An-Najah National University
Faculty of Graduate Studies

Techno – Economic Analysis of Implementation Energy Management Resources in Some Factories in West Bank

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This Thesis was Defended Successfully on 26/4/2016, and approved by:

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Dedication

To my father

To my mother

To my brothers and sister

To my teachers

To my friends

To my colleagues

I dedicate this work

Acknowledgment

The first thing is to thank Allah for helping me to accomplish this work and make it easier to me.

Special thanks to the supervisor of my thesis Dr. Imad Ibrik for his instructions and supporting me in my thesis and to the teachers of the Master of Clean Energy Engineering and Energy Conservations for their efforts.

I would like to thank Golden Wheat Mills Company and National Beverages Company and National Aluminum and Profile Company for their information and data.

Also special thanks to my family for helping and encouraging me to complete this work

Thank you to my friends and colleagues.

Thank you to everyone share to accomplish this work.

الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Techno – Economic Analysis of Implementation Energy Management Resources in Some Factories in West Bank

أقر بأن ما اشتملت عليه هذه الرسالة إنما هي إنتاج جهدي الخاص، باستثناء ما تم الإشارة إليه حيثما ورد، وأن هذه الرسالة ككل، أو أي جزء منها لم يقدم لنيل أي درجة أو لقب علمي أو بحثي لدى أي 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: أنس عمر محمد نصور **اسم الطالب:**

Signature: Anfn **التوقيع:**

Date: 2016/4/26 **التاريخ:**

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Abbreviations

IEC	Israeli Electric Corporation
JDECO	Jerusalem District Electricity Company
LPG	liquefied petroleum gas
GHG	Greenhouse gases
HID	High Intensity Discharge
Lm	lumen
p.f	Power Factor
L.F	Load Factor
H.P	Horse Power
VSD	Variable Speed Drive
IGBT	Insulated – gate Bipolar Transistor
PWM	Pulse Width Modulation
CFL	Compacted Fluorescent Lamp
HPS	High Pressure Sodium
LED	Light emitting diode
FL	Fluorescent
INC	Incandescent
MH	Metal Halide
HVAC	Heating, Ventilation and Air Conditioning
GWMC	Golden Wheat Mills Company
NBC	National Beverages Company
NAPCO	National Aluminum and Profile Company
SWH	Solar Water Heater
SCADA	Supervisory Control and data acquisition

PLC	programmable logic control
LCD	Liquid crystal display
PEA	Palestinian Energy Authority
kWp	Kilowatt peak
GWp	Gigawatt peak
S.P.B.P	Simple Payback period
AW	Annual Worth
ESCO	Energy Service Company
E.C.Ms	Energy Conservation Measures

Values:

Heat value of LPG = 9500 Kcal/Kg

1 kWh = 860 kcal

1 USD dollars = 3.8 NIS

Heat value of LPG = 9500 Kcal/Kg

Price of LPG = 5.8 NIS/Kg

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Abstract

Energy issues are considered one of the important subjects that pay the attention of researchers and this is due to increasing cost of conventional energy as well as the corresponding environmental impacts. The industrial sector represents a significant branch of energy consumption all over the world especially in the industrialized countries. The energy demand in industrial sector in Palestine increases with acceptable rate and in the same time mostly all the energy resources are imported from the Israeli side. To mitigate this problem a further utilization of renewable energy and energy management should be considered. The percentage of electricity consumption in industrial sector is 37% to other sectors and the percentage of fuel and oil consumption is 42%.

This thesis studies the possibility of implementation energy efficiency opportunities to three industries in Palestine in order to efficiently contribute in solving the problems in energy in West Bank.

The Golden Wheat Mills Company (GWMC), National Beverages Company (NBC) and National Aluminum and Profile Company (NAPCO) are taken as samples to assess the available energy efficiency opportunities especially those companies are considered large according to Palestinian classification.

The studied energy efficiency opportunities includes the analyzing of tariff system, load factor, power factor, lighting system, motors, compressed air systems and LPG burners. The achieved saving in energy are ranging from 15.7% to 18.7%. On the other hand a grid-connected PV system is suggested which saves 10% of electrical energy by applying net metering system.

The annual saving in electrical energy is 1.37 MWh and 104 ton LPG which reduces the operating cost to about 2.5 million NIS at simple payback period ranges from 2.42 to 4.45 years. The annual reduced amounts of CO_2 emissions are 450.47 ton, 888.21 ton and 948.85 ton in GWMC, NBC and NAPCO, respectively.

Introduction:

Palestine suffers from lack of energy sources and imports the energy from many countries depending mainly on importation from Israel, which in turn leads to unsecure and unsafe energy resources use and the prices of energy is high in the comparison to other countries in area.

On the other hand the generation of energy is very limited especially after the war on Gaza in 2014 where the generation plants has been destroyed which increases the problem of the electrical energy shortage in Gaza strip. In Palestine there is large number of connection points and that leads to large losses.

Also the inefficient use of energy in general leads to increase the problem and the consumption of energy becomes higher with no need.

One of the solutions to solve this problem in electrical energy is utilizing solar energy to generate electricity by PV technology or to heat water by SWH in homes and institutions; especially Palestine has good potential of solar energy 5.4 kWh/m^2-day, so this solution is feasible.

Another solution is energy conservation and applies energy conservation measures to use the energy efficiently.

The percentage of industrial sector consumption in electrical energy to the total consumption in Palestine is 36.37 % with a value of 63,692,700 USD and the percentage of fuel and oil consumption is 40.69% with a value of 148,057,300 USD. [9]

This thesis focuses on the importance of energy conservation measures in industrial sector and to the feasibility of using solar energy, as well.

The main idea of this work is to apply the energy conservation opportunities to reduce energy consumption based on energy audits to many facilities in West Bank as shown below.

Energy conservation also has a good and big impact in air pollution due to reduction of GHG especially CO_2 gas.

The objectives of this thesis are:

1- Analysis the energy situation in Palestine and West Bank especially in industrial sector.
2- Determine the amount of saving in energy could be gained from energy conservation and after energy audit in many facilities in West Bank.
3- Encourage to install renewable energy systems.
4- Reduce the operation cost of the systems in these companies.
5- Reduce the harmful emissions in the environment.

The structure of the thesis is:

Chapter one: Energy situation in West Bank.

It’s important to talk about the energy situation in West Bank and energy resources also the economical activities established in West Bank

Chapter two: energy management and energy conservation measures in industrial sector.

This chapter comprises the studied measures in industrial sector and the techniques used to apply energy conservation and utilizing solar energy.

Chapter three: Energy audit in different facilities in West Bank.

This chapter contains the facilities chosen to make energy audit on them

Chapter four: Economical evaluation of energy conservation.

It is important to evaluate the energy conservation measures and solar energy utilizing economically to take economical impression of that.

Chapter five: environmental impacts of energy conservation and solar energy use in industrial sector in West Bank.

This chapter contains the environmental impact of energy conservation measures and how these measures of energy conservation and solar energy reduce the harmful emissions especially CO_2 gas.

- **Literature Review:**

Basher Da’as, (2008), said that energy saving proved that are around 10-25% by implementing some energy conservation measures (no and low cost investment) and that can be applied in many sectors such as: boilers, oxygen, generating units, air conditioning, lighting systems and solar water heaters.

The efficient use of energy and energy management in Palestine is not in better condition than most developing countries so we need to apply energy management in Palestine. [1]

Mohammad kaleel, (2008), mentioned that the energy situation in Palestine and efficient use of energy and the energy conservation in universities are not in a better situation than the most developing countries.

So we need to use energy in efficient way where we need to make energy audit in some faculties in the university.

it was proven that there is a huge potential for energy saving in Palestinian universities sector where that around 15-20% by implementing some energy conservation measures on the most energy consumption equipment such as: boilers, air conditioning and lighting systems. In this thesis he developed new energy management software, which is used to estimate the total energy saving from each opportunity. [2]

Ahmad tartit, (2010), He said that the supply of conventional energy electricity and petroleum products is monopolized by Israel.

So it’s important to apply energy management in our country in commercial sector.

He proved that there is a big saving opportunity in energy like lighting, UPS, rectifiers, air conditioning systems and power where the amount of saving was around 15%. [3]

Basil Yaseen, (2008), the developing countries were working in industrial energy since 1973 to improve the efficient use of energy where they reached to good amount of saving.

So he tried to find energy conservation opportunity through conducting energy analysis of industrial consumption in Palestine and through audits in some industries in Palestine.

The saving in electric energy was around 277800 kWh and fuel saving is around 66000liter/year.

On the national level 10-20% saving from the total energy consumption in the industrial sector could be achieved by implementing some energy conservation measures like boilers, compressors, lighting systems and low power factor. [4]

Greuville J. Croll, (1980), Computers and allied technologies can be used to increase energy efficiency.

In UK 40% of the energy is in industrial sector.

The computer has a fairly well defined role in industrial energy conservation at the design stage; computers may be used to simulate the likely operational characteristics of several preliminary designs.

Before installation of energy management it is necessary to perform an energy Audit to ensure that the proposed system is justified on a cost basis alone, since that is the only acceptable method of assessing a systems worth.

Measure and tools are boilers, turbine generators lines, pipes transformers, process equipment and demand control.

Computer technology is increasingly being used to help perform these functions more efficiently, electricity supply networks are invariably large and several computers will be used, typically in some form of structured control hierarchy.

The use of the computer in electricity supply management brings about certain improvements in overall system efficiency and reduces the probability of total network failure such as happened in New York 1965.

Tyler estimates that improving the efficiency of electricity supply and distribution from 25% to 30% will bring about 5% reductions in UK primary energy consumption. [5]

Siemens, (2011), It’s important to use the energy in efficient way to reduce the cost and CO_2 emissions on the other hand the world’s population is growing fast and that leads to increase the use of the energy year by year. There are many forms of energy and energy management. Also, mentioned the standard components for energy efficiency, energy management and the control process of that to apply that in many fields like heating, motors, stabilized power supplies and energy efficient pneumatic positioner's.

How computers can help us to conserve energy, information and communication technology play a critical role in supporting the necessary paradigm shifts within the energy sector towards a more sustainable generation of electricity. [6]

Chapter One
Energy in West Bank and energy use in industrial sector

1.1 Energy situation in West Bank:

As mentioned in the introduction Palestine depends on the importation of energy and the table 1.1 shows the importation of energy according to its form in 2012 in West Bank:

Table 1.1: Importation of energy in West Bank in 2012 [7, 8].

Electricity (MWh)	Gasoline (1000 L)	Diesel (1000 L)	Kerosene (1000 L)	LPG (Ton)	Tar (Ton)	Oil and Grease (Ton)	Wood (Ton)
3659623	193140	413847	1722	95113	5436	1755	24726

Table 1.2 shows the purchased electrical energy (MWh) in West Bank in 2012 according to month and source:

Table 1.2: Purchased electrical energy (MWh) in West Bank in 2012 [7].

Month	IEC	Jordan	Total
January	395517	7054	402571
February	363706	6489	370195
March	339140	5921	345061
April	234512	7663	242175
May	240013	10016	250029
June	257615	10715	268330
July	295019	9707	304726
August	294471	9601	304072
September	266950	8790	275740
October	261521	3178	264699
November	275085	1115	276200
December	353752	2073	355825
Total (MWh)	**3577301**	**82322**	**3659623**

Clearly the purchased electrical energy from IEC is larger than Jordan and that shown in the following pie chart Figure 1.1:

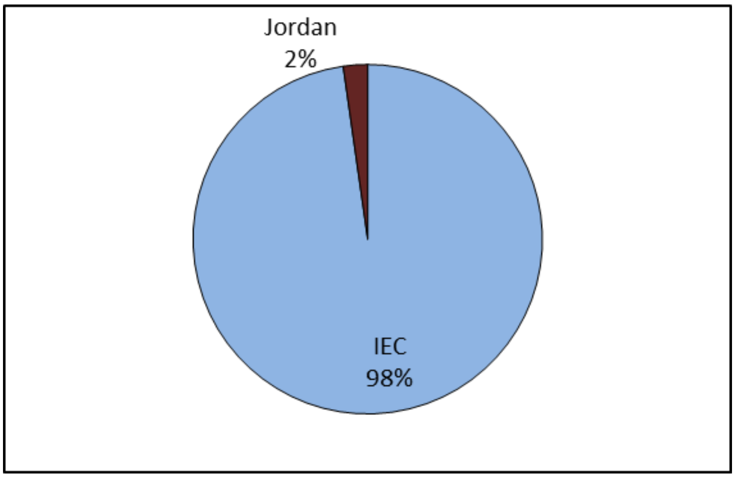

Fig 1.1: Percentage of purchased electrical energy according to source [7]

1.2 Economical activities in general in West Bank:

In West Bank there are many economical activities and each activity has its own specification and category. we can easily concentrate the studies in the industrial activities and on related data which reflects the energy situation in West Bank especially for industrial activities, where the economical activities categorized to Industrial activities, Construction activities, Internal trade activities, Transport and storage activities, Information and communications activities and Services activities and each activity has important data like: Number of Enterprises, output, production input, fuel and oil, Electricity and energy use , Table 1.3 shows the economical activities according to number of enterprises and output (in USD 1000)

Table 1.3: Economical activities according to number of enterprises and output (in USD 1000) [9]

Activities	No. of Enterprises	output (value in USD 1000)
Industrial activities	11666	3133808.4
Construction activities	392	452507.7
Internal trade activities	46730	2260312.2
Transport and storage activities	628	146612.2
Information and communications activities	452	724424.9
Services activities	22861	1447742.5
Total	**82729**	**8165407.9**

Figure 1.2 shows the percentage of economical activities according to number of enterprises:

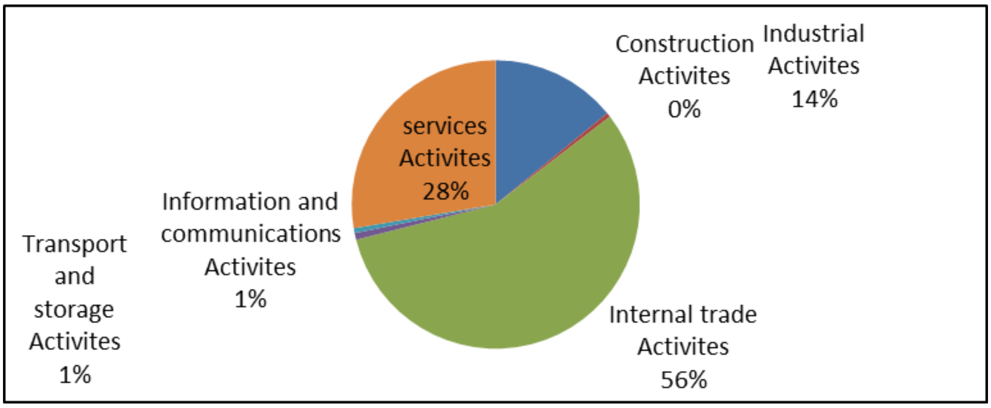

Fig 1.2: Percentage of economical activities according to number of enterprises [9]

Figure 1.3 shows the percentage of the outputs from different activities:

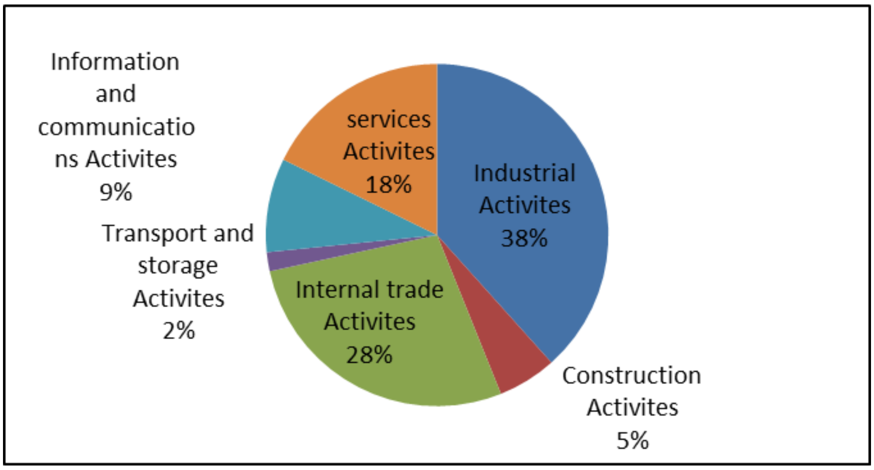

Fig 1.3: Percentage of the outputs from different activities [9]

As shown above there are 11666 enterprises related to industrial activities with a percentage of 14% and the output (value in USD 1000) is 3133808.4 with a percentage of 38%.

Economical activities according to needed production input in general and according to fuel and oil, Electricity and Energy use and the percentage of them to the total production inputs (values in USD 1000) shown in table 1.4:

Table 1.4: Economical activities according to needed production input [9]

Activities	**Total (value in USD 1000)**
Industrial activities	1600344.1
Construction activities	193893.2
Internal trade activities	200724.4
Transport and storage activities	46420.2
Information and communications activities	24839.4
services activities	210284.6
Total	**2276505.9**

Figure 1.4 shows the percentage of needed production inputs for different activities:

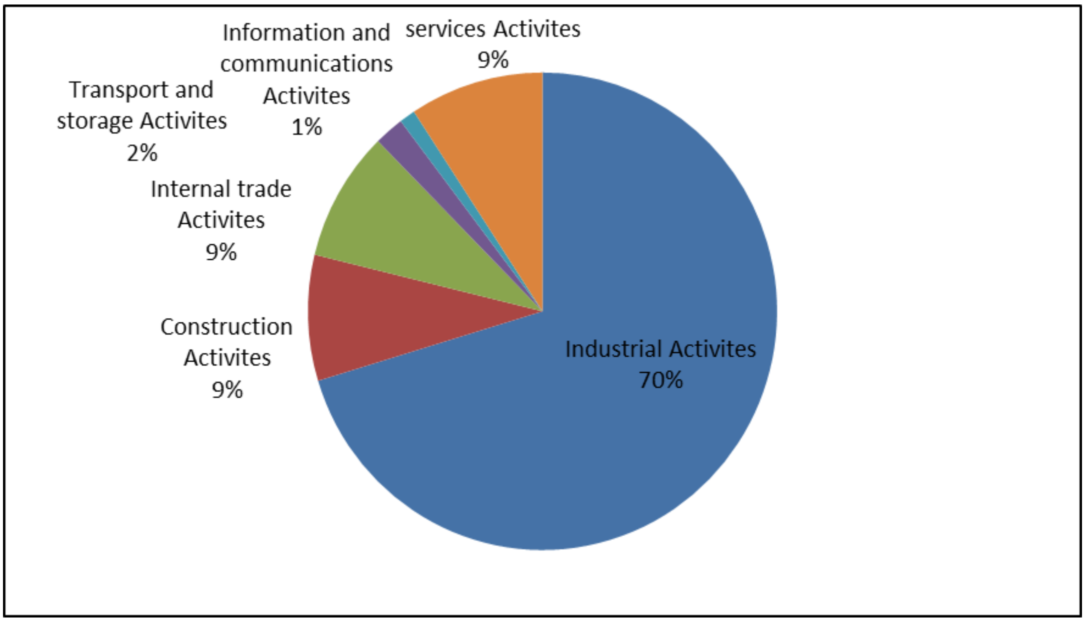

Fig 1.4: Percentage of needed production inputs for different activities [9]

As shown above, the industrial activities has the largest production in comparison to other activities with a value of (value in USD 1000) 1600344.1 and a percentage of 70%.

Table 1.5 shows the fuel and oil needs and its percentage to the total production inputs for different activities:

Table 1.5: fuel and oil needs and its percentage to the total production inputs for different activities [9]

Activities	fuel and oil (value in USD 1000)	Percentage (%)
Industrial Activities	120165.9	7.508753899
Construction Activities	13789.4	7.11185333
Internal trade Activities	67688.2	33.72195906
Transport and storage Activities	41982	90.43907609
Information and communications Activities	7602.6	30.60701949
services Activities	36753	17.47774207
Total	**287981.1**	**12.2**

Figure 1.5 shows the percentage of demands of fuel and oil for different activities:

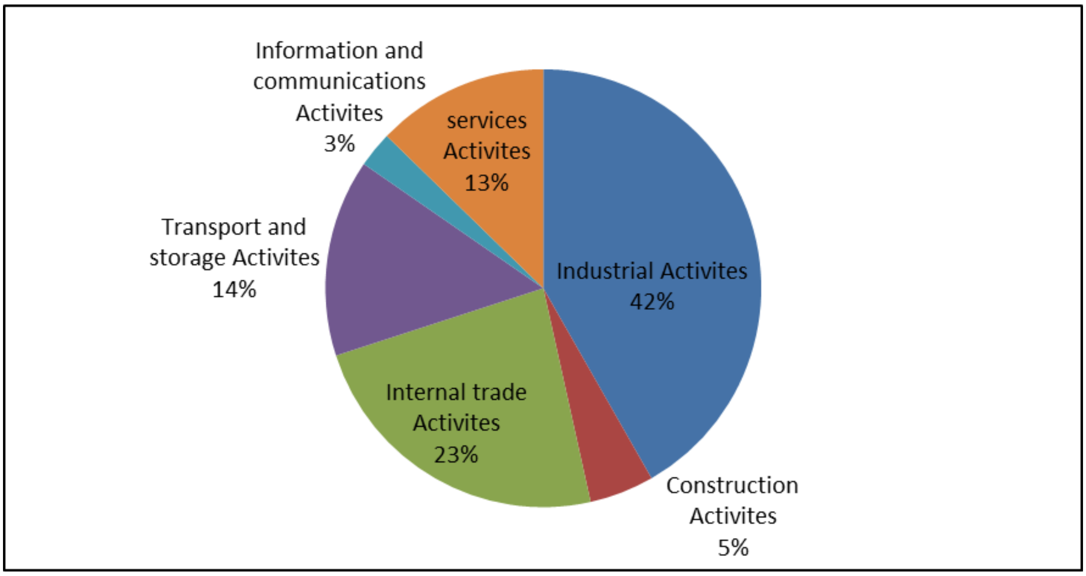

Fig 1.5: Percentage of needs of fuel and oil for different activities [9]

As shown in table 1.5 and figure 1.5, the use of fuel and oil in industrial activities has the largest value in comparison of other activities with a value of 120165.9 (value in USD 1000) and a percentage of 42%. On the other hand the percentage of fuel and oil to the total production inputs in industrial activities is 7.5%. Table 1.6 shows the consumption of electricity for different activities:

Table 1.6: consumption of electricity for different activities [9]

Activities	Electricity (value in USD 1000)	Percentage (%)
Industrial activities	55432.1	3.463761325
Construction activities	805.6	0.415486464
Internal trade activities	46718.8	23.2750976
Transport and storage activities	885.7	1.908005567
Information and communications activities	8964.5	36.08984114
services activities	35349.9	16.81050348
Total	**148156.6**	**6.5**

Figure 1.6 shows the percentage of electricity consumption for different activities:

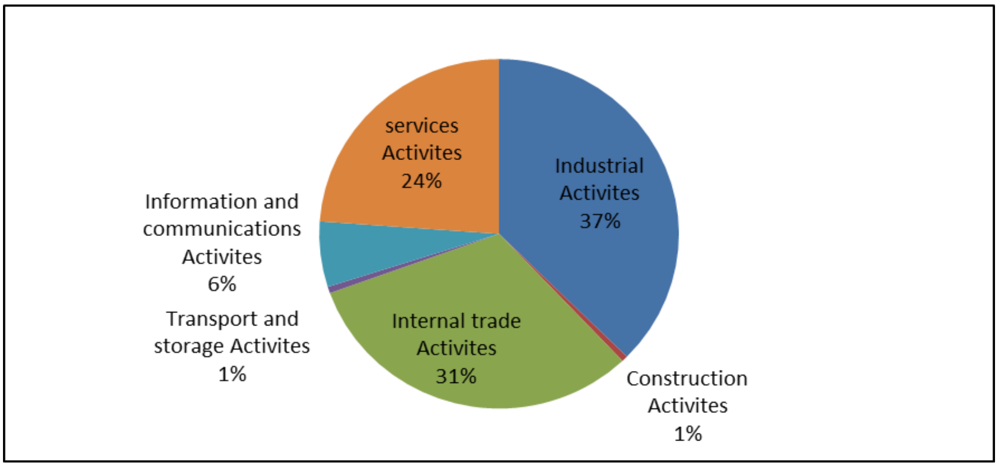

Fig 1.6: percentage of electricity consumption for different activities [9]

As shown above in table 1.6 and figure 1.6 the use of electricity in industrial activities has the largest value in the comparison of the other activities with a value of 55432.1 (value in USD 1000) with a percentage of

37% and the percentage of the electricity use in the comparison of the total production inputs in industrial activities is 3.46%. [9]

As illustrated above, the energy use in West Bank not small so, any saving technique applied can lead to large saving values.

1.3 Implementation of solar systems in Palestine:

Palestine lies in the east coast to Mediterranean Sea between 34^{o}:15`-35$^{o}$:40`E and 30^{o}:29` - 33$^{o}$:15` N. [10]

According to Palestine's location, Palestine receives high solar radiation where the daily average solar radiation is 5.4kWh/m^2-d with total average sunshine duration 2850 hours. [11]

Average monthly solar energy varying through the year where it is 2.724kWh/m^2 -day in December with lowest value and it is 8.19kWh/m^2 -day in June with highest value and that shown in details in figure 1.7:

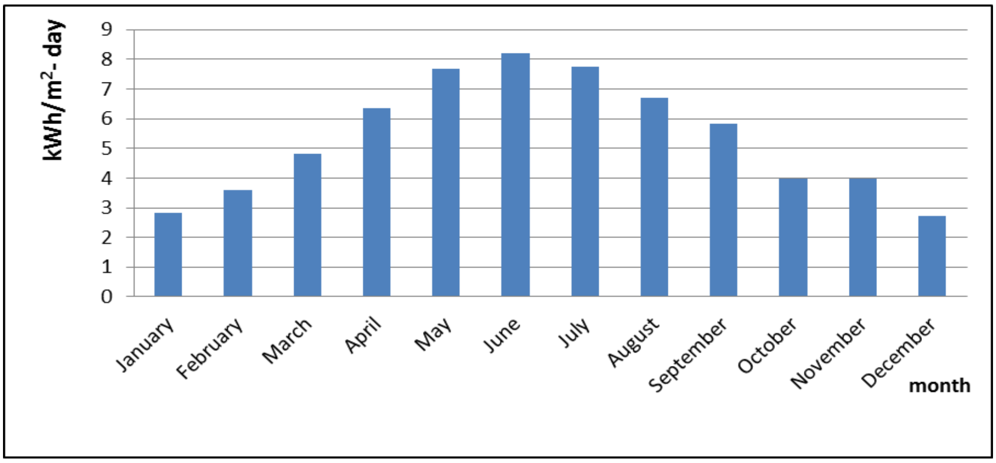

Fig 1.7: Average solar energy through the year [12]

1.3.1 Energy strategy by 2020 in Palestine:

According to energy problems in Palestine, PEA prepared a renewable energy strategy and set goals in 2020 to apply that as the following:

Gradually, achieve at least 240 GWh to generate electricity from renewable energy resources with a percentage of 10% from the locally generated electricity in 2020 according to strategy plan in energy sector.

The estimation use of thermal renewable resources is 18% from total energy consumption in Palestine with a value of 2287 GWh which used especially in water heating and from that the percentage of renewable energy using is 25% from electrical energy in 2020.

According to evaluation studies in renewable energy resources which are done by PEA, suitable choices and technologies determined as shown in table 1.7:

Table 1.7: Expected Power from renewable energy in 2020 from determined technologies [13]

Used technology	**Power (MW)**
Solar cells stations	25
Roof top solar cells	20
CSP stations (thermal)	20
Biogas from landfills	18
Biogas from animal waste	3
Small wind stations	4
Wind farms stations	40
Total	**130**

This strategy is going to be applied in two stages, first stage (2012-2015) for small projects and second stage (2016-2020) for large projects with higher power. [13]

1.3.2 Solar energy projects in Palestine:

There are many projects of solar energy established in many cities in Palestine with different scales and techniques, where these projects differ between lighting, electricity production and water pumping systems.

Isolated and far areas were the concentrated due to leakage in energy and their far locations from the main cities.

In Jabat Dheeb village in Bethlehem lighting poles installed fed by solar energy and store it to 5 days with a power of 500Watt and daily energy 1300Wh, in Al – Bireh the project of lighting the park of children happiness center established with a yearly consumption of 5000 kWh and the project of lighting the industrial area in Jericho with a power of 350 kVA.

