Grid electricity

Demand Reduction through Applying Passive and Active Strategies for a House in Baghdad, Iraq

تقليل استخدام الطاقة من الشبكة الكهربائية من خلال استخدام استراتيجيات سلبية وايجابية لتصاميم المباني لبيت في بغداد- العراق

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Abstract

Over the last decade, electricity conservation has been at the core of global attention as every aspect of modern life depends on electrical energy. More so, all new and improved technologies are accompanied by the rapid growth in the economy and population which has led to an increase in the demand for electricity. Consequently, these factors could influence humanity, the environment and cause energy resource depletion. Therefore, the principles of sustainability have been required to reduce this negative impact on our natural environment and on mankind.

This research aims at exploring the impact of incorporating passive and active strategies on electricity demand reduction in a typical household in Baghdad. According to the Ministry of Electricity, Iraq generates only 8,000 megawatts, while currently, the required power consumption is rising to between 13-15,000 megawatts. For more than 20 years, the Iraqi people have suffered due to the lack of electrical supply.

The motive was to reduce the dependency of the national electricity grid that is not reliable and suffers frequent daily interruptions. Simulation methodology was used to carry out this study in accordance with the flexibility to achieve energy usage, calculate, and evaluate the power consumption and energy saving. The study covered the following strategies: shading devices, insulation materials, and glazing as passive strategies while the coefficient performance of air-conditioning systems, solar domestic hot water, and photovoltaic panels were examined as active strategies.

IES-VE software was used to analyze the performance of each passive and active strategy and their impression on energy consumption. The study covered different scenarios to estimate the optimal case for each parameter to highlight their effects on preserving energy. The results collected from all the running simulations were categorized according to each parameter. The outcome of using passive strategies shows that the most affected parameter is the roof insulation (1 Pearl and 2 Pearls) which achieved the maximum reduction among other passive scenarios. By adopting 1Pearl, it provided 4.33% energy reduction while 2 Pearls can achieve about 4.37% decrease in energy. This means that roof insulation should take priority when considering the passive solutions for conserving energy. The second effect factor is wall insulation which can achieve a 3.75 - 3.82% savings for 1 Pearl and 2 Pearls.

Meanwhile, the glazing system has a much lower reduction of about 1.2-1.4% energy saving for 1 Pearl and 2 Pearls. The results of adopting a glazing system could vary from one project to another in relation to the ratio of openings to walls. However, it was found that by using a shading device scenario, the minimum impact on energy consumption through saving is about 0.29-0.11% depending on location, and the size of the shading elements. Overall, the passive strategies combined using 1 Pearl representing the economic case can achieve 8.3% energy demand reduction while the efficient cause which adopts two Pearls has little improvement in achieving an 8.6% energy reduction. There is little benefit when moving from a 1 Pearl to a 2 Pearl refurbishment level. Thus by using 1 Pearl it was evaluated to be a more practical and economical option.

While increasing the coefficient performance of an air-conditioning system, energy consumption can be reduced by 8.5%. The research found that the use of Solar DHW is not worth comparing with the lack of PV energy production that is caused especially in hot climates. The little improvement of the boiler load reduction will not compensate the shortage of PV output power which leads to an increase in the total electricity demand. The simulations approved that Monocrystalline is the most efficient type of PV cells which generate approximately 52.64 MWh. While the use of Polycrystalline Silicon produce 44.54 MWh, Thin Film production is 29.65 MWh and Amorphous Silicon produces only 21.91 MWh. In other words, the use of Polycrystalline compared to Monocrystalline Silicon output power considering that all the types of cells have the same dimensions, tilted and azimuth angles.

The integration of passive and active strategies can achieve a decrease of 50.6% in the need of electricity consumption. The production time of the PV should be observed to find out if it corresponds with the demand time or needs to be stored either in a battery or connected to the main grid. Ultimately, whatever the impact of each strategy, these could contribute to enhanced energy performance. The study concluded that the integration of passive and active strategies can reduce the demand for electricity in an average home in Baghdad.

ملخص

على مدى العقد الماضي اصبحت الطاقة الكهربائية محور الاهتمام بعد ان باتت كل جوانب الحياة العصرية تعتمد اعتمادا كلياعلي توفر الطاقة الكهربائية . التطور التكنولوجي والنمو السريع في الاقتصاد وتعداد السكان شكلت عوامل مهمهة لزيادة الطلب على الطاقة الكهربائية. كل هذه العوامل مجمتمعة تؤثر على البيئة والبشرية وتسبب نضوب موارد الطاقة الرئيسة.كنيتجة لكل هذه الاسباب ظهرت الحاجة الماسة لضرورة تبني مبدأ الاستدامة للحد من التاثيرات السلبية على البيئة والبشرية وللحفاظ على موارد الطاقة.

هذا البحث يهدف الى تقصي واستكشاف اثر دمج استخدام الاستيراجيات السلبية واوالايجابية للحد من استخدام الطاقة الكهربائية في بيت نموذجي في بغداد .وفقا لوزراة الكهرباء العراقية قدرة توليد الطاقة 8,000 ميغاواط في حين معدل الطاقة المطلوبة والذي مستمر في الارتفاغ هو 15,000 -13 ميغاواط. لأكثر من 20 عاما الشعب العراقي يعاني من نقص الطاقة الكهربائية .

الدافع الرئيسي لهذه الدراسة هو تقليل الاعتماد على شبكة الكهرباء الوطنية التي تعاني نقص في توليد الطاقة بشكل عام و من انقطاعات يومية متكررة. لقد تم استخدام منهجية المحاكاة لتنفيذ هذه الدراسة وفقا لمرونة حساب استهلاك الطاقة وتوفيرها.لقد شملت الدراسة اضافة الاستراجيات السلبية التالية:اضافة عناصر التضليل الخارجي ,اضافة عوازل البناء في السقف والجدران, استخدام انواع زجاج ذات معامل اداء مرتفع. بينما الاستراجيات النشطة تتضمن : استخدام اجهز تكييف ذات كفاءة تشغيل عالية,اضافة سخانات المياه الشمسية و اضافة الخلايا الضوئية لتوليد الطاقة الكهربائية

تم استخدام برنامج IES -VE لتحليل اداء كل الاستراجيات وتقييم مدى تأثيرها على معدل استهلاك الطاقة. لقد تضمنت الدراسة تقييم استخدام سيناريوهات مختلفية لتقييم الحالة الامثل لكل متغير من اجل معرفة مدى جدواها في التقليل من استخدام الطاقة. نتائج الدراسة تبين ان اضافة العوازل في الاسقف تعد من اهم عوامل تقليل استخدام الطاقة والتي تحقق الحد من احمال التبريد . العوازل في الاسقف حققت تقليل بالطاقة بنسبة %4.37- % 4.33 حسب استخدام نوع العازل. هذة النتائج يصنف العزل في الاسقف كأهم معامل من الاستراجيات السلبية التي تؤثر في تخفيض الطاقة وحفظها. استخدام العوازل في الجدران يحتل المرتبة الثانية في التأثير على تقليل استخادام الطاقة والذي ممكن ان يحقق %3.82- 3.75 تقليل استخدام الطاقة. في نفس الوقت استخدام زجاج مع معامل اداء عالي لم يحقق اكثر من% 1.4-1.2 توفيرا في الطاقة واستخدام هذه الاستراتيجية تخلتف نتائجها من مبنى لاخر وعلى نسبة الشبابيك والجدران في المبنى. اضافة التضليل الخارجي لم يحقق الكثير من تقليل الطاقة والذي لم يتعدى اكثر من % 0.29-0.11 وهذه النسبة متغيرة حسب موقع وابعاد عناصر التضليل. على العموم استخدام جميع الاستراجيات السلبية المقترحة في الدراسة قد حقق تخفيض بالطاقة يترواح بين % 8.3 عند اعتماد 1Pearl و8.6% عند استخدام 2Pearls ولقد وجد ان الاختلاف بين الحالتين طفيف مما يرجح استخدام 1Pearl الذي يكون اقتصادي وعملي بينما 2Pearls يعد من الخيارات الاكثر كفاءة في تحسين اداء الطاقة في المبنى.اول الاستراتيجيات النشطة المستخدمة هو تغير معامل كفاءة اجهزة التبريد (COP) من 2.5 الى 3.5 والذي حقق تخفيض للطاقة بنسبة % 8.5 وهذه النسبة تعبر مساوية للنسبة المؤية لتخفيض الطاقة الناتجة من استخدام كل الاستراتيجات السلبية مع بعض.ان استخدام تسخين المياه الشمسي SDHW لايحقق فائدة كبيرة مقارنة مع النقص في الطاقة الكهربائية المنتجة من

الخلايا الكهروضوئية PV (وذلك لان المساحة المطلوبة للخلايا الكهروضوية ستستخدم لنصب اجهزة السخان الشمسي) . هذه النتيجة تأتي حتمية لانه في البلدان ذات الجو الحار استخدام سخانات المياه يكون محدود بينما الحاجة للطاقة الكهربائية يكون أهم بكثير.

