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Models of Electrical Conservation and Efficiency Improvement through Energy Management for Various Facilities in Gaza Strip.

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ABSTRACT

The Palestinian electricity sector suffers from many problems such as high electrical deficit rate, high transmission losses, high electricity prices per kWh, annual growth and absence of energy management strategies and skills.

The case studies are Gaza Training Center (GTC) and Automatic Palestine Factory (APF) located in Gaza Strip selected to demonstrate the use of energy investment models for each facility. The savings opportunities were identified for light system, compressed air, heating, ventilating and air conditioning, induction motor, and power factor correction during energy assessments. Each assessment identifies electrical energy, waste, and cost saving opportunities, and quantifies the expected savings, implementation cost and simple payback of each opportunity. The training center facility consumes 250,820 kWh per year of electricity and factory used 263,875 kWh per year.

This research proposes four investment models for electrical energy conservation in Gaza Strip, no cost model, low cost model, medium cost model, and high cost model to conserve the electrical energy in various plants.

Evaluation of measuring results showed that the estimated energy saving of no cost investment model is 9.6 % in GTC, low cost investment model is 7.5 and 7.8 % in GTC and APF, respectively, medium cost investment model is 19.6 % in GTC, and high cost investment model is 11% and 4% in GTC and APF, respectively.

The outcome research can achieve 17.1 % from the total energy consumption (corresponding to 42890 kWh or 25262 NIS per year) in GTC and 12 % from the total energy consumption (corresponding to 31665 kWh or 18651 NIS per year) in APF by implementing some energy conservation models (no and low cost investment) on the electrical system and most electrical equipment in the facility.

Finally, the research results can be used to assess the impact of electrical conservation models on reduction of electrical deficit rate as the first priority for this research and achieve a good investment in commercial and industrial sectors as a second priority to enhance and support the national economy

ملخص

" نما ذج ترشيد الكهرباء وتحسين كفاءتها من خلال إدارة الطاقة لمرافق مختلفة في قطاع غزة "

إن قطاع الطاقة الكهربية في قطاع غزة يعاني من مشاكل عديدة كإرتفاع في معدل الطلب على استهلاك الكهرباء مع محدودية الكمية المستوردة و كذلك الفقودات الموجودة على شبكة الكهرباء بالإضافة إلى ارتفاع سعر الكيلوات.ساعة و زيادة في معدل النمو السنوي و غياب مهارات واستراتيجيات إدارة الطاقة. تم اختيار حالتين دراسيتين في قطاع غزة وهما مبنى مركز التدريب التابع للوكالة ومصنع فلسطين الآلي ليتم توضيح استخدام نماذج ترشيد الطاقة الكهربية و بالتالي تحديد نسبة توفير الكهرباء في عناصر المنظومة. يتم تقييم الطاقة الكهربائية على أنظمة الإنارة والتبريد والتكييف و الضواغط الهوائية والمحركات الكهربائية وكذلك معامل القدرة لتحديد فرص التوفير للأنظمة الكهربية المختلفة. لقد شمل التقييم تحديد الطاقة الكهربائية الفعلية و كمية الطاقة المهدرة وكذلك تحديد ثمن الطاقة المهدرة و ايضا حساب كمية التوفير والتكاليف المطلوبة للتوفير والمدة الزمنية لإستعادة التكاليف.
إن ما يستهلكه مركز التدريب من طاقة كهربائية ما يعادل 250820 kWh سنويا و ما يستهلكه مصنع فلسطين الألي هو ما يعادل 263875 kWh سنويا.
تقترح الدراسة أربع نماذج استثمارية لترشيد الطاقة الكهربائية وهي نموذج الإستمار بدون تكلفة ونموذج بتكلفة قليلة ونموذج بتكلفة متوسطة ونموذج بتكلفة عالية وذلك لترشيد الطاقة الكهربائية داخل المرافق المختلفة من قطاع غزة.
بين تحليل وتقييم النتائج أن نسبة توفير الكهرباء يصل % 9.6 في مبنى تدريب الوكالة بتطبيق نموذج الإستثمار بدون تكلفة و ما نسبته % 7.5 بتطبيق نموذج الإستثمار بتكلفة قليلة على مبنى تدريب الوكالة و % 7.5 على مصنع فلسطين الآلي. وحقق نموذج الإستثمار بتكلفة متوسطة ما يعادل % 19.6 من الإستهلاك الكلي للطاقة الكهربائية على مبنى التدريب و حقق كذلك نموذج التكلفة العالية ما نسبته 11 و 4 % من الإستهلاك السنوي للطاقة الكهربائية على كل من مركز التدريب و مصنع فلسطسن الآلي عل التوالي.

إن نتيجة البحث تحقق 17.1 % من الإستهلاك الكلي للطاقة الكهربائية على مركز التدريب و 12 % على مصنع فلسطين الألي من خلال تطبيق نموذجين الإستثمار بدون تكلفة و تكلفة قليلة على منظومة الكهرباء داخل المنشأة.

أخيرا إن نيجة الدراسة المقترحة ممكن ان تستخدم لتقدير أثر تطبيق نماذج ترشيد الكهرباء على تخفيض نسبة العجز الكهربائي في قطاع غزة كهدف أول لهذا البحثّ وكذلك تستخدم لتحقيق استثمارا جيدا في مختلف القطاعات كأولوية أخرى لتحسين وتدعيم الإقتصاد الوطني في قطاع غزة.

DEDICATION

This thesis is dedicated to my parents and my family members who have been a constant source of motivation, inspiration, and supported me all the way since the beginning of my studies. This study is also dedicated to my friends who have been a great source of motivation.

ACHNOLOEDGMENT

I thank Allah, the lord of the worlds, for His mercy and limitless help and guidance. May peace and blessings be upon Mohammed the last of the messengers.

I would like to express my deep and sincere gratitude to my research supervisors, Dr. Imad Ibrik, Electrical Engineering Department, Director of Energy Research Centre at Al-Najah University of Nablus and and Dr.Hatem El-Aydi Electrical Engineering Department at Islamic University of Gaza, for their outstanding level of knowledge, constant understanding, encouraging, personal guidance and for having led me into a fascinating area of research. I thank them for his extreme patience and excellent technical guidance in writing and presenting research.

I would like also to thank the other committee members Dr.Mohammed Hussein and Dr. Juma El-Aydi for their valuable feedback, which helped me to improve the thesis in many ways.

I would like to thank my family for all their love and encouragement. For my parents who raised me and have been a constant source of support emotional, moral and of course financial.

There are no words that describe how grateful I am to my family specially my wife for her support and encouragement through the years. My deepest thanks go to my brother, my sisters and my children for their patience and understanding during my busy schedule.

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ABBREVIATIONS

ANSI	American National Standards Institute
ASHREA	American Society of Heating, Refrigerating and Air conditioning Engineers
AAPF	Automatic Power Factor Control
Bcf	Billion cubic feet
BG	British Gas
C^{o}	Degree Celsius
CFL	Compact Fluorescent Lamp
EC	Energy Conservation
ECO	Energy Conservation Opportunity
EMS	Energy Management System
FL	Fluorescent
GPGC	Gaza Power Generating Company
GS	Gaza Strip
GTC	Gaza Training Center
HID	High-Intensity Discharge
HPS	High Pressure Sodium
HVAC	Heating Ventilating and Air Conditioning

IEA	International Energy Agency
IEC	Israeli Electric Corporation
IEEE	Institution Electrical & Electronic Engineering
Inc	Incandescent
LED	Light Emitting Diode
NIS	New Israeli Shekel
O.H	Operating Hour
PEA	Palestinian Energy Authority
PA	Palestinian Authority
PCBS	Palestinian Central Bureau of Statistics
PEA	Palestinian Energy Authority
PNA	Palestinian National Authority
PT	Palestinian Territories
SPBP	Simple Pay Back Period
WB	West Bank

CHAPTER 1

INTRODUCTION

1.1 Overview

Energy management is the judicious and effective use of energy to maximize profits (minimize costs), reduce energy consumption, protect the environment, and save money. The first step should take is to conduct an energy audit. Also called an energy survey, energy analysis, or energy evaluation, the energy audit examines the ways energy is currently used in that facility and identifies some alternatives for reducing energy cost [2]. Electrical conservation through energy management plays an important role in the reduction of load consumption for various sectors. Statistics for energy consumption by sector show that the commercial and industrial sectors in Gaza Strip and West Bank compose roughly one-third of the total G.S and W.B energy consumption in 2009, and also electrical energy consumption is approximately 30 % of the total energy sources in G.S &W.B [9,10].

Currently, the electrical power in Gaza Strip relies on three main sources of electrical energy: Gaza Generation Power Plant (GPGC), the Israeli Electricity Company (IEC), and the Egyptian Channel Company (ECC) and then distributed through the power grid low voltage to customers.

Energy audit is the study of the energy flow in and out in electrical distribution system on visited sites [1]. The selected facilities for this study are Gaza Training Center (GTC) and Palestinian Factory for Construction as medium class electrical consumption. The electrical conservation approach through energy management was evaluated and analyzed inside the two selected facilities to determine the annual savings in electrical consumption.

The study revealed that there are a huge wasted electrical consumption and money due to the absence of energy management and experiences for energy conservation in the two selected case studies. This research comes to highlight the importance for electrical energy saving to reduce the deficit between supply and demand, and the need for implementing energy saving opportunities on various electrical systems such as light fitting, heating, ventilating and air conditioning (HVAC), compressed air, induction motor in different sectors of Gaza Strip.

1.2 The Need of Energy Management for Gaza Strip

Palestine faces sustainable growth in energy demands, especially in electrical energy. Currently, electrical energy supply in Gaza Strip is about 212MW, provided by Israel Electrical Company (IEC) 120 MW, Gaza Power Generation Company (GPGC) 70MW, and Egyptian Channel Company (ECC) 17MW[12].

The estimated electrical demand according to Palestrina Energy National and Resources Authority (PENRA) in Gaza Strip is about 300 M+W in 2011 [14]; therefore, the rate of electrical deficit is 30 % in case no disturbances or faults occurred in the feeder lines. One of the strategy solutions to overcome the electrical crises in Gaza Strip is reduction of electrical deficit rate by using energy saving models through energy management. Energy management is mainly important to Gaza Strip because: `

1. Energy management is essential to decrease the rate of electrical deficit in Gaza distribution network by practices of energy management programs. The electrical conservation programs through energy management decreases the electrical consumption rate of equipment and consequently increase the availability power in the electrical network.
2. Energy management is good for the Palestinian economy. The wasted money for industrial and commercial sectors can be dropped by implementing the electrical conservation programs.
3. Electrical energy management cooperates to decrease the electrical cutoffs cycle time due to the electrical consumption load drops in line feeders and this leads to increase the power availability.
4. Energy management is friendly to our environment as it eases some of the strain on our natural resources and may leave a better world for future generation. The electrical energy is saving result in more CO2 is decreasing.
5. Not only does energy conservation reduce energy bills but also it helps to improve countries economic performances and also provides environmental benefits such as the reduction of carbon dioxide, thus contributing to the global environmental concerns [11].

1.3 Classification of Energy Conservation Measures

The research proposes a model for energy saving measures and classifies them into four categories as follow:

- No cost measure- high return: The cost is zero and the return of investment is high (return profits).
- Low cost measure- high return; The cost level is above 0 NIS to 1000 NIS
- Medium cost measure- medium return; the cost level is between 1000 NIS to 5000 NIS.

- High cost measure- high return; the cost level is above 5000NIS.

Normally, no cost and low cost - high return projects receive priority. Other projects have to be analyzed, engineered and budgeted for implementation in a phased manner [15].

1.4 Objectives of Study

The main idea of this work is conducting energy audits; thus, leading to energy conservation opportunities. The research identifies those opportunities and measures for electrical equipment that can help to attain energy and money saving. The following are the research objectives:

1. To conduct energy audits at both GTC and APF.
2. To determine the potential of energy consumption patterns in Gaza training center and Palestinian factory for construction.
3. To determine the potential of energy savings in different energy consumed equipment through energy audits in different load sectors.
4. To review and select energy conservation opportunities suitable for Gaza Strip.
5. To investigate the feasibility of implementing the proposed energy conservation techniques.
6. To improve power factor by proposing automatic power factor regulator with capacitor stages in the facilities under low power factor value to reduce the losses and maximize the cost saving.
7. To decrease the rate of electrical deficit in distribution network in Gaza strip.

1.5 Motivation

Many of the 1.5 million Palestinians residing in the Gaza Strip must cope with scheduled electricity cuts of 6-8 hours daily due to the limited of electrical resources to matching the demand side and the limited of allocated budget to increase the electrical purchasing in Gaza Strip.

The Palestinians governments can’t cover the deficit of electrical energy until now due to needs to high budget for purchasing the electrical energy quantities and rehabilitation of Gaza distribution network, also the terrible political situation dropped all projects and plans to solve the electrical problem in Gaza Strip.

A considerable amount of energy and money exists in industrial, commercial, residential sectors in Gaza due to the lack of energy management skills. The energy management at Gaza Strip is almost up to zero due to no energy management strategy was applied in most of all various sectors in Gaza Strip. All of above motivated us to search for solution to decrease the electrical deficit and therefore, the scheduled electricity cut off.

1.6 Statement of Research Problem

The rate of electrical deficit in Gaza Strip approximates 30% according to Palestinian Energy and Natural Resources Authority estimation [12] and the technical and nontechnical losses are 32% according to Gaza Electricity Distribution Network in electrical distribution network [12, 13]. A considerable amount of energy and money is wasted in industry, commerce, transport, agriculture and the household sector of Gaza Strip. The limited of electrical resources to matching the demand side and the limited of allocated budget to increase the electrical purchasing are the role of the electrical crises in Gaza Strip.

According to the above problem statement, a model of electrical saving opportunities and measures are demonstrated using case studies of actual energy assessments. The case studies are selected because they cover the electrical energy used in in industry, commerce, transport, agriculture and the household sector of Gaza Strip. The following are considered the roots of the problem:

1. The rate of electrical deficit to cover the electrical demand approximates 30 % and the losses in distribution network are to 32 % [12, 13].
2. The structure electrical tariff is very high due to the limited supply of electrical energy and the profits for IEC and GEDCO. Currently the average kWh price is in range 0.49-0.598 NIS [17].
3. The net budget allocated to purchase the electricity is very high and equal to 583, 163, 859 NIS while the losses costs reaches 174, 955, 519 NIS [17].
4. The absence of energy management strategies and skills such as using energy efficient components, equipment, automation system, process improvements and power factor correction expanded the gap between electrical supply and demand.
5. The power demand is increasing with no plans to cover future demand. The expected demand in the year 2015 is 415 MW in Gaza Strip [18].
6. Renewable energy has not reached a satisfactory level of utilization and pollution from conventional resources is a potential environmental threat. The direction towards getting use from renewable energy sources such as solar or photovoltaic energy from sun was a competitive and good option to Palestinians; especially Palestine has been gifted with huge solar radiation. This type of renewable energy was excellently utilized in water heating, but without clear feasibility to use it in utilizing electricity because of the high cost of photovoltaic system per watt [11].

1.7 Research Methodology

The study proposes models for electrical saving opportunities for various facilities in Gaza Strip. The models of achieving energy saving have been recognized. This approach includes gathering information about selected of various facilities including their characteristic and investigates the potential to energy conservation opportunities.

The tools of collecting information for the research included review of relevant literature in international countries, neighboring Arab countries, and in Palestine. The collected data also includes personal interview with the facilities managers and questionnaire survey for the electrical equipment rating and consumption, and monthly bill invoice analysis, review of measurement of all electrical equipment certain parameters that are indicative of energy consumption in the space.

1.8 Limitation & Restriction

The limitations and restrictions to energy conservation and efficiency improvement in the Gaza Strip industrial and commercial sectors were identified as follow:

1. Lack of management awareness related to energy saving investment for improvements efficiency restricted the production capability.
2. Lack of instruments limited the audited equipment and restricted the number of selected facilities.
3. The political and economic situation limited the energy audit for high-class electrical consumption factories and many of them were closed due to lack of raw materials and equipment.
4. Lack of technical data for electrical equipment and components to identify energy and investigate the potential for energy saving opportunities complicated the energy audits.

1.9 Standards and Codes

1. IEEE STD 739-1995, IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities (IEEE Bronze Book).
2. ASHRAE/IEEE 90A-1-1988, Energy Conservation in New Building Design (Sections 1–9).
3. ANSI/ASHRAE 135-1995, BACnet: A Data Communication Protocol for Building Automation and Control Networks.
4. ANSI/ASHRAE/IESNA 100.3-1985, Energy Conservation in Existing Buildings—Commercial.

5. ANSI/ASHRAE/IESNA 100.4-1984, Energy Conservation in Existing Facilities—Industrial.

1.10 Thesis Structure

This thesis consists of eight chapters on the basis of proposed research methodology of study. **Chapter 2** Provides the necessary background for the energy situation in Gaza strip and west bank. **Chapter 3** highlights the approaches to energy conservation opportunities, energy management aspects and classification various facilities. **Chapter 4** presents the literature review for the energy conservation in the neighboring countries and international countries. **Chapter 5** provides the audited of electrical energy for the various facilities in Gaza Strip for lighting, HVAC, Air compressor. Induction motor and power factor correction. **Chapter 6** presents the economic and technical analysis of the data collected from various commercial and industrial facilities. **Chapter 8** illustrates the conclusions and recommendations.

CHAPTER 2

THE ENERGY SITUATION IN PALESTINE

2.1 Introduction

The electrical sector in Gaza Strip and West Bank is not in satisfied condition due to the lack of energy sources and Israel occupation. The Israeli occupation is suppressing all possibilities of developing the Palestinian energy plans & projects in the West Bank & Gaza Strip.

Palestine has forced to depend almost exclusively on external imports to meet its energy needs and has had essentially no fossil fuel resources of its own. The limited amounts of energy sources in Gaza Strips during the severe siege in Gaza strip have pushed the Palestinian toward Egyptian to compensate its energy needs.

The only domestic energy source in Palestine is the two discovered gas fields by British Gas Company (BG) in December 2000 at Gaza shore. The gas reserves are estimated to be around 1.4 TcF, while the needs for gas by the Gaza power station and other industrial transport and household consumption was estimated at nearly 14.8 BcF each year. Replacement of oil products with gas at the plant would require up to 8.5 BcF/year if all power generating capacity could be used[20, 21, 222].

Most Palestinian people have access to electricity, whether by the general electricity network or by small community diesel generators [23]. The West Bank depends on Israel for 98% of its electricity supply, and the Gaza Strip relies on Israel for at least 58% of its supply of electricity. After Israel military bombed the Gaza power plant in June 2007, Palestine was interconnected with Egypt by means of a medium line grid to supply 17 megawatts and the other between Jordan and Jericho with 20 megawatts capacity [18].

2.2 The Electrical Energy Consumption in Palestine

Table 2.1 shows total electrical imports, electricity consumption of household, industry, construction and services, and total final electrical consumption in Gaza Strip and West Bank from the year 2003 to 2009 [9, 10]. Based on the above findings and observations, the following notes have been made:

1. It is obvious that the estimated electricity is over 30 % of total annual final

consumption of energy including all various energy sources

2. It is very clear that household is the main consumer of electrical energy with an 75% in the average case.
3. It is also clear that services are the second consumer of electrical energy with a highly rapid growth from 3 % to 18 %.

Table (2.1): Electricity consumption for different consumers in MWh.[9, 10]

Year	2003	2004	2005	2006	2007	2008	2009
Industry	648	980.48	643.55	646	739	1032	878
Construction	22	120	41	87	3	31	99
Household	6561.8	6802.73	6685.35	6585	7545	7893.81	8373.84
Services	209	643	633	567	1493.81	1744.68	2325
Total Electrical imports	8336	9355.54	10306	11147	11478	13913	14338.58
Electricity Production	1233	1423	1802	1243	1501	1536	1802
Final Electrical Consumption	7984	9328	8604.41	8497.56	10642.95	10985	12657
Final Energy Consumption	35653	36168.42	35647.49	33550.91	35900	33983.36	41098.5
Electrical Consumption/Total Energy Consumption	22.39%	25.79%	24.14%	25.33%	29.65%	32.32%	30.80%
Production/Consumption	14.79%	15.21%	17.48%	11.15%	13.08%	11.04%	12.57%
Industry/Electricity consumption	8.12%	10.51%	7.48%	7.60%	6.94%	9.39%	6.94%
Household /Electricity Consumption	82.19%	72.93%	77.70%	77.49%	70.89%	71.86%	66.16%

2.3 Electrical Network in Gaza Strip:

Gaza Strip receives its electricity from three sources: Israel Electric Corporation (IEC)-120 megawatts (58 %); Gaza power plant (GPP) supplies between 65-80megawatts (34%); Egypt-17 megawatts (8 %). The estimated total power demand according to Gaza Electrical Distribution Company (GEDCO) approximate 300 MW and the total available load is 212 MW, so the deficit in the network is 30% [13, 14].

Figure 2.1 shows that there are ten lines of electricity coming from Israel to the strip with capacity 12 MW , seven lines of electricity from Gaza power plant with different capacity, and two lines of electricity coming from Egyptian to Gaza with different capacity 5 and 12 MW[14].

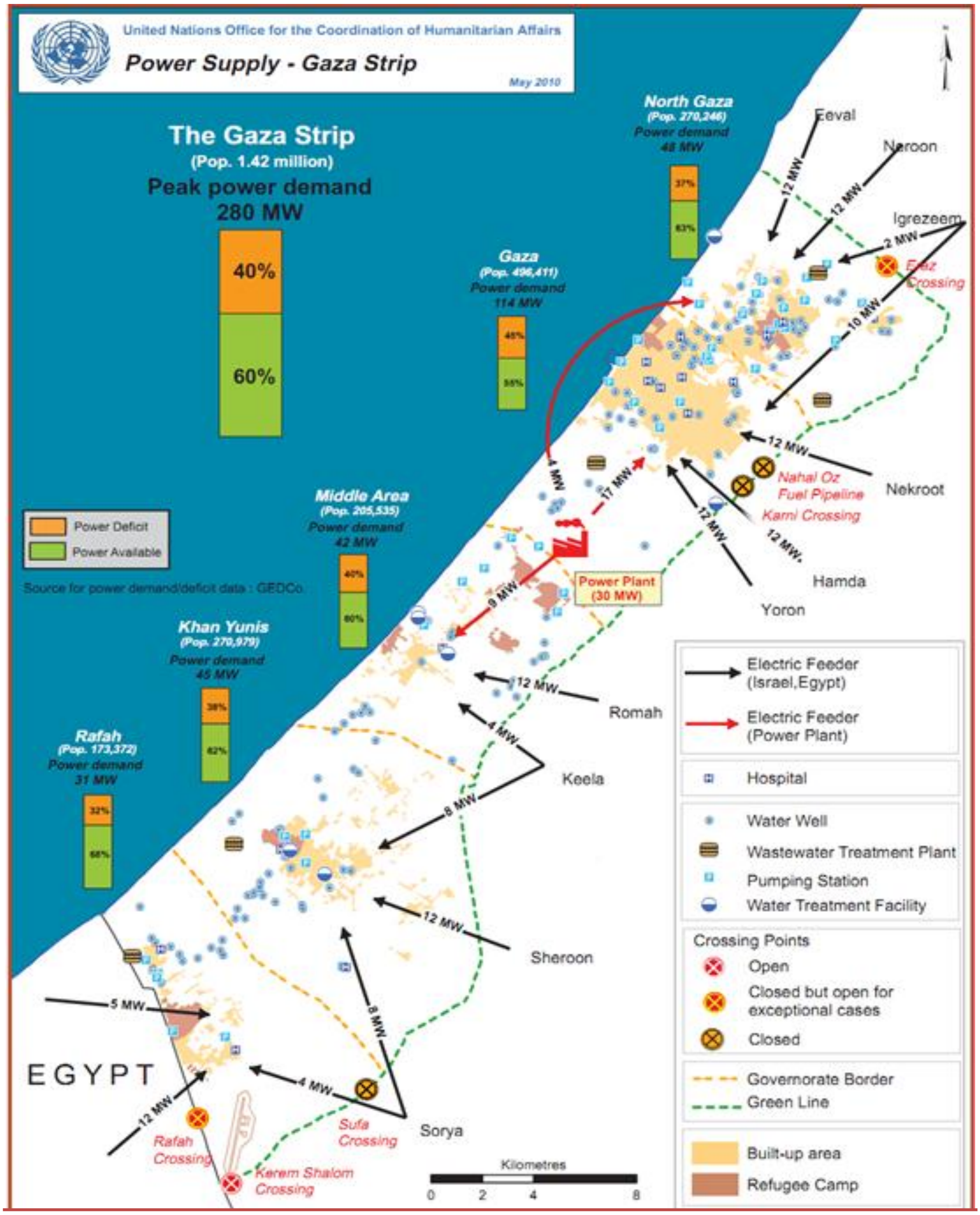


Figure 2.1: Electrical power supply for Gaza Strip [16].

However, the power plant generation capacity was further limited because its operation was depended on the purchase of industrial diesel from Israel. In the second quarter of the year 2010, the PEA efforts in Gaza strip succeeded to obtain alternative fuel supplier from Egyptian for operating Gaza power plant during Gaza Strip siege. Because of the sufficient liquid fuel in Gaza Power Plant, GPP has operated additional Gas turbine to increase the production and net load; hence, the rate of electrical deficit decreased by 7 %.*

2.4 Electrical Energy Price in Gaza Strip:

Electrical prices typically are very high compared to international prices; this is considered one of the main problems for the Palestinian energy sector. Currently, a new electricity tariff structure was approved and implemented in Aug 2011 by GEDCO and became with average rate 0.479 NIS for household prices and 0.592 NIS for other sectors [17].

The fact that electricity production is monopolized by the IEC giving him the power to impose high prices .The price of energy differs between regions due to the full control of Israeli Authority on energy sources for the Palestinian Territory [20, 21].

Most utilities offer industrial customers a lower price per kWh as consumption increases but in Gaza, a higher price per kWh as consumption and this situation is abnormal and differs from international regulations. This is in particular to encourage less consumption during the peak period of the power system.

2.5 Costs of Electrical Energy Purchases

The total electrical energy purchases in the Gaza Strip in 2010 reached 1,544,043,055 KW (1,094,197,582 kW from Israel, 304,984,270 kW from Palestinian Electric Company and 144,861,203 kW from Egyptian Channel Company) as shown in Figure 2.2.

The average annual cost of the total quantity of electrical energy purchases is 583,163,859 NIS (424,329,822 NIS for IEC, 118,272,900 for PEC and 40,561,137 NIS for Channel Company) as shown in Figure 2.3. The annual net sales reached

* Gaza power plant was 55 MW, then it became 75 MW(summer) after using Egyptian fuel to power plant

1,080,830,138kW and the total technical and non-technical losses is 463,212,917 kW(174,955,519 NIS) about 30% [17].

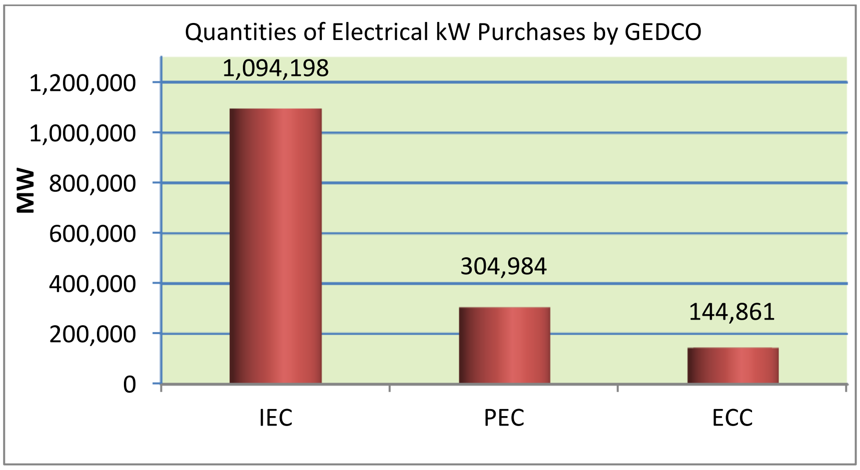


Figure 2.2: Total Quantities of Electricity purchases in 2010.

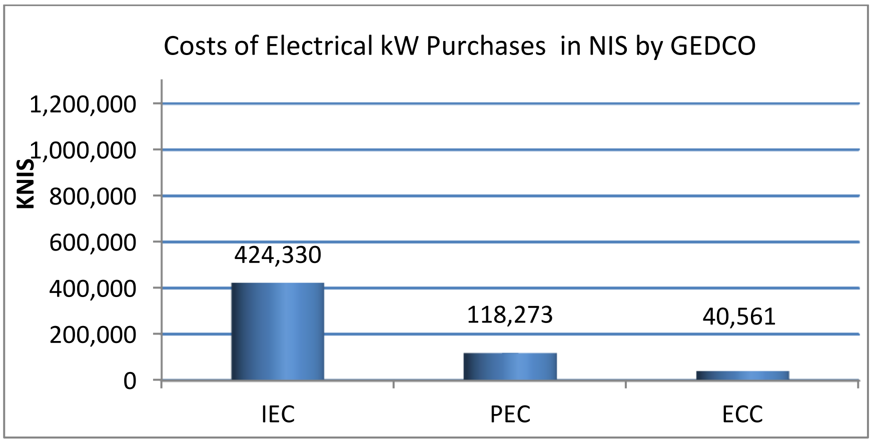


Figure 2.3: Total Costs of Electricity purchases in 2010.

2.6 Description of Audited Facilities

A- Gaza Training Center (GTC):

1. Facility description

There are more than a thousand students in addition to the staff at the college of management and trainers, with an almost 150 employees, the operation hours are between 1800 to 2400 hours per year for 7-9 hours daily. Management staff attends six days of a weak and other staff I five days of a weak. There are many building such as commerce building, electronic and communication building, engineering building, English and administration building, workshops buildings, and other services.

2. Energy bill Analysis:

Table 2.2 shows annual energy, electric consumption in the factory for the period of 12 months. The electrical bill is low during the months Hun, July, Aug due to the student's vacation and only the institution management is inside the training

Table (2.2): Energy consumption and cost for the year 2010/2011 for GTC

Month	Electrical Cost	Electrical Consumption
	NIS/Month	kWh/Month
Sep	11162.294	23254.78
Oct	13711.44	28565.5
Nov	11632.91	24235.23
Dec	13709.914	28562.32
Jan	13370.99	27856.23
Feb	13711.334	28565.28
Mar	13229.87	27562.23
April	12304.901	25635.21
May	10730.189	22354.56
Jun	4111.2	8565
July	1709.76	3562
Aug	1009.1136	2102.32
	95520.182	250820.66

Figures 2.4 and 2.5 illustrate the monthly electricity consumption and the delivered cost of GTC, the high load consumptions are from the light fittings HVAC system, and the motors inside the workshops.

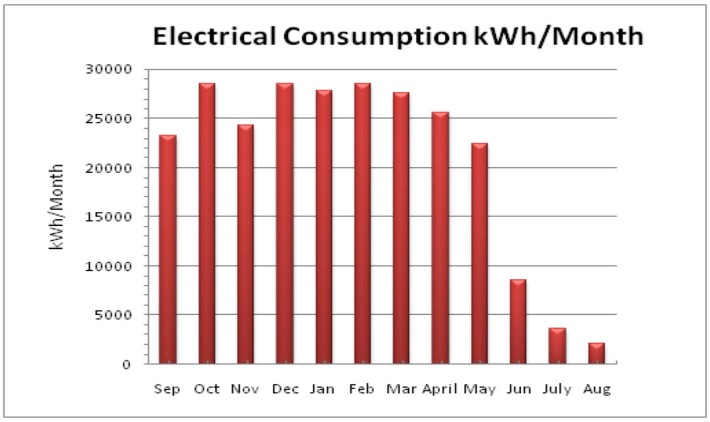


Figure 2.4: Month electricity energy consumption at GTC

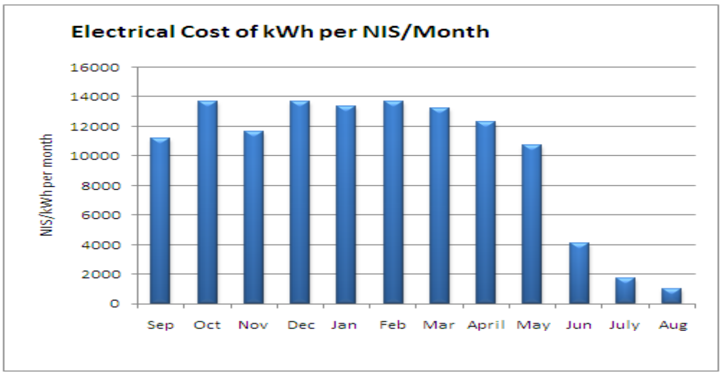


Figure 2.5: Monthly electrical consumption at GTC

It is obvious that the GTC consumes high electrical (around 95520.182 NIS/year) corresponding to Table 2.3 and Figures 2.4 and 2.5. The big deviation in energy consumption between months as seen in graphs is due to vacation of students in months July and Aug.

B- Palestinian Construction Factory (APF)

The operation hours are about 6400 hours per year between 18 -22 hours; a day (two shifts work cycle is 10 hrs.) and seven days a week. The factory depends on the automation operation of the equipment and machines inside the factory. Each shift has control room engineer and 16 employees.

3. Energy Bill Analysis:

Table 2.3 shows annual energy, electric consumption in the factory for the period of 12 months.

Table (2.3): Energy consumption and cost for the year 2010/2011 for APF

Month	Electrical Cost	Electrical Consumption
	NIS/Month	kWh/Month
Sep	3138.384	6538.3
Oct	1810.5216	3771.92
Nov	6912.94	12546.17
Dec	10931.52	19839.42
Jan	11482.48	20839.35
Feb	24355.5	44202.36
Mar	16243.6	29480.22
April	14931.12	27098.22
May	17050.64	30944.9
Jun	12532.6	22745.19
July	12058	21883.85
Aug	13215.6	23984.75
Total	144662.91	263874.65

Figures 2.6 and 2.7 illustrate the monthly electricity consumption and the cost consumption of APF.

