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Energy Efficient Sustainable Buildings: Case study Irada Building at IUG

المباني الكفؤة الموفرة للطاقة: دراسة خاصة مبنى إرادة في الجامعة الإسلامية بغزة

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DEDICATION

This thesis is sincerely dedicated

To my beloved parents,

my wife,

lovely kids (Yara and Mahmoud)

and

my brothers and sisters

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Acknowledgment is due to Islamic University of Gaza for supporting of this research.

I wish to express my deepest gratitude to my supervisor Dr. Hatem El aydi for his professional advice and guidance to complete this research.

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ABSTRACT

This study aimed at identifying passive and active design features through extensive literature study that can be incorporated in buildings to make them energy efficient. The study also aimed at identifying changes in the design process that can affect energy efficiency in buildings.

The study has analyzed the design features of typical buildings in Gaza Strip through a case study conducted on Irada building at Islamic University of Gaza. It also analyzed the present electric energy used for lighting, HVAC and induction motor loads.It offers possible energy saving by adopting certain energy efficient features in Irada building at Islamic University of Gaza. It also analysis proposal for building envelop insulation in Irada building that improve energy efficiency, based on the calculation of energy savings associated with the use of HVAC system (to assure a certain comfort temperature).

The findings from this study indicate that by adopting certain energy efficient features in Irada building, we can reduce the annual energy consumption by 24% for low cost model and by 41% for high cost model. It also finding from feasibility study through using three methods which are; simple payback method (S.P.B.P), net present value (NPV) and interest rate of return (IRR) that this type of projects is feasible to encourage the investors to invest In it.

Finally it can be concluded that the process of designing energy efficient buildings is the best method to improve the efficiency of electricity sector in Gaza Strip which 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.

الملخص

هدفت هذه الدراسة إلى تحديد سمات التصميم السلبي والإيجابي من خلال الدراسات الواسعة النطاق التي يمكن إدراجها في المباني لجعلها كفؤة في استخدام الطاقة وتهدف الدراسة أيضا إلى تحديد التغيرات في عملية التصميم التي يمكن أن تؤثر على كفاءة استخدام الطاقة في المباني.

وقامت الدراسة بتحليل ملامح تصميم المباني النموذجية في قطاع غزة من خلال الدراسة على الحالة التي أجريت عليها وهي مبنى إرادة في الجامعة الإسلامية في غزة. وتم تحليل أيضا الطاقة الكهربائية الحالية المستخدمة للإضاءة، التبريد والتهوية والتكييف وأحمال المحركات الحثية، والطاقة التي يمكن توفيرها من خلال اعتماد بعض الميزات الكفؤة في استخدام الطاقة لمبنى إرادة بالجامعة الإسلامية بغزة وتم تحليل اقتراح لعزل الغلاف الخارجي لمبنى إرادة ليعمل على تحسين توفير الطاقة والذي يستند على مدخرات توفير الطاقة لنظام التدفئة والتهوية والتكييف (التأكد من درجة حرارة الراحة).

النتائج المستخلصة من هذه الدراسة تشير إلى أنه من خلال اعتماد بعض الميزات الموفرة للطاقة في بناء إرادة يمكن أن تقلل من استهلاك الطاقة السنوي بنسبة 24% لنموذج الكلفة المنخفض وبنسبة 41% لنموذج الكلفة العالية. تم استخلاص من دراسة الجدوى من خلال ثلاث طرق وهي الطريقة البسيطة لفترة العائد، طريقة الفائدة الصافية وطريقة الفائدة العائدة بان هذا النوع من المشاريع مجدي لتشجيع المستثمرين للاستثمار فيه.

وأخيرا فإنه يمكن استنتاج أن عملية تصميم المباني الموفرة للطاقة هو أفضل طريقة لتحسين كفاءة قطاع الكهرباء في قطاع غزة الذي يعاني من العديد من المشاكل مثل ارتفاع معدل العجز الكهربائية، وخسائر النقل العالية، وارتفاع أسعار الكهرباء لكل كيلو وات ساعة، وزيادة في معدل النمو السنوي وغياب مهارات واستراتيجيات إدارة الطاقة.

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ABBREVIATIONS

A.F.C.	Automatic Fuzzy Controller
APFR	Automatic Power Factor Regulator
ADC	Analog to Digital Converter
BREEAM	Building Research Establishment Environmental Assessment Method
COA	Center of Area
C°	Degree Celsius
CFL	Compact Fluorescent Lamp
DS	Demand Saving
EMF	Electro Magnetic Field
ES	Energy Saving
F.L.C.	Fuzzy Logic Controller
FL	Fluorescent Lamp
MF	Membership Function
MW	Mega Watte
NPV	Net Present Value
GEDCO	Gaza Energy Distribution Company
GPP	Gaza Power Plant
HVAC	Heating Ventilating and Air Conditioning
HEM	High Efficiency Motor
HPS	High Pressure Sodium
IEA	International Energy Agency
IRR	Interest Rate of Return
IUG	Islamic University of Gaza

IEC	Israel Electric Corporation
IEEE	Institution of Electrical and Electronic Engineering
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
NIS	New Israeli Shekel
O.H	Operating Hour
P.F	Power Factor
T.S.P.	Thermal Set Point
VSD	Variable Speed Derive
S.P.B.P	Simple Pay Back Period

CHAPTER 1

INTRODUCTION

1.1 General Introduction about Energy

Energy is vital for all living-beings on earth. Modern life-style has further increased its importance, since a faster life means faster transportation, faster communication and faster manufacturing processes. All these lead to an increase in energy required for all those modern systems.

Arising out of comparison of status of nations, the progress is related in item of per capita consumption of electrical energy (i.e. KWH consumed per person per year). At present this parameter for India is about 300, for UK it is 12 to 15 times more, and for USA it about 30 times more [1].

It simply means that Electrical energy is the most popular form of energy, whether we require it in the usable thermal form (= heating applications), in mechanical form (= electrical motors), for lighting purpose (= illumination systems), or for transportation systems.

The following types of resources are available for generating electrical energy:

1- Conventional methods:
- Thermal: Thermal energy (from fossil fuels) or Nuclear Energy used for producing steam for turbines which drive the alternators(= rotating a.c. generators).
- Hydro-electric: Potential of water stored at higher altitude is utilized as it is passed through water-turbines which drive the alternators.

2- Nonconventional methods
- Wind power: High velocities of wind (in some area) are utilized in driving wind turbines coupled to alternators. Wind power has a main advantage of having zero production cost.
- Fuel cells: These are devices which enable direct conversion of energy, chemically, into electrical form. This is an up-coming technology and has a special merit of being pollution-free and noise-free. It is yet become popular for bulk-power generation.
- Photo voltaic cells: These directly convert solar energy into electrical energy through a chemical action taking place in solar cells. These operate based on the photo-voltaic effect, which develops an EMF on absorption of ionizing radiation from sun.

From the above we can summarized that energy resources can be divided into fossil fuels, renewable resources, and nuclear resources. The current world demand depends mainly on the conventional energy which pollute the environment. The renewable energy sources presents alternative sources but they need more development to compete the fossil fuels source.

1.2 Modern Energy Conservation Techniques

In this thesis we are taking a closer look at the most important energy saving/conservation techniques and tips that we can implement in our building to increase energy efficiency and cut costs. Some of the techniques are simple and can be implemented straight away – others require more carefully planning and can have high initial costs (these usually have the highest gains in the long run) [2].

1. Get rid of incandescent light bulbs

Thomas Edison's incandescent light bulbs have been on the market since the 19^{th} century. The quality of light is close to ideal, however, they are incredible inefficient – only 10% of the electricity is converted into light while the rest ends up as heat. It's about time they are replaced with light bulbs that are more environmentally friendly.

Some places in the world, the old incandescent light bulbs have been banned (the U.S has planned their phase-out to start in 2014), leaving you only to pick from a range of energy efficient light bulbs.

2. Seal air leaks

Is your house uncomfortable when it gets cold outside despite the fact that all the heating is switched on? If you think it is due to poor insulation you may need to think again. Air leaks are often the main culprit in cold houses and sealing them can make a big difference

3. Use energy-efficient windows, doors and skylights

Even though the windows in an average house only covers about 5-10% of the outer surface, it is not uncommon that they are responsible for over 40% of the heat loss. A building's heating costs can therefore be drastically lowered if old windows with poor energy ratings are replaced with energy-efficient alternatives. The same goes for doors and skylights as well. Reduced energy bills is not the only thing that people who have replaced old fenestration report of, but also increased indoor comfort.

The lower the U-value, the better. Old windows have an average U-value (or U-factor) of around 2.7. As a comparison, today's modern energy-efficient windows with triple layer designs can have U-values of 1.0 or lower.

4. Lower the room temperature

If you can handle it, lowering room temperature by only a degree or two, can result in big energy savings. The greater the difference between outdoor and indoor temperature is the more energy is used to maintain room temperature. You can always put on more clothes!

There are smarter and more comfortable ways of doing this. If you set your thermostat lower at night and at times when you are not home, you can still end up saving a lot of money. Get a programmable thermostat that allows you to do these things.

5. Get an energy audit

Before you start optimizing your house with ways to conserve energy you might want a consultation on where your house is *leaking* energy. This is exactly what an energy audit is.

An expert performs a comprehensive home energy checkup: A series of tests to find out where your money is best spent to make your house more energy efficient.

1.3 Problem Formulation

1.3.1 General problem

Gaza Strip is a small but one of the most density populated area in the world. About 1.7 million people live in 360 square kilometers. Gaza Strip has come to be known as a fast growing area of the Middle East in terms of population in recent years. It began with a manageable population of 1.2 million in 2002, which reached 1.7 million in 2012. Gaza Strip's population is expected to grow at a rate of 4.2% annually and reach a total of 2.13 million in 2020 [3].

The energy infrastructure of Palestine is quite small, insufficient and poorly managed. As shown in Fig.(1.1), Gaza Strip is supplied with electricity from three main sources [4]:

1- Israel Electricity Corporation provide 120 MW to the northern and central area of the Gaza Strip.
2- Gaza Power Plant ("GPP") provides 70 MW to the northern and central area of the Gaza Strip; and
3- Egypt provide 21 MW to the Rafah area.

There are Currently a shortage of at least 30% which stems from Israel bombing of the Gaza Power Plant in June 2006. The Palestinian Energy Authority is managing the current shortage by implementing a scheduled cut off of electrical power to different parts of the Gaza Strip; in the peak seasons, the scheduled cut off reaches 50%.

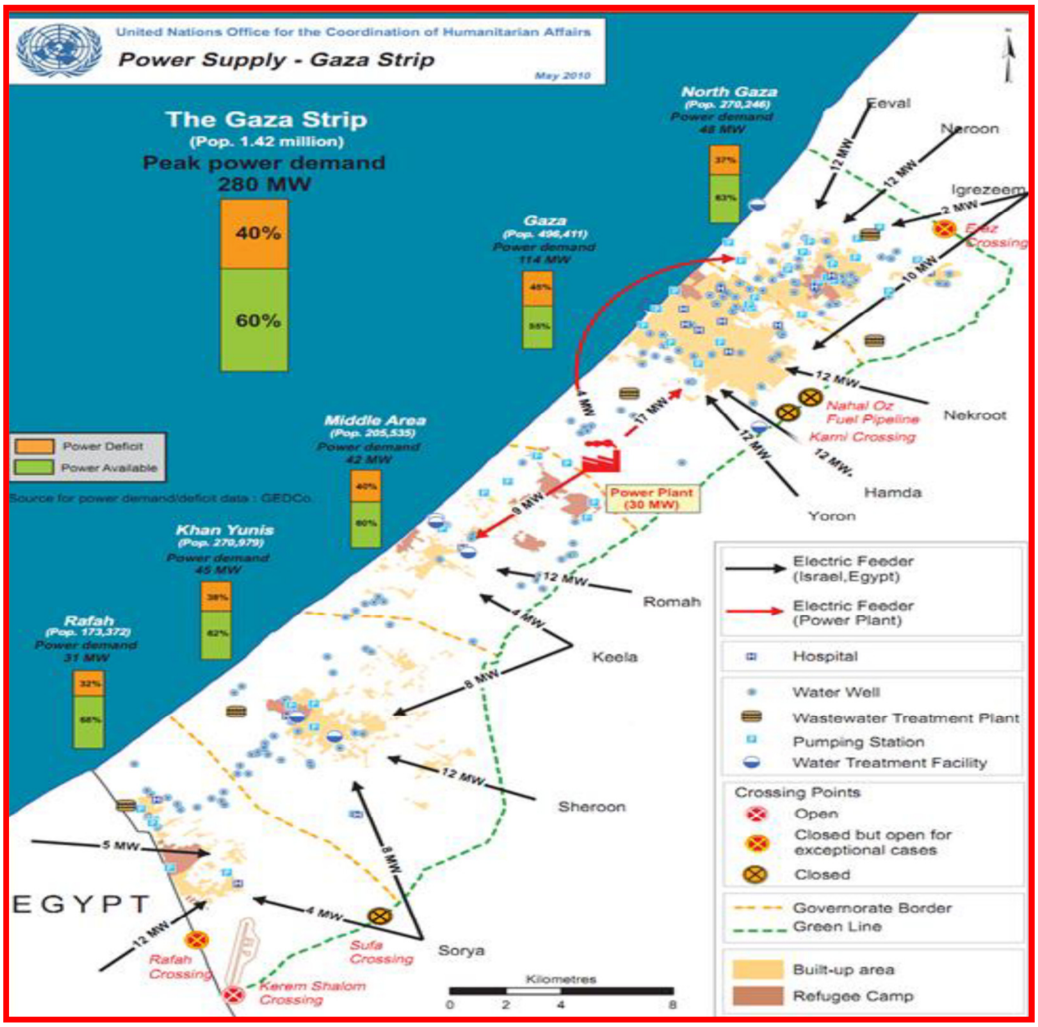


Figure 1.1 : Electrical power supply for Gaza Strip

The demand for electricity is growing at a rate of 7% per year without any well-designed plan to meet the demand. The average generation capacity of power in 2011 was about 216MW per day, whereas the average peak demand of national power was about 300 MW, also adds that during summer, when the maximum temperature ranges from 25°C to 38°C, the average peak demand can increase around 20%. This deficit leads to extensive load shedding. Other problems in the Gaza Strip electric power sector include high system losses, delays in completion of new plants, low plant efficiencies, erratic power supply, electricity theft, blackouts, and shortages of funds for power plant maintenance [4].

1.3.2 Specific problem

According to IEA [5], generated power can be increased by finding renewable power energy; moreover, saving measures can increase the available power. Today, buildings worldwide account for up to 48% of total end-use energy. The US, OECD/ Europe and Russia consume most of their energy in the building sector (about48%) as shown in Fig.(1.2) [46].

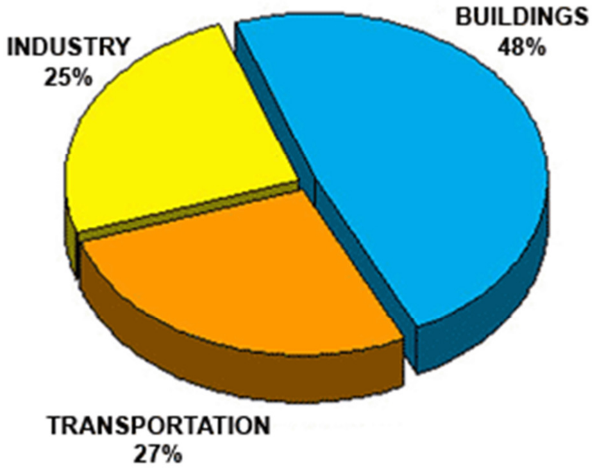


Figure 1.2: Global energy demand by sector in 2005

The use of electricity in Gaza Strip is represented such as industrial (16%), residential (73%), commercial (8%) and others (3%). Much of the increased demand for electricity is due to the increased standard of living among the wealthier income groups. One of the major factors in the increased use of electricity by the higher income group is the use of air conditioning units, which has only recently become quite popular.

Increase in electricity use by the Gaza Strip residential buildings during the summer months has been caused by the growing demands for air conditioning systems. Air conditioners are increasingly used in hot and humid regions to attain thermal comfort. However, they argue that air conditioning is highly energy intensive and suggest developing alternative energy efficient means to achieve comfort. By the year 2020 the population of Gaza will increase to around 2.13 million, from an estimated 1.6 million people today [3]. The substantial population growth rate will thus add some 500,000 people to a living area which is restricted and already heavily urbanized. Fundamental infrastructure in electricity, water and sanitation, municipal and social services, is struggling to keep pace with the needs of the growing population. By 2020, electricity provision will need to double to meet demand, damage to the coastal aquifer will be irreversible without immediate remedial action, and hundreds of new schools and expanded health services will be needed for an overwhelmingly young population. Tens of thousands of housing units are needed today. Moreover, a study of the regulations in the national building code of Palestine shows that the building codes do not address the issues of energy efficiency in any building category. Architects and developers of residential buildings, too, have not considered ways in which energy use can be reduced. The specific problems that signify the importance of energy-efficiency in residential buildings are as follows:

- ✓ High-energy use of residential buildings in Gaza,
- ✓ Growing population and rising number of apartments,
- ✓ Increased standard of living that would further add to energy usage
- ✓ interrupted power supply due to power deficits.

1.4 Thesis objectives

The main objective of this thesis is to introduce the concept of sustainable buildings. All of the factors for sustainable buildings are related to: environmental benefits, long economic benefits, simple implementation and better performance in terms of comfort. The best way for identifying sustainable buildings assessment criteria is by studying, surveying and comparing the various researches and finally achieving a set of criteria that can assess truly the performance of such buildings.

We will select a new building at the Islamic University of Gaza, and design it according to sustainability standards.

This research aims to achieve a number of other specific objectives, including:

- To highlight the energy situation of the world by estimating the global energy consumption.
- To identify the problem of energy shortage in the Gaza Strip and its negative impact on all aspect of Palestinian life.
- To discuss the potential solutions of available renewable energy sources such as solar and wind energies that can contribute to solve the energy problem.
- To find out the basic principles of thermal comfort, and its personal and environmental determinants.
- To study the strategies of energy-efficient building design, which include the planning aspects, or building envelope, and to clarify.

1.5 Methodology

The best methodology to overcome the problem in this research is by introducing the concept of sustainable buildings. All of the factors for sustainable buildings are related to: environmental benefits, long economic benefits, simple implementation and better performance in terms of comfort. The best way for identifying sustainable buildings assessment criteria is by studying, surveying and comparing the various researches and finally achieving a set of criteria that can assess truly the performance of such buildings.

We will select a new building at the Islamic University of Gaza, and design it according to sustainability standards. There are five steps to a sustainable building a performance path [6].

Step One: SETTING of the building with a low impact on the land, paying attention to solar gain, prevailing winds, and water issues is key. Good orientation is one of the greatest gifts for a high performance building.

Step Two: ENERGY EFFICIENCY is a quality building envelope along with good insulation, low energy lighting and appliances throughout.

Step Three: NATURAL LIGHTING means bringing the sun deep into the space, putting light where you need it. NATURAL HEATING/COOLING being with solar tempering a space, using thermal mass wisely, good overhang for the summer's heat, and natural ventilation.

Step Four: SOLAR POWER often is the best on site renewable choice, both electrical and thermal.

Step Five: REGENERATIVE/ ADAPTIVE is the future of building, utilizing technologies and techniques that positively respond to the greater environment.

We will concentrate our attention and discuss in details the five steps.

1.6 Thesis Contribution

This study is expected to provide the following benefits to the development of residential buildings in Gaza Strip:

1- The study will improve the understanding of a typical residential building in Gaza Strip (case study building), including its energy use.

2- The study will determine the amount of electric energy used for cooling and lighting in typical residential buildings of Gaza Strip.

3- The study will provide guidelines to assist architects for designing energy-efficient residential buildings in Gaza Strip.

1.7 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- It was not possible to identify a very good example of an energy-efficient residential building in a similar climatic context as of Gaza Strip from which energy efficiency criteria could be studied. Instead, the identification of energy efficient design features depended on an ex

2- Extensive literature study.

3- The study considers energy use of electrical appliances to find out the energy used for cooling and lighting. However, it does not consider the efficiency or the possible improvements in efficiency of these devices; it considers only replacing them by passive techniques.
4- Lack of management awareness related to energy saving investment for improvements efficiency restricted the production capability.
5- Lack of instruments limited the audited equipment and restricted the number of selected facilities.
6- 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.
7- Lack of technical data for electrical equipment and components to identify energy and investigate the potential for energy saving opportunities complicated the energy audits.

1.8 Literature Review

In 2005, Minni Mehrotra [14] investigated Green building solutions. He suggested an economically viable solution with minimal environmental footprint which can bring about 30-40% energy savings in new buildings and 20% savings in existing buildings with reduction in demand on the fossil fuels, emissions, pressure on natural resources e.g. water and waste generation. The problem which face him is that the existing building lies in crowded area and this make problem in using passive techniques to save energy inside this building.

In 2006, Persson and et al. [15] examined how decreasing the window size facing south and increasing the window size facing north in the low energy houses would influence the energy consumption and maximum power needed to keep the indoor temperature between 230 C and 260 C. Different orientations have been investigated as well as the influence of window type. The dynamic building simulation tool, DEROB-LTH, was used. The results showed that the size of the energy efficient windows does not have a major influence on the heating demand in the winter, but is relevant for the cooling need in the summer. This indicated that instead of the traditional way of building passive houses it is possible to enlarge the window area facing north and get better lighting conditions. To decrease the risk of excessive temperatures or energy needed for cooling, there is an optimal window size facing south that is smaller than the original size of the investigated buildings.

In 2009, GE Jian and et al. [16] studied the potential of energy conservation of existing residential buildings was studied in the Hot Summer and Cold Winter Region of China. The present envelop thermal performance of three residential case buildings: a general urban building, a historic residential building and a rural building, were investigated, which illustrated that all these three residential buildings are poor in thermal performance and comfort no matter when they were built. Then, the suitable envelop renovation plans of the case buildings were formulated considering less retrofit, simple technology, short construction period and clear effect. The effects of energy conservation were simulated under the renovation plan. Simulation results shows that the general urban case building could achieve 46.28% reduction of the annual energy consumption, historic case building 59.45%, and the rural building 24.13% respectively. This result illustrates that for China the existing residential buildings have huge potential of energy conservation, and the renovation plans formulated in their paper could be effective and suitable.

In 2009, Luigi Martirano [17] investigated 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%.

In 2009, Tahmina [18] identified passive design features through extensive literature study that can be incorporated in residential buildings to make them energy efficient. The study also aimed at identifying changes in the design process that can affect energy efficiency in residential buildings. It has analyzed the design features of typical residential buildings representative of upper middle income households in Dhaka through a case study conducted in Dhaka. It also analyzed the present electric energy use for cooling and lighting typical residential buildings of upper middle income households in Dhaka and the possible energy savings by adopting certain energy efficient features in the case study building. It also distinguishes the different roles of developers, architects, interior designers, land owners (clients) and residents that can act as a barrier in achieving energy efficiency in residential buildings. The findings from this study indicate that doubling the thickness of external walls on east and west, use of hollow clay tiles instead of weathering course for roofs and use of appropriate horizontal overhang ratios for all four orientations can reduce the cooling load of the case study building by 64% and hence reduce the total energy use of the building by 26%. Finally it can be concluded that the process of designing energy efficient residential buildings is not a ‘one-man’s show’. Architects, developers, interior designers and clients are the other actors who can bring a change in the design practice.

In 2010, Khoudary [19] presented two case study. The case studies were Gaza Training Center (GTC) and Automatic Palestine Factory (APF) located in Gaza Strip and were 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 identified electrical energy, waste, and cost saving opportunities, and quantifies the expected savings, implementation cost and simple payback of each opportunity. The training center facility consumed 250,820 kWh per year of electricity and factory used 263,875 kWh per year. This research proposed 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 achieved 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.

In 2011, Dabboor Hazem [20] investigated four factors that control the solar gain entering through windows which were: size, orientation, glass material and shading device of windows in accordance with local environmental conditions of the Gaza Strip. In order to achieve the purpose of research, an parametrical study was carried out by "IES VE" and "ECOTECT" programs to assess the effect of window on energy consumption of a typical residential building in the Gaza Strip. The study concluded that the appropriate window design in the Gaza Strip buildings can effectively reduce the energy consumption. It found that the optimal windows orientation is by elongating the long axis of the building along east-west direction. It also concluded that the minimum percentage of windows by (10%) of the total facade area is the optimum size for all facades. The direct impact of south window was considered the worst, as it causes the largest energy consumption. In addition, the study emphasized that using advanced glazing materials with low U-value was an important factor in reducing the energy demand. It also confirmed that the horizontal device with relatively short depth is the appropriate type for south window, whereas the compound (horizontal and vertical) device with long depth is the most effective for west and east windows.

In 2011, Tang [21] proposed building smart, green and people- friendly building based on Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM). However, he did not present specified details in his paper.

In 2011, Bardhan and Karoll [22] explored in depth how the decisions on whether or not to make green or energy efficiency investments in buildings were made, and by examining the larger diffusion of green and energy efficient buildings throughout the urban landscape. They presented a thorough review of research that focused on the benefits of green design, the costs of green and energy efficient buildings and geographic characteristics that influenced the adoption of green design and energy efficiency future. They also examined empirical data and included a preliminary statistical analysis of the factors influencing the diffusion of LEED and Energy star buildings among geographic areas. In addition to market factors, they focused on underlying structural urban variables and the overall socio-cultural and regulatory environment that made the green labeling or energy efficiency more desirable.

In 2011, Roberston and Athienitis [23] presented basic information on solar buildings design which include passive solar heating, ventilation, air heating, solar domestic water heating and shading. They suggested ways to incorporate solar design in multi-unit residential buildings and provided calculation and example to show how early decisions can increase the usable solar energy. In order to reduce cost of passive solar to minimum, it must be incorporated in the initial design stages. Presently, photovoltaic's are an expensive way to provide electricity; however, the cost of building-integrated PV (BIPV) systems is coming down as competition and market share increase.

In 2012, Qaemi and Heravi [24] investigated energy efficiency key performance criteria for sustainable buildings. The performance criteria was based on local experts. The main obstacles were: lack of funding, poor planning, and lack of public support. This study was just the beginning and lacks major issues.

In 2012, David Austin [25] presented an examples of energy-saving building technologies include familiar products like programmable thermostats, low-energy lighting, and on/off timers for electrical outlets (to reduce energy use when equipment is in standby mode); durable technologies such as low-emissivity windows and variable-speed motors for furnaces and air conditioner systems; and spray-foam insulation of attics, reflective roofing materials, insulated-concrete foundation walls, and other construction technologies. Whether a technology's energy savings are worth a higher purchase price (relative to the price of a conventional technology) will depend on each potential adopter's particular circumstances. Thus, policies that preserve the choice of whether to adopt a technology—policies that create incentives or disseminate information rather than imposing mandates—are less likely to impose costs in excess of benefits. Still, there are circumstances in which mandates—minimum-efficiency standards and building energy codes—can be justified on a cost-benefit basis.

1.9 Thesis Structure

This thesis aims to identify the best design alternatives and to determine the energy saving rate as a result of using modern energy efficient techniques, and it is structured into seven chapters:

Chapter 2 introduces to energy situation in Gaza Strip, Gaza Strip buildings, electrical network in Gaza Strip, cost of electrical energy purchases in Gaza strip and energy bill analysis to our case study: Irada building at IUG.

Chapter 3 presents a literature review about the energy and building design including the energy situation in the world with special focus on the Gaza strip. In addition, the basic principles of energy efficient building design are discussed in this chapter.

Chapter 4 introduce to efficient energy building design, investigate description of climatic data, determinants of thermal comfort, planning principles of energy efficient building, orientation, vegetation, building envelope and fenestration principles and passive cooling and heating techniques.

Chapter 5 investigates the impact of building envelope insulation, efficient and automation lighting system, efficient energy HVAC system, replacing conventional motors by HEM, and adding APF regulator on the overall energy consumption at Irada building.