اثبتت الدراسة ان Monocrystalline هي النوع الاكثر كفاءة من الخلايا الكهروضوئية والتي انتجت ما يقارب 52.64 MWh. بينما استخدام Polycrystalline حقق 54. 44 MWh Thin Film , انتجت 29.65 MWh واخيرا Amorphous Silicon انتجت 21.91 MWh علما ان كل الخلايا الضوئية كانت ذات تمتتع بنفس الصفات من قياسات واتجاهات.

بشكل عام استخدام كل الاستراجيات السلبية والتي هي اضافة التضليل, والعزل في السقف والجدران واستخدام زجاج ذو معامل اداء عالي حقق 8.2 -8.6% تقليل للطاقة بينما دمج الاستراتيجات السلبية والايجابية حقق تقليل للطاقة يصل الى 50.6% . في نهاية المطاف اضافة كل الاستر ايتجات السلبية والنشطة يمكن ان يقلل الطلب على الطاقة الكهربائية في منزل نموذجي في بغداد .

Dedication

I dedicate this study to my beloved family, my husband Mohammed, my sons, Ahmed and Abdullah. I dedicate also to my parents (Rashid and Mohsinah), to my sisters (Fatima and Eman), to my brothers (Faisal and Ihssan) and to all those friends and relatives who wished me success and prosperity.

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The writing of this dissertation has been one of the most significant academic challenges I have ever faced in my life. I would never have been able to finish my dissertation without the support, assistance, and patience of the following people who I owe my deepest gratitude.

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My warm thanks to my husband Mohammed for his support and encourage that inspire me to be stronger throughout the Master course, and of course a great thanks to my sons Ahmed and Abdullah as they represent my motivation and inspiration to begin and finish the Master course. They always believed in me.

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Chapter 1

Introduction

1.1 Overview

This chapter constitutes a preface of the dissertation in order to present and highlight the phenomena of climate change and global warming. The effect of these phenomena coupled with the high rate of electricity demand to exacerbate the level of the catastrophe globally. The need for other alternatives is illustrated within; it also expresses the dissertation outline.

1.2 Global Climate Change and CO2 Emission

"There is little time left. The opportunity and responsibility to avoid catastrophic climate change is in your hands," through these words Mr. Ban Ki-Moon, the Secretary - General of United Nations (UN) ended the day-long Summit on Climate Change in September 2009. (UN, 2009)

Over the last decade the climate change has had a significant effect on global warming. This phenomenon has been a result of human activities and the rapid growth of global economies. The Earth's climate must be changed in order to keep the balance between the outgoing and incoming emissions. Global warming has attracted significant attention from scientists. It reflects a serious environmental problem, which leads to climate change and environmental catastrophes.

According to Granados, Ionides, and Carpintero (2012), Carbon dioxide CO_2 represents the key factor in recognizing and understanding global warming. During the 1990s, it was estimated that CO_2 emission increased annually around 1.1% while it reached 3% in 2000 – 2004. Consequently, the growth of CO_2 emissions in the 2000s has been greater than emissions in the 1990s at global and national levels. While Shi, Wang and Yang (2010) noted the major challenge of climate change is to reduce the consideration of harmful gases such as CO_2 and CH_4 in the atmosphere which are known as the greenhouse gasses (GHG).

Rapid growth in the economy and population are the main factors that are related to the increase in CO_2 concentrations in the atmosphere in the short and long run. The National Oceanic & Atmospheric Administration (NOOA 2010) report the increment of Carbon

Dioxide levels in the atmosphere from 1960 to 2010 as shown in Figure 1.1 Data are reported as a dry mole fraction defined as the number of molecules of carbon dioxide divided by the number of molecules of dry air multiplied by one million (ppm).

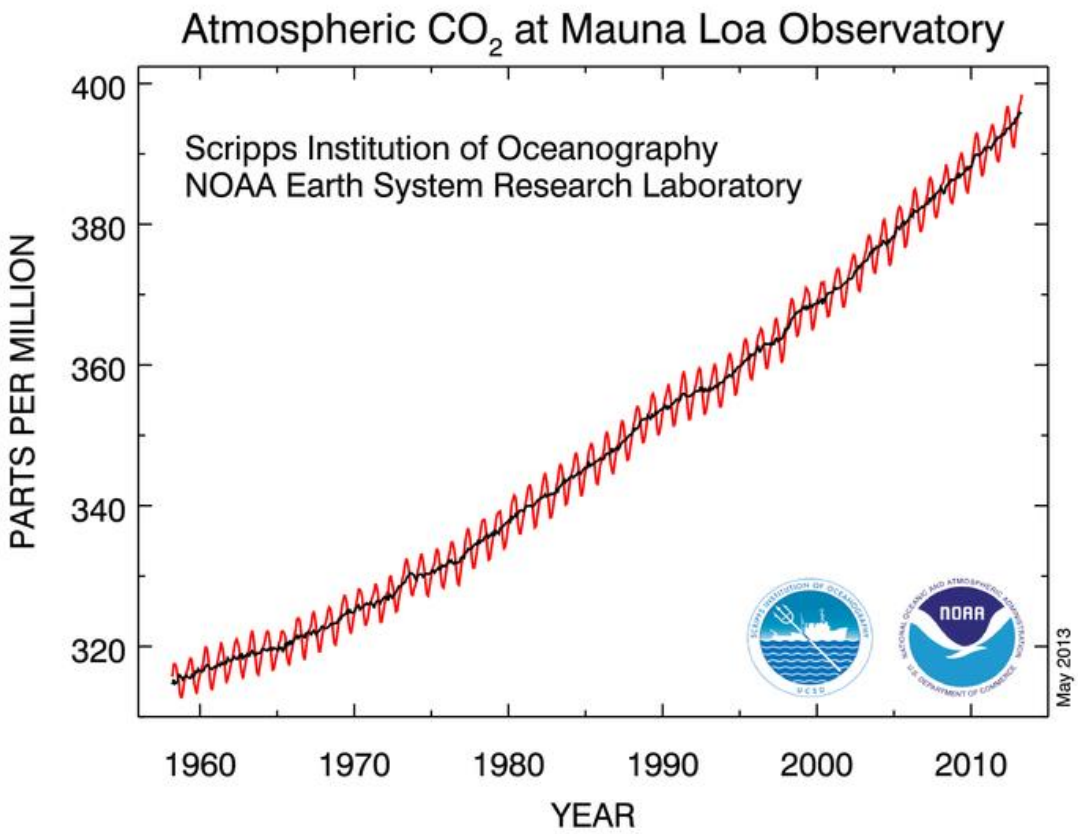

Figure 1.1 Monthly mean atmospheric Carbon Dioxide as Mauna Loa Observatory, Hawaii. The carbon dioxide data (red curve), measured as the mole fraction in dry air (NOAA, 2010)

1.3 Energy Demand and Sustainability

Over the last decade, electricity conservation has been at the core of attention. Every aspect of modern life has been dependant on electricity. As well as all technologies improved and accompanied with the rapid growth in economic and population that leads to an increase in the energy demand. Consequently, all these factors could influence humanity and the environment and caused energy depletion.

Therefore, the principle of sustainability has been required in order to reduce this negative influence on the environment and humanity. A report published in 1987 contained the sustainability definition that is still used till now “The needs of the present without compromising the ability of future generation to meet their own needs”. In 1992, these principles were the backdrop in the Rio Earth Summit (Blackburn 2007).

In developing countries, it seems that there is a huge gap between the current practices and sustainable principle, which need more attention to clarify and define the problems in order to find suitable solutions before it becomes more difficult and expensive.

Sustainability has two major approaches: which are passive and active strategies. Each strategy has several parameters that can improve the energy performance.

1.4 Thermal Comfort

Thermal comfort can be defined as a condition of mind that expresses satisfaction with the thermal environment. There are major factors affecting the level of thermal comfort, such as: air temperature, air humidity, air velocity, radiant temperature, human activity types, levels, and human clothing level. All these factors determine the heat balance of the human body and give the indication of the thermal comfort level in the space. Al-Homoud (2009)

1.5 Passive Design Strategies

The term of passive design, defined as a series of architectural design strategies used by the architect and designer to develop the building in order to respond adequately to climatic conditions among other contextual necessities. Ochoa (2008)

Passive design has acquired great importance due to the increase in living standards and energy consumption. A passive design architecture approach aims to use specific building design principles to minimize the energy requirements in order to achieve a high level of thermal comfort. There are several parameters, which can affect passive design criteria like, thermal comfort, climate condition, orientation, building shape, building opening, the type of sunshade, the selection of building materials, vegetation etc. All these parameters can be integrated or used separately to achieve the goal of passive concept.