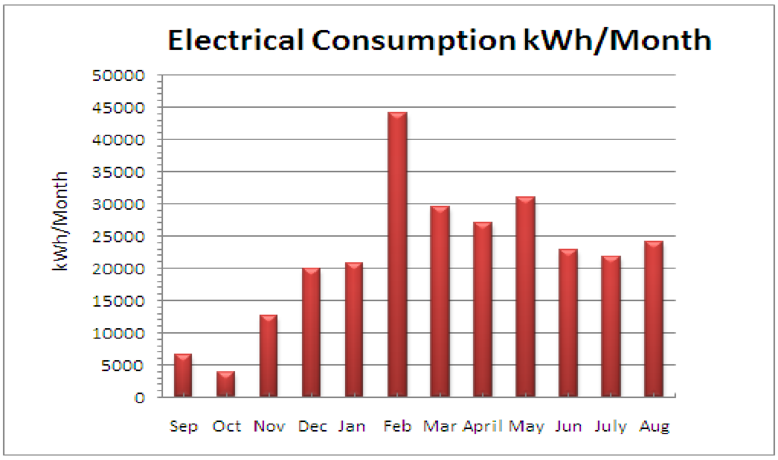


Figure 2.6: Month electricity energy consumption at GTC

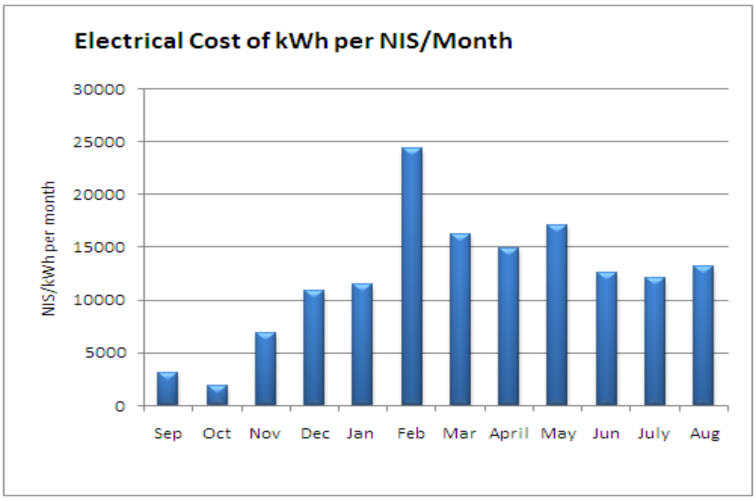


Figure 2.7: Monthly cost NIS/month at GTC.

It is obvious that the factory consumes high electrical (around 144663 NIS/year) according to Table 2.3 and Figures 2.6 and 2.7. The big deviation in energy consumption between months as seen in graphs is due to seasonal production for stone interlocking.

Summary:

The energy sector in Palestine suffers from major distortion and developments due to Israel occupation. During the Israeli occupation period, the infrastructures of the West Bank and Gaza Strip were largely neglected by Israel.

Gaza Strip receives its electricity from three sources: Israel Electric Corporation (IEC)-120 megawatts (58 %); Gaza power plant (GPP) supplies between 65-80 megawatts (34%); Egypt-17 megawatts (8 %). In general, the electricity sector is characterized by a relatively low level of electricity consumption; in the Gaza Strip, electricity consumption was estimated at 1544.043 GWh/year.

Statistic for energy consumption revealed that the electrical energy consumption per person is the lowest indicator in the region and the electrical consumption rose by 30 % in Palestine during the period 2003-2009.

The Palestinian electricity sector suffers from many problems, such as high electrical deficit rate, transmission losses, electricity prices per kWh, annual demand growth and lack of the energy management strategies and skills. The Palestinian Territories have practically no energy resources, with the exception of the modest natural gas reserve on the shore of the Gaza Strip.

Energy priorities require the rehabilitation and development of the electricity system, rural electrification, and utilization of renewable energy and energy conservation. Therefore, the energy efficiency improvements in different sectors by finding suitable energy management measurements are very important for energy sector in Palestine.

CHAPTER 3

LITRATURE REVIEW

Several published studies have investigated the potential for electrical energy saving opportunities in various facilities in the world through energy management. Energy savings programs have been in existence since the 1970s [73] and their evaluation is an internationally accepted field of study. These studies could be implemented for various plants in the world.

1. In Australia, a study was carried out in 2010 for various energy conservation measures (ECMs) on heating, ventilating and air conditioning (HVAC) and lighting systems for a four-storied institutional building. Three categories of ECMs, namely major investment ECMs (variable air volume (VAV) systems against constant air volume (CAV); and low coefficient of performance (COP) chillers against high COP chillers); minor investment ECMs (photo electric dimming control system against general lighting, and double glazed low emittance windows against single-glazed windows) and zero investment ECMs (reset heating and cooling set point temperatures) are evaluated. All zero investment measures can be applied to the existing buildings which include reset heating and cooling set point temperatures. With zero investment, about 2.99% of electric energy can be saved annually by resetting cooling and heating temperature of HVAC system. With minor investment, about 12.02% of electric energy can be saved annually by implementing stepped dimming day lighting control and double-glazing. With major investment, about 26.86% of electrical energy can be saved annually by replacing CAV to VAV of HVAC system and low COP chillers to high COP chillers. Finally, by implementing all of these ECMs together, about 41.87% electrical energy can be saved annually. It is noted that an annual energy saving of up to 16.9% can be achieved by only implementing a VAV system with outside air re-set instead of the current CAV system [71].

2. In Europe [72], the amount of the electrical energy used in illuminating the interiors of medium and large buildings is considerable of about 40%. Energy saving actions could follow two basic directions: efficiency and effectiveness: efficiency, by new more performing equipment (lamps, control gear, etc.) and by utilization of improved lighting design practices (localized task lighting systems); effectiveness by improvements in lighting control systems to avoid energy waste and by adopting a technical building management system (maintenance and

metering). By controlling the lighting in such a way, that the lighting level is always accurately matched to the actual need allows to save on the energy costs and to improve the human comfort and efficiency. To adopt smart lighting control systems allows saving the energy consumed for lighting up to 25% in industrial and commercial and up to 45% in tertiary and educational. To meter the actual electric energy consumption is an important goal in the management time and can enable effectiveness of the system with savings up to 15% [72].

3. In Pakistan, a study was carried out in 1993 [39], to find out the possibility of energy savings in sheet glass industry. The sheet glass industry namely the Nowshera Sheet Glass industries (NSGI) in Pakistan were chosen as a case study. The industry had about 136 motors of various sizes, 60% of which are rewound. Studies have shown that eclectic motors lost about 3-7% in efficiency when rewound, and also 30 electrical heaters. The study replaced the inefficient motor with efficient electric motor and use gas heater instead of electrical heater. It achieved return in investment 23% / month in gas heater, and 16 % / month for electrical motor.

4. In Thailand, 1996 to1998 , [35]the studies, from energy conservation programs for commercial and government buildings in accordance with the Energy Conservation Promotion Act of Thailand, state that The audit results confirm the typically air conditioning is responsible for 60% of electricity consumption in a commercial building, heat gain through the building envelope contributes up to 60% of the total cooling load, electric lighting contributes 20% of the electricity consumption and also contributes up to 20% to the cooling load. The study achieving, by utilizing and implementation the energy conservation programs, the energy saving from 9.5% to 17% for the four different commercial buildings [35].

5. In USA, Eastern Illinois University (Fickes, M., 2002)[47] estimated that it had avoided several million dollars in utility costs through the past six to 10 years. EIU structured their early efforts around a series of no-cost initiatives (such as education programs about importance of saving energy aimed at students, faculty and staff, and review of maintenance practices) and low-cost initiatives (such as replacing incandescent bulbs in all desk lamps with screw-in fluorescent lamps; installing sensors on 115 soda machines that turn the machines off when no one is around; installing showerheads that reduced water flow from 5 gallons per minute to 2.5 gallons per minute). Low cost programs had total investment costs of around $55,000 and resulted in savings of over $270,000.

In recent years, the Arab countries placed in recent years a growing interest in improving the efficiency of energy use in the manufacturing sector, and implemented the energy conservation programs in industrial and commercial sectors.

6. In Egypt, a study for five energy audits have been carried out in governmental buildings, water stations, irrigation pump stations, sewage stations; transportation,

telecommunications and street light lighting. The energy saving opportunities were by using high efficient air condition and using high efficient lamps, replacement of magnetic ballast by electronic ones and using daylight dimming in both governmental buildings and street lighting. The annual energy saving was about 21 GWh (4 % of saving energy) for the large governmental buildings and about 1430 GWh(34 % of saving energy) for public lighting. Thus, the total annual energy saving was about 1451 GWh representing 15% of the total electricity consumption for large governmental customers in 2003 [42].

7. In Saudi Arabia, a study for five buildings was conducted a survey for HVAC system that consumed 65% of the total energy delivered to the building; hence, implementing appropriate HVAC operation strategies might lead to reduction energy consumption. Operation strategies such as a thermostat control, night setback and fan control and the investigation produced energy saving of 6.5%, 7% and 10% respectively, with no investment made, and Employing VAV system, in these centralized systems provides substantial energy savings (21.4 %) [37].

8. In Jordan, the industry sector forms 24% of the total energy consumption in Jordan [36]. In 2009, the study was to focus on the energy consumed by the mechanical equipment in the meat production factory. The author concentrated on analyzing the energy consumed such as steam boiler, condensation systems, cooling towers, pumps, and steam supply system, fuel and water consumption. The opportunity for energy saving was installing economizer for steam boiler to rise feed water temperature. The investment cost of installing economizer was 12000 JD and saving cost was 1881889 JD and energy was 32125 litters of fuel, and the payback period is 0.637 year [36].

9. In Palestine in 2008, An-Najah National University [11] studied and improved the industrial sector in West Bank through conducting energy audits in some industries, which they considered high-energy consumers and allocated the potential for energy savings opportunities. It was showed that there was a decent potential for energy savings in the audited industrial facilities. The load demand management concentrated to improve electrical efficiency by using compact efficient light, reducing air leak of electrical compressor, improving power factor and improve thermal efficiency of boiler by controlling the excess air and increased feed water temperature. The savings in electric energy was around 11% by using the energy conservation measures of no and low cost investment.

10. I. Ibrik and M. Mahmoud in 2002[46] , The residential sector in Nablus - Palestine represent 48% of the total electric power consumption while the power losses in it amount to 8.1 %. Implementing of a project aiming at

energy conservation in households which included wide range of diversified power measurements, had led to creating this paper. Measurement results, had shown that power losses in the residential sector are mainly caused due to low power factor of the household - loads varying in the range: 0.55 - 0.75. The higher the reactive power transported by the distribution network the lower will be the power factor. Due to high cost of electric energy transport, it is more feasible to generate the required reactive power directly at the inductive loads by installing capacitors. The study developed a proper mathematical model representing the power losses in the residential sector, evaluation of measuring results show that an energy saving of 53.18%, by improving the power factor in the households to 0.95, is possible. This percentage corresponds to 3242430 kWh I year or to money saving of 353035 US $ I year.

CHAPTER 4

MODELS OF ELECTRICAL CONSERVATION THROUGH ENERGY MANAGEMENT

This research presents the proposed models of energy saving opportunities and measures to be implemented in Gaza strip, and classifies the models into no cost, low cost, medium cost, and high cost energy saving energy investment to implement in various facilities of Gaza Strip. The study discovered that the technical options available for energy savings in various facilities in Gaza Strip principally revolve around the saving of energy in areas such as:

1. Electrical Light System
2. Air-conditioning system
3. Air Compressor
4. Induction Motor
5. Power factor improvement

4.1 Models of Energy Conservation Opportunities in Gaza Strip

The potentials for energy saving opportunities can be found in different electrical equipment and components such as electrical system, light system, HVAC system, air compressor, induction motor, and power factor correction.

4.1.1 No cost energy saving model:

The no cost saving model implements the lumen method in light fittings and thermostat set point control in HVAC system

1. Light system: Lumen method to reduce excess lamp

The main parameters for this approach are the specific standard level of illumination intensity, area dimension, and the utilization factor. The objective of this technique is removing the excess artificial lamps from specific area, consequently, reducing of electrical consumption. This can be arranged by measuring the illumination level at the specific area and comparing it with the international standards for illumination

(IESNA). In order to calculate the optimum number of fixtures and reduce the number of excessive lamps, equation 4.1(lumen method) is applied.

$$N = (E \times A) / (n \times \phi \times K_u \times K_m) \qquad 4.1$$

Where:

N: number of units, E: illumination lm/m² (lux), A: area in m², n: number of lamps in the unit, Φ: luminous flux in lumen, K u: reflectance factor (it depends on the color of walls, 0.6-0.8), Km: maintenance factor (it depends on the condition of the lamp, clean or not, 0.6- 0.8) [48]. The lumen design method was applied in offices, labs, classes, corridors buildings of GTC.

2. HVAC system: Adjusted the thermostat temperature:

Efficiency is always the ratio of useful output to required input. For an air conditioner as shown in Figure 4.1, the useful 'output' is the heat removed from the space and the required input is the electrical energy.

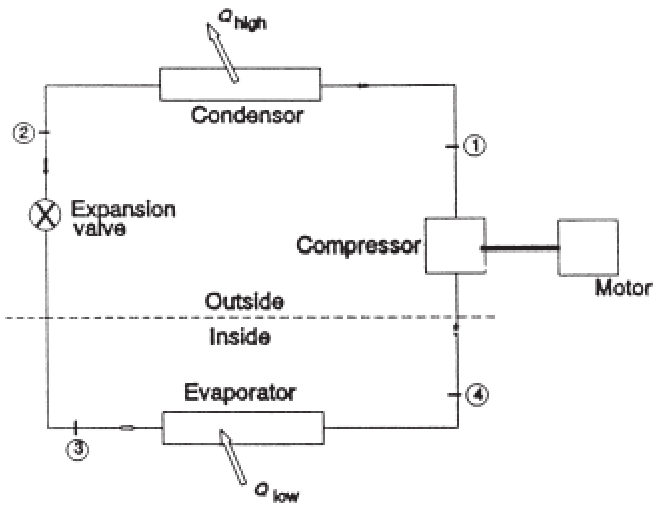


Figure 4.1: Air condition components for add and remove heating.

The efficiency of devices such as air conditioners and refrigerators that extract more energy from a space than electrical energy consumed is also called Coefficient of Performance (COP):

$$\eta = \frac{E_{useful}}{E_{required}} = \frac{\dot{Q}_{evap}}{\dot{W}_{comp}} = \frac{\dot{Q}_{evap}}{\dot{Q}_{cond} - \dot{Q}_{evap}} = COP \qquad 4.2$$

Thus, the efficiency of an ideal Carnot air conditioner is given by:

$$\eta_{carnot} = \frac{\dot{Q}_{evap}}{\dot{Q}_{cond} - \dot{Q}_{evap}} = \frac{T_{evap}}{T_{cond} - T_{evap}} = \frac{T_{indoor}}{T_{outdoor} - T_{indoor}} \qquad 4.3$$

Thus, the evaporator temperature is equal to the temperature of the space being cooled and the condenser temperature is equal to the outside air where heat is being rejected [62].

This demonstrates the tremendous potential for improving the performance of air conditioners by reducing temperature difference. It is claimed that an increase of 1^{o}C in the thermostat setting can achieve as much as 6% reduction in the load. The majority of people feel comfortable at a room temperature of 21-26 ^{o}C depending on the relative humidity (less than 60 %) and other factors [37, 54,64, 65,60,67](see Appendix G). The proposed set point of thermostats to achieve saving cost in summer seasonal in this study is 24 ^{0}C for cooling distribution load. Adjust the air conditioner thermostat set point temperature percentage of saving in cooling system in summer can be calculated by equation 4.4 [54]:

$$Energy\ saving\,\% = \frac{[(T_{exisit} - T_{out}) - (T_{suggested} - T_{out})]}{[(T_{existing} - T_{out})]} \qquad 4.4$$

Where

Texisting : The temperature inside the mom
Tout : Before cooling the space
Tsuggested : Suggested room temperature

HVAC involves sensible heat exchange to control the space temperature and latent heat exchange to add or remove water vapor for control of humidity (difference humidity). Increasing thermostat temperature from 20 C to 24 C will reduce the cooling sensible load according to the following equation. [67]

$$Q_s = f_a \times (T_1 - T_2) \times 4.345$$

Where, Qs = sensible heat flow in kJ/h
fa = rate of air flow (L/s)
T1 = warmer temperature ^{o}C
T2 = cooler temperature ^{o}C

The reduction of cooling load from increasing the thermostat temperature keep the area under thermal comfort standard condition (24 C @ less than humidity 60 %) stated by ASHRE 55 [67].

4.1.2 Model of low cost energy investment:

The low cost model consists of efficient components in light system and reducing of air leak and air intake temperature for electrical compressed air.

1. Light system: Energy-Efficient Light:

The main parameters for this approach are power rate and lumen efficiency (lumen/w) to select optimal component for the indoor and outdoor light fitting. It can clearly be seen from Figure 4.2 that there is a wide variation in the luminous efficacy between the various lamp types [48]. CFL and HPS lamps are selected in indoor and outdoor light efficient lamps. This method was adopted in indoor and outdoor buildings for two selected plants.

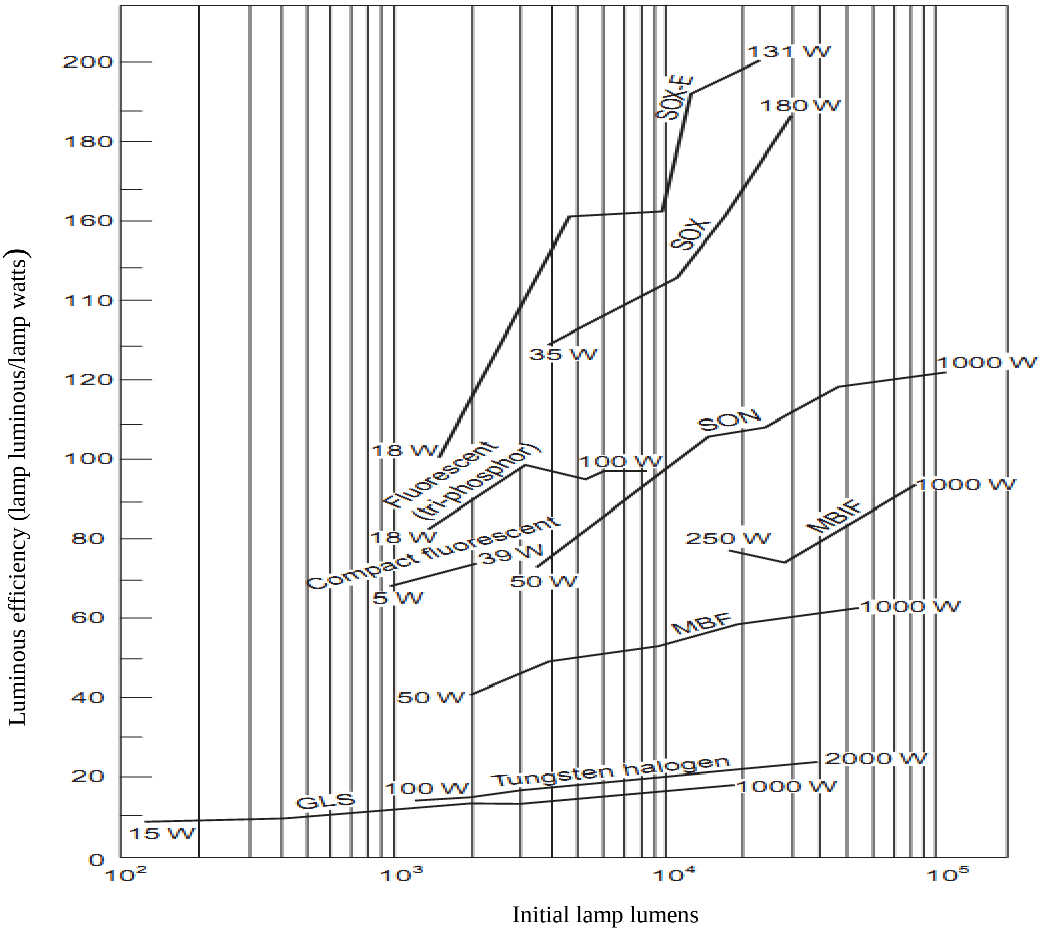


Figure 4.2: Efficiencies of various lamps [48]

Key: GLS Tungsten filament
MBF High-pressure mercury discharge (fluorescent)
MBIF High-pressure mercury discharge (metal halide)
SON High-pressure sodium discharge
SOX Low-pressure sodium discharge

A: Indoor light fitting: CFL instead of incandescent lamp

Compact fluorescent lamps have an efficiency of approximately 70lm/W, while tungsten filament lamps exhibit an efficiency of approximately 10 lm/W. Where possible, tungsten lamps should be replaced by compact fluorescent lamps. CFL consumes approximately 20% of the power required by tungsten [32]. If all incandescent lamps worldwide were to be replaced by CFLs, an additional 728 TWh of electricity would be saved per annum and global lighting energy demand would be lowered by 27% [48].

B: Outdoor light fittings: HPS instead of MHL

Metal halide lamps offer efficiencies today up to 125 lm/W of white light. High-pressure sodium (HPS) lamps offer efficiencies that exceed those available from most metal-halide lamps. Current available types offer efficiencies up to 140 lm/W [47, 48]. It could be adopted in outdoor or floodlight area in two selected facilities.

2. Light System: Installing reflectors in lamp fixture

Special reflectors are available for fluorescent lamp fixtures. These reflectors approximately double the light output of the light fixture. Once the reflectors installed in the fixtures, one lamp could be disconnected in every two-lamp fixture. When the lamp disconnected, the ballast also should be disconnected for that lamp because ballasts draw energy whether the lamp is working or not [50].

3. Opportunities for Air Compressor:

It is estimated that only 20%–25% of input electrical energy is delivered as useful compressed-air energy [6] and leaks are reported to account for 10%–50% of the waste and misapplication accounts for 5–40% of loss in compressed air [1]. Leak repair and maintenance can reduce this number to less than 10% [4]. Fresh air is drawn into the compressor by way of an air filter and is usually compressed to a pressure of 7–8 bar for distribution around the factory.

A. Reduce leak in distribution system:

The main parameter are loading and unloading time for electrical compressor. The calculation of the additional power demand for the coverage of the wasted energy is done by applying equation 4.5 [6].

$$Air\,leak\ \% = \frac{T}{T+t}\ X\ 100\% \qquad 4.5a$$

$$\text{Additional power }(\text{kW}) = (\text{W loaded} - \text{W unloaded})\ {*Air\,leak} \qquad 4.5b$$

Where:

- W loaded: Power requirement during "loaded" mode (kW)
- W unloaded: Power requirement during "unloaded" mode (kW)
- T = Time running "loaded" (mints or seconds)
- t = Time running "unloaded" (mints or seconds)

B. Reduction of inlet air temperature:

The intake line for the air compressor should be at the lowest temperature available. The reduced temperature of air intake results in a smaller volume of air to be compressed. As a rule of thumb, each 5°F (3°C) lower air temperature will save 1% compressor energy [52]. This is because the cooler air is dense supplying more compressed air, and thereby reducing the total operating time [4]. In addition to energy savings, compressor capacity is increased when cold air from outside is used. This normally means outside air, simply by installed additional duct directed to outside air or changing the compressor location. The reduced power requirement can be calculated from equation 4.6, which is derived from the ideal compression power equation [4]:

$$W2 = W1 \text{ x } \left\{1 + \left[0.00341 \text{ x } \left(T2 - T1\right)\right]\right\} \qquad 4.6$$

- W1, W2 = initial and final ideal compression powers (kW)
- T1, T2 = initial and final inlet air temperatures (°K)
- .00143 the rate of change per K

4.1.3 Model of medium energy saving investment

1. Light System: Automatic light system

Occupancy -linked control can achieve a huge of waste energy using infrared, acoustic, ultrasonic or microwave sensors, which detect either movement or noise in room spaces [48]. These sensors switch lighting on when occupancy is detected, and of again after a set time, when no occupancy movement is detected. Lighting controls have been shown to reduce lighting energy consumption by 50% in existing buildings and by at least 35% in new construction [52]. Table 4.1 presents estimates of the maximum yearly energy savings that would be expected per controlled circuit according to control type, space type and typical hours of operation.

Table 4.1: Light control savings by application and control type [53].

No	Space Type	Control type	Max. Saving
1	Private Office	Occupancy Sensor	45%
2	Laboratory	Occupancy sensor	35%
3	Classroom	Occupancy sensor	25%

Figure 4.3 shows the proposed Watt Stopper DT-200 Dual Technology occupancy sensors in this study that combine advanced passive infrared (PIR) and ultrasonic technologies into one unit. The combination of these technologies helps to eliminate false triggering problems even in difficult applications [70].

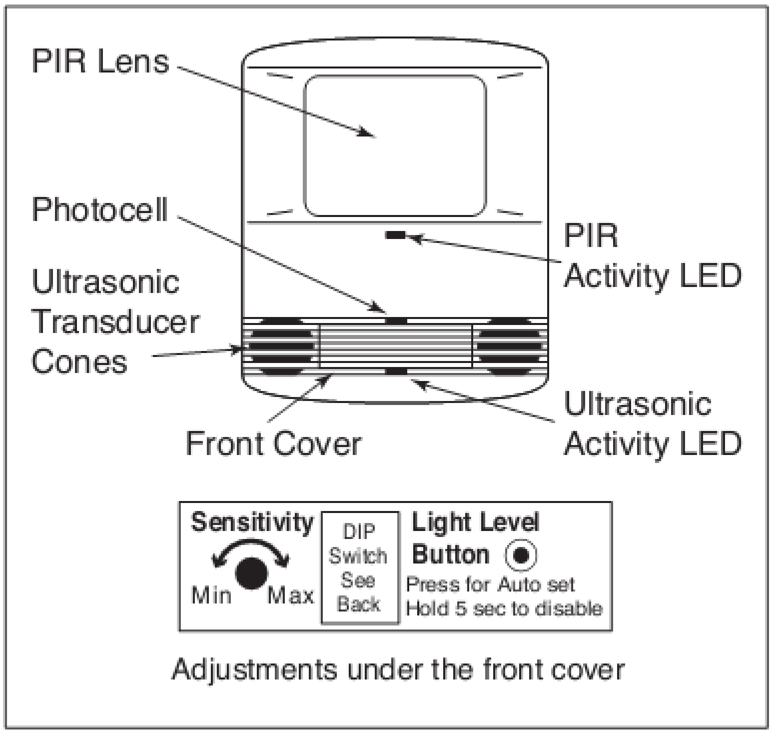
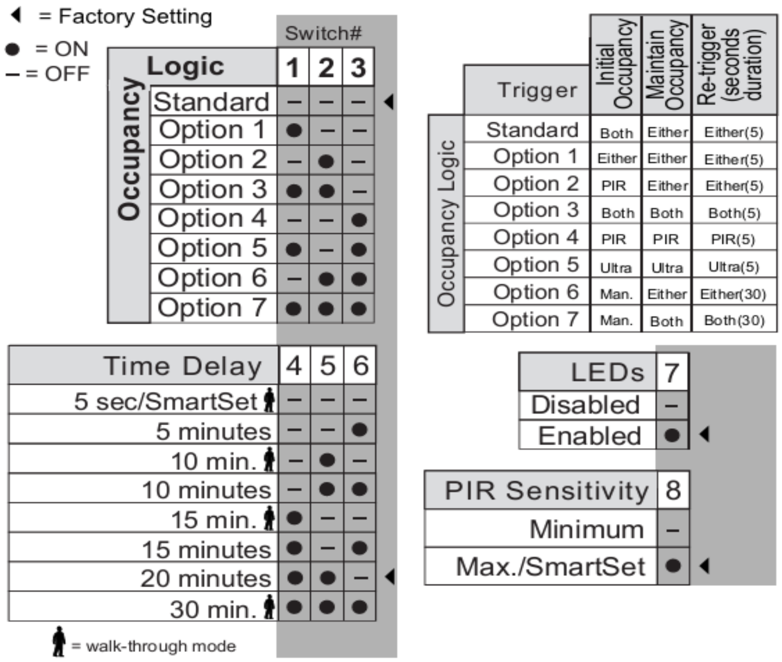


Figure 4.3: DT-200 Dual Technology occupancy sensors [70].

PIR technology senses motion via a change in infrared energy within the controlled area, whereas ultrasonic uses 40 kHz high frequency ultrasound. Once on, detection by either technology holds lights on. Sensors can also be set to trigger lights on when either technology or both detect occupancy, or to require both technologies to hold lighting on

[70]. The sensors can be configured to turn lighting on, and hold it on as long as either or both technologies detect occupancy. After no movement is detected for the duration of the time delay (5 to 30 minutes) the lights are switched off. The DT-200 has 8 logic configurations for occupancy triggers, set with DIP switches 1, 2 & 3 as shown in Figure 4.4. Initial Occupancy is the method that activates a change from “Standby” (area unoccupied and loads are off) to “Occupied” (area occupied and loads are on).

- Both requires detection by PIR and Ultrasonic.
- Either requires detection by only one technology.
- PIR requires detection by the PIR.
- Ultra requires detection by the Ultrasonic.
- Man. requires activation of the Manual Switch.


◄ = Factory Setting
● = ON
– = OFF

Occupancy Logic	Switch# 1	2	3	
Standard	–	–	–	◄
Option 1	●	–	–	
Option 2	–	●	–	
Option 3	●	●	–	
Option 4	–	–	●	
Option 5	●	–	●	
Option 6	–	●	●	
Option 7	●	●	●	

Occupancy Logic / Trigger	Initial Occupancy	Maintain Occupancy	Re-trigger (seconds duration)
Standard	Both	Either	Either(5)
Option 1	Either	Either	Either(5)
Option 2	PIR	Either	Either(5)
Option 3	Both	Both	Both(5)
Option 4	PIR	PIR	PIR(5)
Option 5	Ultra	Ultra	Ultra(5)
Option 6	Man.	Either	Either(30)
Option 7	Man.	Both	Both(30)

Time Delay	4	5	6	
5 sec/SmartSet (walk-through)	–	–	–	
5 minutes	–	–	●	
10 min. (walk-through)	–	●	–	
10 minutes	–	●	●	
15 min. (walk-through)	●	–	–	
15 minutes	●	–	●	
20 minutes	●	●	–	◄
30 min. (walk-through)	●	●	●	

= walk-through mode

LEDs	7	
Disabled	–	
Enabled	●	◄

PIR Sensitivity	8	
Minimum	–	
Max./SmartSet	●	◄

Figure 4.4: Logic configurations for DT-200 with dip switch [70].

The wiring diagram to connect the circuit with low voltage 220 V is shown in Figure 4.5 and DT-200 contains an isolated relay with N/O and N/C outputs; rated for 1 Amp at 24 VDC/VA.

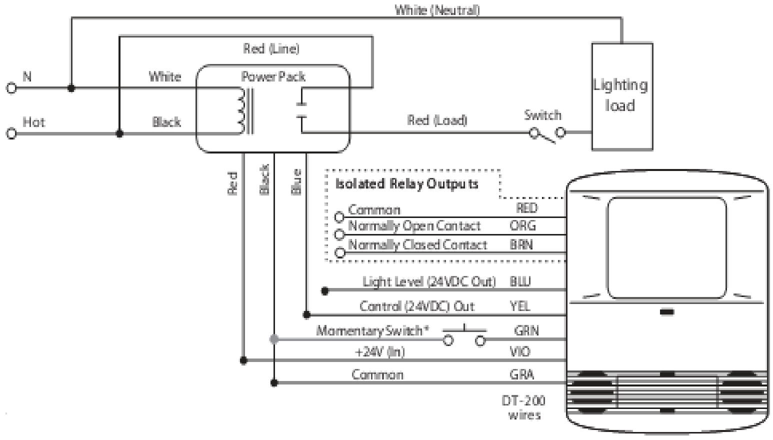


Figure 4.5: Occupancy sensor DT-200 wiring diagram [70].

The DT-200 provides an elliptical coverage pattern. The coverage shown in Figure 4.6 represents the walking motion at a mounting height of 10 feet (3 meter). For building spaces with lower levels of activity or with obstacles and barriers, coverage size may decrease. Under ideal conditions with no barriers or obstacles, coverage for half-step walking motion can reach up to 2000 ft2(185.8m2), while coverage for typical desktop activity can reach up to 1000 ft2(92.9 m2).

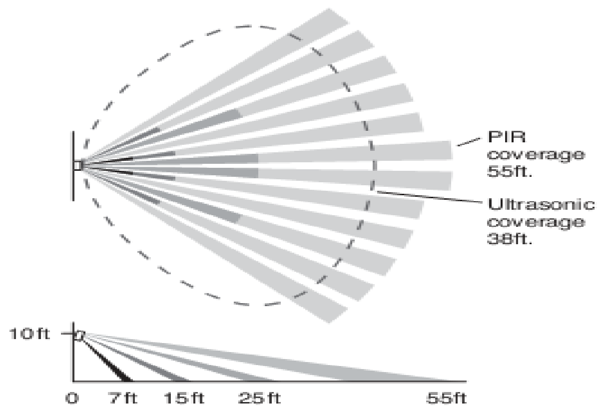


Figure 4.6: An elliptical coverage pattern for DT-200 [70].

2. HVAC: install inverter compressor type.

Modern electronic VSD systems adjust the mains alternating current to regulate motor speed. Various electronic VSD systems are available. One of the most popular types is the variable frequency drive, which achieves speed control by varying the voltage and frequency output. VSD signifies the ability of the unit to regulate its thermal power flow by altering the speed of the compressor in response to cooling demand. It can save 30 % more energy saving than non-inverter [55, 66].

4.1.4 Model of High Cost energy saving investment

The high cost model includes high efficient induction motor and high technology LED lamp and this model require high initial cost to achieve the energy saving.

1. Light System: High technology LED lamp

The LED lamp (**LED light** bulb) is a solid-state lamp that uses light-emitting diodes (LEDs) as the source of light and the average luminous efficacy of LED is 160 lm/W, the maximum should be much higher [49,50].

An important consideration when replacing linear fluorescent lamps with LED products is electrical safety. Nearly all LED replacements bypass the existing ballast. Most have their drive electronics integrated in the tube, while some are provided with external drivers that replace the existing fluorescent ballast.

Advantages of LEDs include:

1. LEDs typically use 90 to 95 percent less energy than incandescent bulbs.
2. LEDs last 10 to 20 years and provide tens of thousands of hours of light.
3. LEDs don't produce as much heat as other lighting,
4. LEDs achieve full brightness in microseconds, much faster than fluorescents and about 10 times faster than incandescent [31, 32].

2. Opportunities for Induction Motor:

Incremental efficiency improvements are still possible with the use of superior materials (e.g., amorphous silicon steel) and optimized computer-aided design techniques. High-performance permanent-magnet materials such as neodymium–iron–boron alloys, with a large energy density and moderate cost, offer the possibility of achieving high efficiency and compact lightweight motors [2, 3].

A. Improvement of voltages level:

Motor voltages below nameplate rating result in reduced starting torque and increased full load temperature rise. Motor voltages above nameplate rating result in increased torque, increased starting current and decreased power factor. The increased starting torque will increase the accelerating forces on couplings and driven equipment. Increased starting current causes greater voltage drop in the supply circuit and increases the voltage dip on lamps and other equipment [6,7,8]. The improvements of voltage levels can be adjusted by tap changer, power factor correction, or installed additional cable on the main power cable connected in parallel to the main board.