Chapter 6 gives an economical analysis about the design principles of energy efficient building, finding out saving factor, cash flow analysis and rate of return for the energy saving models (Case study: Irada building at IUG).

Chapter 7 gives a conclusion about the design principles of energy efficient building(Case study: Irada building at IUG). Some recommendations are provided in this chapter as well.

CHAPTER 2

SITUATIONAL SETTING OF PROBLEM IN GAZA

2.1 Energy situation in Gaza Strip

As shown in Fig.(2.1), Gaza strip is located at the south-west area of Palestine. It expands along the Mediterranean Sea with 40 km long and between 6 and 12 km wide. The total area of the Gaza strip is estimated at 365 km^2. Its height above sea level reach 50 m in some locations. It is located on Longitude 34^o 26' east and Latitude 31^o 10' north [8].

Figure 2.1: The Gaza Strip map[15]

The Gaza strip depends on three main sources of electricity supply including (Israeli) Electricity Company, Egyptian Electricity Company, and local Gaza Power Plant. Also, it imports the fossil fuels by two ways either directly from Israel or indirectly (by tunnels) from Egypt. Fig.(2.2) obviously shows the electricity load required for the Gaza strip from 2001 to 2010. It's clear that the electricity needs increase by about 10-15 MW annually, as a result of the natural population growth and the expansion in the different sectors requiring electricity supply[9].

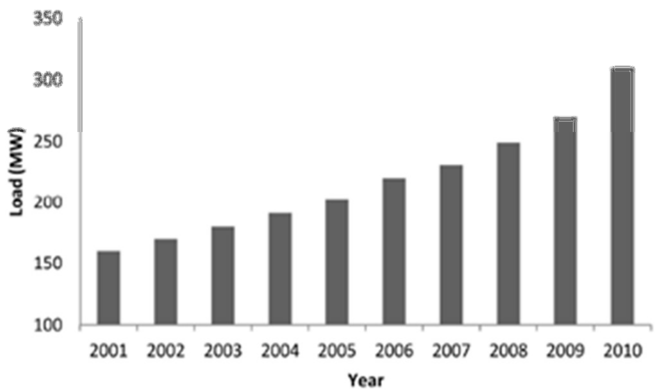


Figure 2.2: The electricity load required for Gaza Strip from 2001 to 2010 [9]

The significant exploration of the gas field near the Gaza Strip shore can play important role in the development of energy sector in Gaza. There are a positive indicators for existence of approximately 50-60 billion m3 of natural gas in this field. This massive amounts of natural Gas is enough to meet the Palestinians requirements of gas for 30 years, while the surplus will be exported. Unfortunately, the project has not been implemented yet due to the bad political status [9]. Gaza power plant consists of 6 turbines, four of them work on either light fuel oil or gas and two are steam turbines. Although its real total capacity is 140 MW, it generates just 90 MW. Bombing the plant on June 28th 2006 by Israel caused a large damage and the production decrease from 90 MW to 30 MW. This reduction affects negatively all areas of the Palestinians life.

Unfortunately, the main problem of energy in the Gaza Strip is that it has almost no conventional energy sources. This problem becomes worse by the high density pollution of the Gaza strip and the difficult political status caused by (Israel) occupation. According to Kandeel [36], the Gaza strip needs (360) MW of electricity. The available supply is (197) MW. The large share of this supply about (60%) with an average load (120) MW is provided by (Israeli) Electricity Company. Locally, about (32%) with an average load (60) MW is provided by Gaza Power Plant. In addition, about (8%) with an average load (21) MW is provided by Egyptian electric company.

In the light of previous statistics, the Gaza strip has been suffering from a real shortage in electricity supply estimated to about 25%. This lead to scheduled cuts of electricity supply for several hours per day which affect negatively on all aspects of the Palestinians life and make it very hard. This shortage rate of electricity supply will be increased by the time if other options are not found. One of the available and considerable options in the Gaza strip is renewable energy sources, particularly solar and wind energy.

2.2 Gaza Strip buildings

Due to the limited land in the cities of Gaza Strip, buildings are mostly multi-story, convergent to each other. The most common construction system in the residential buildings of Gaza is the structural system (reinforced concrete foundations, columns, and ceilings). In this study, building materials are defined to match the most common ones in Gaza. This is intended to explore thermal performance of the reference building, and decide whether it needs some improvement or not. The following is a description of several materials used in the reference modeling case:

A. *External walls*

Most commonly, walls in Gaza are made of hollow concrete blocks and thin layers of cement plastering applied to the internal and external walls as shown in Fig.(2.3). A typical section of external walls shows 20 cm hollow concrete blocks, with 1-1.5 cm of internal plaster and 2-3 cm of external plaster. Thermal properties of this element are as follows: U-value: 2.3 W/m^{2}K, admittance: 4.4 W/m^{2}K, decrement factor: 0.3, time lag: 7.4 hrs [10].

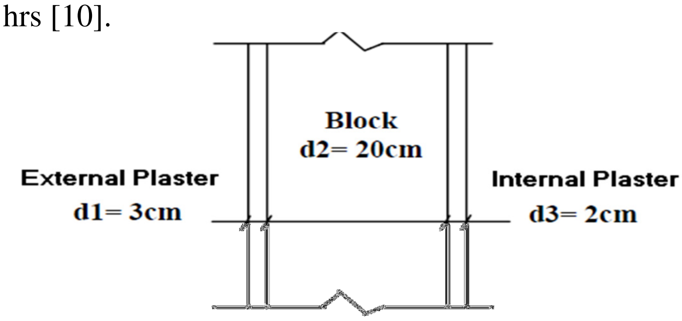


Fig. 2.3: External Wall of Gaza Building

B. Ceilings

The typical ceiling section shows three parts: 8 cm layer of reinforce concrete, 17cm layer of hollow concrete blocks, and 2 cm layer of plastering as shown in Fig.(2.4). Thermal properties of this element are as follows: U-value: 2.6 W/m^{2}K, admittance: 4.9 W/m^{2}K, decrement factor: 0.4, time lag: 6.8 hrs [10].

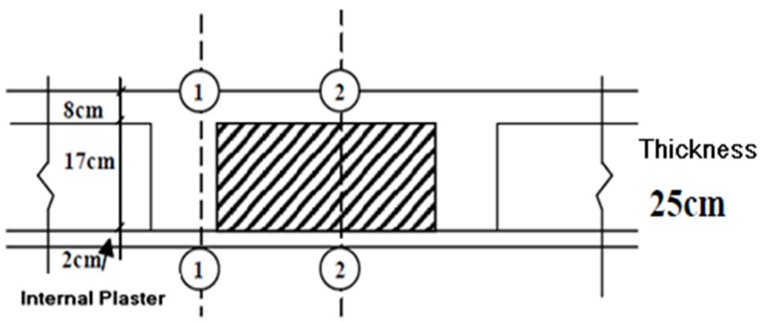


Fig. 2.4: Ceiling of Gaza Building

C. Glazing

Windows are important parts of the building envelope since they provide both lighting and ventilation. A typical single-glazed window with aluminum frame is assumed here. Thermal properties of this element are as follows: U-value: 5.5 W/m^{2}K, admittance: 5.5 W/m^{2}K, solar heat gain coefficient: 0.9 [10].

2.3 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 0.5 NIS for household prices and 0.592 NIS for other sectors [11].

The fact that electricity production is monopolized by the IEC with 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 [12].

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.

To solve the problem of long time electricity cut off, Gaza Strip people used small power generating units in houses and small business, and used large and medium power generating units in multi-story buildings and factories. Fuel consumption of typical of 1 KVA is approximately 1L/hr, the cost of fuel is around 3.2 NIS/L, while the cost of electricity using large generation unit is cheaper and equal around 1 NIS/Kw.

2.4 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 Fig.(2.5) [13].

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 Fig.(2.6) [13].

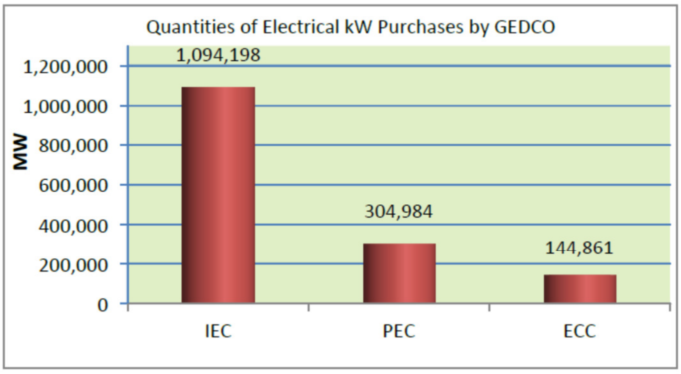


Figure 2.5: Total Quantities of Electricity purchases in 2010.

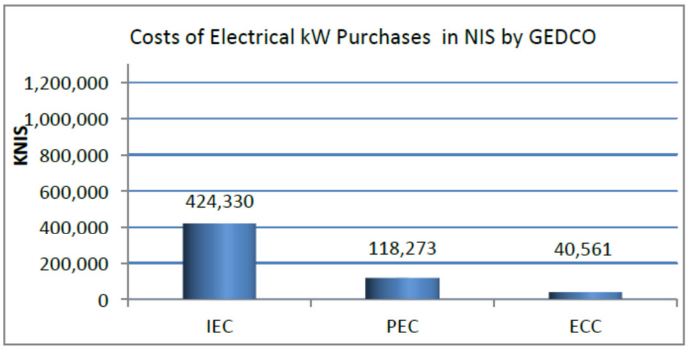


Figure 2.6: Total Costs of Electricity purchases in 2010.

2.5 Description of our case study: Irada building at IUG

The Irada building hosts more than one hundred craftsman in addition to the staff at the college of management and trainers. The operation hours are between 1600 to 1800 hours per year for an average of 6-8 hours daily with five working days weekly. There are three floors in the building; basement, ground and first floor (see Fig. 2.7 and Fig. 2.8). All workshops are in the basement floor, all management offices and laboratory are in ground floor while showroom are in first floor.

Figure 2.7: Irada building photo from south direction

Figure 2.8: Irada building from west direction

2.6 Energy bill analysis

Table 2.1 shows approximate values of annual energy consumption because there is no separate KWHM fixed for Irada building. These value are talking using Ampere meter reading for all three phases and we compared the other months by total consumption of electrical bill of IUG university, electric consumption in Irada building for the period of 12 months.

The electrical bill is low during Winter months; Dec, Jan, Feb since there is no heating machines were used, and very high in Summer months; Jun, July, Aug since air condition machines operate all working times.

Table (2.1): Energy consumption and cost for the year 2011/2012 for Irada

Month	Electrical Consumption kWh/Month	Electrical Cost NIS/Month
Sep	11894.89	5697.65
Oct	10037.12	4807.78
Nov	8978.02	4300.47
Dec	7635.55	3657.43
Jan	8038.31	3850.35
Feb	7099.75	3400.78
Mar	9937.08	4759.86
April	9393.88	4499.67
May	10341.46	4953.56
Jun	12109.87	5800.63
July	12002.05	5748.98
Aug	12500.31	5987.65
Total	119968.29	57464.81

Fig.(2.9) and (2.10) illustrate the monthly electricity consumption and the delivered cost of Irada, the high load consumptions are from the light fittings, HVAC system, and the motors inside the workshops.

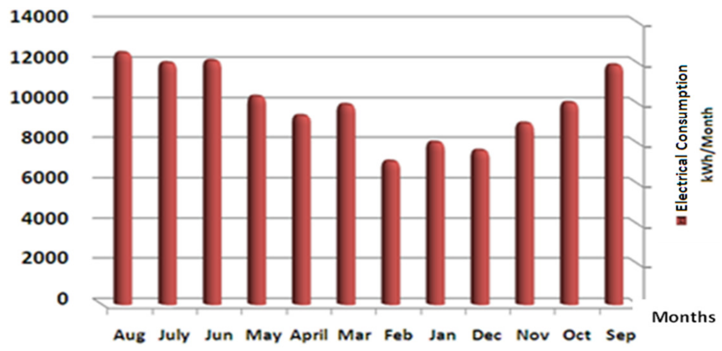


Figure 2.9: Month electricity energy consumption at Irada

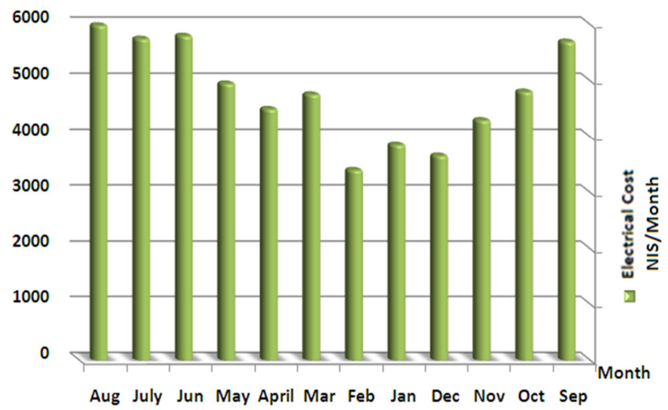


Figure 2.10: Monthly electrical cost at Irada

From Table(2.1), Fig.(2.9) and Fig.(2.10), we can summarized that Irada building at IUG total annually electrical consumption is 119968.29 kWh with total electrical cost 57464.81 NIS**.**

CHAPTER 3

ENERGY EFFICIENT BUILDING DESIGN

Passive Solar design is an aspect of building design in which the solar cycle is exploited in Winter to provide passive building heating for free. In essence the heat of the Sun is 'captured' in Winter to provide building heat - so known as designing for solar gain. The Passive part of passive solar design comes from the fact nothing 'active' is done to achieve this, i.e. no machinery or complex technology is employed, just the way the building is constructed that does the work. The big win for the home owner is that the cost of keeping the house comfortable is greatly reduced; no 'active' air cons etc are required. This also protects the owner from rising fuel costs in the future. Also a Passive Solar designed house often has a better air quality and general 'atmosphere' than a traditional house as more light enters the property [26].

There are four primary steps in energy efficient buildings approach to meet the occupant's need for thermal comfort at low levels of energy consumption [27], as mentioned below:

- Integrate solar passive techniques in a building design to minimize load on conventional systems (heating, cooling, ventilation, and lighting).
- Design energy efficient lighting and HVAC (heating, ventilation, and air conditioning) systems.
- Use renewable energy systems (solar photovoltaic systems , solar water heating.
- Use low energy materials and methods of construction and reduce transportation energy.
- Use smart technology to reduce energy consumption.

Generally, energy efficient buildings can be achieved through two approaches which are active and passive. The active system employ hardware and mechanical equipment to collect and transport heat. In contrast, the passive system collect and transport heat by non-mechanical means. In the other words, the specific difference between the two systems is that the passive system operates on the energy available in its immediate environment while the active system imports energy, such as electricity, to power fans and pumps which make the system work [29]. This thesis, focuses on discussing the principles of passive design approach.

Before going into the details of principles design of energy efficient building. It is important to introduce the topic of thermal comfort that describe the interactive relation between humans and surrounding environment. It is also considered as important one of thermal performance parameters in buildings.

3.1 Description of climatic data

Gaza Strip is considered a transition zone between the coastal area wetlands and the dry desert region (Negev desert in the south-east and Sinai desert in the south-west). It is located in hot humid region on longitude 34^0 26' east and latitude 31^0 10' north.

Winter in Gaza area is rainy and mild, while summer is hot and dry, and extends over longer period of the year [30]. The following sections discuss in details the climatic elements of the Gaza strip.

3.1.1 Temperature

The average daily mean temperature ranges from 24^{o}C in summer (May-August), to 15^{o}C in winter (November-February). The average daily maximum temperature ranges from 27^{o}C to 19^{o}C, and minimum temperature from 21^{o}C to 11^{o}C, in the summer and winter respectively [30]. Fig. (3.1) shows the annual average temperatures (C) in the Gaza strip.

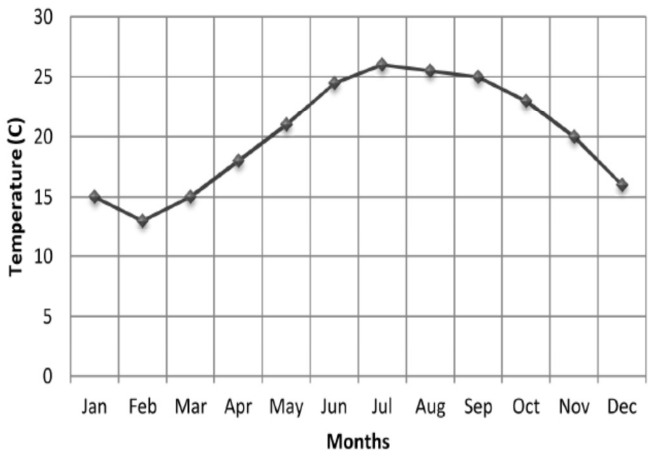


Figure 3.1: The annual average temperatures (C) in the Gaza Strip.
Source : (Ministry of Local Government, 2004)

3.1.2 Relative Humidity

Relative humidity fluctuates between (65%) and (85%) in summer, and between (60%) and (80%) in winter. Fig. (3.2) shows the annual average Relative Humidity in Gaza Strip [31]. Rain is the main source of water in Palestine as it provides the underground water reservoir with water. Although rain fall in Gaza is unsteady, it is useful for irrigating farmlands. The amount of rain increases in the interior parts because these areas are higher than the sea surface. Annually, the amount of rain in the Gaza Strip is between 100-130 million m^3 [32].

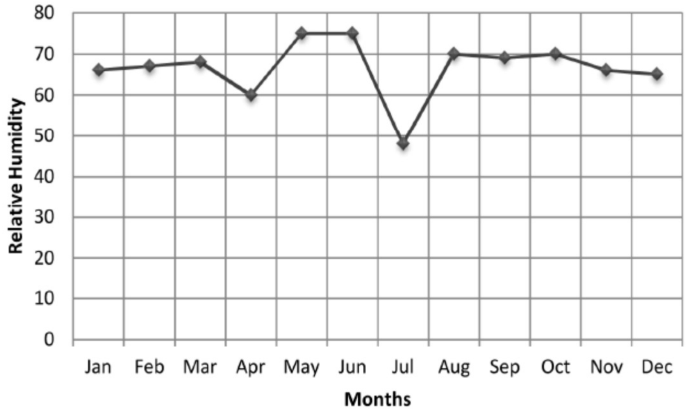


Figure 3.2: The annual average relative humidity (%) in the Gaza Strip
Source : (Ministry of Local Government, 2004)

3.1.3 Wind Speed

The prevailing winds in Gaza Strip is northwesterly in the summer. The speed of these wind is variable reaching the speed of (3.9) m/s during the afternoon. The prevailing wind direction and speed change during the winter, as it turns to the southwesterly wind and speed increase up to (4.2) m/s with nonvolatile speed. Sometimes, it is noticed that there is blowing southwesterly winds increase up to (18) m/s [31]. Fig. (3.3) shows the annual average wind speed (m/s) in the Gaza Strip.

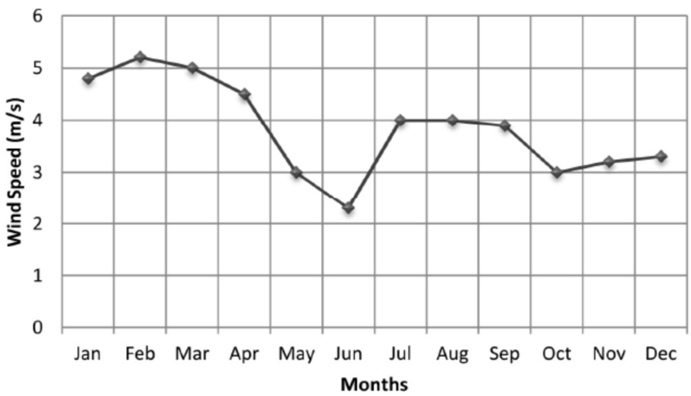


Figure 3.3: The annual average wind speed (m/s) in the Gaza Strip
Source : (Ministry of Local Government, 2004)

3.1.4 Solar Radiation

Gaza Strip has a relatively high solar radiation. It has approximately 2861, annual sunshine–hour throughout the year [30]. The daily average solar radiation on a horizontal surface is about 222 W/m^2 (7014 MJ/m^2/yr). This varies during the day and throughout the year. Fig. (3.4) illustrates the variation in the monthly daily average in total insulation on horizontal surface for each month.

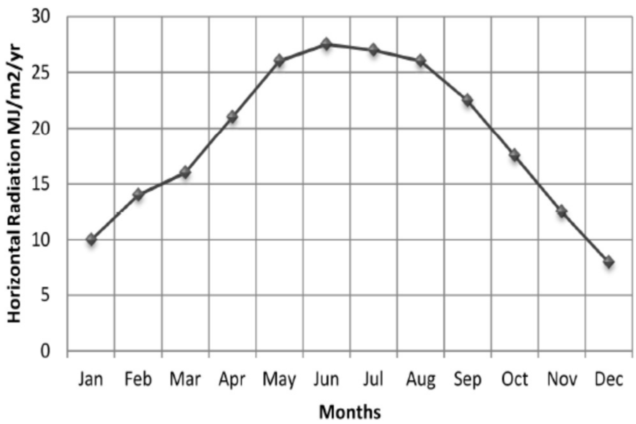


Figure 3.4: The annual variation in solar radiation in the Gaza Strip
Source : (Palestinian Energy Authority, 2010)

3.2 Determinants of thermal comfort

According to Ampofo [28] thermal comfort is defined as ''that condition of mind which expresses satisfaction with the thermal environment''. This satisfaction with the thermal condition is dependent on the balance between the heat produced or received by the body, and heat lost from the body to the surrounding environment. Continuously, the human body produces heat by its metabolic processes. The average of this heat is about 100W, and it can vary from about 70W in sleep to over 700W in heavy work [33]. Part of this heat must be transferred to the environment because human body needs constant internal temperature to energize all process of human systems. Thus, there is a continuous exchange of heat between human bodies and the surrounding environment. This heat exchange occurs in four different ways: through radiation, convection, evaporation and sometimes conduction [34].

- **Radiation***:* it is the net exchange of radiant energy between two bodies across an open area. The human body gains or losses radiant heat depends on the temperature difference between the surface of the body temperature and the surrounding surfaces bodies.

- **Conduction:** the conduction heat loss or gain occurs through contact of the body with physical object such as the floor and chairs.

- **Convection:** which is the transference of sensible heat to or from the body. The faster the rate of air movement, the larger temperature different between the body and surrounding air, the greater the rate of heat transfer.

- **Evaporation:** as a cooling mechanism, sensible heat here is flowed from the skin to the surrounding air. The amount of this sensible heat depends upon the temperature different between the skin and air.

These ways are illustrated in Fig.(3.5), which also shows the relative percentage in a normal comfort situation.

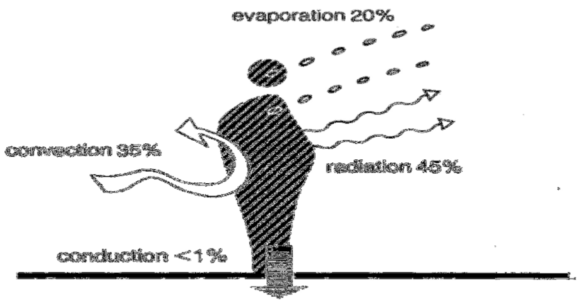


Figure 3.5: The mechanisms of heat loss from the body

People feel thermal comfort differently depending on their particular conditions. The parameters affecting thermal balance are divided into environmental and personal determinants. The following discussion concentrates on these parameters [35]:

1. Environmental Determinants
    - Air temperature
    - Air movement
    - Relative Humidity (RH)
    - Mean radiant temperature (MRT)
2. Personal Determinants
    - Clothing
    - Activity level

3.3 Principles of energy efficient building design

According to Majumda [27] the design principles of energy efficient buildings can be categorized into four sections planning principles, building envelope and fenestration principles, passive cooling techniques and passive heating techniques.

3.4 Planning principles

Planning principles study the macro and microclimate of the site to avoid the adverse conditions, and taking advantage of the desirable conditions:

3.4.1 Building form/surface-to-volume ratio

Building form is one of the most important principles due to the fact that it determines the amount of heat loss or heat gain through the building envelope. Building form can be defined by the shape factor (the ratio of building length to building depth), height and roof type.

As shown in Fig. (3.6), it is possible to determine a lot of building forms that have same volume, but different façade area. Thus, The ratio of total facade area to building volume (A/V) is the best indicator describing the building form [36]. Also, the building form determines the airflow pattern around the building, and affect its ventilation. Additionally, The depth of a building determines the requirements for artificial lighting, so the greater depth needs more artificial lighting [27].

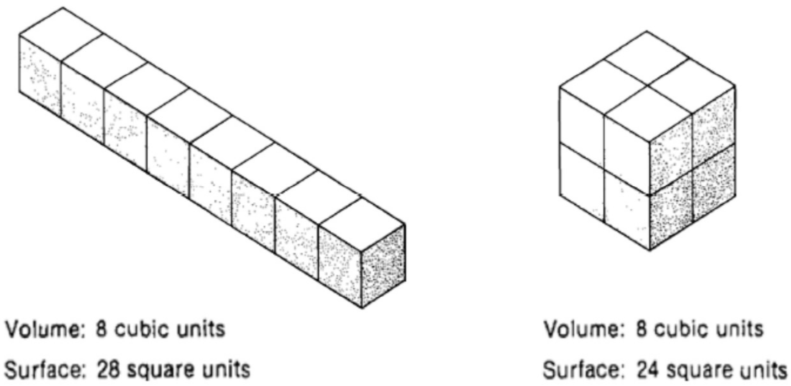


Figure 3.6: Surface-to-volume ratio

3.4.2 Orientation

Building orientation is an important design consideration, mainly with regard to solar radiation and wind. In hot humid climates, buildings should be oriented to minimize thermal impact from solar radiation and maximize effectiveness of ventilation. This can be achieved by lying the longer axis of building along east-west direction, as shown in Fig. (3.7) . That because the longer sides of the buildings should face the prevailing winds (north direction) and the shorter sides should face the direction of the strongest solar radiation (east and west directions) [37].

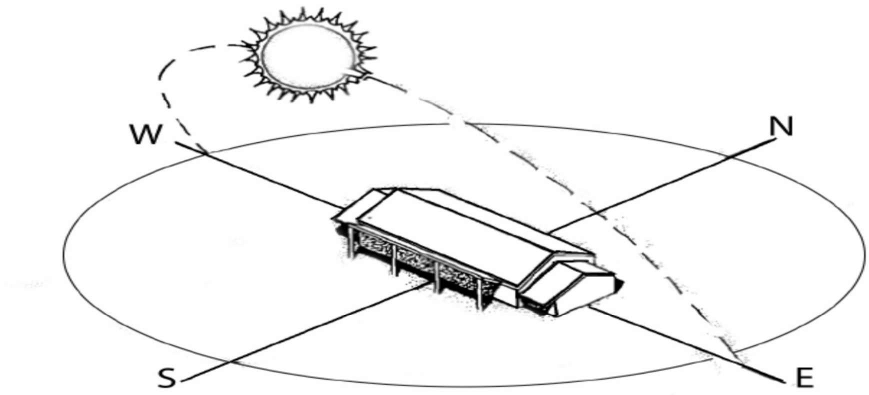


Figure 3.7: The best orientation of the building to solar radiation and wind

3.4.3 Vegetation

Vegetation can play an important role of reducing the temperature around the buildings. It can reduce the solar heat gains on windows, walls and roof through shading. Ground cover by plants also reduces the reflected solar radiation and long-wave radiation emitted towards the building. In hot humid climates, the adverse effects from increased humidity due to the evapotranspiration process should be taken into consideration, especially when plants are grown near ventilation inlets [38]. According to [35] there are four characteristics of vegetation affect both indoor and outdoor thermal conditions in any location which are density of plants, types of plants, size and shape of trees and shrubs, and locations of plants, trees, etc.