Passive strategies can reduce the temperatures in hot climates, which lead to minimizing energy consumption and CO_2 emission. The integration between many strategies can achieve a high level of building performance.

1.6 Active Design Strategies

A great interest has been growing among engineers and architects to design and create intelligent buildings. According to Ochoa and Capeluto (2008) the active strategies are the active features or elements which are designed or added to the building to be self-adjusted to changes initiated by their internal or external environment. These strategies enhance the design of the building to achieve the thermal comfort conditions while reducing energy consumption.

Silva et al (2012) noted that "intelligent building" has become important infrastructures to minimize the operation cost of the building and provide comfort and safety for the occupant. The building that has active strategies must be able to respond to the environment. Ochoa and Capeluto (2008) believed that the combination of active features and optimized passive strategies can achieve a savings of about 50 - 55% for most cases.

One of the significant important active strategies is adopting renewable energy (RER) to enhance the building's energy performance. While there are many other strategies such as: Building Management System (BMS), adopting high Coefficient of Performance (COP) of cooling and heating system etc…

1.7 Renewable Energy

Over the last decade, the depletion of energy resources has required us to find another alternative to energy. According to Manzano-Agugliaro *et al* (2013), renewable energy source (RES) can be highlighted, as an obtainable resource, which is, it can be available for a long time with practical cost. In other words, it could be considered a clean energy resource without a negative impact on the environment and humanity.

Moriarty & Honnery (2012) have addressed that renewable energy will be the most promising energy of the future. There are several types of renewable energy that vary from one place to another depending on the location and the climate of the area. These types are as follows:

- Solar Energy
- Wind Energy
- Biomass Energy
- Geothermal Energy
- Hydroelectric Power
- Ocean Energy
- Nuclear Energy

One of the most significant types of renewable energy is solar energy especially in the Arabian Peninsula that has a higher proportion comparing with other renewable energy sources.

Moriarty & Honnery (2012) noted that over the last 30 years half of the global research effort, 56%, has been concerned about biomass while 26% related to the use of solar energy which represents the double of the one about wind energy 11% as shown in Figure 1.2.

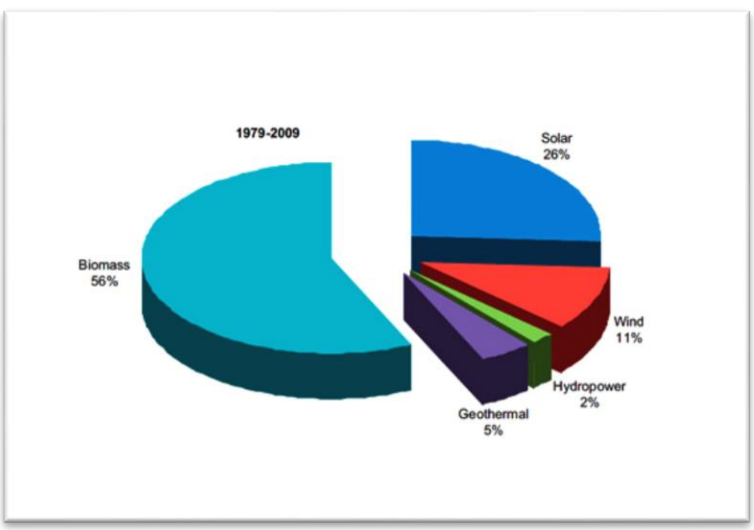

Figure 1.2 Distribution of scientific research about renewable energy from 1979 -2009 (Moriarty & Honnery 2012)

1.8 Solar Resources

According to Al -Naser (2011) the Gulf Cooperation Council (GCC) countries have enormous solar power that can be reached approximately (500-600 W/m2) for each Km2 of land annually. In other words, this amount of solar is equivalent to 1.5 million barrels of crude oil. There has been increasing environmental pressure from international authorities and countries on (GCC) countries in order to force them to improve their green credentials. The (GCC) government, especially in United Arab Emirates, began to flow many strategies to improve the environmental situation.

Nowadays, the GCC countries have a high level of awareness to adopt several alternatives in order to reduce energy consumption. The United Arab Emirates demonstrates a significant effort concerning the renewable energy sources particularly the used of solar energy in order to achieve the balance between the supply of fossil fuels and energy required. One of significant importance is the solar application especially PV which is the best, most inexpensive energy because the region has significant potential solar comparing with other renewable energies of the future According to a forecast of the Scientists Council of the German Government, solar electricity will be the most significant source of energy in the long term. It estimated that solar energy will contribute 24 percent of the world power generation in 2050 while it will recodes 63 by the year 2100 as shown in Figure 1.3

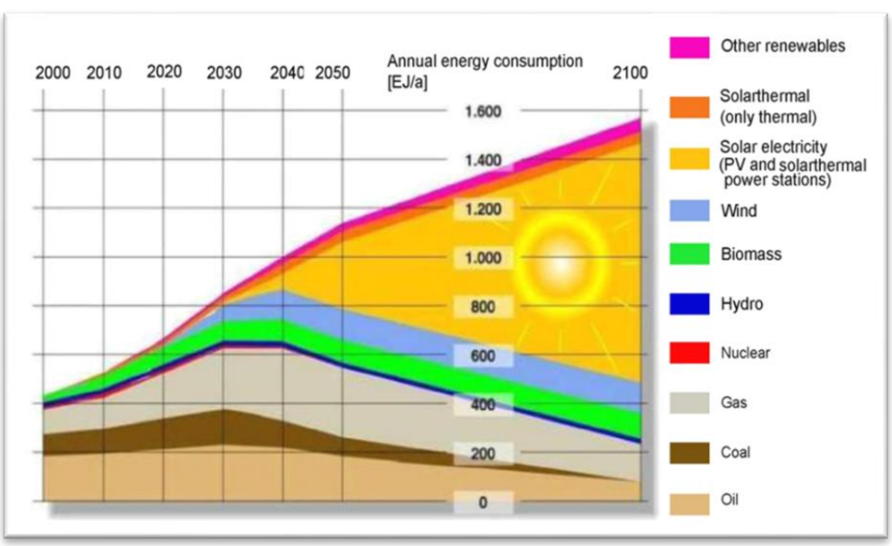

Figure 1.3 Estimation of the solar energy development and other renewable energy till 2100 (www.eng.dnt-solar.com)

1.9 Iraq

Iraq is located in the Middle East between Iran and Kuwait and bordering the Arabian Gulf. According to the Central Intelligence Agency (CIA) The World Fact book 2013, Iraq has 38.317 sq km, which includes 437,367 sq km land and 950 sq km water. Figure 1.3 shows the map and location of Iraq. However, Iraq has a hot, dry climate in summer and cold in winter which expands the period of electricity demands for the whole year. Domestic hot water DHW is properly increasing the energy consumption during the winter. One of the big challenges for the Iraqi people is to provide their homes with electricity all day without any shortage. This dream might only come true through connecting to private generators, which almost always have bad consequences on the environment and humanity in addition to higher costs.

Figure1. 4 Map of Iraq (www.cia.gov) The World Fact book 2013

1.10 Motivation of the Research

The rationale of this research is to establish advanced integrated solutions to enhance the energy performance and saving of residential sectors in Iraq. The new challenge is to combine several passive and active strategies to achieve high levels of occupant comfort and energy savings with minimum cost.

Overall, the situation in Iraq has acquired significant attention from scientists and researchers to establish and consider other alternatives. On the other hand, there are very limited investigations to improve energy performance. Thus, the motivation of this study is to highlight part of these alternatives in order to achieve electricity demand reduction through adopting passive and active strategies. The passive and active strategies have been introduced as a solution that can achieve the above-mentioned concerns. The proposed solution should be undertaken to test and investigate the visibility of the adoption of such strategies.

The main focus of literature and analyzing data of the passive and active strategies are based on energy consumption and savings. The combination of passive and active solutions has been rarely studied in hot climates such as in Iraq. The lack of research and academic references that cover the energy demand and consumption in Iraq create an incentive for the author to establish this study. Also, the suffering and complaining of relatives and friends has contributed to the reasons for the author to carry out this study.

The dissertation presents a simulation study of adopting several passive and active strategies to investigate the impact of each strategy on electricity demand reduction and savings. Passive and active features will be concentrated in the literate review; in addition, many results of the previous studies will be illustrated in-depth to estimate the feasibility of the study. A typical house in Baghdad, Iraq will be selected as a basic case. The passive and active strategies will be examined in separate scenarios to determine the impact of each one on energy performance and savings. The results will be assessed and compared based on the total energy consumption, cooling and heating loads, and the percentage of energy savings. These simulations will run under the climatic condition of Baghdad considering the same construction materials that are adopted in Iraq. According to the results, recommendations will be offered to support the present development and enhance future studies.