B. Install high efficiency motor

The efficiency of a motor-driven process depends upon several factors that may include:

1. Motor efficiency
2. Motor speed controls
3. Proper sizing
4. Power supply quality
5. Distribution losses
6. Transmission
7. Maintenance

Figure 4.3 shows the distribution of the losses of an induction motor as a function of the load. At low load, the core magnetic losses (hysteresis and eddy currents) are dominant, whereas at higher loads the copper resistive losses are the most important. Mechanical losses are also present in the form of friction in the bearings and windage [1]. High efficiency motors are designed and manufactured to reduce these losses. In addition to having lower losses, high efficiency motors also have higher power factors during operation [2].

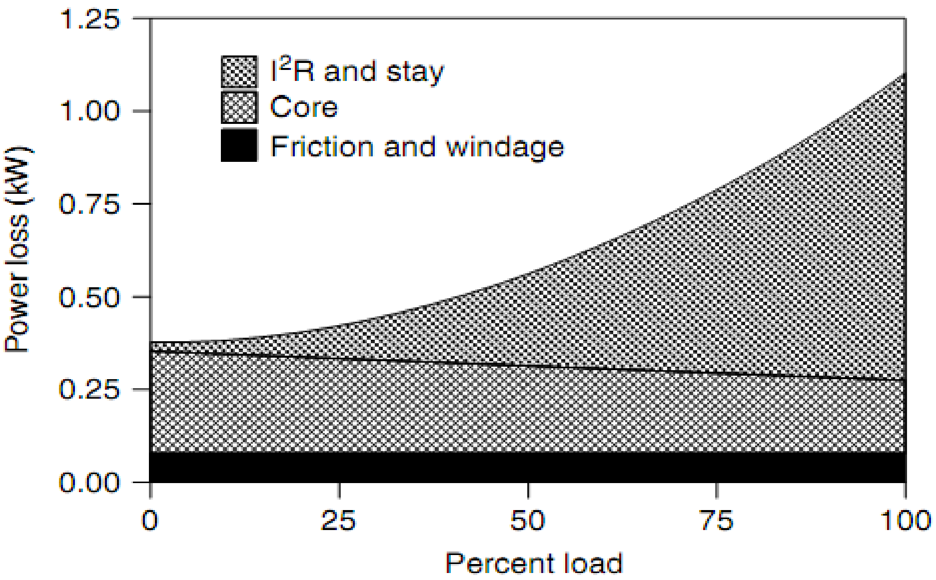


Figure 4.7: Power losses vary with load motor. [1]

Approach Procedure:

The easy method for calculation the saving energy of electrical motor is by using tachometer instrument for shaft speed measurement according to equation 4.7 [2, 3].

$$\text{Motor load}=\frac{RPM_{synch}-RPM_{measured}}{RPM_{synch}-RPM_{full\ load\ (name\ plate)}} \qquad 4.7$$

The other way relies on the data nameplate or catalogue manufacturing to obtain the efficiency at Input power at full-rated load in kW (reference point), then, determining motor load according to equation 4.8[3,4]:

$$Motor\ load\ \% = \frac{kW_{measured}}{kW_{input-fullload}} = \frac{kW_{measured} \times \text{Motor Efficiencyat Load Point}}{hp_{nameplate} \times 0.746} \qquad 4.8$$

The annual energy savings were determined by inserted the estimated existing motor load and also operating efficiencies for existing and high efficiency motors according to equations 4.9 and 4.10 [2,3].

$$\text{powerreduction=hp(M)*L*0.746(}\frac{1}{\eta_{STD}}-\frac{1}{\eta_{HEM}}\text{)} \qquad 4.9$$

$$\text{Energy saving=hp(M)*L*0.746*OH(}\frac{1}{\eta_{STD}}-\frac{1}{\eta_{HEM}}\text{)} \qquad 4.10$$

Where :

- hp(M) : Rated output power of the motor
- L : Motor Loading
- η_{std} : Efficiency of standard motor
- η_{hem} : Efficiency of the high efficient motor
- O.H : Running Hour (three month the center on holidays)

4.1.5 Opportunities for Power Factor Correction:

Power factor correction is applied in most systems to achieve lower cost operation [8]. The overall power factor of electrical systems should be checked for low power factor. In certain applications as much as 10%–15% savings can be achieved in poorly operating plant(low power factor). Power factor is defined as the ratio of real (working) power in kW to apparent (total) power in kVA according to equation 4.11 [7].

$$Power\,Factor = \frac{\text{Re}al\ Power(Kw)}{Appearnt\ power} \qquad 4.11$$

or

$$Power\,Factor = \cos\left(\tan^{-1}\frac{kVarh}{kWh}\right) \qquad 4.12$$

Many utility companies charge an additional fee when power factor is less than a certain value which determined by the electric company, 0.92 in Palestine. Low power factor has negative impacts on the electric distribution network represented in voltage and power losses, as well as on large consumers (factories, municipalities) represented in high penalties [46].

- **Selected approach: Install automatic power factor regulator.**

Automatic power factor regulator (APFR) is an electrical board includes capacitor banks and controller. It is designed to maintain the target power factor by regulating lagging or leading current.

The controller is a microprocessor device that is designed to monitor the reactive power within the circuit continuously and to provide ON/OFF signals automatically to control circuit breakers in capacitor banks. It supervises and regulates the preselected value of power factor in the plant by automatic switching capacitors ON and off as the situation required in the face of reactive leading or lagging load**.** In the factories, a number of induction motors are very high to consume reactive power from L.V distribution network so that the power factor drops to penalty region. This causes a power loss and line voltage drop. The wiring diagram of APFR from ABB manufacturer is shown in Figure 4.4 with the required components:

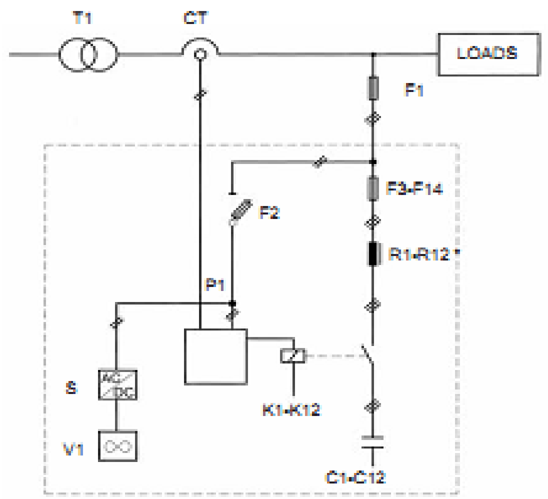


Figure 4.8: Wiring diagram of APFR from ABB [58]

- C1...C12 capacitor steps, F1 main fuses or protective devices, F2 control fuses
- F3...F14 capacitor step fuses, K1...K12 contactors, P1 PF controller
- T1 power transformer,
- S Fan DC supply
- CT current transformer
- V1 fan
- R1...R12 reactors (APCR only)

The benefits by applying this approach of power factor correction are:

1. **Reduction of electricity bills**

   To lower the cost of electric energy, when the electric utility rates vary with the power factor at the metering point

2. **Extra kVA available from the existing supply**

   The percent released capacity resulting from an improvement in power factor is as follows:

$$\%\ \text{Released system capacity} = 100 * \left(1 - \frac{P.F_{original}}{P.F_{new}}\right) \qquad 4.13$$

3. **Reduction of I^2R losses in transformers and distribution equipment**

   Since power losses are proportional to the current squared, and the current is proportional to the power factor, an improvement in power factor will cause a reduction in system losses and reduce power bills [7,47].

$$\%\ \text{Loss Reduction} = 100 * \left(1 - \frac{P.F^2{}_{original}}{P.F^2{}_{new}}\right) \qquad 4.14$$

4. **Reductions of voltage drop in long cables.**

When capacitors are added to the power system, the voltage level will increase. The percent voltage rise associated with an improvement in power factor can be approximated as follows:

Under normal operating conditions, the percent voltage rise will only amount to a few percent. Therefore, voltage improvement should not be regarded as a primary consideration for a power-factor improvement project [7, 47] .

$$\%\ \text{Voltage rise} = \frac{Capacitor\ Kvar * Transformer\ \%ZI}{Transformer\ kVA} \qquad 4.15$$

5. **Environmental benefit**

   Reduced power consumption means less greenhouse gas emissions and fossil fuel depletion by power stations [11].

CHAPTER 5

TECHNICAL ANALYSIS OF ELECTRICAL CONSERVATION OPPORTUNITIES IN GAZA STRIP

5.1 Introduction:

During our site visits for the two selected facilities, it was tried to identify electrical energy saving opportunities exist in facilities. The first step is to use an energy audit to determine the amount of electrical energy that enters and leaves a plant by listing major energy-using equipment with nameplate data relating to electrical consumption. The required measurement instruments to do electrical energy audits in this research are the following instruments:

1. Power analyzer: An instrument for measuring and recording the power factor and also the power consumption for seventy two hours (72 hr). This instrument was borrowed from GEDCO.
2. Clamp meter: An instrument for measuring the three phase currents& voltages.
3. LUX meter: An instrument for measuring illumination in locations and places of GTC. This instrument was borrowed from GTC.
4. Timer: An instrument for recording the on-loading and un-loading time for air compressor.
5. Thermometer: An instrument for temperature measurement for indoor and outdoor places. This was borrowed from GTC.

In this study, the analytical options study for energy savings in various facilities of Gaza Strip principally revolve around the saving of energy in areas such as the energy conservation opportunities in light fittings, HVAC, air compressor, induction motor and power factor improvements.

5.2 Case Study 1: Gaza Training Center (GTC)

5.2.1 Auditing of electrical lighting system

The energy audit of all indoor and outdoor light fittings through collected data nameplate of light types in GTC was performed to calculate the overall rate of electrical light fitting in Gaza Training Center. The overall rate of electrical light fittings is approximated by 118.909 kW under assumption all indoor and outdoor light fittings within the plant are in operation mode.
Table 5.1 illustrates the surveying of lighting distributions in GTC buildings included the rate consumption of lamp & ballast, and the quantities of lamps.

Table (5.1): Summary of Light fitting ratings & Quantities in GTC

No	Building	Description	Unit	Quantity	Lamp	Ballast*	Total	Ratio
					W	W	kW	%
1	**Commerce Building**	Fluorescent Light 2*36w	Nos	146	36	5.4	6.3072	6.87%
2		Incandescent Light 1*60W	Nos	27	60	9	1.863	
3	**Engineering Building**	Fluorescent Light 2*36w	Nos	490	36	5.4	21.168	19.31%
4		Incandescent Light 1*60W	Nos	26	60	9	1.794	
5	**English & Administration Building**	Fluorescent Light 2*36w	Nos	374	36	5.4	16.1568	13.94%
6		Incandescent Light 1*60W	Nos	6	60	9	0.414	
7	**Communication & Electronic Building**	Fluorescent Light 2*36w	Nos	238	36	5.4	10.2816	9.34%
8		Incandescent Light 1*60W	Nos	12	60	9	0.828	
9	**Workshops & Misc, Buildings**	Fluorescent Light 2*36w	Nos	880	36	5.4	38.016	48.22%
10		Incandescent Light 1*60W	Nos	30	60	9	2.07	
11		Floodlight Sodium	Nos	100	150	22.5	17.25	
12	**Wall Mounted Outdoor**	400w Metal Halide Floodlight	Nos	6	400	60	2.76	2.32%
13	**Total**						**118.909**	

* Ballast circuit consumes about additional wattage power accounted for 10-20 % of lamp power rate [1].

The energy saving opportunities of electrical light system in GTC buildings were being conducted as follow:

A. Removal extra lamp:

This can be arranged by implementing lumen method to calculate the optimum number of required lamps in the specific area such as offices, classes, and corridors. Returning to Appendix B of illumination level measurements by lux meter in (GTC) and comparing it with the international standards (IESNA = Illuminating Engineering Society of North American, 1993 in USA/Canada) for illumination in Appendix A [49]. The measurement data is analyzed through Excel office software and the results are summarized in Table 5.2.

Table (5.2): The existing and proposed fluorescent lamps after apply Lumen method.

Existing of Fluorescent Lamps							**Proposed of Fluorescent Lamps**			
No	**Building**	**Type**	**Q**	**Rate**	**OH**	**Energy Used**	**Required Lamps**	**Out Lamps**	**Energy Used**	**Energy Saving**
				W	**hr**	**kWh/year**			**kWh/year**	**kWh**
1	Commerce	FL	146	36	1800	11353	126	20	9798	1555
2	Engineering	FL	490	36	1800	38102	389	101	30249	7854
3	English & Admin	FL	374	36	1800	29082	280	94	21773	7309
4	Electronics & Comm.	FL	238	36	1800	18507	218	20	16952	1555
5	Workshops & Misc	FL	880	36	1800	68429	746	134	58009	10420
6	Total					**165473**				**28693**

Note: Energy used = power rate X Operating hours X quantity x 0.2(ballast power rate/lamp)

The peak saving of electrical light energy after adopting the lumen method in all buildings was 28693kW.

B. Install high efficiency lighting lamps

The proposed alternatives of replacing the low efficient lamps to high efficient lamps rely on the power rate and flux intensity for the selected efficient lamps.

(1) **Replacement of CFL lamps instead of incandescent lamps**

The proposed is to install compact fluorescent lamps instead of incandescent lamps. Replace lamps from incandescent lamp 60 W to PL spot light 1x14 W in W.C place. Table 5.3 illustrates the expected annual energy achieved upon the replacing lamps from incandescent to CFL.

Table (5.3): The annual energy saving by replacing incandescent lamp to CFL

Existing of Incandescent Lamps						Proposed of CFL			
No	Building	Q	Rate	OH	Energy Used	Q	Rate	Energy Used	Energy Saving
		Nos	W	hr	kWh/year	Nos	W	kWh/year	kWh
1	Commerce	27	60	1800	2916	27	14	816	2100
2	Engineering	26	60	1800	2808	26	14	786	2022
3	English & Admin	6	60	1800	648	6	14	181.2	466.8
4	Electronics & Communication	12	60	1800	1296	12	14	362.4	933.6
5	Workshops & Misc.,	30	60	1800	3240	30	14	907.2	2332.8
6	Total				10908			3052.8	7855.2

(2) Replacement of HPS 150W instead 400W ML mercury lamps (Low cost):

The existing outdoor lights in GTC are metal halide lamps with power rate 400 W and the proposed lamps is high pressure sodium (HPS) lamps with rate 150 W. Replacement of the ML (400W) external outdoor lamps with HPS(150W) lamps is recommended. Table 5.4 illustrates the expected annual energy and saving achieved upon the replacement of the specified lamps.

Table (5.4): Energy saving by replacement from ML to HPS

Existing of Outdoor light(Metal halide)						**Proposed of Outdoor Light (HPS)**			
No	**Building**	**Q**	**Rate**	**OH**	**Energy Used**	**Q**	**Rate**	**Energy Used**	**Energy Saving**
		Nos	**W**	**hr**	**kWh/year**	**Nos**	**W**	**kWh/year**	**kWh**
1	Outdoor Area	6	420	3600	8640	6	150	3240	5400
2	**Total**				**8640**			**3240**	**5400**

(3) Replacement of LED lamps instead of all fluorescent lamps (high cost)

After removing excess lamps (by applying Lumen method in section 5.2.1-A), we replace remain lamps from fluorescent lamps 36 W to high technology lamps 18 W in specific places such as classrooms, laboratories, offices. Table 5.5 illustrates the expected annual energy achieved upon the replacing lamps from linear fluorescent lamps T12 to high technology LED lamps. The annual energy saving of 45949.68 kWh/year after installing the new technology high efficient LED lamps.

Table (5.5): the saving energy by used LED lamps instead of fluorescent lamp

Existing of Fluorescent Lamps						Proposed of High Technology LED			
No	Building	Q	Rate	OH	Energy Used	Q	Rate	Energy Used	Energy Saving
		Nos	W	Hr	kWh/year	Nos	W	kWh/year	kWh
1	Commerce	126	36	1800	9797.76	126	18	4082.4	5715.36
2	Engineering	389	36	1800	30248.64	389	18	12603.6	17645.04
3	English & Admin	280	36	1800	21772.8	280	18	9072	12700.8
4	Electronics & Comm.,	218	36	1800	16951.68	218	18	7063.2	9888.48
5	**Total**				**78770.88**			**32821.2**	**45949.68**

C. **Install reflector in lamp fixture**

Special reflectors are available for fluorescent lamp fixtures. These reflectors approximately double the light output of the light fixture. Once the reflectors installed in the fixtures, one lamp could be disconnected in every two-lamp fixture. When the lamp disconnected, the ballast also should be disconnected for that lamp because ballasts draw energy whether the lamp is working or not [53]. Table 5.6 shows the energy saved after installed reflectors for specific fluorescent lamps in computer lab.

Table (5.6): Energy saving by installing reflector for light fittings

Existing of Light lamps without Reflector(9 x4)						Proposed of Light with Reflector(9 x2)			
No	Building		Rate	OH	Energy Used	Q	Rate	Energy Used	Energy Saving
		Nos	W	hr	kWh/year	Nos	W	kWh/year	kWh
1	Computer Lab	36	32	1800	2488	18	32	1244	1244
2	**Total**				**2488**			**1244**	**1244**

D. **Installing Occupancy-Linked Systems (Medium Cost Programs)**

The two types of proposed occupancy sensors were DT 2000 dual technology sensor with light level and WT 1105 ultrasonic. The Watt Stopper DT-200 Dual Technology occupancy sensors combine advanced passive infrared (PIR) and ultrasonic technologies into one unit. The combination of these technologies helps to eliminate false triggering problems even in difficult applications.

The research selects the standard saving factor due to borders closed to get the occupancy sensor from aboard. The specific ratio relies on the occupation level of classes and labs, and cutoff the electricity from the main sources. The Distribution power and energy in Classes of GTC and laborites in GTC are summarized in Table 5.7, 5.8, respectively.

Table (5.7): Distribution power and energy in Classes of GTC

Distribution Classes in GTC without Removing Excess Lamps							
Nr	Building	Lamp/Class	Rate Lamp	Consumption/Class	Classes	O.Hours	Energy Used
		Nos	W	W	Nos	hr	kWh/year
1	Commerce	16	36	576	12	1800	12441.6
2	Engineering	20	36	720	9	1800	11664
3	English	20	36	720	8	1800	10368
4	Communication and Electronic	24	36	864	11	1800	17107.2
5	Workshops	36	36	1296	20	1800	46656
6	Total						98236.8

Table (5.8): Distribution power and energy in Labs of GTC

Distribution Labs in GTC without Removal Excess Lamps							
Nr	Building	Lamp/Class	Rate Lamp	Consumption/Class	Classes	O.Hours	Energy Used
		Nos	W	W	Nos	hr	kWh/year
1	Engineering	32	36	1152	2	1800	4147.2
2	English	36	36	1296	5	1800	11664
3	Communication and Electronic	12	36	432	1	1800	777.6
4	Workshops	36	36	1296	5	1800	11664
5	Total						28252.8

The annual electrical energy saving from installing occupancy sensor at labs and classes is shown in Table 5.9.

Table (5.9): Estimation of energy saving by Occupancy sensor

Space Type	Annual Energy Used	Saving Factor	Annual Energy Saving
	kWh/Year	%	kWh/Year
Class	98236.8	25 %	24559.2
Lab	28252.8	20 %	5650.6

5.3.2 Auditing of cooling system:

This study investigates the energy conservation opportunities for HVAC system in GTC and seen that the potential energy opportunities were:

1. Increase the air conditioner thermostat set point temperature:

The first step for HVAC system auditing was an observation of thermostats temperature set point value. Then, record the temperature measurements for indoor and outdoor area. Percentage of power saving in cooling system in summer was calculated according to equation 4.2 or 5.1. Table 5.10 shows the percentage of saving power from raising the thermostat temperature to 24 ^{o}C (Majority efficient condition 24 C and less than 60 % humidity in summer) [37]. The annual energy saving is 7950 kWh/year if change the thermostat set point to 24 C in summer seasonal.

$$Energy\ saving\,\% = \frac{[(T_{exisit} - T_{out}) - (T_{suggested} - T_{out})]}{[(T_{existing} - T_{out})]} \qquad 5.1$$

Table (5.10): The thermostats temperatures and energy savings for GTC offices

Area		S.P	Tinlet	Toutlet	Tsugg	Rate	O.H	Using	Saving	Power saving	Energy saving
No	Name	^{0}C	^{0}C	^{0}C	^{0}C	Kw	Hour	kWh/year	%	KW	kWh/Year
1	Library	16	21	32	24	6.3	620	3906	27%	1.1	692.4
2	Commerce	15	21	34	24	2.6	620	1612	23%	0.4	241.8
3	Electronic Bldg	17	21	33	24	6.3	620	3906	25%	1.0	634.7
4	Admin.Bldg	16	21	34	24	14.7	620	9114	23%	2.2	1367.1
5	Engineerg.Bldg	18	21	32	24	12.6	620	7812	27%	2.2	1384.9
6	Workshop	15	21	34	24	8.4	620	5208	23%	1.3	781.2
7	Communication	16	20	35	24	26.5	620	16430	27%	4.6	2847.9
8	Total							47988.0			7950.0

Note: the input power of A/C measured according to $P = \sqrt{3} \times Current(A) \times Voltage \times 0.85\ kW$

2. Replacement the conventional split unit to A/C included inverter:

When using the air condition included the inverter, the saving energy reaches up to 30 % [66]. Table 5.11 shows energy saving for using the air conditioner with inverter in GTC based on the measurements of power and energy consumption for air conditioners with inverter compressor type.

Table (5.11): The energy savings by using HVAC with inverter for GTC offices

Area		S.P	Tinlet	Toutlet	Tsugg	Power	O.H	Using	Saving	Power saving	Energy saving
No	Name	^{0}C	^{0}C	^{0}C	^{0}C	Kw	hour	kWh/year	%	KW	kWh/Year
1	Library	16	21	32	24	6.3	1120	4586	30%	1.2	1376
2	Commerce	15	21	34	24	2.6	1120	1893	30%	0.5	568
3	Electronic Bldg	17	21	33	24	6.3	1120	4586	30%	1.	1376
4	Admin.Bldg	16	21	34	24	14.7	1120	10702	30%	3	3210
5	Engineerg.Bldg	18	21	32	24	12.6	1120	9173	30%	2.5	1376
6	WorkShop	15	21	34	24	8.4	1120	6115	30%	1.6	2752
7	Communication	16	20	35	24	26.5	1120	19292	30%	5.2	5788
8	Total							56347.2			16904

The annual energy saving is 16904 kWh/year if replace the existed air conditioner with new inverter compressor type.

5.3.3 Auditing of power factor correction

The improvement of Power factor is to avoid the penalty. In Palestine, the penalty for power factor supposes to be imposed by the municipality soon according to Table 5.12 [55].The power analyzer was installed at the main electrical distribution board for measuring the average power factor. The measurement collected data for load profile and power factor values in GTC dated on 23th April, 2011 for 72 hrs was summarized in Appendix C.

Table (5.12): Power factor proposed penalties in Palestine [54]

Power factor Value	Penalty
Power Factor ≥ 0.92	None
.92≤Power Factor ≤ 0.80	1% of the total bill for every 0.01 of Power factor less than .92
.80<Power Factor ≤ 0.70	1.25 % of the total bill for every 0.01 of Power factor less than 0.92
Power Factor < 0.70	1.5% of the total bill for every 0.01 of Power factor less than .92

Returning to Appendix C, the values of power factor were not fixed for different times whereas P.F values sometimes located in the penalty region. The electrical board of

Automatic Power Factor controller (APF) for GTC was already installed and the investigation revealed that some of the installed capacitor stages are out of service as shown in Figure 5.1.

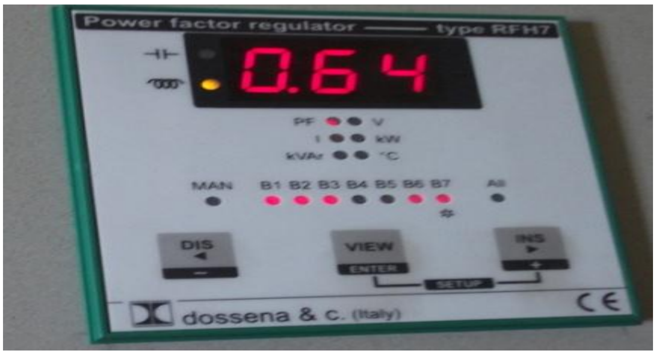


Figure 5.1: Capacitor stages C4, 5 are out of service.

Figure 5.2a shows that the power factor during the test period (red color curve) and 5.2b the daily real and reactive power (green curve is daily real power; blue curve is reactive daily load). The P.F values sometimes occur in the penalty region as shown in Figure 5.2a (x: time hour; y: P.F value). The electrical board of Automatic Power Factor was already installed before the test was done. The test revealed that two of capacitor stages were out of services.

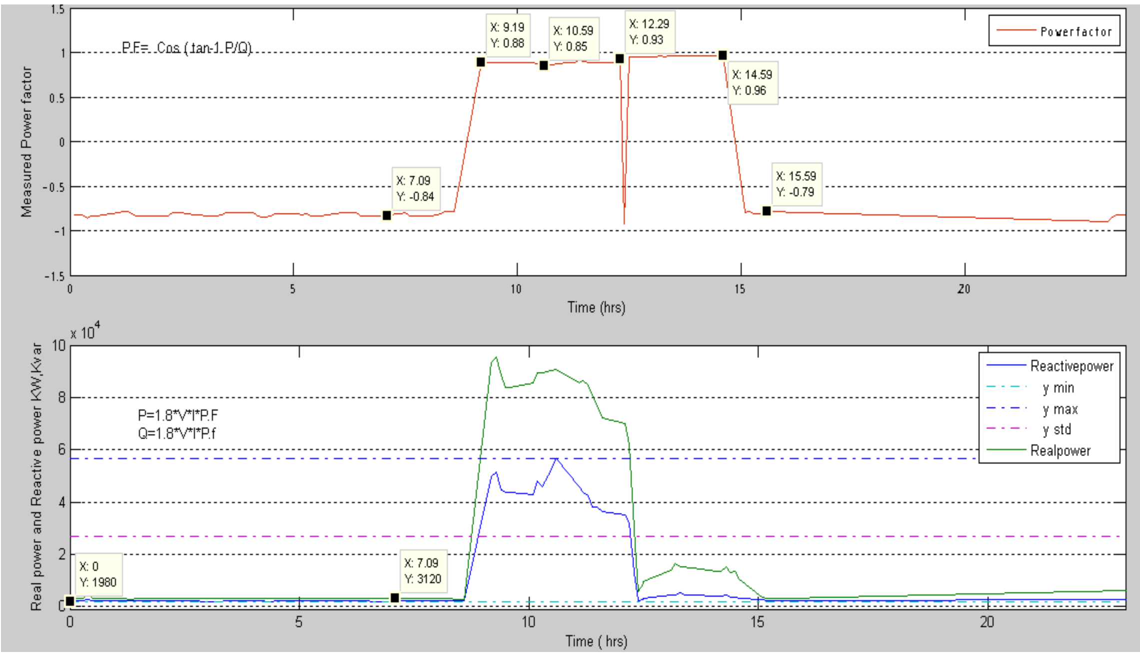


Figure 5.2: Average power factor and daily load power measured at GTC (Before Improvement)

The recommended solution was to re-install new capacitor stages to stabilize P.F above 0.92 as shown in Figure 5.3 and hence no a penalty for low power factor in the future. The proposed approach keeps the values of power factor during 24 hrs above 0.92, so that GTC plant can avoid penalty from low power factor. Figure 5.4 shows the situation of daily power load after the proposed approach for improvement power factor inside GTC plant. The demand reactive power of plant drops after applied reactive power compensation by APF and consequently, increases power factor.

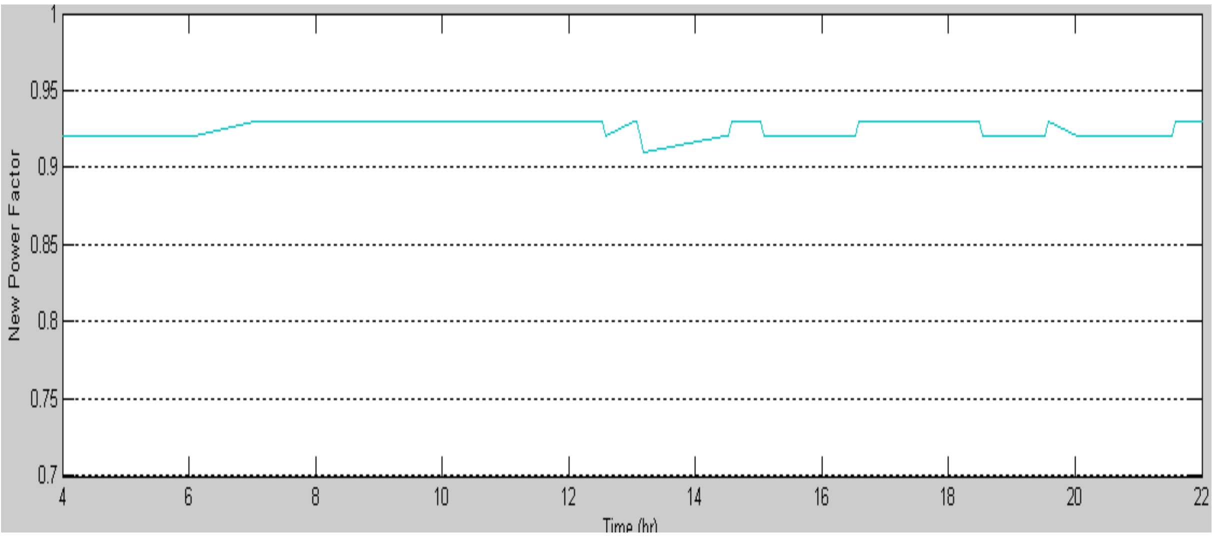


Figure 5.3: Average power factor at GTC (after improvement).

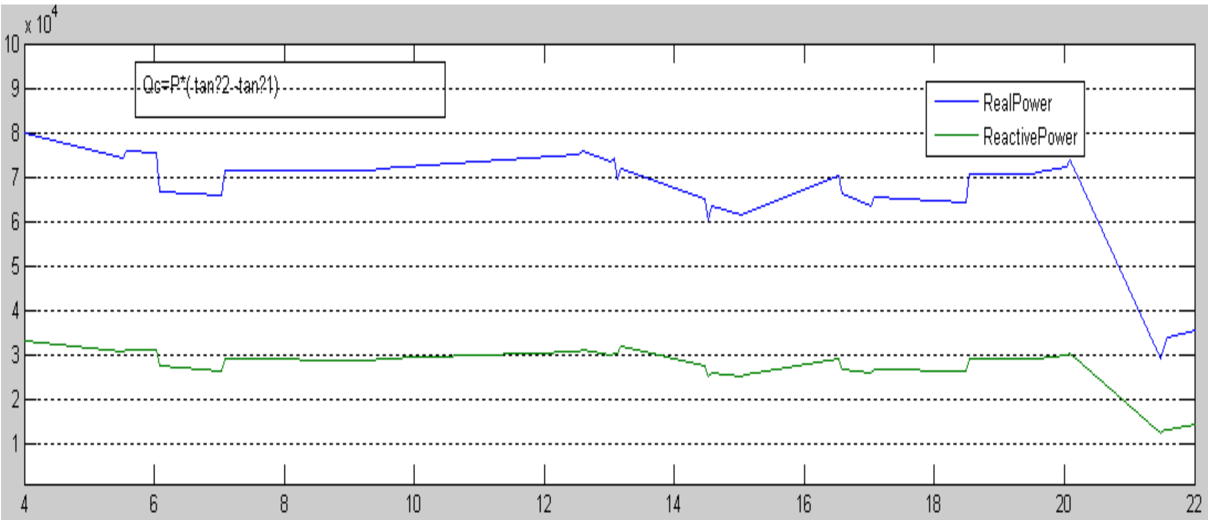


Figure 5.4: Average daily power measured at GTC (after improvement).

The energy saving for power factor improvement is determined according to the equation 5.2.

$$\text{Penality saving}=\text{Penalty.factor}(\text{P.F}_{new} - P.F_{old}) \times electricity\ consumption\ kWh/Year \quad 5.2$$

$$= 0.01 \times (92-89) \times 250820.66 = 7524.6 kwh/year$$

Then,

$$\text{The saving money} = \text{energy saving} * \text{price kWh} \quad 5.3$$

$$Money\ Saving = 7524.6 kWh/year \times .48 NIS/kWh = 3612 NIS/Year$$

5.3.4 Auditing of three phase induction motor

The energy conservation opportunity of electrical motor in this study was to replace of high efficiency motor (HEM) instead of existing standard induction motor. The easy method for calculating the saving energy of electrical motor requires tachometer to measure the motor shaft speed according to equation 4.7 or 5.4 [3, 4].

$$\text{Motor load}=\frac{RPM_{synch} - RPM_{measured}}{RPM_{synch} - RPM_{full\ load\ (name\ plate)}} \quad 5.4$$

The study can't use the speed method due to tachometer instrument is not available in Gaza Strip. The alternative method is full load efficiency and at t full load, the motor efficiency is known through the manufacturer catalogue (see Appendix E), then, apply equation 5.5:

$$Motor\ load = \frac{kW_{measured} \times \text{Motor Efficiency at Load Point}}{hp_{nameplate} \times 0.746} \quad 5.5$$

The typical load factor of industrial motors is around 75%[2].The annual energy savings were determined by inserting the estimated existing motor load and also operating efficiencies for existing and high efficiency motors according to equations 5.6 and 5.7.

$$\text{power reduction}=\text{hp(M)*L*0.746}\left(\frac{1}{\eta_{STD}} - \frac{1}{\eta_{HEM}}\right) \quad 5.6$$

$$\text{Energy saving}=\text{hp(M)*L*0.746*OH}\left(\frac{1}{\eta_{STD}} - \frac{1}{\eta_{HEM}}\right) \quad 5.7$$

- hp(M) : Rated output power of the motor
- η_{std} : Efficiency of standard motor
- η_{HEM}: Efficiency of the high efficient motor
- O.H=: Running Hour (three month the center on holidays)
- L : Motor Loading

The following example illustrates the above procedures for energy saving if replacement of HEM instead of conventional motor. The collected measuring data rate of induction motor for well pump was recorded into Table 5.13.

Table 5.13: Auditing for three phase induction motor of well pump

Data Rate				**Data Measurements**		
Power (hp)	**Current (A)**	**Voltage (V)**	**Efficiency %**	**Current (A)**	**Voltage (V)**	**Power (kW)**
15	22.9	380	86.7	14.7	398	8.46

- **First step**: Specify loading motor %:

Apply equation 5.8 to compute the loading motor (Returning to Appendix E for standard efficiency of electrical motor to get the efficiency motor).

$$Motor\ load = \frac{kW_{measured} \times \text{Motor Efficiency at Load Point}}{hp_{nameplate} \times 0.746} \qquad 5.8$$

The motor efficiency at rate 15 hp was obtained from manufacturers catalogues at Appendix E and equal to 86.7 %.

Loading Motor % = 8.46*0.867/0.746*15 = 65 %

- **Second Step**: Select the required high efficiency motor HEM with η_{HEM}=.915 (See Appendix E)
- **Third Step**: The saving power was calculated from equation 4.9 and equal to 0.44 kW.
- **Fourth Step**: The annual energy saving based on the operating hour was 1415 kWh/year as illustrated in Table 5.14.