3.5 Building envelope and fenestration principles

The building envelope and its components determine the amount of heat gain and heat loss and wind that enters inside. The basic elements of building envelope and its effects are discussed below:

3.5.1 Materials and construction techniques

According to Majumda [27] selecting the building materials is essential in reducting the demand of energy. Thermal insulation which is one of materials properties can effectively reduce the space conditioning loads. It needs a careful study of its location and thickness. For example, in hot climates, insulation should be located on the outer face of the wall to separate the external hot temperature. Also the external finish of a surface determines the amount of heat absorbed or reflected by it. For example, a smooth and light colour surface reflects more light and heat than a dark colour surface.

3.5.2 Roof

The roof receives large amount of solar radiation which causes large heat gain and heat loss. Thus, it is required treatments according to climatic characteristics. For example, in a hot region, the roof should have enough insulation to minimize heat loss. In addition, the roof can be used for useful ventilation and daylighting by added vents and skylights [27].

3.5.3 Fenestration and shading

All the elements in the building envelope, windows and others glazed areas are the weakest link between the building and outdoor. The most important design parameters affecting the thermal performance of windows are orientation, glass, size and shading device. All of these parameters will be discussed in more details in the next chapter [27].

3.5.4 Natural ventilation

Natural ventilation is one of the requirements for low-energy building design. It is the use of wind pressure and stack effect as a natural forces to move the air through buildings. These effects are different according to the strength of the prevailing wind and the temperature conditions.

The effect of wind pressure is a very complex process. It mainly depends on the principle that air always flow from a region of high pressure to a region of lower pressure. In the light of this principle there are many factors affecting natural airflow in and around buildings.

Briefly, the outdoor factors include suction and wind flow around buildings, the shape and orientation of the building relative to the direction of the wind, effects of coastal areas and effects of vegetation. Inside the building, the main factors affecting the pattern of airflow entering a building are opening size and shape, opening location, opening types and vertical and horizontal projections [39]. According to Omer [40], the most widely used methods in natural ventilation is classified into three types, see Fig. (3.8).

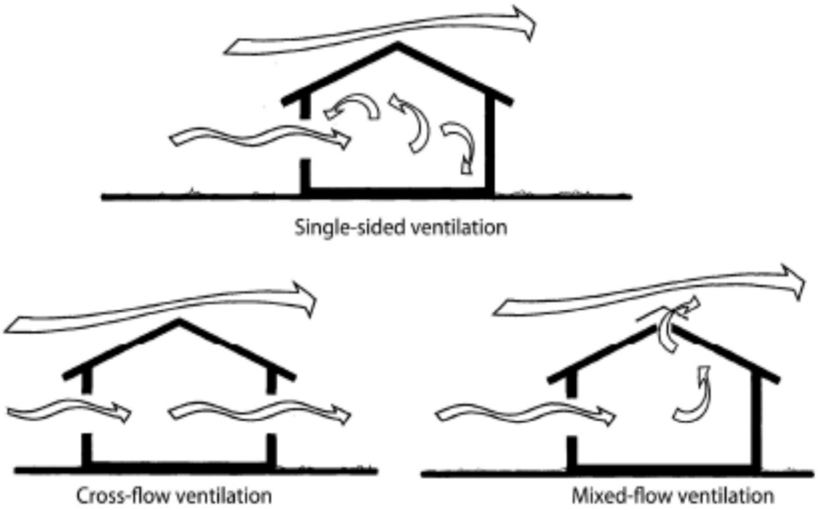


Figure 3.8: The most common methods used in natural ventilation

The stack effects are caused by temperature differences between the inside and outside of buildings. When the inside building temperature is greater than the outside, a warm air in building rises to escape through upper openings, and it is replaced by cooler outside air entering through low openings around the building. To increase the effectiveness of this system the sun can be used to create a solar thermal chimney to increase the air flow by increasing the temperature differences [41], as shown in Fig.(3.9).

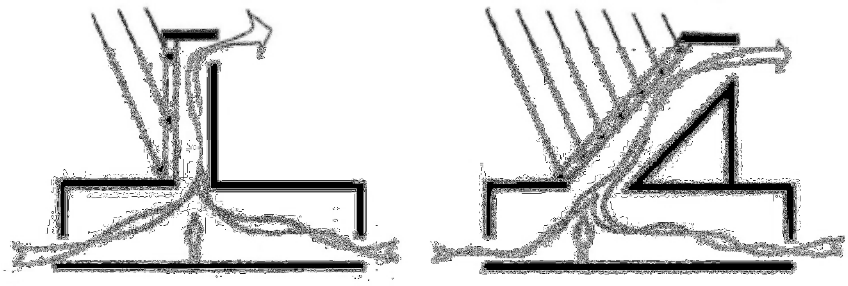


Figure 3.9: The vertical and inclined solar chimney

3.5.5 Daylighting

Daylight integration is an important aspect of energy-efficient building design. It can bring a sense of well being and awareness of the wider environment. According to Majumda [27]. Many factors should be taken into consideration to achieve good daylighting system in building:

- Orientation, space organization, and geometry of the space to be light.
- Location form, and dimensions of the fenestrations to allow entering of daylight.
- Location and surface properties of internal partitions that affect daylight distribution by reflection.
- Location, form, and dimensions of shading devices that provide protection from excessive light and glare.
- The Light and thermal characteristics of the glazing materials

3.6 Passive cooling techniques

This section briefly discuss the passive techniques that aid heat loss from the building by ventilation, radiation, and evaporation, or by using storage capacity of surrounding spaces like mass effect [42].

3.6.1 Passive cooling by ventilation

According to Moore [42], the concept of passive cooling by ventilation depends on replacement of warmer inside air with cooler outside air at various rates (5 to 500 air changes per hour). In arid climates, night-only ventilation has been generally used. This takes advantages of the cool night air temperatures while isolating the interior from the extremely hot daytime condition.

3.6.2 Passive cooling by radiation

Radiative cooling is the transfer of heat from a warmer surfaces of buildings to cooler surrounding surfaces. The following discuss the performance of some radiative systems such as courtyards, roof pond, and cool pool.

Courtyards is considered one of the radiative cooling systems when its surfaces are exposed to the night sky. The radiation of these surfaces can be increased by designing the roof surrounding the courtyard to be sloped toward the courtyard, as shown in Fig. (3.10) [42].

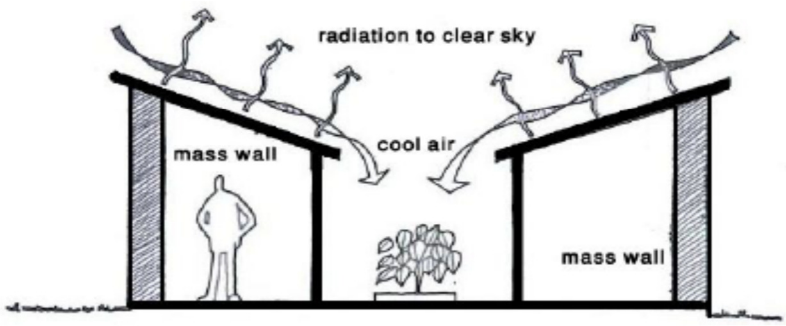


Figure 3.10: Courtyard as a radiative cooling system

The roof pond system also provides summer passive solar cooling, see Fig. (3.11). During a day, the water pond is covered by the insulating panels to reduce solar heat gain and to absorb internal heat. At night, the pond are uncovered and it radiates storage heat to outside.

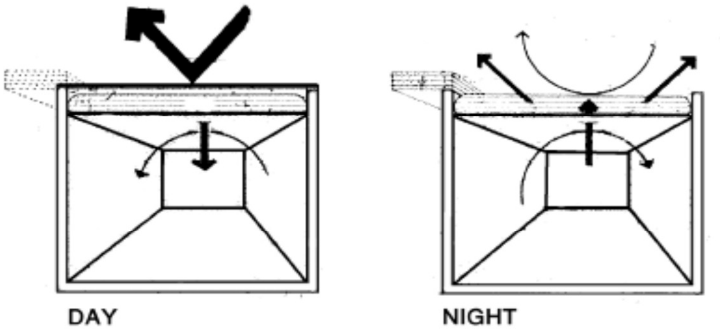


Figure 3.11: The roof pond as a radiative cooling system

The cool pool is a passive roof-cooling system. As shown in Fig. (3.12), the pool is cooled by radiation to the sky. Then the cooled water is piped to a large water storage tube inside the building below. So a thermal circulation occurs when the roof pool is cooler than storage tube [42].

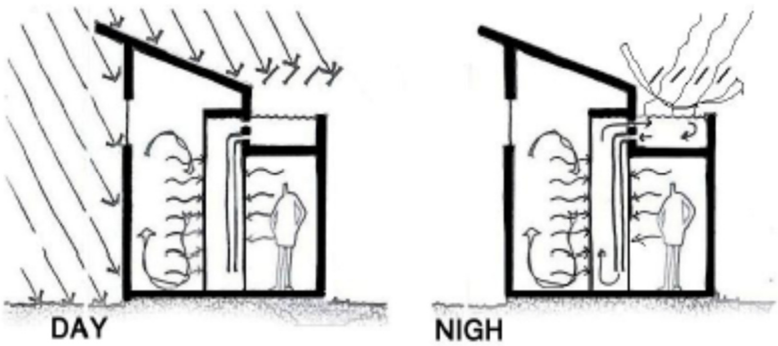


Figure 3.12: The cool pool as a radiative cooling system

3.6.3 Passive cooling by evaporation

According to Moore [42], evaporation cooling is the process of extracting sensible heat from the air while adding an equal amount of latent heat (in the form of water vapor), the total heat remains the same. As shown in Fig. (3.13), there are two methods to cool building air either directly by evaporation or indirectly by contact with a surface previously cooled by evaporation.

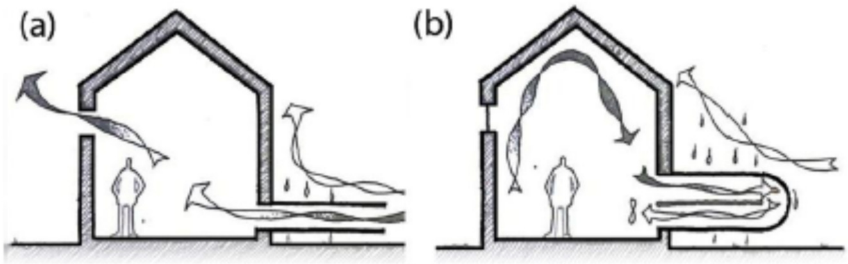


Figure 3.13: Indirect evaporative air coolers: (a) open-loop, and (b) closed-loop

3.6.4 Passive cooling by mass effect

Buildings with substantial mass can utilize their thermal storage capabilities to achieve cooling in three ways. First, dampening out interior daily temperature swings, by using interior building materials for walls and floors of conductive and massive construction, they gradually absorb and release heat. Second, delaying temperature extremes, by using building materials for walls and floors also of conductive and massive construction, there is a significant time delay (time lag). Third, earth contact to achieve seasonal storage, by using the earth ability of heat storage for seasonal storage purposes [42].

There are two basic strategies for using earth contact: direct and indirect contact. In the direct contact, the building envelope is partially or completely buried underground. While indirect contact, the building is cooled by buried heat exchangers such as pipes or air tubes.

3.7 Passive heating techniques

Passive heating techniques are used by architects in building design to achieve thermal comfort conditions in cold climate. There are two basic elements in every passive solar-heating system. First element is the south-facing glass (or transport plastic) for solar collection. Second element is the thermal mass for heat absorption, storage and distribution [29].Generally, passive solar heating systems can be classified into direct gain systems, indirect gain systems and isolated gain system.

3.7.1 Direct gain system

According to Mazria [29] in the direct gain approach the actual living space is used as a solar collector and directly heated by sunlight, as shown in fig. (3.14). It contains a method for absorbing and storing enough daytimes heat for cold winter night.

In this approach there is an expanses of south-facing glass and enough thermal mass, straightly located in space, for heat absorption and storage. The two most common materials used for heat storage are masonry and water.

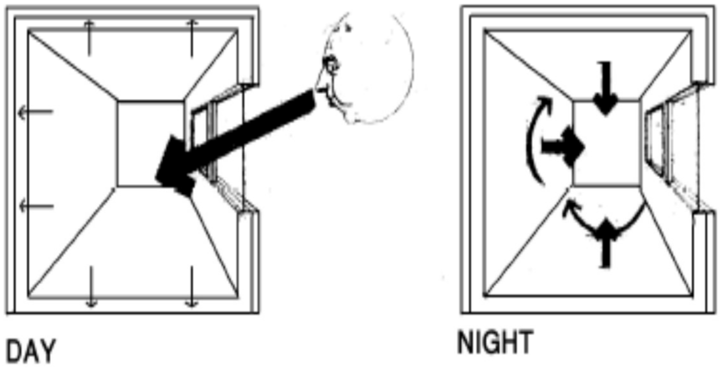


Figure 3.14: Direct gain system – masonry heat storage

3.7.2 Indirect gain system

In this system, the sunlight first strikes the thermal mass which is located between the sun and the space. The sunlight absorbed by the mass is converted to thermal energy (heat) and then transferred into the living space. There are basically three types of indirect gain systems.

The first system is thermal storage walls system. It uses either masonry or water walls to collect and distribute heat to space. Only one difference between two types, a water transfers this heat through the wall by convection, while masonry by conduction, see Fig. (3.15) [29].

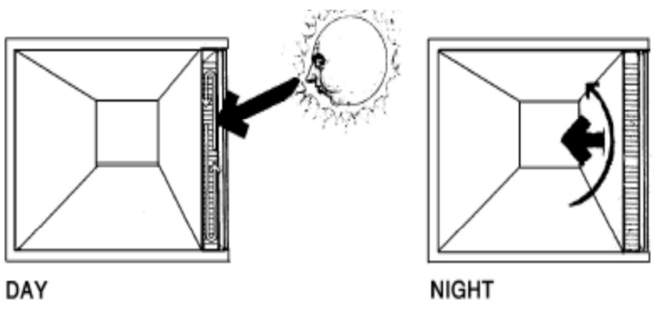


Figure 3.15: Indirect gain – water thermal storage wall

The second system is attached sunspace. As shown in Fig. (3.16), it is essentially a combination of direct and indirect gain systems. Basically, sun light is absorbed by the back wall in the sunspace, converted to heat, and a portion of this heat then transferred into the building [29].

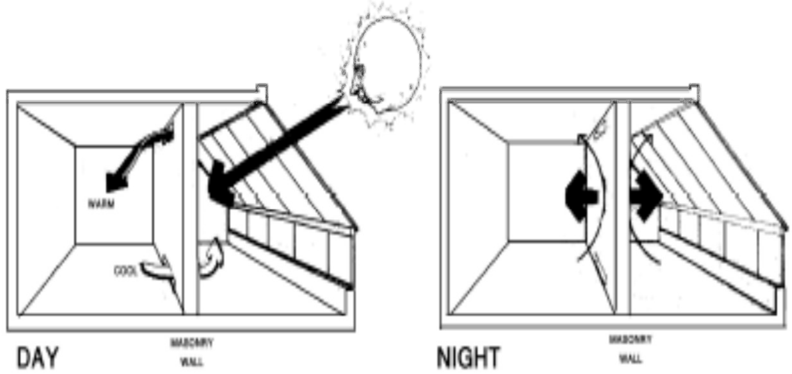


Figure 3.16: Indirect gain – attached sun space

The third system is the roof pond. As shown in Fig. (3.17), in this system, the thermal mass is located on the roof of the building.

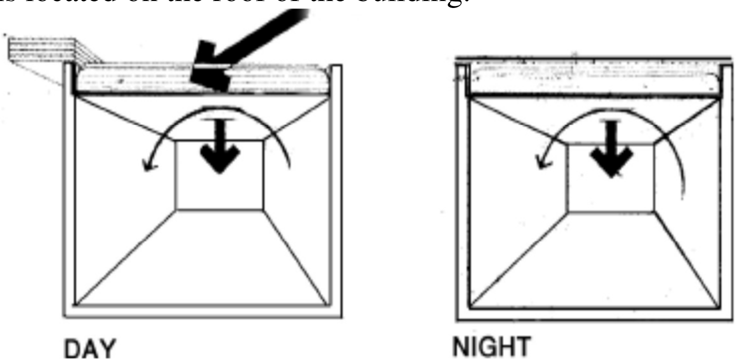


Figure 3.17: Indirect gain – roof pond

3.7.3. Isolated gain system

In this system, solar collection and thermal storage are isolated from the living spaces. The most common application of this concept is the natural convective loop, see Fig. (3.18). The major components of this system include a flat plate collector and heat storage tank. Two types of heat transfer and storage mediums are used: water and air with rock storage [29].

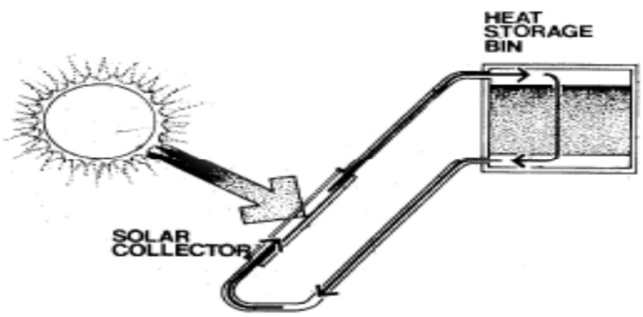


Figure 3.18 : Convective loop

CHAPTER 4

CASE STUDY TECHNICAL DATA ANALYSIS

Having justify the need for energy efficiency, it is now important to focus on the basic principles that can bring about energy efficiency specifically in Irada building and generally in buildings in Gaza Strip. Below is the list of aspects for energy efficient residential buildings that has been arrived at from literature review:

1- Building envelope:

- External wall
- Thermal insulation
- Building materials
- Roof
- Windows and doors

2- Electrical equipment inside the building:

- Lighting system
- HVAC system
- Induction motors
- Power factor corrector

We will discuss the above aspect in detail according the data we had obtained during to our visit to Irada building at IUG.

4.1 Building Envelope

The building envelope and its components determine the amount of heat gain, heat loss and wind that enter inside the building. We will focus our study in external wall, ceiling and windows as following:

1- Wall and ceiling regulation

Fig. 2.3, Fig. 2.4 in chapter 2 and Table 5.1 below clarify the current status Irada building wall and ceiling, and present recommendations needed to obtain the best performance for efficient energy Irada building [43].

Table (4.1): Wall and Ceiling regulation

No.	Topic	Standard	Current Status	Recommendation	Cost % (More than standard)	Saving % (More than standard)
01	External Walls	Normal Walls	20×20×40 cm hollow concrete blocks, with 1-1.5 cm of internal plaster and 2-3 cm of external plaster	15×20×40 cm hollow concrete blocks from external side, 7×20×40 cm hollow concrete blocks from internal side, 3 cm polystyrene sheet between [43].	30%	28%
02	Ceilings	Normal Ceilings	8 cm layer of reinforce concrete, 17cm layer of hollow concrete blocks, and 2 cm layer of plastering	2 cm screed sheet from the external side, 8 cm layer of reinforce concrete, 17cm layer of hollow concrete blocks, and 2 cm layer of plastering [43].	20%	24%

Fig 4.1 below explains the modification on Fig 2.3 in chapter 2 which clarify external wall new suggestion with insulation of Irada building at IUG that satisfy the recommendation as it is clear in Table 4.1.

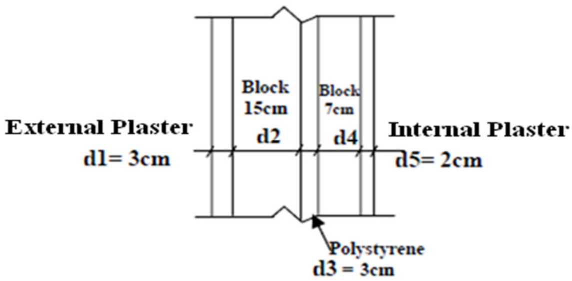


Figure 4.1: New suggestion external wall with insulation

Fig. 4.2 below explains the modification on Fig. 2.4 which clarify the new suggested ceiling of Irada building at IUG with insulation that satisfy the recommendations as it is clear in Table 4.1.

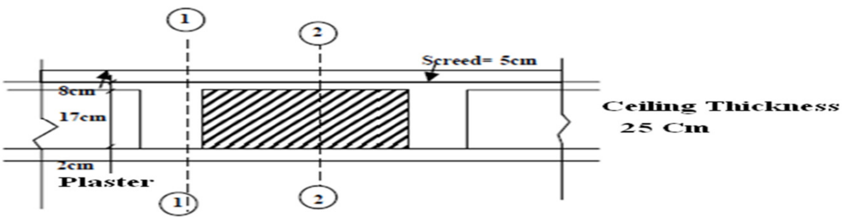


Figure 4.2: New suggestion ceiling with insulation

2- Windows and doors regulation

Fig. 2.3, Fig. 2.4 in chapter 2 and Table 4.2 below clarifies the current status Irada building windows and doors, and present recommendations needed to obtain the most efficient energy [44].

Table (4.2): Windows and doors regulation

Topic	Standard	Current status	Recommendation	Cost (%)	Saving (%)
Solar & Thermal Control	Normal windows and doors	Single glass, Aluminum profile frame.	1-Double glass 2-Aluminum Frame 3-Low-emitting glazing (low-e). 4-Shading devices, such as awnings, exterior shutters, or screens 5-Reflective glass	20-30%	30-50%
Air tightness	Normal windows and doors	Nothing	1-Robber around internal frame, 2-Silicone foam or polymer around external frame	5-8%	**90%**
Ventilation	Normal windows and doors	1- Slider 2- Double hang 3- Casement 4- Awing 5- Hopper	1- Air grille 2- Air louver 3- Indoor air curtain and outdoor air curtain (very expensive) 4-The optimum window to wall ratio is equal to 0.24 for the optimum natural ventilation	20% 200-500% excluded	**50%**
Lighting	Normal windows and doors	1- Coated glass 2- Sun Reflector 3-Colored glass	1- Large clear glass 2- The window area which transmits light must be at least 1/20 of the surface area of the floor in the work space areas 3-The total width of all the windows must amount to at least 1/10 of the total width of all the wall	0%	**50-80%**
Condensation	Normal windows and doors	Nothing	1-Low-emissivity (Low-E) glass, 2-Double pan windows, 3-Ventilation	Included	100%

4.2 Data Analysis of Irada Building Envelope

According to our site visit to Irada building at IUG, we noted that there is two air conditioning machine each of them 18.2KW; these air conditions serve only six rooms in ground floor with room descriptions are shown in Table 4.3.

Table (4.3): HVAC rooms detail

No.	Room name	Room area (m^2)	External wall area (m^2)	Windows number	Windows area (m^2)
1	Multimedia laboratory	6 × 8	19.20	2	1.92
2	Pyrography workshop	6 × 8	19.20	2	1.92
3	Staff (A)	4.15 × 6	13.28	1	3.00
4	Staff (B)	3.85 × 6	12.32	1	3.00
5	Staff (C)	3.5 × 5.45	17.44	1	2.16
6	Pc, Mobile & S. devices main. Workshop	6 × 8	19.20	2	1.92

Thermal transmittance commonly known as the U-value, it is a measure of the rate of heat loss of a building component. It is expressed as watts per square meter, per degree Kelvin, W/m^2K. The U-value is calculated from the reciprocal of the combined thermal resistances of the materials in the element, air spaces and surfaces, also taken into account is the effect of thermal bridges, air gaps and fixings.

To calculate heating and cooling load we can use the following equations [45,46]:

$$U = \frac{\sum U_d A_d + \sum U_w A_w + \sum U_{win} A_{win}}{A_t} \qquad 4.1$$

Where;

U = total thermal transmittance $(W/m^2.k)$
U_d = external door thermal tranmittnce $(W/m^2.k)$
U_w = external wall thermal transmittance $(W/m^2.k)$
U_{win} = external wall thermal transmittance $(W/m^2.k)$
A_d = external door area (m^2)
A_w = external wall area (m^2)
A_{win} = external window area (m^2)
A_t = total area of external wall included all opening (m^2)

$$U_w = \frac{1}{0.18 + \frac{d_1}{k_1} + \dots + \frac{d_i}{k_i}} \qquad 4.2$$

where;

1/k = thermal resistivity *(w/m.k)* , *d* = thickness (m)

With;

$U_{win} = 5.6\ (W/m^2.k)$, for single glass aluminum window

$U_{win} = 2.8\ (W/m^2.k)$, for double glass aluminum window

First: Calculate thermal transmittance for current status wall without insulation (**see Appendix A).**

A_t = Area of wall = 19.2 m^2

A_{win} = External window area = 3.84 m^2

A_w = Clear wall area = 19.2 − 3.84 = 15.36 m^2

$$U_w = \frac{1}{0.18 + \frac{d_1}{k_1} + \frac{d_2}{k_2} + \frac{d_3}{k_3}} = \frac{1}{0.18 + \frac{0.03}{1.2} + \frac{0.2}{0.8} + \frac{0.02}{1.2}}$$

$$= 2.12\ W/m^2.k$$

U_{win} = 5.6 $W/m^2.k$ for single glass aluminum window (Appendix A)

$$U = \frac{U_{win} \times A_{win} + U_w \times A_w}{A_t}$$

$$U = \frac{5.6 \times 3.84 + 2.12 \times 15.36}{19.2} = 2.82\ W/m^2.k$$

Second: Calculate thermal transmittance for recommended wall with insulation as per Fig 4.1.

$$U_w = \frac{1}{0.18 + \frac{d_1}{k_1} + \frac{d_2}{k_2} + \frac{d_3}{k_3} + \frac{d_4}{k_4} + \frac{d_5}{k_5}}$$

$$= \frac{1}{0.18 + \frac{0.03}{1.2} + \frac{0.15}{0.8} + \frac{0.03}{0.04} + \frac{0.07}{0.8} + \frac{0.02}{1.2}}$$

$$= 0.8\ W/m^2.k$$

U_{win} = 2.8 (W/m^2 .k), for double glass aluminum window.

$$U = \frac{U_{win} \times A_{win} + U_w \times A_w}{A_t}$$

$$= \frac{2.8 \times 3.84 + 0.8 \times 15.36}{19.2} = 1.2\ W/m^2.k$$

4.2.1 Heat load calculation of Irada building

To calculate heat load of Irada building we used the following equation [43]:

$Q_t = Q_c + Q_v - Q_m$ where; 4.3

Q_t is total heat loss(w)

Q_c is the Conduction of heat may occur through the walls either inwards or outwards(w).

Q_v is the rate of heat exchange that may take place in either direction with the movement of air, i.e. ventilation (w).
Q_m is the heat flow rate of deliberate introduction or removal of heat (heating or cooling), using some form of outside energy supply. The heat flow rate of the mechanical systems is subject to the designer's intention and is deliberately controllable (w).

$$Q_c = Q_{win} + Q_w = U_{win} \times A_{win} \times \Delta t + U_w \times A_w \times \Delta t \qquad 4.4$$

$$Q_v = \frac{\rho.C.V.n.\Delta t}{3600} \quad \text{where;} \qquad 4.5$$

ρ = intensity of air = 1.25 kg/m^3;

C= spacific heat capacity = 1000 J/kg. C°

V = room volume (m^3); n = time of air change/hours = 2

Δt = change in temperature C°, where;

In this study we will take an example Multimedia laboratory and the others room will calculate same.