1.11 Structure of Dissertation

The dissertation contains six chapters, which are as follows:

The first chapter highlights the reasons of demand for passive and active strategies and the motivation of this research. The second chapter is the literature review. This chapter illustrates and reviews the impact of passive and active strategies on energy consumption and saving. A brief description of many pervious investigations will be highlighted within their finding and results to be given as basic knowledge of the current study. The literature review will provide an overview of PV system used and its impact on electricity demand reduction. In addition, this chapter considers the problem of electricity demand in Iraq.

The third chapter describes and assesses the methodology that has been used in this research. Simulation methodology presents an active method to carry out this study according to the flexibility to achieve the energy consumption and saving.

Chapter four shows the results of the simulations for all scenarios. A test matrix will configure the main parameters of passive and active strategies and their impact of each one on energy performance and saving.

The fifth chapter discusses the results and analyzes the data through comparing the different scenarios. Furthermore, comparisons between all cases will be highlighted to recognize which is the most worthy scenario due to energy consumption and saving.

Finally, chapter six will provide a conclusion of this study and recommendations based on the analysis in chapter five. This chapter will draw a full perspective of conclusions to achieve the answer of the research’s question which is:

How can Passive and Active strategies reduce the grid electricity demand in residential houses in Iraq?

Chapter 2

Literature Review

2.1 Introduction

This chapter is conducted to review the previous and current state of knowledge that covered passive and active strategies. The literature review provides a good understating of the passive and active strategies in order to investigate the main characteristics of each one and their impact on energy consumption and saving.

Over the past years, a significant interest has been growing among researchers and architects to achieve energy efficient building through adopting either passive or active strategies while in many cases it has been combined to achieve a high rate of energy demand reduction. The main focus point of this chapter is the finding of various studies in order to highlight the reasons of the motivation for this research.

2.2 Passive strategies

Passive design architecture approach aims to use specific building design principles to minimize the required energy in order to achieve thermal comfort. In many instances, the design approach neglected these parameters in order to achieve the new contemporary concept of design building while the traditional building considered them in spite of the limitation in knowledge and technologies.

Over the last decade, rapid growth in the economy and population accompanied by depletion of energy resources lead to serious impacts on the environment and humanity. This development coupled with active constructions, which in some examples ignore the impact on the environment and human activities. Therefore, the principle of passive design has been required in order to reduce this negative impact on the environment and humanity. In developing countries, it seems that there is a huge gap between the current construction practices and sustainable principles. These need more attention to clarify and define the problems in order to find suitable solutions before it becomes more difficult and expensive. Ralegaonkar, (2010)

Stevanović, (2013) Ralegaonkar & Gupta, (2010) and Kaklauskas *et al*. (2012) conducted many extensive research tests to assess the most important components of passive design strategies, which can significantly reduce the cooling, heating and lighting load energy consumption. The studies found that two-thirds of the discomfort was eliminated by the wise decisions of simple passive options. Many techniques can be used to assess the thermal performance of buildings.

Dili (2010*),* AboulNaga and Elsheshtawy (2001) point out that the majority of building designs neglected passive methods to provide the required thermal conditions, which forced people to depend on a mechanical system that was associated with high-energy consumption especially in the warm –humid climatic zone. They are also exploring a comparison of thermal comfort between modern and traditional buildings during various seasons to conclude that traditional residential buildings are very efficient in providing a comfortable indoor environment for all seasons due to the virtue of design, a special method of construction, and the type of materials used. The traditional building maintains a balanced condition of humidity and airflow combined with temperature to provide thermal comfort during all seasons. Consequently, architects and the designer should align the construction sector with a passive design development approach. In addition, a new regulation and a sustainable guideline should be established to achieve passive design strategies.

According to Frontczak *et al* (2012) in developing countries people spend approximately 90% of their time indoors. Thus, it is very significant to identify the major factors that affect the indoor environment of the inhabitants in their homes and determine the behavior that may influence their comfort. The most important ways to do that is to improve the awareness about the indoor environmental quality and its impact and consequences on their health and comfort.

Gong *et al* (2012) concluded that passive strategies are the most practical and economically efficient way to enhance energy performance and savings. The paper examines seven different passive strategies which are: external wall thickness, wall insulation, roof insulation, window orientation, the ratio of window to wall, glazing type, and the type and size of the shading device. The investigation has been done in different cities of China to evaluate the strategies in different conditions. It concluded that with optimized design strategies, the annual thermal load can be reduced considerably which led to a reduction in the total energy consumption.

The building should be more than a shelter; it should be a series of characteristics, which create the indoor comfortable construction. Thus, architects and designers should consider many parameters during the concept and design phase in order to achieve passive design. There are several passive strategies such as: orientation, natural ventilation, insulation material, shading devices, and thermal mass etc...

The research focused on shading devices and insulation materials through reducing the U-Values of roofs and walls. In addition, the study examines different solar heat gain coefficient (SHGC) of glazing system as will be explained in the next sections.

2.2.1 Passive Solar Background

A thousand years ago, several ancients used and developed passive solar techniques. They were used widely and successfully. The vernacular architecture in many countries that are considered the main factors of solar passive strategies include: orientation, natural ventilation, and thermal mass. The Greeks and Chinese are the first ancients who oriented buildings to the south in order to get warmth and light, while Romans used large windows in the façade facing south. This concept was adopted in Europe after the fall of Rome.

Over the past century, the technical development of the building construction industry has determined different ways of utilizing the sun in lighting and heating space.

In 1948, the famous architect Frank Lloyd Wright designed the (Solar Hemicycle) with the main concept of using the sun for providing part of the required heating during the winter as shown in figure 2.1 and 2.2.

According to Coupland (1997), the first design that used a solar heated courtyard is the Santa FE Municipality in the U.S.A. The building used a traditional concept that had been used in northern New Mexico for over 1000 years. The building rotates to the south in order to increase the solar gain through windows and the clearstories to provide light and heat as shown in Figure 2.3.

Figure 2.1 Solar Hemicycle house by Frank Lloyd Wright using the south façade as the main factor to provide heating for space in 1948 (greenarchitecturenotes.com)

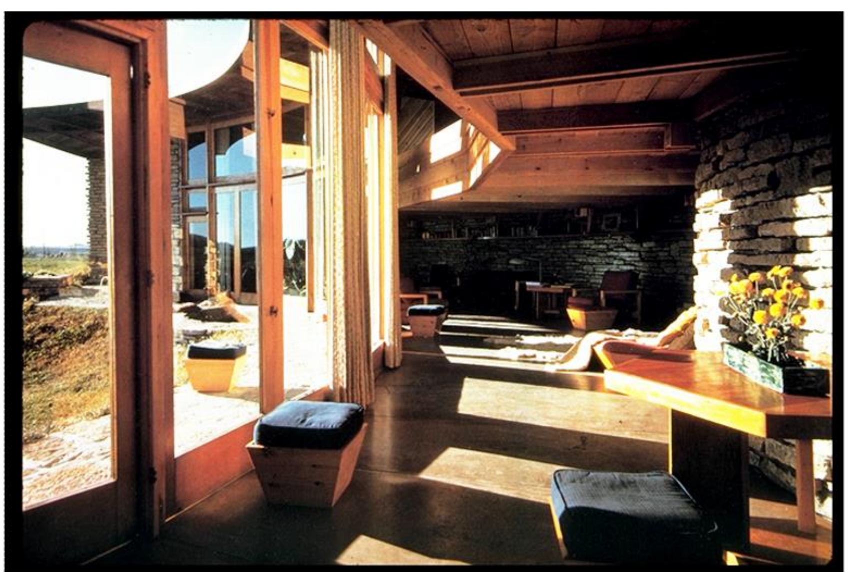

Figure 2.2 The interior of the Solar Hemicycle house by Frank Lloyd Wright using the south façade as a main factor in providing heat for the space in 1948 (greenarchitecturenotes.com)

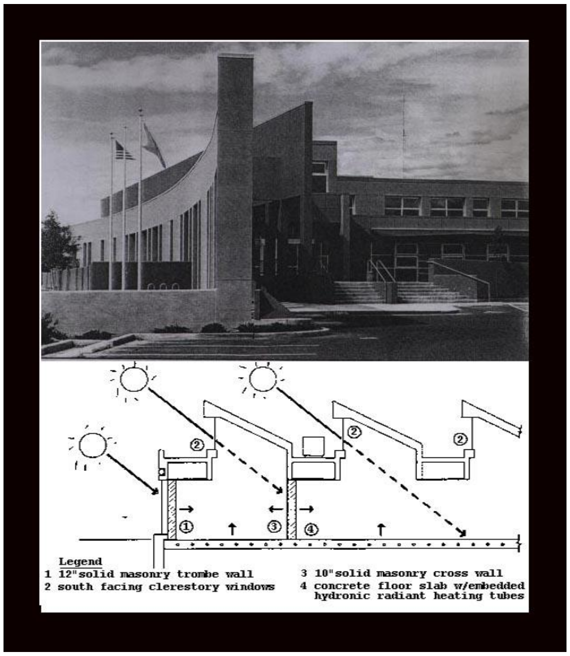

Figure 2.3 Santa Fe Municipality in USA used solar heated concept Coupland (1997)

The solar energy approach can be defined as the use of specific building design principles to reduce the artificial energy needs in order to achieve indoor thermal comfort. In other words, it is the method of extracting energy from the environment. According to Feist *et al* (2005), the energy for heating can be approximately 78% of the total domestic delivered energy consumption in a cold climate. This approach can be achieved by designing the buildings to comply with the passive solar strategies in order to achieve energy consumption.