Table 5.14: Energy saved by replacing well pump motor by HEM

Name	Standard	HEM	Power Saving	OH	Annual energy saving
	Efficiency	Efficient	Efficient	hr	Efficient
Unit	%	%	kW	hr	kWh/y
Well Pump	86.7	91.5	0.54	3600	1944

The running hours are high due to the continuous daily operation of the pump (8 hrs/day) to transfer the fresh water into service water tanks of plant, and the number of starting and stopping electrical motor increases the equivalent running hours.

5.3.5 Auditing of air compressor:

The presence of air leakage deducts the energy efficiency of air compressor due to waste power consumption delivered to air leak. The study applied the procedure from the IEEE standard 730 in order to calculate the waste power for air leak.

A: Air leak tests (Load/ No Load Test)

The test of air leak was achieved by accounting for rising and drop time and recorded the measurements of power consumption, then, calculates waste power of air leak during loading and loading of electrical air compressors.

1- Air Compressor at welding shop:

This is an electrical compressor place in the welding workshop for cleaning and actuating pneumatic valves. Recording and Measurements for rising, drop time, and real power (Loading and unload) are summarized in Table 5.15. The test is done without running the final air consumption in distribution air network to get accurate results.

Table (5.15): Air Leak Test in Work Shops of GTC

Mode	Rising Time T_{rise}	Drop Time T_{drop}
Cycle Time	Mints	mints
Cycle 1	2.5	4.2
Cycle 2	2.3	4.19
Cycle 3	2.5	4.15
Cycle 4	2.6	4.15
Average time (mints)	2.43	4.17
Real loading Power(kW)	4.9	

The percentage of air leaking from the system can be estimated as follow [6].

$$Air\ leak\ \% = \frac{T_{rise}}{T_{drop} + T_{rise}} = \frac{2.43}{2.43+4.17} * 100\% = 36\% \qquad 5.9$$

The waste consumption power was determined according to equation 5.10:

$$\text{Waste Power(kW)} = \frac{t_{rise}}{t_{rise} + t_{drop}} (P_{loaded} - P_{unloaded}) \qquad 5.10$$

Where:

- P loaded: Power requirement during "loaded" mode (kW)

- P unloaded: Power requirement during "unloaded" mode (kW)
- t_{rise} = The rise time running "loaded"(mints)
- t_{drop} = The drop time running "unloaded"(mints)

$$\text{Waste Power(kW)} = \frac{t_{rised}}{t_{rised} + t_{drop}}(P_{loaded} - P_{unloaded}) = .36(4.9) = 1.8kW \quad 5.11$$

2- Air compressor at carpentry shop:

The Measurements for time rising and drop (Loading and unload), and power consumption were summarized in Table 5.16.

Table (5.16): Air leakage test in the carpentry for GTC

	Rising Time T rise	Drop Time T drop
Cycle Time	mints	mints
Cycle 1	2.6	4.6
Cycle 2	3	5
Cycle 3	2.5	4.6
Cycle 4	2.5	5.7
Average time (mints)	2.67	5
Real Power(kW)	5.43	

The percentage of air leaking from the system can be estimated as follow:

$$Air\,leak\ \% = \frac{t_{rise}}{t_{drop} + t_{rise}} = \frac{2.67}{5+2.67} * 100\% = 34\% \quad 5.12$$

The compressor air leak in Welding and Carpentry workshops equals 36% and 34%, respectively, as shown in Table 5.17. The waste consumption power was determined according to equation 4.5b:

$$\text{Additional Power(kW)} = \frac{t_{rised}}{t_{rised} + t_{drop}}(P_{loaded} - P_{unloaded}) = .34(5.43) = 1.9\ kW \quad 5.13$$

Table (5.17): Summary of Annual energy saving from sealing air leak

Name	Air Leak	Power Saving	O.H	Saving energy
	%	Kw	Hr	kWh/Year
Welding shops	0.37	1.8	648	1,182
Carpentry	0.35	1.9	648	1,223
Total				2,405

B: Improving the inlet air temperature conditions

Table 5.18 shows the measurement for indoor and outdoor temperature for the three air compressors in GTC workshops.

(Table 5.18): The Measured temperature at different locations in GTC workshops

Location	T_{old}	T_{new}	Real Power
	^oC	^oC	Kw
Welding & Turning	36	24	4.9
Carpentry	33	25	5.43
Diesel	38	22	6.8

The reduced power requirement can be calculated from equation 4.6, which is derived from the ideal compression power equation [62]:

$$W2 = W1 \text{ x } \{1 + [0.00341 \text{ x } (T2 - T1)]\} \quad 5.14$$

- $P_{initial}$, P_{final} : initial and final ideal compression powers (kW)
- T1, T2 : initial and final inlet air temperatures (°K)

The results were analyzed by the energy software and summarized in Table 5.19.

Table (5.19): the temperature measurements for different locations in GTC

Location	Exist	Proposed	Loading Power	Initial Power	Final Power	Power Saving	Running Hours	Energy Saving
	T_{old}	T_{new}	P_{real}	Pini	P_{final}	Ps	O.Hr	Es
	C	C	kW	kW	kW	KW	Hrs	kWh/year
Turning	36	24	4.9	4.9	4.0	0.9	648.00	583
Carpentry	33	25	5.5	5.5	5	0.5	648.00	324
Diesel	38	22	6.8	6.8	6	0.8	648.00	518
Total								1425

.

5.4 Automatic Palestinian Factory

5.4.1 Auditing of electrical lighting system

The light fitting in Palestinian factory was much less than the light fitting in educational institution. The research adopts energy conservation opportunity in light fitting by using high efficient lamps instead of convention lamp.

1. Indoor efficient lamps

The light fittings are not the majority load in industrial sector and the potential for energy saving in indoor incandescent lamps. Table 5.20 shows the energy used and saving by replacing conventional lamps with CFL.

Table (5.20): Comparing of CFL and Conventional lamps

Conventional Lamps		**Compact efficient lamps**		**Saving Power**	
KW	kWh/year	KW	kWh/Year	KW	kWh/Year
1.6	2799.36	0.6	1088.64	0.9504	1710.7

2. Outdoor efficient lamp

Table 5.21 shows the energy used and saving by replacing outdoor ML lamps with high-pressure sodium HPS in outdoor building.

Table (5.21): Comparing of HPS and MHL Lamps

Metal Halide Lamp		High Pressure Sodium		Saving Power	
KW	kWh/year	KW	kWh/Year	KW	kWh/Year
3.5	5760	1.5	2160	2	3600

5.4.2 Auditing of power factor correction

The measuring of the average power factor for 48 hr by power analyzer was shown in Appendix D. The results show that p.f varies around .55 to .88 during daily load of the factory. Figure (5.5) shows average power factor, average real, apparent and reactive power before install APF controller for 48 hours at factory (Appendix D).

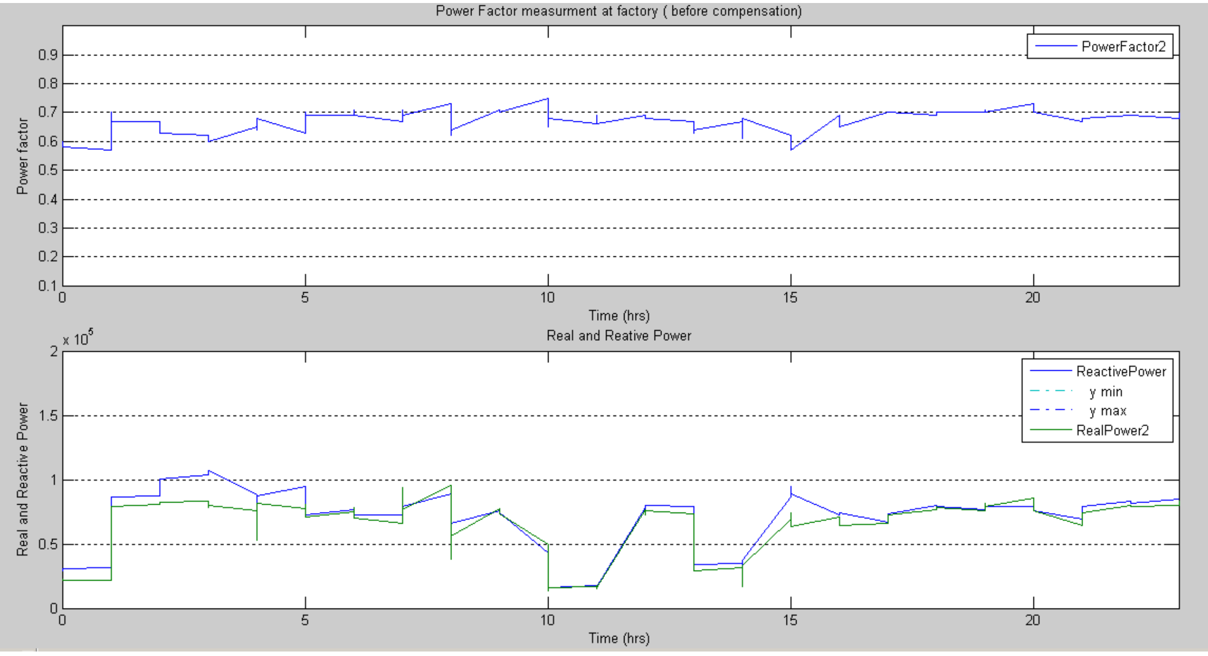


Figure 5.5: Average power factor and daily load power measured at APF (Before improvement)

The analysis of the collected data in Appendix D indicates that the factory needs to automatic power factor to keep the power factor above 92. The reactive power of the capacitor Qc required for improving the PF is calculated from equation 5.15.

$$Q_C = P(\tan\phi_2 - \tan\phi_2) \qquad 5.15$$

Where Qc is the reactive power of the capacitor in (kVAr), P is the active power (kW); Φ1 and Φ2 are the angles between voltage and current before and after power factor correction respectively. Figure 5.6 illustrates the average power factor after proposed approach for installing APF controller. The APF controller was selected based on the equation 5.15 and the measurements of average power factor, and found that Qc=100 kVar.

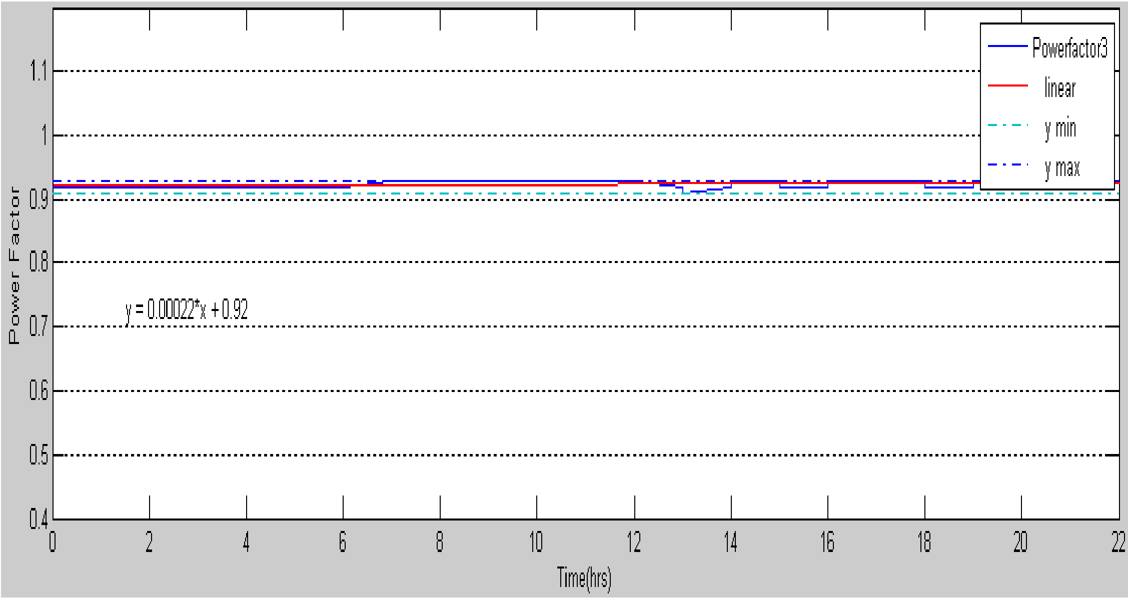


Figure 5.6: Illustrates the average power factor after installing Automatic power factor

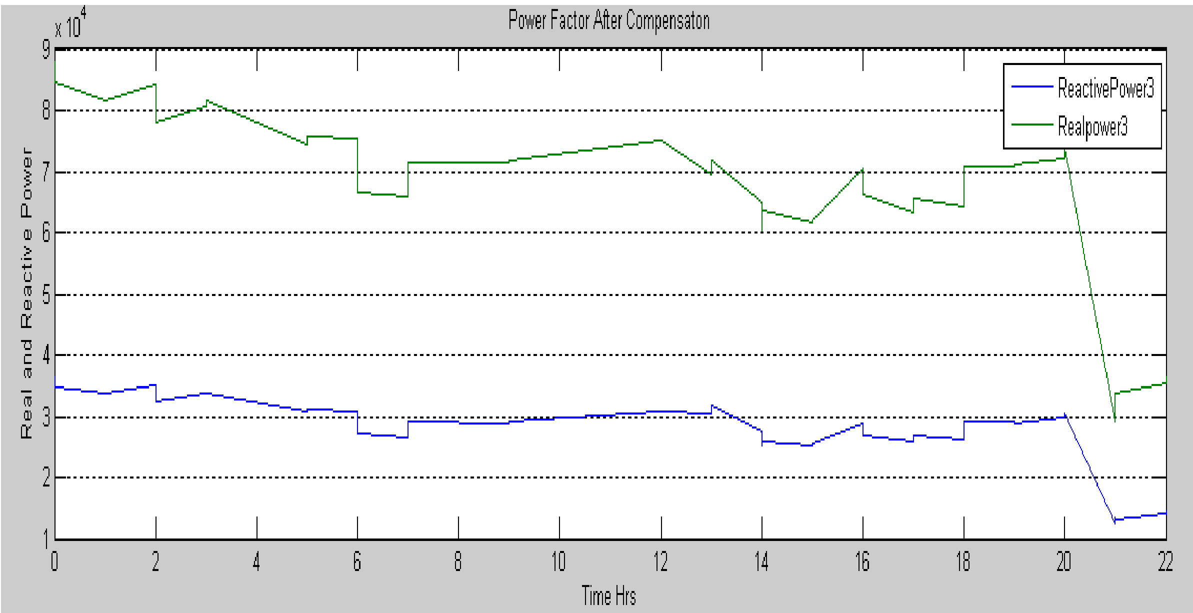


Figure 5.7: Average daily load power measured at APF (before improvement).

The energy saving of improvement of power factor was calculated based on Table 5.12 .

$$\text{Energy saving} = \text{Penalty.factor}(P.F_{new} - P.F_{old}) \times electricity\ consumption\ kWh/Year \qquad 5.16$$

$$= 1.25\% \times (.92 - .75) \times \ 263874.65 = 56073.3\, kwh / year$$

5.4.3 Auditing of three phase electrical induction motor

The same procedure in GTC was implemented for the measurements of the induction motor in the factory. Table 5.22 was summarized the electrical measurements for electrical motor at the factory.

Table (5.22): Electrical Measurements For three Phase Motors

Motor name	Voltage L1-L2	Voltage L2-L3	Voltage L1-L3	Current	Power	Horsepower Rate
	V	V	V	A	kW	Hp
Well Pump	374	375	373	19.5	10.179	15
Breaker Motor1	372	374	376	22.5	11.766	20
Breaker Motor2	372	374	376	22.9	12.0	20
Elec. Motor for Hydraulic System	372	374	376	43.8	22.7	50

The power reduction and saving energy was calculated according to equations 5.6-5.8 and the result data was summarized in Table 5.23.

Table (5.23): Energy saved by replacing motors by high efficient motor (HEM)

Name	Efficiency	HEM.Eff	Power Saving	OH	Annual Energy Saving
	Standard	Efficient		Hr	Efficient
Unit	%	%	kW	Hr	kWh/y
Well Pump	88.4	93.2	0.524	6200	3250
Breaker1	87.2	91.6	0.592	6200	3674
Breaker2	87.2	91.6	0.592	6200	3674
Elec. Motor for Hydraulic System	90.1	93.2	0.88	6200	4681

5.4.4 Auditing of electrical air compressors

The Measurements for time rising and drop (Loading and unload) were summarized in Table 5.24.

Table (5.24): Air leakage test for air compressor in factory

Mode	Rising Time T_{rise}	Drop Time T_{drop}
Cycle Time	**mints**	**Mints**
Cycle 1	1.23	6.25
Cycle 2	1.19	6.31
Cycle 3	1.28	6.55
Cycle 4	1.53	6.6
Average time (mints)	1.3	6.4
Real Measuring Power(kW)	8.56	

The percentage of air leaking from the system can be estimated as follow:

$$Air\ leak\ \% = \frac{t_{\text{rise}}}{t_{\text{drop}} + T_{\text{rise}}} = \frac{1.3}{1.3+6.7} * 100\% = 16.9\% \qquad 5.17$$

The waste consumption power was determined according to equation (5.12) and illustrated to Table 5.25:

$$\text{Additional Power(kW)} = \frac{t_{rise}}{t_{rise} + t_{drop}} * (\text{P}_{loaded} - P_{unloaded}) \qquad 5.18$$

$$= .168(8.56 - 0) = 1.4kW$$

Table (5.25): Summary of Annual energy saving from sealing air leak

Name	**Air Leak**	**Power Saving**	**O.H**	**Saving energy**
	%	**Kw**	**hr**	**kWh/Year**
Air Compressors1,2,3	34	1.445	4320	6243
Total				6243

B: Improving the inlet air temperature conditions

Table 5.26 shows the measurement for indoor and outdoor temperature for the three air compressors for factory.

Table (5.26): the temperature measurements for different locations in APF

Location	T_{old}	T_{new}	Real Power
	^oC	^oC	kW
Air Compressor 1	28	22	8.56
Air Compressor 2	28	22	8.67

The reduced power requirement can be calculated from equation 5.20 which is derived from the ideal compression power equation [62]:

$$W2 = W1 \times \{1 + [0.00341 \times (T2 - T1)]\} \qquad 5.19$$

- W1, W2 = initial and final ideal compression powers (kW)
- T1, T2 = initial and final inlet air temperatures (°K)

It was found that W 2 = 8 kW and this means 0.7 kW power reduction per hour. The summary of saving energy by cooling air intake for air compressor in factory is shown in Table 5.27.

Table (5.27): Saving energy by decreasing air intake Temperature for air compressor

Location	Exist	Proposed	Initial Power	Final Power	Running Hour	Power Saving	Energy Saving
	T_{old}	T_{new}	P_1	P_2	O.H		
	C	C	kW	kW	Hr	kW	kWh/Year
Air Compressor 1	27	20	8.7	8.0	4320	0.7	3024
Air Compressor 2	27	20	8.7	8.1	4320	0.6	2592
Total							5616

CHAPTER 6

ECONOMIC ANALYSIS OF ELECTRICAL CONSERVATION OPPRTUNITIES IN GAZA STRIP

6.1 Introduction:

There are two general methods of evaluating energy options: simple break-even analysis and a more complex method called life cycle costing. Simple payback is the simplest index of economic feasibility, and one that is very widely used. Life cycle costing is most likely needed when the project costs are large compared to the energy savings or when there are significant future Costs.

6.2 Simple Payback (SP):

The break-even methods do not use the time value of money, and they all answer the same question: At what point will I get my money back? [6].
This study evaluates the energy conservation measures by use of the simple payback expression as follow:

$$\text{Simple Payback }(\text{years}) = \frac{\text{InitialCost}}{\text{SavingsPerYear}}\left(\frac{\$}{\$/\text{yr}}\right) \qquad 6.1$$

6.3 Life Cycle Cost Method:

The purpose of the evaluation is to show whether the project meets a specified criterion for acceptability. It is useful to convert all cash flows to a common time. Cash flows involving future amounts of money can be converted to their present values using two important equations, present value of a future amount and a series of annuities.

6.3.1 Present value of a future amount

Equation 6.2 is the fundamental equation of exponential growth and can be applied whenever growth is a fixed percentage of the current quantity.

$$F = P(1+i)^n \qquad 6.2$$

Equation 6.2 can be rearranged to show the present value of a future amount, as in Equation 6.3.

$$P = F(1+i)^n \qquad 6.3$$

Where: P is the present value; F: future value; i: interest rate; n: number of years.

6.3.2 Present value of a series of annuities

An annuity is a regular payment of income made at the end of a fixed period. Consider investing an annuity of amount, A, during each of n compounding periods with an interest rate i. This situation can be shown graphically in a cash flow diagram. The present value of a series of n payments of amount A is mainly calculated from equation:

$$P_n = A\left[\frac{1-(1+i)^n}{i}\right] \qquad 6.4$$

The factor $\left[\frac{1-(1+i)^{-n}}{i}\right]$ is sometimes called the series present worth factor, SPWF(i,n). The reciprocal of the series present worth factor is sometimes called the capital recovery factor, CRF(i,n). Thus,

$$A = P_n * CRF(i,n) \qquad 6.5$$

It is sometimes easier to understand “annualized savings” than the “present value” of savings”. To find annual savings, find the present value of savings (equation 6.4), and then annualize that amount by solving equation 6.5. The study evaluates and analysis the economic state for saving energy models through both methods to determine the saving energy effective cost and the feasibility for implementing the models for various facilities in Gaza strip.

6.4 Case Study 1: GTC as educational institution

6.4.1 Economic evaluation of ECO for lighting systems:

A. Reducing the number of lighting lamps

Returning to Table 5.2, the peak annual energy saving was **28693** kWh/year due to removing the extra lamps by using lumen method. The corresponding savings were calculated as shown in Table 6.1, knowing that lamps removal doesn't incur any costs from GTC, and the implementation cost is zero so that the simple payback period is immediate.

Table (6.1): Annual saving of energy & money for light fitting in GTC

Saving Energy & Money from Lumen Method Implementation									
No	**Building**	**Removal lamp**	**Rate**	**Power Reduction**	**OH**	**Energy Saving**	**Money Saving**	**CO_2 Reduction**	**S.P.B.P**
		Q	**W**	**kW**	**Hr**	**kWh**	**NIS**	**kg/year**	**Year**
1	Commerce	20	36	0.86	1800	1555	715	1121	Immediate
2	Engineering	101	36	4.36	1800	7854	3613	5663	Immediate
3	English Admin,	94	36	4.06	1800	7309	3362	5270	Immediate
4	Electronics & Comm,	20	36	0.86	1800	1555	715	1121	Immediate
5	Workshops Misc	134	36	5.79	1800	10420	4793	7512	Immediate
6	**Total**					**28693**	**16900**	**20688**	

Key: Saving energy equals power saving X Operating hours
Money saving equals to energy saving X price NIS/kWh
Electrical tariff is in average 0.589 NIS/kWh.
Saving one kWh can save 0.721 kg of CO2 [68]
S.P.B.P= Investment cost/ money saving.

The estimated maximum saving of electrical light consumption by adopting excess lumen method is **28693kWh/year** and the net cost saving from reduction in light energy is **16900 NIS/year.** The classes and labs are not fully occupied in the same time so that the selected reasonable saving estimation is about 52 % of peak saving corresponding to **16053 kWh/year** and about **6.4 %** of total electrical consumption.

B. Saving energy & money by replacement of high efficient lamps:

(1) **Replacement of CFL instead of incandescent lamps**

Returning to Table 5.3, the annual energy saving of 7853.76 KWh upon using more efficient lighting fixture like CFL14W instead of incandescent 60W are calculated as shown in Table 6.2.

Table (6.2): Annual energy & money saving for light fitting in GTC by using CFL

Saving energy & Money from Install new CFL instead of Incandescent								
No	**Building**	**Power Reduction**	**OH**	**Energy Saving**	**Money Saving**	**Cost**	**CO_2 Reduction**	**S.P.B.P**
		kW	**hr**	**kWh**	**NIS**	**NIS**	**kg/year**	**Month**
1	Commerce	1.17	1800	2100	966	270	1514	3.35
2	Engineering	1.12	1800	2022	930	260	1458	3.35
3	English	0.26	1800	467	215	60	337	3.35
4	Electronics	0.52	1800	933	429	120	673	3.35
5	Workshops	1.30	1800	2333	1073	300	1682	3.35
6	**Total**	**4.36**		**7855**	**4626.5**		**5663**	

(2) Replacement of HPS 150 instead of ML 400 W:

Returning to Table 5.4, the annual energy saving of **5400 kWh** upon using HPS 150 W instead of ML 400W can be achieved. The corresponding savings are as shown in Table 6.3.

Table (6.3): Annual saving of energy & money for light fitting in GTC by using CFL

Saving energy & Money from Install new HPS instead of ML								
No	Alternative Proposal	Power Reduction	OH	Cost	Energy Saving	Money Saving	CO_2 Reduction	S.P.B.P
		kW	hr	NIS	kWh	NIS	kg/year	Month
1	HPS 150 instead of ML	1.50	3600	420	5400	3180.6	3893	1.9

The estimated saving potential of electrical light consumption by install energy efficient lamps such as indoor and outdoor efficient lamps is **13255 kWh/year** and the saving money from reduction in light energy is **7807 NIS/year** and about **5%** of total electrical consumption**.**

(3) **Replacement of high technology LED lamps instead of fluorescents**

Returning to Table 5.5, the annual energy saving of 45949.7 **kWh** is upon using high technology LED lamp 18 W instead of fluorescent lamp 36W and adopting lumen method. The corresponding savings are calculated as shown in Table 6.4.

Table (6.4): Annual energy & money saving for light fitting in GTC by using LED

Saving energy & Money by adopting new technology LED lamps								
No	**Building**	**Power Reduction**	**OH**	**Cost**	**Energy Saving**	**Money Saving**	**CO_2 Reduction**	**S.P.B.P**
		kW	**hr**	**NIS**	**kWh**	**NIS**	**kg/year**	**Year**
1	Commerce	3	1800	15120	5715	3366	6173	4.5
2	Engineering	10	1800	46680	17645	10392	19057	4.5
3	English	7	1800	33600	12701	7481	13717	4.5
4	Electronics	5	1800	26160	9888	5824	10680	4.5
5	**Total**				**45949.7**	**27064**	**33130**	

The maximum saving potential of electrical light consumption by install new technology LED lamp after adopting lumen method at the operation peak is **45949.7 kWh/year** and the net cost saving is **27064 NIS/year.** The classrooms are not fully occupied in the same time so that the selected reasonable saving estimation is about 52 % of peak saving corresponding to is 23894 kWh/year and about 9.5 % of annual electrical consumption..

(4) Saving energy & money by install reflectors:

Returning to Table 5.6, the annual energy saving of **1244 kWh** upon installing reflectors. The corresponding savings are calculated as shown in Table 6.5.

Table (6.5): Annual Energy & Money Saving for Using Reflector

Saving energy & Money from Install Reflector FL light 2*18W							
No	Power Reduction	OH	Cost	Energy Saving	Money Saving	CO_2 Reduction	S.P.B.P
	kW	hr	NIS	kWh	NIS	kg/year	Month
1	0.69	1800	630	1244	732	897	12

The estimated saving potential of electrical light consumption by install reflector for lamps is **1244kWh/year** and the net cost saving is **732 NIS/year.**

C. Saving Energy & Money by Installing Occupancy Systems:

Returning to Table 5.9, the annual energy saving is 30210 **kWh** upon using Dual technology occupancy sensor in class and lab. The corresponding savings are calculated as shown in Table 6.6.

Table (6.6): Economic analysis of occupancy system used at the main Location

Saving energy & Money from Install Occupancy sensor							
No	Building	Alternative Proposal	Cost	Energy Saving	Money Saving	CO_2 Reduction	S.P.B.P
		Install DT200 Dual	NIS	kWh	NIS	kg/year	Year
1	Classes	Occupancy Sensor	25800	24559.2	14465	17707	1.78
2	Labs	Occupancy Sensor	5600	5650.6	3328	4074	1.68

The estimated maximum saving potential of electrical light consumption by install automatic light control technique for classes is **24559.2kWh/year** and **5650.6 kWh/year** for labs. The summary list of electrical, financial and environment saving by implementation of lighting energy saving method is as follow:

Table (6.7): Summary of Light System Economic analysis in GTC

Saving energy & Money from light systems						
No	**Opportunity**	**Cost Investment**	**Energy Saving**	**Money Saving**	**CO_2 Reduction**	**S.P.B.P**
		NIS	**kWh**	**NIS**	**kg/year**	**Month**
1	Removal Lamps	0	16057	9457	11577	Immediate
2	CFL instead of Incand	1010	7855	4626	5663	3
3	LED technology Lamps	121560	45949/23894	14073	30313.44	4.5 year
4	HPS 150	180	5400	3180	3893	2
5	Occupancy sensor	31400	30209	17793	21781	2 year
6	Install Reflector	600	1244	732	897	12
7	**Total**	**263362**		**155120**	**217254**	

6.4.2 Economic evaluation of ECO for HVAC

A. Increase A/C thermostat set point temperature

Returning to Table 5.10 and by using equation 4.2, it is expected to achieve an annual energy saving of **7950 kWh/year** upon increasing the air conditioner thermostat set point temperature. Table 6.8 illustrates the conservation by using this technique.

Table (6.8): Economic analysis upon increase temperature set point (24C)

Saving Energy & Money from Re-adjusting Thermostat						
No	**Opportunity**	**Cost Investment**	**Energy Saving**	**Money Saving**	**CO_2 Reduction**	**S.P.B.P**
		NIS	**kWh**	**NIS**	**kg/year**	**Year**
1	Thermostat Setpoint=24 °C	0	7950	4682	2751	Immediate
2	**Total**		7950	**4682**	**2751**	

The estimated saving potential of electrical air conditions consumption by re-adjust the thermostat set point to is **7950 kWh/year** and equivalent to **4682 NIS/year** and the energy saving is **3 %** of the total electrical consumption in the GTC.

B. Energy conservation upon Replace A/C to inverter type:

Returning to Table 5.11, it is expected to achieve an annual energy saving of 8452 kWh/year upon increasing the air conditioner thermostat set point temperature. Table 6.9 illustrates the conservation by using this technique.

Table (6.9): Economic analysis for A/C with inverter compressor type

Saving Energy & Money from New A/C inverter Compressor type						
No	**Opportunity**	**Cost Investment**	**Energy Saving**	**Money Saving**	**CO_2 Reduction**	**S.P.B.P**
		NIS	**kWh**	**NIS**	**kg/year**	**Year**
1	HVAC with Inverter Compressor Type	27000	16904	9956	12187	2.6
2	**Total**	**27000**	**16904**	**9956**	**12187**	2.6

The summary of annual energy and money saving is illustrated in Table 6.10. The implementation of the energy saving opportunities in HVAC is considered important due to the waste consumption power in the HVAC system.

Table (6.10): Summary of annual saving of energy and CO2 emission

Summary of energy & money saving for HVAC						
No	**Opportunity**	**Cost Investment**	**Energy Saving**	**Money Saving**	**CO_2 Reduction**	**S.P.B.P**
		NIS	**kWh**	**NIS**	**kg/year**	**Year**
1	Thermostat Set point=24 °C	0	7950	4682	569	Immediate
2	HVAC with Inverter Compressor Type	27000	16904	9956	12187	2.6
3	**Total**	**27000**	**24854**	**14639**	**78424**	

The total electricity consumption per year in GTC was 250820.66kWh. The saving by increasing thermostat set point is **3.2%** and by replacing the A/C to inverter type is **7 %** with 2.6 years of return of investment.

6.4.3 Economic evaluation of ECO for power factor improvements

Referring to Figure 5.5 for the power factor situation in GTC, the power factor becomes less than **0.9** sometimes due to defect in APC and that cost to repair the defect of capacitor bank according to local supplier of new bank capacitor is **800 NIS**. The expected work to achieve annual money saving 3612 **NIS** is highly return profits.

Table (6.11): Economic analysis of fixed the APF regulator

Energy Conservation Opportunity	Saving	Investment	S.P.B.P
ECO	NIS	NIS	Year
improvement of APF defect	3612	800.00	0.30

The total electricity consumption per year in GTC is 250820 kWh. The saving energy is 3 % by fixed the defect in GTC and the result indicates that simple payback period is 4 month.

6.4.4 Economic evaluation of ECO for induction motor:

Returning to Table 5.14, it is expected to achieve an annual energy saving of **3418 kWh/year** upon changing the standard motor comparable to high efficient motor. In case, the need to replace the motor, the price of the standard motor and high efficient motor was summarized in Appendix E. The study deducts 70 % from the list price of existing standard motor due to amortization and avoids uncertainty conditions.

1. Price of the saved energy = 1944 × 0.589 = 1145 NIS
2. The difference price between the standard and high efficient motor is 660$ (864$-0.3*677) and adds 15 % of uncertainty cost. Then, the investment cost is 2761 NIS.
3. SPBP = 2761 / 1145 = 2.4 years for high efficient motor
4. SPBP =2.4 for HEM

The results indicated that the replacement to HEM is recommended. The summary of economic and environmental analysis was shown in Table 6.12.

Table (6.12): Economic analysis of replacement standard motor with HEM

name of motor	Energy saved	Money saved	Investment	CO2 Saving	S.P.B.P
	kWh/year	NIS/year	NIS/year	Kg/year	Year
Well Pump	Efficient	Efficient	Efficient	Efficient	Efficient
	1944	1145	2761	1041	2.4

6.4.5 Economic evaluation of ECO for air compressor:

A. Repaired air leakage

1- Air compressor for Welding shop

Returning to Table 5.17, the waste power consumption is obtained by using equation 4.5b.

$$\text{Air leakage cost} = \text{Waste power} \times \text{annual operating hours} \times \text{price of kWh} \qquad 6.6$$
$$= 1.8 \times 648 \times 0.589 = 559 \text{ NIS } / \text{Year}$$

If we assume that **90 %** of the leaks can be sealed, so the annual saving will be about **492 NIS**. The investment cost is about **200 NIS** due to the material requirements and labors are free due to mobilizing them from inside the center.
The result indicates that **S.P.B.P is 4 month**.

2- Air compressor for carpentry shop

Returning to Table 5.17, the waste power consumption is obtained by using equation 4.5b.

$$\text{Air leakage cost} = \text{Waste power} \times \text{annual operating hours} \times \text{price of kWh} \qquad 6.7$$
$$= 1.9 \times 648 \times 0.589 = 591 \text{ NIS } / \text{Year.}$$

If we assume that **90 %** of the leaks can be sealed, so the annual saving will be about **504 NIS**. The investment cost is about **200 NIS** due to the material requirements and labors are free due to mobilizing them from inside the center. The result indicates that the **S.P.B.P is 4 month** and illustrated in Table 6.13.