In Atouf in Tubas solar project installed to feed the village with a power of 12kW and in Dawa area east to Aqrba in Nablus solar system established feed the area with electricity and pump water system through centralized solar system. [14]

Chapter Two

Energy management and energy conservation measures in industrial sector

- **Introduction:**

Industrial sector consumes energy more than other sectors due to the production inputs have a large cost which the energy in one of these inputs. Therefore, it’s necessary to reduce these production inputs cost to achieve larger benefits.

Energy consumption can be reduced by many ways like energy management and energy conservation.

Globally, industrial sector has an important role in last twenty first century. Thus, it is increased and led to increase in the demand of energy. [15]

World annual consumption of energy increased more than ten times through the twentieth century.

In year 2002 the total consumption in the world was $451*10^{18}$ Joule in forms of energy such as oil, natural gas, coal, traditional biomass, nuclear, large hydropower and other renewable. [17].

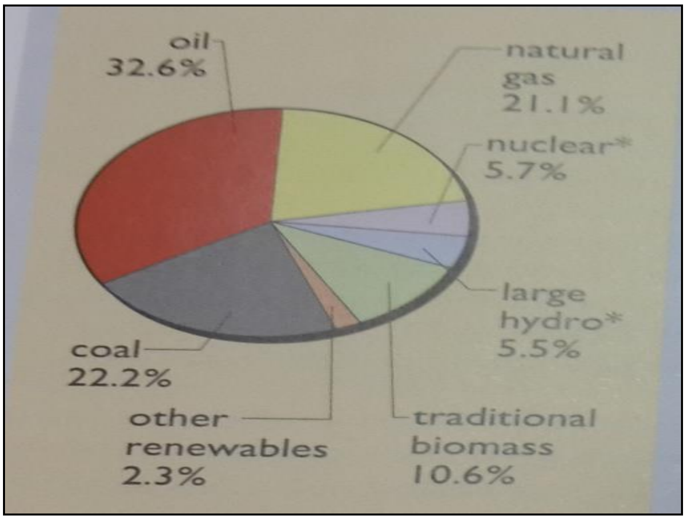

Fig 2.1: Percentage of various energy sources to world primary energy consumption in 2002 [17]

On the other hand the annual energy consumption per person in the world is 74GJ which equivalent to nearly 6 liters of oil per day. [17]

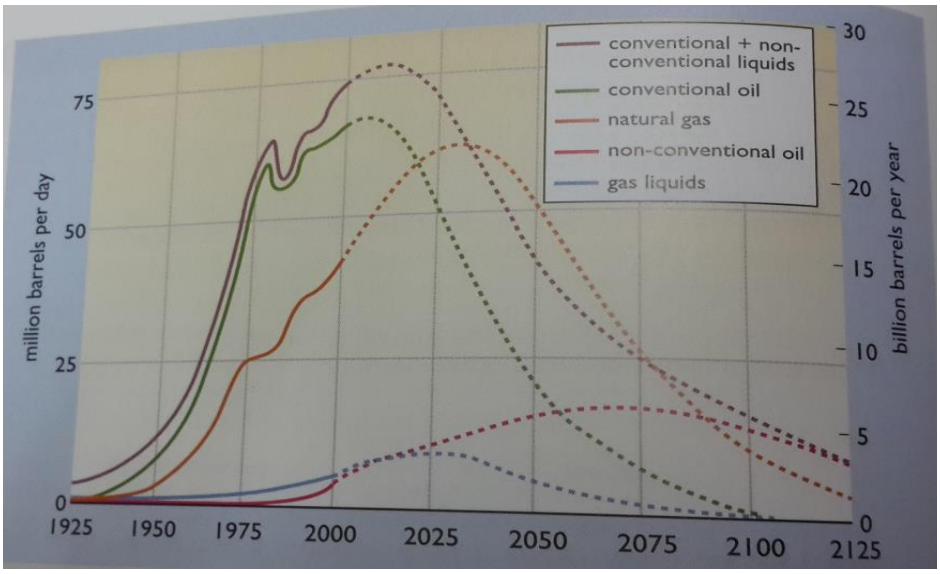

Fig 2.2: world production of oil and gas [17]

For instance, in India the electrical peak demand has grown from 30000 MW to 120000 MW within ten years and the oil for transport sector has grown as well. [15]

To achieve the successful management for energy use, it is important to manage all the consumption of energy and control the costs of energy, so it is important to understand rates of energy, rate schedules, metering method and the use of various fuels in the facility.

Rate schedule is the guide to determine how the costs are allocated and that's the key for reducing utility costs as well as using energy more efficiently.

One of the important aspects in that field is measuring and accounting for energy consumption, which can be verified by energy auditing program which enable the energy manager to know more about the main energy consumption equipment in the facility.

The data will be used to evaluate the energy consumption in the facility and determine realistic estimation of energy use.

These facilities are the mission of finding a ratio between energy consumption and production to monitor production efficiency. [18]

To apply energy management and energy conservation in industrial sector too many measures must be applied to reduce the energy consumption.

Many systems are working in industrial sectors such as electrical, mechanical, chemical and thermal systems. So, it's important to study the suitable measures for each system to reach the optimum energy consumption.

- **Energy conservation opportunities in industrial sector:**

a- Electrical motors.

b- Lighting systems.

c- Power factor.

d- Energy management techniques.

e- Compressed air.

f- Waste heat recovery.

g- Utilizing solar energy.

2.1 Energy conservation opportunity in electrical motors:

Polyphase induction is commonly used and widely spread as AC motors, where more than 90% of mechanical power used in industry is provided by 3-phase induction motors, due to low cost of this type, without commentator, good power factor and high efficiency and good speed regulation. [16]

The power in these motors is in horse power and it can be converted to KVA using equation (2.1).

$$kVA = \frac{HP * 0.746}{\eta * p.f} \qquad (2.1)$$

Where η is the motor efficiency, p.f is motor power factor and HP is horse power capacity of the motor.

Whereas the efficiency and power factor for motor vary with load. [18]

Motors running in full load give highest efficiency and power factor while if motors running with partial load will give poor efficiency and power factor, if power factor increases for equipment the losses in conductor will be reduced.

As known there is a distance between the load and distribution board of the electricity company.

If conductor is thin, losses could be ranging from 1% to 5% of the power flow and if power factor is corrected the conductor losses due to increase of apparent power can be reduced. Nowadays, most equipment has power factor corrector. [15]

2.1.1 Power losses and efficiency of motors:

There are electrical losses due to heat produced from the stator current and rotor windings (copper losses) and these losses are varying with the load, magnetic losses in the iron due to hysteresis and eddy currents (core losses), mechanical losses due to friction in the bearings and ventilation (friction losses) and these losses considered to be constant and stray load losses. [16]

- **Factors affecting efficiency of induction motors:**

i) Operating motors on higher than the rated voltage may decrease the efficiency and affect negatively on other performance characteristics.

ii) The electrical supply should be balanced voltage of 3.5% may increase the losses of the motor about 20%.

iii) The efficiency of the motor change as load changes, so it is important to choose a suitable size of the motor because using over size motor increases the motor losses and then decrease the motor efficiency.

iv) In general the motor with higher speed has higher efficiency and higher power factor than other motors with lower speed.

v) Multi-speed motor at each operating speed has efficiency somewhat lower than that of a single speed motor. [14]

Efficiency of the motors can be expressed as in equation (2.2) which include the losses occurred and in figures 2.3 and 2.4 the losses explained in details. [16]

$$\eta_m = \frac{P_{mech}}{P_{mech} + P_{const} + P_{cu}} \times 100 \qquad (2.2)$$

Where: P_{mech} is the mechanical losses, P_{const} is the constant losses and P_{cu} the copper losses.

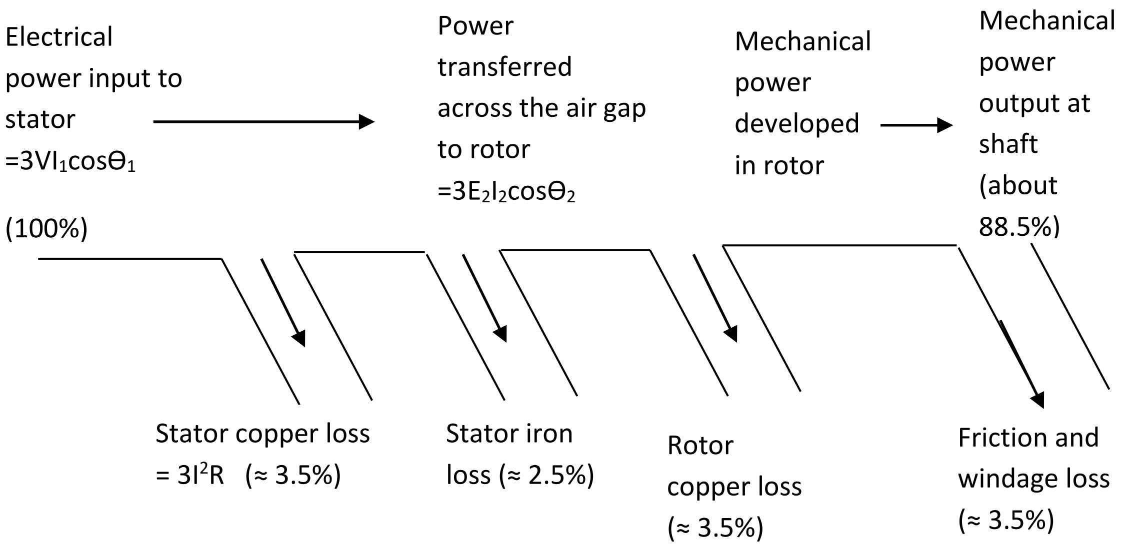

Fig 2.3: power flow diagram for induction motor [16].

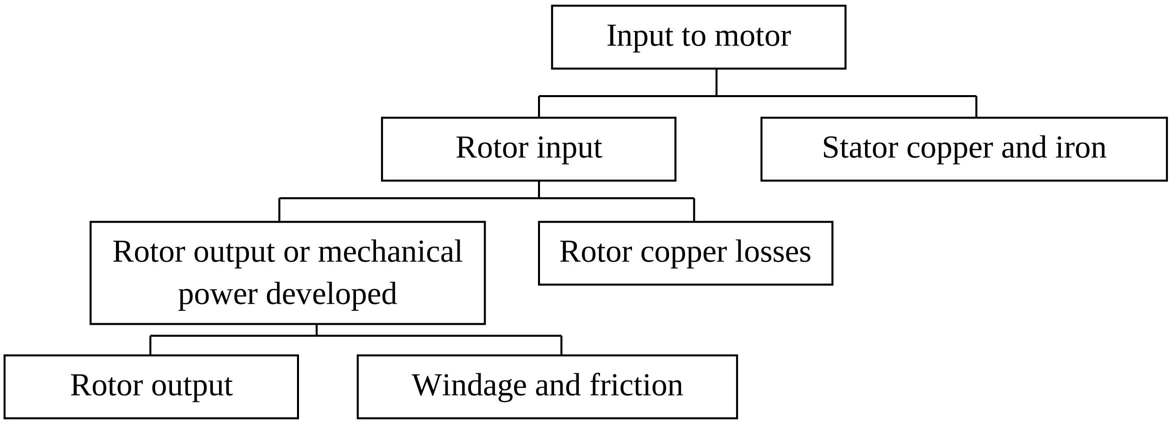

Fig 2.4: power stages in induction motors [16]

2.1.2 Energy conservation methods in motors

Many measures can be applied to conserve energy in motors but in this thesis two important methods are studied:

1- Inverters.

2- Replacing existing motors by efficient motors.

- **Inverters:**

This method can change voltage and frequency together and sometimes it is called variable – speed drive (VSD).

Magnetic flux of the motor can be regulated by the optimized amount using voltage and frequency regulation.

In the past motors is running at low speed by reducing voltage, but now that done by changing voltage and frequency.

As known the efficiency of motors is inversely proportion to slip frequency that is the difference between frequency of the stator and frequency of the rotor, by this method we can drive motors efficiently at any rotor speed and the saving rate is between 30% and 40%.

Firstly AC rectifies to DC and then DC inverted to AC by adopting IGBT high frequency sinusoidal PWM.

Switching mode of IGBT can change output voltage and frequency to control motor effectively. [15]

Figure 2.5 shows the schematic of inverter:

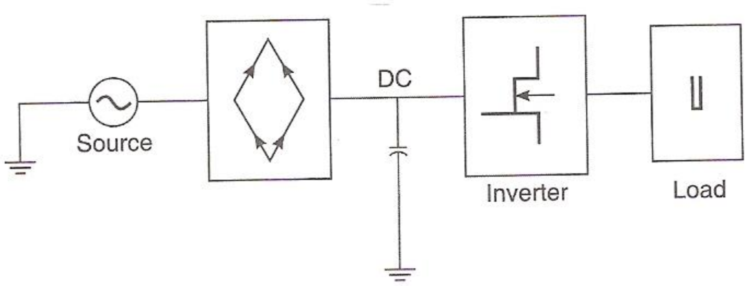

Fig 2.5: Schematic of inverter [15]

In industrial application three phase bridge inverters used commonly for frequency adjustment. [16]

- **Replacing existing motors by efficient motors:**

This method is feasible for motors in the range between 0.75kW to 150kW and in the following will be the explanation in details of this method in energy saving.

In the past the users of motors were considering factors motors choosing like: size, weight and operating characteristics more than the efficiency of the motors, on the other hand the motor’s first cost was considered more than the life time operating cost, but as the cost of energy increased it is important to consider the operating cost to minimize it.

The efficiency and power factor of high efficient motors 4% to 5% higher compared to normal conventional motors.

This type of motors has a number of features in construction and used materials which make this type more expensive than conventional type.

The main losses are stator copper loss, rotor copper losses, core losses, friction and windings loss, and by suitable design steps, these losses reduced then the motor efficiency increased.

The following are the details in the component of high efficient motors and how the losses are reduced:

a) Reduce stator copper losses by increasing the amount of copper where the resistance becomes lower and thus stator copper losses and by reducing the number of turns in the slots of the stator to reduce the stator resistance and thus stator copper losses.
b) Reduce rotor copper losses can be achieved by using large, high conductivity rotor bars and end rings.
c) The losses of core can be reduced by using thinner lamination steel which reduces eddy current losses, increasing stator and rotor core length which leads to lower magnetic energy and using high silicon laminated steel which reduces hysteresis losses.
d) Stray losses reduced by installing rotor bars from the lamination.
e) Reduce windings losses by using low losses motor cooling fans.[19]

2.2 Lighting Systems:

Lighting has a large part of total consumption of electrical energy, so it is important to save energy in lighting which that leads to good values of saving.

Saving in lighting system can achieved by reducing illumination levels, improving the efficiency of lighting system, reduce operating hours and use the day lighting as possible as.

To apply energy conservation in lighting many things must be considered as the following:

1- Asses the recent case: - Room classification, Room characteristics and fixture characteristics.
2- Evaluation of lighting levels and lighting quality.
3- Estimation electrical consumption.
4- Calculation of energy cost saving after applying the energy conservation in lighting.

2.2.1 Lighting Efficiency and Lighting Basics:

There are many ways to improve the lighting systems efficiency and after studying the lighting systems and understanding them it will be easy to choose a suitable way to improve the efficiency of lighting systems.

There are two common lighting methods can applied, one is called the “lumen method” and the other is the “point by point method” and we will talk in details about “lumen method because this method will be used.

- **Lumen method:**

Foot- candle is the luminance on a surface of one square foot in area having a uniformly distributed flux of one lumen, this method used commonly due to its simplicity.

The following formula shows this method clearly:

$$N = \frac{F_1 * A}{L_u * L_1 * L_2 * C_u} \qquad (2.3)$$

Where:

N= number of required lamps.

F_1= required foot- candle level at the task and that taken from standard catalogues, A = Area of the space.

L_u= output lumen per lamp and that taken from the catalogue of the lamp,

C_u= Coefficient of utilization and that related to reflected or absorbed light and its value from catalogues.

L_1= Depreciation factor of the lamp and that factor takes into account that the lamp lumen depreciates with time.

L_2= It is luminare (fixture) dirt depreciation factor and that depending on the space.

To reduce the energy of lighting there are four options as the following:

i) Reduce light levels.

ii) Use more efficient equipment.

iii) Provide light when needed at the task with required level.

iv) Use control and reduce lighting loads automatically.

It's important to consider the trade-off between the initial and operating costs upon product perform like: life, efficacy, color, glare and color rendering. [18]

2.2.2 Light sources:

Many types used for light sources and each type has characteristics and it differs from type to another and that will be explained briefly in the following:

1- Incandescent lamps:

This type is the lowest efficiency type in the comparison to other commonly used lamps.

Incandescent lamps not used in large areas, but it used in general and in large scale due to its low capital cost.

This type of lamps has not good lumen maintenance throughout their life time.

2- Fluorescent lamps:

This type has big advances in the last ten years and this type has several styles of wattage, compacted lamps recently there has been new style of products.

The efficacy range of this type is from 65lm/w to over 90lm/w; also the range of colors is more complete than mercury vapor.

- Compacted fluorescent lamps (CFL) open up a whole new market for fluorescent sources, this type has a design of much smaller luminaries which can complete with incandescent and mercury vapor in the low cost.

In general this type is good, but lumen maintenance throughout the lifetime of lamp is a problem for some types of fluorescent lamps.

- Energy efficient “plus” fluorescents:

This type represents the second generation of improved fluorescent lighting.

The bulbs are available for replacement of standard 4 – foot 40 W, bulbs and require only 32 W with the same light levels but it need to change the ballast.

Metal halide lamps:

This type has efficacy range from 50 to100 lm/W, so this type more energy efficient than mercury vapor but some – what than high pressure sodium.

These types generally have fairly good color rendering qualities, it also has some distinct drawbacks including relatively short life for an HID lamps.

3- High pressure sodium lamps (HPS):

The efficacy of this type is from 60 to130 lm/W and that considered as high efficacy.

The construction is very similar to mercury vapor and metal halide, lifetime if this type is around 2400 hours and the lumen maintenance is good and due to high efficacy these lamps used in industrial sector and outdoor applications. [18]

2.2.3 Ways and techniques to energy conservation in lighting systems:

2.2.3.1 Electronic ballasts:

This method used for fluorescent lamps to save energy where it adopts high frequency inverter to drive fluorescent lamps (20 – 30 KHz) and these lamps have good efficiency when it works in high frequency and the efficiency of lighting units is 20 – 30 % higher than the lighting units driven by magnetic ballasts.

It supplies power to fluorescent lamps by a power factor corrector in series with a high frequency inverter where the power factor in magnetic ballast very low while in electronic ballasts may be up to 99%. [15, 18]

Figure 2.6 shows the schematic of electronic ballasts:

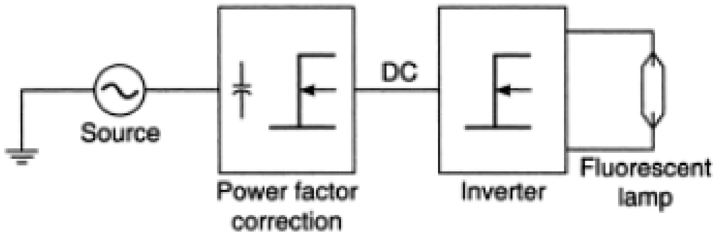

Fig 2.6: schematic of electronic ballasts [15]

Certainly that's lead to increase in the efficacy of the lamp, for example the efficacy of two lamps 40 W T-12 rapid- stand system increased from 63lm/W to over 80 lm/W. [18]

2.2.3.2 Applying Lumen method:

This method will depend on applying equation (2.3) according to standard tables of lighting levels and properties of working space.

2.3 Power factor:

Inefficient operation of electrical distribution systems is mainly from a low power factor.

Power factor correction is cost – effective when utility penalties are imposed.

Improving power factor can achieve by power factor correction devices and ways.

The power has two parts: resistive and reactive part, where the pure resistive power is known as watt, while reactive power is referred to as the reactive volt amperes. [18]

For a balanced 3- phase load:

$$P = \sqrt{3} * \underbrace{V_L * I_L}_{\text{Volt ampere}} * \underbrace{\cos \Theta}_{\text{power factor}} \quad (2.4)$$

And for single phase:

$$P = V * I * \cos \Theta \quad (2.5)$$

Power factor can be corrected by using passive power and active power methods where the passive power method installed to compensate inductive loads by capacitor and the active power method installed to control input current to be in phase with voltage by using semiconductors. [15]

2.3.1 Methods to improve the power factor:

1- Energy efficient motors: where this method is a better alternative for small motors (5 – 20 hp) and from the characteristics of energy efficient motors that they provide high efficiency and power factor in both partial and full load conditions.

2- Capacitor compensation: where that used especially for motors below 5 hp and above 20 hp and this method is usually more economical, also this method used to correct the power factor to overall the utility where the capacitors installed in the main electrical distribution boards and controlled by power factor controller. [15]

2.3.2 Impacts of low power factor in industrial sector and electrical network:

Low power factor lead to increase in the current drawn from the network, then increase the power losses in the network, also that leads to voltage drop in the distribution lines, on the other hand low power factor leads to high penalty on the facilities and distribution companies to main supply company. [20]

Figure 2.7 shows power losses as a function of p.f:

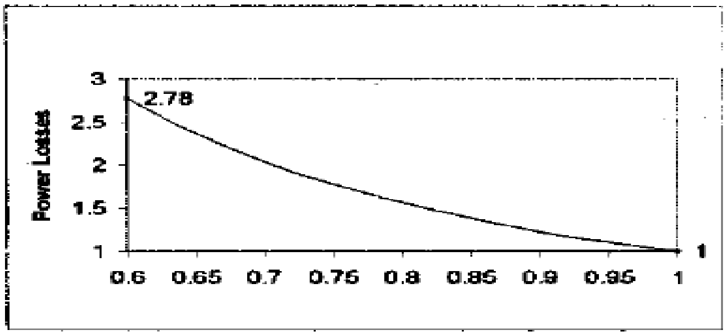

Fig 2.7: power losses as a function of p.f [20]

Figure 2.8 shows voltage drop as a function of p.f:

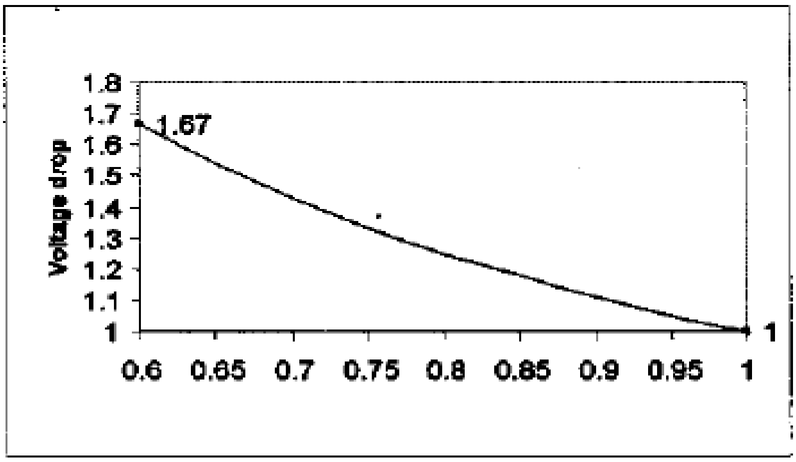

Fig 2.8: voltage drop as a function of p.f [20]

Table 2.1 shows power factor penalties in Palestine:

Table 2.1: Power factor Penalties in Palestine [20]

Power factor	Penalty
0.92 or more	No penalty
Less than 0.92 to 0.8	1% of the total bill for every 0.01 of power factor less than 0.92
Less than 0.8 to 0.7	1.25% of the total bill for every 0.01 of power factor less than 0.92
Less than 0.7	1.5% of the total bill for every 0.01 of power factor less than 0.92

2.4 Energy management techniques:

2.4.1 Time of day billing:

Many utilities charge their users according to the time of day, where the energy and demand during peak periods billed at much higher rates than consumption during other times. [18]

2.4.2 Load management:

It is the method of scheduling the loads to reduce the consumption of electrical energy and reduce the maximum demand which leads to improve the load factor of the system, load factor is a measure of electrical efficiency of a facility and it is a relationship between consumed electrical energy and the maximum demand through the same period.

$$L.F\,(\%) = \frac{kWh}{Kw * hours} \tag{2.6}$$

This equation has another simpler form $L.F\,(\%) = \frac{P_{av}}{P_{max}}$

Theoretical maximum load factor is one and the ideal load factor will be close to one as possible. [18, 21]

This method can be applied by:

1- Utility rate structure: to reduce use of electricity during peak periods.
2- Re – schedule the consumption of energy to non peak periods.
3- Control the loads automatically by using load demand controller or computers. [15]

2.5 Compressed air systems:

Compressed air systems used widely in industrial sector due to its availability, cleanness, easy using and importance in manufacturing, but unfortunately compressed air systems considered as an expensive form of energy in the plant where located because only 19% of used power converted to useful form and the other 81% is lost as heat.

Figure 2.9 shows the compressor costs over a ten year lifecycle:

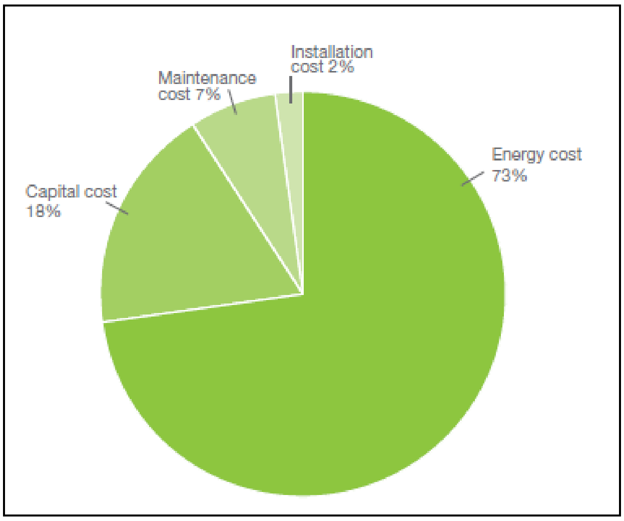

Fig 2.9: compressor costs over a ten years lifecycle [22]

With a value of 73% of the cost of energy, that indicate to a great cost savings will be gained by energy efficiency improvement of compressed air systems, also which will improve the system's performance.

Energy efficiency also reduces the ratio of the compressed air used for production and minimizes unwanted losses.

Figure 2.10 shows how much demand on compressed air systems can be lost:

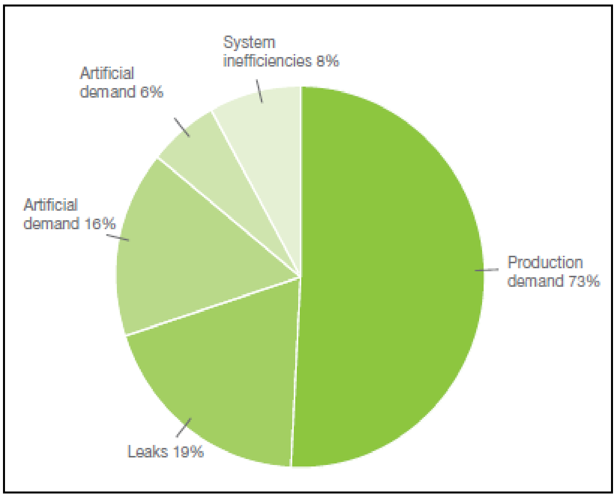

Fig 2.10: compressed air usage and potential savings for the typical compressed air use [22]

The cost of compressed air has two important factors which are: the type of compressor control and the suitable size of compressor, where the oversized compressors and inefficient control modes of compressors consume highest energy and highest annual costs. [22, 23, 24, 25]

2.5.1 Ways to improve efficiency of compressed air systems:

2.5.1.1 Using outside intake air:

Generally, the air supplied to the compressor's intake is from the compressor room and that consume more energy, because the air expands at higher temperature, so the compressor need to work harder to compress this hot air.

The solution of that is by using cooler air from outside instead of the air from the compressor room, as thumb rule each 3°C will save 1% of compressor energy. [25]

Table 2.2 shows clearly the effect of inlet air temperature to the energy reduction and amount of saved money in Australia: [22]

Table 2.2: annual energy and cost savings with reduced compressor inlet temperature [22].

Air Intake temperature reduction	3°C		6°C		10°C		20°C	
Comparative average load (kW)	kWh/yr savings	$/yr savings	kWh/yr savings	$/yr savings	kWh/yr savings	$/yr savings	kWh/yr savings	$/yr savings
4	80	8	160	16	264	26	528	53
7.5	150	15	300	30	495	50	990	99
11	220	22	440	44	725	73	1450	145
15	300	30	600	60	990	99	1980	198
22	440	44	880	88	1450	145	2900	290
30	600	60	1200	120	1980	198	3960	396
37	740	74	1480	148	2440	244	4880	488
55	1100	110	2200	220	3625	363	7251	725
75	1500	150	3000	300	4950	495	9900	990
110	2200	220	4400	440	7260	726	14520	1452
160	3200	320	6400	640	10550	1055	21100	2110

From table 2.2 it's clear that this depends on the power of the compressor and the reduction in the air intake temperature.