2.2.2 Shading Devices

Kima (2011) and Al-zoubi (2010) investigate the optimal shading system that can provide daylight and reduce the solar gain through software simulations. It has been found that a shading device can be considered as one of the key design factors in the determination of energy assessment.

Kima (2011) has used IES-VE Virtual Environment software to investigate the most appropriate configuration of shading device systems to achieve thermal performance in the building. The study selects a high-rise residential building as its prototype unit, which is located in Korea with 20 stories to run the simulations in. The glass area of the case study is about 90% of the southern wall surfaces and balcony while the main function of the unit, such as the bedrooms and living room, are oriented to the south. The software tested four different configurations of the shading device as shown in figure 2.4 depending on its projecting depth, type and the slat angle gives in order to compare between them according to the results.

The IES -VE software provides specific calculations and graphs to clarify that the external shading device has a higher level of efficiency than any other form of internal device that absorbs solar heat and radiates to the interior space. Based on the simulation, one can determine the cooling load of each case and the annual total heating load of proposed devices.

Hammad and Abu-Hijleh (2010), investigate the impact of dynamic louvers on the energy consumption of an office building in Abu Dhabi, U.A.E through software simulations. The results of simulations show that the use of light dimming strategies only achieve an energy savings of about 24.4% in the south facade while it saves, 24.45%, and 25.19% for east and west oriented facades. The dynamic louvers coupled with the dimming strategies can record energy savings of 28.57% and 30.31% for east and west orientation, while it can achieve 34.02% energy savings for the south.

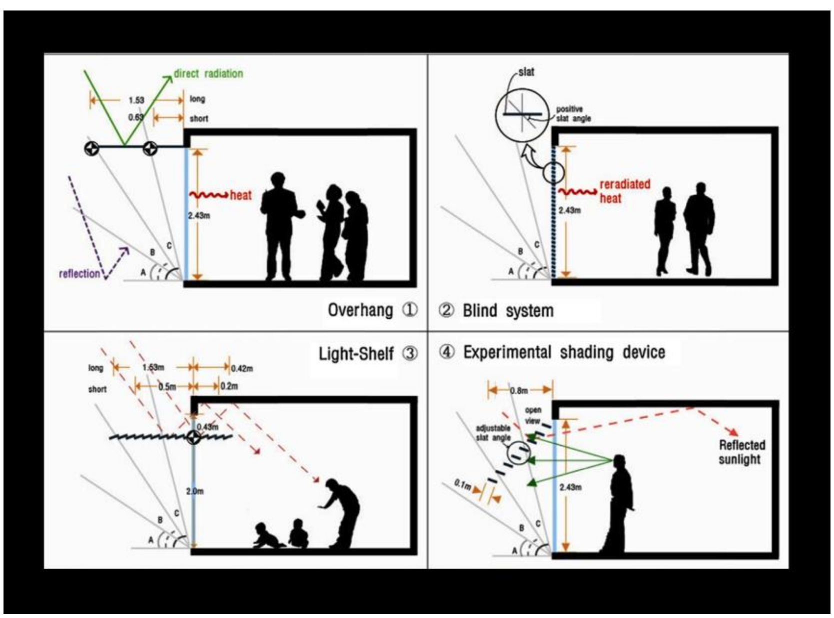

Figure 2.4 Shows the four different configurations of the shading device adopted from (Kima 2011)

David *et al* (2011) explored that designing the solar shading devices must be assessed for both a thermal and visual point of view. In order to avoid reducing the visual comfort and increasing the use of artificial lighting that leads to more energy consumption, proper assessment must first be made.

Marrero and Oliveira (2010), Sherif *et al* (2012) found that the integration of external louvers and screens in the building can achieve a high level of thermal comfort and energy saving significantly through providing solar protection for the glazing surfaces.
Chang (2012) believed that there are several types of shading that sometimes was caused by nearby trees or imposed by part of the building itself. The impact of shading devices depends on different factors such as the layout of the building, the location, building regulations, scenic view, the site limitation, and the balance between the type of shading and daylight. The study found that in some cases over-shading could incur a reduction of daylight received which leads to an increase in energy consumption. On the other hand, shading can reduce the amount of solar gain, which affects the cooling and heating loads of A/C system. In addition, it could mitigate visual glare problems by minimizing the direct solar radiation.

2.2.3 Insulation Materials in Wall and Roof

Kumar and Suman (2013) evaluated the impact of insulation material for roofs and walls on energy savings. The insulation materials not only reduce the energy demand for heating and cooling loads, it extends the period of thermal comfort without depending on the mechanical air conditioning system. The paper used an experimental method to examine two prototypes of constructing buildings; the first one was built with conventional clay brick walls, which had a 50 mm thickness. In addition, the outside had thermal insulation and reinforced cement concrete. The other prototype was built with the same construction elements without insulation. Several insulation materials were used to reduce heat loss such as: polystyrene, urethane foam, rock wool, fiberglass, and vermiculite. It was recommended to adopt an insulation material such as polyurethane. That means reducing the U-Values of the roofs and walls can reduce the cooling load and achieve a reduction in energy demand.

The amount of heat flow through materials mainly depends on the quality of thermal insulation. Sixty percentof thermal transfer can occur across the roof only.

Kolaitis *et al* (2013), Yu *et al* (2011) Gong *et al* (2012) investigated the impact of insulation materials in walls and roofs on energy consumption in residential buildings. The study found that using insulation materials in walls and roofs has enhanced the energy performance significantly. It also concluded that the amount of energy reduction depends on the type, thickness, and location of insulation materials, and all these factors varied from one climate zone to another.

Kolaitis *et al* (2013) examined a series of parametric to assess the impact of insulation layers located either internally or externally on energy savings. The study concludes that both types of insulations (internal and external) can achieve approximately 21-89% of the total annual HVAC energy consumption. This range of reduction depends on occupant behavior and climate region. The higher energy savings occurred in the warm, Mediterranean climate region which was 56-89% while it achieved 21- 47% in the harsh, temperate Oceanic climate zone.

Friess *et al (*2012) and Al Awadhi *et al* (2013) investigated the impact of thermal insulation on energy consumption of several villas in United Arab Emirates. The studies examine several low U-Values for walls and roofs to determine the impact of each strategy on energy saving.

Friess *el at (*2012) selected two floors of a semi-detached villa in Dubai, to monitor over a full year based on building performance through the monthly billing cycle. The study used DesignBulider / EnergyPlus software to establish the base-case model to simulate a range of external insulation. The results indicate that an un-insulated constructed villa has approximately 24.5% more energy consumption than the same villa with insulation.

Al Awadhi *et.al* (2013) examines five houses, which were built in 1974-2012 in the United Arab Emirates in order to investigate the impact of reducing the U-Values on total energy consumption and saving. The paper adopted Estidama building regulation, which included several energy saving requirements. Estidama regulations were produced by the Abu Dhabi Urban Planning Council (DUP) in order to enforce and increase the use of energy saving practices. The study adapted two types of U-Values, which are 1Pearl and 2Pearls as shown in Table 2.1.

Table 2.1 ESTIDAMA requirements 1Pearl and 2Pearls for (Al Awadhi *et.al*. 2013)

	1 Pearl	2 Pearl
Wall U-Value (W/m C)	0.32	0.29
Roof U- Value (W/m C)	0.14	0.12
Glazing U-Value (W/m C)	2.2	1.9
Glazing Solar Heat Gain Coefficient (SHGC)	0.4	0.3
Maximum Window /Wall area %	15%	10%

The results of the simulations show that the insulation characteristics can enhance energy consumption and savings ranging from 27.5% - 30.8%. Meanwhile there was a very slight energy consumption reduction when going from 1 Pearl to 2 Pearls.

The study recommended 1 Pearl as the most economical and practical case as shown in Figure 2.5.