Table (6.13): Economic analysis of arrested air leakage in the distribution network

Saving energy & Money from sealing of air leak						
No	**Opportunity**	**Cost Investment**	**Energy Saving**	**Money Saving**	**CO_2 Reduction**	**S.P.B.P**
		NIS	**kWh**	**NIS**	**kg/year**	**Year**
1	Welding & Turning Workshop	200	1182	492	852	0.41
2	Carpentry Workshop	200	1223	504	881	0.40
3	**Total**	**400**	**2405**	**996**	**1734**	

B. Improving the inlet air temperature conditions:

Returning to Table 5.19 and obtain the reduction power consumption by using of equation 4.6 for change the location of air compressor into the cold side. The achieving this work requires changing the position of air compressor or the air intake direction. The estimated investment cost is around 150 NIS for material ducts and its accessories. The summary of economic and environmental analysis upon improvements the air intake condition for air compressors in GTC is shown in Table 6.14.

Table (6.14): Economic analysis of improvement the air intake conditions

Economic Analysis for improvements of air intake conditions						
No	**Opportunity**	**Cost Investment**	**Energy Saving**	**Money Saving**	**CO_2 Reduction**	**S.P.B.P**
		NIS	**kWh**	**NIS**	**kg/year**	**Year**
1	Welding	150	583	268.8	313	0.6
2	Diesel	150	324	201.6	320	0.8
3	Carpentry	150	518	403.2	474	0.4
4	**Total**	**450**	**1425**	**873.6**	**1947.4**	

6.4.6 Model of no cost investment analysis

The no cost model of electrical conservation in GTC are using of Lumen method for light system and controlling the thermostat set point temperature to 24 C.

$$\text{Saving Factor} = \frac{\text{Saving of light system by Lumen Method} + \text{Saving of HVAC by adjust S.P}}{\text{Annual Electrical Consumption kWH}} \quad 6.14$$

$$\text{Saving Factor} = \frac{\text{Saving of light system by Lumen Method} + \text{Saving of HVAC by adjust S.P}}{\text{Annual Electrical Consumption kWH}} \quad 6.15$$

$$\text{Saving Factor} = \frac{7950+16053}{250821} = 9.6\%$$

6.4.7 Model of low cost investment analysis

Low- cost electrical conservation model are adopting compact efficient light, install reflectors for light fitting, sealing of air compressor distribution network, using cold air intake of air compressor, and excluding power factor penalty. The saving of electrical conservation programs of low-cost programs for GTC can calculate according to the following:

$$\text{Saving Factor} = \frac{\text{Saving Low Cost programs}}{\text{Annual Electrical Consumption kWH}} \qquad 6.16$$

$$\text{Saving Factor} = \frac{7855|_{indoor} + 5400|_{outdoor} + 1244|_{reflector} + 2405|_{sealing} + 1425|_{cooling}}{250821} = 7.5\%$$

6.4.8 Medium cost investment analysis:

The medium- cost electrical conservation programs are adopting automatic light fitting by occupancy sensor and replace the conventional HVAC units with new inverter compressor type one. The saving of electrical conservation programs of medium-cost programs for GTC can calculate according to the following equation:

$$\text{Saving Factor} = \frac{\text{Saving Medium Cost programs}}{\text{Annual Electrical Consumption kWH}} \qquad 6.17$$

$$\text{Saving Factor} = \frac{30210|_{sensor} + 16904|_{inverter}}{250821} = 18.7$$

6.4.9 Model of high- cost analysis:

The high-cost electrical conservation model are adopting new technology LED lamps, and install high efficient motors, the saving of electrical conservation programs of high-cost programs for GTC can calculate according to the following equation :

$$\text{Saving Factor} = \frac{\text{Saving high Cost programs}}{\text{Annual Electrical Consumption kWH}} \qquad 6.18$$

$$\text{Saving Factor} = \frac{23894\ |_{LED} + 1944\,|_{HEM_{efficient}}}{250821} = 11\%$$

6.4.9 Cash flow analysis:

Each year income and costs are experienced. In general, a cash flow is the difference between income and costs. All costs are assumed to occur at the end of each year. The total initial investment cost of saving energy in GTC is the required costs for implementing the proposed saving energy models included the installation cost and uncertainty conditions and illustrated in Table 6.15.

Table (6.15): Initial investment cost for saving energy in GTC

	Quantity	Unit Cost (NIS)	Total Cost (NIS)	Years
Indoor efficient Light	101	10.00	1,010.00	10
Outdoor Efficient Light	6	66.00	396.00	10
Install fixed capacitor	2	400.00	800.00	10
High efficient motor	1	2,761.00	2,761.00	20
Reflector	9	70.00	630.00	20
Automatic light fittings	73	430.00	31,390.00	20
High Technology LED	1013	120.00	121,560.00	20
Total Supply Cost	L.S		158,547.00	
Installation 7 % of total	L.S	1.00	11,000.00	
Uncertainty or unforeseen (2 % of total supply cost)	L.S	1	3170	
Total Initial Cost			172717	

The study will briefly review the economic analysis of the implemented models through advanced economic method called life cycle cost (LCC). The LCC method takes all costs and investments at their appropriate points in time and converts them to current costs [63]. The study assumes that the cycle time of project is 20 years and the interest value is 10 %.

Total initial Cost = Cost of supplying or replacement material + Installation material+ uncertainty or unforeseen (2 % of total initial cost).

= 158,547 + 11000 + 3170=172717 NIS

The annual Operation and maintenance Cost (O& M) is about 800 NIS and the salvage value of the design models after 20 years is taken 5 % and approximate 8636 NIS. The cost of replacement the old fixture with new one is about 2206 NIS in the second 10 years.

The life cycle cost of implement the energy saving models in GTC is obtained by drawing cash flow as in Figure 6.1:

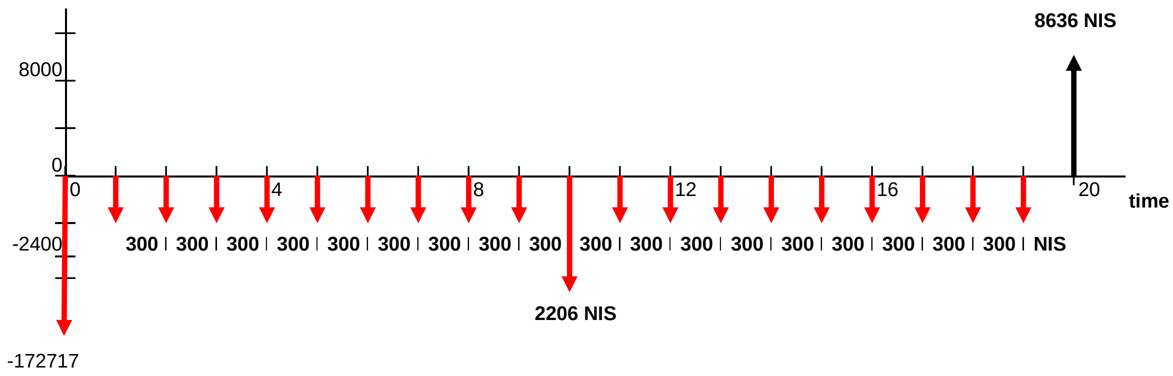


Figure 6.1: Cash flow of energy saving models for GTC.

The most important fact to remember is to convert everything to a present worth or a future worth. Then the equivalent uniform series is obtained with appropriate A/P or A/F factor according to equations 6.3 and 6.4.

The life cycle cost of implement the proposed models = initial cost of models + present worth of maintenance and operation (O&M) – present worth of salvage value + present worth of second group of replacement materials.

In order to simplify the routine engineering economy calculations involving the factors, tables of factors values have been prepared for interest rates from 0.25 to 50% and time from 1 to large n values (see Appendix H).

- P.W= 172717 + 800 (P / A i ,n)- 8636(P / F i ,n)+ 2206 (P / F i ,n)
- P.W= 172717 + 800 $(P/A_{10\%,20})$- 8636 $(P/F_{10\%,20})$+ 2206 $(P/F_{10\%,10})$

The factors [$(P/A_{10\%,20})$; $(P/F_{10\%,20})$; $(P/F_{10\%,10})$] are obtained from interest factor tables in Appendix H. The following is the simplified procedure to explain LCC analysis.

- P.W = 172717 + 800 x 8.5136-8636*.1486+2206*.3855 =179095.3

Then the equivalent annual worth AW is obtained with appropriate A/P, as follow:

- A.W= PW$(A/P_{10\%, 20})$=179095.3 (0.11746)=21036.65 NIS
- The life cycle cost is 21036.65 NIS

6.4.10 Rate of Return for the energy saving models:

Rate of return (ROR) is the rate of interest paid on the unpaid balance of borrowed money, or the rate of interest earned on the un-recovered balance of an investment, so that the final payment or receipt brings the balance to exactly zero with interest considered [63].

The annual saving money from implement four models and salvage value are saving values (Income values), but initial cost of the implemented models, cost of new replacement components and annual cost of maintenance are assuming to be outcome values.

Step 1: Specify income values for annual saving money and salvage value

- Income values = 42195(P / A i, 20) + 8636 (P / F i, 20)

Step 2: Specify outcome values including total initial cost and maintenance costs

- Outcome values = 172717+ 800 (P / A i, 20) +2206 (P / F i, 10).

Step 3: Make balance between income and outcome to specify ROR value

- Income + Outcome = zero.
- 42195(P / A i, 20)+ 8636 (P / F i, 20)- 172717-800 (P / A i, 20) -2206 (P / F i, 10)=0
- 41392 (P / A i, 20)+ 8636(P / F i, 20)-172717-2206 (P / F i, 10) =0

Step 4: Use try and error method:

By try and error the approximate i is between 22% and 24% to achieve the balance between income and outcome value of the proposed investment for electrical conservation.

Use i = 22% to estimate the actual rate of return.

- 41392*4.46+8636*0.0187-172717-2206*0.1074=11709.6 >>> 0

We are too large on the positive side, indicating that the return is more than 22%.

Try i = 24 %:

41392*4.1103+7927*0.0135-162547-2206*0.11644=-2723 <<0

Step 5: Do interpolation to estimate the value of ROR:

Since the interest rate of 24% is too high, interpolate between 22% and 24% to obtain:

$$i = .22 + \left(\frac{11709.6 - 0}{11709.6 - (-2723)}\right) * .02 = 22.8\ \%$$

R.O.R =23.6 %

6.5 Case study 2: APF as industrial sector:

6.5.1 Economic evaluation of ECO for Lighting Systems:

(A) **Replacement of CFL instead of Incandescent lamps**

Returning to Table 5.20, the annual energy saving of 1711 **kWh** is upon using more efficient lighting fixture like CFL14W instead of standard fluorescent lamp. The corresponding savings are calculated as shown in Table 6.16.

Table (6.16): Economic analysis and CO2 reduction for light fitting

Saving energy & Money from use CFL					
No	Cost	Energy Saving	Money Saving	CO_2 Reduction	S.P.B.P
	NIS	kWh	NIS	kg/year	Month
Workshop	600	1710.7	821.28	1233.77	0.73056692

(B) **Replacement of HPS 150 instead of ML 400 W:**

Returning to table 5.21 the annual energy saving of 3500 KWh upon using HPS 150 W instead of ML 400W can be achieved. The corresponding savings are as shown in table 6.17.

Table (6.17): Annual energy & money saving for light fitting by using HPS

Saving energy & Money from Install new HPS instead of ML								
No	Alternative Proposal	Power Reduction	OH	Cost	Energy Saving	Money Saving	CO_2 Reduction	S.P.B.P
		kW	hr	NIS	kWh	NIS	kg/year	Month
1	HPS 150 instead of ML 400	2	3600	560	7200	3456	5191	1.7

The amount of savings for ECO in light system reaches amount of 3 % from total electric consumption.

6.5.2 Economic evaluation of ECO for Power Factor Improvements

The energy saving of improvement of power factor was calculated from equation 5.3. The avoided penalties that considered as savings in case of imposing the penalty law are calculated according to Table 5.12 as follows:

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

$$\text{Avoided penalties} = 1.25 \times \left(\text{P.F}new - \text{P.F}old\right) \times \text{Electricity consumption}\left(\text{kWh / year}\right) \times \text{cost of kWh}$$
$$= 26915 \text{ NIS / Year.}$$

The investment cost of power factor improvement is the cost of electrical board for automatic power factor regulator including variable capacitors banks and approximates **10170NIS (Appendix F).** Table 6.18 summarizes the economic analysis of supplying and installation of APF regulator including the saving money, which reached to **18 % (26915 NIS)** from total cost of electric consumption in APF**.**

Table (6.18): Economic analysis of supplying and installation APF regulator

Energy Conservation Opportunity	Saving	Investment	S.P.B.P
ECO	NIS	NIS	Year
Supply & Install APF Regulator	26915	10170	0.37

6.5.3 Economic Evaluation of ECO for Induction Motor:

Returning to Table 5.22, 5.23, the total energy saving to install new efficient motor instead of standard motor was calculated according to equations 4.5. The results in Table 6.19 indicates that the replacement from standard motors to HEM is recommended for well pump and breakers but hydraulic motor is not recommended due to about 3 year for return of the investment. The amount of electrical savings is **10598** kWh without adding hydraulic motor.

Table (6.19): Economic analysis of changing the standard motor with HEM

name of motor	Energy saved	Money saved	Investment	CO2 Saving	S.P.B.P
	kWh	NIS	NIS	Kg	Year
Well Pump	3250	1914	3228	2574.97	1.68
Breaker1	3674	2163	1993	2242	1.0
Breaker2	3674	2163	1993	2242	1.0
Motor for Hydraulic	4681	2298	6277	1041	3

6.5.4 Economic evaluation of ECO for Air Compressor:

1. Repaired air leakage:

Returning to Table 5.25 and obtain the waste power consumption by using equation 5.5b for air leak. If we assume that **90 %** of the leaks can be sealed according to IEEE 739-1995, so the annual saving will be about **2774.7 NIS**. The investment cost is about **420 NIS** due to the material requirements and labors cost. The result indicates that **S.P.B.P is about 2 month and illustrated in Table 6.20**.

$$\text{Air leakage cost} = \text{annual Waste power} \times \text{price of kWh}$$
$$= 6243 \times 0.589 = 3677 \text{ NIS } / year$$

Table (6.20): Economic Analysis for Air Compressor by arrested air leak

Air leak						
No	**Opportunity**	**Cost Investment**	**Energy Saving**	**Money Saving**	**CO_2 Reduction**	**S.P.B.P**
		NIS	**kWh**	**NIS**	**kg/year**	**Month**
1	Air Compressor 1,2,3	420	6243	3677	4501	1.8
2	**Total**	**420**	**6243**	**3677**	**4501**	1.8

2. Improving the inlet air temperature conditions

Returning to Table 5.27 and obtain the reduction power consumption by using of equation 5.6 for change the location of air compressor into the cold side. The average power saving is about **0.65 kW** for air compressors in factory.

$$\text{Energy reduced} = \text{power saving} \times \text{operating hours}$$
$$= 5616 \text{ kWh / Year.}$$

$$\text{Money saving} = \text{energy reduced} \times \text{cost of kWh}$$
$$= \; = 5616 \times 0.589 = 3307.8 \text{ NIS per year.}$$

Changing the position of air compressor or the air intake direction is only required. The investment cost for improving the inlet air intake for the air compressor in Palestinian factory was estimated **650 NIS** for supply and installation ducts from outside into inside the allocation of air compressor.

The result indicates that the return the investment cost is about **6 month**, so the change of inlet air position is needed immediate. The summary of economic and environmental analysis upon improvements the air intake condition for air compressors in APF was shown in Table 6.21.

Table (6.21): Annual saving for energy & money, and CO2 reduction

Economic Analysis for improvements of air intake conditions						
No	**Opportunity**	**Cost Investment**	**Energy Saving**	**Money Saving**	**CO_2 Reduction**	**S.P.B.P**
		NIS	**kWh**	**NIS**	**kg/year**	**Month**
1	Air Compressor1	650	3024	1781	2180	4.0
2	Air Compressor2	650	2592	1526.7	1867	6.0
3	**Total**	**1300**	**5616**	**3307.8**	**4049**	

6.5.5 Model of low cost saving analysis:

The low- cost electrical conservation model is adopting compact efficient indoor and outdoor light, sealing of compressor air leak, using cold air intake of air compressor. The saving of electrical conservation model of low-cost programs for GTC can calculate according to the following equation:

$$\text{Saving Factor} = \frac{\text{Saving Low Cost programs}}{\text{Annual Electrical Consumption kWH}} \qquad 6.19$$

$$\text{Saving Factor} = \frac{1711|_{indoor} + 7200|_{outdoor} + 6243|_{sealing} + 5616|_{cooling}}{263874.65}$$
$$= 7.8\%$$

6.5.6 Model of high- cost analysis:

The high- cost electrical conservation model is adopting automatic power factor controller and install high efficient motors. The power factor penalties excludes from saving calculation. The saving of electrical conservation programs of high-cost programs for GTC can calculate according to the following equation:

$$\text{Saving Factor} = \frac{\text{Saving high Cost programs}}{\text{Annual Electrical Consumption kWH}} \qquad 6.20$$

$$\text{Saving Factor} = \frac{10598|_{HEM_{efficient}}}{263874.65}$$
$$= 3.5\%$$

6.5.7 Cash flow analysis:

Each year income and costs are experienced. In general, a cash flow is the difference between income and costs. All costs are assumed to occur at the end of each year. The total initial cost of energy saving investment in APF is the required costs for implementing low cost and high cost models, and illustrated in Table 6.22.

Table (6.22): Initial investment cost for saving energy in APF

	Quantity	Unit Cost (NIS)	Total Cost (NIS)	Years
Indoor efficient Light	60	10.00	600.00	10
Outdoor Efficient Light	8	70.00	560.00	10
APF with capacitor banks	L.S	1	10170.00	10
High efficient motor	1	7214.00	7214.00	20
Accessories for air compressor	9	70.00	1300.00	20
Total Supply Cost	L.S	1	27,058.00	
Installation cost 10 %	L.S	1.00	2705.00	
Uncertainty or unforeseen (6 % of total supply cost)	L.S	1	1047	
Total Initial Cost			30810	

The economic procedure to calculate the life cycle cost of our study can perform similar to LCC evaluation in APF.

Total initial Cost = Cost of supplying or replacement material + Installation material+ uncertainty or unforeseen (2 % of total initial cost).

= 27058 + 2705 + 1047=30810 NIS

The annual Operation and maintenance Cost (O & M) cost is about 200 NIS and the salvage value (the residual value) of the design models is taken 10 % (approximates 2705 NIS) after cycle time is completed. The cost of replacement the old fixture and capacitor banks with new one is about 6245 NIS in the second 10 years.

The life cycle cost of implement the energy saving models in GTC is obtained by drawing cash flow as in Figure 6.2:

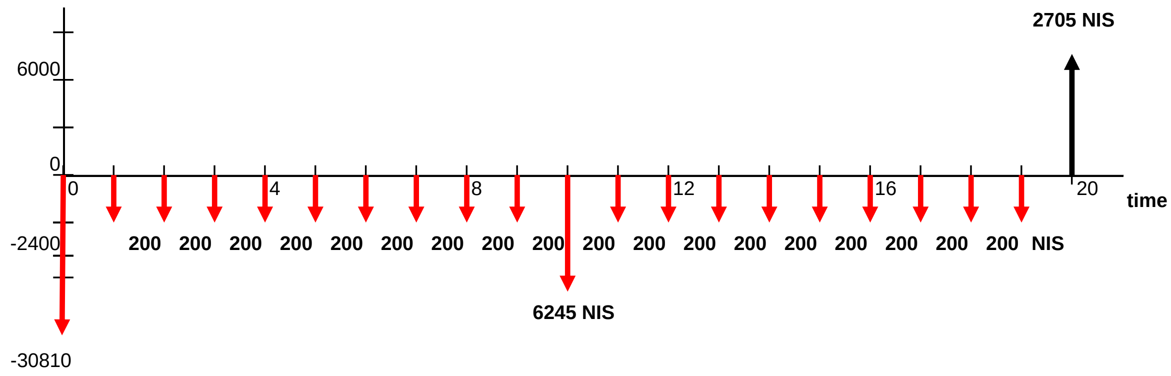


Figure 6.2: Cash flow of energy saving models for APF

We assume that the lifetime of project is 20 years and the interest value is 10 %.

The life cycle cost of implement the proposed models = initial cost of models + present worth of maintenance and operation – present worth of salvage value + present worth of second group of replacement materials.

- P.W= 30810+ 200 (P / A i ,n)- 2705 (P / F i ,n)+ 6245 (P / F i ,n)
- P.W= 30810 + 200 $(P/A_{10\%,20})$- 2705 $(P/F_{10\%,20})$+ 6245 $(P/F_{10\%,10})$

The factors of above equation are obtained from interest factor tables in Appendix H.

- P.W = 30810 + 200 x 8.5136-2705*.1486+6245*.3855 =34518 NIS

Then the equivalent annual worth AW is obtained with appropriate A/P as follow:

- A.W= PW$(A/P_{10\%,\ 20})$=33567* (0.11746)=4054.5 NIS

6.5.8 Rate of Return for the energy saving models

The annual saving money from implement four models and salvage value are saving values (Income values), but initial cost of the implemented models, cost of new fixtures and annual cost of maintenance are assuming to be outcome values.

Step 1: Specify income values for annual saving money and salvage value

- Income values = (10951)(P / A i, 20) + 2705 (P / F i, 20).

Step 2: Specify outcome values including total initial cost and maintenance costs

- Outcome values = 30810+ 200 (P / A i, 20) +6245 (P / F i, 10).

Step 3: Make balance between income and outcome to specify ROR value

- Income + Outcome = zero.
- 10951(P / A i, 20)+ 2705 (P / F i, 20)- 30810-200 (P / A i, 20) -6245 (P / F i, 10)=0

- 10751 (P / A i, 20)+ 2705 (P / F i, 20)- 30810-6245 (P / F i, 10) =0

Step 4: Use try and error method:

By try and error the approximate i is between 30% and 35% to achieve the balance between income and outcome value of the proposed investment for electrical conservation.

Use i = 30% to estimate the actual rate of return.

- 10751*3.3185+2705*0.0053-30810-6245*0.0497=477.65 >>> 0

Try i=35.

- 10751*2.85+2705*0.00247-30810-6245*0.0725=-473<< 0

Step 5: Do interpolation to estimate the value of ROR:

Since the interest rate of 35 % is too high, interpolate between 30% and 35 % to obtain:

$$R.O.R = i = 32.5122$$

6.6 Summary of Electrical Energy Results:

1. GTC:

Table (6.23): Summary of outcome research included the electrical and money saving in GTC.

ECM	Energy Opportunity	Electrical Consumption kWh/year	Saving KWh kWh/Year	Saving Money NIS	Saving CO2 Kg	Saving Factor %
Model of No Cost Opportunities	Removing Excess Light	250820	16053	7705.44	11574	6.40%
	HVAC S.P=24 C	250820	7950	3816	5732	3.17%
	Total		24003	11521.44	17306	9.6 %
Model of Low Cost Opportunities	Compact Efficient Light	250820	7855	4626.6	5663	3.1%
	Outdoor Sodium Lamp	250820	5400	3181.6	3893	2.2%
	Sealing air leak of Air Compressor	250820	2405	1107.36	1734	1.2 %
	Cooling Air intake of Air Compressor	250820	1425	873.6	1106	1%
	Total		17194	10127	12912	7.5 %
Model of Medium Cost Opportunities	Automatic Light System	250820	30210	17793.7	21781	12%
	HVAC Inverter Type	250820	16904	8113.92	12188	7%
	Total		47105	22610.4	33962	19 %
Model of high Cost Opportunities	High Technology LED Lamps	250820	23894	14073.6	17227	9.5 %
	High Efficient Motor	250820	1944	1140	2464	1.36%
	Total		27312	16114	19692	11 %

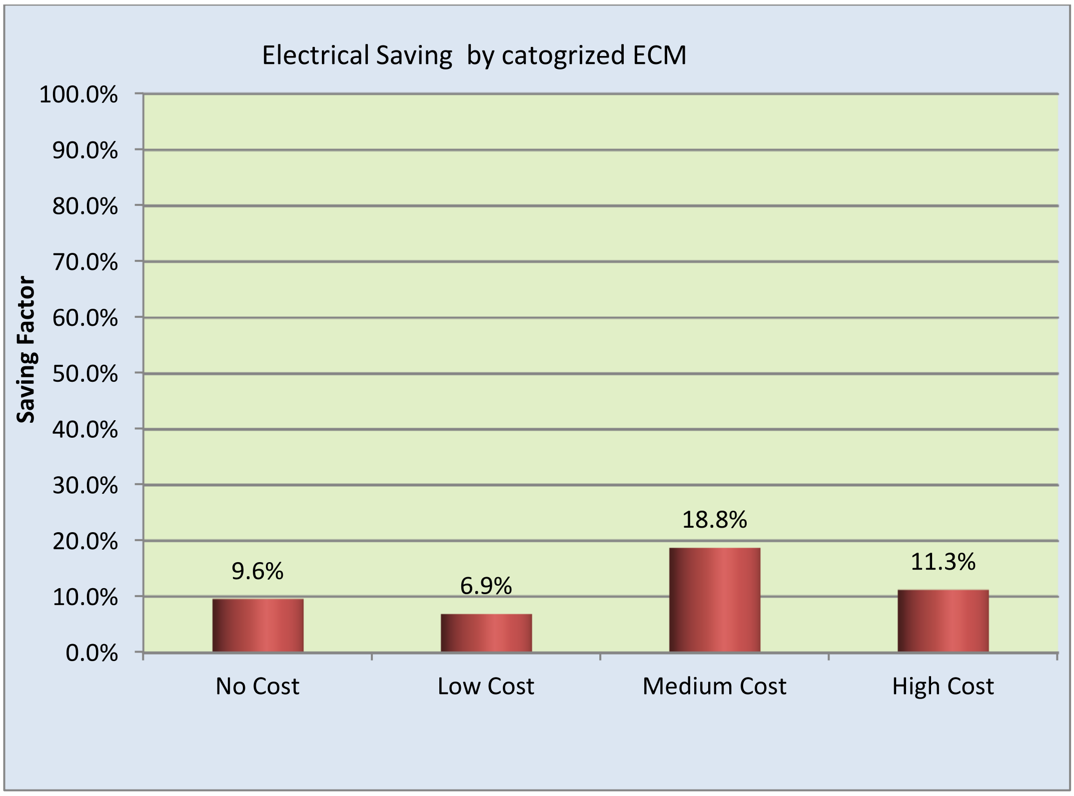


Figure 6.3: Cost and Energy Saving in GTC

1- Palestinian Construction factory

Table (6.24): Summary of outcome research included the electrical and money saving in APF.

ECM	Energy Opportunity	Electrical Consumption	Saving KWh	Saving Money	Saving CO2	Saving Factor
		kWh/year	kWh/Year	NIS	Kg	%
Model of No Cost Opportunities						
Model of Low Cost Opportunities	Compact Efficient Light	263875	1710.7	821.28	1233	1.1%
	Outdoor Sodium Lamp	263875	7200	4240	5191	3.2%
	Sealing air leak of Air Compressor	263875	6243	3677	4501	2.2%
	Cooling Air intake of Air Compressor	263875	5616	3307	4049	2.2%
	Total		20769.7	12233	14974.04	7.8 %
Model of Medium Cost Opportunities						
Model of high Cost Opportunities	High efficient Motor	263875	10598	6242	7345	3.71%

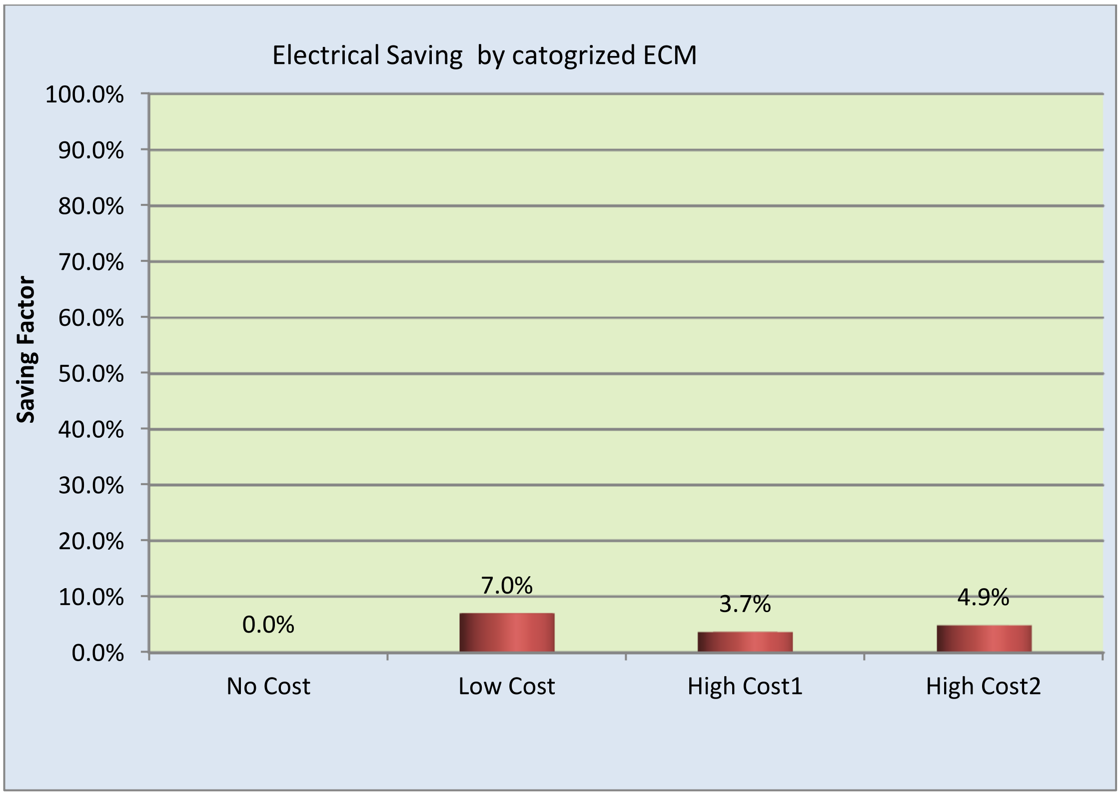


Figure 6.4: Effective-cost energy saving in APC

Summary:

The study revealed from the previous economic analysis that no cost energy saving actions in training center achieved annual saving of 11521 NIS undertaken the removing the excess lamp and readjust the thermostat set point.

Low cost energy saving actions also achieved in GTC annual saving money about 10127 NIS and 12233.3 NIS in Factory by adopting compact fluorescent lamps instead of incandescent lamps, outdoor high-pressure sodium, sealing air leak in distribution network of air compressors and cooling air intake of air compressors.

Medium cost energy saving actions in GTC achieved annual saving money about 22610 NIS undertaken install automatic light system and HVAC system with inverter type.

High cost energy saving actions achieved annual saving cost 16114 NIS with average simple payback period for GTC and 6242.2 NIS for APF. A huge amount of energy and carbon dioxide savings in various facilities could be achieved by implementing no cost and low cost energy conservation measures.

It means that we could save a good percentage in energy consumption by just a simple changing in the behavior of energy utilization (no cost) or by a small amount of investment in order to achieve the required goal (low cost).

Table 6.23 and 6.24 summarized the percentage of saving energy after implementing the energy conservation strategies and measures. Those amount of savings mentioned here are not including the amount of savings achieved by avoiding the low power factor penalties, due to that the municipalities did not start yet to impose these penalties.

CHAPTER 7

ELECTRICAL CONSERVATION SIMULATION

7.1 Introduction:

The mathematical electrical conservation formulas models in the previous chapters were converted into interface user to facilitate the calculation of energy saving for electrical conservation models in this research. The designing program allows any user to insert measurement data for each energy conservation opportunity in any plant and get the saving ratio of electrical energy and reduction money, and finally print the summary report. The summary report can raise top management of the specified plant to make decision. The objectives in developing the software are; to identify electrical energy, waste, and cost saving opportunities, and calculate the expected savings, implementation cost and simple payback of each opportunity, to assist managers and engineers to manage their electrical energy consumption

7.2 Software components and features

The features of this software can be divided into four models as shown in Figure 7.1. Each model consists of the proposed opportunities in light system, HVAC system, electrical air compressor, power factor corrections and induction motors under this research. The designing software can determine the technical analysis output and the economic analysis for each opportunity in the proposed designing model in this resrach. There are menu bars in the software, which are the pop-up menu bar. The appearance of these bars allows the user to select and enter the desired function for each model. The structure of the program was divided into the following menu functions; an introduction, theory of induction motor, determination of motor performance, analysis of standard motor and HEM and help function which consist of useful information for the user

7.3 Software Language

In this project, I used ActionScript 3.0 as programming language to implement the entire simulation, because it's a cross-platform runtime environment developed by Adobe Systems for building Rich Internet Applications (RIA) using Adobe Flash, Adobe Flex, HTML, and Ajax, that can be run as desktop applications or on mobile devices.

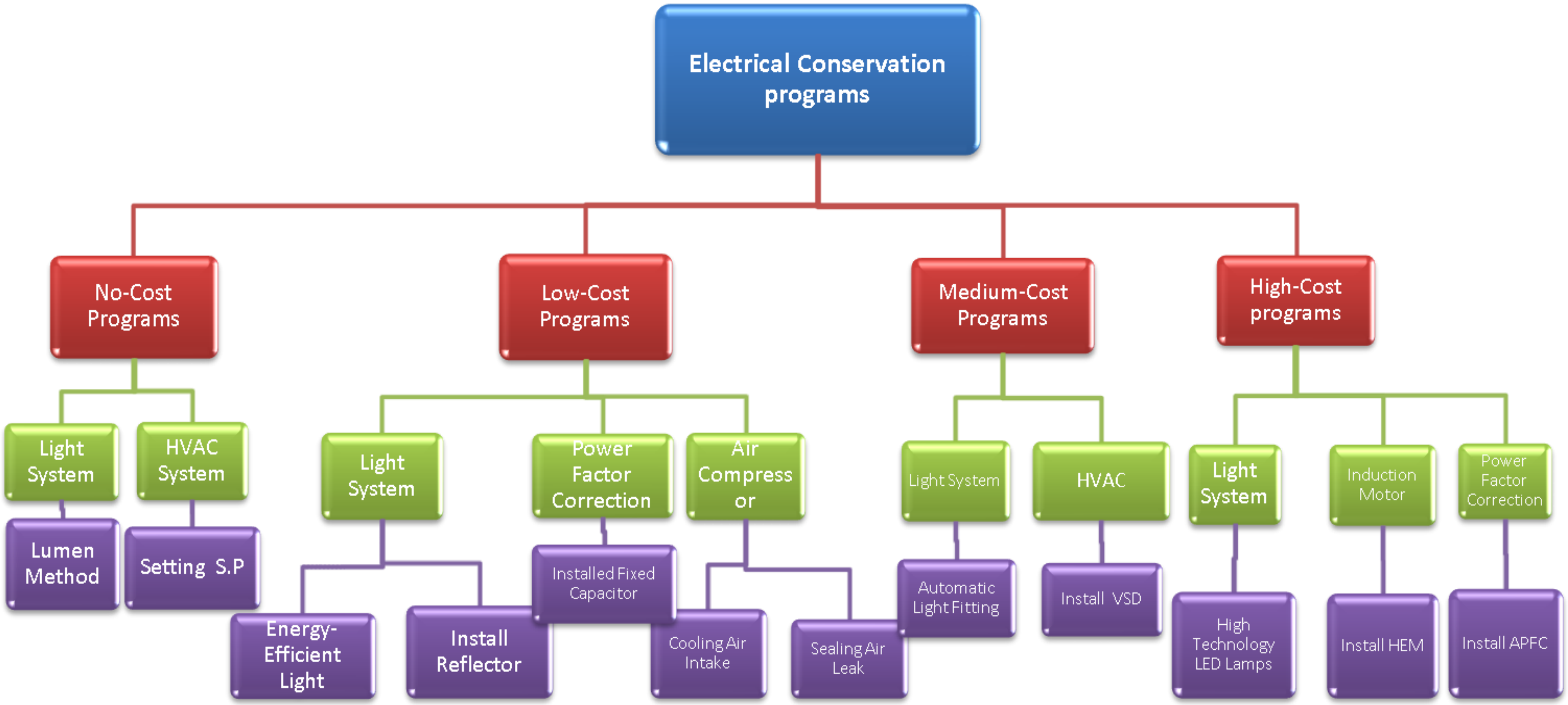


Figure 7.1: Simulation Program Structure

7.4 User Graphic interface:

The main screen desktop of the designing simulation software is shown in Figure 7.2. The software include a security level to restrict the using software and only authorized engineers allow to access to software.

