17:12 | 69230 | 47640 | 50230 | 30230 | 10230 | 0.84 | 0.95 | -20000 |
| 07/02/2007 17:22 | 68800 | 47970 | 49310 | 29310 | 9310 | 0.85 | 0.95 | -20000 |
| 07/02/2007 17:32 | 69550 | 50460 | 47870 | 27870 | 7870 | 0.88 | 0.96 | -20000 |
| 07/02/2007 17:42 | 67610 | 49940 | 45560 | 25560 | 5560 | 0.89 | 0.98 | -20000 |
| 07/02/2007 17:52 | 66530 | 49330 | 44630 | 24630 | 4630 | 0.89 | 0.98 | -20000 |
| 07/02/2007 18:02 | 60490 | 41020 | 44450 | 24450 | 4450 | 0.86 | 0.98 | -20000 |
| 07/02/2007 18:12 | 70360 | 54500 | 44500 | 24500 | 4500 | 0.91 | 0.98 | -20000 |

**Annex (6)**

| | A | B | D | E |
|---|---|---|---|---|
| 1 | MARR = | 15% | | |
| 2 | Capital Investment = | $ 12,712 | | |
| 3 | Market Value = | $ 706 | | |
| 4 | Useful Life = | $ 5 | | |
| 5 | Net Annual Savings = | $ 4,131 | | |
| 6 | | | | |
| 7 | EOY | Cash Flow | EOY | Cash Flow |
| 8 | 0 | $ (12,712) | 0 | $ (12,712) |
| 9 | 1 | $ 4,131 | 1 | $ 4,131 |
| 10 | 2 | $ 4,131 | 2 | $ 4,131 |
| 11 | 3 | $ 4,131 | 3 | $ 4,131 |
| 12 | 4 | $ 4,131 | 4 | $ 4,131 |
| 13 | 5 | $ 4,131 | 5 | $ 4,837 |
| 14 | 5 | $ 706 | | |
| 15 | | | | |
| 16 | | | IRR = | 19.74% |
| 17 | | | | |
| 18 | B8 | = - B2 | | |
| 19 | E8 | = B8 | | |
| 20 | B9 | = $B$5 | | |
| 21 | E13 | = B13 + B14 | | |
| 22 | B14 | = B3 | | |
| 23 | E16 | = IRR( E8:E13, B1 ) | | |

Annex 6

| i | NPV(i) |
|---|---|
| 0% | $ 8,649 |
| 1% | $ 8,009 |
| 2% | $ 7,399 |
| 3% | $ 6,816 |
| 4% | $ 6,259 |
| 5% | $ 5,728 |
| 6% | $ 5,217 |
| 7% | $ 4,729 |
| 8% | $ 4,262 |
| 9% | $ 3,815 |
| 10% | $ 3,388 |
| 11% | $ 2,975 |
| 12% | $ 2,580 |
| 13% | $ 2,201 |
| 14% | $ 1,837 |
| 15% | $ 1,487 |
| 16% | $ 1,150 |
| 17% | $ 827 |
| 18% | $ 515 |
| 19% | $ 215 |
| 20% | $ (74) |
| 21% | $ (353) |
| 22% | $ (621) |
| 23% | $ (880) |
| 24% | $ (1,130) |
| 25% | $ (1,371) |
| 26% | $ (1,604) |
| 27% | $ (1,829) |
| 28% | $ (2,047) |
| 29% | $ (2,257) |



جامعة النجاح الوطنية
كلية الدراسات العليا

# تحسين كفاءة الطاقة ووسائل التقليل في التكلفه لبعض الصناعات المختلفة في فلسطين

إعداد

**باسل تحسين قاسم ياسين**

إشراف

**د. عماد بريك**

**د. وليد الكخن**

قدمت هذه الأطروحة استكمالا لمتطلبات نيل درجة الماجستير في هندسة الطاقة النظيفه واستراتيجية الترشيد بكلية الدراسات العليا في جامعة النجاح الوطنية، نابلس – فلسطين.

2008

**تحسين كفاءة الطاقة ووسائل تقليل التكلفه لبعض الصناعات المختلفه في فلسطين**

**إعداد**

**باسل تحسين قاسم ياسين**

**إشراف**

**د. عماد بريك**

**د. وليد الكخن**

## الملخص

ازمة النفط التي نتجت عقب حرب حزيران القت بظلالها بشكل مباشر على معدلات استهلاك الطاقة وامكانية الترشيد في استخدام الطاقة في القطاع الصناعي مما حدا بالباحثين والدارسين في مجال الطاقة على ايجاد سبل ووسائل للتقليل من حجم استهلاك الطاقة والذي بدوره ادى الى تطور ملحوظ في كفاءة استخدام الطاقة.

وضع الطاقة في فلسطين, كفاءة استخدام الطاقة وترشيد استهلاك الطاقة في المصانع ليس في احسن حال من معظم الدول النامية. تحاول هذه الاطروحه وضع حجر الاساس لكفاءة استخدام وترشيد استهلاك الطاقة في المصانع من خلال القيام بعملية تحليل وتقييم لوضع واستهلاك الطاقة في فلسطين من خلال انجاز عمليات تدقيق وتحليل على الطاقه في عدة مصانع مختلفة في فلسطين (مصنع الصفا للألبان, مصنع الكرتون, مصنع الأرز للبوظه ومصنع العقاد للنسيج) والتي تعتبر من المصانع ذات الاستهلاك المرتفع للطاقة واكثرها فرصا لترشيد استهلاك الطاقة.

يعنى هذا البحث بمعرفة فرص ترشيد استهلاك الطاقة في المصانع التي تم دراستها وتحليلها وذلك من خلال التعرف على اكثر المجالات استهلاكا للطاقة في المصانع ومن ثم وضع بعض الاجراءات وتحليلها فنيا واقتصاديا والتي تؤدي في حال تطبيقها لترشيد الاستهلاك في الطاقة.

من خلال البحث تم التوصل الى ان هناك كمية لا يستهان بها من الطاقة يمكن توفيرها اذا ما طبقت اجراءات ترشيد الطاقه في المصانع . بلغت كمية التوفير في الطاقه الكهربائية حوالي 277800kWh في حين بلغت كمية التوفير في الوقود حوالي 66000 لتر في المصانع التي شملها هذا البحث. وعلى المستوى الوطني يمكن توفير ما نسبته 10 −20% من مجمل استهلاك الطاقة

في القطاع الصناعي وذلك من خلال تطبيق بعض اجراءات ترشيد استهلاك الطاقة ذات التكلفه الاستثمارية المعدومه او المتدنية.

تم تطبيق اجراءات ترشيد استهلاك الطاقة على المعدات والأنظمه الأكثر استهلاكا للطاقة في المصانع مثل الغلايات, الضواغط, انظمة الانارة ومعامل القدرة.

بالإضافه الى الجانب الاقتصادي لعملية ترشيد استهلاك الطاقة الذي يؤدي الى تقليل الطلب و تعزيز الاقتصاد الوطني, هناك الجانب البيئي الناتج عن عملية احتراق الوقود وارتفاع الملوثات البيئية حيث تم تخفيض ما قيمته 175 طن من ثاني اكسيد الكربون ($CO_2$) باتباع اجراءات ترشيد وحفظ الطاقة في المصانع التي شملها البحث.