- Calculate heating load for current wall using (Equ. 4.3) &(Equ. 4.4)
  We take, $t_{\circ=}0\ C^{\circ}$ (real temperature), $t_{i=}20\ C^{\circ}$ (design temperature)

  $$Q_{win} = 5.6 \times 3.84 \times 20 = 430.08\ W$$

  $$Q_w = 2.12 \times 15.36 \times 20 = 651.26\ W$$

  $$Q_c = 430.08 + 651.26 = 1081.34\ W$$

  $$Q_v = 1.25 \times 1000 \times (6 \times 8 \times 3.2) \times \left(\frac{2}{3600}\right) 20 = 2133.3\ W$$

  $$Q_m = 9 \times (2 \times 36) + 6 \times 140 = 1488\ W \qquad \text{where;}$$

  Number of lights fitting in the room =9

  Number of persons inside the room=6

  $$Q_t = 1081.34 + 2133.3 - 1488 = 1726.6\ W$$

- Calculate heating load for recommended wall using (Equ. 4.3) &(Equ. 4.4)

  $$Q_{win} = 2.8 \times 3.84 \times 20 = 215.04\ W$$

  $$Q_w = 0.8 \times 15.36 \times 20 = 245.76\ W$$

  $$Q_c = 215.04 + 245.76 = 460.8\ W$$

$$Q_v = 1.25 \times 1000 \times (6 \times 8 \times 3.2) \times \left(\frac{2}{3600}\right) 20 = 2133.3\ W$$

$$Q_m = 9 \times (2 \times 36) + 6 \times 140 = 1488\ W$$

$$Q_t = 460.08 + 2133.3 - 1488 = 1106.1\ W$$

$$\%\ \text{of energy saving in heating load} = \frac{1726.6-1106.1}{1726.2} \times 100\% = 35.9\ \%$$

4.2.2 Cooling load calculation of Irada building

$t_i = 20C^{\circ},\ t_{\circ} = 32C^{\circ} \qquad \Delta t = 32 - 20 = 12C^{\circ}$

$$Q_t = -(Q_c + Q_s + Q_v + Q_i) \qquad 4.6$$

where;

Q_s is the effects of solar radiation on opaque surfaces can be included by using the sol air temperature concept, but through transparent surfaces (windows)

Q_i is an internal heat gain may result from the heat output of human bodies, lamps motors and appliances.

$t_s = t_{\circ} + \frac{I \times a}{h_{\circ}}$ where; I = intensity of radiation = 645

a = absorption coefficient of outer wall surface = 0.58

$f_{\circ} = \frac{1}{R_{\circ}}$, $h_{\circ} = \frac{1}{R_{\circ}}$, $t_s = 32 + \frac{645 \times 0.58}{16.6} = 54.5C^{\circ}$, $\Delta t_s = 54.5 - 20 = 34.5C^{\circ}$

- Calculate cooling load for current wall using (Equ. 4.6)

$$Q_c = Q_{win} + Q_w = U_{win} \times A_{win} \times \Delta t + U_w \times A_w \times \Delta t_s$$

$$= 5.6 \times 3.84 \times 12 + 2.12 \times 15.36 \times 34.5 = 1373.48\ W$$

$Q_s = A_{win} \times I \times \theta$ where; θ = solar gain factor = 0.75 (single glass window)

$$Q_s = 3.84 \times\times 645 \times 0.75 = 1857.6\ W$$

$$Q_v = \frac{\rho.C.V.n.\Delta t}{3600} = \frac{1.25 \times 1000 \times (6 \times 8 \times 3.2)12}{3600} = 640\ W$$

Where; air change one time per hour

$Q_i = 6 \times 140 = 840\ W$ where;

No light on and there is six persons inside the room

$$Q_t = -(1373.48 + 1857.6 + 640 + 840) = -4711.08\ W$$

- Calculate cooling load for recommended wall using (Equ. 4.6)

$$Q_c = Q_{win} + Q_w = U_{win} \times A_{win} \times \Delta t + U_w \times A_w \times \Delta t_s$$

$$= 2.8 \times 3.84 \times 12 + 0.8 \times 15.36 \times 34.5 = 552.96\ W$$

$$Q_s = A_{win} \times I \times \theta$$

where; θ = solar gain factor = 0.65 (double glass window)

$$Q_s = 3.84 \times 645 \times 0.65 = 1609.92\ W$$

$$Q_v = \frac{\rho.C.V.n.\Delta t}{3600} = \frac{1.25 \times 1000 \times (6 \times 8 \times 3.2)12}{3600} = 640\ W$$

Where; air change one time per hour

$Q_i = 6 \times 140 = 840\ W$ where;

No light on and there is six persons in the room

$$Q_t = -(552.96 + 1609.92 + 640 + 840) = -3642.88\ W$$

% of energy saving in heating load $= \frac{3642.88-4711.08}{4711.08} \times 100\%$ =22.7%

Table 4.4 shows comparison for heating and cooling load calculation before and after making insulation and it shows also the percentage energy saving in each room have HVAC system in Irada building at IUG.

Table(4.4): Heating and cooling load calculation before and after insulation

No.	Room name	U Exist	U Recommend	Heating load			Cooling load		
				Q_t Exist	Q_t Recommend	Energy saving	Q_t Exist	Q_t Recommend	Energy saving
		W/m². k	W/m². k	W	W	%	W	W	%
01	Multimedia laboratory	2.8	1.2	1726.6	1106.1	35.9	-4711.8	-3642.8	22.7
02	Pyrography workshop	2.8	1.2	1726.6	1106.1	35.9	-4711.8	-3642.8	22.7
03	Staff (A)	2.9	1.25	1030.5	591.1	42.6	-3305.7	-2534.3	23.3
04	Staff (B)	2.9	1.29	1049.8	635.8	39.4	-3062.5	-2343.8	23.5
05	Staff (C)	2.5	1.1	1169.5	645.2	44.8	-2817.8	-1982.6	29.6
06	Pc, Mobile & S. devices main. workshop	2.8	1.2	1726.6	1106.1	35.9	-4711.8	-3642.8	22.7

4.3 Lighting System

There are substantial variations in energy used for lighting residential buildings. In the United States, lighting uses 12% of the energy used by a residential building while 9% of energy used in residential buildings of India contributes to lighting [47]. On the other hand residential buildings in China use 23% of the total residential electricity for lighting [48]. Here at IUG, based on our visit to Irada building, we summarized below tables of lights fitting inside each floor in the building as shown in Table 4.5-Table 4.8.

Table (4.5): Summary of Light fitting ratings & Quantities in BF

No.	Location	Unit	Qty	Lamb	Ballast *	Total	Type
				W	W	W	
01	Carpentry Workshop Manufacturing section (A)	Nos	12	2×36	5.4	928.8	Fluorescent
02	Carpentry Workshop Manufacturing section (B)	Nos	9	2×36	5.4	696.6	Fluorescent
03	Furniture Painting Workshop, Prep. And Sanding section (A)	Nos	8	2×36	5.4	619.2	Fluorescent
04	Upholstery Workshop, Assembly section	Nos	8	2×36	5.4	619.2	Fluorescent
05	Furniture Painting Workshop, Prep. And Sanding section (B)	Nos	9	2×36	5.4	696.6	Fluorescent
06	Furniture Painting Workshop, Varnishing section	Nos	7	2×36	5.4	541.8	Fluorescent
07	CNC Wood Craving Workshop	Nos	6	2×36	5.4	464.4	Fluorescent
08	Store	Nos	6	2×36	5.4	464.4	Fluorescent
09	Loopy	Nos	3	1×36	5.4	124.2	Fluorescent
10	Corridor	Nos	21	4×18	5.6	1713.6	Fluorescent
11	Toilet (A)	Nos	3	4×18	5.6	244.8	Fluorescent
12	Toilet (B)	Nos	3	4×18	5.6	244.8	Fluorescent
13	Kitchen	Nos	1	4×18	5.6	81.6	Fluorescent
14	Staircase (A)	Nos	2	1×26	3.5	59.0	Compact FL
15	Staircase (B)	Nos	2	1×26	3.5	59.0	Compact FL
Total Load Power (W)						7558	

Table (4.6): Summary of Light fitting ratings & Quantities in GF

No	Location	Unit	Qty	Lamb	Ballast	Total	Type
				W	W	W	
01	Ceramic and Poltery Painting Workshop	Nos	9	2×36	5.4	696.6	Fluorescent
02	Pyrography Workshop	Nos	6	2×36	5.4	464.4	Fluorescent
03	Staff (A)	Nos	4	2×36	5.4	309.6	Fluorescent
04	Staff (B)	Nos	4	2×36	5.4	309.6	Fluorescent
05	Staff (C)	Nos	4	2×36	5.4	309.6	Fluorescent
06	Pc, Mobile and Smart Devices Maintenance Workshop	Nos	6	2×36	5.4	464.4	Fluorescent
07	Multimedia Laboratory	Nos	14	2×36	5.4	1083.6	Fluorescent
08	Entrance	Nos	2	2×36	5.4	154.8	Fluorescent
09	Rest Room	Nos	6	2×36	5.4	464.4	Fluorescent
10	Waiting Room	Nos	4	4×18	5.6	326.4	Fluorescent
11	Meeting Room	Nos	4	4×18	5.6	326.4	Fluorescent
12	Toilet	Nos	6	4×18	5.6	489.6	Fluorescent
13	Kitchen	Nos	1	4×18	5.6	81.6	Fluorescent
14	Staircase (A)	Nos	2	1×26	3.5	55.5``	Compact FL
15	Staircase (B)	Nos	2	1×26	3.5	55.5	Compact FL
Total Load Power (W)						5592	

* Ballast circuit consumes about additional wattage power accounted for 10-20 % of lamp power rate [63].

Table (4.7): Summary of Light fitting ratings & Quantities in FF

No	Location	Unit	Qty	Lamb W	Ballast W	Total W	Type
01	Open Area	Nos	68	2×36	5.4	5263.2	Fluorescent
		Nos	20	1×36	5.4	828	
02	Toilet (A)	Nos	4	4×18	5.6	326.4	Fluorescent
03	Toilet (B)	Nos	4	4×18	5.6	326.4	Fluorescent
04	Staircase (A)	Nos	2	1×26	3.5	59	Fluorescent
05	Staircase (B)	Nos	2	1×26	3.5	59	Fluorescent
Total Load Power (W)						6862	

Table (4.8): Summary of Light fitting ratings & Quantities in Roof

No	Location	Unit	Qty	Lamb W	Ballast W	Total W	Type
01	Roof Parapet	Nos	8	400	60	3680	Metal Halide Flood light

There are a number of different types of light sources available on the market today, namely incandescent lights, Fluorescent/Compact Fluorescent (CFL) tubes/bulbs, Halogen/Metal Halide lamps and LED (Light Emitting Diode) lights. Upon initial examination, incandescent lights and halogen/metal halide lamps were eliminated for their higher energy consumption and spot lighting characteristics. CFL tubes were also not considered for it incompatibility to fit with the existing T-8 FL light fixtures. In order to switch over to CFL tubes, all the light trays and fixtures would have to be replaced which would mean a substantial increase in capital investment.

In this study, we will use two option efficient energy light the first option is medium cost light which is T-5 tube FL in placed of T-8 tube light and HPS in placed of MHL. The second option is a fast developing technology, but is still quite expensive which is LED light .

4.3.1: Replace T-8 FL by T-5 and 400W ML by 150W HPS

T-8 and T-5 FL tubes on the market today have the typical performance and technical specifications as stated in Table 4.9 below [49]:

Table (4.9): T-8 vs. T-5 FL Tube Technical Specifications

No.	Lamp Type	lumen output/Watt	Wattage	Lumen
01	T-8	75 lumen/w	48 W	3600
02	T-5	90 lumen/w	32 W	2880

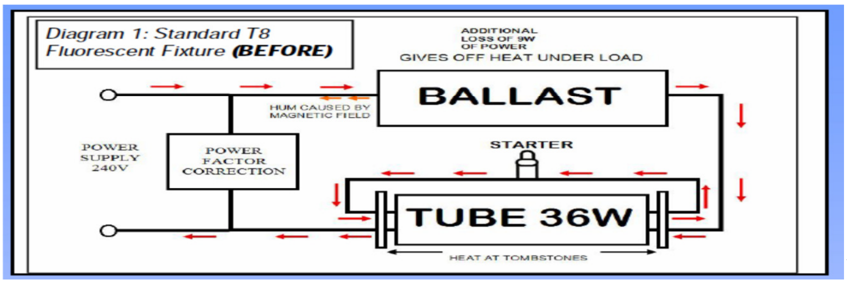
In terms of energy consumption, a 1200mm T-5 FL tube uses about 33% less energy than a T-8 FL tube, but due to the lower voltage output, a T-5 FL tube would also generate less light than a T-8 FL tube. For example, if a T-8 FL tube is replaced with a T-5 FL tube under a control situation where condition remains the same; there should be a theoretical decrease in brightness of about 20-30%. This calculation could easily be verified on by simply measuring the Lux levels at a specified distance [49].

(a) (b)

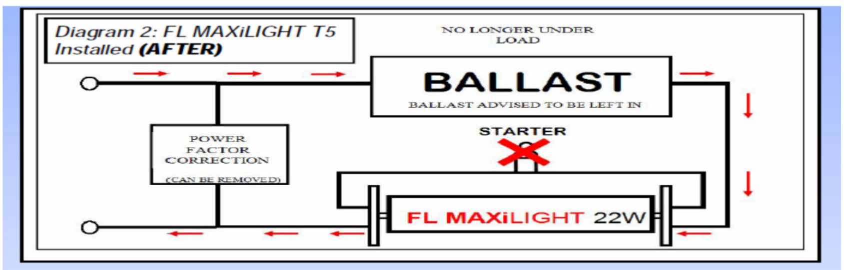
Figure 4.3: (a) T8 FL light fitting (b) T5 FL light fitting with special reflector

With the addition of the special light enhancing reflector, the normally waste light of about 30% beaming towards the backside of the light tray is reflected back downwards; thus, becoming useful light again [49]. The total useful light from a T-5 tube beaming downward would effectively be equal to the light from a T-8 light tube. In other word, this combination of T-5 light tube with reflector could achieve the 33% energy saving whilst matching the brightness performance of a T-8 light tube, i.e. one-to-one replacement [49].

By achieving one-to-one replacement, there would be no need to add additional light tubes or trays in order to compensate the decrease in brightness level. Alteration or additional works to the existing lighting arrangement could therefore be minimized [49].



(a)



(b)

Figure 4.4: (a) Current status T-8 FL (b) Proposed T-5 FL [50]

According to luminaries reading and light, Replacement of the ML (400W) external outdoor lamps with HPS (150W) lamps is recommended [19] .

Using the data in Table 4.10, we can find out the annual energy saving by made lights fitting replacement method (i.e.T5 instead T8 and HPS instead of ML), The annual energy saving of 18363.2 kWh/year after installing the new technology high efficient LED lamps. We also conclude that the average lighting energy used by all floors of the case study has been calculated as 29%.

Table (4.10): Annual energy saving replacing T8 by T5 and ML by HPS lamp

No	Existing lamp					Proposed lamp			Energy saving
	Light type	Q	Rate	OH	Energy used	Light type	Rate	Energy used	
		Nos	W	hr	kWh/year		W	kWh/year	kWh/year
01	2 × 36W FL	188	77.4	1600	23281.92	2 × 22W FL	44	13235.20	10046.72
02	1 × 36W FL	23	41.4	1600	1523.52	1 × 22W FL	22	809.60	713.92
03	1 × 26W CFL	12	26	1600	499.20	1 × 26W CFL	26	499.20	0
04	4 × 18W FL	51	77.6	1600	6332.16	4 × 14W FL	56	4569.60	1762.56
05	1 × 400W ML	8	400	2920	9344.00	1 × 150W HPS	150	3504.00	5840
Total Load Power (W)					40980.80			22617.6	18363.2

4.3.2 Replacement of LED lamps instead of FL and ML lamp

Table (4.11): Comparison between LED Tube and Conventional FL Tube [51]

No.	Characteristic	LED tube	Conventional Fluorescent tube
01	Power consumption (tube only)	18 W	36 W
02	Life span	40,000 hours	8,000 hours
03	Radiation	CE compliant, no UV or IR	UV, IR
04	Toxic contents	RoHS compliant	Toxic phosphor powders Mercury (Hg), Lead (Pb)
05	CO_2 emission	Low	High
06	Heat damage	No	High
07	Durable	Unbreakable Aluminium Housing and Poly Carbonate Cover	Fragile Glass
08	Burn out failure	No	Yes
09	Flicker	Never	Frequently
10	Light wasted on reflector	No	High
11	Buzzing	No	Yes
12	Recyclable	Yes	No
13	Low temperature working environment	Compatible	Incompatible
14	Starter needed	Without	Yes
15	Maintenance schedule	Low	High
16	Light up time	instant-on	3-5 seconds

In this method, we will replace lamps from fluorescent lamps 36W to high technology LED tube lamps 18W [52] in specific places such as workshops, laboratories and offices, we also replace 150 W HPS by 54W led light [53]. Expected annual energy achieved upon replacing lamps from linear fluorescent lamps T8 to high technology LED lamps is 24791.36 kWh/year.

Table (4.12): The annual energy saving by replacing T8 FL by LEDs tube lamp

No	Existing lamp					Proposed lamp			Energy saving
	Light type	Q	Rate	OH	Energy used	Light type	Rate	Energy used	
		Nos	W	hr	kWh/year		W	kWh/year	kWh/year
01	2 × 36W FL	188	77.4	1600	23281.92	2 × 18W LED	36	10828.80	12453.12
02	1 × 36W FL	23	41.4	1600	1523.52	1 × 18W LED	18	662.40	861.12
03	1 × 26W CFL	12	26	1600	499.20	1 × 26W CFL	26	499.20	0
04	4 × 18W FL	51	77.6	1600	6332.16	4 × 9W LED	36	2937.60	3394.56
05	1 × 400W ML	8	400	2920	9344.00	1 × 54W LED	54	1261.44	8082.56
Total Load Power (W)					40980.80			16189.44	24791.36

4.3.3 Automation System for Lighting Based on Fuzzy logic Controller

In the life of human-being, lighting is something needed during night time or day time. However, human-beings always give a little attention only to the operation of the lamp, they always forget to switch the lamp off as the room is empty or to decrease the number of lamps to be switched on, if the incoming light to the room is brighter. In general, the electricity consumption for the lighting will be around 25% - 50% [54].

One of the lighting energy efficiency researches is using lighting control method. The controller will control the number of lamps to be switched on while maintaining suitable illuminance for the specific condition of the room. By the use of an automatic controller, then lighting energy consumption can be reduced. Fuzzy logic is proposed as the control method for a room lighting system with LEDs light as the controlled objects. The number of lamps depends on the condition of the room function and the standard illumination level. By using fuzzy logic controller, there are three benefits contributed, those are:

(1) Implementation of a low-cost control hardware by using microcontroller based system
(2) An automatic control system based on fuzzy logic with occupation and illumination sensing
(3) Easiness of installation and expansion for a bigger system.

Fig.4.5 below clarify our system which have two sensor, the first one is occupancy sensor installed above the door, the other one is illumination sensor butted above the windows. These sensors are connected to a microcontroller which is connected to TRIACs driver that control the number of lights fitting [54].

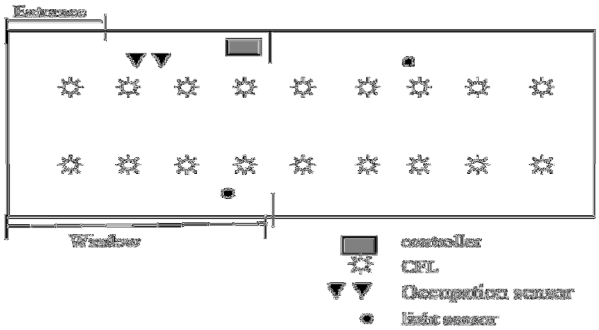


Figure4.5: Room lighting based on fuzzy logic controller

- **System requirement:**

1- Determination of Illumination Level for the Room
2- Measurement and Calculation of Room Parameter
3- Lamp Position Arrangement and Measurement of Illumination Uniformity

$$E = \frac{\varphi + CU + LLF}{A} \qquad 4.7$$

Where;

E : illuminance (Lux), φ: Luminance (Lumen), CU : Coefficient of Utility, A : area of illumination(m2), LLF: Light Loss Factor.

- **Fuzzy inference system**:

The processes is done using fuzzy inference system (FIS) which consists of:

1) *Fuzzification*: is the process of mapping of crisp value to a degree of membership. The crisp values are presented by sensors.
2) *Fuzzy operator* (AND or OR) implementation to obtain one number that represents the result of the antecedent for that rule.
3) *Implication method* (min or product): the result of if-then rule.
4) *Aggregate* (max or sum) of all implication result.
5) *Defuzzification*: process to obtain the crisp value.

The membership function used were triangular and trapezoidal function, the method used in defuzzification was center of area (COA) as shown in equation (4.8).

$$Z_{\circ} = \frac{\sum_{j=1}^{n} u_z(w_j) w_j}{\sum u_z(w_j)} \qquad 4.8$$

The membership function (MF) grouping for input variables and MF for output variable are shown in Fig.4.6 and Fig.4.7. The membership functions are grouped as Very Low (VL), Low (L), Middle (M), High (H) and Very High (VH).

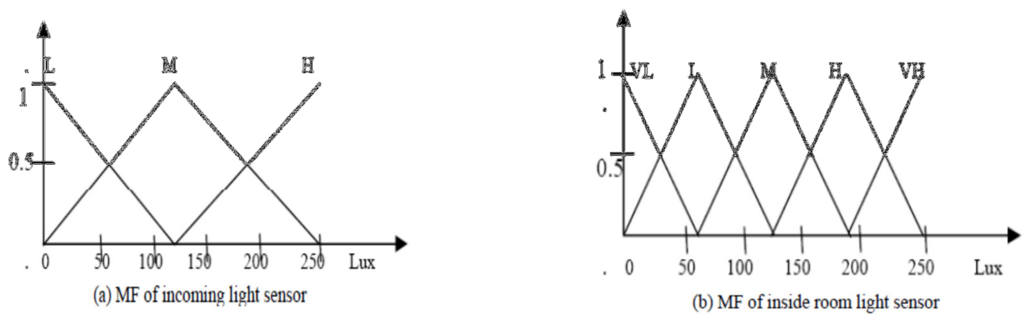


Figure 4.6: MF of input variable

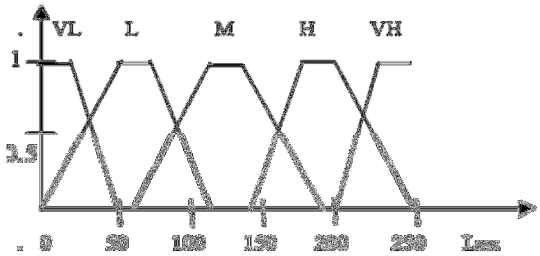


Figure 4.7: MF of output variable

Table 4.13 shows that there are 15 rules for the lighting system control, the rules are stated as follows:
R(n): IF *x1* is *A1n* and *y1* is *B1n* THEN *z* is *Qn*

Table (4.13): Fuzzy rules for lighting control system

Input X_1	Input y_1				
	VL	L	M	H	VH
L	VH	H	H	H	M
M	H	M	M	D	L
H	M	L	L	L	VL

- **Hardware and software design**

1- Hardware Design

The block diagram of the system hardware is shown in Fig.4.8. The microcontroller system receives two input signals: one is from incoming light to the room sensor and the other is from inside room sensor. These signals are put through multiplexer and Analog to Digital Converter (ADC) interface to the microcontroller system. The other inputs are occupation sensors, which are used to sense the people going into or out of the room [54]. The communication between the occupation sensors to the microcontroller system was accomplished through the system interrupt. The output signals of the microcontroller system are connected to the driver for controlling the switching of TRIACs those function to switch the LED on or off.

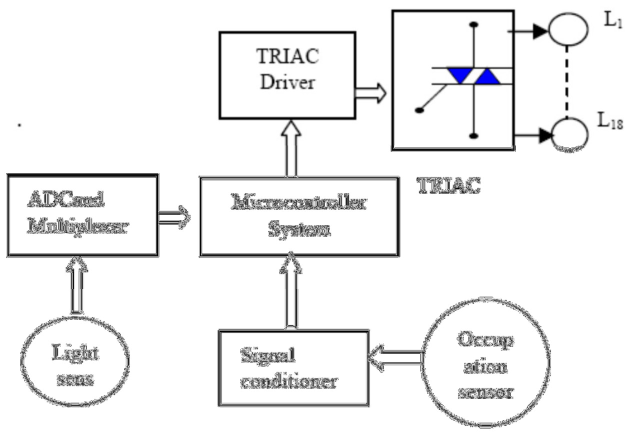


Figure 4.8: Fuzzy controller hardware block diagram

2- Software Design

The design of control system software algorithm is shown in Fig.4.9. The algorithm involves the following working steps:

1- Initialization of the I/O port and system interrupt. This step is purposed to determine the I/O ports that are assigned either as input or output, also for the interruption.
2- Check the Counter (CT), if CT=0 then switch off all lamp, otherwise do sensor reading. This step is purposed to detect the occupation of the room in order to activate the lighting system once the room is occupied.
3- Fuzzification of inputs is performed where it will convert the crisp value from the illuminance sensor to the fuzzy value in the software. This fuzzy value is a variable in the membership function input. The value later on will be used to decide the fuzzy value of the membership function output.
4- Application of the if-then rule is performed to select which rule(s) will be used in the computation.
5- Defuzzification is done when the value is converted to crisp value which is used as output control signal for lamps.
6- If the program was stop , go back to step number 2.

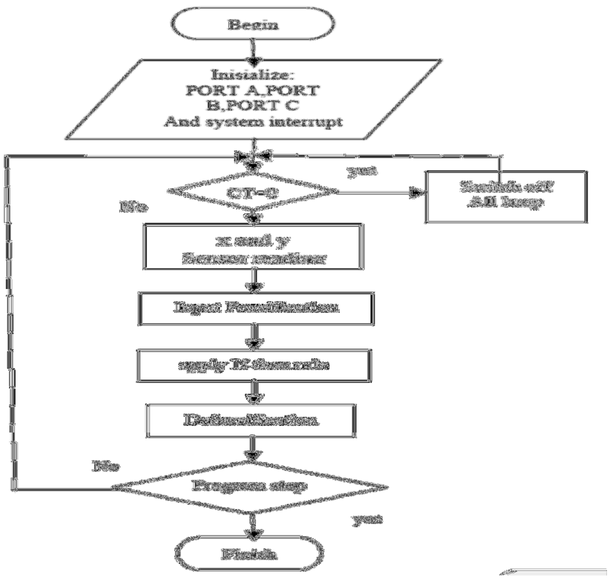


Figure 4.9: Fuzzy logic controller Software algorithm

Using fuzzy logic controller to control the on/off of LEDs lights which are currently used in most of buildings can save the energy around 23.9 % [54]. These results proved that the proposed controller could contribute a benefit in increasing energy usage efficiency.

After replace T8 fluorescent by high technology LEDs tube lamps, as shown in Table 4.12, we will apply fuzzy logic controller to control the on/off LEDs in specific places such as showroom, laboratories, workshops.

Table 4.14, illustrates the location choosing to apply automation control to light fittings and the remaining quantity each place.

Table (4.14) : Annual energy saving by using fuzzy logic controller on LEDs

No.	Floor	Room Name	Light type	Q	Q deduct	Q balance	Energy saving
			LED	Nos	Nos	Nos	kWh/year
01	Basement	Carpentry Workshop Manufacturing section (A)	2 × 18W	12	3	9	172.8
		Carpentry Workshop Manufacturing section (B)	2 × 18W	9	2	7	115.2
		Furniture Painting Workshop, Prep. And Sanding section (A)	2 × 18W	8	2	7	115.2
		Upholstery Workshop, Assembly section	2 × 18W	8	2	7	115.2
		Furniture Painting Workshop, Prep. And Sanding section (B)	2 × 18W	9	2	7	115.2
02	Ground	Multimedia Laboratory	2 × 18W	14	3	11	172.8
		Ceramic and Poltery Painting Workshop	2 × 18W	9	2	7	115.2
03	First	Open Area	2 × 18W	68	16	52	921.6
Total				137	32	105	**1843.2**
04	First	Open Area	1 × 18W	20	5	15	144
Total				20	5	15	**144**
Total annual energy saving							**1984.7**

Note: Energy saving = LEDs light power rate X Operating hours(1600) X Q deduct

Annual energy achieved upon the replacing lamps from linear fluorescent lamps T8 to high technology LED lamps and installing automation fuzzy controller is 26778.56 kWh/year, as shown in Table 4.15.