Figure 7.2: Security access of electrical conservation program.

The new widow at desktop will open as shown in Figure 7.3 after insert the user and password, the open window includes five top menu bars for the designing electrical conservation models in this research and the summary report.

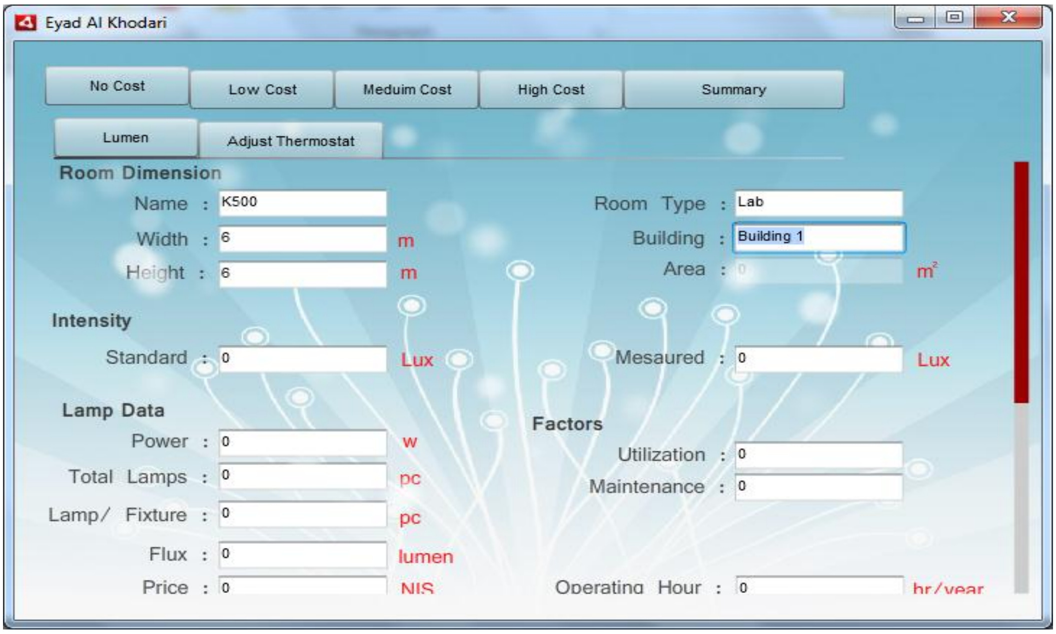


Figure 7.3: Main menu bars of the designing software.

The simulation of lumen method is shown in Figure 7.4; the user inserts the measuring and rating inputs according to the specific space in the software. The outcome result appears after pressing insert new item to get the results or output as shown in Figure 7.5.

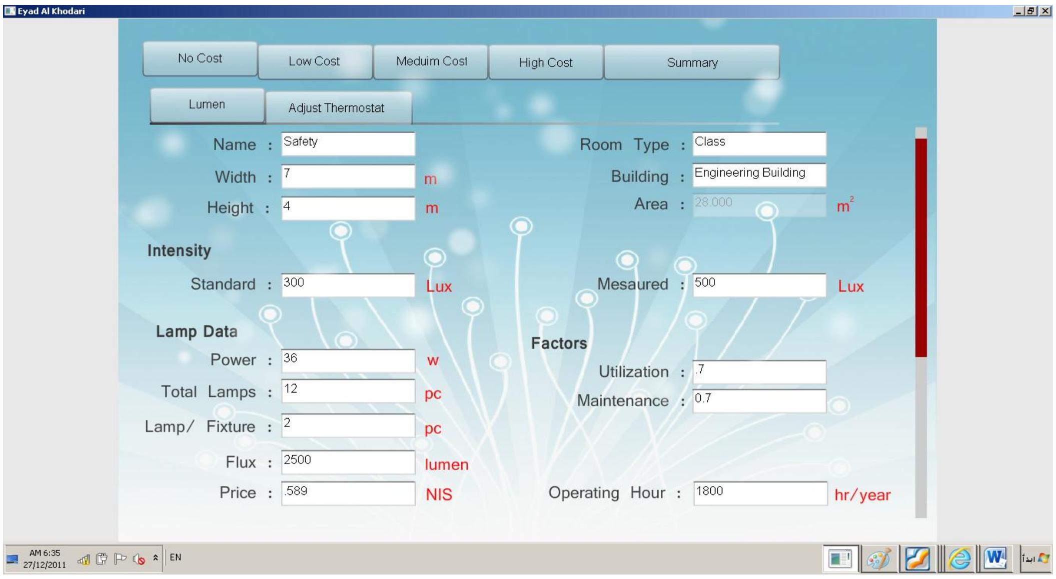


Figure 7.4: Lumen method window showing the required parameters.

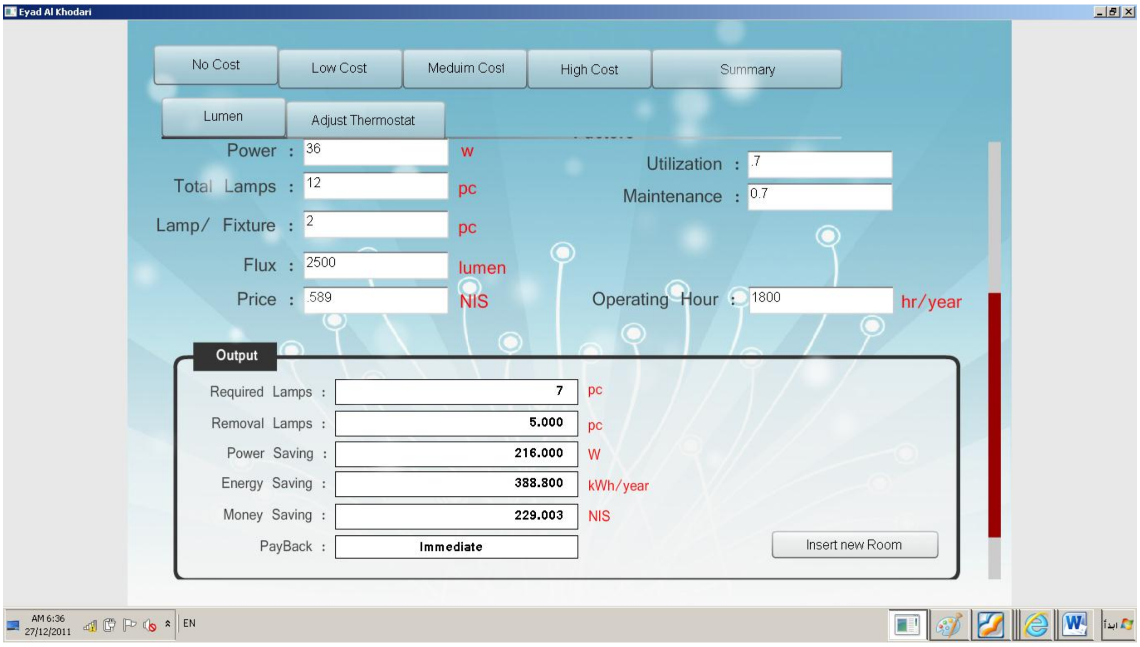


Figure 7.5: Lumen method window showing the output results.

The test value to get the summary report for the adopting models of electrical conservation opportunities in plant is shown in Figure 7.6.

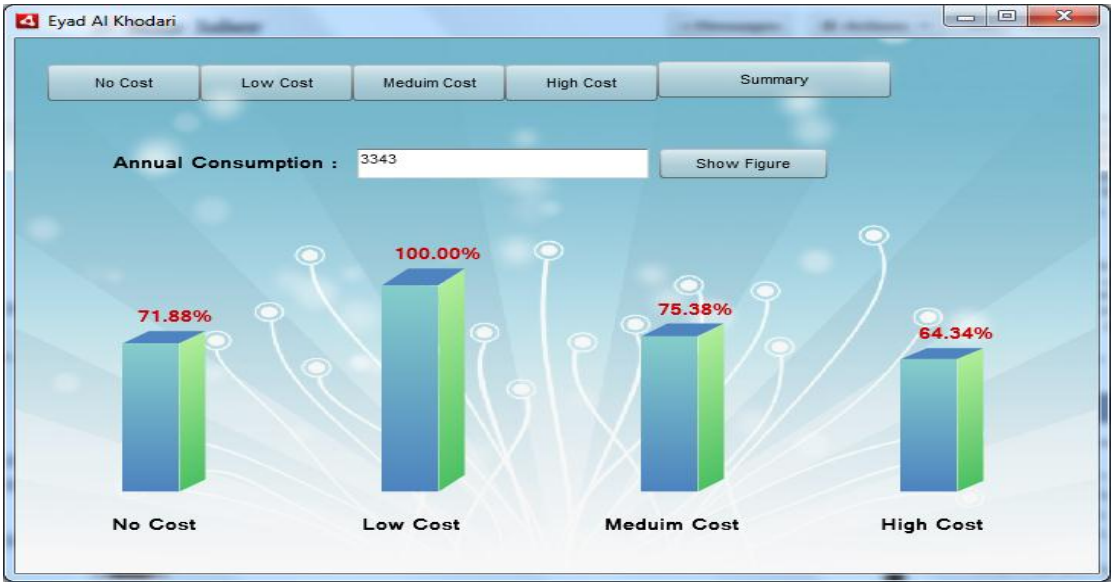


Figure 7.6: Test simulation summary report results.

The actual result of GTC plant is shown in Figure 7.7; the user can insert only the annual electrical bill consumption after recorded all measuring and data inputs for each investment model in the plant

Figure 7.7: GTC summary report results.

CHAPTER 8:

CONCLUSION AND RECOMMENDATION

8.1 Conclusion

In general, the electricity sector is characterized by a relatively low level of electricity consumption; in the Gaza Strip, electricity consumption was estimated at 1031.514 GWh/year in the year 2010**.** Statistics for energy consumption by sector showed that the commercial and industrial sectors in Gaza Strip and West Bank compose roughly one-third of the total G.S and W.B energy consumption in 2009. The electrical energy consumption approximates 30 % of the total energy sources in G.S & W.B.

The Palestinian electricity sector suffers from many problems, such as high electrical deficit rate, high transmission losses, high electricity prices per kWh, unbalanced annual demand and growth and absence of energy management strategies and skills.

This research investigated the potential of energy conservation opportunities in various facilities in G.S through energy management techniques in order to reduce energy consumption, protect the environment, and save money. The main purpose of this study was to decrease the rate of electrical deficit between demand and supply in Gaza strip to enhance and support the national economy.

One of strategic solution to reduce the rate of electrical deficit is energy improvements for the commercial and industrial sectors in Gaza Strip. The case studies selected to demonstrate the use of method in order to measure energy savings into components. The savings opportunities were identified for light system, compressed air, heating, ventilating and air conditioning, induction motor, and power factor correction. Each assessment identifies energy, waste, and cost saving opportunities, and quantifies the expected savings, implementation cost and simple payback of each opportunity.

In this research, the proposed models in industrial and commercial facilities were no cost model energy investment by adopting lumen method of light system and adopting thermostat set point of HVAC system, low cost model by adopting high efficient lamps indoor and outdoor buildings, sealing air of compressed air, and air intake cooling source, in medium cost model by adopting automatic light fittings and install new air condition with inverter type, and in high cost model by implementing high technology LED lamps and high efficient motor.

The expected energy saving for no cost energy saving model achieves annual average energy saving of 9 % with 24003 kWh of electricity and equivalent to 11521.44 NIS and the model includes the lumen method and readjust HVAC thermostat set point. The lumen method implements into all classes, labs, offices, and other areas to reduce excess lamps and evaluation of thermostat set point of cooling system to optimal set point in summer seasonal in order to reduce the electrical consumption by internal electrical equipment of air condition.

Low cost energy saving actions achieve annual average energy saving of 7.5 % with 17194 and equivalent to 10127 NIS in GTC , in addition to 8 % with 20770 kWh and equivalent to 12233NIS in factory and low cost energy saving model includes installed high efficient lamps indoor and outdoor buildings such as compact florescent lamps and high pressure sodium and improves the performance of electrical air compressors in GTC and APF.

Medium cost energy saving actions achieve average energy saving of 19 % with 47105 kWh and equivalent to 22610 NIS in GTC and medium cost model includes evaluation of automatic light fittings and install new air condition with inverter type, automatic light fittings consists of occupancy sensor with illumination level and timer set to activate the lamp group switch after a set period.

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High cost energy saving actions achieve average energy saving of 11 % corresponding 27312 kWh and equivalent to 16114 NIS in GTC , in addition to 4.5 % with 10598 kWh and equivalent to 6242.2 NIS in some of induction motor in APC and high cost model includes evaluation of installed high technology LED lamps and high efficient motor in GTC and APF. High technology LED lamps evaluate in offices, labs, and offices through the power consumption rate for the fluorescent and LED lamps. High efficient motor is primary characterized by low losses in windings and it is proper to installed in industrial factories in G.S in replace of standard motor.

The research proposes a model included five energy savings of electrical conservation for energy used light system, HVAC system, air compressor, partial of induction motors, and power factor correction. The total expected savings from implementing all five recommendations of electrical conservation models was 85,418 kWh per year corresponding to 50311 NIS per year for GTC and 24070 kWh per year corresponding to 14177 NIS per year in APF.

The outcome research in particular contribute to reduce the electrical deficit rate with ratio as the first priority for this research and achieve a good investment in commercial and industrial sectors as a second priority to enhance and support the national economy.

Based on the results of this research, the following recommendations are hereby made:

8.2 Future Work

1. The models of electrical conservation through energy managements can be applied at various facilities in Gaza Strip, especially house holding, services, universities, hospitals, mosques, etc.
2. The research recommended setting up the local regulation and issuing legal enforcement of energy codes and practices for energy conservation and efficiency.
3. The research recommended establishing a research energy center at IUG to support and develop the models of electrical conservation and encourage the research related to new technology and automation control models.
4. The study recommends performing more energy audits at more sites
5. The research suggests starting a public awareness of energy management in the schools and universities, and using public multimedia programs.
6. The research recommends interactions among Palestinian universities and research centers in Gaza Strip and West Bank regarding electrical conservation through energy management.
7. The research recommends performing researches combining automation and control systems with electrical conservation models.

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APPENDIX A: ILLUMINATION STANDARDS IESNA [48,61]

Place	Standard illumination (lm/m²) or lux
Classrooms	300-500
Offices	250-500
Laboratories	300`
Conference Room	700
Dissect Hall	700
Drawing Halls	500
Building Entrance	10-50
boiler Area	20-50
Parking Area	10-20
Studio	300
Lobbies	150
Corridors	150
Cafeteria	150
Electrical Room	150
Boiler Room	150
Store	200
Mosque	100
W.C	100

APPENDIX B: ILLUMINATION MEASUREMENT IN GTC

1- Commerce Building

Room Description				Light Existing Data				Measured	Stand.	Consumption		Proposed Energy			Saving Energy	
No	Name	Type	Area m2	Type	Manf	Total Lamp Pc	Rating W	Lux	Lux	KW	(kwh/y)	Removal	(kw)	(kwh/y)	Kw	(kwh/y)
First Floor																
1	K/F1/R60	Office	12	FL	Osram	**4**	**36**	**221**	**250**	**0.17**	**311.04**	**0**	**0.17**	**311.04**	**0.00**	**0**
2	K/F1/R65	Class	32	FL	Osram	**6**	**36**	**280**	**300**	**0.26**	**466.56**	**0**	**0.26**	**466.56**	**0.00**	**0**
3	K/F1/R64	Class	42	FL	Osram	**8**	**36**	**390**	**300**	**0.35**	**622.08**	**0**	**0.35**	**622.08**	**0**	**0**
4	K/F1/R66	Class	67	FL	Osram	**10**	**36**	**390**	**300**	**0.43**	**777.6**	**0**	**0.43**	**777.6**	**0.00**	**0**
5	Corridor	Corridor	23	FL	Osram	**12**	**36**	**160**	**150**	**0.52**	**933.12**	**4**	**0.35**	**622.08**	**0.17**	**311.04**
Second Floor																
6	F2/R102	CLASS	46	FL	Toshiba	**6**	**36**	**180**	**300**	**0.26**	**466.56**	**0**	**0.26**	**466.56**	**0.00**	**0**
7	F2/R105	Class	45	FL		**6**	**36**	**340**	**300**	**0.26**	**466.56**	**0**	**0.26**	**466.56**	**0.00**	**0**
8	F2/R103	Class	44	FL	Toshiba	**6**	**36**	**230**	**300**	**0.26**	**466.56**	**0**	**0.26**	**466.56**	**0.00**	**0**
9	F2/R104	Class	45	FL	Toshiba	**6**	**36**	**300**	**300**	**0.26**	**466.56**	**0**	**0.26**	**466.56**	**0.00**	**0**
10	F2/R108	Corridor	22	FL	Toshiba	**8**	**36**	**170**	**150**	**0.35**	**622.08**	**4**	**0.17**	**311.04**	**0.17**	**311.04**
Third Floor																
11	K/F3/R78	Class	38	FL	Toshiba	**8**	**36**	**300**	**300**	**0.35**	**622.08**	**0**	**0.35**	**622.08**	**0.00**	**0**
12	K/F3/R81	Class	46	FL	Osram	**12**	**36**	**350**	**300**	**0.52**	**933.12**	**0**	**0.52**	**933.12**	**0.00**	**0**
13	K/F3/R79	Class	43	FL	Osram	**8**	**36**	**225**	**300**	**0.35**	**622.08**	**0**	**0.35**	**622.08**	**0.00**	**0**
14	Library	Lib	88	FL	Toshiba	**24**	**36**	**320**	**300**	**1.04**	**1866.24**	**2**	**0.95**	**1710.72**	**0.09**	**155.52**
15	Office	Office	30	FL	Toshiba	**8**	**36**	**325**	**250**	**0.35**	**622.08**	**2**	**0.26**	**466.56**	**0.09**	**155.52**
16	K/F3/R77	Class	46	FL	Toshiba	**4**	**36**	**250**	**300**	**0.17**	**311.04**	**0**	**0.17**	**311.04**	**0.00**	**0**
17		Class	43	FL	Toshiba	**12**	**36**	**390**	**300**	**0.17**	**311.04**	**4**	**0.00**	**0**	**0.17**	**311.04**

18	Corridor	Corridor	22	FL	Toshiba	**6**	**36**	**160**	**150**	**0.26**	**466.56**	**2**	**0.17**	**311.04**	**0.09**	**155.52**
19	Total					146					11352.96	20.00		9797.76		1555.20

2- Engineering Building

Area Description				Fixture		Rating	Measurd	Stand.	Consumtion		Proposed Energy Consumption			Saving Energy	
No	Name	Type	m2	Type	Nos	W	Lux	Lux	kW	kWh/year	Removal	kW	kWh/year	kW	KWh/YEAR
First Floor															
1	B2-02	Office	13	FL	4	36	260	250	0.1728	311.04	2	0.0864	155.52	0.0864	155.52
2	B2-05	Class	104	FL	36	36	350	300	1.5552	2799.36	12	1.0368	1866.24	0.5184	933.12
4	B2-07	Class	108	FL	24	36	330	300	1.0368	1866.24	0	1.0368	1866.24	0	0
5	fashioncor	corridor	18	FL	6	36	200	150	0.2592	466.56	2	0.1728	311.04	0.0864	155.52
6	B2/04	LAB	19	FL	8	36	400	500	0.3456	622.08	0	0.3456	622.08	0	0
7	B2-03	Store	12	FL	4	36	220	200	0.1728	311.04	0	0.1728	311.04	0	0
8	B2-017	Class	40	FL	8	36	200	300	0.3456	622.08	0	0.3456	622.08	0	0
9	corridor	corridor	95	FL	14	36	200	150	0.6048	1088.64	3	0.4752	855.36	0.1296	233.28
10	corridor	corridor	35	FL	6	36	800	150	0.2592	466.56	2	0.1728	311.04	0.0864	155.52
11	corridor	corridor	97	FL	16	36	750	150	0.6912	1244.16	4	0.5184	933.12	0.1728	311.04
12	corridor	corridor	99	FL	16	36	200	150	0.6912	1244.16	4	0.5184	933.12	0.1728	311.04
15	B2/015	Office	21	FL	6	36	290	250	0.2592	466.56	1	0.216	388.8	0.0432	77.76
16		Office	13	FL	4	36	850	250	0.1728	311.04	1	0.1296	233.28	0.0432	77.76
17		kitchen	11	FL	4	36	210	500	0.1728	311.04	0	0.1728	311.04	0	0
Second Floor															
18	CT	Class	60	FL	26	36	370	300	1.1232	2021.76	11	0.648	1166.4	0.4752	855.36
19	Safety	Class	28	FL	12	36	500	300	0.5184	933.12	5	0.3024	544.32	0.216	388.8
20	b2-105	Office	21	FL	6	36	220	250	0.2592	466.56	1	0.216	388.8	0.0432	77.76
21	B2116	Office	16	FL	4	36	200	250	0.1728	311.04	0	0.1728	311.04	0	0
22	B2118	Office	14	FL	4	36	113	250	0.1728	311.04	0	0.1728	311.04	0	0
22	CT2	Class	37	FL	8	36	350	300	0.3456	622.08	0	0.3456	622.08	0	0
24		Drawing	111	FL	48	36	750	500	2.0736	3732.48	8	1.728	3110.4	0.3456	622.08
25	b2/22	Class	92	FL	40	36	450	300	1.728	3110.4	20	0.864	1555.2	0.864	1555.2

26		Office	11	FL	6	36	310	250	0.2592	466.56	3	0.1296	233.28	0.1296	233.28
27		Store	11	FL	4	36	275	200	0.1728	311.04	2	0.0864	155.52	0.0864	155.52
28	b2/23	class	112	FL	36	36	400	300	1.5552	2799.36	8	1.2096	2177.28	0.3456	622.08
29	b2/24	Class	53	FL	16	36	350	300	0.6912	1244.16	3	0.5616	1010.88	0.1296	233.28
30		Office	27	FL	4	36	340	250	0.1728	311.04	0	0.1728	311.04	0	0
31		corridor	35	FL	6	36	340	150	0.2592	466.56	0	0.2592	466.56	0	0
32		corridor	97	FL	16	36	340	150	0.6912	1244.16	0	0.6912	1244.16	0	0
34		corridor	99	FL	16	36	340	150	0.6912	1244.16	0	0.6912	1244.16	0	0
Third Floor															
36		corridor	67	FL	10	36	150	150	0.432	777.6	2	0.3456	622.08	0.0864	155.52
37	b2-250	Office	15	FL	4	36	270	250	0.1728	311.04	1	0.1296	233.28	0.0432	77.76
38	B2-28	Office	13	FL	4	36	255	250	0.1728	311.04	1	0.1296	233.28	0.0432	77.76
39	B2-215	Office	8	FL	4	36	255	250	0.1728	311.04	2	0.0864	155.52	0.0864	155.52
40	B2-213	Office	11	FL	4	36	255	250	0.1728	311.04	1	0.1296	233.28	0.0432	77.76
41	B2-214	Office	11	FL	4	36	255	250	0.1728	311.04	1	0.1296	233.28	0.0432	77.76
42		fabrication	122	FL	24	36	220	250	1.0368	1866.24	0	1.0368	1866.24	0	0
43		waiting	17	FL	4	36	220	250	0.1728	311.04	0	0.1728	311.04	0	0
44		Corridor	35	FL	8	36	220	250	0.3456	622.08	1	0.3024	544.32	0.0432	77.76
45		corridor	99	FL	16	36	220	250	0.6912	1244.16	0	0.6912	1244.16	0	0
	Total				490					38102.4	101		30248.64		7853.76

3- English and Administration Building

Area Description				Fixture		Rating	Measured	Stand.	Old Consumption		New Consumption			Saving Energy	
No	Name	Type	m2	Type	Nos	W	Lux	Lux	KW	Kwh/year	Removal	kW	kWh/year	Kw	kWh/year
First Floor															
1	Sport	Office	98	FL	16	36	192	250	0.6912	1244.16	0	0.6912	1244.16	0	0
2	Fabrication	class	69	FL	14	36	203	300	0.6048	1088.64	0	0.6048	1088.64	0	0
3	men food	fooding	143	FL	24	36	403	150	1.0368	1866.24	6	0.7776	1399.68	0.2592	466.56
4	Women Food	fooding	253	FL	40	36	240	150	1.728	3110.4	8	1.3824	2488.32	0.3456	622.08
6	Kitchen	kitchen	87	FL	18	36	330	150	0.7776	1399.68	6	0.5184	933.12	0.2592	466.56
7		office	17	FL	2	36	170	250	0.0864	155.52	0	0.0864	155.52	0	0
8	Supervisor	office	11	FL	2	36	170	250	0.0864	155.52	0	0.0864	155.52	0	0
9		Washing	14	FL	4	36	150	100	0.1728	311.04	2	0.0864	155.52	0.0864	155.52
10	Cleaning	Store	14	FL	2	36	200	100	0.0864	155.52	0	0.0864	155.52	0	0
11	Tools	Store	11	FL	2	36	140	150	0.0864	155.52	0	0.0864	155.52	0	0
12	Fooding	Store	11	FL	2	36	225	150	0.0864	155.52	0	0.0864	155.52	0	0
14	comuter Lab	Lab	46	FL	8	36	244	300	0.3456	622.08	0	0.2592	466.56	0.0864	155.52
15	management	office	17	FL	4	36	157	250	0.1728	311.04	0	0.1728	311.04	0	0
16	management	office	17	FL	8	36	500	250	0.3456	622.08	4	0.1728	311.04	0.1728	311.04
17	M.F1/R92		17	FL	6	36	190	150	0.2592	466.56	2	0.1728	311.04	0.0864	155.52
18	M.F1/R90		29	FL	8	36	330	150	0.3456	622.08	4	0.1728	311.04	0.1728	311.04
20	management	office	30	FL	10	36	370	150	0.432	777.6	6	0.1728	311.04	0.2592	466.56
21	R61	Lab	70	FL	36	36	137	150	1.5552	2799.36	12	1.0368	1866.24	0.5184	933.12
22	R62	Lab	71	FL	36	36	137	150	1.5552	2799.36	12	1.0368	1866.24	0.5184	933.12

23	Room2007	class	47	FL	8	36	260	250	0.3456	622.08	2	0.2592	466.56	0.0864	155.52
24	Teach.Room	office	49	FL	12	36	330	250	0.5184	933.12	4	0.3456	622.08	0.1728	311.04
25	English	class	49	FL	8	36	520	300	0.3456	622.08	0	0.3456	622.08	0	0
26	English	class	49	FL	8	36	507	300	0.3456	622.08	0	0.3456	622.08	0	0
27	English	class	49	FL	8	36	420	300	0.3456	622.08	0	0.3456	622.08	0	0
28	English	class	49	FL	8	36	430	300	0.3456	622.08	0	0.3456	622.08	0	0
29	English	class	49	FL	8	36	316	300	0.3456	622.08	0	0.3456	622.08	0	0
30	f2/r60	lab	87	FL	36	36	487	300	1.5552	2799.36	12	1.0368	1866.24	0.5184	933.12
31	f2/r63	lab	87	FL	36	36	450	300	1.5552	2799.36	12	1.0368	1866.24	0.5184	933.12
33	Total				374					29082.2	94		21772.8		7309.44

4- Electronic and Communication Building

Area Description				Fixture		Rating	Measurd	Stand.	Old consumption		New Consumption			Saving Energy	
No	Name	Type	Value(m2)	Type	nos	W	Lux	Lux	KW	Kwh/year	Removal	kW	Wkh/year	kW	kWh/year
First Floor															
1	Engineers	Office	18	FL	4	36	300	250	0.1728	311.04	0	0.1728	311.04	0	0
2		class	57	FL	12	36	532	300	0.5184	933.12	4	0.3456	622.08	0.1728	311.04
3		class	57	FL	10	36	380	300	0.432	777.6	2	0.3456	622.08	0.0864	155.52
4		class	106	FL	22	36	540	300	0.9504	1710.72	0	0.9504	1710.72	0	0
								FL							
		Class	115	FL	36	36	335	300	1.5552	2799.36	6	1.296	2332.8	0.2592	466.56
5		Class	96	FL	30	36	351	300	1.296	2332.8	6	1.0368	1866.24	0.2592	466.56
6		Office	14	FL	4	36	330	250	0.1728	311.04	2	0.0864	155.52	0.0864	155.52
Theoretical Building: First Floor															
7	Physic	Lab	62	FL	12	36	185	300	0.5184	933.12	0	0.5184	933.12	0	0
8		Class	57	FL	12	36	200	300	0.5184	933.12	0	0.5184	933.12	0	0
Second Floor															
9		Class	51	FL	12	36	203	300	0.5184	933.12	0	0.5184	933.12	0	0
10		Class	76	FL	18	36	175	300	0.777	1399.68	0	0.777	1399.68	0	0
11		Class	76	FL	18	36	190	300	0.7776	1399.68	0	0.7776	1399.68	0	0
Third Floor															
12		Office	50	FL	12	36	200	250	0.5184	933.12	0	0.5184	933.12	0	0
13		Class	50	FL	12	36	180	300	0.5184	933.12	0	0.5184	933.12	0	0
14		Class	50	FL	12	36	177	300	0.5184	933.12	0	0.5184	933.12	0	0
15		Class	50	FL	12	36	180	300	0.5184	933.12	0	0.5184	933.12	0	0
16	Total				238					18506.88	20		16951.68		1555.2

5- Workshop Building and Miscellanies

Area Description			Fixture			Rating	Measured	Stand.	Old Consumption		New Consumption			Saving Energy	
No	Name	Type	Value(m2)	Type	Nos	W	Lux	Lux	KW	Kwh/year	Removal	kW	kWh	kW	kWh
First Floor															
1	B1-110	Class	148.2	FL	38	36	370	300	1.6416	2954.88	2	1.5552	2799.36	0.0864	155.52
2	Teachers	Office	12.25	FL	4	40	865	250	0.192	345.6	0	0.192	345.6	0	0
3	B1-111	Class	114.378	FL	32	36	203	300	1.3824	2488.32	0	1.3824	2488.32	0	0
4	B1-111	Office	14.455	FL	4	36	319	250	0.1728	311.04	2	0.0864	155.52	0.0864	155.52
5	B1-113	Lab	60.049	FL	6	36	200	500	0.2592	466.56	0	0.2592	466.56	0	0
6	B1-17	Office	13.65	FL	4	40	460	250	0.192	345.6	2	0.096	172.8	0.096	172.8
7		Class	35.625	FL	12	36	670	300	0.5184	933.12	4	0.3456	622.08	0.1728	311.04
8		Class	83.05	FL	24	36	320	300	1.0368	1866.24	4	0.864	1555.2	0.1728	311.04
9		Office	11.375	FL	4	36	360	300	0.1728	311.04	2	0.0864	155.52	0.0864	155.52
10		Lab	58.875	FL	16	36	368	500	0.6912	1244.16	0	0.6912	1244.16	0	0
11		W/C	29.64	FL	0	36	165	100	0	0	0	0	0	0	0
12	B1-12	HVAC	242.288	FL	58	36	260	150	2.5056	4510.08	30	1.2096	2177.28	1.296	2332.8
13	B1-15	HVAC	242.288	FL	58	36	260	150	2.5056	4510.08	28	1.296	2332.8	1.2096	2177.28
14	Office	Office	11.68	FL	4	36	252	250	0.1728	311.04	0	0.1728	311.04	0	0
15	Store	Store	32	FL	10	36	134	150	0.432	777.6	0	0.432	777.6	0	0
16	B1-1	Class	200.25	FL	48	36	290	300	2.0736	3732.48	0	2.0736	3732.48	0	0
17	Teachers	Office	16.1124	FL	4	36	541	250	0.1728	311.04	0	0.1728	311.04	0	0
19									0	0		0	0	0	0
20	W/C	W/C	28.5	FL	4	36	165	100	0.1728	311.04	0	0.1728	311.04	0	0
21	B1-22	Class	234.997	FL	64	36	330	300	2.7648	4976.64	8	2.4192	4354.56	0.3456	622.08
22		Office	18.56	FL	6	36	350	250	0.2592	466.56	2	0.1728	311.04	0.0864	155.52
23		Class	198.75	FL	56	36	300	300	2.4192	4354.56	8	2.0736	3732.48	0.3456	622.08
24		Store	11.39	FL	4	36	150	150	0.1728	311.04	2	0.0864	155.52	0.0864	155.52
25		Store	16.3216	FL	4	36	402	150	0.1728	311.04	2	0.0864	155.52	0.0864	155.52