2.6 Waste heat recovery:

Waste heat is a heat produced from a process of fuel combustion and released to outside or not use it although it could be used in useful and economic applications and the device used to apply that is economizer or heat exchanger.

By heat recovery technique many benefits could achieved such as: increase the efficiency of the system which lead to reduction in fuel consumption and reduce the harmful emissions then make the system more environmentally.

Waste heat recovery can apply for example in burners where the stacks pass the flue gases which holding thermal energy where normally it released to atmosphere, then that lead to reduction in fuel consumption. [26]

2.7 Utilizing solar energy:

According to the dependence on fossil fuels to generate energy and the ratio of 80% from the global energy consumption from conventional energy resources, there are two important facts must be known:

1- Coal and oil production in the world will reach its maximum in 2015, and then it will decrease.
2- The global uranium production is expected to reach its maximum in 2035, but the biggest problem is in the waste of this fuel. [15,27]

Industrial sector has large energy consumption, so it is feasible to study how to use some renewable energy sources to reduce the energy consumption and environmental impact.

Fig 2.11 shows the global energy consumption in industrial sector and it increase from period to period:

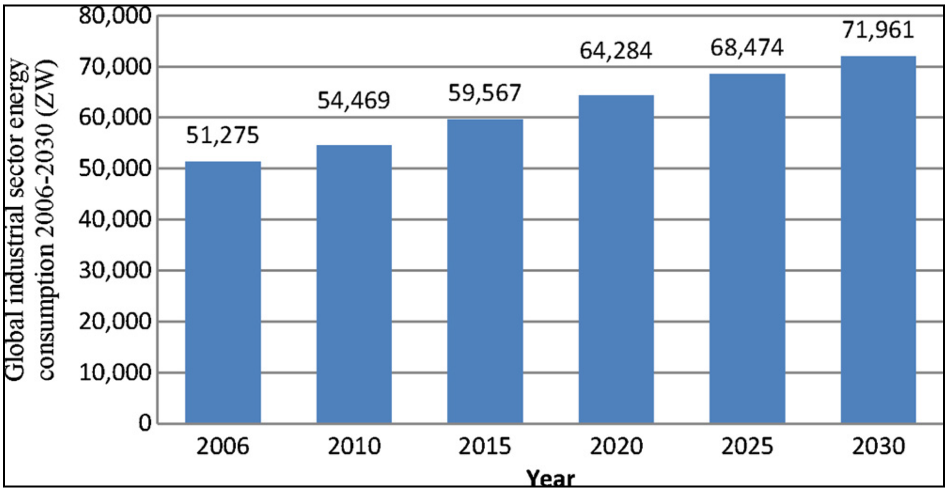

Fig 2.11: Global industrial sector energy consumption during 2006-2030 [27].

According to figure 2.11, due to increase in conventional fuel prices and environmental impacts, companies are looking to another energy source.

Among all renewable energy resources, solar energy has a best choice and it is the preferred from other renewable resources.

Solar energy available with big quantities, free, clean and it does not make any noise. [27].

Solar energy eliminate the need of fossil fuel in energy generation, but it is varying from place to another unlike fossil fuel which completely available.

Many types of renewable energy like solar energy can provide very large quantities of sustainable energy with overall efficiency higher than 10% with small environmental impacts. [28].

Solar energy applications in industrial sector divided to two main categories: solar thermal and photovoltaic.

Commonly applications in industrial sector are: hot water, steam, drying, preheating… Etc. [27]

Table 2.3 shows the use of renewable energy in industrial sector in 2001.

Table 2.3: The use of renewable energy in industrial sector [27]

Renewable source	Annual production (TJ)	% Global demand
Solar thermal	228720	0.523
Solar thermal (electric)	1200	0.003
Photovoltaic	630	0.001
Geothermal	128060	0.292
Geothermal (electric)	151390	0.345
Wind	35760	0.082
Tidal	2160	0.005
Total	547920	0.806

In this section I will explain two solar systems used in industrial sector:

- Solar thermal and solar water heaters.
- PV on – grid systems.

2.7.1 Solar thermal and SWH:

Solar thermal is the transformation of solar radiation to heat, it considered the most economical alternative and it used in many applications such as: heating air or water in domestic uses, commercial or industrial plants.

Most thermal industrial energy depends on burning fossil fuels to generate thermal energy, so the renewable energy is good choice for that.

Commonly the applications of solar thermal energy in industry are SWH (where that will explained in details), solar dryers, space heating and cooling systems and water distillation. [27]

As mentioned SWH is one of the applications of solar thermal, this type is commonly used to heat water where the sun is the source of that type.

2.7.1.1 Optimum design of SWH in Palestine:

SWH technology started in Palestine before 45 years ago and nowadays SWH used commonly to heat water and the type of thermosyphon open loop system used commonly.

The following equations used to design SWH in right way:

$$Q = m * C_w * \Delta T \tag{2.7}$$

$$A_{SWH} = \frac{Q * S_f}{\eta * E_{sd}} \tag{2.8}$$

Where:

Q: Thermal Energy required for heating (W s)

m: mass of water to be heated (Kg).

C_w: specific heat of water = 4186 Ws/kg- ºC

ΔT: temperature difference. (ºC)

η: efficiency of solar collector = 40% in Palestine.

Esd: Daily average of solar radiation intensity = 5.4kWh / m^2 – day.

S_f: Factor of safety (1.15 – 1.3 in Palestine).

Usually the system consists of three parallel connected collectors and each collector area is 1.7 m^2 and the storage rank of hot water is 200 liters. [11]

2.7.2 PV systems technology:

PV is a direct method of generating electricity from solar radiation by using solid – state devices without any heat engine.

PV devices are simple in design and require very little maintenance and operate for an indefinite period without wearing out.

PV consists of multiple components like: cells, mechanical and electrical connection and mountings and means of regulating and / or modifying the electrical output. [17, 29]

PV is elegant, but unfortunately expensive technology and it used in specialized markets like: consumer electronics remote are power supplies and satellites.

More than 90% of PV market is crystalline silicon solar cells and this dominance is likely to extend for many years.

Manufacturing of PV are doubling every 20 months for past 7 years. [28]

On the other hand the production of PV cells in the world increased from 10MWp / year to 1200 MWp in 2004.

Table 2.4 shows the development of PV technology between 1995 and 2005 and how that reflected to efficiency, cost and life. [27]

Table 2.4: Development of PV technology between 1995 and 2005 [27]

Parameters	1995	2000	2005
PV modules efficiency (%)	7–17	8–18	10–20
PV modules cost ($/Wp)	7–15	5–12	2–8
System life (years)	10–20	>20	>25

PV systems categorized to two main groups: stand – alone and grid connected.

Stand – alone system is not connected to grid, and this type usually supported by energy storage systems like rechargeable batteries to provide electrical energy when there is no sunlight.

Sometimes wind or hydro systems supporting each other and that called PV hybrid systems, while grid connected system is PV system connected to the electricity grid.

In this type the energy is consumed from grid where PV system energy not enough and feed in the energy to the grid when there is additional energy higher than needed and that which called “net – metering”. Grid connected PV system will explained in details and focus the study to this type. [27]

2.7.2.1 PV – on Grid systems:

Grid connected PV systems is connected to big grid mostly to the public electricity grid.

The range of PV systems size is from few kWp for residential purpose to up to tens of GWp for solar power stations. [29]

In developed world, grid electricity is easily accessible as a convenient use the grid as ‘giant battery’.

Grid can absorb PV power that is surplus to current needs especially in sunny summer times and make that available to use by other customers and reduce the amount of generation from conventional supply at night or cloudy times, when the output of the PV insufficient, the grid can provide backup energy from conventional sources.

In these PV systems a synchronous inverter is used which transfers the DC power from PV into AC power at voltage and frequency accepted to the grid, while debit and credit meters measure the power brought from or sold to the utility. [17]

2.7.2.1.1 Elements of on - grid PV systems:

Figure 2.12 shows the components of grid connected PV systems, where as shown the main two components are: PV panel and inverter.

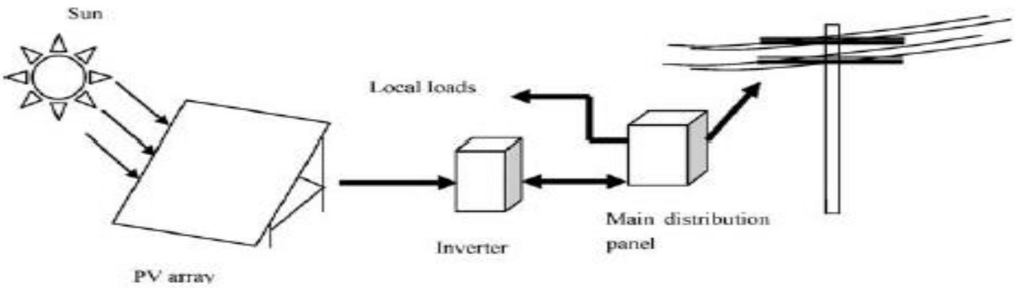

Fig 2.12: PV – on grid system [30]

PV panel receive the solar radiation and transfer it to electrical energy and it has a properties according to types and location conditions as mentioned before in details.

Inverter fix the voltage of panel operation or use maximum power point tracking function to reach to the best operating voltage for the panel. Inverter operates in phase with the grid and Delivers power as much as it can to the electricity grid, also inverter convert the DC power received from PV panel to AC power with desired voltage and frequency to be able to use it. [30]

2.7.2.1.2 Design of on - grid PV systems:

It's important to design grid connected PV system in right way to be able to use its power as possible as, so it's important to use the following equations in the design of grid connected PV system components.

$$PV_{energy} = \frac{\text{Energy consumption per day}}{\text{Inverter efficiency}} \quad (2.9)$$

$$PV_{peak\ power} = \frac{PV_{energy} * \text{safety factor}}{\text{Peak sun hours}} \quad (2.10)$$

$$\text{Number of series modules} = \frac{\text{Voltage of the PV generator}}{\text{Voltage of one module}} \quad (2.11)$$

$$\text{Number of strings} = \frac{\text{Number of modules}}{\text{Number of series modules}} \quad (2.12)$$

While for the inverter the following conditions must take in consideration:

- The input rating of the inverter must be equal to PV panel rating for safety and efficient operation.
- Inverter power must be greater than to the required power.
- The inverter efficiency must be greater than 90%. [31]

Chapter Three

Energy audit in different facilities in West Bank

Three facilities are studied in this thesis which are:

- Golden Wheat Mills Company. (GWMC)
- National Beverages Company. (NBC)
- National Aluminum and Profile Company. (NAPCO)

3.1 Energy audit in Golden Wheat Mills Company (GWMC):

3.1.1 About the company:

Golden Wheat Mills Company established in Ramallah in 1995 as public share holding company, this company produces flour with many types and this company consists of Swiss motors and machines.

There are many building in the company: Management building, Mill building which consists of 5 floors, scale, maintenance, cafeteria, watchman and warehouse.

Milling process consumes the highest scale of energy consumed and there are programs in milling process and each program consists of group of machines related to specific task and all these machines controlled by SCADA software fully automatic.

The company fed by three transformers each transformer rated at 630 KVA and there is standby generator with rated 620KVA and JDECO is the main supplier to the electricity power.

3.1.2 Energy measures opportunities in GWMC company:

In this company the situation of existing energy consumption will studied in different systems as the following:

1- Power transformers.
2- Tariff system.
3- Motors.
4- Lighting systems.
5- Compressed air system.
6- Utilizing solar energy.

In this facility the energy audit needed the following instruments:

- Multimeter.
- Power meter.
- Energy analyzer.
- Luxmeter.
- Thermometer.

3.1.2.1 Power transformers:

The annual electrical energy consumption in 2013 was 1863616 kWh and no power factor penalties because the power factor corrected in right way, figure 3.1 shows the monthly consumption of electricity during 2013. [32]

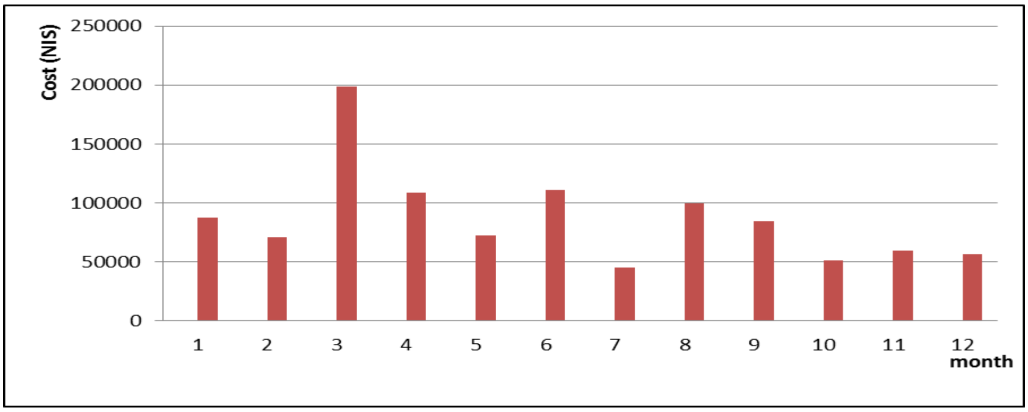

Fig 3.1: monthly consumption of electrical energy (GWMC) [27]

The energy analyzer device is installed on the three transformers and data were analyzed and formed the following curves.

- **Transformer 1 data:**

Figure 3.2 shows the daily apparent power consumed for transformer 1:

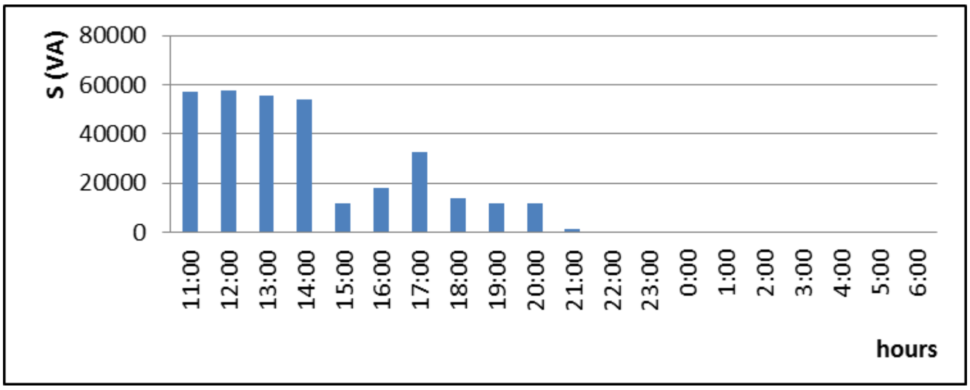

Fig 3.2: Time Vs. Apparent power curve (transformer 1, GWMC)

Figure 3.3 shows Time Vs. Three phase currents curve for transformer 1:

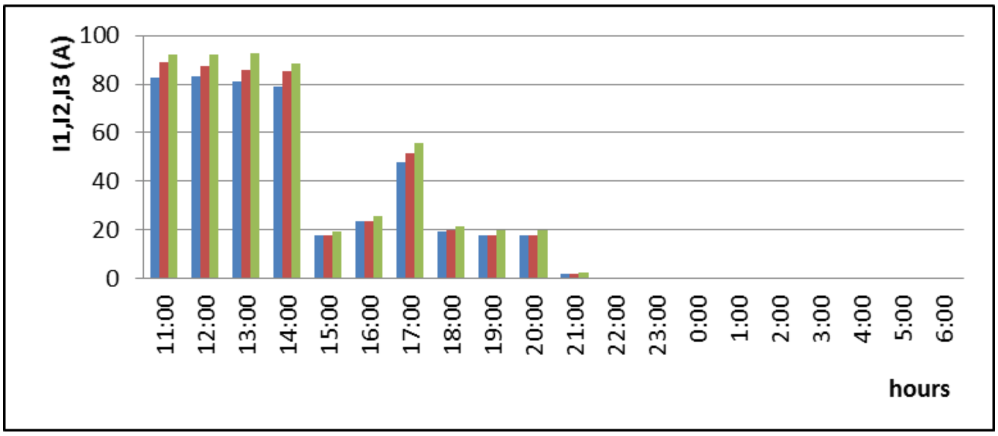

Fig 3.3: Time Vs. three phase currents curve (transformer 1, GWMC)

Figure 3.4 shows Time Vs. power factor curve for transformer 1:

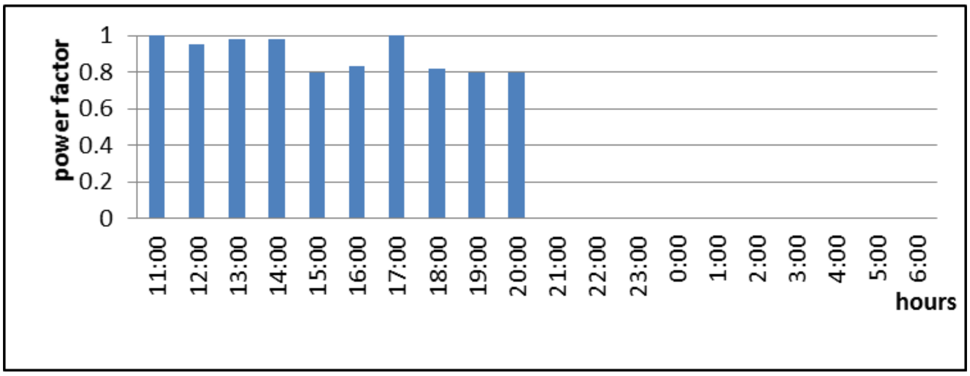

Fig 3.4: Time Vs. power factor curve (transformer 1, GWMC)

- **Transformer 2 data:**

Figure 3.5 shows the daily apparent power consumed for transformer 2:

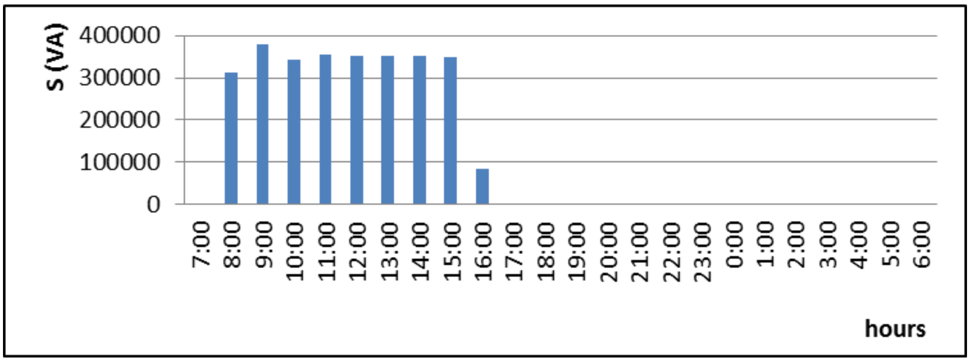

Fig 3.5: Time Vs. apparent power curve (transformer 2, GWMC)

Figure 3.6 shows Time Vs. Three phase currents curve for transformer 2:

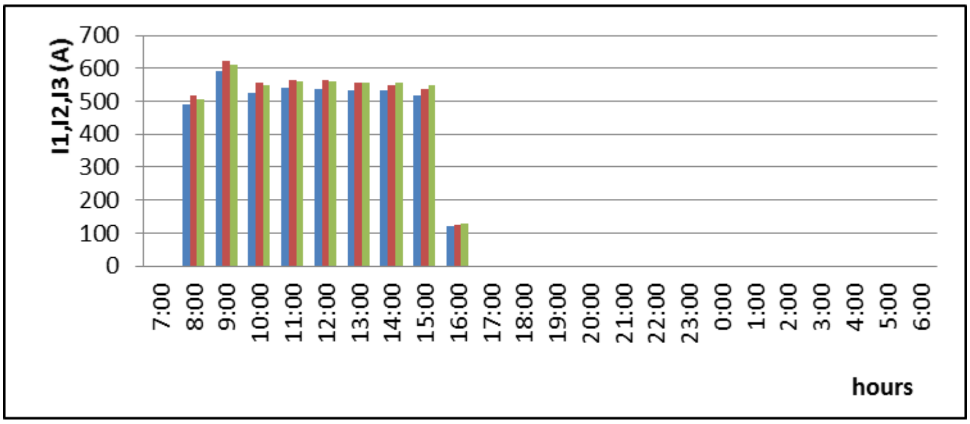

Fig 3.6: Time Vs. three phase currents curve (transformer 2, GWMC)

Figure 3.7 shows Time Vs. Power factor curve for transformer 2:

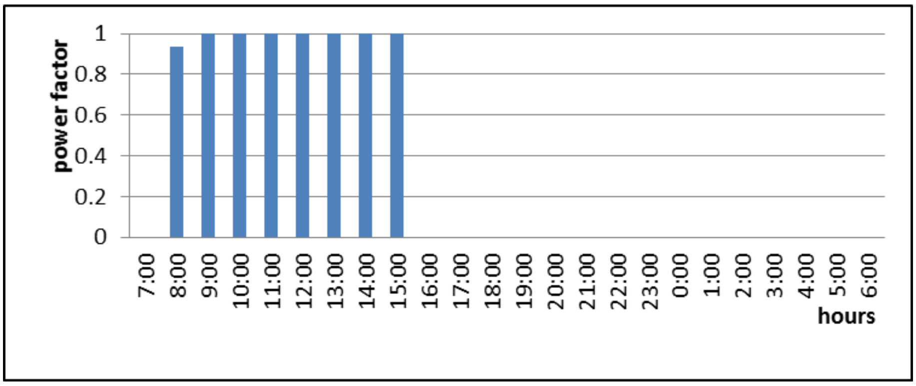

Fig 3.7: Time Vs. power factor curve (transformer 2, GWMC)

- **Transformer 3 data:**

Figure 3.8 shows the daily apparent power consumed for transformer 3:

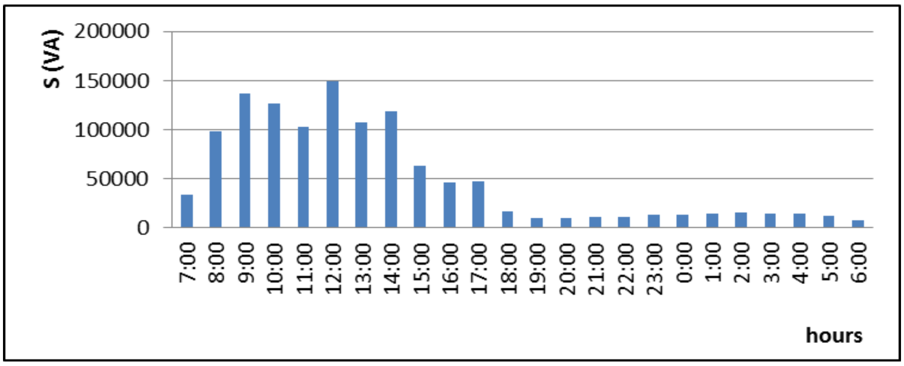

Fig 3.8: Time Vs. apparent power curve (transformer 3, GWMC)

Figure 3.9 shows Time Vs. Three phase currents curve for transformer 3:

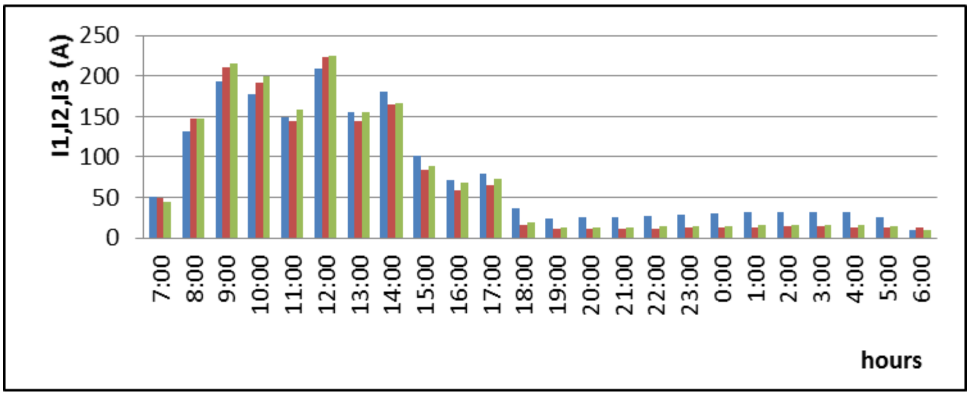

Fig 3.9: Time Vs. three phase currents curve (transformer 3, GWMC)

Figure 3.10 shows Time Vs. Power factor curve for transformer 3:

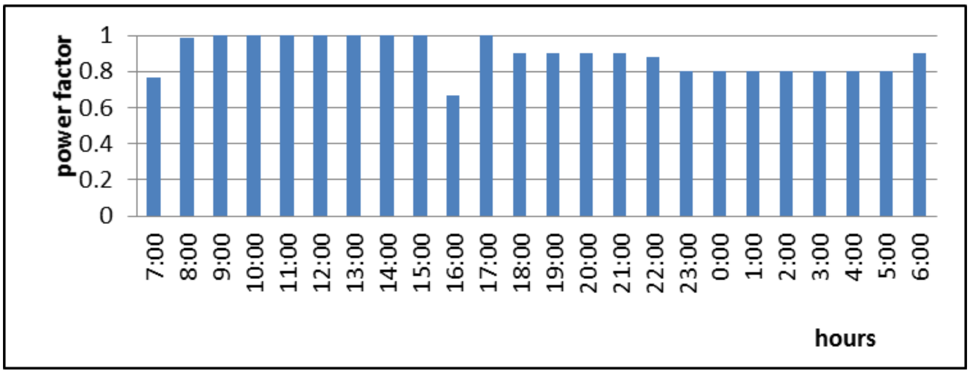

Fig 3.10: Time Vs. power factor curve (transformer 3, GWMC)

Good results didn't obtained in transformers 1 and 3 due to not normal operation so, instead of that, I got readings from LCD display and took data from it, to know the currents and power consumed in the company in the normal operation I found the following curves :

- Transformer 1 : time Vs. Apparent power (reading taken every 30 minutes):

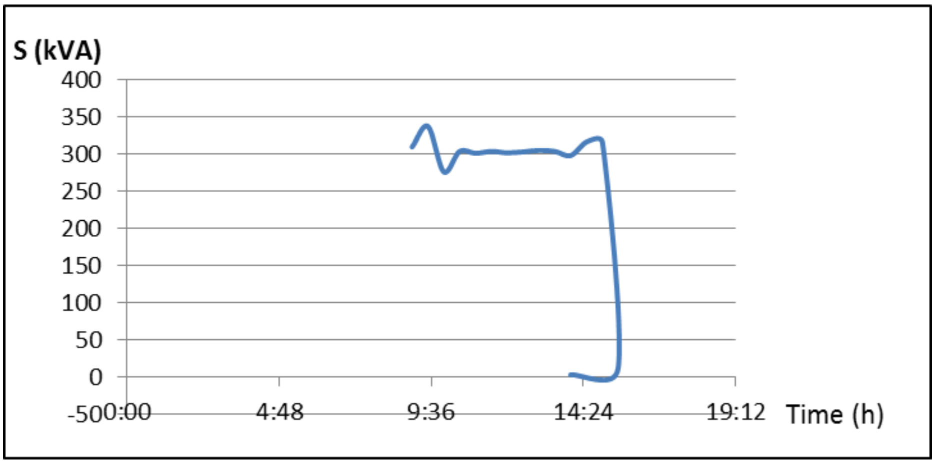

Fig 3.11: Time Vs. apparent power [enhanced readings, transformer 1, GWMC]

- Transformer 3 time Vs. apparent power (reading taken every 30 minutes):

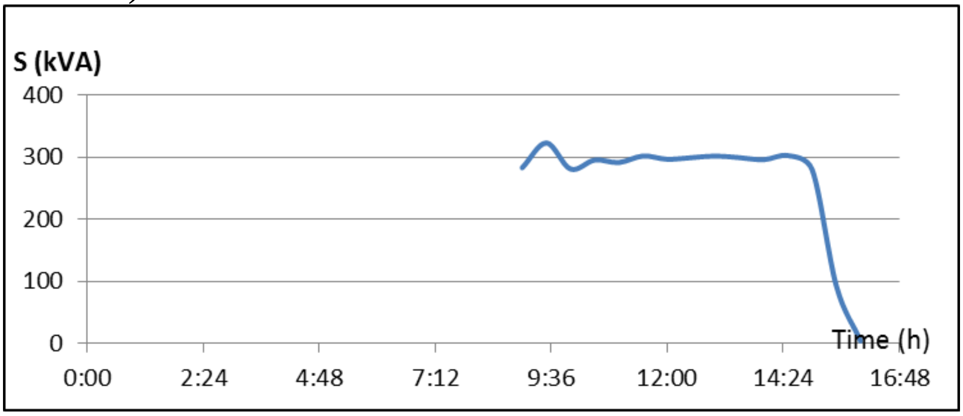

Fig 3.12: Time Vs. apparent power [enhanced readings, transformer 3, GWMC]

Now it's clear to make the needed calculations to load factor for the transformers and utility according to daily load curve and according to equation (2.6) $\{L.F = S_{av}/ S_{max}\}$

Load factor for transformers will show in table 3.1 considering the average apparent power in each transformer and the rated for transformers:

Table 3.1: load factor for transformers

Transformer number	S_{av} (KVA)	S_{max} (KVA)	Load factor (%)
Transformer 1	103	630	16.35
Transformer 2	123.35	630	19.58
Transformer 3	100.11	630	15.89

Load factor for the daily load curve of the utility panels show in table 3.2 as the following:

Table 3.2: Load factor for the utility panels

Panel Number	S_{av} (kVA)	S_{max} (kVA)	Load factor (%)
Panel 1	103	340	30.29
Panel 2	123.35	390	31.62
Panel 3	100.11	325	30.8

The average apparent power in three transformers were small because the load daily operation is 8 hours not during 24 hours, on the other hand the results from one time not enough to reflect the accurate results.