Table (4.15): Annual energy saving by replacing T8 to LEDs with A.F.C.

No	Existing lamp					Proposed lamp with fuzzy controller				Energy saving
	Light type	Q	Rate	OH	Energy used	Light type	Q New	Rate	Energy used	
		Nos	W	hr	kWh/year		Nos	W	kWh/year	kWh/year
01	2 × 36W FL	188	77.4	1600	23281.92	2 × 18W LED	156	36	8985.60	14296.32
02	1 × 36W FL	23	41.4	1600	1523.52	1 × 18W LED	18	18	518.4	1005.12
03	1 × 26*W* CFL	12	26	1600	499.20	1 × 26*W* CFL	12	26	499.20	0
04	4 × 18*W* FL	51	77.6	1600	6332.16	4 × 9*W* LED	51	36	2937.60	3394.56
05	1 × 400W ML	8	400	2920	9344.00	1 × 54W LED	8	54	1261.44	8082.56
Total Load Power (W)					40980.80				14202.24	26778.56

4.4 HVAC System

Table 4.16 below illustrate the total load of air condition machine fed six rooms in ground floor as mention in Table 4.3.

Table (4.16): Summary of Air Condition ratings & Quantities in Building

No	Air Condition Type	Unit	Qty	Load (W)	Total Load (W)	Location
01	Split Unit	Nos.	2	18200	36400	Top Roof

In this thesis, we will apply two methods to get efficient energy HVAC system as follows:

1- Increase the air conditioner thermostat set point temperature
2- Using VSD inverter compressor

After that we will apply the result that we get in Table 4.4 for building envelop insulation.

4.4.1 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 4.9. Table 4.17 shows the percentage of saving power from raising the thermostat temperature to 24 ℃ (Majority efficient condition 24 ℃ and less than 60 % humidity in summer) [19,55]. The annual energy saving is 5069.44 kWh/year if change the thermostat set point to 24 ℃ in summer seasonal.

$$\text{Energy saving } (\%) = \frac{[(T_{inlet} - T_{out}) - (T_{suggested} - T_{out})]}{[(T_{inlet} - T_{out})]} \qquad 4.9$$

Table (4.17): Increase the air conditioner T.S.P. temperature

No.	Room name	S.P	T In	T Out	T Sugg	Rate	O.H	Using	Saving	Power Saving	Energy Saving
		℃	℃	℃	℃	Kw	Hour	kWh/year	%	KW	kWh/Year
01	Multimedia laboratory	18	21	36	24	7.6	640	4864	20%	1.52	972.80
02	Pyrography workshop	17	21	37	24	7.6	640	4864	18%	1.37	875.52
03	Staff (A)	16	21	36	24	4.9	640	3136	20%	0.98	627.20
04	Staff (B)	16	21	34	24	4.5	640	2880	23%	1.04	662.40
05	Staff (C)	15	21	34	24	4.2	640	2688	23%	0.97	618.24
06	Pc, Mobile & S. devices main. workshop	18	21	32	24	7.6	640	4864	27%	2.05	1313.28
Total =								23296			5069.44

4.4.2 Energy efficient HVAC system using VSD inverter compressor

Most fixed-speed compressors in traditional HVAC systems only operate at 0% and 100%; in other words, fixed-speed compressors are either off or on, wasting energy when partial-load conditions prevail. And even if you have a traditional system with 2 or 3 stages, it doesn't compare to the full-range variable capacity of the inverter-driven system that fully supports part-load operation.

In comparison, VSD inverter compressors ramp up quickly, providing the energy necessary to achieve the cooling or heating demand of the zone. Then, working in tandem with system controls and sensors, the VSD inverter compressor varies its speed to maintain the desired comfort level. Fig.4.10 clarifies the basic existing technology of VSD, the system performs at only the minimum energy levels necessary and does not waste electricity when partial-load conditions are present, which is 97% of the time in most locations [56].

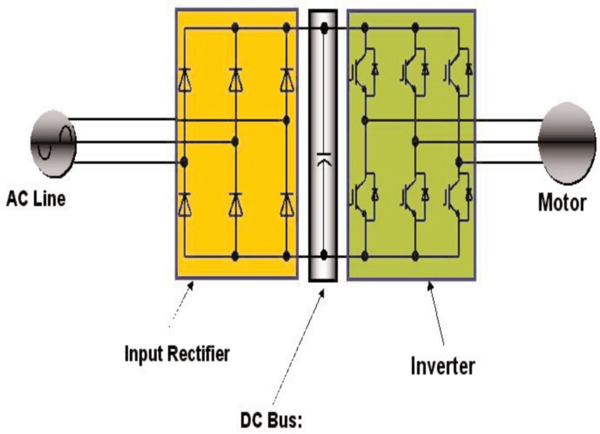


Figure 4.10: VSD basics existing technology

As VSD usage in HVAC applications has increased, fans, pumps, air handlers, and chillers can benefit from speed control. Variable frequency drives provide the following advantages:

- energy savings
- low motor starting current
- reduction of thermal and mechanical stresses
- simple installation
- high power factor
- lower KVA

When using the air condition included the inverter, the saving energy reaches up to 50 % [19,57]. Table 4.18, shows energy saving for using the air conditioner with VSD inverter in Irada based on the measurements of power and energy consumption for air conditioners.

Table (4.18): Annual energy saving for using the air conditioner with VSD

No.	Room Name	Power	O.H.	Energy used	Saving	Power saving	Energy saving
		W	Hour	kWh/year	%	W	kWh/year
01	Multimedia laboratory	7.6	640	4864	50%	3.8	2432
02	Pyrography workshop	7.6	640	4864	50%	3.8	2432
03	Staff (A)	4.9	640	3136	50%	2.45	1568
04	Staff (B)	4.5	640	2880	50%	2.25	1440
05	Staff (C)	4.2	640	2688	50%	2.10	1344
06	Pc, Mobile & S. devices main. workshop	7.6	640	4864	50%	3.8	2432
Total				23296			11648

Finally, we will add the result of percentage energy saving in cooling load that we get it in Table 4.4 (room envelop with wall insulation and double glass windows) to the result we get it in Table 4.17 (thermostat set point) and Table 4.18 (air conditioner with VSD inverter), the final result illustrate in Table 4.19 below.

The annual energy saving is 10584.9 kWh/year if change the thermostat set point to 24 ℃ in summer seasonal and making room insulation. The annual energy saving is 17163.4 kWh/year if adding VSD inverter to the air conditioner and making room insulation.

Table (4.19): Annual energy saving for using insulation with (T.S.P.) and VSD

No.	Room Name	Energy used	Insulation & thermostat set point		Insulation & VSD inverter	
			Saving	Energy saving	Saving	Energy saving
		kWh/year	%	kWh/year	%	kWh/year
01	Multimedia laboratory	4864	42.7%	2076.9	72.7%	3536.1
02	Pyrography workshop	4864	40.7%	1979.6	72.7%	3536.1
03	Staff (A)	3136	43.3%	1357.9	73.3%	2298.7
04	Staff (B)	2880	46.5%	1339.2	73.5%	2116.8
05	Staff (C)	2688	52.6%	1413.9	79.6%	2139.6
06	Pc, Mobile & S. devices main. Workshop	4864	49.7%	2417.4	72.7%	3536.1
		23296.0		10584.9		17163.4

4.5 Induction Motors

Table 4.20 illustrates summary of electrical machines ratings and quantities that have induction motor. All of these machines lay in Basement floor in Irada at IUG. We will concentrate on finding out the best energy saving method.

Table (4.20): Summary of Electrical Machine ratings & Quantities in Building

No	Machine Name	Unit	Qty	Load (W)	Total Load (W)	Location
01	Panel Saw Machine	No.	1	7500	7500	Carpentry Workshop Manufacturing Section (A)
02	Vertical Saw Machine	No.	1	3000	3000	
03	Sanding Machine	No.	1	4500	4500	
04	Five in one Machine (Saw, Sanding, Drilling, Milling and Cleaning)	No.	1	4000	4000	
05	Wood Cutting Machine	No.	1	1000	1000	Carpentry Workshop Manufacturing Section (B)
06	Drilling Machine	No.	1	750	750	
07	CNC Wood Craving Machine	Nos.	2	1500	3000	CNC Wood Craving Workshop
08	Water Pump	Nos.	2	2500	5000	Top Roof
09	Extract Fan (Ventilation)	Nos.	3	3000	9000	
Total Load Power (W)					37750	

We will use the method of replacing the standard motor by premium efficiency motor. Premium efficiency motors use less energy to do the same work as standard motors. Install premium efficiency electric motors rather than rewinding the existing motors, this will lead to greater efficiencies and decrease energy costs. Depending on horsepower, high efficiency motors operate from 1% to 10% more efficiently than standard motors. The savings are larger on smaller motors because the efficiency improvement is greater, and on motors that operate for long periods [58].

Anticipated Savings

The Motor Efficiency worksheet (Appendix A.4) tabulates the motor tag, standard or premium efficiency, demand, energy, and incremental cost by replacing all standard (1200, 1800, or 3600 rpm) motors with energy efficient motors. The electrical energy savings (ES) and electrical demand savings (DS) can be calculated from the following equation for each motor:

$$ES\ (Kwh/yr) = HP \times LF \times Conversion \times (1/\eta_S - 1/\eta_h)) \times Hrs \qquad 4.10$$

$$DS(Kw) = HP \times LF \times Conversion \times (1/\eta_S - 1/\eta_h) \times CF \qquad 4.11$$

Where:

Hrs = Annual operation hours per year of motor.
LF = Motor load factor as percentage (0-100); if motor specific load factor is not available, use default 0.75 load factor.
HP = Rated motor horsepower
η_h = Efficiency of high efficiency motor.
η_S = Efficiency of standard motor.
Conversion = 0.746 (1 HP = 0.746 Kw).
CF = Coincidence factor = 0.78.

We will take an example Panel Saw machine and apply the above algorithms on it and we will do the same for others machine. Taking into consideration that all machine in Table 4.20 mentioned its standard efficiency on its manufacturing plate, and we will assume the load factor equal 0.75, and the coincidence factor equal 0.78 (Returning to **Appendix D** for standard efficiency of electrical motor to get the efficiency motor).

$$ES\ (Kwh/yr) = 10.05 \times 0.75 \times 0.746\ (1/0.816 - 1/0.895) \times 720 = 435.6\ Kwh/yr$$

$$DS(Kw) = 10.05 \times 0.75 \times 0.746\ (1/0.816 - 1/0.895) \times 720 = 0.47\ Kw$$

Table 4.21 illustrates that the annual energy saving is 1830.6 kWh/year when changing the standard motor by premium high efficiency motor.

Table (4.21): Energy saved by replacing standard motor by HEM

No.	Machine Name	Q	Standard	HEM	Power Saving	OH	Annual energy saving
			Efficiency	Efficient	Efficient	hr	Efficient
		Nos	%	%	kW	hr	kWh/y
01	Panel Saw Machine	1	81.6	89.5	0.47	720	435.6
02	Vertical Saw Machine	1	80.9	86.5	0.14	720	100.8
03	Sanding Machine	1	81.2	87.5	0.28	720	259.2
04	Five in one Machine (Saw, Sanding, Drilling, Milling and Cleaning)	1	83.4	87.5	0.26	720	184.3
05	Wood Cutting Machine	1	76.8	84.0	0.05	720	34.5
06	Drilling Machine	1	75.3	84.0	0.11	720	104.4
07	CNC Wood Craving Machine	2	78.5	84.0	0.09	720	129.6
08	Water Pump	2	79.6	86.5	0.15	720	267.8
09	Extract Fan (Ventilation)	3	80.7	86.5	0.14	720	314.4
Total =							1830.6

4.6 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 4.12 and equation 4.13 [19,59].

$$Power\ Factor = \frac{Real\ Power\ (Kw)}{Apperant\ Power} \qquad 4.12$$

or

$$\text{Power Factor} = \cos(\tan^{-1}\frac{KVarh}{Kwh}) \qquad 4.13$$

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 [19,60].

- **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 Fig. 4.11 with the required components

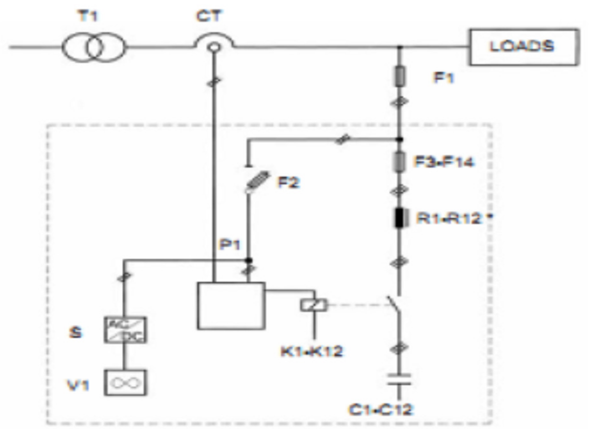


Figure 4.11: Wiring diagram of APFR from ABB

- 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**

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

$$\% \text{ Released system capacity} = 100 \times \left(1 - \frac{P.F_{original}}{P.F_{new}} \right) \qquad 4.14$$

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 [59,60].

$$\% \text{ Loss reduction} = 100 \times \left(1 - \frac{P.F^2_{original}}{P.F^2_{new}} \right) \qquad 4.15$$

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 [60].

$$\% \; Voltage \; rise = \frac{Capacitor \; Kvar \times Transformer \; \%ZI}{Transformer \; KVA} \qquad 4.16$$

5. Environmental benefit

Reduced power consumption means less greenhouse gas emissions and fossil fuel depletion by power stations [11]. 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 4.22 [19].

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 Irada Building at IUG dated on 29th March, 2013 for 7 hrs was summarized in **Appendix E**.

Table (4.22): Power factor proposed penalties in Palestine [19]

No.	**Power factor Value**	**Penalty**
01	Power Factor ≥ 0.92	None
02	0.92≤Power Factor ≤ 0.80	1% of the total bill for every 0.01 of Power factor less than 0.92
03	0.80<Power Factor ≤ 0.70	1.25 % of the total bill for every 0.01 of Power factor less than 0.92
04	Power Factor < 0.70	1.5% of the total bill for every 0.01 of Power factor less than 0.92

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

Fig. 4.12 shows that the power factor during the test period (red color curve) and Fig. 4.13 shows the daily real and reactive power (red curve is daily real power; blue curve is reactive daily load). The P.F values sometimes occur in the penalty region as shown in Fig. 4.12 (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.

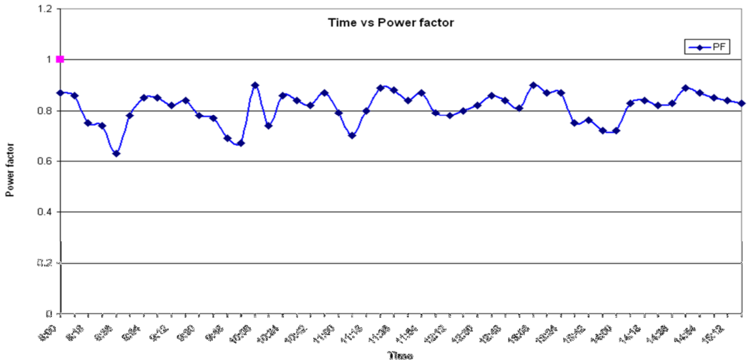


Figure 4.12: Average power at Irada (Before improvement)

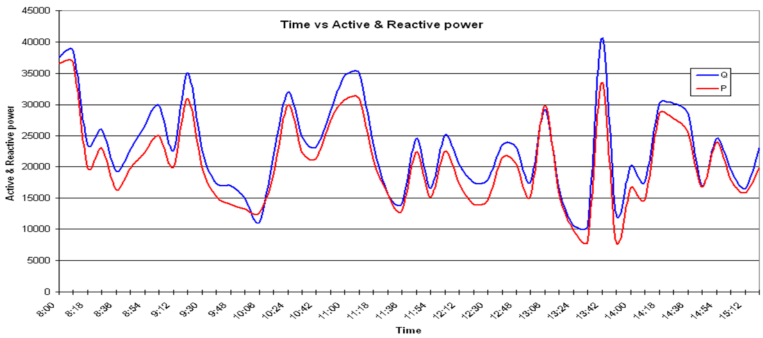


Figure 4.13: Daily load power measured at Irada (Before improvement)

The recommended solution was to re-install new capacitor stages to stabilize P.F above 0.92 as shown in Fig. 4.14 and hence no 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 Irada building can avoid penalty from low power factor.

Fig. 4.15 shows the situation of daily power load after the proposed approach for improvement power factor inside Irada building. The demand reactive power of plant drops after applied reactive power compensation by APF and consequently, increases power factor.

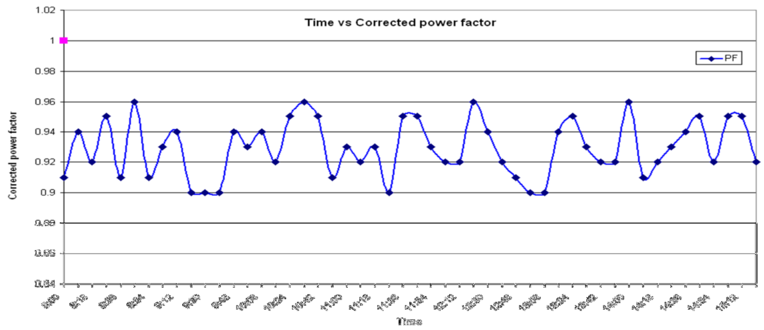


Figure 4.14: Average power factor at Irada (after improvement).

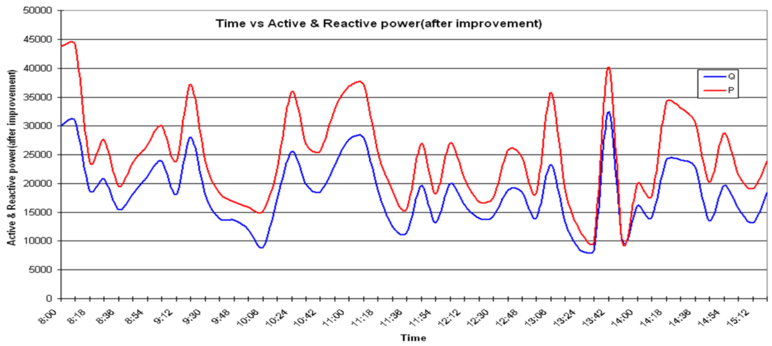


Figure 4.15: Average daily power measured at Irada (after improvement).

The energy saving for power factor improvement is determined according to the equation 4.17.

$$\textit{Penalty saving=Penalty factor } (P.F_{new} - P.F_{old}) \times \textit{electrical consumption Kwh/yr} \quad 4.17$$

$$= 0.01 \times (92 - 89) \times 119968.29 = 3599.05 \text{ Kwh/yr}$$

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CHAPTER 5

FEASIBILITY STUDY

As businesses expand and grow, managers must decide which projects warrant further investment. Budgeting of capital expenditures is a crucial skill that managers need to learn to avoid wasting money on uneconomical investments.

The objective of the feasibility study of our project in this research is to determine the amount of profit or loss in investing money on reducing annual electricity bill of Irada building at IUG. If there is a loss, there is no need for implementation of this project, but if there was profit we measure it and decide, is it feasible or not?.

If it were not feasible (profit return a few), this will pay investors to reject this project and go to other projects or get interest by depositing their money in the banks. If this project feasible (profit benefit too large), it will encourage investors to invest in this type of projects and therefore this will contribute in solving the problem of electricity in the Gaza Strip, which suffers from a deficit reach to 30% of the total energy needed by the Strip.

Capital Investment Decision Rules that we will used in this chapter are the most common approaches to project selection and divide into three methods as the following:

- Simple Payback Period (S.P.B.P)
- Net Present Value (NPV)
- Internal Rate of Return (IRR)

Although an ideal capital budgeting solution is such that all three metrics will indicate the same decision, these approaches will often produce contradictory results. Depending on managements' preferences and selection criteria, more emphasis will be put on one approach over another.

5.1 Simple Payback Period (S.P.B.P)

The payback method is defined as the time, usually expressed in years, it takes for the cash income from a capital investment project to equal the initial cost of the investment. The choice between two or more projects is to accept the one with the shortest payback time. The determination of the payback period is a simple calculation of dividing the amount of the investment by the projected cash inflow per year [65].

A shorter payback period equates to a higher return on the capital investment. Many companies have a maximum acceptable payback period and will only consider those projects whose payback period is less than the target number of years.

The advantages of payback method are that it is popular with business analysts for several reasons. The first is its simplicity. Most companies will use a team of employees with varied backgrounds to evaluate capital projects. Using the payback method and reducing the evaluation to a simple number of years is an easily understood concept. Identifying projects that provide the fastest return on investment is particularly important for companies with limited cash that need to recover their money as quickly as possible.

Managers use the payback method to make quick evaluations of projects with small investment. These small projects do not necessarily involve a group of employees, and it is not necessary to conduct a rigorous economic analysis.

The disadvantages of payback method are that it is ignores the time value of money. The cash inflows from a project may be irregular, with most of the return not occurring until well into the future. A project could have an acceptable rate of return but still not meet the company's required minimum payback period. The payback model does not consider cash inflows from a project that may occur after the initial investment has been recovered. Most major capital expenditures have a long life span and continue to provide income long after the payback period. Since the payback method focuses on short-term profitability, an attractive project could be overlooked if the payback period is the only consideration [65].

Managers often use the payback method as an initial screening tool when evaluating projects. If a project passes the payback period test, it gets further detailed and sophisticated analysis with methods that use the time value of money and the internal rate of return.

The payback period is calculated as follows:

$$S.P.B.P = \frac{Investment\ cost}{Money\ saving} \qquad 5.1$$

All other things being equal, the better investment is the one with the shorter payback period. For example, if a project costs \$100,000 and is expected to return \$20,000 annually, the payback period will be \$100,000 / \$20,000, or five years.

1. S.P.B.P Calculation for Building Envelope

Returning to Table 4.4, the peak annual energy saving was 22037.6 kWh/year due to external wall insulation and double glass windows as it is clear in Fig 4.1. The corresponding savings and payback period were calculated as shown in Table 5.1, knowing that the extra costs of making wall insulation equal 30NIS/m^2 more than standard wall square meter cost , and the extra cost of double glass wood windows equal 210NIS/m^2 more than single glass aluminum window.

Table (5.1): S.P.B.P calculation for building insulation at Irada

No.	Room name	Power saving	O.H	Energy saving	Money saving	Extra cost	CO_2 reduction	S.P.B.P
		KW	hour	kWh/yr	NIS	NIS	kg/yea	year
01	Multimedia laboratory	1.07	640	6848.8	3424.4	2046	4937.9	0.6
02	Pyrography workshop	1.07	640	6848.8	3424.4	3408.0	4937.9	1.5
03	Staff (A)	0.77	640	492.8	246.4	692.4	355.3	2.9
04	Staff (B)	0.72	640	460.8	230.4	672.0	332.2	3.1
05	Staff (C)	0.84	640	537.6	268.8	825.4	387.6	3.2
06	Pc, Mobile & S.devices main. workshop	1.07	640	6848.8	3424.4	3408.0	4937.9	1.5

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 [62]
S.P.B.P= Investment cost/ money saving

2. S.P.B.P calculation for Light Fittings

A. S.P.B.P calculation for replacing T8 by T5 and ML by HPS lamp\

Returning to Table 4.10, the peak annual energy saving was 18363.2 kWh/year due to replacing T8 by T5 and ML by HPS lamp. The corresponding savings and payback period were calculated as shown in Table 5.2, knowing that the extra costs of replaced 2×36 w T8 FL by 2×22w T5 FL with good reflector equal 70NIS/pec , the extra cost of replaced 1×36w T8 FL by 1×22w T5 FL with good reflector equal 45 NIS/pes, the extra cost of replaced 4×18w T8 FL by 4×14w T5 FL with good reflector and diffuser equal 82NIS/pec, and the extra cost of replaced 400w ML by 150 HPS equal 400NIS/pec.

Table (5.2): S.P.B.A calculation for replacing T8 by T5 and ML by HPS lamp

No	Energy saving	Money Saving	Extra cost	CO_2 reduction	S.P.B.P
	kWh/year	NIS	NIS	NIS	year
01	10046.72	5023.3	13160	7243.6	2.6
02	713.92	356.9	1035	514.7	2.9
03	0	0	0	0	0
04	1762.56	881.3	4182	1270.8	4.7
05	5840	2920.0	3200	4210.6	1.1

B. S.P.B.P calculation for replacing T8 FL and ML by LED lamp

Returning to Table 4.12, the peak annual energy saving was 24791.36 kWh/year due to replacing T8 FL and ML by LED lamp. The corresponding savings and payback period were calculated as shown in Table 5.3, knowing that the extra costs of replaced 2×36 w T8 FL by 2×18w LED equal 130NIS/pec , the extra cost of replaced 1×36w T8 FL by 1×18w LED 72NIS/pec, the extra cost of replaced 4×18w T8 FL by 4×9w LED equal 160NIS/pec and the extra cost of replaced 400w ML by 54w LED equal 1050NIS/pec.

Table (5.3): S.P.B.A calculation for replacing T8 FL by LEDs tube lamp

No	Energy saving	Money Saving	Extra cost	CO_2 reduction	S.P.B.P
	kWh/year	NIS	NIS	NIS	year
01	12453.12	6226.6	24440	8978.7	3.9
02	861.12	430.6	1656	620.8	3.8
03	0	0	0	0	0
04	3394.56	1697.3	8160	2447.4	4.8
05	8082.56	4041.3	8400	5827.5	2.1

C. S.P.B.P calculation for replacing T8 FL and ML by LED lamp with F.C.

Returning to Table 4.14 and Table 4.15, the peak annual energy saving was 26778.56 kWh/year due to replacing T8 FL and ML by LED lamp and added fuzzy lighting controller in some places. The corresponding savings and payback period were calculated as shown in Table 5.4, knowing that the extra costs of replaced 2×36 w T8 FL by 2×18w LED equal 130NIS/pec and add seven number of fuzzy lighting controller with two sensor its price equal 140NIS/pec , the extra cost of replaced 1×36w T8 FL by 1×18w LED 72NIS/pec and add one number of fuzzy lighting controller with two sensor its price equal 1400 NIS/pec (**see Appendix B**), the extra cost of replaced 4×18w T8 FL by 4×9w LED equal 160 NIS/pec and the extra cost of replaced 400w ML by 54w LED equal 1050NIS/pec.

Table (5.4): S.P.B.A calculation for replacing T8 FL by LEDs lamp with F.C.

No	Energy saving	Money Saving	Extra cost	CO_2 reduction	S.P.B.P
	kWh/year	NIS	NIS	Kg/year	year
01	14296.32	7148.16	30080	10307.6	4.2
02	1005.12	502.56	2696	724.7	5.3
03	0	0	0	0	0
04	3394.56	1697.3	8160	2447.4	4.8
05	8082.56	4041.3	8400	5827.5	2.1

Table 5.5 below illustrate summary of all methods used for lighting system to decrease energy bill and reduce the quantity of CO_2.

Table (5.5): Summary of S.P.B.P calculation for Light System

No.	Reduction method	Cost Investment	Energy Saving	Money Saving	CO2 Reduction	S.P.B.P
		NIS	Kwh/yr	NIS	Kg/year	Year
01	Replacing T8 by T5 and ML by HPS lamp	21577	18363.20	9181.5	13239.7	2.8
02	Replacing T8 FL and ML by LED lamp	42656	24791.36	12395.8	17874.4	3.7
03	Replacing T8 FL by LEDs lamp with F.C	49336	26778.56	13389.32	19307.2	4.5

3. S.P.B.P calculation for HVAC

A. S.P.B.P calculation upon increase A/C thermostat set point temperature

Returning to Table 4.17 and by using equation 4.9, it is expected to achieve an annual energy saving of **5069.4 kWh/year** upon increasing the air conditioner thermostat set point temperature. Table 6.6 illustrates the conservation by using this technique.