26		Corridor	67.95	FL	12	36	190	150	0.5184	933.12	2	0.432	777.6	0.0864	155.52
27		Corridor	105.4	FL	16	36	100	150	0.6912	1244.16	2	0.6048	1088.64	0.0864	155.52
28		Corridor	52.5	FL	12	36	300	150	0.5184	933.12	4	0.3456	622.08	0.1728	311.04
29	Mechtron	Class	84	FL	24	36	445	300	1.0368	1866.24	4	0.864	1555.2	0.1728	311.04
30	B1-24	Office	13.104	FL	4	36	145/290	250	0.1728	311.04	0	0.1728	311.04	0	0
31	B1-22	Class	32.742	FL	12	36	555/297	300	0.5184	933.12	4	0.3456	622.08	0.1728	311.04
32	B1-26	Class	32.742	FL	12	36	550/300	300	0.5184	933.12	4	0.3456	622.08	0.1728	311.04
33	B1-29	Office	14.3416	FL	4	36	166	250	0.1728	311.04	0	0.1728	311.04	0	0
34	B1-28	Class	58.9424	FL	8	36	680	300	0.3456	622.08	0	0.3456	622.08	0	0
35	B1-231	Class	151.333	FL	44	36	265	300	1.9008	3421.44	8	1.5552	2799.36	0.3456	622.08
36	Teac	Office	12.6	FL	4	36	645	250	0.1728	311.04	0	0.1728	311.04	0	0
37		BT-232	199.056	FL	48	36	323	300	2.0736	3732.48	2	1.9872	3576.96	0.0864	155.52
39	Total				664					51701.76	126		41886.72		9815.04
40	Miscellanies Building														
43		Class	224	FL	42	36	250	300	0.9072	1632.96	0	0.9072	1632.96	0	0
44	carpentry 1	Office	14.8	FL	4	36	250	250	0.1728	311.04	0	0.1728	311.04	0	0
45	carpentry 2	Class	218.4	FL	42	36	403	300	0.9072	1632.96	6	0.648	1166.4	0.2592	466.56
46		Office	8.74	FL	4	36	215	250	0.1728	311.04	2	0.0864	155.52	0.0864	155.52
47	Smkara1	class	129.244	FL	16	36	195	300	0.6912	1244.16	0	0.6912	1244.16	0	0
49	Smkara2	class	129.244	FL	16	36	195	300	0.6912	1244.16	0	0.6912	1244.16	0	0
50	Smkara3	class	86.11	FL	14	36	167	300	0.6048	1088.64	0	0.6048	1088.64	0	0
51	mechanic	class	453.14	FL	52	36	173	300	2.2464	4043.52	0	2.2464	4043.52	0	0
52	Electrician	class	138.718	FL	16	36	170	300	0.6912	1244.16	0	0.6912	1244.16	0	0
53		Office	10.933	FL	16	36	205	250	0.6912	1244.16	0	0.6912	1244.16	0	0
54															
55	Electrician	class	133.73	FL	20	36	215	300	0.864	1555.2	0	0.864	1555.2	0	0
56	Security	office	14.364	FL	4	36	235	250	0.1728	311.04	0	0.1728	311.04	0	0
57	Security	W/C	3.23	FL	2	36	79	100	0.0864	155.52	0	0.0864	155.52	0	0
58	Cafeteria	Cafeteria	25.9992	FL	10	36	186	150	0.432	777.6	0	0.432	777.6	0	0
	Total				216					16796.16	8		16174.08		622.08

APPENDIX C: POWER FACTOR MEASUREMENT IN GTC

DATE	TIME	U1_AVE[V]	U2_AVE[V]	U3_AVE[V]	Uave_AVE[V]	Iave_AVE[A]_1	P_AVE[W]_1	Q_AVE[var]_1	S_AVE[VA]_1	PF_AVE_1
05/05/2011	09:09:50	217.25	216.66	217.86	217.25	170.71	95070.00	57560.00	111240.00	0.86
05/05/2011	09:19:50	216.94	216.60	217.98	217.17	162.31	93320.00	49570.00	105730.00	0.88
05/05/2011	09:29:50	216.52	216.58	217.59	216.90	166.73	95550.00	51240.00	108470.00	0.88
05/05/2011	09:39:50	217.37	216.58	217.55	217.17	151.97	88480.00	44340.00	99000.00	0.89
05/05/2011	09:49:50	217.05	216.44	217.02	216.83	145.39	83780.00	43740.00	94560.00	0.89
05/05/2011	09:59:50	217.18	216.22	216.54	216.64	145.50	83770.00	43740.00	94550.00	0.89
05/05/2011	10:09:50	217.02	217.11	217.11	217.08	147.16	85550.00	43020.00	95830.00	0.89
05/05/2011	10:19:50	217.11	217.65	217.17	217.31	155.56	89260.00	47800.00	101400.00	0.88
05/05/2011	10:29:50	217.29	217.67	217.09	217.35	154.38	89440.00	45960.00	100650.00	0.89
05/05/2011	10:39:50	217.45	217.62	216.97	217.34	156.94	91520.00	45620.00	102320.00	0.90
05/05/2011	10:49:50	217.37	217.44	216.95	217.25	160.24	90180.00	52170.00	104410.00	0.87
05/05/2011	10:59:50	215.38	215.64	215.56	215.52	165.27	90580.00	56440.00	106840.00	0.85
05/05/2011	11:09:50	214.83	214.75	215.30	214.96	150.55	85350.00	45950.00	97070.00	0.88
05/05/2011	11:19:50	214.72	214.16	214.95	214.61	150.78	86550.00	43810.00	97060.00	0.89
05/05/2011	11:29:50	214.65	214.32	214.95	214.64	147.32	84760.00	42520.00	94850.00	0.89
05/05/2011	11:39:50	214.62	214.17	215.53	214.77	138.83	80930.00	38010.00	89430.00	0.91
05/05/2011	11:49:50	214.72	214.25	215.53	214.84	132.86	76740.00	37910.00	85620.00	0.90
05/05/2011	11:59:50	215.00	214.35	215.74	215.03	125.29	72040.00	36540.00	80810.00	0.89
05/05/2011	12:09:50	216.36	215.60	217.01	216.32	120.76	70020.00	35180.00	78370.00	0.89
05/05/2011	12:19:50	216.15	214.96	216.69	215.93	107.53	61920.00	31880.00	69650.00	0.89
05/05/2011	13:59:50	225.07	223.74	226.35	225.05	22.60	14600.00	4310.00	15230.00	0.96
05/05/2011	14:09:50	232.02	230.60	232.08	231.57	20.44	13630.00	3930.00	14190.00	0.96

05/05/2011	14:19:50	232.10	231.01	232.14	231.75	20.43	13640.00	3960.00	14200.00	0.96
05/05/2011	14:29:50	232.16	230.70	232.04	231.63	22.69	15180.00	4220.00	15760.00	0.96
05/05/2011	14:39:50	232.45	230.97	231.99	231.80	19.78	13240.00	3690.00	13750.00	0.96
05/05/2011	14:49:50	231.95	230.97	232.16	231.70	19.91	13320.00	3680.00	13820.00	0.96
05/05/2011	14:59:50	231.91	231.33	232.52	231.92	15.88	10560.00	3200.00	11040.00	0.96
05/05/2011	15:09:50	232.87	231.94	232.48	232.43	6.29	3560.00	2500.00	4380.00	-0.80
05/05/2011	15:19:50	233.01	231.98	232.47	232.49	5.62	3110.00	2380.00	3920.00	-0.79
05/05/2011	15:29:50	232.79	231.79	232.48	232.35	5.55	3150.00	2250.00	3870.00	-0.81
05/05/2011	15:39:50	233.44	231.88	232.23	232.52	5.62	3190.00	2290.00	3920.00	-0.81
05/05/2011	15:49:50	233.38	231.90	232.30	232.53	5.56	3140.00	2280.00	3880.00	-0.81
05/05/2011	15:59:50	233.21	231.72	232.39	232.44	5.62	3080.00	2420.00	3920.00	-0.79
05/06/2011	03:19:50	230.84	230.35	231.92	231.04	5.22	3030.00	1990.00	3620.00	-0.84
05/06/2011	03:29:50	230.96	230.52	232.08	231.19	5.22	3020.00	1990.00	3620.00	-0.84
05/06/2011	03:39:50	230.23	230.26	231.61	230.70	5.21	2950.00	2070.00	3600.00	-0.82
05/06/2011	03:49:50	230.46	230.14	231.84	230.81	5.20	2900.00	2140.00	3600.00	-0.80
05/06/2011	03:59:50	230.62	230.26	231.69	230.86	5.21	2900.00	2150.00	3610.00	-0.80
05/06/2011	04:09:50	230.64	230.12	231.62	230.79	5.21	2900.00	2140.00	3600.00	-0.80
05/06/2011	04:19:50	230.78	229.98	231.58	230.78	5.36	3100.00	2040.00	3710.00	-0.83
05/06/2011	04:29:50	230.84	230.08	231.76	230.89	5.40	3160.00	1990.00	3740.00	-0.85
05/06/2011	04:39:50	230.74	229.98	231.74	230.82	5.46	3200.00	2020.00	3780.00	-0.85
05/06/2011	04:49:50	230.94	230.26	231.97	231.06	5.39	3130.00	2030.00	3740.00	-0.84
05/06/2011	04:59:50	231.07	230.20	231.86	231.04	5.47	3080.00	2210.00	3790.00	-0.81
05/06/2011	05:09:50	231.48	230.62	232.32	231.47	5.42	3040.00	2220.00	3760.00	-0.81
05/06/2011	05:19:50	231.52	230.84	232.79	231.72	5.75	3290.00	2270.00	3990.00	-0.82
05/06/2011	05:29:50	231.37	230.69	232.91	231.65	5.39	3060.00	2170.00	3750.00	-0.81
05/06/2011	05:39:50	231.31	230.47	232.79	231.52	5.46	3190.00	2050.00	3790.00	-0.84

05/06/2011	05:49:50	230.68	229.79	232.13	230.87	5.45	3170.00	2050.00	3780.00	-0.84
05/06/2011	05:59:50	230.70	229.58	232.20	230.83	5.48	3180.00	2070.00	3800.00	-0.84
05/06/2011	06:49:50	236.24	234.74	237.38	236.12	5.34	3150.00	2100.00	3780.00	-0.83
05/06/2011	06:59:50	234.97	233.56	235.91	234.82	5.24	3120.00	1980.00	3690.00	-0.84
05/06/2011	07:09:50	234.99	233.72	235.88	234.86	5.24	3120.00	1980.00	3700.00	-0.84
05/06/2011	07:19:50	235.68	234.40	236.36	235.48	5.27	3070.00	2100.00	3720.00	-0.82
05/07/2011	06:39:50	234.13	231.78	230.87	232.26	88.94	54210.00	29880.00	61960.00	0.88
05/07/2011	06:49:50	233.62	232.23	231.33	232.40	93.90	57960.00	30400.00	65460.00	0.89
05/07/2011	06:59:50	233.29	231.96	231.39	232.21	93.84	57760.00	30560.00	65360.00	0.88
05/07/2011	07:09:50	233.37	232.21	231.63	232.40	89.96	54780.00	30530.00	62720.00	0.87
05/07/2011	07:19:50	233.23	232.12	231.74	232.36	91.76	56020.00	30870.00	63970.00	0.88
05/07/2011	07:29:50	233.05	232.04	231.80	232.30	92.27	56200.00	31220.00	64300.00	0.87
05/07/2011	07:39:50	233.33	232.08	231.75	232.39	92.74	56770.00	30920.00	64650.00	0.88
05/07/2011	07:49:50	233.21	232.74	232.07	232.67	91.16	56130.00	29990.00	63640.00	0.88
05/07/2011	07:59:50	232.96	232.05	232.00	232.33	90.36	55100.00	30400.00	62980.00	0.88
05/07/2011	08:09:50	233.06	231.82	231.56	232.15	85.55	53260.00	26660.00	59570.00	0.89
05/07/2011	08:19:50	233.31	232.05	231.65	232.34	83.03	51340.00	26690.00	57870.00	0.89
05/07/2011	08:29:50	232.92	232.38	231.94	232.42	105.33	60820.00	40920.00	73440.00	0.83
05/07/2011	08:39:50	232.44	231.53	231.61	231.86	122.88	69880.00	49160.00	85460.00	0.82
05/07/2011	08:49:50	232.57	231.02	230.95	231.51	122.21	70000.00	47910.00	84870.00	0.83
05/07/2011	08:59:50	232.20	231.63	231.32	231.72	125.48	70260.00	51520.00	87220.00	0.81
05/07/2011	09:09:50	231.89	231.52	231.32	231.58	132.30	71950.00	57100.00	91910.00	0.78
05/07/2011	09:19:50	231.85	231.90	231.31	231.69	136.36	74190.00	58860.00	94780.00	0.78
05/07/2011	09:29:50	231.84	231.00	231.09	231.31	141.85	75870.00	62620.00	98430.00	0.77
05/07/2011	09:39:50	231.63	230.43	231.29	231.12	139.11	76230.00	58950.00	96420.00	0.79
05/07/2011	09:49:50	231.59	230.78	231.28	231.22	136.99	77240.00	55200.00	95010.00	0.81

05/07/2011	09:59:50	231.92	231.12	231.40	231.48	140.53	77390.00	59260.00	97580.00	0.79
05/07/2011	10:09:50	231.77	231.16	231.67	231.53	141.45	76790.00	61170.00	98240.00	0.78
05/07/2011	10:19:50	231.85	231.53	231.76	231.71	138.03	76380.00	57830.00	95940.00	0.80
05/07/2011	10:29:50	231.54	231.07	231.74	231.45	143.46	78090.00	61690.00	99590.00	0.79
05/07/2011	10:39:50	231.73	231.27	231.62	231.54	139.83	76650.00	59530.00	97120.00	0.79
05/07/2011	10:49:50	231.87	231.53	231.74	231.71	134.99	74910.00	56380.00	93830.00	0.80
05/07/2011	10:59:50	231.82	231.84	231.84	231.83	123.60	71500.00	47570.00	85960.00	0.83
05/07/2011	11:09:50	232.06	231.93	231.94	231.97	115.90	70020.00	40000.00	80660.00	0.87
05/07/2011	11:19:50	232.13	231.89	231.92	231.98	114.57	69070.00	39810.00	79730.00	0.87
05/07/2011	11:29:50	232.52	231.73	231.49	231.91	113.61	67060.00	41560.00	79040.00	0.85
05/07/2011	11:39:50	232.41	232.05	231.49	231.98	117.41	66240.00	47730.00	81720.00	0.81
05/07/2011	11:49:50	232.37	231.65	231.82	231.95	107.68	63570.00	39490.00	74930.00	0.85
05/07/2011	11:59:50	232.46	231.48	231.90	231.95	95.35	57480.00	33050.00	66340.00	0.87
05/07/2011	12:09:50	232.76	231.84	231.87	232.16	85.35	52590.00	27730.00	59450.00	0.88
05/07/2011	12:19:50	233.07	232.40	231.86	232.44	77.05	47580.00	24940.00	53730.00	0.89
05/07/2011	12:29:50	233.33	232.39	232.60	232.77	18.79	12070.00	5120.00	13110.00	0.92
05/07/2011	12:39:50	233.28	232.10	232.89	232.76	7.25	4600.00	2110.00	5060.00	-0.91
05/07/2011	12:49:50	232.95	231.62	232.92	232.50	7.16	4580.00	2000.00	5000.00	-0.92
05/07/2011	12:59:50	233.20	231.70	232.89	232.60	7.29	4660.00	2030.00	5090.00	0.92
05/07/2011	13:09:50	233.16	231.76	233.00	232.64	7.41	4740.00	2050.00	5170.00	0.92
05/07/2011	13:19:50	232.81	231.51	232.96	232.43	7.89	5080.00	2100.00	5500.00	0.92
05/07/2011	13:29:50	233.11	231.75	232.99	232.62	7.88	5030.00	2210.00	5500.00	0.92
05/07/2011	13:39:50	233.34	231.96	232.92	232.74	7.73	4910.00	2230.00	5400.00	0.91
05/07/2011	13:49:50	233.42	231.92	232.96	232.77	7.82	4980.00	2240.00	5460.00	0.91
05/07/2011	13:59:50	233.26	231.88	232.89	232.68	7.83	5040.00	2130.00	5470.00	0.92
05/07/2011	14:09:50	233.51	231.86	232.81	232.73	7.87	5050.00	2150.00	5490.00	0.92

05/07/2011	14:19:50	233.30	231.66	232.82	232.59	7.84	5040.00	2120.00	5470.00	0.92
05/07/2011	14:29:50	233.42	231.79	232.91	232.71	7.86	5010.00	2230.00	5480.00	0.91
05/08/2011	06:29:50	226.39	225.50	226.38	226.09	67.51	40800.00	20480.00	45770.00	0.89
05/08/2011	06:39:50	225.60	224.46	224.79	224.95	85.19	50270.00	27800.00	57480.00	0.88
05/08/2011	06:49:50	224.36	223.07	223.20	223.54	92.09	52040.00	32990.00	61730.00	0.85
05/08/2011	06:59:50	222.62	221.42	221.87	221.97	111.08	58360.00	45150.00	73950.00	0.79
05/08/2011	07:09:50	221.85	220.72	221.38	221.32	119.25	66690.00	42540.00	79150.00	0.84
05/08/2011	07:19:50	219.20	218.87	219.34	219.14	135.05	73280.00	49910.00	88760.00	0.83
05/08/2011	07:29:50	219.64	219.87	219.76	219.76	152.56	80800.00	59720.00	100570.00	0.81
05/08/2011	07:39:50	217.83	217.82	218.05	217.90	148.08	78450.00	56600.00	96780.00	0.81
05/08/2011	07:49:50	216.85	216.97	216.75	216.86	145.62	78310.00	53120.00	94730.00	0.83
05/08/2011	07:59:50	216.62	216.71	216.52	216.62	133.39	75840.00	41950.00	86680.00	0.88
05/08/2011	08:09:50	219.11	219.06	219.51	219.23	132.85	76280.00	42580.00	87360.00	0.87
05/08/2011	08:19:50	218.58	217.96	218.65	218.39	132.34	75110.00	43300.00	86700.00	0.87
05/08/2011	08:29:50	218.44	217.53	218.44	218.14	141.89	79340.00	48130.00	92840.00	0.86
05/08/2011	08:39:50	216.89	216.82	217.67	217.13	157.41	86260.00	55240.00	102510.00	0.84
05/08/2011	08:49:50	216.50	216.52	217.69	216.90	163.37	90630.00	55340.00	106290.00	0.85
05/08/2011	08:59:50	215.31	215.39	216.74	215.81	168.68	87010.00	65760.00	109180.00	0.80
05/08/2011	09:09:50	214.83	214.85	216.72	215.47	175.63	89150.00	70080.00	113500.00	0.79
05/08/2011	09:19:50	214.30	214.36	216.25	214.97	173.55	89340.00	67200.00	111890.00	0.80
05/08/2011	09:29:50	216.04	215.90	217.42	216.45	178.46	91640.00	70750.00	115860.00	0.79
05/08/2011	09:39:50	216.39	216.01	217.54	216.65	175.65	91170.00	68540.00	114140.00	0.80
05/08/2011	09:49:50	217.23	216.75	218.19	217.39	179.11	91340.00		116780.00	0.78
05/08/2011	09:59:50	217.54	217.39	218.61	217.85	180.89	93660.00	71970.00	118190.00	0.79
05/08/2011	10:09:50	216.75	216.56	218.07	217.13	171.15	91670.00	63330.00	111470.00	0.82
05/08/2011	10:19:50	215.69	215.67	217.45	216.27	168.10	90220.00	61190.00	109040.00	0.83

05/08/2011	10:29:50	215.69	215.88	217.18	216.25	163.22	90180.00	55360.00	105880.00	0.85
05/08/2011	10:39:50	216.40	215.94	217.52	216.62	156.15	87150.00	51860.00	101460.00	0.86
05/08/2011	10:49:50	216.81	216.63	218.07	217.17	147.49	82970.00	48330.00	96070.00	0.86
05/08/2011	10:59:50	216.66	216.65	218.40	217.24	149.96	85410.00	47280.00	97690.00	0.88
05/08/2011	11:09:50	217.00	216.79	218.57	217.45	147.14	85160.00	44090.00	95960.00	0.89
05/08/2011	11:19:50	216.77	216.95	218.59	217.44	138.82	80870.00	40580.00	90530.00	0.89
05/08/2011	11:29:50	216.54	216.54	218.30	217.13	137.00	79650.00	40170.00	89210.00	0.89
05/08/2011	11:39:50	216.82	216.51	218.31	217.21	135.17	80300.00	36100.00	88050.00	0.91

APPENDIX D: POWER FACTOR MEASUREMENT IN APC

02/21/2011	U1_INST[V]	U2_INST[V]	U3_INST[V]	Uave_INST[V]	Iave_INST[A]_1	P_INST[W]_1	Q_INST[var]_1	S_INST[VA]_1	PF_INST_1	F_INST[Hz]
02/21/2011	228.8	229.49	228.33	228.87	159.78	76400	78730	109700	0.696	49.989
02/21/2011	229.62	230.59	229.23	229.81	150.5	63670	81910	103750	0.614	49.982
02/21/2011	231.78	231.75	231.18	231.57	145.47	59020	82030	101060	0.584	49.729
02/21/2011	232.17	232.19	231.51	231.96	148.49	66000	79450	103330	0.639	50.002
02/21/2011	225.21	225.69	225.43	225.44	127.65	56510	65270	86330	0.655	49.997
02/21/2011	227.34	227.72	227.76	227.61	62.02	18580	37940	42350	0.441	49.992
02/21/2011	231.39	231.57	230.77	231.24	92.96	34070	54740	64480	0.528	49.986
02/21/2011	227.38	228.03	226.86	227.42	147.22	62880	78280	100430	0.626	50
02/21/2011	220.8	221.95	221.25	221.33	128.92	57070	63790	85600	0.667	49.989
02/21/2011	211.03	212	211.25	211.43	159.51	76500	66200	101170	0.756	49.999
02/21/2011	219.12	219.04	218.3	218.82	165.35	81500	71670	108540	0.751	50.003
02/21/2011	227.21	225.46	227.11	226.59	132.85	55070	71540	90280	0.61	50.006
02/21/2011	227.22	227.55	227.2	227.32	162	65390	88760	110480	0.59	49.998
02/21/2011	228.05	228.2	228.05	228.1	187.72	86450	94820	128420	0.671	49.997
02/21/2011	232.86	233.32	233.2	233.12	35.47	19320	15560	24810	0.779	49.986
02/21/2011	233.33	234.32	232.62	233.42	63.76	28310	34490	44640	0.634	49.996
02/21/2011	234.64	239.19	236.97	236.93	56.71	33060	22970	40250	0.821	50.07
02/21/2011	232.53	232.68	233.56	232.92	34.98	18980	15400	24440	0.777	49.999
02/21/2011	233.99	233.78	234.76	234.18	28.79	15670	12790	20220	0.775	49.998

02/22/2011	228.63	228.62	229.53	228.93	48.35	17790	27940	33200	0.535	49.997
02/22/2011	231.33	231.28	231.89	231.5	54.44	22340	30470	37810	0.591	50.01
02/22/2011	233.26	232.88	233.9	233.35	73.59	30010	41870	51520	0.583	49.997
02/22/2011	229.37	228.66	229.35	229.12	242.11	120840	114420	166420	0.726	49.993
02/22/2011	231.91	230.9	231.25	231.35	197.65	93650	100210	137180	0.683	49.994
02/22/2011	232.14	231.81	231.92	231.96	198.77	93570	101800	138320	0.676	50.002
02/22/2011	232.97	232.54	232.44	232.65	175.34	69950	100400	122380	0.572	49.996
02/22/2011	233.15	232.25	232.43	232.61	167.09	75210	89070	116600	0.645	49.991
02/22/2011	229.91	229.46	229.61	229.66	168.91	74230	89630	116370	0.638	49.996
02/22/2011	225.8	225.17	225.55	225.51	167.3	65100	92590	113180	0.575	49.988
02/22/2011	216.96	217.04	217.02	217.01	239.62	119590	100150	155990	0.767	49.972
02/22/2011	221.51	221.11	221.59	221.4	143.38	60390	73630	95240	0.634	49.952
02/22/2011	218.89	219.3	219.8	219.33	226.22	106470	103920	148790	0.716	50.001
02/22/2011	220.17	220.64	220.99	220.6	182.64	86580	84340	120870	0.716	49.993
02/22/2011	222.43	223.23	223.31	222.99	137.04	61500	67980	91680	0.671	50.001
02/22/2011	220.05	221.22	221.33	220.87	156.65	76640	69990	103800	0.738	49.979
02/22/2011	221.04	221.52	222.83	221.8	149.7	68210	72590	99610	0.685	50.002
02/22/2011	217.02	219.9	220.66	219.19	200.4	98760	87160	131720	0.75	49.992
02/22/2011	223.61	225.11	225.36	224.69	36.36	16380	18210	24500	0.669	49.988
02/22/2011	223.99	225.53	225.64	225.05	55.29	28260	24330	37300	0.756	50.01
02/22/2011	223.79	225.53	225.5	224.94	52.11	26990	22520	35150	0.768	49.998
02/22/2011	220.39	221.16	221.51	221.02	165.91	79380	76140	110000	0.722	49.988
02/22/2011	222.09	223.01	223.17	222.76	157.43	67890	80360	105200	0.645	50.009
02/22/2011	225.84	226.89	227.09	226.61	156.11	76150	73900	106120	0.718	50.014
02/22/2011	226.66	227.31	227.71	227.23	70.77	29550	38100	48240	0.611	49.986
02/22/2011	229.43	229.91	231.17	230.17	84.26	41410	40830	58180	0.713	50.004

02/22/2011	224.83	224	224.54	224.46	220.2	91580	116600	148280	0.618	49.994
02/22/2011	226.77	226.67	225.89	226.45	133.29	69830	57620	90540	0.771	49.996
02/22/2011	228.55	228.7	228.82	228.69	61.46	28120	31410	42170	0.667	50.011
02/22/2011	223.36	224.22	223.58	223.72	185.09	74350	99340	124210	0.598	49.997
02/22/2011	220.13	219.82	219.69	219.88	150.4	70730	69560	99210	0.713	49.992
02/22/2011	221.71	221.51	220.97	221.4	159.59	75030	74850	105990	0.708	50.008
02/22/2011	223.08	222.94	223.3	223.1	151.81	70820	72860	101610	0.697	50
02/22/2011	221.41	221.63	221.56	221.53	141.01	60450	71610	93710	0.645	50.003
02/22/2011	220.86	220.53	220.78	220.72	178.61	86560	80590	118270	0.732	50.016
02/22/2011	219.46	219.51	220.06	219.68	156.28	74090	71540	103000	0.719	49.991
02/22/2011	220.27	220.48	220.34	220.36	187.68	94130	80710	124030	0.757	49.999
02/22/2011	223.69	223.39	223.57	223.55	168.13	77470	81920	112750	0.687	49.986
02/22/2011	224.25	224.58	224.71	224.51	155.85	74590	73870	104970	0.711	49.989
02/22/2011	224.63	225.21	225.3	225.04	142.03	62410	72790	95890	0.651	49.997
02/22/2011	225.26	225.28	225.87	225.47	185.05	91130	85800	125170	0.728	49.993
02/23/2011	228.46	228.57	228.79	228.6	188.96	91820	91420	129590	0.708	49.99
02/23/2011	229.98	229.78	230.77	230.18	162.01	72510	85200	111880	0.648	49.975
02/23/2011	229.93	229.86	230.16	229.98	148.09	68230	76040	102180	0.667	49.99
02/23/2011	231.24	230.65	231.12	231	148.68	68400	77060	103040	0.664	49.995

APPENDIX E: EFFICIENCIES AND PRICE OF HEM [4]

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

1800 RPM Totally Enclosed Fan-Cooled Motors

hp	Average Standard Motor Efficiency, %	Average Energy-Efficient Motor Efficiency, %	Efficiency Improvement, %	Typical Standard TEFC Motor List Price	Typical Energy-Efficient TEFC Motor List Price	List Price Premium
5	83.3 (11)	87.3 (32)	4.6	$344 (6)	$448 (5)	$104
7.5	85.2 (20)	89.5 (22)	4.8	494 (7)	647 (5)	153
10	86.0 (10)	89.4 (30)	3.8	614 (6)	780 (5)	166
15	86.3 (8)	90.4 (27)	4.5	811 (7)	1042 (5)	231
20	88.3 (13)	92.0 (20)	4.0	1025 (6)	1268 (5)	243
25	89.3 (14)	92.5 (19)	3.5	1230 (7)	1542 (5)	312
30	89.5 (9)	92.6 (23)	3.3	1494 (6)	1824 (5)	330
40	90.3 (10)	93.1 (21)	3.0	1932 (7)	2340 (5)	408
50	91 .0 (9)	93.4 (22)	2.6	2487 (5)	2881 (4)	394
60	91.7 (11)	94.0 (19)	2.4	3734 (7)	4284 (5)	514
75	91.6 (6)	94.1 (24)	2.7	4773 (7)	5520 (5)	747
100	92.1 (13)	94.7 (17)	2.7	5756 (5)	6775 (4)	1019
125	92.0 (10)	94.7 (19)	2.9	7425 (5)	9531 (5)	2106
150	93.0 (10)	95.0 (18)	2.1	9031 (6)	11123 (3)	2092
200	93.8 (9)	95.4 (14)	1.7	10927 (5)	13369 (4)	2442

Table 6
Average Efficiencies and Typical List Prices for Standard and Energy Efficient Four-Pole (1800 RPM) Motors

hp	Average Standard Motor Efficiency, % 1	Average Energy-Efficient Motor Efficiency, % 2	Energy Savings, % 3	Typical Standard TEFC Motor List Price 4	Typical Energy-Efficient TEFC Motor List Price 4	List Price Premium
1	77.4 (58)	83.7 (24)	7.5	$203 (55)	$211 (19)	$8
1.5	79.6 (58)	85.2 (22)	6.6	$217 (55)	$262 (17)	$45
2	80.7 (55)	85.3 (21)	5.4	$226 (52)	$259 (16)	$33
3	82.3 (73)	88.8 (25)	7.3	$252 (67)	$325 (17)	$73
5	83.9 (56)	89.1 (21)	5.8	$310 (51)	$379 (18)	$69
7.5	85.0 (51)	90.1 (31)	5.7	$408 (50)	$538 (26)	$130
10	86.0 (50)	90.9 (27)	5.4	$516 (49)	$650 (24)	$134
15	87.7 (43)	92.2 (37)	4.9	$677 (42)	$864 (24)	$187
20	88.2 (39)	92.4 (32)	4.5	$843 (38)	$1,055 (27)	$212
25	88.9 (60)	93.1 (24)	4.5	$993 (41)	$1,226 (13)	$233
30	88.8 (50)	93.3 (23)	4.8	$1,160 (32)	$1,425 (15)	$265
40	90.0 (34)	94.0 (24)	4.3	$1,446 (33)	$1,772 (14)	$326
50	90.6 (32)	94.1 (24)	3.7	$1,688 (29)	$2,066 (14)	$378
60	91.3 (22)	94.8 (26)	3.7	$2,125 (19)	$2,532 (18)	$407
75	91.9 (21)	94.9 (26)	3.2	$2,703 (18)	$3,084 (14)	$381
100	92.3 (18)	95.3 (30)	3.1	$3,483 (15)	$3,933 (15)	$450
125	92.1 (10)	95.2 (18)	3.3	$4,006 (09)	$4,709 (13)	$703
150	92.8 (16)	95.6 (13)	2.9	$5,760 (12)	$6,801 (10)	$1,041
200	93.1 (15)	95.6 (12)	2.6	$7,022 (12)	$8,592 (09)	$1,570
250	94.1 (18) [5]	96.0 (10)	2.0	$8,863 (15)	$12,701 (09)	$3,838
300	94.1 (13)	95.9 (05)	1.9	$10,871 (11)	$14,479 (04)	$3,608
350	93.6 (07)	95.7 (07)	2.2	$13,262 (07)	$15,800 (06)	$2,538
400	94.1 (08)	95.9 (08)	1.9	$14,938 (08)	$16,731 (07)	$1,793
450	94.2 (10)	96.0 (05)	1.9	$14,890 (10)	$19,333 (04)	$4,443
500	94.2 (07)	96.0 (04)	1.9	$18,190 (07)	$18,271 (02)	$82

hp	Average Standard Motor Efficiency, % 1	Average Energy-Efficient Motor Efficiency, % 2	Energy Savings, % 3	Typical Standard TEFC Motor List Price 4	Typical Energy-Efficient TEFC Motor List Price 4	List Price Premium
1	76.9 (50)	85.2 (29)	9.7	$234 (47)	$362 (24)	$128
1.5	78.9 (48)	85.9 (35)	8.1	$241 (45)	$402 (30)	$161
2	80.4 (42)	85.8 (38)	6.3	$306 (39)	$442 (33)	$136
3	81.6 (38)	88.7 (46)	8.0	$308 (37)	$488 (41)	$180
5	83.6 (30)	89.1 (47)	6.2	$344 (29)	$544 (42)	$200
7.5	85.6 (46)	90.8 (47)	5.7	$494 (45)	$743 (42)	$249
10	85.8 (23)	90.9 (49)	5.6	$614 (23)	$888 (44)	$274
15	86.7 (20)	92.2 (46)	6.0	$879 (20)	$1,194 (41)	$315
20	88.6 (40)	92.5 (51)	4.2	$1,102 (40)	$1,441 (46)	$339
25	89.3 (36)	93.3 (44)	4.3	$1,321 (35)	$1,778 (39)	$457
30	89.5 (23)	93.5 (45)	4.3	$1,628 (22)	$2,111 (40)	$483
40	90.1 (23)	94.0 (44)	4.1	$2,056 (22)	$2,746 (39)	$690
50	91.2 (25)	94.0 (48)	3.0	$2,567 (24)	$3,399 (43)	$832
60	91.6 (26)	94.8 (43)	3.4	$3,897 (25)	$4,970 (37)	$1,073
75	91.6 (18)	94.9 (43)	3.5	$4,891 (18)	$6,080 (38)	$1,189
100	92.2 (29)	95.2 (43)	3.2	$5,793 (28)	$7,790 (38)	$1.997
125	92.2 (21)	95.5 (38)	3.5	$7,584 (21)	$10,000 (33)	$2,416
150	93.0 (28)	95.7 (38)	2.8	$9,167 (27)	$11,667 (33)	$2,500
200	93.5 (22)	95.8 (39)	2.4	$11,318 (21)	$14,500 (33)	$3,182
250	93.7 (24) [5]	95.8 (35)	2.2	$14,246 (23)	$17,741 (33)	$3,495
300	94.2 (12)	95.9 (21)	1.8	$16,715 (11)	$18,813 (17)	$2,098
350	94.4 (10)	96.0 (14)	1.7	$21,525 (10)	$24,271 (12)	$2,746
400	94.4 (10)	95.9 (08)	1.6	$27,391 (10)	$27,920 (07)	$529
450	94.5 (08)	95.8 (03)	1.4	$28,775 (07)	$29,731 (02)	$956
500	94.8 (06)	96.3 (04)	1.6	$33,300 (06)	$37,800 (03)	$4,470

APPENDIX F: QUOTATION REQUEST- W.ALKHOZENDAR FOR AAPF

شركة وسيم الخزندار للصناعة والتجارة والمقاولات م.خ.م

WASEEM AL KHAZENDAR ELECTRICAL INDUSTRIES Co. LTD.