3.1.2.2 Energy conservation in the motors in the company:

Motors are the main loads in factories in general and the saving on them reflects to big effect in the reducing the consumption which leads to reduce the running cost.

There are many motors in the company (around 200 motors), but the studied sample was 30 motors which are high power motors and drives heavy loads.

The range of the power for these motors is from 5.5kW to 132kW and the types are ABB and Brock Hansen.

In these motors two energy saving methods could be applied, using inverters and replacing with efficient motors and that shown in tables 3.2 and 3.3.

Table 3. 3 show the measured data of these motors and the electrical energy saved by using inverters where the saving could be gained of electrical energy is 30%.

Also Table 3.4 showing the needed measured data which held to evaluate the operation of these motors and see the ability to replace these motors by high efficient according to appendix [F], also decide if the size is suitable according to loads and measured currents and power, then show the energy saved by this method.

a) Energy saving in motors by using inverters:

Table 3.3: motors consumption and saving in electrical energy from using inverters

Motor number	Power (kW)	Yearly operating hours	Yearly consumption of electrical energy (kWh)	Yearly saving in electrical energy (kWh)
3-M014	13.63	1600	21808	6542.4
3-M026	13.65	1600	21840	6552
3-M524	13.5	1600	21600	6480
3-M012	24	1600	38400	11520
3-M504	17.5	1600	28000	8400
3-M503	20.7	1600	33120	9936
3-M006	27	1600	43200	12960
3-M021	12.5	1600	20000	6000
3-M022	17.6	1600	28160	8448
3-M525	16.5	1600	26400	7920
3-M040	9.73	1600	15568	4670.4
3-M037	12.85	1600	20560	6168
3-M036	13.28	1600	21248	6374.4
3-M035	9.95	1600	15920	4776
3-M023	12.78	1600	20448	6134.4
3-M043	6.5	1600	10400	3120
3-M532	7.5	1600	12000	3600
3-M044	7.1	1600	11360	3408
3-M045	7	1600	11200	3360
3-M061	2.4	1600	3840	1152
3-M531	4.14	1600	6624	1987.2
3-M546	1.14	1600	1824	547.2
3-M505	17.9	1600	28640	8592
3-M500	62	1600	99200	29760
3-M001	118	1600	188800	56640
4-M502	6.7	1600	10720	3216
3-M025	14.25	1600	22800	6840
2-M011	7.78	3000	23340	7002
5-M001	8	3000	24000	7200
4-M001	41.78	1200	50136	15040.8
Total yearly consumption (kWh)			**881156**	**Total yearly saving (kWh)** **264346.8**

b) Energy saving in motors by replacing them with efficient motors:

Table 3.4: motors consumption and saving in electrical energy from replacing motors by efficient motors.

Motor number	Power (kW)	Yearly operating hours	Yearly consumption of electrical energy (kWh)	Old efficiency	Ability to replacement	New efficiency	Yearly saving in electrical energy (kWh)
3-M014	13.63	1600	21808	0.911	yes	0.928	720.05
3-M026	13.65	1600	21840	0.892	yes	0.928	1297.74
3-M524	13.5	1600	21600	0.916	yes	0.928	421.25
3-M012	24	1600	38400	0.931	yes	0.936	273.96
3-M504	17.5	1600	28000	0.95	no need	**	0
3-M503	20.7	1600	33120	0.933	no need	**	0
3-M006	27	1600	43200	0.933	no need	**	0
3-M021	12.5	1600	20000	0.912	yes	0.928	676.95
3-M022	17.6	1600	28160	0.912	yes	0.928	676.95
3-M525	16.5	1600	26400	0.892	yes	0.928	1297.74
3-M040	9.73	1600	15568	0.884	yes	0.92	1056.71
3-M037	12.85	1600	20560	0.884	yes	0.92	1056.71
3-M036	13.28	1600	21248	0.884	yes	0.92	1056.71
3-M035	9.95	1600	15920	0.884	yes	0.92	1056.71
3-M023	12.78	1600	20448	0.916	yes	0.928	421.25
3-M043	6.5	1600	10400	0.879	yes	0.915	7590.93
3-M532	7.5	1600	12000	0.908	yes	0.92	342.93
3-M044	7.1	1600	11360	0.879	yes	0.915	7590.93
3-M045	7	1600	11200	0.879	yes	0.915	7590.93
3-M061	2.4	1600	3840	0.862	yes	0.879	3595.61
3-M531	4.14	1600	6624	0.908	yes	0.911	13188.66
3-M546	1.14	1600	1824	0.853	yes	0.879	3705.19
3-M505	17.9	1600	28640	0.937	no need	**	0
3-M500	62	1600	99200	0.939	yes	0.945	807.07
3-M001	118	1600	188800	0.958	no need	**	0
4-M502	6.7	1600	10720	0.831	yes	0.911	1261.32
3-M025	14.25	1600	22800	0.909	yes	0.928	672.11
2-M011	7.78	3000	23340	0.879	yes	0.92	2269.33
5-M001	8	3000	24000	0.869	yes	0.915	1942.72
4-M001	41.78	1200	50136	0.939	yes	0.945	453.98
Total yearly consumption (kWh)			**881156**	**Total yearly saving (kWh)**			**61023.81**

This sample of motors consumes around **47.28%** from the total electrical energy.

As mentioned before the percentage of expected saving in electrical energy by using inverters is **30%** and from the total yearly saving in electrical energy is **14.18%.**

Equation (2.2) shows the efficiency of the motors and according to this equation another simplified form of this equation formed to calculate the effect of replacing conventional motors by efficient easily as shown below.

$$\Delta P = P_{out}\,(1/\eta_1 - 1/\,\eta_2) \qquad (3.1)$$

The percentage of expected saving in electrical energy from this method is around **6.93%** and from the total yearly electrical energy is **3.27%.**

From all that the total yearly saving in electrical energy in motors is **325370.61kWh** and the percentage of total saving in motors is **36.93%** and from the total electrical energy consumption in the company is **17.46%.**

3.1.2.3 Energy conservation in the lighting systems in the company:

Lighting systems has a good chance in energy conservation because many ways to reduce consumption can apply for example in awareness, using efficient equipments and using the solar radiation to supply electrical energy.

According to large number of fluorescent lamp units the suggestion is to replace the magnetic ballast by electronic where that lead to good value of energy conservation.

In general most spaces used natural light and the concentration of lighting study is replacing the magnetic ballasts with electronic in fluorescent lamps, but we noticed a dark space in the mill (11lm/m^2) and not possible to use the natural light where we didn't stop, so we measured the lux by luxmeter for this space and it was11lm/m^2 and see the suitable lights suggestion to the space and if it needs to add unit lamps according to standards in this space (100 lm/m^2) and the equation used to make the calculations of install or remove units is equation (2.3) by using lumen method.

From all that in lighting system the concentration will be on:

- Study the lighting level in mentioned space in the company to reach to optimum case.
- Replace the magnetic ballasts in fluorescent lamps by electronic ballasts.
- Replace incandescent lamps with CFL 20 watt lamps.

Table 3.5 shows the lighting types in company spaces with a yearly consumption of electricity:

Table 3.5: Lighting types and yearly consumption of electricity in the company

Space	Lamps types	Number of units	Power (W) [include ballasts]	Yearly operating hours	Yearly consumed electrical energy (kWh)
Offices	FL 4*18 W	45	3600	1848	6652.8
	FL 1*36 W	5	205	600	123
	CFL 2*26 W	28	1680	1848	3104.64
	CFL 1*13 W	6	96	1848	177.408
	CFL 1*20 W	2	40	1200	48
Watchman	FL 2*36 W	4	331.2	8760	2901.312
	INC 1*75 W	1	75	1460	109.5
Cafeteria	FL 4*18 W	8	640	3600	2304
	FL 2*36 W	1	82.8	3600	298.08
	CFL 2*26 W	21	1260	3600	4536
maintenance	FL 2*36 W	20	1656	1200	1987.2
	INC 1*75 W	2	150	600	90
Bags printing	FL 2*36 W	3	248.4	900	223.56
Bran warehouse	Metal halide 400 W	8	3360	600	2016
Scale	FL 2*36 W	2	165.6	1200	198.72
Mill, ground floor	FL 2*36 W	93	7700.4	3600	27721.44
Mill, 1st floor	FL 2*36 W	84	6955.2	3600	25038.72
Mill, 2nd floor	FL 2*36 W	46	3808.8	3600	13711.68
Mill, 3rd floor	FL 2*36 W	41	3394.8	3600	12221.28
Mill, 4th floor	FL 2*36 W	47	3891.6	3600	14009.76
Mill, 5th floor	FL 2*36 W	59	4885.2	3600	17586.72
External	MH 400W	13	5460	4380	23914.8
Total (kWh)					**158974.6**

Lighting system has a percentage of **8.53%** of total electrical energy.

- **Suggestions in lighting system conservation opportunities in the company:**

a) In the company there is a space darker than needed and by measuring lighting level in this space it was 11lm/m^2, and according to the standards it must be 100 lm/m^2 and the suggestion is to reduce the height of lamp units by using chains and increase the tall of the wires to increase lighting level and that lead to remove extra lighting units and I found 15 units (FL 2*36 W) need to reduce their heights. The saving gained by this method is removing 2 units (FL 2*36 W) which leads to yearly saving in electrical energy **596.16kWh**.

b) Replacing incandescent lamps with CFL 20 watt lamps:

Most lamps in the company are CFL 20 watt lamps, but there are 3 incandescent lamps 75 watts as shown in table 3.4, I propose to replace them with CFL 20 watt lamps and from that the total yearly saving is **53.2kWh.**

c) Opportunity to replace magnetic ballast by electronic ballast:

1- FL 2*36 W units:

In magnetic ballast each unit consume 82.8 W after measuring by powermeter and in electronic ballast the consumption became 72.128 W after measuring by powermeter where the amount of saving is **$10.672*10^{-3}$ kW** for each unit where each one needs two ballasts with one ballast for one lamp.

2- FL 1*36 W units:

In magnetic ballast each unit consume 41.4 W after measuring by powermeter and in electronic ballast the consumption became 36.064 W after measuring by powermeter where the amount of saving is **$5.336*10^{-3}$ kW** for each unit where each one needs one ballast.

3- FL 4*18 W units:

In magnetic ballast each unit consume 80.04 W after measuring by powermeter and in electronic ballast the consumption became 72.128 W after measuring by powermeter where the amount of saving **is$7.912*10^{-3}$kW** for each unit where each one needs two ballasts with one ballast for two lamps.

Table 3.6 shows in details yearly saving electrical energy in fluorescent lamps after using electronic ballast instead of magnetic.

Table 3.6: yearly saving in electrical energy in fluorescent lamps after using electronic ballasts

space	Lamps types	Number of units	saving for each unit (kW)	Yearly operatin g hours	Yearly saved electrical energy (kWh)
offices	FL 4*18 W	45	0.007912	1848	657.96
	FL 1*36 W	5	0.005336	600	16.01
Watchman	FL 2*36 W	4	0.010672	8760	373.94
Cafeteria	FL 4*18 W	8	0.007912	3600	227.87
	FL 2*36 W	1	0.010672	3600	38.41
maintenance	FL 2*36 W	20	0.010672	1200	256.13
Bags printing	FL 2*36 W	3	0.010672	900	28.81
scale	FL 2*36 W	2	0.010672	1200	25.61
Mill, ground floor	FL 2*36 W	93	0.010672	3600	3572.99
Mill, 1st floor	FL 2*36 W	84	0.010672	3600	3227.213
Mill, 2nd floor	FL 2*36 W	46	0.010672	3600	1767.28
Mill, 3rd floor	FL 2*36 W	41	0.010672	3600	1575.19
Mill, 4th floor	FL 2*36 W	47	0.010672	3600	1805.702
Mill, 5th floor	FL 2*36 W	59	0.010672	3600	2266.733
Total yearly saved electrical energy (kWh)					**15839.86**

The total yearly saving in lighting system is **16489.22 kWh**, so the percentage of total saving in lighting system is **10.37%** and from total yearly electrical energy is **0.88%.**

3.1.2.4 Analysis of compressed air system in the company:

Compressed air system is a very important system in this company because every element in manufacturing processes use compressed air also this system has a large consumption in the comparison with other systems and that found clearly in this company where the compressed air system has a percentage of **2.96%** from overall consumption of electrical energy.

Compressor unit has the following characteristics:

Pressure: 10 bar.

Flow rate: 58.1 L/sec.

Power: 22kW, 30 HP.

Rotation: 2940 r/min.

During the operation the load factor was around 50% and daily consumption in electrical energy is 176kWh/day with 16 operating hours daily day and night and the yearly electrical consumption is 52800kWh with a percentage of total electrical consumption 2.83%

Leakage detection in compressed air system is difficult and need special detection device also the pipes installation and design, so the suggestion is to reduce the temperature of inlet air to see how that reduce the consumption of electrical energy.

According to thumb rule each 3^{o}C of reduced temperature save around 1% of compressor energy [25], table 3.7 shows the yearly saving in electrical energy in compressed air system:

Table 3.7: yearly saving in electrical energy in compressed air system

Season	Temperature difference (^oC)*	Percentage of saving	Operating hours	Saving in electrical energy (kWh)
Summer	10	3%	864	285.12
Spring and autumn	12	4%	2688	1182.72
Winter	15	5%	1248	686.4
Total yearly saving in electrical energy (kWh)				**2154.24**

- These values taken according to estimated temperature from the installed thermometer during the year.

From all that the percentage of saving in compressed air system is around **4.08%** and from the total yearly consumption of electrical energy is **0.12%.**

Summary:

The overall yearly saving in electrical energy after applying the suggestion methods to reduce the consumption of electrical energy will show in table3.8:

Table 3.8: overall yearly saving in electrical energy (GWMC)

System	Amount of yearly saving (kWh)	Percentage of yearly saving from system's consumption	Percentage of yearly saving from total electrical energy
Motors (inverters and efficient motors)	325370.61	36.93%	17.46%
Lighting	16489.22	10.37%	0.88%
Compressed air	2154.24	4.08%	0.12%
Overall yearly saving	**344014.07**	-----	**18.46%**

3.1.2.5 Analysis of utilizing solar energy in GWMC company:

In this company the proposed use of solar energy divided to two uses which are solar water heater to heat water and PV on grid system to generate electricity and that will explain in the following sections with take consideration of daily electricity consumption of **5105.8 kWh**.

3.1.2.5.1 Solar thermal energy and SWH in GWMC company:

In this company the use of hot water is only for domestic uses where there are three hot water boilers in: maintenance, cafeteria and management building and table 3.9 show the yearly consumption of electrical energy for hot water boilers which measured by multi meter.

Table 3.9: yearly consumption of hot water boilers

location	Current (A)	Voltage (V)	Power (kW)	Yearly operating hours	Yearly consumed of electrical energy (kWh)
Maintenance	10.67	219	2.3367	900	2103.03
Cafeteria and toilets	10.21	219	2.23599	1500	3354
Management building	10.48	220	2.3056	600	1383.36
Total					**6840.39**

The percentage of the electrical consumption of hot water boilers is **0.38%** from the total electrical consumption.

The suggestion is using SWH to reduce the consumption of electrical energy and save good amount of cost.

- Design of SWH:

To compute the energy consumed by this 200 liter of hot water, we assumed that the average temperature of the water is 20°C, and the solar collectors will increase it to 65°C; then energy needed could be calculated using equation (2.7)

So after using the equation (2.7) to compute energy consumption I obtain:

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

$$Q = 200 * 4.186 * [65 - 20]$$

$$Q = 37674 \text{ KJ}$$

$$E = 37674\text{kj} * \frac{1\text{kWh}}{3600\text{kj}} = 10.4654\text{kWh/day}$$

Now after calculating the energy needed per day on the basis of kWh/day, the solar panels could be designed by using equation (2.8):

$$\mathbf{A}_{collector} = \frac{\text{Energy}}{\text{Solar radiation daily intensity} * \eta_{collector}}$$

$$\mathbf{A}_{collector} = \frac{10.4654}{5.4 * 0.4} = 4.85 \text{ m}^2.$$

$$\text{Number of collectors} = \frac{\text{Area of SWH}}{\text{Area of Collector}}$$

The number of collector as the following:

$$\text{Number of collectors} = \frac{4.85m^2}{1.7\ m^2} = 2.85$$

So, three collectors will be used, and the actual area of collectors is 3*1.7 = 5.1 m^2.

Table 3.10 shows the amount of saving in electrical energy after installing SWH:

Table 3.10: yearly saved electrical energy after installing SWH

Location	Yearly operating hours of SWH	Yearly saving in electrical energy (kWh)
Maintenance	630	1472.121
Cafeteria and toilets	1050	2347.79
Management building	420	968.352
Total (kWh)		**4788.263**

The percentage of saving is around 70% of the consumption of hot water boilers and from the total yearly electrical energy is **0.26%.**

3.1.2.5.2 Analysis of utilizing on – grid PV system in GWMC company:

The proposed PV on grid systems in this company and other companies is design PV systems to reduce the total electricity consumption with a percentage **10%** as the following:

The daily electricity consumption is 5105.797kWh and 10% of this value is 510.58kWh, so the minimum produced PV energy is 510.58kWh and in design the system must be larger to be able to sell the surplus electrical energy.

We need to apply equations (2.9) and (2.10) to design good PV system as the following:

PV_{energy} = 510.58/0.9 = 567.31kWh.

$PV_{peak\ power}$ = (567.31/5.4) * 1.2 = 126kW.

The suggestion is to use PV module type Poly HSL 72 300 W where its peak power is 300 W at standard conditions.

Number of modules = 126/0.3 = 420.23 modules.

To make sure to cover needed load and to obtain net metering tariff my suggestion is to use 500 modules, so the peak power of this PV system is 150kW.

Then divide this system to 5 subsystems (arrays) with 100 modules and the peak power 30kW for each to make the system easier in maintenance and provide many sectors in the facility as possible as.

According to equation (2.11) and the electrical properties of PV module the number of series modules in one array is 48/36.1 = 1.33 ≈2 modules.

According to equation (2.12) to calculate the number of strings it will be 100/2 = 50 strings in each array.

From all that the inverters used are 5 three phase on grid inverters and their type is ABB PRO – 33.0 – TL – OUTD with 33kW rated and 90% efficiency.

If each 1 kilowatt peak PV modules need $9m^2$ area, so this system needs 150*9 = 1350 m^2 divided to 5 arrays where each array needs 270 m^2 areas.

Fig 3.13 shows the diagram of on – grid PV system in GWMC:

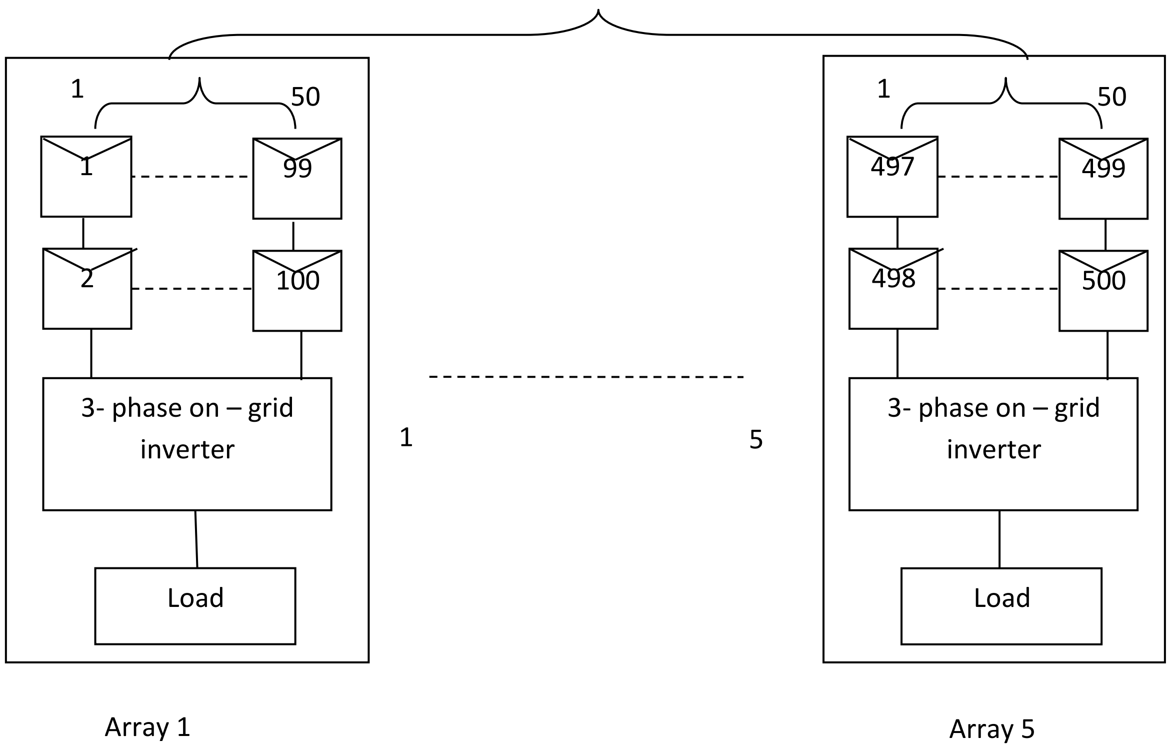

Fig 3.13: PV – on grid diagram in GWMC

- **Summary:**

Table 3.11 will shows the overall saving could gain from utilizing solar energy (SWH and PV – on grid system).

Table 3.11: the overall saving from utilizing solar energy (GWMC)

system	Amount of yearly saving (kWh)	Percentage of yearly saving from system's consumption	Percentage of yearly saving from total electrical energy
Hot water and SWH	4788.263	70%	0.26%
PV – on grid system	186361.6	-----	10%
Overall yearly saving	**191149.863**	-----	**10.26%**

3.2 Energy audit in National Beverages Company (NBC):

3.2.1 About the company:

National Beverages Company established by a group of Palestinian businessmen in 1998 as a private limited company in the food and beverage sector and this company comprises of more than 350 employees and its location in Ramallah.

NBC is licensed with the international Coca-Cola Company to produce high quality carbonated soft drinks, mineral water and juices using state of the art manufacturing technologies.

The area of the factory is about 1200 m^2 with two buildings: offices and factory.

The company fed by two transformers with a rated of 1000 KVA each and JDECO is the supplier of the electricity.

3.2.2 Energy management opportunities in NBC:

During the visit to the company, we found that the following systems can be included in our analysis for determining energy conservation measures:

1- Power transformers.
2- Motors.
3- Lighting systems.
4- Compressed air system.
5- Utilizing solar energy.

In this facility the energy audit needed the following instruments:

- Multimeter.
- Power meter.
- Energy analyzer.
- Luxmeter.
- Thermometer.

3.2.2.1 Power transformers:

The annual electrical energy consumption is **4723914.6kWh** according to estimation from energy analyzer readings and no power factor penalties because the power factor corrected.

The energy analyzer device is installed on the two transformers and data were analyzed and formed the following curves.