Table (5.6): S.P.B.P calculation upon increase temperature set point 24℃

No.	Method	Cost Investment	Energy Saving	Money Saving	CO2 Reduction	S.P.B.P
		NIS	Kwh/yr	NIS/yr	kg/year	Year
01	Thermostat Set point=24 °C	0	5069.4	2534.7	3655.0	Immediate
Total			5069.4	2534.7	3655.0	

B. S.P.B.P calculation for HVAC system upon Replace A/C to inverter type:

Returning to Table 4.18, it is expected to achieve an annual energy saving of **11648** kWh/year for using the air conditioner with VSD inverter. Table 5.7 illustrates the conservation by using this technique, the price of 18.2 kw package unit air condition with VSD was summarized in **Appendix C**.

Table (5.7): S.P.B.P calculation upon using the air conditioner with VSD

No.	Method	Cost Investment	Energy Saving	Money Saving	CO2 Reduction	S.P.B.P
		NIS	Kwh/yr	NIS/yr	kg/year	Year
01	Inverter type	34000	11648	5824	8398.2	5.8
Total			11648	5824	3655.0	

4. S.P.B.P calculation for Induction Motor

Returning to Table 4.21, it is expected to achieve an annual energy saving of **1830.6**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 D**. The results indicated that the replacement to HEM is recommended. The summary of economic and environmental analysis was shown in Table 5.8.

Table (5.8): S.P.B.P calculation for replacing standard motor by HEM

No	Machine Name	Q	Annual energy saving	Money saved	Investment	CO2 reduction	S.P.B.P
			Efficient	Efficient	Efficient	Efficient	Efficient
		Nos	Kwh/yr	NIS/year	NIS	Kg/year	Year
01	Panel Saw Machine	1	435.6	217.8	423.4	314.0	1.9
02	Vertical Saw Machine	1	100.8	50.4	200.7	72.7	3.9
03	Sanding Machine	1	259.2	129.6	292.0	186.8	2.2
04	Five in one Machine (Saw, Sanding, Drilling, Milling and Cleaning)	1	184.3	92.1	255.5	132.9	1.4
05	Wood Cutting Machine	1	34.5	92.2	219.0	24.9	2.3
06	Drilling Machine	1	104.4	52.2	189.8	75.3	3.6
07	CNC Wood Craving Machine	2	129.6	129.6	445.3	93.4	3.4
08	Water Pump	2	267.8	267.8	394.2	193.1	1.5
09	Extract Fan (Ventilation)	3	314.4	157.2	602.25	226.7	3.8
Total =			1830.6	1267.5	3060.22	1319.8	

5. S.P.B.P calculation for Power Factor Improvements

The energy saving of improvement of power factor was calculated from equation 5.12. The avoided penalties that considered as savings in case of imposing the penalty law are calculated according to Table 4.22 as follows:

Penalty saving = 0.01 × (Improved power factor – Old power factor) × Electricity consumption (kWh/year)

$= 0.01 \times (P.F_{new} - P.F_{old}) \times$ Electricity consumption (kWh/year)

$= 0.01 \times (92 - 89) \times 119968.29 = 3599.05$ Kwh/yr

Avoided penalties = Penalty saving × cost of kWh

$= 3599.05 \times 0.5$

$= 1799.5$ NIS

The investment cost of power factor improvement is the cost of electrical board for automatic power factor regulator including variable capacitors banks and approximates 4200 NIS **(Appendix F).** Table 5.9 summarizes the economic analysis of supplying and installation of APF regulator including the saving money.

Table (5.9): Economic analysis of supplying and installation APF regulator

No.	Energy saving method	Annual energy saving	Money saving	Investment	CO2 reduction	S.P.B.P
		Kwh/yr	NIS/yr	NIS	kg/year	Year
01	Supply & Install APF Regulator	3599.05	1799.5	4200	2594.9	2.3

5.2 Net Present Value Method (NPV)

The net present value NPV method is an important criterion for project appraisal. Profitability of a project is evaluated by this method. It is also called as present value method. Net present value is calculated by using an appropriate rate of interest which is the capital cost of a firm. This is the minimum rate of expected return likely to be earned by the firm on investment proposals.

To find out the present value of cash flows expected in future periods, all the cash outflows and cash inflows are discounted at the above rate. Net present value is the difference between total present value of cash outflows and total present value of cash inflows occurring in periods over the entire life of project. When the net present value is positive, the investment proposal is profitable and worth selecting. But if it is negative, the investment proposal is non-profitable and rejectable. The method to compute the net present value index of different investment proposals is as under.

$$NPV = \frac{\text{Total Present Value of All Cash Flows}}{\text{Initial Investment}} \quad 5.2$$

NPV method considers the time value of money. it compares time value of cash flows.
NPV = Present Value of Gross Earnings – Net Cash Investment
NPV can be found out from the following:

$$NPV = \frac{A_1}{(1+i)^1} + \frac{A_2}{(1+i)^2} + \ldots\ldots\ldots + \frac{A_n}{(1+i)^n} \quad 5.3$$

Where A_1, A_2 are cash inflows at the end of first year and second year respectively, n is the expected life of investment proposals, i is Rate of discount which is equal to the cost of capital, C is present value of costs.

Thus NPV = Sum of Discounted Gross Earnings - Sum of Discounted Value of Cost.

The total initial cost of energy saving investment in Irada building is the required costs for implementing low cost and high cost models, and illustrated in Table 5.10.

Table (5.10): Initial investment cost for saving energy in Irada

No.	Item	Quantity	Unit Cost (NIS)	Total Cost (NIS)	Years
01	VSD	2	17000	34000	20
02	HEM	L.S	L.S	3060.2	20
03	APF regulator	1	4200	4200.0	20
04	LEDs & F.L.C.	L.S	L.S	49336.0	20
06	Building insulation	L.S	L.S	11051.8	20
Total supply cost =				101648	
07	Installation (5%)	L.S	L.S	5082.4	
08	Uncertainty or unforeseen (2 % of total supply cost)	L.S	L.S	2032.9	
Total Initial Cost =				108763.3	

The NPV 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 12 %.

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

$= 101648 + 5082.4 + 2032.9 = 108763.3$ NIS

The annual Operation and maintenance Cost (O& M) is about 600 NIS and the salvage value of the design models after 20 years is taken 7 % and approximate 7115 NIS.
The NPV cost of implement the energy saving models in Irada building is obtained by drawing cash flow as in Fig. 5.1.

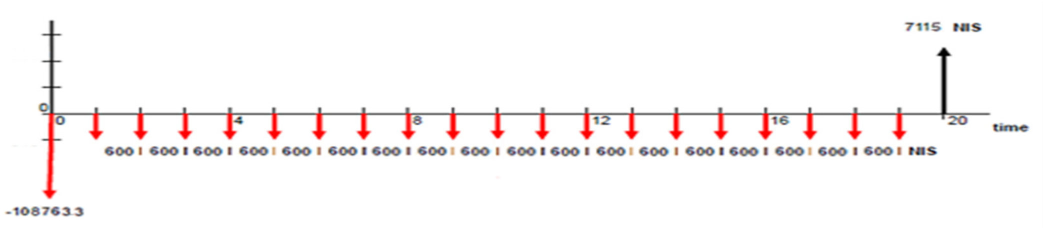

Figure 5.1: Cash flow of energy saving models for Irada.

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 the following two equations [63].

$$F = (1 + i)^{n} \qquad 5.4$$

Where; F is the future worth, *i* is the interest rate , n is project period. Equation 6.2 is the fundamental equation of exponential growth and can be applied whenever growth is a fixed percentage of the current quantity.

Equation 6.4 can be rearranged to show the present value of a future amount, as in Equation 6.5.

$$P = F (1 + i)^{n} \qquad 5.5$$

The NPV 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= 108763.3 + 600 (P / A i ,n)- 7115 (P / F i ,n)+ 0 (P / F i ,n)
- P.W= 108763.3 + 600 $(P/A_{12\%,20})$- 7115 $(P/F_{12\%,20})$+ 0 $(P/F_{12\%,20})$

The factors [$(P/A_{12\%,20})$; $(P/F_{12\%,20})$; $(P/F_{12\%,10})$] are obtained from interest factor tables in **Appendix H**. The following is the simplified procedure to explain NPV analysis.

- P.W = 108763.3 + 600 x 7.4694 - 7115 x 0.1037+ 0 = 112507.1 NIS

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

- A.W= PW(A/P12%, 20)= 112507.1 (0.13388)= 15062.4 NIS
- NPV cost is 15062.4 NIS

5.3 Internal Rate of Return Method (IRR)

This method refers to the percentage rate of return implicit in the flows of benefits and costs of projects A. Margin defines the internal rate of return IRR "as the discount rate at which the present value of return minus costs is zero". In other words, the discount rate which equates the present value of project with zero, is known as IRR.

Thus, IRR is the discounted rate which equates the present value of cash inflows with the present value of cash outflows. IRR is also based on discount technique like NPV method. Under this technique, the future cash inflows are discounted in such a way that their total present value is just equal to the present value of total cash outflows.

It is assumed that the management has knowledge of the time schedule of occurrence of future cash flows but not of the rate of discount. IRR can be measured as:

$$\text{IRR} = \frac{A_1}{(1+i)^1} + \frac{A_2}{(1+i)^2} + \ \ldots\ldots\ldots + \frac{A_n}{(1+i)^n} - C = 0 \qquad 5.6$$

Where, A_1, A_2 are the cash inflows at the end of the first and second years respectively. And the rate of return is computed as follows:

$$C = \frac{A_1}{(1+i)^n} \qquad 5.7$$

Where, 1 is the cash outflow or initial capital investment, A_1 is the cash inflow at the end of first year, i is the rate of return from investment.

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 = 24685.8(P / A i, 20) + 7115 (P / F i, 20)

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

- Outcome values = 108763.3 + 600 (P / A i, 20) + 0 (P / F i, 20).

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

- Income + Outcome = zero.
- 24685.8 (P / A i, 20)+ 7115 (P / F i, 20)- 108763.3-600 (P / A i, 20) - 0 (P / F i, 20)=0

- 24085.8 (P / A i, 20) + 7115 (P / F i, 20) - 108763.3 - 0 (P / F i, 20) =0

Step 4: Use try and error method:
By try and error the approximate i is between 20% and 22% to achieve the balance between income and outcome value of the proposed investment for electrical conservation.
Use i = 20% to estimate the actual IRR.

- 24085.8×4.869 + 7115×0.00261-108763.3 – 0 = 8710.6 >>> 0

We are too large on the positive side, indicating that the return is more than 20%.
Try i = 22 %:
24085.8×4.4603+7115×0.0187-108763.3- 0= -1200.4 <<0

Step 5: Do interpolation to estimate the value of IRR:
Since the interest rate of 22% is too high, interpolate between 20% and 22% to obtain:

$$i = 0.2 + \left(\frac{87106-0}{87106-(-1200.4)}\right) \times 0.02 = 21.9\ \%$$

IRR =21.9 %

From the result we get above we can see that the annual IRR is 21.9% and this a good result to encourage the investors to invest their money in this type of projects.

5.4 Saving Factor Calculation

A. Model of Low Cost Investment Analysis

Low cost model of electrical conservation in Irada building at IUG are using the followings :

1- Replacing T8 by T5 and ML by HPS lamp.
2- Controlling thermostat set point temperature to 24 °C with building insulation.
3- Replacing standard motor by HEM.
4- Power Factor Improvements.

Saving Factor =

$$\frac{\text{Saving by replce T8 by T5 FL+Saving by T.S.P+Saving by HEM+Saving by PF}}{\text{Annual Electrical Consumption kWH}}$$

$$= \frac{18363.2 + 5069.4 + 1830.6 + 3599.05}{119968.29} = 24\ \%$$

B. Model of High Cost Investment Analysis

High cost model of electrical conservation in Irada building at IUG are using the followings :

1- Replacing T8 by LEDs and automation system (F.L.C).

2- Controlling thermostat set point temperature to 24 °C, add VSD and building insulation .
3- Replacing standard motor by HEM.
4- Power Factor Improvements.

$$\text{Saving Factor} = \frac{\text{Saving by replce T8 by LEDs and automation FL} + \text{Saving HVAC by VSD and insulation} + \text{Saving by HEM} + \text{Saving by PF}}{\text{Annual Electrical Consumption kWH}}$$

$$= \frac{26778.56 + 17163.4 + 1830.6 + 3599.05}{119968.29} = 41\ \%$$

Fig.(5.2) and Fig.(5.3) clarifies the annual change in energy and price after apply improvement methods.

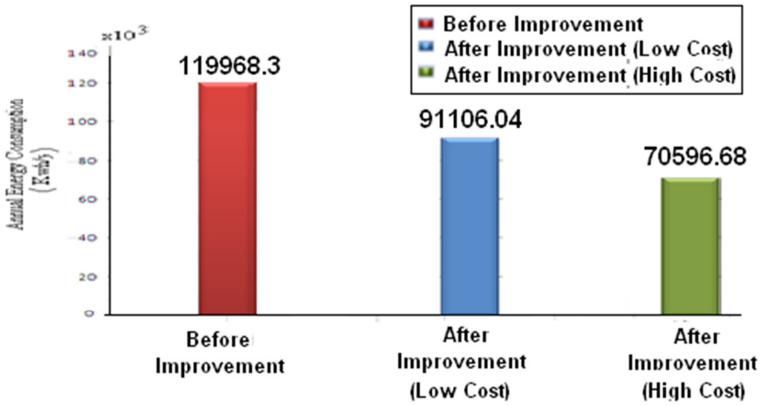

Figure 5.2: Annual energy consumption before and after improvement

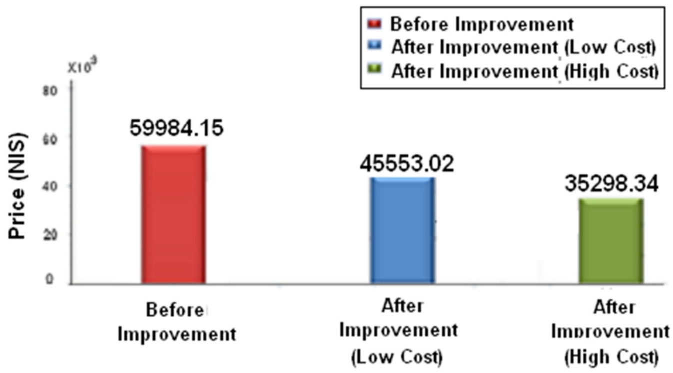

Figure 5.3: Annual energy price before and after improvement

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Energy is essential to economic and social development and improved quality of life as it is used in all aspects of modern life such as transportation, agriculture, industries, buildings. World energy demand is expected to increase by about 60% from 2002 to 2030 with an average annual increase of 1.7% per year. This steady increasing in energy supply is returned to the population growth which is expected to grow by 4.2% a year on average to 2020, and to economic development which is growing at an annual rate of 1.4% per year.

The energy resources can be categorized into three sources which are fossil fuels, renewable resources, and nuclear resources. Nowadays, the world mainly depends on the fossil conventional. The renewable energy sources appear to be one of the most efficient and effective alternatives. However, in 2010 these sources supplied only about 16.6% of the total world energy demand.

For the Gaza Strip, the main problem of energy is that it has almost no conventional energy sources. This problem becomes worse by the high density pollution and the difficult political procedures of Israel occupation. Gaza strip needs (340) MW of electricity, while the available supply is (211) MW. The large part of this supply about (60%) is provided by Israeli Electricity Company. Locally, about (32%) is provided by Gaza Power Plant. In addition, about (8%) is provided by Egyptian electric company. In light of previous statistics, the Gaza strip has been suffering from a real shortage in electricity supply estimated by 30% which affect negatively on Palestinians life and make it very hard.

The thesis is carried out with the main objective to investigate the potential of reducing the energy consumption that is needed in heating, cooling, lighting, HVAC and induction motor. All the features that were analyzed in this study for adoption in the case study Irada building at IUG reduce the energy used. The study shows that it is possible to reduce the energy consumption load of Irada building by 41%. It should also be stressed that the theoretical framework has outlined many other options that reduce energy consumption load and also improve passive design features for energy-efficient residential buildings. However, only those features were selected that can quantify the energy savings and can be adopted in Gaza Strip.

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, 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.

Low cost energy saving actions achieve annual average energy saving of 24 % with 28862.2 Kwh/year and equivalent to 14431.1 NIS in Irada building, and low cost energy saving model includes replacing T8 by T5 and ML by HPS lamp, controlling thermostat set point temperature to 24 $^{\circ}$C with building insulation, replacing standard motor by HEM and add power factor improvements in Irada building at IUG.

High cost energy saving actions achieve average energy saving of 41 % corresponding 49371.6 kWh/year and equivalent to 24685.8 NIS in Irada building, and high cost model includes evaluation of replacing T8 by LEDs and automation system (F.L.C), controlling thermostat set point temperature to 24 $^{\circ}$C, add VSD with building insulation, replacing standard motor by HEM and add power factor improvements.

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.

6.2 Recommendations

In light of the above findings, the following points are recommended:

- Renewable energy sources that are available in the Gaza strip, namely solar and wind energy, should be considered and thought about as potential and clear alternative to solve the problem of energy shortage.

- Because the residential sector consumes the large part of the energy in the Gaza Strip, this sector should be the focus to develop plans and strategies for reducing energy demand.

- Increasing the awareness of architects about the importance of integrating energy efficient building techniques during the different design stages.

- Directing the officials in government to the necessary of developing regulations and standards which ensure the use of energy-efficient principles in building design.

- Using media and school education to assist in increasing the awareness of general public about the dimensions of energy problem and the means of energy conservation which can contribute in the solution.

- Encouraging researchers to carry out more studies about other factors that help in reducing the energy consumption in buildings such as building form, vegetation, natural ventilation, daylighting, passive cooling etc.

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APPENDIX A: THERMAL TRANSMITTANCE AND THERMAL RESISTIVITY

الجدول رقم (١)

قيم الانتقالية الحرارية للأبواب(U_d) والنوافذ الخارجية (U_{win})، (واط /م٢ . ك) ($W/m^2.K$)

نوع المادة المكونة للأبواب وأطر النوافذ		الأبواب*	النوافـذ**					
			زجاج مفرد			زجاج مزدوج		
			شديدة التعرض	معتدلة التعرض	محمية	شديدة التعرض	معتدلة التعرض	محمية
خشب		3.5	5.0	4.3	3.8	2.7	2.5	2.3
معدن	ألومنيوم	*7.0	6.7	5.6	5.0	3.5	3.2	3.0
	فولاذ	*5.8						
مبلمـــــر كلوريـــــد		–	5.0	4.3	3.8	2.7	2.5	2.3

* الأبواب المعدنية هي تلك التي لا تزيد فيها نسبة الفتحات الزجاجية عن (30) بالمائة من كامل مساحتها.

** عند استخدام زجاج من نوع خاص للنوافذ، تؤخذ قيم الانتقالية الحرارية من النشرات الفنية للشركات الصانعة

ملاحظات: (١) لاتقل سماكة الزجاج عن (3) مليمتر والمسافة بين الألواح المزدوجة عن (12) مليمتر.

(٢) لاتقل سماكة خشب الأبواب عن (25) مليمتر.

الجدول رقم (٥)

الموصلية الحرارية (k) لبعض المواد الإنشائية بدلالة كثافتها

المادة		الكثافة (ρ) (kg/m^3)	الموصلية الحرارية (k) (W/m.K)
حجارة طبيعية	* حجر جيري (Limestone)	2200 2180 1650	1.53 1.50 0.93
	* حجر رملي (Sandstone)	2300 2000	1.50 1.30

2.20	2500	* رخام (Marble) أو حجر بناء صلب	
2.30	2600	* جرانيت (Granite)	
2.30	2600	* بازلت (Basalt)	
0.30	1500	* رمل (Sand)	ركام ناعم وخشن
0.42	1750	* رمل سيل (Wadi Sand) (20-100 mesh)	
0.42	1540	* حصى سيل (Wadi Pebbles) (3-6 mm)	
0.30	1250	* حصى سيل (Wadi Gravel) (10-19 mm)	
1.73	2600	* دولومايت (Dolomite)	
0.85	-	* لابة (صهارة بركانية) (Lava)	
0.09	480	* خفاف (Pumice)	
0.16	400	* الصلصال الممدد (Foamed Clay)	
0.11	560	* خبث الأفران (Blast Furnace Slag)	
0.13	640	* خبث الأفران المدد (Foamed Slag)	
0.14	450	* دياتومايت (Diatomite)	
1.40	1900	* حصى مفكك رطب	تربة
1.40	1800	* رملية مفككة رطبة	
0.70	1300	* رملية مفككة جافة	
1.50	-	* طينية (Clay)	
1.20	-	* رملية طينية (Loam)	
1.16	600	* تربة طينية قابلة للإنتفاخ (Expansive Clay)	

تابع الجدول رقم 5

الموصلية الحرارية (k) (W/m.K)	الكثافة (ρ) (kg/m^3)	المادة	
1.85 1.75 1.48 1.17 0.89 0.68 0.56	2400 2300 2200 2000 1800 1600 1400	* خرسانة إنشائية (ركام عادي، ركام خفيف)	خرسانة
		* خرسانة خفيفة	
0.40 0.30 0.25	1200 1000 800	– خرسانة ركام خفيف أو معالج صناعيا	
0.20 0.16 0.12	600 500 400	– خرسانة رغوية وخلوية معالجة بالبخار	
0.72 0.53	1850 1570	* قصارة اسمنتية	قصارة وملاط
0.48	1440	* قصارة اسمنتية جيرية	
0.46 0.38	1280 1120	* قصارة جبسية	
0.19 0.08	610 400	* قصارة بيرلايتية	
0.30 0.26 0.20 0.14	960 800 640 480	* قصارة فيرميكيولايتية	
0.25	880	* قصارة خرسانة رغوية	
1.40 0.54 0.32	2200 1880 1720	* ملاط (مونة اسمنتية)	
		* طوب خرساني عادي	طوب خرساني
1.20	1900	– مصمت	
1.00 0.90 0.77 0.65	1600 1400 1200 1000	– مفرغ	
0.95	1400	– مفرغ للعقدات	

تابع الجدول 5

تابع الجدول رقم (٥)

المادة		الكثافة (ρ) (kg/m^3)	الموصلية الحرارية (k) (W/m. K)
تابع الطوب الخرساني	* طوب خرسانة خفيفة (ركام خفيف)		
	– مصممت	1600	0.79
		1400	0.64
		1200	0.52
		1000	0.47
	– مفرغ	1600	0.56
		1400	0.49
	– طوب خرسانة خفيفة (خلوية معالجة بالبخار)	780	0.41
		640	0.38
		470	0.33
طوب طيني مشوي	* طوب طيني مشوي للواجهات		
	– مصمت	1900	1.05
	– مثقب	1700	0.79
	* طوب طيني مشوي للبناء		
	– مصمت	1800	0.79
		1400	0.60
		1200	0.52
	– مثقب ومفرغ	1400	0.60
		1200	0.52
		1000	0.47
	– طوب طيني مشوي خفيف	1000	0.47
		800	0.41
		700	0.38
		600	0.35
طوب رملي جيري	* طوب رملي جيري		
	– مصمت	2000	1.10
		1800	0.99
		1600	0.79
	– مثقب	1600	0.79
		1400	0.70

طوب (أنواع أخرى)	* طوب زجاجي مفرغ (سماكة 8 سم) (Hollow Glass)	1100	0.44
	* طــوب رملي راتنجــي (Sand/Epoxy Resin)	2000	1.10

تابع الجدول رقم (٥)

	المادة	الكثافة (ρ) (kg/m^3)	الموصلية الحرارية (k) (W/m.K)
تابع طوب (أنواع أخرى)	* طوب حراري (ناري)		
	– ألومينا		
	(500 ° س)	720	0.29
	(1000 ° س)	720	0.34
	– دياتومايت		
	(500 ° س)	720	0.18
	(1000 ° س)	720	0.21
	(500 ° س)	480	0.13
	(1000 ° س)	480	0.14
	– سيليكي		
	(500 ° س)	1900	1.30
	(1000 ° س)	1900	1.40
	– فيرميكيولايتي		
	(500 ° س)	700	0.26
	(1000 ° س)	700	0.29
بلاط وأرضيات	* بلاط اسمنتي	2100	1.10
	* بلاط تيرازو	2450	1.60
	* بلاط طيني مشوي	1900	0.85
	* بلاط قرميد للأسقف	1800	0.79
	* بلاط سيراميكي	1900	1.05

تابع الجدول رقم (٥)

	المادة	الكثافة (ρ) (kg/m^3)	الموصلية الحرارية (k) (W/m.K)
ألواح زجاج	* ألواح زجاج الشبابيك	2500	1.05
	* ألواح الزجاج المقاوم للحرارة	2250	1.10
	* ألواح الزجاج الصواني (كريستال) (Flint Glass)	3500	0.70
ألواح (أنواع أخرى)	* ألواح دياتومايت	1200	0.23
	* ألواح بيرلايت	800	0.18
	* ألواح مازونايت (Mosonite)	320	0.048
	* ألواح سيليولوزية ورقية (Cellulosic)	600	0.07
	* ألواح نشارة الخشب (Sawdust)	550	0.10
	* ألواح قش (Straw board)	700	0.72
	* ألواح كرتون مقوى (Cardboard)		
	– عادي	-	0.22
	–* مشمّع	710	0.12
	* ألواح ذات خلايا من كرتون (Honeycomb paper board)		
	– غير محشوة	-	0.18
	– محشوة بالفلين	-	0.08
	– محشوة بالفيرميكيولايت	-	0.10

APPENDIX B: QUTATION FOR OCCUPANCY SENSOR – SHARAF ELECTRO COMPANY.

شركة الكترو شرف للصناعات المعدنية وكهربائية م.خ.م

هاتف: ٢٨٤٨٢١٦
جوال: ٠٥٩٩٨٠٢١٢٠

Date: 2/04/2013

QUOTATION REQUEST

OCCUPANCY SENSOR

No	Description	Qty	Price/$	Total Price/$
	Infrared High-Bay Wall-Mount ODWHB-IRW 120 ft, 14 ft wide **Occupancy Sensor with Ambient Light @** 30 ft height Override and Secondary Relay **(White)**	01	L.s	480

Terms and conditions:

1- Warranty on year
2- Excluded VITAE
3- Quotation valid only one month
4- Price in USA Dollars

Electro Sharaf Company

صفحة 1 Electro Sharaf for Metal & Electrical works Tel.0097022848216

Occupancy Sensor Lighting Controls

Leviton's Wall Switch and Ceiling Mounted Occupancy Sensors use passive infrared or ultrasonic sensing technology to provide cost-effective lighting control. Leviton Occupancy Sensors are capable of monitoring conference rooms, classrooms, stairwells, stock rooms, lounges, rest rooms, and outdoor areas.

The Passive Infrared (PIR) units respond to change in the infrared background by turning lights ON when people enter a space being monitored, and OFF when the space is unoccupied. The ultrasonic units transmit ultrasound and monitor for changes in the signal's return time to detect occupancy, turning lights ON when movement is detected, and OFF when the space is unoccupied. By analyzing traffic flow, Leviton Occupancy Sensors can be installed to generate significant lighting cost savings combined with energy efficiency.