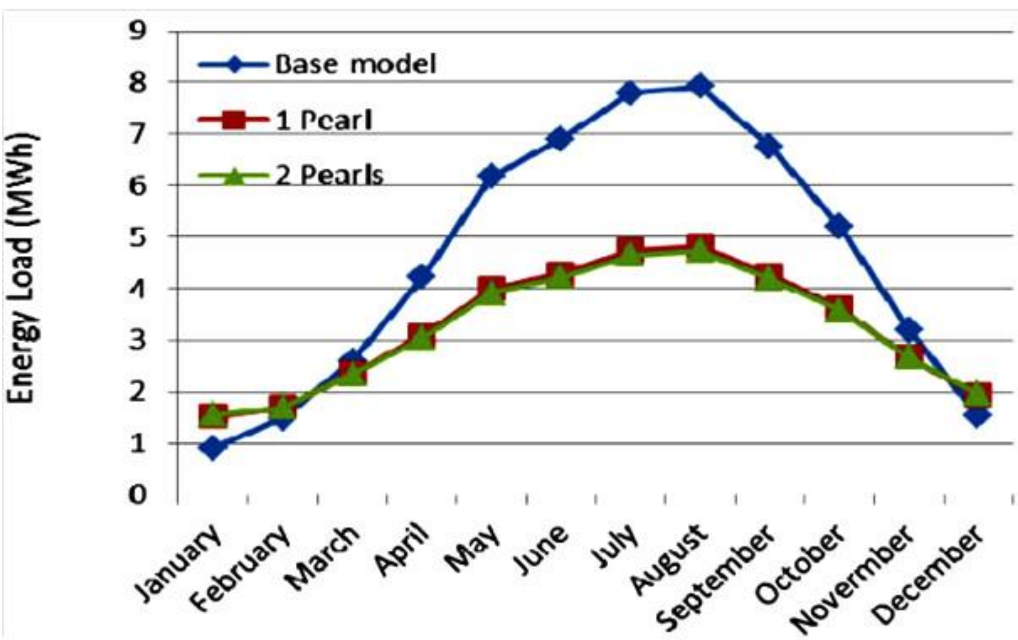

Figure 2.5 Shows the little difference between 1 Pearl and 2 Pearls (Al Awadhi *et.al*. 2013)

Kaynakli (2012) believed that 40% of the global energy consumption occurs by buildings while approximately 60% of this consumption is going for cooling or heating of these buildings. The study focused on economical and optimum thermal insulation thickness for building applications. The study estimated the initial cost of the insulation coupled with the value of energy savings considering the total life-cycle cost of the insulation materials in order to determine the proper thickness and cost of the insulation material as shown in Figure 2.6.

The study summarized a literature review of the thermal insulation in external walls in order to compare the amount of benefit of energy savings with the cost of insulation materials.

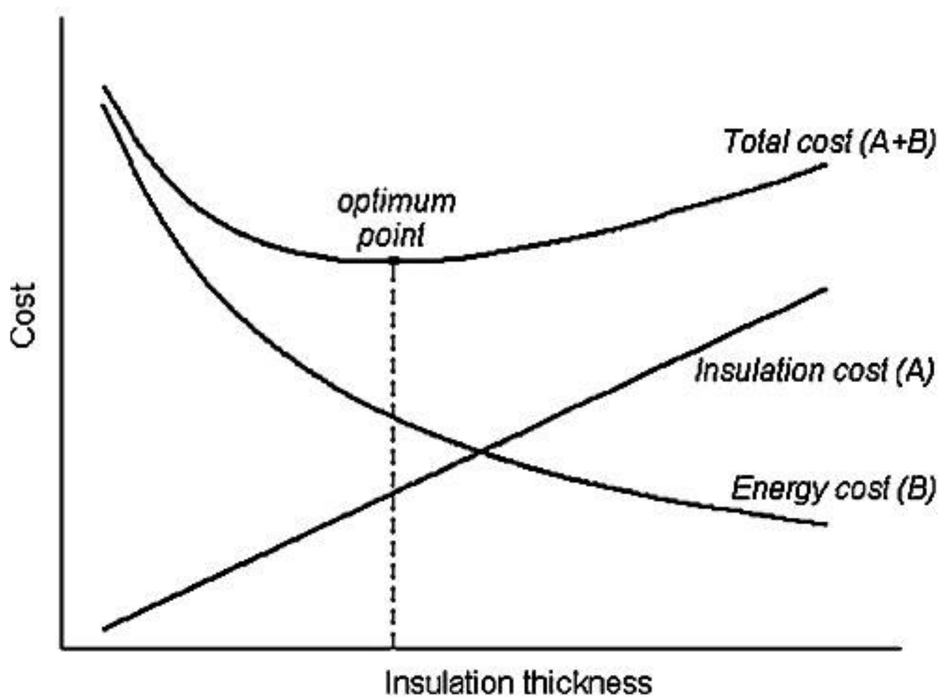

Figure 2.6 The optimum insulation thickness with the cost (Kaynakli 2012)

Al-Radom (2003) has selected a typical house in Kuwait for retrofitting through adding insulation materials such as polystyrene in walls and roofs. The study addresses the cost of implementing effective retrofitting approaches for energy savings. Fifteen retrofitting scenarios have been simulated through DOE-2.1E software.

The base case has incorporated foam concrete with a high level of thermal resistance value. It has been concluded that the impact of roof insulation is less than the impact of wall insulation. However, the study achieved a 7% reduction of the annual energy consumption through adding thermal insulation for the roof. Using an efficient glazing system can reduce the electrical load by 9.1%. Furthermore, it can reduce energy by approximately 17.69% when using double clear or double reflected glass. The results show that reducing the opening ratio can achieve almost 10% of energy savings.
The study summarized that the used of insulation materials in wall and roof. Coupled with minimizing the window area with using reflective double glass is the most effective scenario that can achieve a high level of energy saving.

Taleb & Sharples (2011) noted that as well as the U-Values represent the rate of heat transfer through the construction element, reducing these values should consequently lead to energy savings. It has concluded that sufficient insulation for roofs and walls could lead to having low U-Values and a high level of thermal inertia of the building. The study examined a typical Saudi residential building to illustrate how several design approaches can have a significant effect on energy performance and savings. The study summarized the improvement of thermal insulation of roofs and external roofs could achieve a higher rate of energy reduction than adopting glazing, efficient lighting and external shading devices.

2.2.4 Solar Heat Gain Coefficient (SHGC) of Glazing

Ihm *et al* (2012) and Lopez and Molina (2013) explored and investigated the impact of different techniques of glazing systems on total energy consumption in residential buildings. Double-glazing with water circulation chamber and low-e glazing were examined to determine the impact of advanced glazing systems on energy performance. Ihm *et al* (2012) examined a typical housing unit located in South Korea at a milder climate zone. Many simulations have been run to conclude that there are three main factors influencing the glazing performance: wall to window ratios, glazing U-factor and SHGC values. These factors can significantly affect the cooling and heating load with lead to reduce energy consumption.

Moreover, it's recommended that the levels for the SHGC should be imposed especially for residential buildings that used high ratios of opening façade or were located in mild climates. While many buildings are considered only U- values without any requirements on SHGC values for glazing. It summarized that adopting the double low-e clear-filled with argon gas represented the most cost-effective option for residential buildings.

Lopez and Molina (2013) found that using double-glazing with chamber water instead of regular double-glazing with air could achieve an 18.26% reduction of the total energy consumption in residential buildings.

Mingotti, Chenvidyakarn & Woods (2013) investigated the impact of single and double glazing on energy demands and the amount of solar radiation that entered the space. It found that in cold climates double-glazing can reduce the heating load even with poor wall insulation or small occupancy. In addition, in warm climates when the solar flux will be higher, the double-glazing can reduce the cooling load but it should have good wall insulation. It concludes that in hot climates with low levels of wall insulation, the energy savings provided by another layer of glazing is very limited. Figure 2.7 shows the impact of single and double-glazing in cold and warm climates.

Ebrahimpour & Maerefat (2011) and Song *et al* (2007) examined the advanced glazing and assessed the cooling energy performance of windows for residential buildings. It was found that there are many factors that can affect the glazing system such as: glass type and thermal breaker in the frame and spacer. It concluded that residential buildings should adopt the thermal and optical properties of the transparent glazing elements. Furthermore, the orientation of the glazing should be taken into account to reduce the cooling load energy especially in warm climates.