- Transformer 1 data:

Figure 3.14 shows the daily apparent power consumed for transformer 1:

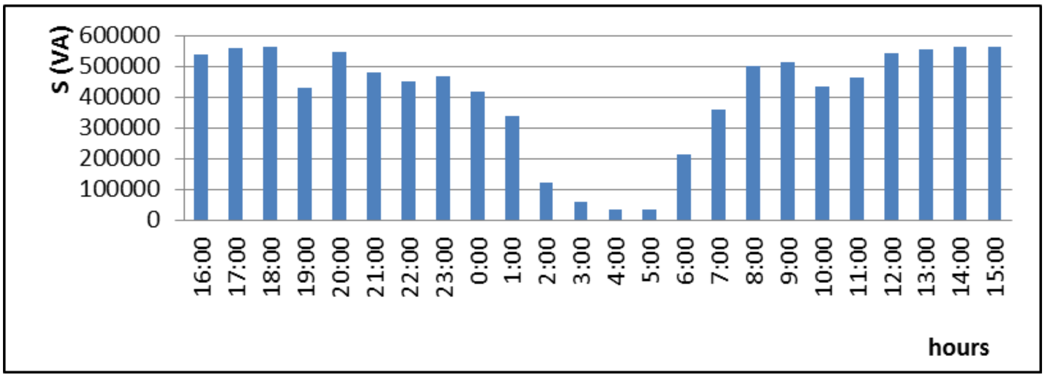

Fig 3.14: Time Vs. apparent power curve (transformer 1, NBC)

Figure 3.15 shows Time Vs. Three phase currents curve for transformer 1:

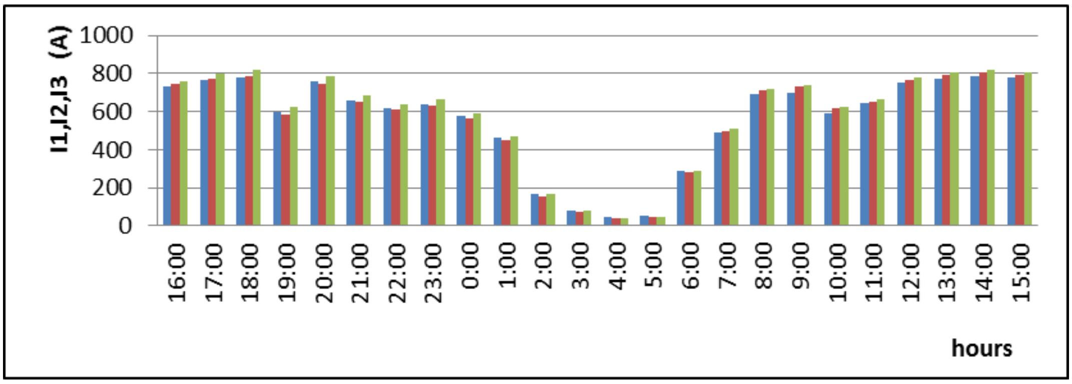

Fig 3.15: Time Vs. Three phase currents curve (transformer 1, NBC)

Figure 3.16 shows Time Vs. Power factor curve for transformer 1:

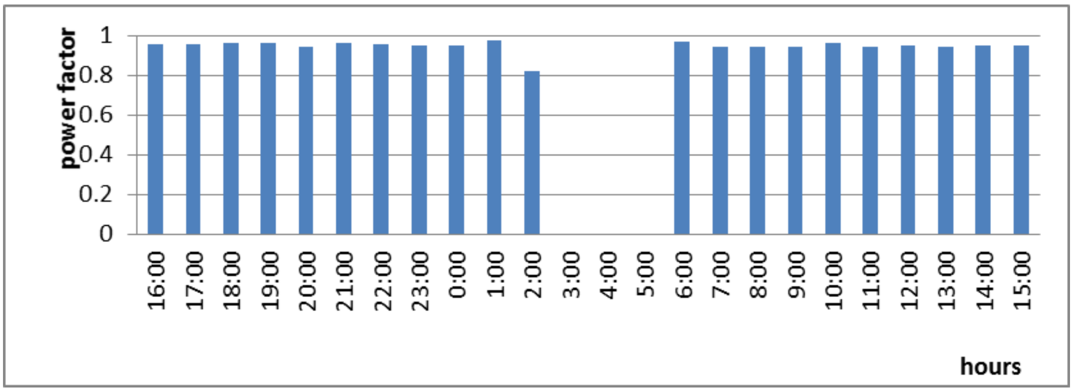

Fig 3.16: Time Vs. power factor curve (transformer 1, NBC)

- **Transformer 2 data:**

Figure 3.17 shows the daily apparent power consumed for transformer 2:

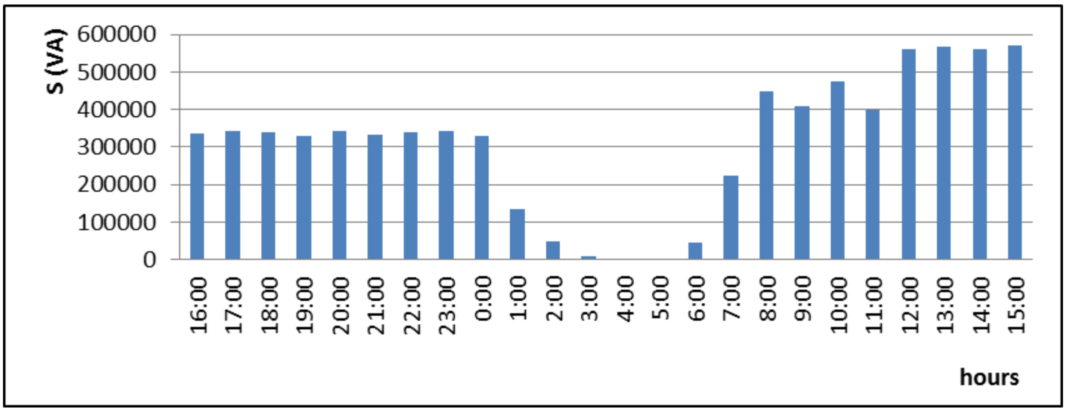

Fig 3.17: Time Vs. apparent power curve (transformer 2, NBC)

Figure 3.18 shows Time Vs. Three phase currents curve for transformer 2:

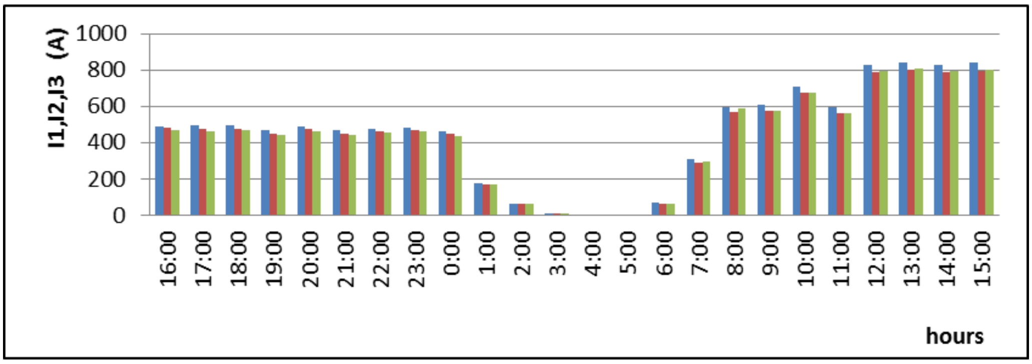

Fig 3.18: Time Vs. Three phase currents curve (transformer 2, NBC)

Figure 3.19 shows Time Vs. Power factor curve for transformer 2:

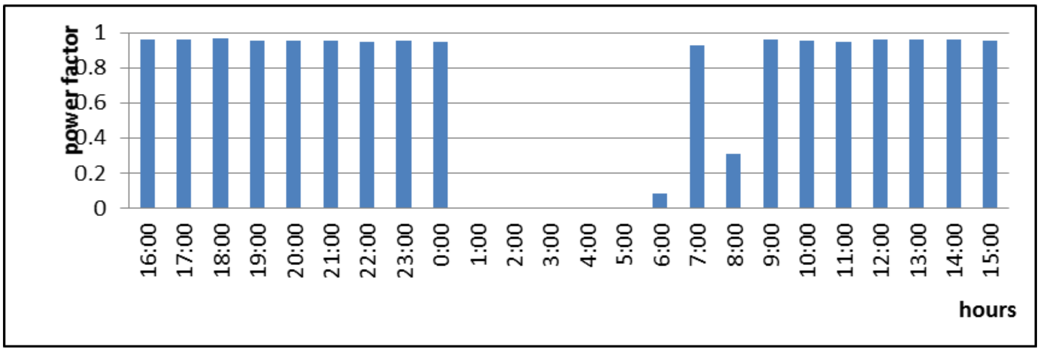

Fig 3.19: Time Vs. power factor curve (transformer 2, NBC)

Now it's clear to make the needed calculations to load factor for the transformers panels of the utility by using equation (2.6) as the following:

For transformers table 3.12 shows that in details:

Table 3.12: load factor for transformers

Transformer number	S_{av} (KVA)	S_{max} (KVA)	Load factor (%)
Transformer 1	417.93	1000	41.79
Transformer 2	325.59	1000	32.56

Load factor for the daily load curve of the utility panels show in table 3.13 as the following:

Table 3.13: load factor for utility panels

Panel number	S_{av} (KVA)	S_{max} (KVA)	Load factor (%)
Transformer 1	417.93	564.77	74
Transformer 2	325.59	571.21	57

Load factor for the transformers is low, but take one reading not reflect the normal condition of the loads, on the other hand the daily load factor of the utility in good.

3.2.2.2 Energy conservation in the motors in the company:

In this company there are many motors drive loads and certainly it's feasible to see techniques to save energy in motors.

Most motors are small and drive small loads, but there are seven big motors used to compression processes and their rating from 55kW to 280kW.

Table 3.14 show the needed measured data to evaluate the operation of these motors and see the ability to replace these motors by efficient motors according to appendix (F), also decide if the size is suitable or not according to loads and measured currents and power, and see the effect of using inverters in these motors then show the energy saved by this method.

- Due these motors are compressors the estimated load factor is 50%, and that means half time working with no load and the another half time working with load.

Table 3.14: motors consumption and saving in electrical energy from

Motor name	Power (kW)	Yearly operating hours	Yearly consumption of electrical energy (kWh)	Old efficiency	Ability to replace ment	New efficiency	Yearly saving in energy (kWh)
40 bar comp	158	6000	474000	0.854	Yes	0.955	69288.35
PET 1 comp	66	3000	99000	0.804	Yes	0.944	25801.21
PET2 comp	66	3000	99000	0.804	Yes	0.944	25801.21
CAN1 comp	57	3000	85500	0.822	Yes	0.945	17718.69
CAN2 comp	57	3000	85500	0.822	Yes	0.945	17718.69
NRB1 comp	44	3000	66000	0.849	Yes	0.945	10042.07
NRB2 comp	44	3000	66000	0.849	yes	0.945	10042.07
Total yearly consumption (kWh)			**975000**	Total yearly saving (kWh)			**176412.29**

replacing motors by efficient motors

These data from measurements by power meter and multimeter and analyze them to know the feasibility of suggestion replacing the motors.

The percentage of the consumption of this sample of motors to the total yearly consumption of electrical energy is around **20.64%.**

If we used inverters in these motors we can reduce the electrical consumption with a percentage **30%**, then the total yearly saving will be **292500kWh**.

On the other hand applying equation (3.1) show how replacing conventional motors with efficient where this technique saved energy and this equation applied to these motors to see the amount of total yearly saving in electrical energy as shown in table 3.14.

It's clear that this sample of motors may reduce energy in a percentage of **48.1%** and the amount of total yearly saving in motors is **468912.29kWh** and that with a percentage of **9.9%.**

3.2.2.3 Energy conservation in the lighting system in the company:

As mentioned before about the lighting and how to save energy in this system and show the opportunities to save energy in lighting system in this company, where NBC already saves energy in lighting by using solar radiation as possible as and remove extra lamps, so no need to remove or replace lamps units, while another thing can do in lighting system which is replacing magnetic ballasts in fluorescent lamps by electronic ballasts.

Table 3.15 shows the lighting types and yearly electricity consumption in NBC:

Table 3.15: lighting types and yearly consumption of electricity in NBC

space	Lamps types	Number of units	Power (W) [include ballasts]	Yearly operating hours	Yearly consumed electricity (kWh)
offices	FL 2*36 W	49	4057.2	2400	9737.28
	FL 2*36 W	61	4880	2400	11712
	CFL 2*23 W	57	2850	2400	6840
	CFL 2*23 W	2	50	2400	120
Cafeteria 1	FL 1*36 W	1	41	900	36.9
Cafeteria 2	CFL 2*23 W	17	850	900	765
Store	FL 1*36 W	1	41	600	24.6
Meeting room 1	CFL 2*23 W	4	200	600	120
	CFL 1*23 W	4	100	600	60
Meeting room 2	CFL 2*23 W	18	1116	600	669.6
Factory offices	FL 4*18 W	8	640	6000	3840
Factory	MH 400 W	26	10920	6000	65520
Syrup room	MH 250 W	4	1040	6000	6240
Total (kWh)					**105685.38**

The percentage of the lighting consumption is around **2.24%** from total yearly consumption.

The proposed solution is replace the magnetic ballasts in fluorescent lamps by electronic ballasts to save energy and that shown in details in table 3.16 and the amount of saving will be as the following:

1- FL 2*36 W units: $10.672*10^{-3}$kW.

2- FL 1*36 W units: $5.336*10^{-3}$kW.

3- FL 4*18 W units: $7.912*10^{-3}$kW.

Table 3.16: yearly saving in electrical energy from using electronic ballasts in fluorescent lamps

Space	Lamps types	Number of units	Saving for each unit (kW)	Yearly operating hours	Yearly saved electricity (kWh)
Offices	FL 2*36 W	49	0.010672	2400	1255.03
	FL 4*18 W	61	0.007912	2400	1158.32
Cafeteria 1	FL 1*36 W	1	0.005336	900	4.8024
Store	FL 1*36 W	1	0.005336	600	3.2016
Factory offices	FL 4*18 W	8	0.007912	6000	379.776
Total yearly saving (kWh)					**2801.13**

The percentage of saving in lighting system is **2.65%** and from total yearly consumption is around **0.06%.**

3.2.2.4 Analysis of compressed air system in the company:

Compression processes consume energy with a high scale, so reducing in their electrical energy will lead to saving in operating cost, one of these techniques to save energy is reducing the temperature if input air where each **3^{o}C** reduced temperature will save around **1%** of compressor energy where table 3.17 will show that in details.

Table 3.17: yearly saving in electrical energy in compressed air system (NBC)

compressor	season	Temperature difference (^0C)	Percentage of saving	Operating hours	Saving in electrical energy (kWh)
40 bar comp	summer	10	3%	1080	5119.2
	Spring and autumn	12	4%	3360	21235.2
	Winter	15	5%	1560	12324
PET 1 comp	Summer	10	3%	540	1069.2
	Spring and autumn	12	4%	1680	4435.2
	winter	15	5%	780	2574
PET2 comp	Summer	10	3%	540	1069.2
	Spring and autumn	12	4%	1680	4435.2
	winter	15	5%	780	2574
CAN1 comp	Summer	10	3%	540	923.4
	Spring and autumn	12	4%	1680	3830.4
	winter	15	5%	780	2223
CAN2 comp	Summer	10	3%	540	923.4
	Spring and autumn	12	4%	1680	3830.4
	winter	15	5%	780	2223
NRB1 comp	Summer	10	3%	540	712.8
	Spring and autumn	12	4%	1680	2956.8
	winter	15	5%	780	1716
NRB2 comp	Summer	10	3%	540	712.8
	Spring and autumn	12	4%	1680	2956.8
	winter	15	5%	780	1716
Total yearly saving in electrical energy (kWh)					**79560**

From all that the percentage of saving is around **8.16%** and from the total yearly consumption is around **1.68%.**

- **Summary:**

Resulting in applying all these measures to reduce the consumption of yearly electrical energy, table 3.18 shows the overall yearly saving in electrical energy.

Table 3.18: overall yearly saving in electrical energy (NBC)

system	Amount of yearly saving (kWh)	Percentage of yearly saving from system's consumption	Percentage of yearly saving from total electrical energy
Lighting	2801.13	2.65%	0.06%
motors	468912.29	48.1%	9.9%
Compressed air	79560	8.16%	1.68%
Overall yearly saving	**551273.42**		**11.64%**

3.2.2.5 Analysis of utilizing solar energy in NBC company:

The same thing will applied to this company, but no need to solar thermal energy because to not use of hot water, so PV on grid system will be the proposed system to achieve the percentage of reduction 10% from the total electrical energy consumption.

The daily electricity consumption in this facility is12942.23kWh and 10% of this value is 1294.22kWh, so the minimum produced PV energy is 1294.22kWh and in the design the system must be larger to be able to sell the surplus electrical energy.

We need to apply equations (2.9) and (2.10) to design good PV system as the following:

PV_{energy} = 1294.22/0.9 = 1438.02kWh.

$PV_{peak\ power}$ = (1438.02/5.4) * 1.2 = 319.56kW.

The suggestion is to use PV module type Poly HSL 72 300 W where its peak power is 300 W at standard conditions.

Number of modules = 319.56/0.3 = 1065.2 modules.

To make sure to cover needed load and to obtain net metering tariff the suggestion is to use 1200 modules, so the peak power of this PV system is 360kW.

Then divide this system to 10 subsystems (arrays) with 120 modules and the peak power 36kW for each to make the system easier in maintenance and provide many sectors in the facility as possible as.

According to equation (2.11) to calculate the modules in series 48/36.1 = 1.33 ≈2 modules.

According to equation (2.12) to calculate the number of strings 120/2 = 60 strings.

From all that the inverters used are 10 three phase on grid inverters and their type is TRESS TL S 50 KTS with 50kW rated and 90% efficiency.

If each 1 kilowatt peak PV modules need 9m^2 area, so this system needs 360*9 = 3240 m^2 divided to 10 arrays where each array needs 324 m^2 areas.

Figure 3.20 will show that in details clearly:

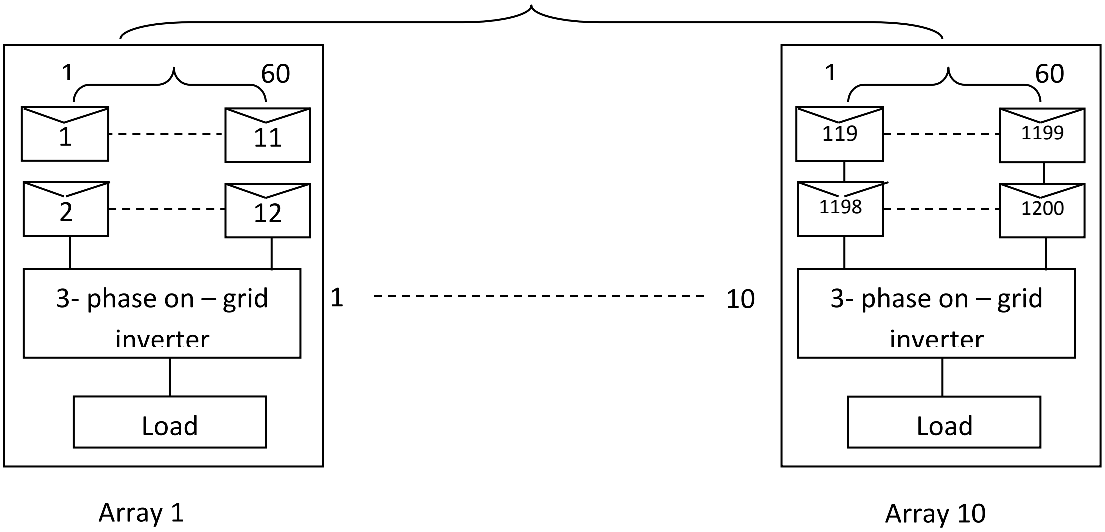

Fig 3.20: PV on – grid diagram in NBC

3.3 Energy audit in national aluminum and profile company (NAPCO):

3.3.1 About the company:

National Aluminum and Profile Company (NAPCO) established as a company in the year of 1991 in Nablus where this company produce Aluminum and Profile products for doors, windows, kitchens, gardens and others.

The area of the company is around 28000 m^2 and this company has more than 200 employees.

The capacity of production of the company is 6000 tons for various production lines.

This company is a main source of Aluminum manufacturing in Palestine.

NAPCO connected to IEC Company through a distribution transformer with a rated of 1000kVA, and there is standby diesel generator with a rated of 1000kVA.

3.3.2 Energy measures opportunities in NAPCO company:

According to the site visit of the company, the following measures could be studied and analysis them in details to conserve energy:

1- Power transformers.
2- Motors.
3- LPG burners and recovering waste heat from them.

In this facility the energy audit needed the following instruments:

- Multimeter.
- Power meter.
- Energy analyzer.
- Thermometer.

And we will explain in details these systems and study how to improve efficiency and reduce consumed energy in these systems.

3.3.2.1 Power transformer in NAPCO:

The yearly consumption of electrical energy is around **2979600kWh** with monthly electricity cost **166277 NIS** and yearly cost **1995324 NIS**,and no power factor penalties because the power factor corrected in right way, and the consumption of LPG is **52 Ton/ month** with a cost of **303000 NIS monthly** and from that the average yearly consumption is **624 Tons** with a cost of **3636000 NIS.**

The energy analyzer device was installed on the transformer and data were analyzed and formed the following curves.

Figure 3.21 shows the daily apparent power consumed of the transformer:

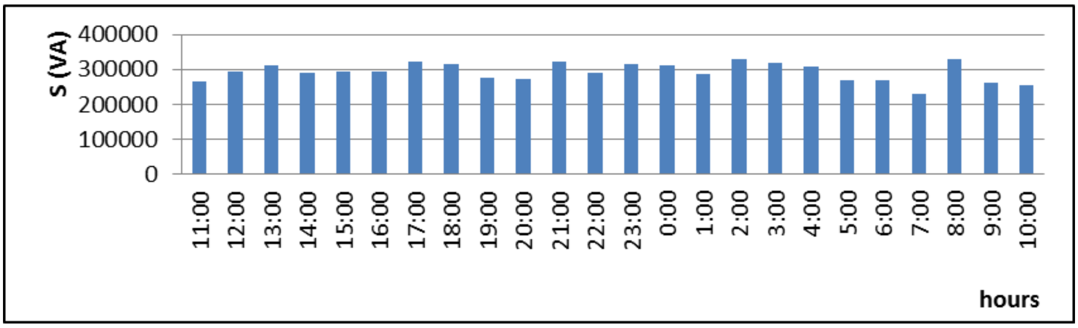

Fig 3.21: Time Vs. apparent power curve (NAPCO)

Figure 3.22 shows Time Vs. Three phase currents curve for the transformer:

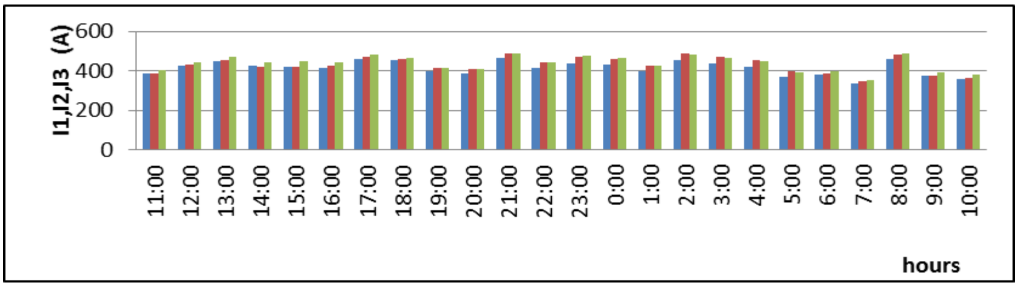

Fig 3.22: Time Vs. Three phase currents curve (NAPCO)

Figure 3.23 shows Time Vs. Power factor curve for the transformer:

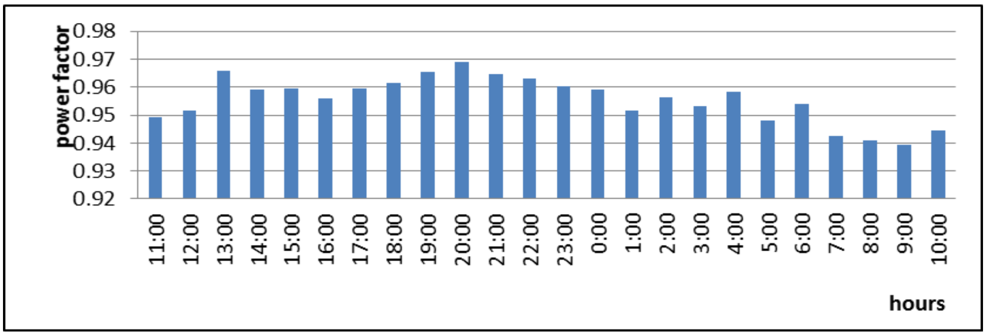

Fig 3.23: Time Vs. power factor curve (NAPCO)

Now it's clear to calculate the load factor of the transformers according to equation (2.6):

L.f = S_{av} / S_{max} = 293.29/1000 = **29.33%.**

It seems that the connected transformer is higher than the needed rated, but that not enough to decide the replacement of the transformer where that need to reading during a year and make sure that all loads are connected.

The daily load factor of the company is also according to equation (2.6), but it's important to know the maximum load during a day where it found and its value is 329750 VA.

So L.f = 293290.96 / 329750 = **88.94%.**

According to that, the values of daily load factor are suitable.

3.3.2.2 Energy conservation in the motors in the company:

In NAPCO there are many motors driving many types of loads, but we choose big motors to make our study on them according to the high electricity consumption and their continuous operation.

The sample of motors are three 150 HP motors where these motors drive the hydraulic pumps in the aluminum extrusion line and we will see the effect of using inverters and replacing them with efficient motors and that will shown clearly in tables 3.19 and 3.20.

a) Energy saving in motors by using inverters:

Table 3.19: motors consumption and saving in electrical energy from using inverters

Motor number	Power (kW)	Yearly operating hours*	Yearly consumption of electrical energy (kWh)	Yearly saving in energy (kWh)	
1	112	7488	419328	125798.4	
2	112	7488	419328	125798.4	
3	112	7488	419328	125798.4	
Total yearly consumption (kWh)			**1257984**	**Total yearly saving (kWh)**	**377395.2**

- With 50% loading factor according to load varying.

b) Energy saving in motors by replacing them with efficient motors:

Table 3.20: motors consumption and saving in electrical energy from replacing motors by efficient motors.

Motor number	Power (kW)	Yearly operating hours*	Yearly consumption of electrical energy (kWh)	Old efficiency	Ability to replacement	New efficiency	Yearly saving in energy (kWh)
1	112	7488	419328	0.89	Yes	0.95	29757.16
2	112	7488	419328	0.89	Yes	0.95	29757.16
3	112	7488	419328	0.89	Yes	0.95	29757.16
Total yearly consumption (kWh)			**1257984**	**Total yearly saving (kWh)**			**89271.48**

- With 50% loading factor according to load varying.

This sample of motors consumes **42.2%** from the total yearly electricity consumption in the company.

As mentioned before the percentage of expected saving in electrical energy by using inverters is 30% and from that the total yearly saving in electrical energy is **12.67%.**

According to equation (3.1) which shows how the amount of saving in electrical energy from replacing standard motors by efficient the calculated saving value is **89271.48kWh** yearly and that means **7.09%** of their consumption and **3%** from the total electricity consumption.

The total yearly saving in electrical energy is **466666.68kWh** and the percentage of total saving in motors is **37.09%** and from the total electrical consumption in the company **15.67%.**

3.3.2.3 LPG burners and recovering waste heat from them in the company:

In NAPCO there are four burners with LPG fuel, where these burners used in melting line, homogeneity line, extrusion line and powder line.

Heating processes consume large quantities of fuel and energy conservation on them lead to good results then to reduce the cost of these processes.

One of techniques could be applied in these burners is recovering waste heat from flue gases.

As known the combustion processes consists of LPG as a fuel and air then the results are flue gases and heat.

These burners have stacks for flue gases with a temperature of 200°C and the following tables and equations show how to reduce the quantities of LPG in these processes.

Table 3.21 shows the monthly consumption of burners and type of used fuel:

Table 3.21: burners' monthly consumption of fuel and type of fuel

Burner	**fuel**	**Calorific value (Kcal/Kg)**	**Consumption (Kg/month)**
Melting line	LPG	9500	4686
Homogeneity line	LPG	9500	2500
extrusion line	LPG	9500	14201
Powder line	LPG	9500	9260
Total (Kg/month)			**30647**

From these data the yearly fuel consumption is **367764 Kg** and the percentage of total LPG consumption is **58.94%.**

- **LPG combustion equation (air / fuel ration 15:5):**

$C_3H_8 + 5(O_2 + 3.76N_2) \rightarrow 3CO_2 + 4H_2O + 18.8N_2$ (3.2)

1 mole 5 moles of air $\rightarrow$ 3 moles 4 moles 18.8 moles

Then,

1 mole fuel $\rightarrow$ 3 moles CO_2, 4 moles H_2O and 18.8 moles N_2

44.097 Kg/Kmol   44 Kg/Kmol   18kg/Kmol   28 Kg/Kmol

44.097 Kg   132 Kg   72 Kg   526.4 Kg

** Considering the molar mass 44.097 Kg/ Kmol and the heat value of LPG is 9500 Kcal/ Kg.

So, from the combustion equation every 44.097 Kg from the fuel will lead to 730.4 Kg of flue gases and the temperature in the stack of flue gases is around 200°C.

Now it's easy to calculate the amount of glue gases as in table 3.22:

Table 3.22: flue gases quantities

Burner	Fuel consumption (Kg/month)	Flue gases quantity (Kg/month)
Melting line	4686	77319
Homogeneity line	2500	41250
extrusion line	14201	234316.5
Powder line	9260	152790

Heat value of flue gases can be calculated according to equation (3.3)

$$Q = m \ Cp \ \Delta T \qquad (3.3)$$

Where:

Q: heat of flue gases (kWh).

m: mass of flue gases (Kg).

Cp: specific heat of flue gases (KJ/Kg. °C). {1}

ΔT: temperature difference of flue gases (°C). {200 – 25}

**As known that 860 Kcal ≡ 1 kWh.

- For melting line the monthly quantity of flue gases is 77319 Kg,

Q = 77319 * 1 * (200-25) = 13530825 KJ

13530825 / 3600 = 3758.56 kWh

3758.56 * 860 = 3232363.75 Kcal

3232363.75/9500 = 340.25 Kg.

By applying equation (3.3) and from the calculated waste heat it is clear how to calculate the amount of saved fuel which can be done by heat recovery heat exchanger device and that will be shown in table 3.23.

Table 3.23: Amount of reduced fuel consumption

Burner	**Flue gases quantity (Kg/month)**	**Waste energy (KJ)**	**Waste energy (kWh)**	**Calorific value of fuel (Kcal/Kg)**	**Reduced quantity of fuel (Kg/month)**
Melting line	77319	13530825	3908.91	9500	340.25
Homogeneity line	41250	7218750	2005.21	9500	181.52
extrusion line	234316.5	41005387.5	11390.39	9500	1031.13
Powder line	152790	26738250	7427.29	9500	672.37
Total (Kg/month)					**2225.27**

From these results the yearly reduced quantity of fuel is **26703.24 Kg** with a percentage of **7.26%** of LPG used in burners and from the total LPG yearly consumption **4.28%.**

- **Summary:**

After applying the suggested measures to save energy the amount of energy will reduce and the overall reduction in energy will show in tables3.24 and 3.25:

Table 3.24: overall yearly saving in electrical energy (NAPCO).

system	Amount of yearly saving (kWh)	Percentage of yearly saving from system's consumption	Percentage of yearly saving from total electrical energy
Motors	466666.68	37.09%	15.67%
Overall yearly saving	**466666.68**		**15.67%**

Table 3.25: yearly saving in LPG consumption (NAPCO).

system	Amount of yearly saving in LPG (Kg)	Percentage of yearly saving from system's consumption	Percentage of yearly saving from total LPG consumption
LPG burners	26703.24	7.26%	4.28 %
Total yearly saving	**26703.24**		**4.28%**

3.3.2.4 Analysis of utilizing solar energy in NAPCO company:

In this company the proposed use of solar energy divided to two uses which are solar water heater to heat LPG instead of LPG heating boiler which used to change the state of LPG from liquid to gas and PV on grid system to reduce the consumption of electrical energy with a percentage **10%** with take consideration of the daily electricity consumption of **8276.67kWh.**

3.3.2.4.1 Solar thermal energy and SWH in NAPCO company:

The suggestion is to use SWH to change the state of LPG from liquid state to gas state to be able to use it in burners instead of using the current boiler.