OCCUPANCY SENSOR LIGHTING CONTROLS

SECTION P

Commercial Grade

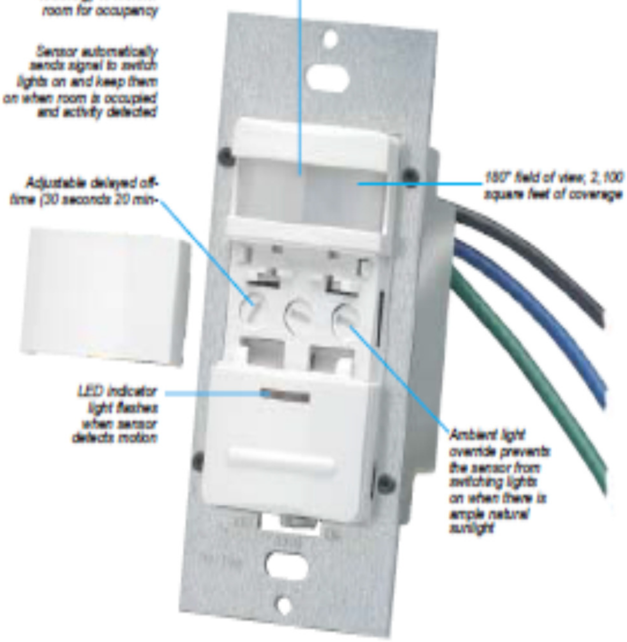
Occupancy Sensor Lighting Controls

LEVITON. Lighting Control Division. Building a Connected World

Leviton provides a variety of space-monitoring Occupancy Sensor Lighting Controls for virtually any room, space, facility, home or office. Wall or ceiling, passive infrared or ultrasonic, end users will benefit from Leviton's Occupancy Sensors as a direct result of their energy efficiency and obvious cost-effectiveness.

Features and Benefits

- 180° field of view, covers approximately 2100 square feet
- Selectable base time-delay interval from 30 seconds to 20 minutes
- Self-adjusting delayed off time interval compensates for real time occupancy patterns, preventing unnecessary on/off switching
- Can be used with incandescent or fluorescent lighting
- Motion-activated; infrared sensing technology turns lights ON when room is occupied and OFF when unoccupied
- Replaces standard switches in existing wallboxes
- Ambient light override keeps lights off when there's plenty of sunlight
- Push-button manual override allows controls to be used like standard ON/OFF switches; manual-ON/Auto-OFF mode
- "Walk-Through" feature shuts off lights after 2 1/2 minutes rather than an extended period
- Compatible with Decora designer-styled devices
- Backed by a Limited Five-Year Warranty



Cat. No. ODS15-IDW

Versatile Occupancy Sensor Lighting Controls for Cost-Effective Energy Savings

Multi-Technology Ceiling-Mount Occupancy Sensor

Combines infrared and ultrasonic technology for highly accurate monitoring. 360°, 2000 sq. ft coverages.

Cat. No. ODC20-M0W

Multi-Technology Wall-Mount Occupancy Sensor

Combines infrared and ultrasonic technology for highly accurate monitoring. 110°, 1200 sq. ft coverage.

Cat. No. ODW12-M0W

Infrared High-Bay Wall-Mount Occupancy Sensor

Ideal for warehouse aisles, hallways, stairways and other long, narrow spaces.

Cat. No. ODWHB-I0W

Self-Contained Ceiling Mount PIR Occupancy Sensor

Contains sensor and switching relay; 360° field of view; adjustable delayed off time of 20 seconds to 15 minutes.

Cat. No. ODC0S-I1W

Dual-Relay Decora Wall Switch Infrared Occupancy Sensor

Controls two separate lighting loads from a single unit. Features self-adjusting technology and choice of Classroom or Conference Room modes for maximum performance.

Cat. No. ODS0D-IDW

Outdoor Motion Sensor

Ideal for commercial/industrial settings, with temperature compensation to ensure performance in all weather conditions.

Cat. No. PS200-10W

P1 To learn more about Leviton's outstanding offering of devices visit our Website at: www.leviton.com ...*Building a Connected World*

Courtesy of Steven Engineering, Inc.-230 Ryan Way, South San Francisco, CA 94080-6370-Main Office: (650) 588-9200-Outside Local Area: (800) 258-9200-www.stevenengineering.com

Commercial Grade

Occupancy Sensor Lighting Controls

LEVITON.

Multi-Technology Wall-Mount Occupancy Sensor (For use with Leviton Power Pack)* *Advanced motion sensors combine infrared and ultrasonic technology for highly accurate monitoring without false triggering. All-digital self-adjusting technology provides "Install and Forget" solution for automatic lighting control*

DESCRIPTION	CAT. NO.	COVERAGE	OPERATING FREQUENCY	COLOR
Multi-Tech Wall-Mount Occupancy Sensor	ODW12-MOW	110°, 1200 sq. ft	32kHz	White
Multi-Tech Wall-Mount Occupancy Sensor with Ambient Light Override and Secondary Relay	ODW12-MRW	110°, 1200 sq. ft	32kHz	White

*Low-voltage wiring is used to connect Leviton Occupancy Sensors to Cat. No. ODP20 Power Pack (purchased separately). See page P11 for Power Pack information.

All devices are CUL/US Certified.

SPECIFICATIONS & FEATURES

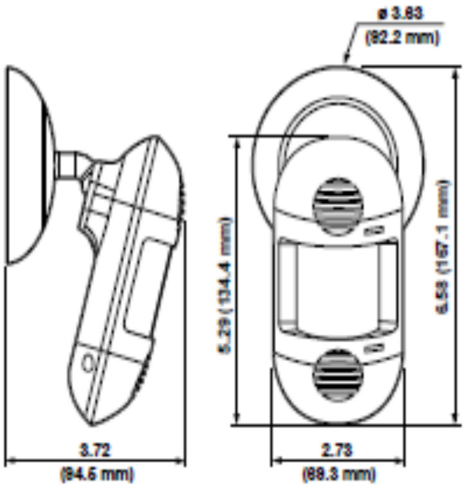
- Ideal for conference rooms, stairwells, high-ceiling rooms, open areas, storage rooms and classrooms. Also ideal for corner mounting in a variety of applications.
- Ultrasonic sensing for maximum sensitivity combined with Passive Infrared (PIR) sensing to prevent false triggering from air conditioning and corridor activity
- Adjustable swivel neck rotates 80° vertically and 60° horizontally— Can be used for ceiling or wall mounting
- Self-adjusting settings continuously analyze and adjust infrared sensitivity, timer operation, and air current compensation for reliable, long-term performance
- Automatic dual-mode operation adjusts to either economy or high-sensitivity mode based on actual occupancy patterns for maximum energy savings
- Built-in Circadian Calendar—Provides 4-week learning period where the sensor monitors occupancy to establish trends that serve as the basis for automatic operation. During peak occupancy periods the sensor remains in high-sensitivity mode and during low occupancy periods it switches to economy mode.
- Manual Delayed-OFF time settings of 4, 8, 16, and 32 minutes, with 8-second test mode
- Self-Adjusting Delayed-OFF time interval settings for 4 to 100 minutes—Compensates for real-time occupancy patterns, preventing unnecessary ON/OFF switching
- Non-volatile memory preserves all automatic and manual settings during power outages
- Fast, simple installation using 3 color-coded low-voltage wires and a single mounting post

Optional Performance Features
(Models with -MRW suffix)

- Ambient light override option prevents lights from turning ON when there is ample natural light
- Secondary Relay—Single-Pole Double-Throw (SPDT), rated 500 mA @ 24V AC/DC, three-wire isolated relay
- Secondary Relay can be used to send control signals to HVAC systems based on occupancy detection

TESTING & CODE COMPLIANCE

- CUL/US Certified



Cat. No. ODW12-M

To learn more about Leviton's outstanding offering of devices visit our Website at: www.leviton.com ...*Building a Connected World*

APPENDIX C: QUTATION FOR 18.2KW VSD AIR CONDITION PACKAGE UNIT.

SHARP

شركة المركز الحديث للإلكترونيات

Modern Electronic Center-MEC

Ref.:MECSD/0ry/2013 **Date: 20 /04/2013**

PROJECT: Islamic university of Gaza (Irada Building)

Dear sir,

Reference to your L.P.O no. 4528, Kindly find attached our best price for supply, install and commission of package unit air conditioning unit as follows:

No.	Specification	QTY	Unit price/NIS	Total Price/NIS	Note
01	Central Air Conditioning unit 18.2 kw,7.2 ton, 87360 BTU, 3 phase, 380/440v without converter	2	54600	109200	
02	Central Air Conditioning unit 18.2 kw,7.2 ton, 87360 BTU, 3 phase, 380/440v with converter, saving energy 50-80%	2	71600	143200	Energy saving around 50-80%

Term and Condition:

- Price in NIS
- Warranty one year
- Price include V.A.T
- Delivery to site

Modern Electronic Center

المركز الحديث للإلكترونيات MEC SHARP Modern Electronic Center المبيعات

فلسطين – غزة – المكتب الرئيسي – شارع الثورة – بناية شارب – هاتف 2849962/3/4 فاكس : 2849968 – ص.ب 5226 – بريد الكتروني: info@mec-pal.com

Palestine-Gaza-Head office-Thawra st. – Tel.2849962/3/4- Fax.2849968-P.O.B5226 –Email:info@mec-pal.com

SHARP

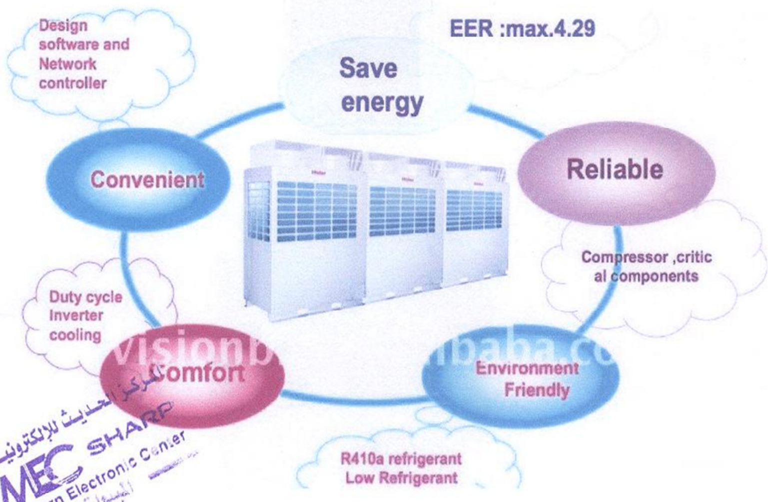
شركة المركز الحديث للإلكترونيات
Modern Electronic Center-MEC

MRV

SERIES (kBTU/h / kW)	7 / 2.2	9 / 2.8	12 / 3.6	16 / 4.5	18 / 5.6	24 / 7.1	28 / 8.0	30 / 9.0	38 / 11.2	48 / 14.0	72 / 22.4	96 / 28
Cassette Type(4-way)		●	●	●	●	●	●	●	●	●		
Vertical Concealed		●		●	●	●						
Floor &Ceiling type		●	●	●	●	●			●	●		
Console type	●	●	●		●							
Ceiling concealed duct type	●	●	●	●	●	●						
Medium static pressure duct type					●	●	●	●	●	●		
High static pressure duct type					●	●	●	●	●	●	●	●
Wall mounted type	●	●	●	●	●	●						

فلسطين – غزة – المكتب الرئيسي - شارع الثورة – بناية شارب - هاتف 2849962/3/4 فاكس : 2849968 - ص. ب 5226 --بريد الكتروني: info@mec-pal.com
Palestine-Gaza-Head office-Thawra st. – Tel.2849962/3/4- Fax.2849968-P.O.B5226 –Email:info@mec-pal.com

Capacity range (HP)																					
8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	
																					
[illegible]																					
Heat pump type (60Hz)																					



فلسطين – غزة – المكتب الرئيسي - شارع الثورة – بناية شارب - هاتف 2849962/3/4 فاكس : 2849968 - ص. ب 5226 --بريد الكتروني: info@mec-pal.com
Palestine-Gaza-Head office-Thawra st. – Tel.2849962/3/4- Fax.2849968-P.O.B5226 –Email:info@mec-pal.com

APPENDIX D: MOTOR EFFICIENCY AND INCREMENTAL COST OF PREMIUM EFFICIENCY MOTOR [57]

Motor Tag	Standard or Premium Efficiency	HP	Speed	Efficiency	Incremental Cost (NWPCC RTF)
Standard Efficiency Motor 1 HP 1200 RPM ODP	Standard Efficiency Motor	1	1200	80	-
Standard Efficiency Motor 1.5 HP 1200 RPM ODP	Standard Efficiency Motor	1.5	1200	84	-
Standard Efficiency Motor 2 HP 1200 RPM ODP	Standard Efficiency Motor	2	1200	85.5	-
Standard Efficiency Motor 3 HP 1200 RPM ODP	Standard Efficiency Motor	3	1200	86.5	-
Standard Efficiency Motor 5 HP 1200 RPM ODP	Standard Efficiency Motor	5	1200	87.5	-
Standard Efficiency Motor 7.5 HP 1200 RPM ODP	Standard Efficiency Motor	7.5	1200	88.5	-
Standard Efficiency Motor 10 HP 1200 RPM ODP	Standard Efficiency Motor	10	1200	90.2	-
Standard Efficiency Motor 15 HP 1200 RPM ODP	Standard Efficiency Motor	15	1200	90.2	-
Standard Efficiency Motor 20 HP 1200 RPM ODP	Standard Efficiency Motor	20	1200	91	-
Standard Efficiency Motor 25 HP 1200 RPM ODP	Standard Efficiency Motor	25	1200	91.7	-
Standard Efficiency Motor 30 HP 1200 RPM ODP	Standard Efficiency Motor	30	1200	92.4	-
Standard Efficiency Motor 40 HP 1200 RPM ODP	Standard Efficiency Motor	40	1200	93	-
Standard Efficiency Motor 50 HP 1200 RPM ODP	Standard Efficiency Motor	50	1200	93	-
Standard Efficiency Motor 60 HP 1200 RPM ODP	Standard Efficiency Motor	60	1200	93.6	-
Standard Efficiency Motor 75 HP 1200 RPM ODP	Standard Efficiency Motor	75	1200	93.6	-
Standard Efficiency Motor 100 HP 1200 RPM ODP	Standard Efficiency Motor	100	1200	94.1	-
Standard Efficiency Motor 125 HP 1200 RPM ODP	Standard Efficiency Motor	125	1200	94.1	-
Standard Efficiency Motor 150 HP 1200 RPM ODP	Standard Efficiency Motor	150	1200	94.5	-
Standard Efficiency Motor 200 HP 1200 RPM ODP	Standard Efficiency Motor	200	1200	94.5	-
Standard Efficiency Motor 1 HP 1800 RPM ODP	Standard Efficiency Motor	1	1800	82.5	-
Standard Efficiency Motor 1.5 HP 1800 RPM ODP	Standard Efficiency Motor	1.5	1800	84	-
Standard Efficiency Motor 2 HP 1800 RPM ODP	Standard Efficiency Motor	2	1800	84	-
Standard Efficiency Motor 3 HP 1800 RPM ODP	Standard Efficiency Motor	3	1800	86.5	-
Standard Efficiency Motor 5 HP 1800 RPM ODP	Standard Efficiency Motor	5	1800	87.5	-
Standard Efficiency Motor 7.5 HP 1800 RPM ODP	Standard Efficiency Motor	7.5	1800	88.5	-
Standard Efficiency Motor 10 HP 1800 RPM ODP	Standard Efficiency Motor	10	1800	89.5	-
Standard Efficiency Motor 15 HP 1800 RPM ODP	Standard Efficiency Motor	15	1800	91	-
Standard Efficiency Motor 20 HP 1800 RPM ODP	Standard Efficiency Motor	20	1800	91	-
Standard Efficiency Motor 25 HP 1800 RPM ODP	Standard Efficiency Motor	25	1800	91.7	-
Standard Efficiency Motor 30 HP 1800 RPM ODP	Standard Efficiency Motor	30	1800	92.4	-
Standard Efficiency Motor 40 HP 1800 RPM ODP	Standard Efficiency Motor	40	1800	93	-
Standard Efficiency Motor 50 HP 1800 RPM ODP	Standard Efficiency Motor	50	1800	93	-
Standard Efficiency Motor 60 HP 1800 RPM ODP	Standard Efficiency Motor	60	1800	93.6	-
Standard Efficiency Motor 75 HP 1800 RPM ODP	Standard Efficiency Motor	75	1800	94.1	-
Standard Efficiency Motor 100 HP 1800 RPM ODP	Standard Efficiency Motor	100	1800	94.1	-
Standard Efficiency Motor 125 HP 1800 RPM ODP	Standard Efficiency Motor	125	1800	94.5	-
Standard Efficiency Motor 150 HP 1800 RPM ODP	Standard Efficiency Motor	150	1800	95	-
Standard Efficiency Motor 200 HP 1800 RPM ODP	Standard Efficiency Motor	200	1800	95	-
Standard Efficiency Motor 1 HP 3600 RPM ODP	Standard Efficiency Motor	1	3600	N/A	-
Standard Efficiency Motor 1.5 HP 3600 RPM ODP	Standard Efficiency Motor	1.5	3600	82.5	-
Standard Efficiency Motor 2 HP 3600 RPM ODP	Standard Efficiency Motor	2	3600	84	-
Standard Efficiency Motor 3 HP 3600 RPM ODP	Standard Efficiency Motor	3	3600	84	-
Standard Efficiency Motor 5 HP 3600 RPM ODP	Standard Efficiency Motor	5	3600	85.5	-
Standard Efficiency Motor 7.5 HP 3600 RPM ODP	Standard Efficiency Motor	7.5	3600	87.5	-
Standard Efficiency Motor 10 HP 3600 RPM ODP	Standard Efficiency Motor	10	3600	88.5	-

Standard Efficiency Motor 15 HP 3600 RPM ODP	Standard Efficiency Motor	15	3600	89.5	-
Standard Efficiency Motor 20 HP 3600 RPM ODP	Standard Efficiency Motor	20	3600	90.2	-
Standard Efficiency Motor 25 HP 3600 RPM ODP	Standard Efficiency Motor	25	3600	91	-
Standard Efficiency Motor 30 HP 3600 RPM ODP	Standard Efficiency Motor	30	3600	91	-
Standard Efficiency Motor 40 HP 3600 RPM ODP	Standard Efficiency Motor	40	3600	91.7	-
Standard Efficiency Motor 50 HP 3600 RPM ODP	Standard Efficiency Motor	50	3600	92.4	-
Standard Efficiency Motor 60 HP 3600 RPM ODP	Standard Efficiency Motor	60	3600	93	-
Standard Efficiency Motor 75 HP 3600 RPM ODP	Standard Efficiency Motor	75	3600	93	-
Standard Efficiency Motor 100 HP 3600 RPM ODP	Standard Efficiency Motor	100	3600	93	-
Standard Efficiency Motor 125 HP 3600 RPM ODP	Standard Efficiency Motor	125	3600	93.6	-
Standard Efficiency Motor 150 HP 3600 RPM ODP	Standard Efficiency Motor	150	3600	93.6	-
Standard Efficiency Motor 200 HP 3600 RPM ODP	Standard Efficiency Motor	200	3600	94.5	-
Standard Efficiency Motor 1 HP 1200 RPM TEFC	Standard Efficiency Motor	1	1200	80	-
Standard Efficiency Motor 1.5 HP 1200 RPM TEFC	Standard Efficiency Motor	1.5	1200	85.5	-
Standard Efficiency Motor 2 HP 1200 RPM TEFC	Standard Efficiency Motor	2	1200	86.5	-
Standard Efficiency Motor 3 HP 1200 RPM TEFC	Standard Efficiency Motor	3	1200	87.5	-
Standard Efficiency Motor 5 HP 1200 RPM TEFC	Standard Efficiency Motor	5	1200	87.5	-
Standard Efficiency Motor 7.5 HP 1200 RPM TEFC	Standard Efficiency Motor	7.5	1200	89.5	-
Standard Efficiency Motor 10 HP 1200 RPM TEFC	Standard Efficiency Motor	10	1200	89.5	-
Standard Efficiency Motor 15 HP 1200 RPM TEFC	Standard Efficiency Motor	15	1200	90.2	-
Standard Efficiency Motor 20 HP 1200 RPM TEFC	Standard Efficiency Motor	20	1200	90.2	-
Standard Efficiency Motor 25 HP 1200 RPM TEFC	Standard Efficiency Motor	25	1200	91.7	-
Standard Efficiency Motor 30 HP 1200 RPM TEFC	Standard Efficiency Motor	30	1200	91.7	-
Standard Efficiency Motor 40 HP 1200 RPM TEFC	Standard Efficiency Motor	40	1200	93	-
Standard Efficiency Motor 50 HP 1200 RPM TEFC	Standard Efficiency Motor	50	1200	93	-
Standard Efficiency Motor 60 HP 1200 RPM TEFC	Standard Efficiency Motor	60	1200	93.6	-
Standard Efficiency Motor 75 HP 1200 RPM TEFC	Standard Efficiency Motor	75	1200	93.6	-
Standard Efficiency Motor 100 HP 1200 RPM TEFC	Standard Efficiency Motor	100	1200	94.1	-
Standard Efficiency Motor 125 HP 1200 RPM TEFC	Standard Efficiency Motor	125	1200	94.1	-
Standard Efficiency Motor 150 HP 1200 RPM TEFC	Standard Efficiency Motor	150	1200	95	-
Standard Efficiency Motor 200 HP 1200 RPM TEFC	Standard Efficiency Motor	200	1200	95	-
Standard Efficiency Motor 1 HP 1800 RPM TEFC	Standard Efficiency Motor	1	1800	82.5	-
Standard Efficiency Motor 1.5 HP 1800 RPM TEFC	Standard Efficiency Motor	1.5	1800	84	-
Standard Efficiency Motor 2 HP 1800 RPM TEFC	Standard Efficiency Motor	2	1800	84	-
Standard Efficiency Motor 3 HP 1800 RPM TEFC	Standard Efficiency Motor	3	1800	87.5	-
Standard Efficiency Motor 5 HP 1800 RPM TEFC	Standard Efficiency Motor	5	1800	87.5	-
Standard Efficiency Motor 7.5 HP 1800 RPM TEFC	Standard Efficiency Motor	7.5	1800	89.5	-
Standard Efficiency Motor 10 HP 1800 RPM TEFC	Standard Efficiency Motor	10	1800	89.5	-
Standard Efficiency Motor 15 HP 1800 RPM TEFC	Standard Efficiency Motor	15	1800	91	-
Standard Efficiency Motor 20 HP 1800 RPM TEFC	Standard Efficiency Motor	20	1800	91	-
Standard Efficiency Motor 25 HP 1800 RPM TEFC	Standard Efficiency Motor	25	1800	92.4	-
Standard Efficiency Motor 30 HP 1800 RPM TEFC	Standard Efficiency Motor	30	1800	92.4	-
Standard Efficiency Motor 40 HP 1800 RPM TEFC	Standard Efficiency Motor	40	1800	93	-
Standard Efficiency Motor 50 HP 1800 RPM TEFC	Standard Efficiency Motor	50	1800	93	-
Standard Efficiency Motor 60 HP 1800 RPM TEFC	Standard Efficiency Motor	60	1800	93.6	-
Standard Efficiency Motor 75 HP 1800 RPM TEFC	Standard Efficiency Motor	75	1800	94.1	-
Standard Efficiency Motor 100 HP 1800 RPM TEFC	Standard Efficiency Motor	100	1800	94.5	-
Standard Efficiency Motor 125 HP 1800 RPM TEFC	Standard Efficiency Motor	125	1800	94.5	-
Standard Efficiency Motor 150 HP 1800 RPM TEFC	Standard Efficiency Motor	150	1800	95	-
Standard Efficiency Motor 200 HP 1800 RPM TEFC	Standard Efficiency Motor	200	1800	95	-
Standard Efficiency Motor 1 HP 3600 RPM TEFC	Standard Efficiency Motor	1	3600	75.5	-
Standard Efficiency Motor 1.5 HP 3600 RPM TEFC	Standard Efficiency Motor	1.5	3600	82.5	-
Standard Efficiency Motor 2 HP 3600 RPM TEFC	Standard Efficiency Motor	2	3600	84	-
Standard Efficiency Motor 3 HP 3600 RPM TEFC	Standard Efficiency Motor	3	3600	85.5	-
Standard Efficiency Motor 5 HP 3600 RPM TEFC	Standard Efficiency Motor	5	3600	87.5	-
Standard Efficiency Motor 7.5 HP 3600 RPM TEFC	Standard Efficiency Motor	7.5	3600	88.5	-
Standard Efficiency Motor 10 HP 3600 RPM TEFC	Standard Efficiency Motor	10	3600	89.5	-

Standard Efficiency Motor 15 HP 3600 RPM TEFC	Standard Efficiency Motor	15	3600	90.2	-
Standard Efficiency Motor 20 HP 3600 RPM TEFC	Standard Efficiency Motor	20	3600	90.2	-
Standard Efficiency Motor 25 HP 3600 RPM TEFC	Standard Efficiency Motor	25	3600	91	-
Standard Efficiency Motor 30 HP 3600 RPM TEFC	Standard Efficiency Motor	30	3600	91	-
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Standard Efficiency Motor 125 HP 3600 RPM TEFC	Standard Efficiency Motor	125	3600	94.5	-
Standard Efficiency Motor 150 HP 3600 RPM TEFC	Standard Efficiency Motor	150	3600	94.5	-
Standard Efficiency Motor 200 HP 3600 RPM TEFC	Standard Efficiency Motor	200	3600	95	-
Premium Efficiency Motor 1 HP 1200 RPM ODP	Premium Efficiency Motor	1	1200	82.5	$52
Premium Efficiency Motor 1.5 HP 1200 RPM ODP	Premium Efficiency Motor	1.5	1200	86.5	$60
Premium Efficiency Motor 2 HP 1200 RPM ODP	Premium Efficiency Motor	2	1200	87.5	$61
Premium Efficiency Motor 3 HP 1200 RPM ODP	Premium Efficiency Motor	3	1200	88.5	$54
Premium Efficiency Motor 5 HP 1200 RPM ODP	Premium Efficiency Motor	5	1200	89.5	$63
Premium Efficiency Motor 7.5 HP 1200 RPM ODP	Premium Efficiency Motor	7.5	1200	90.2	$123
Premium Efficiency Motor 10 HP 1200 RPM ODP	Premium Efficiency Motor	10	1200	91.7	$116
Premium Efficiency Motor 15 HP 1200 RPM ODP	Premium Efficiency Motor	15	1200	91.7	$115
Premium Efficiency Motor 20 HP 1200 RPM ODP	Premium Efficiency Motor	20	1200	92.4	$115
Premium Efficiency Motor 25 HP 1200 RPM ODP	Premium Efficiency Motor	25	1200	93	$201
Premium Efficiency Motor 30 HP 1200 RPM ODP	Premium Efficiency Motor	30	1200	93.6	$231
Premium Efficiency Motor 40 HP 1200 RPM ODP	Premium Efficiency Motor	40	1200	94.1	$249
Premium Efficiency Motor 50 HP 1200 RPM ODP	Premium Efficiency Motor	50	1200	94.1	$273
Premium Efficiency Motor 60 HP 1200 RPM ODP	Premium Efficiency Motor	60	1200	94.5	$431
Premium Efficiency Motor 75 HP 1200 RPM ODP	Premium Efficiency Motor	75	1200	94.5	$554
Premium Efficiency Motor 100 HP 1200 RPM ODP	Premium Efficiency Motor	100	1200	95	$658
Premium Efficiency Motor 125 HP 1200 RPM ODP	Premium Efficiency Motor	125	1200	95	$841
Premium Efficiency Motor 150 HP 1200 RPM ODP	Premium Efficiency Motor	150	1200	95.4	$908
Premium Efficiency Motor 200 HP 1200 RPM ODP	Premium Efficiency Motor	200	1200	95.4	$964
Premium Efficiency Motor 1 HP 1800 RPM ODP	Premium Efficiency Motor	1	1800	85.5	$52
Premium Efficiency Motor 1.5 HP 1800 RPM ODP	Premium Efficiency Motor	1.5	1800	86.5	$60
Premium Efficiency Motor 2 HP 1800 RPM ODP	Premium Efficiency Motor	2	1800	86.5	$61
Premium Efficiency Motor 3 HP 1800 RPM ODP	Premium Efficiency Motor	3	1800	89.5	$54
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Premium Efficiency Motor 150 HP 1800 RPM ODP	Premium Efficiency Motor	150	1800	95.8	$908
Premium Efficiency Motor 200 HP 1800 RPM ODP	Premium Efficiency Motor	200	1800	95.8	$964
Premium Efficiency Motor 1 HP 3600 RPM ODP	Premium Efficiency Motor	1	3600	77	$52
Premium Efficiency Motor 1.5 HP 3600 RPM ODP	Premium Efficiency Motor	1.5	3600	84	$60
Premium Efficiency Motor 2 HP 3600 RPM ODP	Premium Efficiency Motor	2	3600	85.5	$61
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Premium Efficiency Motor 10 HP 3600 RPM ODP	Premium Efficiency Motor	10	3600	89.5	$116