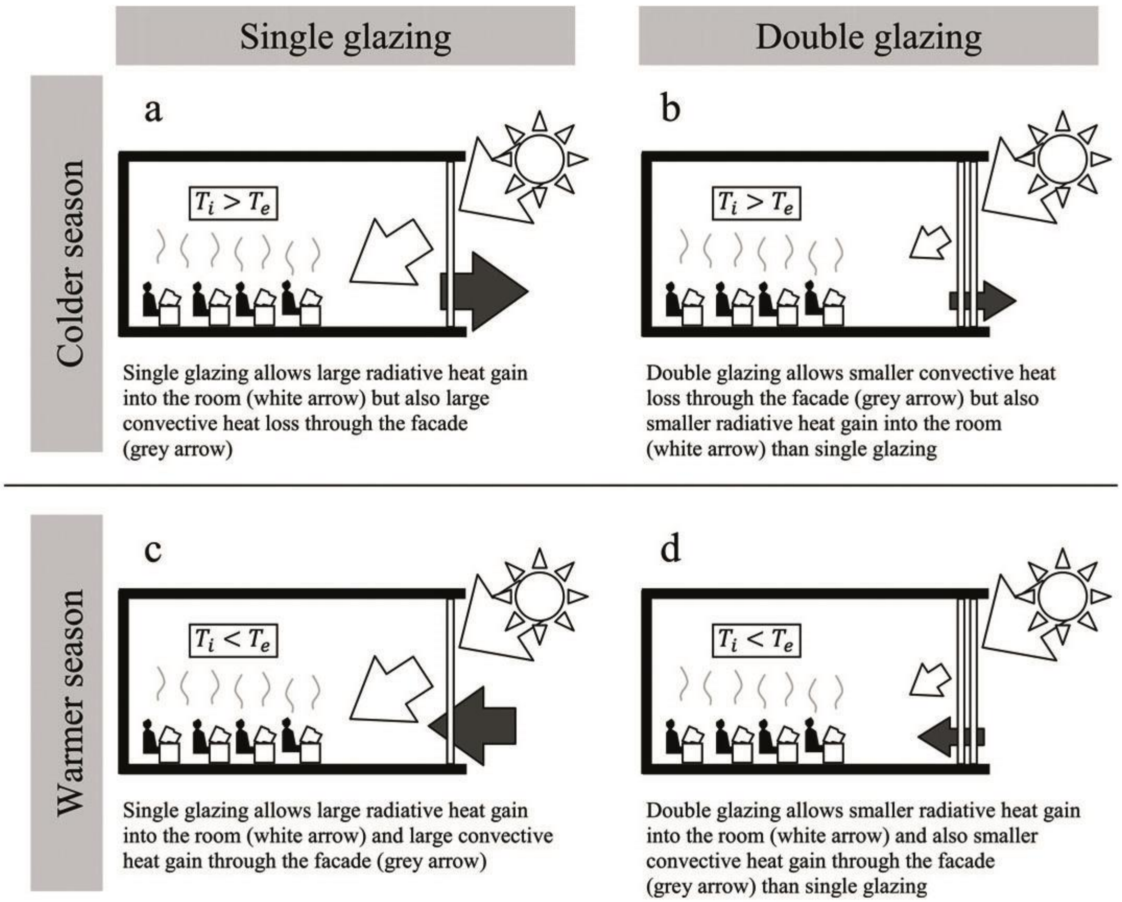

Figure 2.7 The impact of single and double-glazing in cold and warm climates (Mingotti *et al* 2013)

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Aboulnaga (2006) investigates the use and misuse of glazing in the gulf region. The study evaluates the buildings in Dubai in regard to visual factor, glass type, light transmittance, solar heat gain, and reflection (in and out). Many buildings' façades in Dubai, designed to be an icon of large areas of glazing, need protection to avoid overheating and glare. The results recommend the type of glass that provide daylight factor (DF) and daylight level (DL). It concluded that most of the glazing in Dubai was misused in 70% of the buildings in intermediate and low performance groups.

Tsagarakis, Karyotakis and Zografakis (2012) investigated saving energy through using double glazed windows in office buildings. The greatest amount of the total cooling or heating loss occurs through windows.

The use of double-glazing can significantly contribute to enhanced energy performance and savings because it has about half of the heat transfer coefficient of the single glazing type. According to an assessment for a commercial building in the United Kingdom, it estimated that replacing the single glazing with double-glazing achieves energy savings of about 39 - 53%. Changing old window frames with new energy efficient types can also improve energy performance.

Hamza (2008) investigated the impact of double skin facade on cooling loads in an office building with a hot, arid climate though shows a comparison between an optimized single facade and an optimized double skin façade. This was based on a case study located in Cairo, Egypt, which has a climate matching a typical hot, arid climatic profile. There are three sets of independent variables: the climate profile, the model morphology, and the building operation profile. While the dependant variables are concerned with modification of the physical properties of the glazing, this could be affecting the cooling and heating loads in an office building in hot, arid climates. The result shows that the simulation of software can provide a result that is accurate and matching the actual data. Comparing the performance of double skin façade and single ones predicted a decrease of approximately 30% of the total annual cooling loads.

2.3 Active strategies

Ochoa & Capeluto (2008) identified the combination between passive and active strategies when designing buildings can establish what has been known as the intelligent building. Moreover, this principle of intelligent building mainly depends on considering the passive design strategy decisions in the early stage associated with intelligent technological innovations as active strategies. Combining the optimum passive strategies with active features can achieve savings of approximately 50-55% for most cases depending on the combination used.

Chen, Athienitis, and Galal (2010) assessed and examined an integration of three technologies in the same house in order to achieve the concept of zero energy consumption. These technologies are BiPV/T, direct gain passive system, and the ground source heat pump. The study shows that adopting these strategies can approach a zero energy house in cold climates.

This section illustrated several previous research papers that used active strategies to reduce electricity demand reduction. Also, active strategies could replace and reduce energy consumption. There are many types of active strategies. The study adopts some of these straggles such as: Coefficient of Performance (COP) of the air conditioning system, the solar domestic hot water (DHW) and adding photovoltaic panels (PV). We will examine these features in order to recognize the most effective strategy based on energy consumption and savings.

2.3.1 Coefficient of Performance (COP)

The Coefficient of Performance (COP) is defined as the measurement of the amount of input power to the output power of a system. Whenever the value of the COP is higher, the system will be more efficient. However, the other way of measuring system efficiency is the Energy Efficiency Ratio (EER). While The Seasonal Energy Efficiency Ratio (SEER), which is defined as the measurement of a system, behaves over a season considering the outdoor temperature variables.

Shekarchian *et al* (2011) found out that over the last years the rapid use of air conditioning systems and appliances has increased dramatically in commercial and residential sectors. The paper investigated the impact of changing the coefficient of performance (COP) of absorption chillers on cost savings.

According to ASHRAE/ IES Standard 90.1 (2010) the efficiency of air -conditioning systems have improved over the years in order to reduce energy consumption. The Coefficient of Performance (COP) of split units has improved from 1.7 in (1977-1997) to 3.8 in 2006 as shown in Figure 2.8 while the Table of COP ASHRAE Standard has been moved to the Appendix.

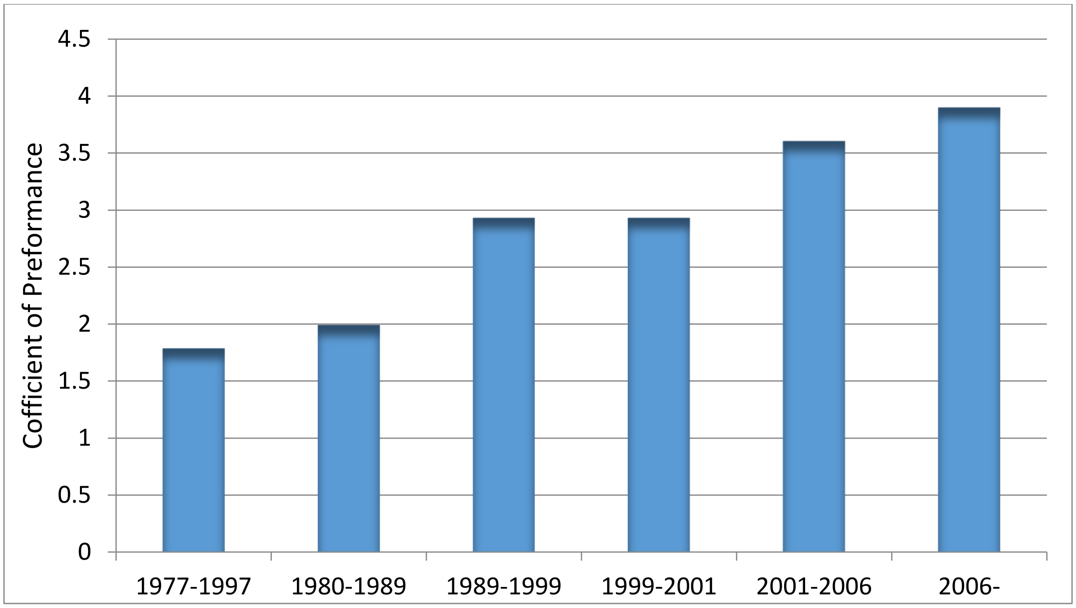

Figure 2.8 Improvement of COP during (1977- 2006) information source (ASHRAE/ IES Standard 90.12010)

Yua & Chan (2013) indicates that half of the electricity demand was consumed by the chiller system operation. The study used a systematic method to evaluate the energy efficiency of chiller systems. The increase of COP from 5.73 to 5.85 can achieve 0.36% savings of electricity.

2.3.2 Renewable Energy

According to Doukas (2006), since 1991, CO_2 emission has increased by more than 50%, which attracted the global attention for the need of action. Therefore, the principle of renewable energy has been required in order to reduce this negative impact on the environment and humanity. In developing countries, it seems that there is a huge gap between current construction practices and sustainable principles. More attention is needed to clarify and define the problems in order to find suitable solutions before it becomes more difficult and expensive.