The recent case is using LPG boiler to do that with daily LPG consumption 270 Kg then the yearly consumption is 77760 Kg.

The efficiency of boiler is 80% = Q_{out}/Q_{in}

Qin = m_{gas} * heat value

= 270 * 9500 = 2565000 Kcal

2565000/860 = 2982.56kWh/day (860 Kcal = 1kWh)

Then Q_{out} = 0.8*2982.56 = 2386.05kWh

This heat energy could generate by using SWH to save this amount of consumed LPG.

As known solar radiation is 5.4kWh/m^2.day and the efficiency of SWH is 40%, and by applying equation (2.8):

Area of SWH = 2386.05 / (5.4 * 0.4) = 1104.65 m^2

Number of collectors 1104.65/ 1.7 = 650 collectors

The percentage of yearly saving of LPG by this saving technique is **12.46%.**

3.3.2.4.2 Analysis of utilizing on – grid PV system in NAPCO company:

The proposed PV on grid systems in this company as in other companies in the design of PV systems to reduce the total electricity consumption with a percentage 10% as the following:

The daily electricity consumption in this 8276.67kWh and 10% of this value is 827.67kWh, so the minimum produced PV energy is 827.67kWh and in the design the system must be larger to be able to sell the surplus electrical energy.

We need to apply equations (2.9) and (2.10) to design good PV system as the following:

PV_{energy} = 827.67/0.9 = 919.63kWh.

$PV_{peak\ power}$ = (919.63/5.4) * 1.2 = 204.36 kW.

The suggestion is to use PV module type Poly HSL 72 300 W where its peak power is 300 W at standard conditions.

Number of modules = 204.36/0.3 = 681.21 modules.

To make sure to cover needed load and to obtain net metering tariff my suggestion is to use 780 modules, so the peak power of this PV system is 234kW.

Then divide this system to 6 subsystems (arrays) with 130 modules and the peak power 39kW for each to make the system easier in maintenance and provide many sectors in the facility as possible as.

Applying equation (2.11) to calculate the modules in series 48/36.1 =1.33 ≈ 2 modules.

Applying equation (2.12) to calculate the number of strings 130/2 = 65 strings.

From all that the inverters used are 6 three phase on grid inverters and their type is TRESS TL S 50 KTS with 50kW rated and 90% efficiency.

If each 1 kilowatt peak PV modules need 9m^2 area, so this system needs 234*9 = 2106 m^2 divided to 6 arrays where each array needs 351 m^2 areas.

All that will be in details in figure 3.24 as in the following:

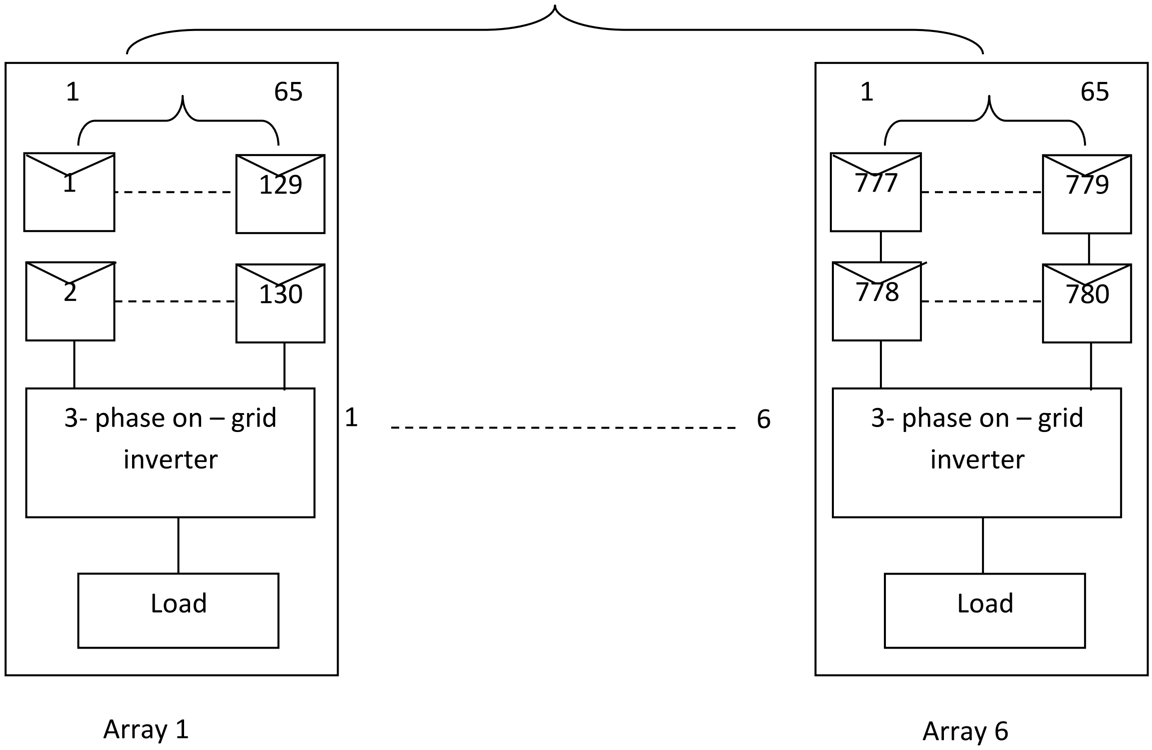

Fig 3.24: PV – on grid diagram in NAPCO

- **Summary:**

Table 3.26 will show the overall saving could gain from using solar energy (SWH and PV – on grid system) with considering the percentage of saving in electrical energy from PV – on grid system is 10%.

Table 3.26: The overall saving from utilizing solar energy (NAPCO)

System	**Amount of yearly saving in LPG (Kg)**	**Percentage of yearly saving from system's consumption**	**Percentage of yearly saving from total LPG consumption**
LPG burners	26703.24	7.26%	4.28%
Heating boiler	77760	100%	12.46%
Overall yearly saving	**104463.24**	**-----**	**16.74%**

Chapter Four
Economical evaluation of energy conservation measures

4.1 Engineering Economy and economical evaluation:

After talking about the technical side in energy management and E.C.Ms, it's important to talk about the economical side to know if that feasible or not economically and how to reduce the cost of consumed energy and to evaluate that we need to study engineering economy.

Engineering economy is done to evaluate the engineering projects to reach to the full conclusion of the work, and then make the decision.

Engineering economy makes formulas and estimations to the expected outcomes of alternatives to reach to optimum alternative or evaluate the proposed project economically.

To evaluate engineering projects, I choose two methods of evaluations: simple payback period (S.P.B.P) and annual worth (AW). [33]

- **Simple Payback Period (S.P.B.P) method:**

This method of engineering economy evaluation does not deal with the time value of the money, where it's only see the saving gained to the cost and what is the needed time to payback the cost and its formula is:

$$S.P.B.P = \frac{\text{Capital cost}}{\text{Yearly saving}} \tag{4.1}$$

- **Annual worth (AW) method:**

Generally most decisions related to time and especially to future, so it's important to evaluate the time value of money where that done by many methods one of the these methods the Annual Worth (AW) and to apply this method we need to cash flow, times, interest and measure of economic worth for selecting the alternative.

In this method there are used symbols such as: (P) which indicates to money at zero time, (A) symbol of series of equal amount of money, (n) meaning the number of interest periods, (i) is the interest value and (t) the time.

In Annual Worth the (A) symbol means the series of annual equal amount of money with the wanted interest value.

In the cash flow the cash inflows represent with up arrow and in indicates to incomes while cash outflows represents with down arrow and it indicates to the costs.

In the Annual Worth two situations could occurred, where the annual values are given and we need the present value as shown in equation (4.2)

$$P = A(P/A, i, n). \tag{4.2}$$

Or if the present value is given and we need the annual values as shown in equation (4.3).

$$A = P(A/P, i, n) \tag{4.3}$$

And the values of these equations got from tables in interest values and periods. [33]

According to these methods in engineering economy evaluations we will apply them to the chosen facilities to see the effect of energy management and E.C.Ms economically.

4.2 Economical evaluation of E.C.Ms in GWMC company:

4.2.1 Economical evaluation of changing tariff system from low tension tariff to high tension tariff:

As shown in appendix (D) there are two types of tariff, low tension tariff and high tension tariff and from the tariff price high tension tariff is lower than low tension tariff, but the losses occurred in the transformers will take into account also the fixed cost will be higher, so I need to calculate the overall cost in the high voltage tariff and reach to the final cost.

After deep calculations the total losses in the transformers is **56148.656kWh**, and the total yearly electricity bill from high tension tariff will be 793432.99 NIS and from that the saving in cost will be 251873.0108 NIS and the cost to purchase these transformers and their accessories is 500000 NIS, so S.P.B.P will be:

S.P.B.P = 500000/251873.0108= 2 years.

4.2.2 Economical evaluation of energy conservation in motors:

Table 4.1 shows the yearly saving in operation cost in motors from using inverters and replace these motors with efficient motors, then calculate the S.P.B.P according to equation (4.1)

Table 4.1: yearly saving in motors (NIS/year) [GWMC]

Motor number	Yearly saving from using inverters (NIS)	Yearly saving from using efficient motors (NIS)
3-M014	2763.84	304.16
3-M026	2767.89	548.17
3-M524	2737.48	177.77
3-M012	4866.624	115.58
3-M504	3548.58	No need
3-M503	4197.46	No need
3-M006	5474.952	No need
3-M021	2534.7	285.91
3-M022	3568.86	285.91
3-M525	3345.804	548.17
3-M040	1973.01	446.11
3-M037	2605.67	446.11
3-M036	2692.87	446.11
3-M035	2017.621	446.11
3-M023	2591.48	177.77
3-M043	1318.044	3206.56
3-M532	1520.82	144.65
3-M044	1439.71	3206.56
3-M045	1419.422	3206.56
3-M061	486.66	1518.79
3-M531	839.49	5570.93
3-M546	231.16	1564.76
3-M505	3629.69	No need
3-M500	12572.11	340.66
3-M001	23927.57	No need
4-M502	1358.6	532.85
3-M025	2889.56	283.89
2-M011	4951.65	1604.81
5-M001	5091.67	1372.63
4-M001	9731.404	293.48
Total yearly saving (NIS)	**119094.4**	**27075**

From table 4.1 the total yearly saving in cost is **146169.4 NIS** and according to equation (4.1) we can calculate the S.P.B.P as the following:

- S.P.B.P from using inverters:

The total cost of inverters is 181800 NIS,

S.P.B.P = 181800/119094.4 = 1.53 years.

- S.P.B.P from using efficient motors:

The total cost of efficient motors is 31020$ and that equal to 117876 NIS,

S.P.B.P = 117876/27075 = 4.35 years.

* If both methods applied the S.P.B.P will be:

S.P.B.P = 299676/146169.4 = 2.05 years.

4.2.3 Economical evaluation of energy conservation in lighting systems:

After applying the proposed methods in lighting to save energy, now the time to evaluate that economically as the following:

- Removing extra lamps:

The yearly saving in the cost of electrical energy consumption is **366.2871 NIS** and applying the equation (4.1) to calculate the S.P.B.P and if the cost to reduce the height of lamps is 400 NIS we found the following:

S.P.B.P = 400/366.2871 = 1.1 years.

- Replace the incandescent lamps with CFL lamps:

The yearly saving in the cost of electrical energy consumption is **87.749 NIS** and applying the equation (4.1) to calculate the S.P.B.P and if the cost of CFL is 60 NIS we found the following:

S.P.B.P = 60/87.749 = 0.68 year.

- Replace the magnetic ballasts with electronic ballasts in fluorescent lamps:

This method will explained economically in details in table 4.2 as the following:

Table 4.2: yearly saving in lighting systems (NIS/year) [GWMC]

space	Yearly saving (NIS)
Offices	410.58
	10.86
Watchman	215.9926
Cafeteria	130.3734
	21.98
Maintenance	173.70
Bags printing	19.54
Scale	19.6
Mill, ground floor	2195.281
Mill, 1st floor	1982.834
Mill, 2nd floor	1085.838
Mill, 3rd floor	967.849
Mill, 4th floor	1109.443
Mill, 5th floor	1392.705
Total yearly saving (NIS)	**9736.567**

According to table 4.2 the total yearly saving in the cost of electrical energy in replacing magnetic ballasts with electronic ballasts in fluorescent lamps is 9736.567 NIS, and the total cost of electronic ballasts is 63770 NIS, according to equation (4.1) to calculate the S.P.B.P we found the following:

S.P.B.P = 63770/9736.567= 6.55 years.

If all these methods applied the S.P.B.P will be:

S.P.B.P = 64230/10190.6 = 6.3 years.

4.2.4 Economical evaluation of using outside air in compressed air system:

According to table 3.7 and from applied tariff system the yearly saving in the cost of electrical consumption is 1324.355 NIS and the cost of installing duct to apply this method is 1000 NIS, so applying equation (4.1) will show the following:

S.P.B.P = 1000/1324.355= 0.76 year.

4.2.5 Economical evaluation of using SWH:

Table 4.3 shows the yearly saving in the cost of electrical consumption as the following:

Table 4.3: yearly saving from using SWH (NIS/year) [GWMC]

Location	Yearly saving from SWH (NIS)
Maintenance	1094.634
Cafeteria and toilets	1047.456
Management building	1080.065
Total yearly saving (NIS)	**3222.155**

From table 4.3 the total yearly saving in the cost of electrical energy from using SWH instead of electrical boilers is **3222.155 NIS** and the following will explain these results in details to calculate S.P.B.P for each location.

- SWH in maintenance:

As shown in table 4.3 the yearly saving is 1094.634 and as known the price of SWH is 1500 NIS with volume 200 liters,

S.P.B.P = 1500/1094.634 = 1.37 years.

- SWH in Cafeteria and toilets:

S.P.B.P = 1500/1047.456= 1.43 years.

- SWH in Management building:

S.P.B.P = 1500/1080.065= 1.39 years.

If we need to apply SWH to these three systems S.P.B.P will be:

S.P.B.P = 4500/3222.155= 1.4 years.

4.2.6 Economical evaluation of utilizing on- grid PV system:

I mentioned before the importance of utilizing PV systems in industrial sector to reduce the consumption of electrical energy and use the electricity with no environmental impacts and reduce the dependency on fossil fuel.

This design of PV - on grid is to reduce the electrical consumption with a 10% and that concentrated to lighting systems and other services to use the solar energy as possible as at day times, then sell surplus electrical energy by using net metering tariff after that evaluate this system economically, especially the PV system will provide the lightings and offices load during working times, so at night the amount of imported energy from the grid will be very little or near to zero and on the other hand in holidays the most electrical energy generated from this PV system will sold to grid.

JDECO use special equation in net metering tariff where it is as the following:

Net value (NIS) = (A_1*tariff) – (A_2 [tariff – 0.12]) where, (4.4)

A_1 = energy consumed from the grid (kWh),

A_2= energy sold to grid (kWh),

Tariff= the price of electrical energy in that period (NIS/kWh).

In GWMC the peak power of the suggested designed PV on grid system is 180kW, and if the cost of one kilowatt peak power is 2000 $, so the cost of this system is 180*2000 = 360000$ and that equal to 1368000 NIS.

Due to multi rate tariff the calculations to evaluate this system economically were very difficult and complex and the following example is a part of these calculations.

The total daily energy generated from PV system is 810kWh/day and the power generated is 150kW, where 94.55kW from this power saved daily and 55.45kW of this power sold to grid by net metering tariff system and these values taking account the normal conditions.

In summer season there are two months (July and August) according to JDECO categorization of the seasons in a year.

For example in a week in July, the saving gained is 4156.05NIS from working days and from Fridays 3.18 NIS and from Saturdays 318.14 NIS, while the value gained from selling to grid is 3917.3 NIS in working days and from Fridays 448.62 NIS and from Saturdays 223.53 NIS, after that we calculate weekly, then seasonally and that applied to all months to reach finally to overall yearly saving in cost and selling to grid.

From these deep calculations the amount of yearly saving is 105552.28 NIS and the yearly money gained from selling to grid is 86941.2 NIS, and from that the total yearly money gained and saved is 192493.48 NIS. Now it is easy to apply equation (4.1) to calculate S.P.B.P where it is as the following:

S.P.B.P = 1368000/192493.48 = 7.11 years.

- **Summary:**

If all above systems and techniques applied the S.P.B.P will modified and it will be as the following:

Total cost of all measures and techniques is 2237406 NIS and the total saving gained is 660981 NIS, then **S.P.B.P will be 2237406/605273 = 3.7 years.**

Another method to evaluate that economically by using AW method according to equations (4.3) along twenty years and the interest 10% and drawing cash flow diagrams as shown in figure 4.1:

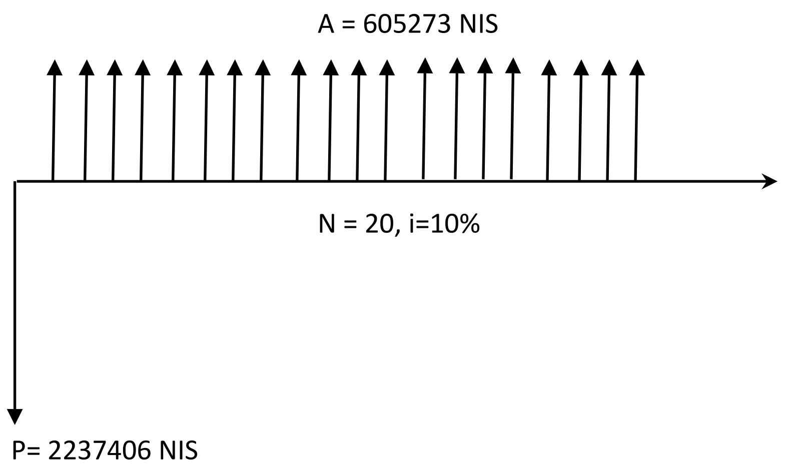

Fig 4.1: Cash flow of E.C.Ms evaluation in GWMC

A = 605273 – P (A/P, 10%, 20) = 605273 – 2237406 * 0.11746
= 342467.29 NIS/year.

It is positive value, so these measures are feasible economically.

4.3 Economical evaluation of E.C.Ms in NBC company:

After talking about the used measures in energy conservation technically we need to evaluate that economically as the following:

4.3.1 Economical evaluation of energy conservation in motors:

Table 4.4 will show in details the economical evaluation of using inverters and replace these motors with efficient motors to be able to calculate S.P.B.P.

Table 4.4: yearly saving in motors (NIS/year) [NBC]

Motor name	Yearly saving from using inverters (NIS)	Yearly saving from using efficient motors (NIS)
40 bar compressor	87093.45	42444.28
PET 1 compressor	18190.405	15801.765
PET 2 compressor	18190.405	15801.765
CAN 1 compressor	15709.895	10859.12
CAN 2 compressor	15709.895	10859.12
NRB 1 compressor	12126.935	6155.34
NRB 2 compressor	12126.935	6155.34
Total yearly saving (NIS)	**179147.92**	**108076.73**

From table 4.4 the total yearly saving in cost is 287224.65 NIS and according to equation (4.1) we can calculate the S.P.B.P as the following:

- S.P.B.P from using inverters:

The total cost of inverters is 146000 NIS,

S.P.B.P = 146000/179147.92 = 0.81 year.

- S.P.B.P from using efficient motors:

The total cost of efficient motors is 27730$ and that equal to 105374 NIS,

S.P.B.P = 105374/108076.73 = 0.97 year.

* If both methods applied the S.P.B.P will be:

S.P.B.P = 251374/287224.65 = 0.88 year.

4.3.2 Economical evaluation of energy conservation in lighting systems:

In lighting systems the proposed method is to replace the magnetic ballasts with electronic in fluorescent lamps and know the time to evaluate that economically as shown in table 4.5:

Table 4.5: yearly saving in lighting systems (NIS/year) [NBC]

space	Yearly saving (NIS/year)
Offices	812.0031
	749.4315
Cafeteria 1	3.26
Store	2.17
Factory offices	232.602
Total yearly saving (NIS)	**1799.47**

The total yearly saving is 1799.47 NIS, while the cost of electronic ballasts is 8400 NIS, so S.P.B.P will be:

S.P.B.P = 8400/1799.47 = 4.67 years.

4.3.3 Economical evaluation of using outside air in compressed air system:

According to table 3.17 and from applied tariff system the yearly saving in the cost of electrical consumption is 50339.04 NIS and the cost of installing duct to apply this method is 7000 NIS, so applying equation (4.1) will show the following:

S.P.B.P = 7000/50339.04= 0.14 year.

4.3.4 Economical evaluation of utilizing on – grid PV system:

According to equation (4.4) which used in Net Tariff system in JDECO and the predicted saving occurred in on – grid PV system in NBC the economical evaluation will be as the following:

In NBC the peak power of the suggested on – grid PV system is 438kW, and the cost of one kilowatt peak power is 2000$, so the cost of allover the system is 438*2000 = 876000$ and that equal to 3328800 NIS.

From deep calculations around the year during the months and seasons and applying equation (4.4) which related to net metering tariff the amount of cost saved from on – grid PV system is 262925.09 NIS, while the sold electricity to grid is 206394.34 NIS, so the amount of total saving and selling is 469319.43 NIS, then S.P.B.P will be:

S.P.B.P = 3328800/469319.43 = 7.1 years.

- **Summary:**

If all above systems and techniques will be applied the S.P.B.P will modified and it will be as the following:

Total cost of all measures and techniques is 3595574 NIS and the total saving gained is 808682.59 NIS, then **S.P.B.P will be 3595574/808682.59 =4.45 years.**

Another method to evaluate that economically by using AW method according to equations (4.3) along twenty years and the interest 10% and drawing cash flow diagrams as shown in figure 4.2:

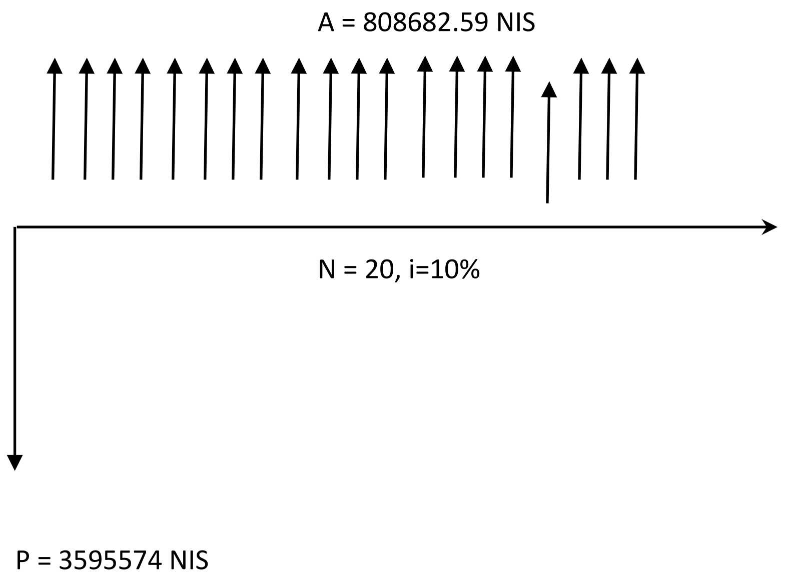

Fig 4.2: Cash flow of E.C.Ms evaluation in NBC

A = 808682.59 – P (A/P, 10%, 20) = 808682.59 – 3595574 * 0.11746

= 386346.47 NIS/year.

It is positive value, so these measures are feasible economically.

4.4 Economical evaluation of E.C.Ms in NAPCO company:

After talking about the E.C.Ms technically, we need to evaluate that economically as the following:

4.4.1 Economical evaluation of energy conservation in motors:

Table 4.6 will show in details the saving in cost in motors by using inverters and replacing them with efficient motors.

Table 4.6: yearly saving in motors (NIS/year) [NAPCO]

Motor name	Yearly saving from using inverters (NIS)	Yearly saving from using efficient motors (NIS)
1	63482.54	14500.41
2	63482.54	14500.41
3	63482.54	14500.41
Total yearly saving (NIS)	**190447.62**	**43501.23**

- S.P.B.P from using inverters:

The cost of inverters around 90000 NIS, then applying equation (4.1) S.P.B.P will be:

S.P.B.P= 90000/190447.62=0.47 year.

- S.P.B.P from replacing these motors with efficient:

The cost of efficient motors is 65664 NIS, and then S.P.B.P will be:

S.P.B.P = 65664/43501.23= 1.51 years.

If the both methods applied, S.P.B.P will be:

S.P.B.P=155664/233948.85 = 0.67 year.

4.4.2 Economical evaluation of recovering waste heat from LPG burners:

Table 4.7 shows in details the amount of saving in the cost of LPG consumption:

Table 4.7: yearly saving in the cost of LPG from recovering waste heat from LPG burners (NIS/year) [NAPCO]

Burner	Reduced cost of fuel (NIS/year)
Melting line	23763.06
Homogeneity line	12677.36
extrusion line	72014.12
Powder line	46958.32
Total (NIS/year)	**155412.86**

The cost of installing heat recovery heat exchanger for the above LPG burners is 72200 NIS and by applying equation (4.1) to calculate S.P.B.P I found the following:

S.P.B.P = 72200/155412.86 = 0.46 year.

4.4.3 Economical evaluation of using SWH instead of conventional heating boiler:

The cost of installing SWH is 325000 NIS, and the yearly saving in LPG is 452563.2 NIS, then applying equation (4.1):

S.P.B.P = 325000/452563.2 = 0.72 year.

4.4.4 Economical evaluation of utilizing on – grid PV system:

In NAPCO the source of electricity is IEC directly and net metering tariff is unknown, so we assume the system applied in JDECO applied also is NAPCO with equation (4.4) which used in Net Tariff system in JDECO and according to the predicted saving occurred in on – grid PV system in NAPCO the economical evaluation will be as the following:

In NAPCO the peak power of the suggested on – grid PV system is 270kW, and the cost of one kilowatt peak power is 2000$, so the cost of allover the system is 270*2000 = 540000$ and that equal to 2052000 NIS.

From deep calculations around the year during the months and seasons and applying equation (4.4) which related to net metering tariff the amount of cost saved from on – grid PV system is 138482.05 NIS, while the sold electricity to grid is 95518.813 NIS, so the amount of total saving is 234000.863NIS, then S.P.B.P will be:

S.P.B.P = 2052000/234000.863 = 8.77 years.

- **Summary:**

If all above systems and techniques will be applied the S.P.B.P will modified and it will be as the following:

Total cost of all measures and techniques is 2604864 NIS and the total saving gained is 1075925.773 NIS, then **S.P.B.P will be 2604867/1075925.773 =2.42 years.**

Another method to evaluate that economically by using AW method according to equations (4.3) along twenty years and the interest 10% and drawing cash flow diagrams as shown in figure 4.3:

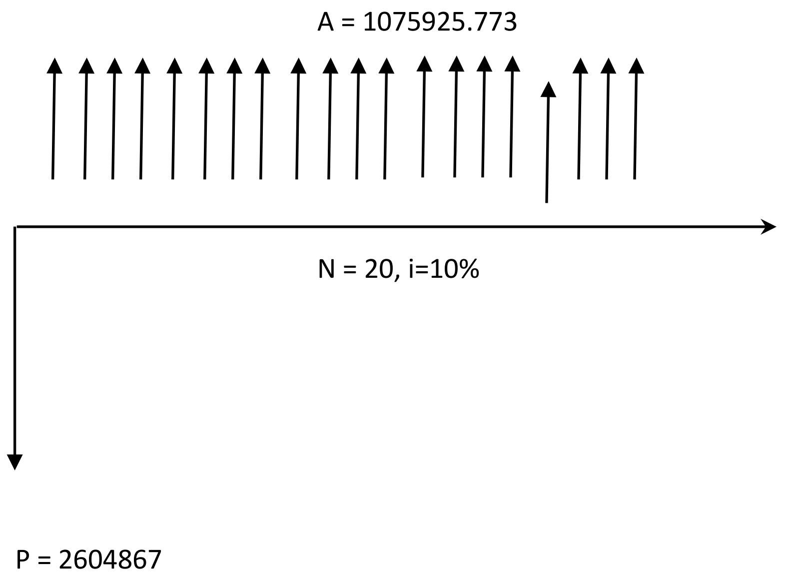

Fig 4.3: Cash flow of E.C.Ms evaluation in NAPCO

A = 1075925.773 – P (A/P, 10%, 20) = 1075925.773 – 2604867 * 0.11746

= 769958.1 NIS/year.

It is positive value, so these measures are feasible economically.

Chapter Five: Environmental and overall impacts of energy conservation measures in industrial sector in West Bank

Introduction:

In 2005 the electricity generation in the world was 17450 TWh and 60% of this energy generated is from fossil fuels especially from the coal.