Date / / التاريخ

لوحة مكثفات 100 كيلو

رقم الصنف	إسم الصنف	الوحدة	الكمية	سعر الوحدة	السعر الإجمالي
8421	لوحة 150/60/50	عدد	1		
8422	جهاز مكثفات دوزينا ايطالي	عدد	1		
8423	قاطع رئيسي 160 امبير مار	عدد	1		
8423	باس بار 3 فاز 250 امبير	عدد	1		
8424	نص 3 فاز مكثفات 16 امبير ملر	عدد	1		
8424	نص 3 فاز مكثفات 25 امبير ملر	عدد	1		
8425	نص 3 فاز مكثفات 63 امبير ملر	عدد	2		
8424	كونتكتور مكثف 10 كيلو ملر	عدد	2		
8425	كونتكتور مكثف 20 كيلو ملر	عدد	1		
8426	كونتكتور مكثف 30 كيلو ملر	عدد	2		
8427	مكثف KVAR 10	عدد	2		
8427	مكثف KVAR 20	عدد	1		
8428	مكثف KVAR 30	عدد	2		
8429	لمبة اشارة مكثفات	عدد	5		
8429	مفتاح مبدل 101	عدد	6		
8430	اسلاك وجاري وتجميع	عدد	1		
				الاجمالي	10,170.00

غزة شارع عمر المختار هاتف المكتب 08 2861861 فاكس 08 2824197

Gaza - Omar El Mokhtar St. 237/47 R.c. 14005 Tel. Off:00 970 8 2861861 Fax: 00 970 8 2824197

E-mail:wkh@palnet.com

Quotation Request- DUCATI energia Supplier for AAPF

DUCATI energia s.p.a.

SERIE PFC Heavy Duty	Ratings V / Hz	Power kVAR	Output power at 400 V kVAR		Code no. 415.04.	Unit Price EURO
	450 V (*)	20	16		0210	€759.94
	50 Hz	25	20		0215	€771.75
		35	28		0220	€822.94
		40	32		0225	€834.75
DUCATI 200-M		50	40		0230	€968.63
		60	47		0235	€1,175.34
AUTOMATIC		70	55		0240	€1,228.50
EQUIPMENT		80	63		0245	€1,317.09
		90	71		0250	€1,647.84
		100	79		0255	€1,720.69
		120	95		0260	€1,984.50
		140	111		0265	€2,138.06
		160	126		0270	€2,303.44
		180	142		0275	€2,520.00
		200	158		0280	€2,671.59
	525 V (*)	20	12		0310	€759.94
	50 Hz	25	15		0315	€771.75
		35	20		0320	€822.94
		40	23		0325	€834.75
		50	29		0330	€968.63
		60	35		0335	€1,175.34
		70	41		0340	€1,228.50
		80	46		0345	€1,317.09
		90	52		0350	€1,647.84
		100	58		0355	€1,720.69
		120	70		0360	€1,984.50
		140	81		0365	€2,138.06
		160	93		0370	€2,303.44
		180	105		0375	€2,520.00
		200	116		0380	€2,671.59

SERIE PFC Heavy Duty	Ratings V / Hz	Power kVAR	Output power at 400 V kVAR		Code no. 415.04.	Unit Price EURO
	415 V (*)	220	204	0510N		€3,872.53
DUCATI 400-M	50 Hz	240	223	0515N		€3,965.06
		260	242	0520N		€4,264.31
AUTOMATIC		280	260	0525N		€4,384.41
EQUIPMENT		300	279	0527N		€4,565.53
		320	297	0530N		€4,921.88
		360	334	0535N		€5,274.28
		400	372	0540N		€5,664.09

- **Quotation Request- WattStopper Supplier for Occupancy Sensor by**

Bill of Materials Quote

Tech Support: 800-879-8585
Quotations: 800-852-2778

WattStopper
legrand

Quote ID: 47952 **Date:** 07/28/2011
Project Name: GPGC Gaza Power Plant - Gaza Strip, AB **Quote Name:**
Notes: **WattStopper reserves the right to substitute products that meet or exceed the specifications and performance of this bill of materials. Some physical dimensions may change.**

All recommended counts and materials should be verified before placing any orders.

From Contact
Company: Watt Stopper / Legrand
Contact: David Handra
Email: David.Handra@WattStopper.com
Phone: 205-271-3442
Fax: 205-271-3450

To Contact
Company: GPGC Gaza Power Plant
Contact: Eyad Adnan
Email: eyad_adnan@yahoo.com
Phone:

Qty	Description	Catalog Number	Unit Price	Ext Price
1	Dual Tech Occupancy Sensor24VDC, corner mount, , 40 Khz	DT-200	$113.10	$113.10
1	Power Pack, 120~277V, 50/60Hz,24VDC, 225mA	BZ-50	$22.10	$22.10
1	Ultrasonic Ceiling Occupancy Sensor24 VDC, 1100 sq ft	WT-1105	$82.55	$82.55
1	Power Pack, 120~277V, 50/60Hz,24VDC, 225mA	BZ-50	$22.10	$22.10
1	Shipping - FEDEX International Economy to Hebron, Palestine	HNONSTOCK	$275.00	$275.00
1	Wire Transfer Charges	HNONSTOCK	$25.00	$25.00
			Total:	$539.85

Quotation Request- Seifarer company for LED lamps

发件人： seifarer
发送时间： 2011-07-06 09:43:22
收件人： eyad_adnan
抄送： Jeffrey.deng@seifarer.com
主题： Re: I am interested in 18W LED Tube, High Luminous Efficiency -- GlobalMarket Online Inquiry

Hi eyad Adnan,

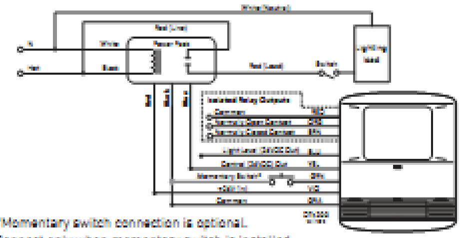
Thank for your Inquiry,
LED 18W fluorescent can replace the 36W fluorescent lamp.
Price:31USD,TT30%,MOQ1000,FOB Shenzhen
If you have questions, please contact me.

Best Regards
Roy Xu

APPENDIX G: TECHNICAL DATA AND COMFORT STANDARD

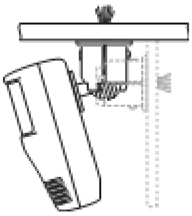
Wiring & Mounting

Wiring Diagram



*Momentary switch connection is optional.
Connect only when momentary switch is installed.

Mounting



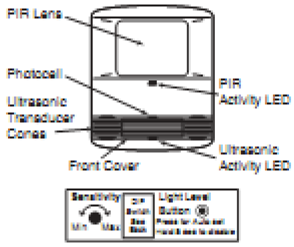
A swivel mounting bracket attached to the sensor allows the sensor to be angled for wall or ceiling mounting.

Grooves on the bracket help to achieve desired angle for coverage.

Mount to mud ring.

Controls & Settings

Product Controls



DIP Switch Settings

◄ = Factory Setting
● = ON
– = OFF

Occupancy Logic	1	2	3	
Standard	–	–	–	◄
Option 1	●	–	–	
Option 2	–	●	–	
Option 3	●	●	–	
Option 4	–	–	●	
Option 5	●	–	●	
Option 6	–	●	●	
Option 7	●	●	●	

Occupancy Logic / Trigger	[illegible]	[illegible]	[illegible]
Standard	Both	Either	Either(8)
Option 1	Either	Either	Either(8)
Option 2	PIR	Either	Either(8)
Option 3	Both	Both	Both(8)
Option 4	PIR	PIR	PIR(8)
Option 5	Ultra	Ultra	Ultra(8)
Option 6	[illegible]	Either	Either(35)
Option 7	[illegible]	Both	Both(35)

Time Delay	4	5	6	
5 sec/SmartSet †	–	–	–	
5 minutes	–	–	●	
10 min. †	–	●	–	
10 minutes	–	●	●	
15 min. †	●	–	–	
15 minutes	●	–	●	
20 minutes	●	●	–	◄
30 min. †	●	●	●	

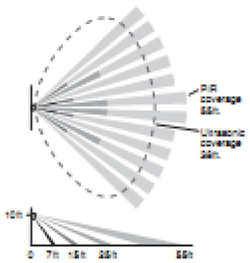
† = walkthrough mode

LEDs	7	
Disabled	–	
Enabled	●	◄

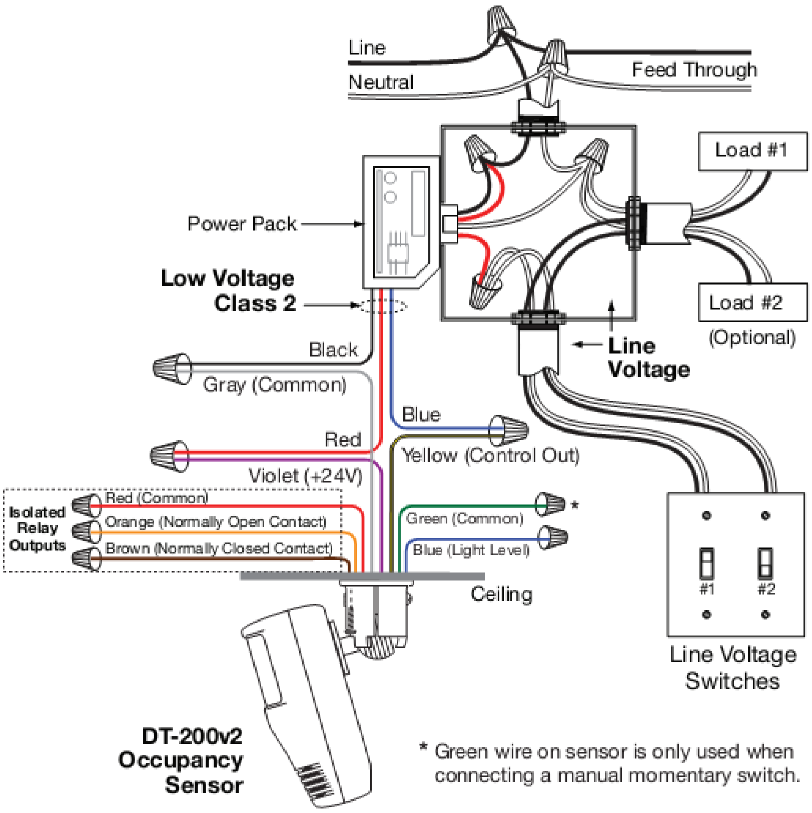
PIR Sensitivity	8	
Minimum	–	
Max./SmartSet	●	◄

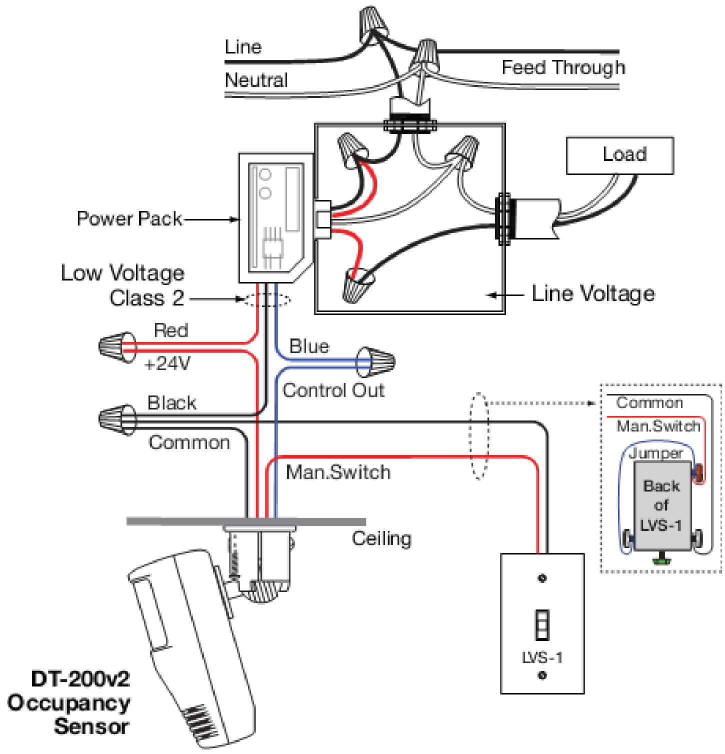
Coverage

Coverage Pattern



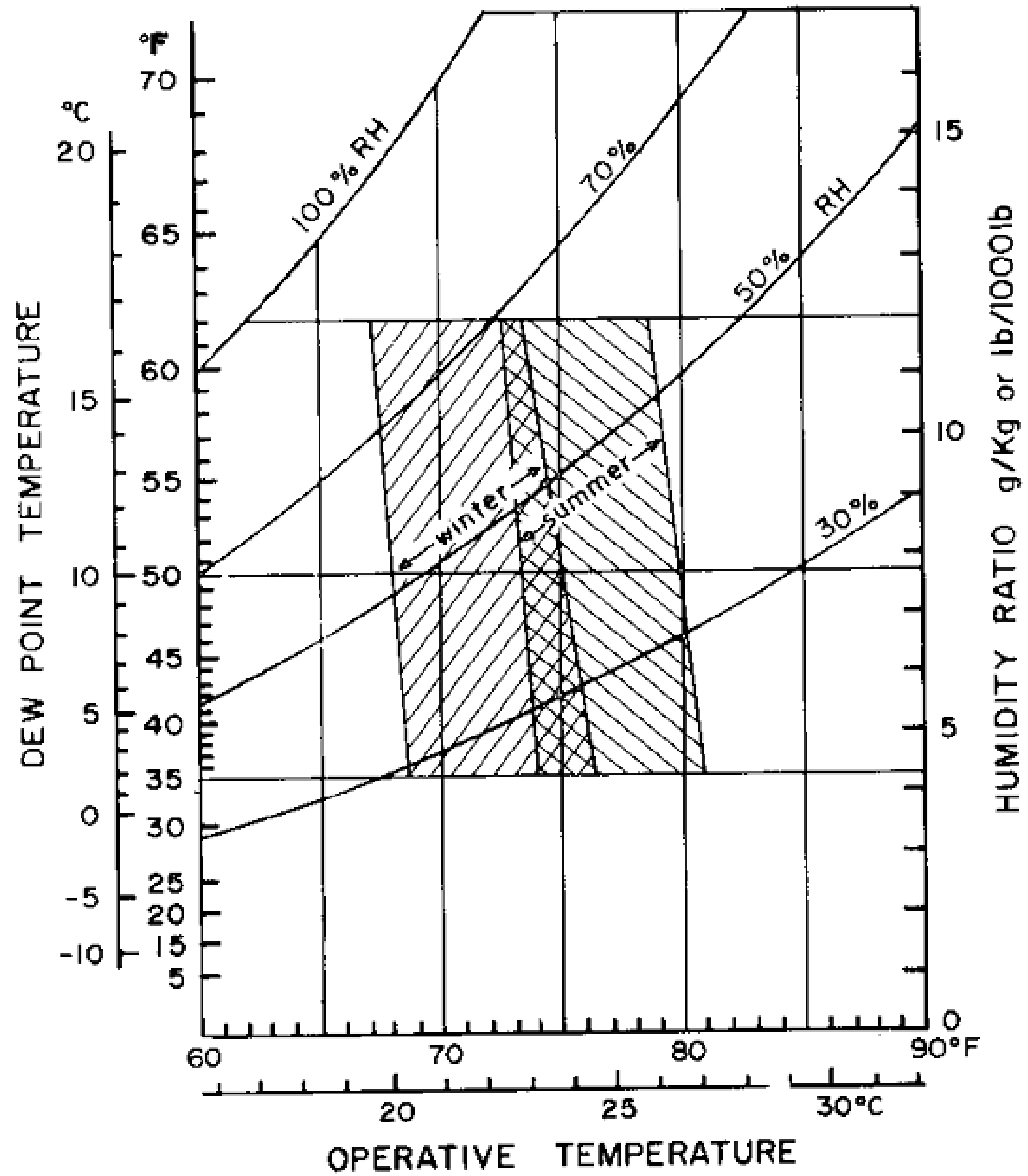
Coverages shown are maximum and represent half-step walking motion. Under ideal conditions with no barriers or obstacles, coverage for half-step walking motion can reach up to 2000 ft², while coverage for typical desktop activity can reach up to 1000 ft².





Manual-On wiring with low voltage momentary switch

2- Comfort Standard By ASHRE 50



APPENDIX H: INTEREST FACTOR TABLES (63)

22%	TABLE 23 Discrete Cash Flow: Compound Interest Factors							22%
	Single Payments		Uniform Series Payments				Arithmetic Gradients	
n	F/P Compound Amount	P/F Present Worth	A/F Sinking Fund	F/A Compound Amount	A/P Capital Recovery	P/A Present Worth	P/G Gradient Present Worth	A/G Gradient Uniform Series
1	1.2200	0.8197	1.00000	1.0000	1.22000	0.8197		
2	1.4884	0.6719	0.45045	2.2200	0.67045	1.4915	0.6719	0.4505
3	1.8158	0.5507	0.26966	3.7084	0.48966	2.0422	1.7733	0.8683
4	2.2153	0.4514	0.18102	5.5242	0.40102	2.4936	3.1275	1.2542
5	2.7027	0.3700	0.12921	7.7396	0.34921	2.8636	4.6075	1.6090
6	3.2973	0.3033	0.09576	10.4423	0.31576	3.1669	6.1239	1.9337
7	4.0227	0.2486	0.07278	13.7396	0.29278	3.4155	7.6154	2.2297
8	4.9077	0.2038	0.05630	17.7623	0.27630	3.6193	9.0417	2.4982
9	5.9874	0.1670	0.04411	22.6700	0.26411	3.7863	10.3779	2.7409
10	7.3046	0.1369	0.03489	28.6574	0.25489	3.9232	11.6100	2.9593
11	8.9117	0.1122	0.02781	35.9620	0.24781	4.0354	12.7321	3.1551
12	10.8722	0.0920	0.02228	44.8737	0.24228	4.1274	13.7438	3.3299
13	13.2641	0.0754	0.01794	55.7459	0.23794	4.2028	14.6485	3.4855
14	16.1822	0.0618	0.01449	69.0100	0.23449	4.2646	15.4519	3.6233
15	19.7423	0.0507	0.01174	85.1922	0.23174	4.3152	16.1610	3.7451
16	24.0856	0.0415	0.00953	104.9345	0.22953	4.3567	16.7838	3.8524
17	29.3844	0.0340	0.00775	129.0201	0.22775	4.3908	17.3283	3.9465
18	35.8490	0.0279	0.00631	158.4045	0.22631	4.4187	17.8025	4.0289
19	43.7358	0.0229	0.00515	194.2535	0.22515	4.4415	18.2141	4.1009
20	53.3576	0.0187	0.00420	237.9893	0.22420	4.4603	18.5702	4.1635
22	79.4175	0.0126	0.00281	356.4432	0.22281	4.4882	19.1418	4.2649
24	118.2050	0.0085	0.00188	532.7501	0.22188	4.5070	19.5635	4.3407
26	175.9364	0.0057	0.00126	795.1653	0.22126	4.5196	19.8720	4.3968
28	261.8637	0.0038	0.00084	1185.74	0.22084	4.5281	20.0962	4.4381
30	389.7579	0.0026	0.00057	1767.08	0.22057	4.5338	20.2583	4.4683
32	580.1156	0.0017	0.00038	2632.34	0.22038	4.5376	20.3748	4.4902
34	863.4441	0.0012	0.00026	3920.20	0.22026	4.5402	20.4582	4.5060
35	1053.40	0.0009	0.00021	4783.64	0.22021	4.5411	20.4905	4.5122
36	1285.15	0.0008	0.00017	5837.05	0.22017	4.5419	20.5178	4.5174
38	1912.82	0.0005	0.00012	8690.08	0.22012	4.5431	20.5601	4.5256
40	2847.04	0.0004	0.00008	12937	0.22008	4.5439	20.5900	4.5314
45	7694.71	0.0001	0.00003	34971	0.22003	4.5449	20.6319	4.5396
50	20797		0.00001	94525	0.22001	4.5452	20.6492	4.5431
55	56207				0.22000	4.5454	20.6563	4.5445

24% **TABLE 24 Discrete Cash Flow: Compound Interest Factors** **24%**

	Single Payments		Uniform Series Payments				Arithmetic Gradients	
n	F/P Compound Amount	P/F Present Worth	A/F Sinking Fund	F/A Compound Amount	A/P Capital Recovery	P/A Present Worth	P/G Gradient Present Worth	A/G Gradient Uniform Series
1	1.2400	0.8065	1.00000	1.0000	1.24000	0.8065		
2	1.5376	0.6504	0.44643	2.2400	0.68643	1.4568	0.6504	0.4464
3	1.9066	0.5245	0.26472	3.7776	0.50472	1.9813	1.6993	0.8577
4	2.3642	0.4230	0.17593	5.6842	0.41593	2.4043	2.9683	1.2346
5	2.9316	0.3411	0.12425	8.0484	0.36425	2.7454	4.3327	1.5782
6	3.6352	0.2751	0.09107	10.9801	0.33107	3.0205	5.7081	1.8898
7	4.5077	0.2218	0.06842	14.6153	0.30842	3.2423	7.0392	2.1710
8	5.5895	0.1789	0.05229	19.1229	0.29229	3.4212	8.2915	2.4236
9	6.9310	0.1443	0.04047	24.7125	0.28047	3.5655	9.4458	2.6492
10	8.5944	0.1164	0.03160	31.6434	0.27160	3.6819	10.4930	2.8499
11	10.6571	0.0938	0.02485	40.2379	0.26485	3.7757	11.4313	3.0276
12	13.2148	0.0757	0.01965	50.8950	0.25965	3.8514	12.2637	3.1843
13	16.3863	0.0610	0.01560	64.1097	0.25560	3.9124	12.9960	3.3218
14	20.3191	0.0492	0.01242	80.4961	0.25242	3.9616	13.6358	3.4420
15	25.1956	0.0397	0.00992	100.8151	0.24992	4.0013	14.1915	3.5467
16	31.2426	0.0320	0.00794	126.0108	0.24794	4.0333	14.6716	3.6376
17	38.7408	0.0258	0.00636	157.2534	0.24636	4.0591	15.0846	3.7162
18	48.0386	0.0208	0.00510	195.9942	0.24510	4.0799	15.4385	3.7840
19	59.5679	0.0168	0.00410	244.0328	0.24410	4.0967	15.7406	3.8423
20	73.8641	0.0135	0.00329	303.6006	0.24329	4.1103	15.9979	3.8922
22	113.5735	0.0088	0.00213	469.0563	0.24213	4.1300	16.4011	3.9712
24	174.6306	0.0057	0.00138	723.4610	0.24138	4.1428	16.6891	4.0284
26	268.5121	0.0037	0.00090	1114.63	0.24090	4.1511	16.8930	4.0695
28	412.8642	0.0024	0.00058	1716.10	0.24058	4.1566	17.0365	4.0987
30	634.8199	0.0016	0.00038	2640.92	0.24038	4.1601	17.1369	4.1193
32	976.0991	0.0010	0.00025	4062.91	0.24025	4.1624	17.2067	4.1338
34	1500.85	0.0007	0.00016	6249.38	0.24016	4.1639	17.2552	4.1440
35	1861.05	0.0005	0.00013	7750.23	0.24013	4.1664	17.2734	4.1479
36	2307.71	0.0004	0.00010	9611.28	0.24010	4.1649	17.2886	4.1511
38	3548.33	0.0003	0.00007	14781	0.24007	4.1655	17.3116	4.1560
40	5455.91	0.0002	0.00004	22729	0.24004	4.1659	17.3274	4.1593
45	15995	0.0001	0.00002	66640	0.24002	4.1664	17.3483	4.1639
50	46890		0.00001		0.24001	4.1666	17.3563	4.1653
55					0.24000	4.1666	17.3593	4.1663

25% TABLE 25 Discrete Cash Flow: Compound Interest Factors 25%

	Single Payments		Uniform Series Payments				Arithmetic Gradients	
n	F/P Compound Amount	P/F Present Worth	A/F Sinking Fund	F/A Compound Amount	A/P Capital Recovery	P/A Present Worth	P/G Gradient Present Worth	A/G Gradient Uniform Series
1	1.2500	0.8000	1.00000	1.0000	1.25000	0.8000		
2	1.5625	0.6400	0.44444	2.2500	0.69444	1.4400	0.6400	0.4444
3	1.9531	0.5120	0.26230	3.8125	0.51230	1.9520	1.6640	0.8525
4	2.4414	0.4096	0.17344	5.7656	0.42344	2.3616	2.8928	1.2249
5	3.0518	0.3277	0.12185	8.2070	0.37185	2.6893	4.2035	1.5631
6	3.8147	0.2621	0.08882	11.2588	0.33882	2.9514	5.5142	1.8683
7	4.7684	0.2097	0.06634	15.0735	0.31634	3.1611	6.7725	2.1424
8	5.9605	0.1678	0.05040	19.8419	0.30040	3.3289	7.9469	2.3872
9	7.4506	0.1342	0.03876	25.8023	0.28876	3.4631	9.0207	2.6048
10	9.3132	0.1074	0.03007	33.2529	0.28007	3.5705	9.9870	2.7971
11	11.6415	0.0859	0.02349	42.5661	0.27349	3.6564	10.8460	2.9663
12	14.5519	0.0687	0.01845	54.2077	0.26845	3.7251	11.6020	3.1145
13	18.1899	0.0550	0.01454	68.7596	0.26454	3.7801	12.2617	3.2437
14	22.7374	0.0440	0.01150	86.9495	0.26150	3.8241	12.8334	3.3559
15	28.4217	0.0352	0.00912	109.6868	0.25912	3.8593	13.3260	3.4530
16	35.5271	0.0281	0.00724	138.1085	0.25724	3.8874	13.7482	3.5366
17	44.4089	0.0225	0.00576	173.6357	0.25576	3.9099	14.1085	3.6084
18	55.5112	0.0180	0.00459	218.0446	0.25459	3.9279	14.4147	3.6698
19	69.3889	0.0144	0.00366	273.5558	0.25366	3.9424	14.6741	3.7222
20	86.7362	0.0115	0.00292	342.9447	0.25292	3.9539	14.8932	3.7667
22	135.5253	0.0074	0.00186	538.1011	0.25186	3.9705	15.2326	3.8365
24	211.7582	0.0047	0.00119	843.0329	0.25119	3.9811	15.4711	3.8861
26	330.8722	0.0030	0.00076	1319.49	0.25076	3.9879	15.6373	3.9212
28	516.9879	0.0019	0.00048	2063.95	0.25048	3.9923	15.7524	3.9457
30	807.7936	0.0012	0.00031	3227.17	0.25031	3.9950	15.8316	3.9628
32	1262.18	0.0008	0.00020	5044.71	0.25020	3.9968	15.8859	3.9746
34	1972.15	0.0005	0.00013	7884.61	0.25013	3.9980	15.9229	3.9828
35	2465.19	0.0004	0.00010	9856.76	.025010	3.9984	15.9367	3.9858
36	3081.49	0.0003	0.00008	12322	0.25008	3.9987	15.9481	3.9883
38	4814.82	0.0002	0.00005	19255	0.25005	3.9992	15.9651	3.9921
40	7523.16	0.0001	0.00003	30089	0.25003	3.9995	15.9766	3.9947
45	22959		0.00001	91831	0.25001	3.9998	15.9915	3.9980
50	70065				0.25000	3.9999	15.9969	3.9993
55					0.25000	4.0000	15.9989	3.9997

	Single Payment		Uniform Payment Series				Arithmetic Gradient		
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Capital Recovery Factor	Compound Amount Factor	Present Worth Factor	Gradient Uniform Series	Gradient Present Worth	
	Find F Given P	Find P Given F	Find A Given F	Find A Given P	Find F Given A	Find P Given A	Find A Given G	Find P Given G	
n	F/P	P/F	A/F	A/P	F/A	P/A	A/G	P/G	n
1	1.300	.7692	1.0000	1.3000	1.000	0.769	0	0	1
2	1.690	.5917	.4348	.7348	2.300	1.361	0.435	0.592	2
3	2.197	.4552	.2506	.5506	3.990	1.816	0.827	1.502	3
4	2.856	.3501	.1616	.4616	6.187	2.166	1.178	2.552	4
5	3.713	.2693	.1106	.4106	9.043	2.436	1.490	3.630	5
6	4.827	.2072	.0784	.3784	12.756	2.643	1.765	4.666	6
7	6.275	.1594	.0569	.3569	17.583	2.802	2.006	5.622	7
8	8.157	.1226	.0419	.3419	23.858	2.925	2.216	6.480	8
9	10.604	.0943	.0312	.3312	32.015	3.019	2.396	7.234	9
10	13.786	.0725	.0235	.3235	42.619	3.092	2.551	7.887	10
11	17.922	.0558	.0177	.3177	56.405	3.147	2.683	8.445	11
12	23.298	.0429	.0135	.3135	74.327	3.190	2.795	8.917	12
13	30.287	.0330	.0102	.3102	97.625	3.223	2.889	9.314	13
14	39.374	.0254	.00782	.3078	127.912	3.249	2.969	9.644	14
15	51.186	.0195	.00598	.3060	167.286	3.268	3.034	9.917	15
16	66.542	.0150	.00458	.3046	218.472	3.283	3.089	10.143	16
17	86.504	.0116	.00351	.3035	285.014	3.295	3.135	10.328	17
18	112.455	.00889	.00269	.3027	371.518	3.304	3.172	10.479	18
19	146.192	.00684	.00207	.3021	483.973	3.311	3.202	10.602	19
20	190.049	.00526	.00159	.3016	630.165	3.316	3.228	10.702	20
21	247.064	.00405	.00122	.3012	820.214	3.320	3.248	10.783	21
22	321.184	.00311	.00094	.3009	1 067.3	3.323	3.265	10.848	22
23	417.539	.00239	.00072	.3007	1 388.5	3.325	3.278	10.901	23
24	542.800	.00184	.00055	.3006	1 806.0	3.327	3.289	10.943	24
25	705.640	.00142	.00043	.3004	2 348.8	3.329	3.298	10.977	25
26	917.332	.00109	.00033	.3003	3 054.4	3.330	3.305	11.005	26
27	1 192.5	.00084	.00025	.3003	3 971.8	3.331	3.311	11.026	27
28	1 550.3	.00065	.00019	.3002	5 164.3	3.331	3.315	11.044	28
29	2 015.4	.00050	.00015	.3001	6 714.6	3.332	3.319	11.058	29
30	2 620.0	.00038	.00011	.3001	8 730.0	3.332	3.322	11.069	30
31	3 406.0	.00029	.00009	.3001	11 350.0	3.332	3.324	11.078	31
32	4 427.8	.00023	.00007	.3001	14 756.0	3.333	3.326	11.085	32
33	5 756.1	.00017	.00005	.3001	19 183.7	3.333	3.328	11.090	33
34	7 483.0	.00013	.00004	.3000	24 939.9	3.333	3.329	11.094	34
35	9 727.8	.00010	.00003	.3000	32 422.8	3.333	3.330	11.098	35
40	36 118.8	.00003	.00001	.3000	120 392.6	3.333	3.332	11.107	40
45	134 106.5	.00001		.3000	447 018.3	3.333	3.333	11.110	45

	Single Payment		Uniform Payment Series				Arithmetic Gradient		
	Compound Amount Factor	Present Worth Factor	Sinking Fund Factor	Capital Recovery Factor	Compound Amount Factor	Present Worth Factor	Gradient Uniform Series	Gradient Present Worth	
	Find *F* Given *P*	Find *P* Given *F*	Find *A* Given *F*	Find *A* Given *P*	Find *F* Given *A*	Find *P* Given *A*	Find *A* Given *G*	Find *P* Given *G*	
n	*F/P*	*P/F*	*A/F*	*A/P*	*F/A*	*P/A*	*A/G*	*P/G*	*n*
1	1.350	.7407	1.0000	1.3500	1.000	0.741	0	0	**1**
2	1.822	.5487	.4255	.7755	2.350	1.289	0.426	0.549	**2**
3	2.460	.4064	.2397	.5897	4.173	1.696	0.803	1.362	**3**
4	3.322	.3011	.1508	.5008	6.633	1.997	1.134	2.265	**4**
5	4.484	.2230	.1005	.4505	9.954	2.220	1.422	3.157	**5**
6	6.053	.1652	.0693	.4193	14.438	2.385	1.670	3.983	**6**
7	8.172	.1224	.0488	.3988	20.492	2.508	1.881	4.717	**7**
8	11.032	.0906	.0349	.3849	28.664	2.598	2.060	5.352	**8**
9	14.894	.0671	.0252	.3752	39.696	2.665	2.209	5.889	**9**
10	20.107	.0497	.0183	.3683	54.590	2.715	2.334	6.336	**10**
11	27.144	.0368	.0134	.3634	74.697	2.752	2.436	6.705	**11**
12	36.644	.0273	.00982	.3598	101.841	2.779	2.520	7.005	**12**
13	49.470	.0202	.00722	.3572	138.485	2.799	2.589	7.247	**13**
14	66.784	.0150	.00532	.3553	187.954	2.814	2.644	7.442	**14**
15	90.158	.0111	.00393	.3539	254.739	2.825	2.689	7.597	**15**
16	121.714	.00822	.00290	.3529	344.897	2.834	2.725	7.721	**16**
17	164.314	.00609	.00214	.3521	466.611	2.840	2.753	7.818	**17**
18	221.824	.00451	.00158	.3516	630.925	2.844	2.776	7.895	**18**
19	299.462	.00334	.00117	.3512	852.748	2.848	2.793	7.955	**19**
20	404.274	.00247	.00087	.3509	1 152.2	2.850	2.808	8.002	**20**
21	545.769	.00183	.00064	.3506	1 556.5	2.852	2.819	8.038	**21**
22	736.789	.00136	.00048	.3505	2 102.3	2.853	2.827	8.067	**22**
23	994.665	.00101	.00035	.3504	2 839.0	2.854	2.834	8.089	**23**
24	1 342.8	.00074	.00026	.3503	3 833.7	2.855	2.839	8.106	**24**
25	1 812.8	.00055	.00019	.3502	5 176.5	2.856	2.843	8.119	**25**
26	2 447.2	.00041	.00014	.3501	6 989.3	2.856	2.847	8.130	**26**
27	3 303.8	.00030	.00011	.3501	9 436.5	2.856	2.849	8.137	**27**
28	4 460.1	.00022	.00008	.3501	12 740.3	2.857	2.851	8.143	**28**
29	6 021.1	.00017	.00006	.3501	17 200.4	2.857	2.852	8.148	**29**
30	8 128.5	.00012	.00004	.3500	23 221.6	2.857	2.853	8.152	**30**
31	10 973.5	.00009	.00003	.3500	31 350.1	2.857	2.854	8.154	**31**
32	14 814.3	.00007	.00002	.3500	42 323.7	2.857	2.855	8.157	**32**
33	19 999.3	.00005	.00002	.3500	57 137.9	2.857	2.855	8.158	**33**
34	26 999.0	.00004	.00001	.3500	77 137.2	2.857	2.856	8.159	**34**
35	36 448.7	.00003	.00001	.3500	104 136.3	2.857	2.856	8.160	**35**