Premium Efficiency Motor 15 HP 3600 RPM ODP	Premium Efficiency Motor	15	3600	90.2	$115
Premium Efficiency Motor 20 HP 3600 RPM ODP	Premium Efficiency Motor	20	3600	91	$115
Premium Efficiency Motor 25 HP 3600 RPM ODP	Premium Efficiency Motor	25	3600	91.7	$201
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Premium Efficiency Motor 150 HP 3600 RPM ODP	Premium Efficiency Motor	150	3600	94.1	$908
Premium Efficiency Motor 200 HP 3600 RPM ODP	Premium Efficiency Motor	200	3600	95	$964
Premium Efficiency Motor 1 HP 1200 RPM TEFC	Premium Efficiency Motor	1	1200	82.5	$52
Premium Efficiency Motor 1.5 HP 1200 RPM TEFC	Premium Efficiency Motor	1.5	1200	87.5	$60
Premium Efficiency Motor 2 HP 1200 RPM TEFC	Premium Efficiency Motor	2	1200	88.5	$61
Premium Efficiency Motor 3 HP 1200 RPM TEFC	Premium Efficiency Motor	3	1200	89.5	$54
Premium Efficiency Motor 5 HP 1200 RPM TEFC	Premium Efficiency Motor	5	1200	89.5	$63
Premium Efficiency Motor 7.5 HP 1200 RPM TEFC	Premium Efficiency Motor	7.5	1200	91	$123
Premium Efficiency Motor 10 HP 1200 RPM TEFC	Premium Efficiency Motor	10	1200	91	$116
Premium Efficiency Motor 15 HP 1200 RPM TEFC	Premium Efficiency Motor	15	1200	91.7	$115
Premium Efficiency Motor 20 HP 1200 RPM TEFC	Premium Efficiency Motor	20	1200	91.7	$115
Premium Efficiency Motor 25 HP 1200 RPM TEFC	Premium Efficiency Motor	25	1200	93	$201
Premium Efficiency Motor 30 HP 1200 RPM TEFC	Premium Efficiency Motor	30	1200	93	$231
Premium Efficiency Motor 40 HP 1200 RPM TEFC	Premium Efficiency Motor	40	1200	94.1	$249
Premium Efficiency Motor 50 HP 1200 RPM TEFC	Premium Efficiency Motor	50	1200	94.1	$273
Premium Efficiency Motor 60 HP 1200 RPM TEFC	Premium Efficiency Motor	60	1200	94.5	$431
Premium Efficiency Motor 75 HP 1200 RPM TEFC	Premium Efficiency Motor	75	1200	94.5	$554
Premium Efficiency Motor 100 HP 1200 RPM TEFC	Premium Efficiency Motor	100	1200	95	$658
Premium Efficiency Motor 125 HP 1200 RPM TEFC	Premium Efficiency Motor	125	1200	95	$841
Premium Efficiency Motor 150 HP 1200 RPM TEFC	Premium Efficiency Motor	150	1200	95.8	$908
Premium Efficiency Motor 200 HP 1200 RPM TEFC	Premium Efficiency Motor	200	1200	95.8	$964
Premium Efficiency Motor 1 HP 1800 RPM TEFC	Premium Efficiency Motor	1	1800	85.5	$52
Premium Efficiency Motor 1.5 HP 1800 RPM TEFC	Premium Efficiency Motor	1.5	1800	86.5	$60
Premium Efficiency Motor 2 HP 1800 RPM TEFC	Premium Efficiency Motor	2	1800	86.5	$61
Premium Efficiency Motor 3 HP 1800 RPM TEFC	Premium Efficiency Motor	3	1800	89.5	$54
Premium Efficiency Motor 5 HP 1800 RPM TEFC	Premium Efficiency Motor	5	1800	89.5	$63
Premium Efficiency Motor 7.5 HP 1800 RPM TEFC	Premium Efficiency Motor	7.5	1800	91.7	$123
Premium Efficiency Motor 10 HP 1800 RPM TEFC	Premium Efficiency Motor	10	1800	91.7	$116
Premium Efficiency Motor 15 HP 1800 RPM TEFC	Premium Efficiency Motor	15	1800	92.4	$115
Premium Efficiency Motor 20 HP 1800 RPM TEFC	Premium Efficiency Motor	20	1800	93	$115
Premium Efficiency Motor 25 HP 1800 RPM TEFC	Premium Efficiency Motor	25	1800	93.6	$201
Premium Efficiency Motor 30 HP 1800 RPM TEFC	Premium Efficiency Motor	30	1800	93.6	$231
Premium Efficiency Motor 40 HP 1800 RPM TEFC	Premium Efficiency Motor	40	1800	94.1	$249
Premium Efficiency Motor 50 HP 1800 RPM TEFC	Premium Efficiency Motor	50	1800	94.5	$273
Premium Efficiency Motor 60 HP 1800 RPM TEFC	Premium Efficiency Motor	60	1800	95	$431
Premium Efficiency Motor 75 HP 1800 RPM TEFC	Premium Efficiency Motor	75	1800	95.4	$554
Premium Efficiency Motor 100 HP 1800 RPM TEFC	Premium Efficiency Motor	100	1800	95.4	$658
Premium Efficiency Motor 125 HP 1800 RPM TEFC	Premium Efficiency Motor	125	1800	95.4	$841
Premium Efficiency Motor 150 HP 1800 RPM TEFC	Premium Efficiency Motor	150	1800	95.8	$908
Premium Efficiency Motor 200 HP 1800 RPM TEFC	Premium Efficiency Motor	200	1800	96.2	$964
Premium Efficiency Motor 1 HP 3600 RPM TEFC	Premium Efficiency Motor	1	3600	77	$52
Premium Efficiency Motor 1.5 HP 3600 RPM TEFC	Premium Efficiency Motor	1.5	3600	84	$60
Premium Efficiency Motor 2 HP 3600 RPM TEFC	Premium Efficiency Motor	2	3600	85.5	$61
Premium Efficiency Motor 3 HP 3600 RPM TEFC	Premium Efficiency Motor	3	3600	86.5	$54
Premium Efficiency Motor 5 HP 3600 RPM TEFC	Premium Efficiency Motor	5	3600	88.5	$63
Premium Efficiency Motor 7.5 HP 3600 RPM TEFC	Premium Efficiency Motor	7.5	3600	89.5	$123
Premium Efficiency Motor 10 HP 3600 RPM TEFC	Premium Efficiency Motor	10	3600	90.2	$116

Premium Efficiency Motor 15 HP 3600 RPM TEFC	Premium Efficiency Motor	15	3600	91	$115
Premium Efficiency Motor 20 HP 3600 RPM TEFC	Premium Efficiency Motor	20	3600	91	$115
Premium Efficiency Motor 25 HP 3600 RPM TEFC	Premium Efficiency Motor	25	3600	91.7	$201
Premium Efficiency Motor 30 HP 3600 RPM TEFC	Premium Efficiency Motor	30	3600	91.7	$231
Premium Efficiency Motor 40 HP 3600 RPM TEFC	Premium Efficiency Motor	40	3600	92.4	$249
Premium Efficiency Motor 50 HP 3600 RPM TEFC	Premium Efficiency Motor	50	3600	93	$273
Premium Efficiency Motor 60 HP 3600 RPM TEFC	Premium Efficiency Motor	60	3600	93.6	$431
Premium Efficiency Motor 75 HP 3600 RPM TEFC	Premium Efficiency Motor	75	3600	93.6	$554
Premium Efficiency Motor 100 HP 3600 RPM TEFC	Premium Efficiency Motor	100	3600	94.1	$658
Premium Efficiency Motor 125 HP 3600 RPM TEFC	Premium Efficiency Motor	125	3600	95	$841
Premium Efficiency Motor 150 HP 3600 RPM TEFC	Premium Efficiency Motor	150	3600	95	$908
Premium Efficiency Motor 200 HP 3600 RPM TEFC	Premium Efficiency Motor	200	3600	95.4	$964

APPENDIX E: POWER FACTOR MEASUREMENT IN IRADA

No.	V1	V2	V3	V_avg	I_avg	P	Q	S	PF	F
01	231	228	219	226.0	97.5	36500	37505	55980	0.87	49.9
02	227	213	225	221.6	98.3	36800	38608	55463	0.86	49.8
03	225	218	224	222.3	74.2	19806	23507	21456	0.75	49.9
04	222	217	216	218.3	83.5	23055	26018	24659	0.74	49.9
05	215	215	208	212.6	59.6	16320	19305	17986	0.63	49.9
06	210	211	209	210.0	68.0	19716	22708	20145	0.78	49.8
07	209	209	219	212.3	77.0	22290	26548	23569	0.85	49.7
08	219	231	220	223.3	85.0	25004	29860	26897	0.85	49.7
09	223	230	211	221.3	68.5	19900	22653	20135	0.82	49.9
10	225	231	215	223.6	93.2	31016	35100	33569	0.84	49.9
11	228	208	214	216.6	74.8	19890	22650	20135	0.78	49.9
12	226	214	216	218.6	55.2	15300	17402	16853	0.77	49.8
13	225	213	218	218.6	52.1	14000	16998	15369	0.69	50.0
14	209	220	219	216.0	48.3	13250	14990	13569	0.67	50.0
15	208	220	214	214.0	44.2	12697	11150	11698	0.90	50.0
16	206	215	215	212.6	67.5	18745	21638	20135	0.74	49.9
17	226	217	216	219.6	92.3	30012	32015	31247	0.86	49.9
18	229	218	231	226.0	78.4	22310	24890	23415	0.84	49.8
19	227	219	230	225.3	72.1	21314	23144	22143	0.82	49.8
20	215	216	223	218.0	88.5	27452	28963	27963	0.87	49.8
21	214	217	232	221.0	92.8	30785	34569	32548	0.79	49.9
22	209	207	217	211.0	93.2	31016	34998	32654	0.70	49.9
23	208	211	214	211.0	76.5	21305	23687	22147	0.80	49.9
24	220	210	219	216.3	55.5	15603	15690	15698	0.89	49.9
25	221	218	220	219.3	45.3	13012	14150	13987	0.88	49.8
26	222	216	222	220.0	82.1	22401	24569	23145	0.84	49.8
27	218	223	223	221.3	54.2	15108	16534	15987	0.87	49.8
28	213	225	221	219.6	77.1	22550	25014	23698	0.79	49.9
29	229	226	224	226.3	66.5	17417	20478	18745	0.78	50.0
30	230	215	218	221.0	52.1	14000	17489	15986	0.80	.50.0
31	231	214	226	223.6	53.9	14608	17855	15478	0.82	49.9
32	231	218	218	222.3	72.3	21516	23547	22130	0.86	49.9
33	231	217	219	222.3	71.1	20409	23114	21456	0.84	50.0
34	224	230	215	223.0	55.3	15204	17458	16354	0.81	49.9
35	226	230	214	223.3	92.5	29870	29150	29658	0.90	49.9
36	229	231	216	225.3	55.7	15870	16700	16125	0.87	50.0
37	215	226	213	218.0	35.3	9816	10532	10160	0.87	49.9
38	214	227	230	223.6	32.5	8015	10325	9631	0.75	50.0
39	208	228	231	222.3	96.2	33561	40596	36547	0.76	49.8
40	209	224	229	220.6	33.5	8060	12530	9986	0.72	49.8
41	211	219	224	218.0	59.7	16709	20145	18746	0.72	49.8
42	220	219	225	221.3	54.2	14760	17569	15896	0.83	50.0
43	221	217	216	218.0	88.2	28546	30156	29746	0.84	49.9

44	222	214	218	218.0	87.5	27690	30125	28631	0.82	49.9
45	226	215	214	218.3	84.2	25478	28569	27486	0.83	49.9
46	227	213	218	219.3	65.6	16809	16932	16859	0.89	49.9
47	227	209	217	217.6	81.9	23980	24578	24231	0.87	49.7
48	223	210	215	216.0	67.9	18002	19687	18803	0.85	49.8
49	223	211	230	221.3	64.8	15900	16547	16249	0.84	49.9
50	219	225	231	225.0	70.8	19876	22987	21354	0.83	49.9

APPENDIX F: QUTATION FOR AAPF – SHARAF ELECTRO COMPANY

شركة الكترو شرف للصناعات المعدنية وكهربائية م.خ.م

هاتف: ٢٨٤٨٢١٦
جوال: ٠٥٩٩٨٠٢٢٢٠

التاريخ ٢٥-٤-٢٠١٣

عرض سعر للوحة مكثفات 35 Kvar

#	الصنف	الوحدة	الكمية	سعر الوحدة/شيكل	الاجمالي/شيكل	ملاحظات
١	توريد وتركيب وتشغيل لوحة مكثفات 35 Kvar داخل طابلون حديد بسمك ٢مم وحجم ١٥٠x١٠٠x٥٠					
٢	مكثف 5 Kvar	عدد	٢	٣٠٠	٦٠٠	
٣	مكثف 7.5 Kvar	عدد	٢	٤٠٠	٨٠٠	
٤	مكثف ١٠ Kvar	عدد	١	٧٠٠	٧٠٠	
٥	Contactor 10 ka with discharging resistor (Moller)	عدد	٢	١٠٠	٢٠٠	
٦	Contactor 1٦ ka with discharging resistor (Moller)	عدد	٢	١٥٠	٣٠٠	
٧	Contactor 20 ka with discharging resistor (Moller)	عدد	١	١٥٠	١٥٠	
٨	Controller Levata- Italy	عدد	١	٦٠٠	٦٠٠	
٩	63ATP MCCB	عدد	١	٤٥٠	٤٥٠	
	اجمالي السعر				٣٨٠٠	

الشروط

١- الاسعار بالشيكل
٢- الاسعار تشمل ضريبة القيمة المضافة
٣- العرض ساري لمدة شهر من تاريخة
٤- السعر شامل توريد وتركيب
٥- اللوحة مكفولة لمدة عام

وتفضلوا بقبول فائق الاحترام والتقدير

شركة الكترو شرف

صفحة 1 | Electro Sharaf for Metal & Electrical works Tel.009702848216

APPENDIX G: INTEREST FACTOR TABEL [62]

10% TABLE 15 Discrete Cash Flow: Compound Interest Factors 10%

	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	1.1000	0.9091	1.00000	1.0000	1.10000	0.9091		
2	1.2100	0.8264	0.47619	2.1000	0.57619	1.7355	0.8264	0.4762
3	1.3310	0.7513	0.30211	3.3100	0.40211	2.4869	2.3291	0.9366
4	1.4641	0.6830	0.21547	4.6410	0.31547	3.1699	4.3781	1.3812
5	1.6105	0.6209	0.16380	6.1051	0.26380	3.7908	6.8618	1.8101
6	1.7716	0.5645	0.12961	7.7156	0.22961	4.3553	9.6842	2.2236
7	1.9487	0.5132	0.10541	9.4872	0.20541	4.8684	12.7631	2.6216
8	2.1436	0.4665	0.08744	11.4359	0.18744	5.3349	16.0287	3.0045
9	2.3579	0.4241	0.07364	13.5795	0.17364	5.7590	19.4215	3.3724
10	2.5937	0.3855	0.06275	15.9374	0.16275	6.1446	22.8913	3.7255
11	2.8531	0.3505	0.05396	18.5312	0.15396	6.4951	26.3963	4.0641
12	3.1384	0.3186	0.04676	21.3843	0.14676	6.8137	29.9012	4.3884
13	3.4523	0.2897	0.04078	24.5227	0.14078	7.1034	33.3772	4.6988
14	3.7975	0.2633	0.03575	27.9750	0.13575	7.3667	36.8005	4.9955
15	4.1772	0.2394	0.03147	31.7725	0.13147	7.6061	40.1520	5.2789
16	4.5950	0.2176	0.02782	35.9497	0.12782	7.8237	43.4164	5.5493
17	5.0545	0.1978	0.02466	40.5447	0.12466	8.0216	46.5819	5.8071
18	5.5599	0.1799	0.02193	45.5992	0.12193	8.2014	49.6395	6.0526
19	6.1159	0.1635	0.01955	51.1591	0.11955	8.3649	52.5827	6.2861
20	6.7275	0.1486	0.01746	57.2750	0.11746	8.5136	55.4069	6.5081
21	7.4002	0.1351	0.01562	64.0025	0.11562	8.6487	58.1095	6.7189
22	8.1403	0.1228	0.01401	71.4027	0.11401	8.7715	60.6893	6.9189
23	8.9543	0.1117	0.01257	79.5430	0.11257	8.8832	63.1462	7.1085
24	9.8497	0.1015	0.01130	88.4973	0.11130	8.9847	65.4813	7.2881
25	10.8347	0.0923	0.01017	98.3471	0.11017	9.0770	67.6964	7.4580
26	11.9182	0.0839	0.00916	109.1818	0.10916	9.1609	69.7940	7.6186
27	13.1100	0.0763	0.00826	121.0999	0.10826	9.2372	71.7773	7.7704
28	14.4210	0.0693	0.00745	134.2099	0.10745	9.3066	73.6495	7.9137
29	15.8631	0.0630	0.00673	148.6309	0.10673	9.3696	75.4146	8.0489
30	17.4494	0.0573	0.00608	164.4940	0.10608	9.4269	77.0766	8.1762
31	19.1943	0.0521	0.00550	181.9434	0.10550	9.4790	78.6395	8.2962
32	21.1138	0.0474	0.00497	201.1378	0.10497	9.5264	80.1078	8.4091
33	23.2252	0.0431	0.00450	222.2515	0.10450	9.5694	81.4856	8.5152
34	25.5477	0.0391	0.00407	245.4767	0.10407	9.6086	82.7773	8.6149
35	28.1024	0.0356	0.00369	271.0244	0.10369	9.6442	83.9872	8.7086
40	45.2593	0.0221	0.00226	442.5926	0.10226	9.7791	88.9525	9.0962
45	72.8905	0.0137	0.00139	718.9048	0.10139	9.8628	92.4544	9.3740
50	117.3909	0.0085	0.00086	1163.91	0.10086	9.9148	94.8889	9.5704
55	189.0591	0.0053	0.00053	1880.59	0.10053	9.9471	96.5619	9.7075
60	304.4816	0.0033	0.00033	3034.82	0.10033	9.9672	97.7010	9.8023
65	490.3707	0.0020	0.00020	4893.71	0.10020	9.9796	98.4705	9.8672
70	789.7470	0.0013	0.00013	7887.47	0.10013	9.9873	98.9870	9.9113
75	1271.90	0.0008	0.00008	12709	0.10008	9.9921	99.3317	9.9410
80	2048.40	0.0005	0.00005	20474	0.10005	9.9951	99.5606	9.9609
85	3298.97	0.0003	0.00003	32980	0.10003	9.9970	99.7120	9.9742
90	5313.02	0.0002	0.00002	53120	0.10002	9.9981	99.8118	9.9831
95	8556.68	0.0001	0.00001	85557	0.10001	9.9988	99.8773	9.9889
96	9412.34	0.0001	0.00001	94113	0.10001	9.9989	99.8874	9.9898
98	11389	0.0001	0.00001		0.10001	9.9991	99.9052	9.9914
100	13781	0.0001	0.00001		0.10001	9.9993	99.9202	9.9927

12% TABLE 17 Discrete Cash Flow: Compound Interest Factors 12%

	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	1.1200	0.8929	1.00000	1.0000	1.12000	0.8929		
2	1.2544	0.7972	0.47170	2.1200	0.59170	1.6901	0.7972	0.4717
3	1.4049	0.7118	0.29635	3.3744	0.41635	2.4018	2.2208	0.9246
4	1.5735	0.6355	0.20923	4.7793	0.32923	3.0373	4.1273	1.3589
5	1.7623	0.5674	0.15741	6.3528	0.27741	3.6048	6.3970	1.7746
6	1.9738	0.5066	0.12323	8.1152	0.24323	4.1114	8.9302	2.1720
7	2.2107	0.4523	0.09912	10.0890	0.21912	4.5638	11.6443	2.5512
8	2.4760	0.4039	0.08130	12.2997	0.20130	4.9676	14.4714	2.9131
9	2.7731	0.3606	0.06768	14.7757	0.18768	5.3282	17.3563	3.2574
10	3.1058	0.3220	0.05698	17.5487	0.17698	5.6502	20.2541	3.5847
11	3.4785	0.2875	0.04842	20.6546	0.16842	5.9377	23.1288	3.8953
12	3.8960	0.2567	0.04144	24.1331	0.16144	6.1944	25.9523	4.1897
13	4.3635	0.2292	0.03568	28.0291	0.15568	6.4235	28.7024	4.4683
14	4.8871	0.2046	0.03087	32.3926	0.15087	6.6282	31.3624	4.7317
15	5.4736	0.1827	0.02682	37.2797	0.14682	6.8109	33.9202	4.9803
16	6.1304	0.1631	0.02339	42.7533	0.14339	6.9740	36.3670	5.2147
17	6.8660	0.1456	0.02046	48.8837	0.14046	7.1196	38.6973	5.4353
18	7.6900	0.1300	0.01794	55.7497	0.13794	7.2497	40.9080	5.6427
19	8.6128	0.1161	0.01576	63.4397	0.13576	7.3658	42.9979	5.8375
20	9.6463	0.1037	0.01388	72.0524	0.13388	7.4694	44.9676	6.0202
21	10.8038	0.0926	0.01224	81.6987	0.13224	7.5620	46.8188	6.1913
22	12.1003	0.0826	0.01081	92.5026	0.13081	7.6446	48.5543	6.3514
23	13.5523	0.0738	0.00956	104.6029	0.12956	7.7184	50.1776	6.5010
24	15.1786	0.0659	0.00846	118.1552	0.12846	7.7843	51.6929	6.6406
25	17.0001	0.0588	0.00750	133.3339	0.12750	7.8431	53.1046	6.7708
26	19.0401	0.0525	0.00665	150.3339	0.12665	7.8957	54.4177	6.8921
27	21.3249	0.0469	0.00590	169.3740	0.12590	7.9426	55.6369	7.0049
28	23.8839	0.0419	0.00524	190.6989	0.12524	7.9844	56.7674	7.1098
29	26.7499	0.0374	0.00466	214.5828	0.12466	8.0218	57.8141	7.2071
30	29.9599	0.0334	0.00414	241.3327	0.12414	8.0552	58.7821	7.2974
31	33.5551	0.0298	0.00369	271.2926	0.12369	8.0850	59.6761	7.3811
32	37.5817	0.0266	0.00328	304.8477	0.12328	8.1116	60.5010	7.4586
33	42.0915	0.0238	0.00292	342.4294	0.12292	8.1354	61.2612	7.5302
34	47.1425	0.0212	0.00260	384.5210	0.12260	8.1566	61.9612	7.5965
35	52.7996	0.0189	0.00232	431.6635	0.12232	8.1755	62.6052	7.6577
40	93.0510	0.0107	0.00130	767.0914	0.12130	8.2438	65.1159	7.8988
45	163.9876	0.0061	0.0074	1358.23	0.12074	8.2825	66.7342	8.0572
50	289.0022	0.0035	0.00042	2400.02	0.12042	8.3045	67.7624	8.1597
55	509.3206	0.0020	0.00024	4236.01	0.12024	8.3170	68.4082	8.2251
60	897.5969	0.0011	0.00013	7471.64	0.12013	8.3240	68.8100	8.2664
65	1581.87	0.0006	0.00008	13174	0.12008	8.3281	69.0581	8.2922
70	2787.80	0.0004	0.00004	23223	0.12004	8.3303	69.2103	8.3082
75	4913.06	0.0002	0.00002	40934	0.12002	8.3316	69.3031	8.3181
80	8658.48	0.0001	0.00001	72146	0.12001	8.3324	69.3594	8.3241
85	15259	0.0001	0.00001		0.12001	8.3328	69.3935	8.3278

20% TABLE 22 Discrete Cash Flow: Compound Interest Factors 20%

	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	1.2000	0.8333	1.00000	1.0000	1.20000	0.8333		
2	1.4400	0.6944	0.45455	2.2000	0.65455	1.5278	0.6944	0.4545
3	1.7280	0.5787	0.27473	3.6400	0.47473	2.1065	1.8519	0.8791
4	2.0736	0.4823	0.18629	5.3680	0.38629	2.5887	3.2986	1.2742
5	2.4883	0.4019	0.13438	7.4416	0.33438	2.9906	4.9061	1.6405
6	2.9860	0.3349	0.10071	9.9299	0.30071	3.3255	6.5806	1.9788
7	3.5832	0.2791	0.07742	12.9159	0.27742	3.6046	8.2551	2.2902
8	4.2998	0.2326	0.06061	16.4991	0.26061	3.8372	9.8831	2.5756
9	5.1598	0.1938	0.04808	20.7989	0.24808	4.0310	11.4335	2.8364
10	6.1917	0.1615	0.03852	25.9587	0.23852	4.1925	12.8871	3.0739
11	7.4301	0.1346	0.03110	32.1504	0.23110	4.3271	14.2330	3.2893
12	8.9161	0.1122	0.02526	39.5805	0.22526	4.4392	15.4667	3.4841
13	10.6993	0.0935	0.02062	48.4966	0.22062	4.5327	16.5883	3.6597
14	12.8392	0.0779	0.01689	59.1959	0.21689	4.6106	17.6008	3.8175
15	15.4070	0.0649	0.01388	72.0351	0.21388	4.6755	18.5095	3.9588
16	18.4884	0.0541	0.01144	87.4421	0.21144	4.7296	19.3208	4.0851
17	22.1861	0.0451	0.00944	105.9306	0.20944	4.7746	20.0419	4.1976
18	26.6233	0.0376	0.00781	128.1167	0.20781	4.8122	20.6805	4.2975
19	31.9480	0.0313	0.00646	154.7400	0.20646	4.8435	21.2439	4.3861
20	38.3376	0.0261	0.00536	186.6880	0.20536	4.8696	21.7395	4.4643
22	55.2061	0.0181	0.00369	271.0307	0.20369	4.9094	22.5546	4.5941
24	79.4968	0.0126	0.00255	392.4842	0.20255	4.9371	23.1760	4.6943
26	114.4755	0.0087	0.00176	567.3773	0.20176	4.9563	23.6460	4.7709
28	164.8447	0.0061	0.00122	819.2233	0.20122	4.9697	23.9991	4.8291
30	237.3763	0.0042	0.00085	1181.88	0.20085	4.9789	24.2628	4.8731
32	341.8219	0.0029	0.00059	1704.11	0.20059	4.9854	24.4588	4.9061
34	492.2235	0.0020	0.00041	2456.12	0.20041	4.9898	24.6038	4.9308
35	590.6682	0.0017	0.00034	2948.34	0.20034	4.9915	24.6614	4.9406
36	708.8019	0.0014	0.00028	3539.01	0.20028	4.9929	24.7108	4.9491
38	1020.67	0.0010	0.00020	5098.37	0.20020	4.9951	24.7894	4.9627
40	1469.77	0.0007	0.00014	7343.86	0.20014	4.9966	24.8469	4.9728
45	3657.26	0.0003	0.00005	18281	0.20005	4.9986	24.9316	4.9877
50	9100.44	0.0001	0.00002	45497	0.20002	4.9995	24.9698	4.9945
55	22645		0.00001		0.20001	4.9998	24.9868	4.9976

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