Unfortunately coal has the highest emissions of carbon dioxide per kWh also other pollutant elements in energy generation, but coal used widely due to its low cost and availability.

Table 6.1 shows the price of electricity generation from many sources and the CO_2 emissions for each type and it is clear that the coal has the highest CO_2 emissions per kWh, but its price is the lowest in the comparison of other energy sources. [34]

Table 5.1: price of energy generation and CO_2 emissions for each type of energy generation [34].

	USD/kW h	g CO_{2-e}/kW h
Photovoltaic	$0.24	90
Wind	$0.07	25
Hydro	$0.05	41
Geothermal	$0.07	170
Coal	$0.042	1004
Gas	$0.048	543

Scientists said that burning fossil fuels in energy generation enhancing greenhouse effect and in the future many things could occur such as:

- Rising in temperature.
- Flooding due to rising in sea levels.

- More frequent extreme weather events. [29]

From all that energy conservation measures and using renewable energy resources reduce the energy, then the combustion of fossil fuels which lead to reduction in GHG.

In West Bank the electricity imported from IEC where each kWh generated 699 grams of CO_2 released [35], on the other hand each Kg of LPG 2.993 Kg of CO_2 released according to equation (3.2).

Now the environmental impact of E.C.Ms in these facilities will show below after talking before technically and economically impacts.

5.1 Environmental impact of E.C.Ms in GWMC company:

As mentioned that every kWh electricity generated 699 grams of CO_2 released, so and from the energy management applied in GWMC the total yearly reduced CO_2 gas is 644452.333*0.699 = 450472.1808 Kg CO_2 = **450.47 Ton of CO_2 yearly**.

5.2 Environmental impact of E.C.Ms in NBC company:

The same thing will applied in NBC as the following:

1270688.42*0.699 = 888211.2056 Kg CO_2 = **888.21 Ton CO_2 yearly**.

5.3 Environmental impact of E.C.Ms in NAPCO company:

In this facility in the addition of using electrical energy there are LPG consumption and that will shown environmentally as the following:

From electrical energy the reduced amount of CO_2 is 910141.68*0.699 = 636189.03 Kg CO_2 yearly.

And from LPG burning it will be 104463.24*2.993 = 312658.48 Kg CO_2 yearly.

Now the total yearly reduction of CO_2 gas from energy management is **948.85 Ton**.

5.4 The impact of applying E.C.Ms in industrial sector in West Bank:

5.4.1 The overall impact of E.C.Ms and PV – on grid system in the specified cases:

According to the studied measures in these companies as a sample of the industrial sector in West Bank the overall study summarized in tables 5.2 and 5.3 as shown below:

Table 5.2: overall electricity consumption and saving technically, economically and environmentally

Company name	Total electricity consumption (kWh/year)	Measures	Energy consumption (kWh/year)	Energy saving (kWh/year)	Power demand saving (kW)	Cost saving (NIS/year)	Environmental impact (CO_2 reduction in Kg/ year)
GWMC company	1863616	Change tariff system	------	------	------	251873.01	-----
		Motors	881156	325370.61	201.21	146169.4	227434.0564
		Lighting	158974.6	16489.22	4.93	10190.6	11072.062
		Compressed air	52800	2154.24	1.32	1324.355	1505.814
		Hot water	6840.38	4788.263	6.878	3222.155	3347
NBC company	4723914.6	Motors	975000	468912.29	121.06	287224.65	327769.69
		lighting	105685.38	2801.13	1.08	1799.47	1957.99
		Compressed air	975000	79560	59.04	50339.04	55612.44
NAPCO company	2979600	Motors	1257984	466666.68	62.32	233948.85	326200.01
Total	**9567130.6**	**----**	**3438440.36**	**1366742.43**	**457.838**	**986091.53**	**954899.06**

Table 5.3: overall LPG consumption and saving technically, economically and environmentally

Company name	Total LPG consumption (kg/year)	Measures	LPG consumption (Kg/year)	LPG saving (Kg/year)	Cost saving (NIS/year)	Environmental impact (CO_2 reduction in Kg/ year)
GWMC company	Nothing	Nothing	------	------	------	-----
NBC company	Nothing	Nothing	------	------	------	-----
NAPCO company	624000	LPG burners	367813.22	26703.24	155412.9	79922.8
		Heating boiler	77760	77760	452563.2	232735.68
Total	**624000**	**----**	**445573.22**	**104463.2**	**607976.1**	**312658.48**

About the analysis of utilizing PV – on grid systems in these companies, table 5.4 will summarize that in details, and as mentioned before that this PV – on grid system designed to save 10% from total electrical energy and buy the surplus electrical energy to the grid.

Table5.4: overall analysis of utilizing PV–on grid system technically, economically and environmentally

Company name	Energy saving (kWh/year)	Cost saving (NIS/year)	Environmental impact (CO_2 reduction in Kg/ year)
GWMC company	186361.7	192493.48	450472.18
NBC company	472390.3	469319.43	888211.21
NAPCO company	302099.55	234000.863	948850
Total	**960851.55**	**895813.773**	**2287533.39**

The analysis divided in two parts: E.C.Ms and PV – on grid system to separate between them and know in accurate the percentage of saving, then make overall evaluation to them.

- **Evaluation of E.C.Ms:**

According to table 5.2 the overall percentage of saving in electrical energy from the system's consumption is 1366742.43/3438440.36 = **39.75%** and the percentage of saving in electrical energy from the total electricity consumption is 1366742.43/9567130.6 = **14.29%.**

On the other hand and according to table 5.3, the overall percentage of saving in LPG consumption from the system's consumption is

104463.2/445573.22 = **23.44%** and the percentage of saving in LPG consumption from the total LPG consumption is 104463.2/624000 = **16.74%.**

And about the saving in the cost of electrical energy the percentage of saving is 986091.53/5366675.945 = 18.37% and to LPG consumption is the same of technical evaluation **16.74%.**

- **Evaluation of PV – on grid system:**

According to table 5.4 and from the proposed PV – on grid to these companies, this PV – on grid system designed to save electrical energy with a percentage of 10% from the total electrical energy.

And about the saving in the cost of electrical energy the percentage of saving is 895813.773/5366675.945 = **16.69%.**

- **Evaluation of E.M.Cs and PV – on grid system:**

From the above analysis, the overall percentage of saving in electrical energy could gained is around **24.29%.**

From all above analysis the overall energy saving expected at implementation of E.C.Ms in all sectors in industry will be saved **1366742.43kWh** from electrical energy, **1594067.63 NIS** as a cost, **104463.2 Kg from LPG** and **1267557.54 Kg from CO_2** emissions.

And from establishing PV – on grid system the overall expected energy will save **960851.55kWh** from electrical energy, **895813.773NIS** as a cost and **2287533.39 Kg from CO_2** emissions.

5.4.2 The estimated impact of applying E.C.Ms in industrial sector in West Bank:

According to Palestinian Central Bureau of Statistics data and reference number [9], the cost of electricity in industrial sector in West Bank in 2012 was 55432100 $ which equal to 210641980 NIS, while the cost of Fuel and oil consumption was 120165900$ which equal to 456630420 NIS.

The above expected cost of saving in electrical energy of E.C.Ms has a percentage of 986091.53/210641980 **= 0.47%** from the cost of total electricity consumption in industrial sector in West Bank while it is **0.13%** in LPG consumption.

If we need to apply E.C.Ms to industrial sector in West Bank in general with the percentage of 18.37% saving from electricity consumption the expected yearly saved cost is **38694931.73 NIS** and from LPG consumption **76439932.31 NIS**.

Conclusions:

Palestine has a special case in energy situation due to lack of natural resources in energy generation materials like oil and coal which are used conventionally to generate energy and the full dependency of energy importation especially from Israel where that led to fluctuation of energy prices and control that by them completely.

The energy demand increases especially in electricity where most areas in Palestine suffering from shortage in electricity especially in peak periods and the amount of imported electricity did not vary and increase due to Israeli polices and if it increased it will be with little quantities, moreover the electricity generation planed which located in Gaza destroyed in the last war and it is in normal conditions it generate electricity with limited quantities and it is suffering from supplying it with fuel.

Industrial sector is a major sector consumes energy especially electrical energy where it depends on that mainly in all manufacturing and production processes, so it is important to study the energy situation in this sector to propose solutions to reduce the energy demand and consumption, then achieve the optimum use of energy.

Energy management and E.C.Ms give some solutions in industrial sector such as energy audits and use renewable energy sources.

The cost of applying energy management and E.C.Ms is high especially in renewable energy, but the high value of tariff prices led to good economical evaluation of energy management and that mean highlights the importance of energy management and trust with proposed solutions could applied.

When talking about the industrial sector that means high electricity bills and high production costs and the energy management lead to minimize these costs and achieve great benefits.

Multi rate tariff which used in the studied facilities play a good role in energy management with minimum or zero cost where it is enough to shift the working periods to minimum tariff periods.

Also net metering system which used in on – grid PV systems led to another meaning of energy management not only to save electrical energy also to sell the surplus electrical energy to the grid, then achieves more benefits.

On the other hand E.C.Ms play a good role to environment where minimizing the energy consumption lead to reduction in the harmful emissions occurred in energy generation and make these facilities environmental friendly.

Recommendations:

According to this thesis and other works related to energy management the following recommendations must considered:

1- Draw the attention the decision makers in the Palestinian Authority about the importance of energy management and how that reflects to the economy in general to support the laws related to that and encourage the public to apply that

2- Organize awareness campaigns to the public to the importance of energy management and renewable energy using and how that reflects to the operation costs and to environmental effects. , and consider the energy use of electrical equipment when buying them and choose the equipment with minimum total cost (capital and running costs) and try to use other efficient types in lighting like LED lamps and see the effect of using them.

3- Support the laws related to renewable energy especially the net metering tariff to encourage more people to use renewable energy.

4- Use smart systems in the facilities in industrial sector to achieve the optimum using of energy and reduce the operation costs as minimum as by using microcontrollers, PLC systems, sensors, photocells …etc.

5- Hire energy manager engineer in the industrial sector to apply energy studies in the facilities.

6- Try to apply passive solar design and use the natural light in the offices as possible as to minimize using of lighting systems.
7- Design smart system to differentiate between the using natural light for lighting and minimizing the temperature from the sunlight.
8- Encourage establishing ESCO companies to do their works in energy management and energy audits.
9- Take care to the insulation in the building to minimize the electricity and power using in HVAC systems.
10- Exploit the roof tops and empty areas as much possible as in the facilities to be able to utilize solar energy.

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Appendices

Appendix (A): Energy analyzer data for GWMC transformer 1

Time	S (VA)	I1 Avg (A)	I2 Avg (A)	I3 Avg (A)	PF
11:00	57365	82.425	89.15	91.9	1
12:00	57640	83.033	87.35	92.1	0.95
13:00	55740	80.9	85.65	92.76667	0.9833
14:00	54210	79.16667	85.1	88.63333	0.983333
15:00	11688.33	17.63333	17.61667	19.33333	0.8
16:00	17801.67	23.56667	23.48333	25.75	0.8333
17:00	32545	47.85	51.45	55.8333	1
18:00	13776.67	19.36667	19.96667	21.48333	0.816667
19:00	11570	17.65	17.88333	19.53333	0.8
20:00	11756.67	17.56667	17.81667	19.61667	0.8
21:00	1127.833	1.9	1.98333	2.15	-0.7
22:00	0	0	0	0	-1
23:00	0	0	0	0	-1
0:00	0	0	0	0	-1
1:00	0	0	0	0	-1
2:00	0	0	0	0	-1
3:00	0	0	0	0	-1
4:00	0	0	0	0	-1
5:00	0	0	0	0	-1
6:00	0	0	0	0	-1

Energy analyzer data for GWMC transformer 2

Time	St/E+ Avg (VA)	I1 Avg (A)	I2 Avg (A)	I3 Avg (A)	Pfti+ Avg
7:00	0	0	0	0	-1
8:00	311095	491.4833	519.1333	504.9833	0.933
9:00	380100	589.7	622.8333	612.7833	1
10:00	344016.67	525.933	556.0167	547.1333	1
11:00	355366.67	539.5667	563.5667	560.0167	1
12:00	352783.33	536.3167	566.05	558.933	1
13:00	351533.33	534.1	557.55	555.1	1
14:00	351400	532.6167	548.85	556.45	1
15:00	349950	518.1833	537.6167	548.6833	1
16:00	82866.67	122.033	126.75	129.5	-0.33
17:00	0	0	0	0	-1
18:00	0	0	0	0	-1
19:00	0	0	0	0	-1
20:00	0	0	0	0	-1
21:00	0	0	0	0	-1
22:00	0	0	0	0	-1
23:00	0	0	0	0	-1
0:00	0	0	0	0	-1
1:00	0	0	0	0	-1
2:00	0	0	0	0	-1
3:00	0	0	0	0	-1
4:00	0	0	0	0	-1
5:00	0	0	0	0	-1
6:00	0	0	0	0	-1

Energy analyzer data for GWMC transformer 3

Time	St/E+ Avg (VA)	I1 Avg (A)	I2 Avg (A)	I3 Avg (A)	Pfti+ Avg
7:00	33436.67	50.433	49.433	44.433	0.766
8:00	97900	131.7	147.1667	147.433	0.9833
9:00	137333.33	193.75	210.8667	214.65	1
10:00	126283.33	176.933	192.1667	199.1833	1
11:00	102371.667	149.5	144.55	158.2	1
12:00	148950	209.7	222.8	224.15	1
13:00	106968.33	155.933	144.1833	154.5667	1
14:00	118271.67	180.133	164.7167	166.633	1
15:00	63728.33	101.633	84.6833	88.5	1
16:00	46665	71.91667	58.333	68.16667	0.667
17:00	47848.333	78.8333	64.86667	72.55	1
18:00	17120	36.58333	15.91667	19.61667	0.9
19:00	9919	24.7	10.81667	12.4833	0.9
20:00	10545.667	25.46667	11.75	12.86667	0.9
21:00	10950	26.26667	11.333	13.16667	0.9
22:00	11791.667	27.28333	12.15	13.91667	0.883
23:00	13020	29.36667	12.61667	14.6	0.8
0:00	13791.667	30.5833	13.3667	14.7833	0.8
1:00	14446.67	31.6333	13.36667	15.5333	0.8
2:00	15336.667	32.7333	14.333	16.15	0.8
3:00	15235	32.45	14.15	16.35	0.8
4:00	14940	32.31667	13.66667	16.01667	0.8
5:00	12474.16667	24.97	13.75	14.1	0.8
6:00	7644.57	10.55	12.93	10.53	0.9

Appendix (B): Energy analyzer data for NBC transformer 1

Time	St+_Avg [VA]	I1_Avg [A]	I2_Avg [A]	I3_Avg [A]	Pfti+_Avg
16:00	536483.3333	731.7	744.65	761.9	0.953
17:00	556866.6667	763.6833333	771.45	801.4333	0.955833
18:00	561500	781.8083333	788.9333	821.375	0.960917
19:00	430008.3333	597.45	582.4333	622.6583	0.965333
20:00	545608.3333	757.45	745.2917	787.55	0.943
21:00	479950	656.1916667	654.0417	684.6	0.959833
22:00	451641.6667	614.5083333	608.5333	638.6	0.9525
23:00	465350	640.85	633.5	661.4	0.947
0:00	418933.3333	578.9416667	566.7667	589.4833	0.950917
1:00	336483.3333	462.7333333	446.7417	467.4083	0.974833
2:00	122415	165.2916667	156.3083	165.7167	0.820333
3:00	58977.5	79.1825	72.98583	77.86417	-0.17725
4:00	32076.66667	47.44	41.37833	41.16917	-1
5:00	34215.83333	49.51083333	44.10583	44.22	-0.671
6:00	212141.6667	289.1666667	281.4833	291.05	0.970583
7:00	358291.6667	491.35	497.4167	509.3083	0.945583
8:00	500216.6667	688.7916667	711.75	719.4167	0.939833
9:00	511575	700.3916667	733.6583	741.1417	0.942083
10:00	433208.3333	591.4	618.0333	625.175	0.96025
11:00	461033.3333	642.3166667	649.1333	661.5667	0.942583
12:00	540358.3333	751.3166667	765.175	777.2167	0.946083
13:00	555183.3333	773.175	792.0833	805.7167	0.944917
14:00	564883.3333	785.1833333	803.4167	821.8833	0.950417
15:00	563550	781.3	795.75	808.05	0.9485

Energy analyzer data for NBC transformer 2

Time	St+_Avg [VA]	I1_Avg [A]	I2_Avg [A]	I3_Avg [A]	Pfti+_Avg
16:00	337344.4444	491.5888889	479.3555556	468.5666667	0.958
17:00	341841.6667	493.825	475.0333333	465.1916667	0.96425
18:00	340541.6667	496.9666667	475.2583333	466.8166667	0.96475
19:00	328075	466.2416667	445.9333333	438.6583333	0.956333333
20:00	344150	491.35	473.7083333	463.975	0.955916667
21:00	333750	469.8166667	451.0666667	442.6833333	0.954833333
22:00	340791.6667	477.0916667	461.775	453.5416667	0.94625
23:00	342483.3333	483.7166667	471.1416667	458.7333333	0.95425
0:00	330383.3333	460.475	446.0583333	434.2583333	0.9485
1:00	135197.5	176.8558333	169.7566667	169.8916667	-0.2135
2:00	47183.33333	63.04333333	61.71916667	64.86	-1
3:00	8956.666667	11.94583333	11.70083333	12.2925	-1
4:00	0	0	0	0	-1
5:00	0	0	0	0	-1
6:00	46342.5	71.60833333	63.51	65.02166667	0.080583333
7:00	223366.6667	311.4916667	290.9083333	298.25	0.925333333
8:00	448933.3333	596.9	570.6916667	589.2083333	0.307833333
9:00	407341.6667	606.3	574.7	575.8666667	0.96325
10:00	475583.3333	709.5	673.1166667	677.4166667	0.953416667
11:00	398658.3333	593.05	561.6166667	563.125	0.946416667
12:00	560125	830.2916667	788.0666667	794.8583333	0.957833333
13:00	566383.3333	842.975	799.9833333	805.5416667	0.959
14:00	560558.3333	828.8083333	786.0083333	793.5333333	0.958833333
15:00	570620	841.04	796.06	802.27	0.9572

Appendix (C): Energy analyzer data for NAPCO

Time	St+_Avg [VA]	I1_Avg [A]	I2_Avg [A]	I3_Avg [A]	Pfti+_Avg
11:00	265116.667	387.1333	389.15	403.25	0.9493
12:00	292833.333	425.333	429.5167	444.033	0.9515
13:00	311900	450.75	454.25	473.8833	0.965667
14:00	290733.33	424.0667	417.7667	445.7167	0.959
15:00	293183.333	423.0833	422.8333	448.7167	0.9595
16:00	294666.6667	414.5167	428.0167	445.0667	0.955833
17:00	323000	457.1333	471.5167	480.9667	0.959333
18:00	315800	452.3	462.75	468.35	0.961667
19:00	275483.333	398.8333	416.1667	417.4333	0.965333
20:00	271333.333	387.85	406.7833	408.2833	0.969
21:00	323650	462.9333	489.45	488.7	0.9645
22:00	291100	413.1	441.8333	440.2833	0.963
23:00	317066.6667	437.1667	472.0167	476.4	0.960333
0:00	311216.6667	429.6167	460.5	463.7167	0.959167
1:00	288050	395.6833	423.55	423.9667	0.9515
2:00	329750	455.55	485.8	485.1	0.956333
3:00	317600	436.2667	470.5	467.0167	0.953167
4:00	307216.6667	421.5333	453.4667	450.9167	0.958167
5:00	270000	372.25	398.95	394.8667	0.948167
6:00	270116.6667	378.8	388.9667	397.3333	0.954167
7:00	231250	334.7333	348.0167	354.5833	0.942333
8:00	329200	460.0167	480.2667	486.1333	0.940833
9:00	263766.6667	373.1	374.7333	393.25	0.9395
10:00	254950	357.3	364.0667	381.8833	0.944667

Appendix (D): Tariff of JDECO

01/06/2013

التعرفة	بالمقطوع		
			تعرفة المشتركين التجاريين الدفع المسبق / تعرفة مستوية
0.6370	0.0000		تجاري دفع مسبق
			تعرفة المشتركين التجاريين / تعرفة مستوية
0.6670	0.6700		تجاري
0.8366	0.3400		مؤقتة دفع مسبق
0.8366	0.6700		مؤقتة

التعرفة	بالمقطوع		
0.6370	1.0000		مضخات / تعرفة مستوية
0.4970	0.3400		التعرفة الزراعية / تعرفة مستوية
0.5366	1.0000		الصناعي / ضغط منخفض
0.4866	4.0000		الصناعي / ضغط متوسط
0.6032	0.3400		إنارة الشوارع

السلطة الفلسطينية

التعرفة اعتبارا من

التعرفة	بالمقطوع				تعرفة المشتركين المنزليين
0.4900	0.34				1- 160
0.5283					161 - 250
0.6350					251 - 400
0.6650					401 - 600
0.7350					600 - &

التعرفة	بالمقطوع			
0.6650	0.0000			المشتركين المنزليين / دفع مسبق / تعرفة مستوية

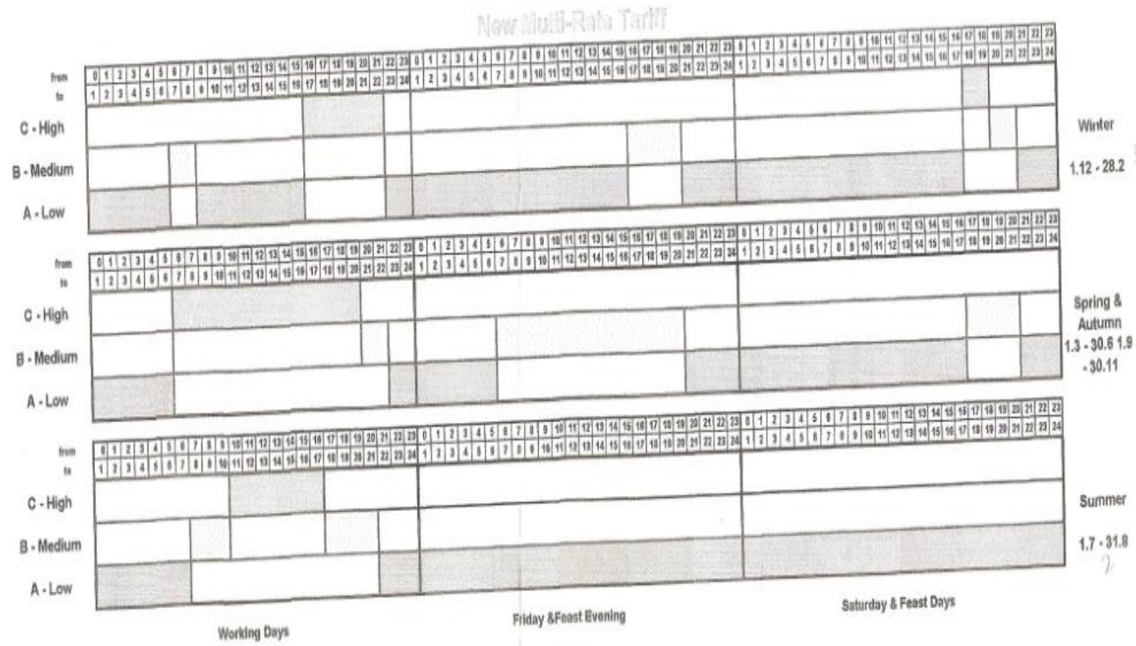
التعرفة	بالمقطوع			
0.3417	297.0800		ضغط عالي تعرفة A	صيف
0.5359			ضغط عالي تعرفة B	
1.3084			ضغط عالي تعرفة C	
0.3322	297.0800		ضغط عالي تعرفة A	ربيع وخريف
0.4203			ضغط عالي تعرفة B	
0.5281			ضغط عالي تعرفة C	
0.3838	297.0800		ضغط عالي تعرفة A	شتاء
0.6963			ضغط عالي تعرفة B	
1.2025			ضغط عالي تعرفة C	
0.4206	182.2600		ضغط منخفض تعرفة A	صيف
0.6341			ضغط منخفض تعرفة B	
1.4652			ضغط منخفض تعرفة C	
0.4051	182.2600		ضغط منخفض تعرفة A	ربيع وخريف
0.6026			ضغط منخفض تعرفة B	
0.6173			ضغط منخفض تعرفة C	
0.4611	182.2600		ضغط منخفض تعرفة A	شتاء
0.7896			ضغط منخفض تعرفة B	
1.3379			ضغط منخفض تعرفة C	

م.م.ع للشؤون المالية
فراس القواسمي

م.م.ع للشؤون الفنية
م. منصور نصار

م.م.ع لشؤون التطوير والتخطيط الاستراتيجي
م. علي حموده

المدير العام
م. هشام العمري



Appendix (E): Tariff of IEC*

<table>
<tr><th colspan="2">Sunday, Monday, Tuesday, Thursday</th><th colspan="2">Friday</th><th colspan="2">Saturday, Wednesday</th><th>Month</th></tr>
<tr><th>Time</th><th>Tariff</th><th>Time</th><th>Tariff</th><th>Time</th><th>Tariff</th><th></th></tr>
<tr><td>10-17</td><td>137.07</td><td colspan="2" rowspan="3">35.8</td><td colspan="2" rowspan="3">35.8</td><td rowspan="3">July, August</td></tr>
<tr><td>17-21
7-10</td><td>56.14</td></tr>
<tr><td>21-7</td><td>35.8</td></tr>
<tr><td>16-22</td><td>125.98</td><td>16-20</td><td>72.95</td><td>21-17</td><td>40.2</td><td rowspan="3">December, January, February</td></tr>
<tr><td>22-6
8-16</td><td>40.2</td><td rowspan="2">20-16</td><td rowspan="2">40.2</td><td>17-19</td><td>125.98</td></tr>
<tr><td>6-8</td><td>72.95</td><td>19-21</td><td>72.95</td></tr>
<tr><td>6-20</td><td>55.32</td><td>20-6</td><td>34.8</td><td>17-21</td><td>44.03</td><td rowspan="3">March, April, May, June, September , October</td></tr>
<tr><td>20-22</td><td>44.03</td><td rowspan="2">6-20</td><td rowspan="2">44.03</td><td rowspan="2">21-17</td><td rowspan="2">34.8</td></tr>
<tr><td>22-6</td><td>34.8</td></tr>
</table>

- The tariff is in part of NIS divided by 100 to be in NIS/kWh.

Appendix (F): High efficient motors data table

Average Efficiencies and Typical List Prices for Standard and Energy-Efficient Motors
1800 RPM Open Drip-Proof Motors

hp	Average Standard Motor Efficiency, %	Average Energy-Efficient Motor Efficiency, %	Efficiency Improvement, %	Typical Standard ODP Motor List Price	Typical Energy-Efficient ODP Motor List Price	List Price Premium
5	83.8 (15)	87.9 (12)	4.7	$329 (4)	$370 (4)	$41
7.5	85.3 (14)	89.6 (15)	4.8	408 (6)	538 (5)	130
10	87.2 (21)	91.1 (7)	4.3	516 (6)	650 (5)	134
15	87.6 (15)	91.5 (11)	4.3	677 (5)	864 (5)	187
20	88.4 (14)	92.0 (11)	3.9	843 (6)	1055 (5)	212
25	89.2 (14)	92.8 (11)	3.9	993 (5)	1226 (5)	233
30	89.2 (12)	92.8 (12)	3.9	1160 (4)	1425 (5)	265
40	90.2 (12)	93.6 (11)	3.6	1446 (4)	1772 (5)	326
50	90.1 (11)	93.6 (13)	3.7	1688 (6)	2066 (4)	378
60	91.0 (11)	94.1 (12)	3.3	2125 (7)	2532 (5)	407
75	91.9 (11)	94.5 (12)	2.8	2703 (5)	3084 (5)	381
100	91.7 (9)	94.5 (14)	3.0	3483 (6)	3933 (5)	450
125	91.7 (7)	94.4 (16)	2.9	4006 (6)	4709 (5)	703
150	92.9 (8)	95.0 (12)	2.2	5760 (5)	6801 (5)	1041
200	93.1 (8)	95.2 (12)	2.2	7022 (3)	8592 (3)	1570

Appendix (G): Data sheet of solar cells

HSL 72 | Poly

Hanwha Solar

Key Feature Set

1 Robust Design: Module withstands up to 7.000 Pa (>690 kg/m²) Snow / 4.000 Pa (>210 km/h) Wind loads *

2 Anti-PID: Modules are qualified to withstand PID related degradation**

3 Guaranteed Quality: 12 Year Workmanship and 25 Years linear Performance Warranty ***

4 Predictable Output: Positive Power Sorting of 0 to +5 Watt

5 Higher Yield: Module Current Sorting provides up to 2.5% more Energy

6 Innovative Solution: Anti-Reflection Glass with Self-Clean hydrophobic Layer

7 Harsh Environment: Verified against Salt Mist and Ammonia Corrosion (IEC 61701 and IEC 62716)

8 Weak Light: Excellent Performance even under low Irradiation

* Please refer to Hanwha Solar Module Installation Guide

** Test conditions: Module negatively charged with 1000 Volts at 25°C for 168 hours with Al-Foil coverage

*** Please refer to Hanwha Solar Product Warranty for details

Quality and Environmental Certificates

- ISO 9001 quality standards and ISO 14001 environmental standards
- OHSAS 18001 occupational health and safety standards
- IEC 61215 & IEC 61730 Application Class A certifications
- Conformity to CE (low Voltage Directive and EMI), fire tested class E (EN 13501-1)

IEC CE PV CYCLE

About Hanwha Solar

Hanwha Solar is a vertically integrated manufacturer of photovoltaic modules designed to meet the needs of the global energy consumer.

- High reliability, guaranteed quality, and excellent cost-efficiency due to vertically integrated production and control of the supply chain
- Optimization of product performance and manufacturing processes through a strong commitment to research and development
- Global presence throughout Europe, North America and Asia, offering regional technical and sales support

HSL 72 | Poly

Electrical Characteristics

Electrical Characteristics at Standard Test Conditions (STC)

Power Class	285 W	290 W	295 W	300 W	305 W
Maximum Power (P_{max})	285 W	290 W	295 W	300 W	305 W
Open Circuit Voltage (V_{oc})	44.3 V	44.5 V	44.8 V	44.9 V	45.1 V
Short Circuit Current (I_{sc})	8.65 A	8.69 A	8.75 A	8.78 A	8.85 A
Voltage at Maximum Power (V_{mpp})	35.1 V	35.4 V	35.8 V	36.1 V	36.3 V
Current at Maximum Power (I_{mpp})	8.13 A	8.20 A	8.26 A	8.32 A	8.42 A
Module Efficiency (%)	14.8 %	15.0 %	15.3 %	15.5 %	15.8 %

P_{max}, V_{oc}, I_{sc}, V_{mpp} and I_{mpp} tested at Standard Testing Conditions (STC) defined as irradiance of 1000 W/m² at AM 1.5 solar spectrum and a temperature of 25±2°C. Module power class have positive power sorting 0 to +5W. Measurement tolerance ±3% (P_{max})

Electrical Characteristics at Normal Operating Cell Temperature (NOCT)

Power Class	285 W	290 W	295 W	300 W	305 W
Maximum Power (P_{max})	208 W	212 W	216 W	220 W	223 W
Open Circuit Voltage (V_{oc})	41.3 V	41.5 V	41.7 V	41.8 V	42.0 V
Short Circuit Current (I_{sc})	7.00 A	7.03 A	7.08 A	7.10 A	7.18 A
Voltage at Maximum Power (V_{mpp})	31.8 V	32.1 V	32.5 V	32.7 V	32.9 V
Current at Maximum Power (I_{mpp})	6.55 A	6.61 A	6.65 A	6.73 A	6.78 A
Module Efficiency (%)	13.5 %	13.7 %	14.0 %	14.2 %	14.4 %

P_{max}, V_{oc}, I_{sc}, V_{mpp} and I_{mpp} tested at Normal Operating Cell Temperature (NOCT, 45±2°C) defined as irradiance of 800 W/m², Ambient temperature 20°C, Wind speed 1 m/s. Measurement tolerance ±3% (P_{max})

Temperature Characteristics

Normal Operating Cell Temperature (NOCT)	45±2°C
Temperature Coefficients of P	-0.43 % / °C
Temperature Coefficients of V	-0.31 % / °C
Temperature Coefficients of I	+ 0.05 % / °C

Maximum Ratings

Maximum System Voltage	1000 V (IEC)
Series Fuse Rating	15 A
Maximum Reverse Current	Series fuse rating multiplied by 1.35

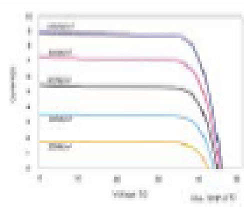
Nomenclature

Full product name:
HSL72P6-PB-1-xxx
xxx represents the power class

Performance at Low Irradiance:

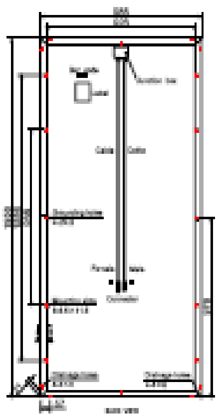
The typical relative change in module efficiency at an irradiance of 200 W/m² in relation to 1000 W/m² (both at 25 °C and AM 1.5 spectrum) is less than 5 %.

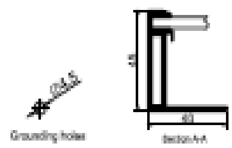
Various Irradiance Levels



Mechanical Characteristics

Dimensions	1956 mm x 988 mm x 45 mm
Weight	27±0.5kg
Frame	Aluminum-alloy, anodized
Front	4mm tempered anti-reflection glass
Encapsulant	EVA
Back Cover	Composite sheet
Cell Technology	Polycrystalline
Cell Size	156 mm x 156 mm (6in x6in)
Number of Cells (Pieces)	72 (6 x 12)
Junction Box	Protection class IP 67; 3 sets of diodes
Output Cables	Solar cable: 4 mm²; length: 1200 mm
Connector	Amphenol H4





System Design

Operating Temperature	– 40 °C to 85 °C
Hail Safety Impact Velocity	25 mm at 23 m/s
Fire Safety Classification (IEC 61730)	Class C
Static Load Wind / Snow	4000 Pa / 7000 Pa

Packaging and Storage

Storage Temperature	– 40 °C to 85 °C
Packaging Configuration	22 pieces per pallet
Loading Capacity (40 ft. HQ Container)	484 pieces

Appendix (H): Data sheet of on grid inverters

Solar inverters

ABB string inverters
PRO-33.0-TL-OUTD
33 kW

ABB string inverters cost-efficiently convert the direct current (DC) generated by solar modules into high quality three-phase alternating current (AC) that can be fed into the power distribution network (i.e. grid). Designed to meet the needs of the entire supply chain – from system integrators and installers to end users – these transformerless, three-phase inverters are designed for de-centralized photovoltaic (PV) systems installed in commercial and industrial systems up to megawatt (MW) sizes.

A new inverter from the world's leading power technology company
ABB, a global leader in power and automation technologies, brings decades of experience, technology leadership and application knowhow from renewable energies to this new string inverter. Such experience and technology ensures high quality, safe and reliable solar inverters are delivered every time.

High power package for de-centralized PV systems
ABB's three-phase PRO-33 string inverter is designed for medium and large de-centralized PV systems either on large-scale commercial and industrial rooftops or ground-mounted PV plants. The inverter offers cost-efficiency in a high power, wall-mountable package with very high conversion efficiency. The all-in-one design with built-in and monitored PV plant protection devices reduces the need of costly external devices.

The single maximum power point tracker (MPPT) and optimized MPPT window are suitable for uniform-shaped PV plants with long strings connected to the inverter. The high maximum DC input voltage of up to 1100 V gives PV plant designers extra flexibility and allows more PV modules to be connected in series to reduce cabling costs.

Highlights
- Compact, high power wall-mountable package
- High maximum DC input voltage of up to 1100 V
- Configurable all-in-one design
- Advanced grid support functions
- Safe and intuitive user interface
- Robust enclosure, with IP65 rating suitable for outdoor installation

Power and productivity for a better world™

ABB string inverters

Configurable all-in-one design

The ABB PRO-33.0 string inverter comes in three product variants. The standard model with or without DC switch is designed for use with an external string combiner box. The all-in-one model with built-in string combiner box includes a DC switch, string current monitoring with alarm, PV fuses, monitored surge protection devices and tool-less solar quick connectors. The inverter's all-in-one design, with built-in and monitored PV plant protection devices, reduces the need of costly external devices.

High total efficiency maximizes return on investment

The PRO-33.0 inverter offers a high conversion and MPP tracking efficiency in all conditions. A flat efficiency curve provides high revenues in low and high radiation conditions.

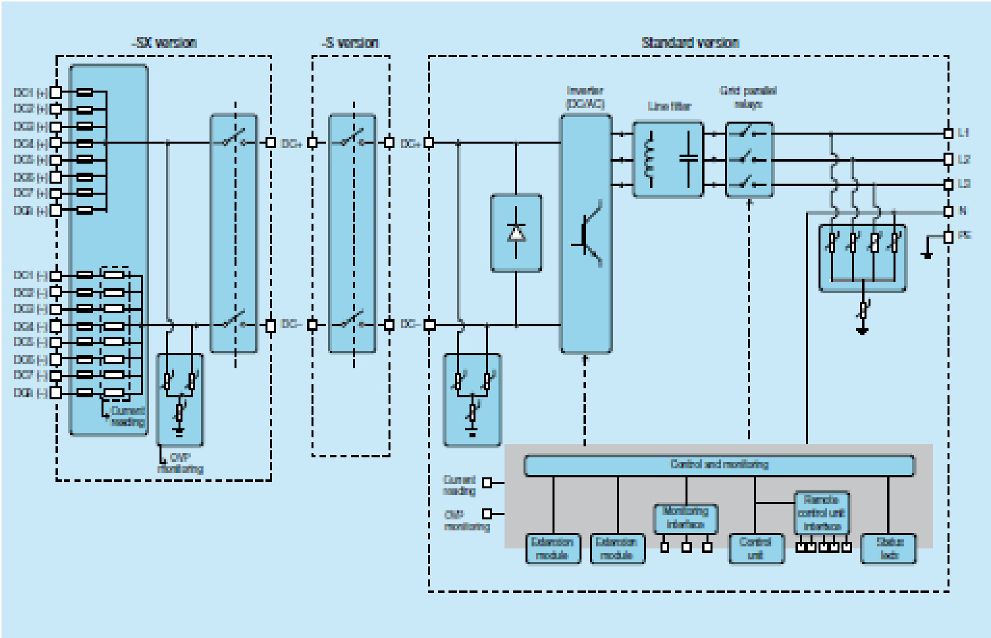
Fast and easy commissioning

Fast PV plant commissioning is enabled via pre-programmed country grid code settings that are easily selectable. Extensive certification ensures wide grid code compatibility. Plug and Play DC and AC connectors enable fast and safe cabling. A touch protected installation area provides additional safety and comfort for inverter installation and maintenance.

Technical data and type

Type designation	33 kW
	PRO-33.0-TL-OUTD
Input side	
Absolute maximum DC input voltage ($V_{max,abs}$)	1100 V 3)
Startup DC input voltage (V_{start})	610 V
Operating DC input voltage range (V_{dcmin}...V_{dcmax})	580 to 950 V
Rated DC input voltage (V_{dcr})	580 V
Rated DC input power (P_{dcr})	33 700 W
Number of independent MPPT	1
MPPT input DC voltage range ($V_{MPPTmin}$...$V_{MPPTmax}$) at P_{acr}	580 to 850 V
Maximum DC input current (I_{dcmax})/for each MPPT ($I_{MPPTmax}$)	58 A
Maximum input short circuit current for each MPPT	80 A
Number of DC inputs pairs for each MPPT	1 in standard and -S version/8 in -SX version
DC connection type	Tool-less PV connector Phoenix Sunclix on -SX version/screw terminal block on standard and -S version
Input protection	
Reverse polarity protection	Yes, from limited current source
Input over voltage protection for each MPPT - varistor (-/S) version	Yes
Input over voltage protection - plug in modular surge arrester (-SX version)	Type 2
Photovoltaic array isolation control	According to local standard
DC switch rating for each MPPT (version with DC switch)	58 A/1000 V, 50 A/1200 V
Fuse rating (versions with fuses)	15 A/1100 V
Output side	
AC grid connection type	Three-phase 3W+PE or 4W+PE
Rated AC power (P_{acr} @cosφ>0.99)	33 000 W
Maximum apparent power (S_{max})	33 000 VA
Rated AC grid voltage ($V_{ac,r}$)	400 V
AC voltage range	320 to 480 V 1)
Maximum AC output current ($I_{ac,max}$)	50.3 A
Contributory fault current	50.3 A
Rated output frequency (f_r)	50 Hz/60 Hz
Output frequency range (f_{min}...f_{max})	47 to 53 Hz/57 to 63 Hz 2)
Nominal power factor and adjustable range	> 0.995, with P_{acr} = 33.0 kW, adj. ± 0.9 with P_{acr} =29.7 kW, adj. ± 0 to 1 with S = 33.0 kVA
Total current harmonic distortion	< 3%
AC connection type	Fixed plug type connector

ABB string inverter design diagram



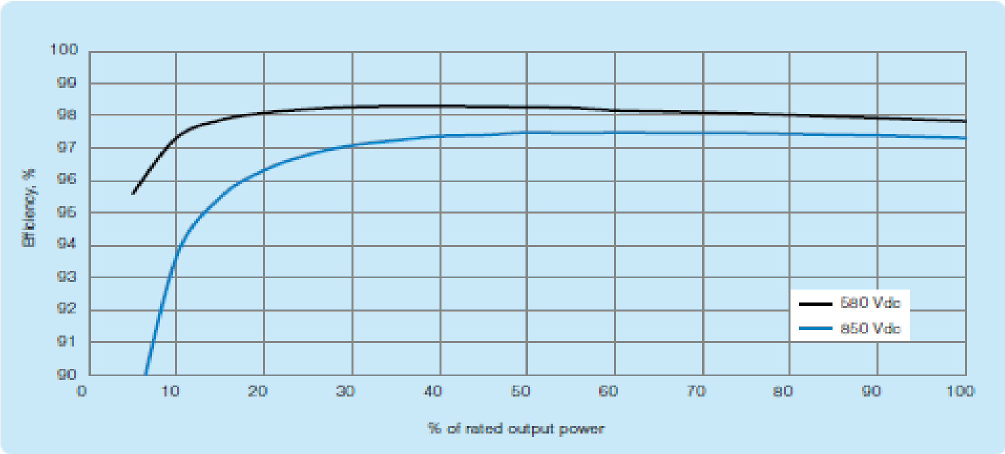
Technical data and type

Type designation	33 kW
	PRO-33.0-TL-OUTD
Output protection	
Anti-islanding protection	According to local standard
Maximum external AC overcurrent protection	80 A
Output overvoltage protection - varistor	5
Operating performance	
Maximum efficiency (η_{max})	98.3%
Weighted efficiency (EURO/CEC)	98.0%/98.1%
Feed in power threshold	20 W
Night consumption	< 1 W
Communication	
Remote monitoring	VSN700 Data logger (opt.)
User interface	Detachable graphical display
Environmental	
Ambient temperature range	-25 to +60°C /-13 to 140°F with derating above 45°C/113°F
Relative humidity	0 to 100% condensing
Sound pressure level, typical	67 dBA @ 1 m
Maximum operating altitude without derating	3000 m / 9840 ft
Physical	
Environmental protection rating	IP 65 (IP54 fans)
Cooling	Forced
Dimension (H x W x D) mm/inch	740 x 520 x 300 mm/29.1" x 20.5" x 11.8"
Weight kg/lb	< 66.0 kg/146 lbs (standard version)
Mounting system	Wall bracket
Safety	
Isolation level	Transformerless
Marking	CE, RCM
Safety and EMC standard	IEC/EN 62109-1, IEC/EN 62109-2, EN61000-6-2, AS/NZS 3200, EN61000-6-3, EN61000-3-11, EN61000-3-12
Grid standard (check availability)	CEI 0-21, CEI 0-16, DIN V VDE V 0126-1-1, VDE-AR-N 4105, G59/3, C10/11, EN 50438 (not for all national appendices), PPC Greece, RD 1699, RD 413, RD 661, P.O. 12.3, UNE206007-1, AS 4777.2, AS 4777.3, BDEW, NRS-097-2-1, SAGC, MEA, PEA, IEC 61727, IEC 62116, ABNT NBR16149/16150
Available product variants	
Standard	PRO-33.0-TL-OUTD-400
With DC switch	PRO-33.0-TL-OUTD-S-400
With DC switch, fuses and DC surge arresters	PRO-33.0-TL-OUTD-SX-400

[1] The AC voltage range may vary depending on specific country grid standard
[2] The frequency range may vary depending on specific country grid standard
[3] Inverter does not start >1000 V

Remark. Features not specifically listed in the present data sheet are not included in the product

Efficiency curves of PRO-33.0-TL-OUTD



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Accessories
- User friendly data logger with web interface for commissioning and monitoring portal for viewing the assets performance
- IO module for programmable relay output
- Warranty extensions

Support and service
ABB supports its customers within dedicated, global service organizations in more than 60 countries and strong regional and national technical partner networks providing a complete range of life cycle services.

For more information please contact your local ABB representative or visit:

www.abb.com/solarinverters
www.abb.com/solar
www.abb.com

VSN700 Data Logger and web user interface

50KW AC 380V/400V/415V PV Grid-Tied Solar Inverter

Advantages

Grid Tie Solar Inverter

PV gridconnected power system includes PV modules, grid tie inverter, meter and power switch board.
The PV modules convert the solar energy into the DC power.
Then the grid tie inverterconverts the DC power into the sine wave AC power
which has the same frequency and phase with the grid voltage.
The AC power supply the local loads and other feed in the grid partly.
More than 10 years of professional production experience and strong technical force,
product quality and reliable,5 years warranty provide.

Can be applied to variours fields,mainly for solar power,wind power,battery power and scenery lamp power

Strong IP65 (NEMA 4) protection,completed sealed cover suitable for harsh environment

Advanced MPPT tracking

No isolation transfomer H6 full-bridge structure,highest efficiency reach 97% (Europe 96.5%)

Over voltage,short circuit,overload,overheat and islanding protection etc

Different national standards for choice

Multi-language LCD display,convenient for users to monitor main parameters from different countries

Max MPPT voltage range

5 years warranty period can be extended to 25 years

- DC INPUT

MPPT Voltage Range	DC200-850V
Rated DC Voltage	DC360V
Control System	MPPT
Start Voltage	DC450V

- AC OUTPUT

Power	30000W	40000W	50000W
Voltage range	3 Phase AC 380V±10% (According To Different Countries And Regions Require The Adjustment)		
Rated Voltage	AC380V		
Normal Grid Frequency	50/60Hz(Can Be Set)		
Phase Number	3 Phase		
Power Factor	0.95		
Max Current	45.5A	61A	75.8A
Current THD	At Rated Power And In The Sine Wave <3.5%		
Max Efficiency	97%		
Euro Efficiency	96.4%		

- STRUCTURE

Protection Degree	IP20		
Cooling Method	Fan Cooling		
Noise	<50dB		
Data Interfaces	External RS 232C/RS485		
Dimension mm W×H×D	520×800×260		525×1000×260
Weight kg	80	83	90
Web Module (Option)	RS 232C To TCP/IP		
Display	LCD		

- PROTECTION

Protection (Inverter)	(Inverter) Input Over Voltage, Output Short Circuit, Overload Overheat
Protection (Grid)	(grid) Anti-islanding(IEEE1547),Over/Under Voltage Of Grid,Over/Under Frequency Of Grid

- ENVIRONMENT

Operation Temperature Range	-10℃~40℃(50℃)
Stored Temperature	-25℃~60℃
Relative Humidity	0~100%
Environment	Have No Corrosion Gas, Flammable Gas, Oil Mist, Dust Etc
Standby Power Consumption	<25, 0mW
Altitude	6600 Feet (2000 m)

Appendix (I): Table of interest 10%

10%	TABLE 15 Discrete Cash Flow: Compound Interest Factors							10%
	Single Payments		Uniform Series Payments				Arithmetic Gradients	
n	Compound Amount F/P	Present Worth P/F	Sinking Fund A/F	Compound Amount F/A	Capital Recovery A/P	Present Worth P/A	Gradient Present Worth P/G	Gradient Uniform Series A/G
1	1.1000	0.9091	1.00000	1.0000	1.10000	0.9091		
2	1.2100	0.8264	0.47619	2.1000	0.57619	1.7355	0.8264	0.4762
3	1.3310	0.7513	0.30211	3.3100	0.40211	2.4869	2.3291	0.9366
4	1.4641	0.6830	0.21547	4.6410	0.31547	3.1699	4.3781	1.3812
5	1.6105	0.6209	0.16380	6.1051	0.26380	3.7908	6.8618	1.8101
6	1.7716	0.5645	0.12961	7.7156	0.22961	4.3553	9.6842	2.2236
7	1.9487	0.5132	0.10541	9.4872	0.20541	4.8684	12.7631	2.6216
8	2.1436	0.4665	0.08744	11.4359	0.18744	5.3349	16.0287	3.0045
9	2.3579	0.4241	0.07364	13.5795	0.17364	5.7590	19.4215	3.3724
10	2.5937	0.3855	0.06275	15.9374	0.16275	6.1446	22.8913	3.7255
11	2.8531	0.3505	0.05396	18.5312	0.15396	6.4951	26.3963	4.0641
12	3.1384	0.3186	0.04676	21.3843	0.14676	6.8137	29.9012	4.3884
13	3.4523	0.2897	0.04078	24.5227	0.14078	7.1034	33.3772	4.6988
14	3.7975	0.2633	0.03575	27.9750	0.13575	7.3667	36.8005	4.9955
15	4.1772	0.2394	0.03147	31.7725	0.13147	7.6061	40.1520	5.2789
16	4.5950	0.2176	0.02782	35.9497	0.12782	7.8237	43.4164	5.5493
17	5.0545	0.1978	0.02466	40.5447	0.12466	8.0216	46.5819	5.8071
18	5.5599	0.1799	0.02193	45.5992	0.12193	8.2014	49.6395	6.0526
19	6.1159	0.1635	0.01955	51.1591	0.11955	8.3649	52.5827	6.2861
20	6.7275	0.1486	0.01746	57.2750	0.11746	8.5136	55.4069	6.5081
21	7.4002	0.1351	0.01562	64.0025	0.11562	8.6487	58.1095	6.7189
22	8.1403	0.1228	0.01401	71.4027	0.11401	8.7715	60.6893	6.9189
23	8.9543	0.1117	0.01257	79.5430	0.11257	8.8832	63.1462	7.1085
24	9.8497	0.1015	0.01130	88.4973	0.11130	8.9847	65.4813	7.2881
25	10.8347	0.0923	0.01017	98.3471	0.11017	9.0770	67.6964	7.4580
26	11.9182	0.0839	0.00916	109.1818	0.10916	9.1609	69.7940	7.6186
27	13.1100	0.0763	0.00826	121.0999	0.10826	9.2372	71.7773	7.7704
28	14.4210	0.0693	0.00745	134.2099	0.10745	9.3066	73.6495	7.9137
29	15.8631	0.0630	0.00673	148.6309	0.10673	9.3696	75.4146	8.0489
30	17.4494	0.0573	0.00608	164.4940	0.10608	9.4269	77.0766	8.1762
31	19.1943	0.0521	0.00550	181.9434	0.10550	9.4790	78.6395	8.2962
32	21.1138	0.0474	0.00497	201.1378	0.10497	9.5264	80.1078	8.4091
33	23.2252	0.0431	0.00450	222.2515	0.10450	9.5694	81.4856	8.5152
34	25.5477	0.0391	0.00407	245.4767	0.10407	9.6086	82.7773	8.6149
35	28.1024	0.0356	0.00369	271.0244	0.10369	9.6442	83.9872	8.7086
40	45.2593	0.0221	0.00226	442.5926	0.10226	9.7791	88.9525	9.0962
45	72.8905	0.0137	0.00139	718.9048	0.10139	9.8628	92.4544	9.3740
50	117.3909	0.0085	0.00086	1163.91	0.10086	9.9148	94.8889	9.5704
55	189.0591	0.0053	0.00053	1880.59	0.10053	9.9471	96.5619	9.7075
60	304.4816	0.0033	0.00033	3034.82	0.10033	9.9672	97.7010	9.8023
65	490.3707	0.0020	0.00020	4893.71	0.10020	9.9796	98.4705	9.8672
70	789.7470	0.0013	0.00013	7887.47	0.10013	9.9873	98.9870	9.9113
75	1271.90	0.0008	0.00008	12709	0.10008	9.9921	99.3317	9.9410
80	2048.40	0.0005	0.00005	20474	0.10005	9.9951	99.5606	9.9609
85	3298.97	0.0003	0.00003	32980	0.10003	9.9970	99.7120	9.9742
90	5313.02	0.0002	0.00002	53120	0.10002	9.9981	99.8118	9.9831
95	8556.68	0.0001	0.00001	85557	0.10001	9.9988	99.8773	9.9889
96	9412.34	0.0001	0.00001	94113	0.10001	9.9989	99.8874	9.9898
98	11389	0.0001	0.00001		0.10001	9.9991	99.9052	9.9914
100	13781	0.0001	0.00001		0.10001	9.9993	99.9202	9.9927

Appendix (J): transformers' properties in GWMC

ELCO LTD	S (kVA)	630
IEC 76		
group	Dyn 11	
No load losses (kW)	1.1	
Load losses (kW)	6	
Impedance %	1	2
trans 1	4.48	3.96
trans 2	4.46	3.94
trans 3	4.45	3.95
type of cooling	ONAN	
S.C Duration Max.	2 Sec	
Insulation class	10 KV	
Volts No Load	1	2
	11275	6765
	11000	6600
	10725	6435
	10450	6270
	10175	6105
	9900	5940
Amp (A)	33	55.1
total weight	2200 Kg	
oil weight	480	

جامعة النجاح الوطنية
كلية الدراسات العليا

التحليل الفني والاقتصادي لتطبيقات إدارة الطاقة في بعض مصانع الضفة الغربية

إعداد
أنس عمر محمد نصوره

إشراف
د. عماد بريك

قدمت هذه الأطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الاستهلاك بكلية الدراسات العليا في جامعة النجاح الوطنية، نابلس – فلسطين.
2016

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الملخص

تعتبر قضايا الطاقة واحدة من المواضيع المهمة التي تستدعي الاهتمام من الباحثين وذلك بسبب زيادة أسعار الطاقة الاعتيادية فضلاً عن الآثار البيئية المماثلة.

يعد القطاع الصناعي فرعاً كبيراً في استهلاك الطاقة في العالم وخاصة في البلدان الصناعية، كما أن الطلب على الطاقة في القطاع الصناعي في فلسطين يزداد بمعدل مقبول وبذات الوقت معظم مصادر الطاقة تستورد من الجانب الإسرائيلي.

للتخفيف من هذه المشكلة ينبغي الاستفادة من الطاقة المتجددة وإدارة الطاقة حيث يمثل استهلاك الكهرباء في القطاع الصناعي نسبة 37% بالنسبة للقطاعات الأخرى ونسبة 42% من استهلاك الوقود والزيوت.

هذه الأطروحة تدرس إمكانية فرص كفاءة الطاقة لثلاث صناعات في فلسطين من أجل المساهمة بشكل فعال في حل مشاكل الطاقة في الضفة الغربية.

تم أخذ شركة مطاحن القمح الذهبي وشركة المشروبات الوطنية والشركة الوطنية للألمنيوم والبروفيلات كعينة لتقييم فرص كفاءة الطاقة المتاحة وخاصة أن هذه الشركات تعتبر من الشركات الكبيرة بناء على التصنيفات الفلسطينية.

فرص كفاءة الطاقة المدروسة تضمنت تحليل نظام التعرفة، معامل التحميل، معامل القدرة، أنظمة الإنارة، المحركات، أنظمة الهواء المضغوط وأفران الغاز المسال.

نسبة التوفير المحققة في الطاقة كانت بين 15.7% و18.7% ومن ناحية أخرى نظام الخلايا الشمسية المربوط على الشبكة مقترح أن يوفر ما نسبته 10% من الطاقة الكهربائية وبيع الفائض إلى الشبكة بتطبيق نظام صافي القياس.

بلغ التوفير السنوي بالطاقة الكهربائية 1.37 ميغا واط ساعة وما قرابته 104 طن من الغاز المسال والذي أدى إلى توفير بالتكلفة التشغيلية بما قيمته 2.5 مليون شيكل إسرائيلي وبفترة استرداد رأس المال ما بين 2.42 عام و4.45 عام.

ومن الناحية البيئية بلغت كمية الانبعاثات المخففة من غاز ثاني أكسيد الكربون سنويا 450 طن و888.21 طن و948.85 طن، في شركة مطاحن القمح الذهبي وشركة المشروبات الوطنية والشركة الوطنية للألمنيوم والبروفيات على الترتيب.