Consequently, the Kyoto Protocol, adopted in 1997 and implemented in February 2005, addresses global warming and the stabilization of greenhouse gases as major issues by UNFCCC (United Nation Framework Convention on Climate Change). A consequence of these sustainability developments, in November 2009, is that 187 states have signed

and ratified the protocol. This includes the United Arab Emirates which ratified the protocol on 26 January 2005. Salama & Hana (2010)
The building sector consumes 40% of the world's energy while it is responsible for 50% of the CO2 emissions. The requirement of optimal shading systems increases to provide daylight and controlling the excessive sunlight, in addition to reducing the glare and discomfort for the occupants. Kima, (2011)

Bahaj (2008) predicted from the simulations that the PV solution covered approximately 40% of the total area of glazed high-rise buildings in the Middle East, Thus, the study concluded that BiPV is the most significant alternative solution for fully glazed buildings in the Middle East. That solution could minimize the energy consumption due to minimizing the cooling load and providing a thermal comfortable indoor environment in hot climates. The climate change and depletion of resources lead many industrialized nations to make an effort to switch to renewable energy. The oldest and most common renewable energy is solar that can provide light and heat with zero cost.

Laughton (2010) and Stapleton & Neill (2012) demonstrated and explored different technologies and implementations of solar power to be converted to electricity. The most significant property of solar power is that once the initial cost has been made, the energy is effectively free while fossil fuel should be purchased continuously considering the variable price. The average solar irradiance is 1368 W/m2, when it is measured at the top of the earth's atmosphere. This means that each square meter is receiving 1368 watts of power. The world's primary energy consumption can easily exceed the solar energy in one year by a factor of 10.000 as shown in Figure 2.9.
Renewal energy using solar or wind power represents the future solution for reducing global GHG emissions. In addition, it will have a large portion of the world's energy production in the future.

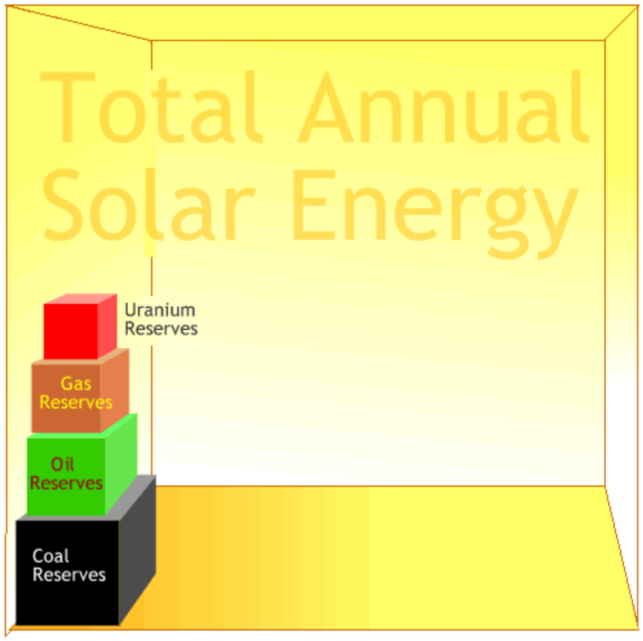

Figure 2.9The total annual solar energy (solarbook.ie)

Al Naser (2011) found that the (GCC) countries have enormous solar power that can reach approximately (500-600 W/m2) for each Km2 of land annually. In other words, this amount of solar energy is equivalent to 1.5 million barrels of crude oil. Since the increasing environmental pressure from international authorities and countries on (GCC) countries in order to force them to improve their green credentials, the (GCC) government in the U.A.E began to flow many strategies to improve the environmental situation.

Harvey (2010) noted that the most significant challenge in our days is to transform our energy sources to be more sustainable and less affecting to the environment. Many types of renewable energy have been considered during the last decade such as: solar energy, wind energy, biomass energy, geothermal energy, hydroelectric power, ocean energy, and nuclear energy. The study focuses on the solar energy in two types of implementation; Solar Domestic Water Heating (DHW) and Photovoltaic panels (PV) as illustrated in the next sections.

2.3.3 Solar Domestic Hot Water (SDHW)

Boait *et al* (2012) explored the production efficiency of hot water for domestic use in the UK. It found that 18% of energy has been consumed by domestic hot water (DHW) as shown in Figure 2.10, which shows the ratio of energy consumption in the UK. The study illustrated five different types of domestic hot water systems that are used in the UK. It concluded that combining the electricity type with solar domestic hot water has the most potential as a low carbon method and energy consumption in the long term of use.

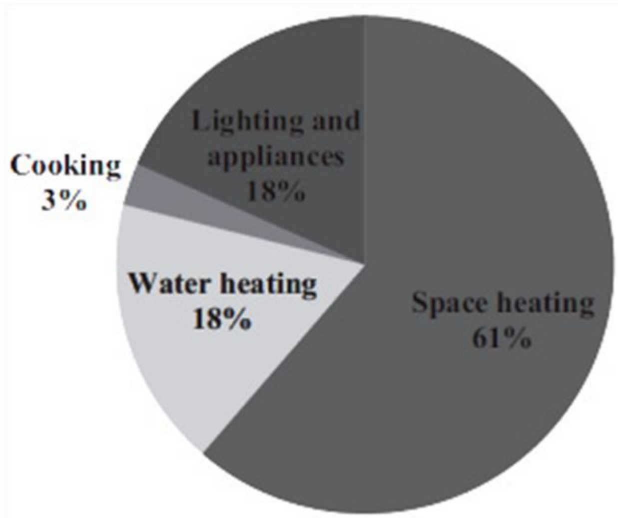

Figure 2.10 shows the ratio of consumption in UK during 2009 (Boait *et al* 2012)

Haillot (2011) believed that the solar domestic hot water (SDHW) is one of the most important, popular, and low cost technologies that enhances energy performance. In spite of the (SDHW) system sometime needing a large tank as storage, it still is the simple and reliable way to provide hot water with minimum cost. The study has investigated the optimal integration of (SDHW) materials through analyzing the preparation and characterization of the solar collector system.

Srinivas *(2011)* and Chow *et al* (2011) evaluated the development of solar domestic hot water through a consolidated review covering technological and economical aspects.

Chow *et al* (2011) used experimental and numerical methods to evaluate the performance of the two common types of (SDHW) systems. The results show that the payback periods of the two are approximately the same because of the higher initial costs, while the type of solar collector should consider the system temperature demand.

Biaoua & Bernier (2008) achieved net zero energy houses (ZNEH) principles by investigating the total domestic hot water production with renewable energy for two climate zones that are Los Angeles and Montréal. The results show that solar collector DHW with an electric backup provided by either the grid or the PV panels represents the most significant solution for a ZNEH. Figure 2.11 shows the outline of the zero net energy houses.

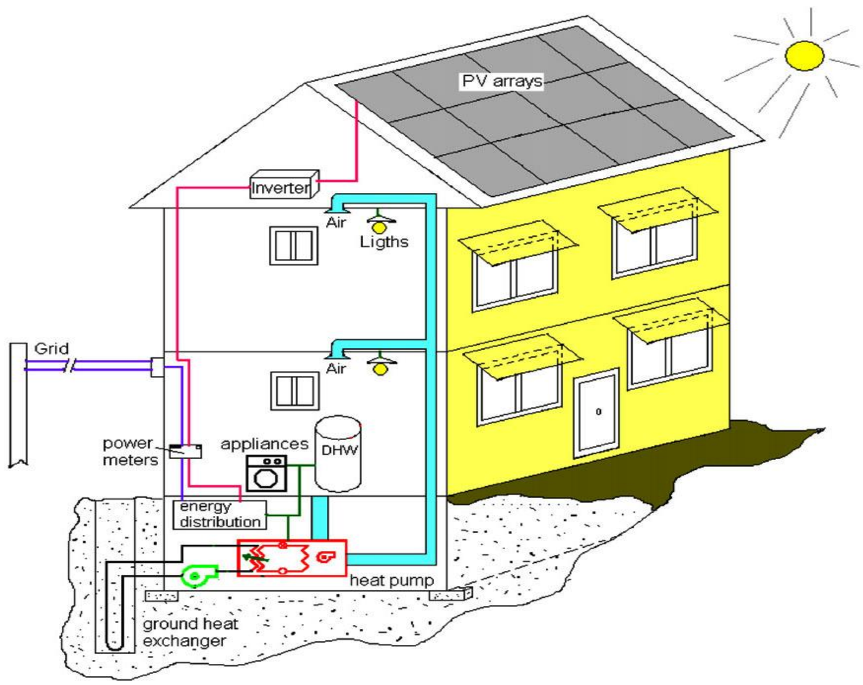

Figure 2.11 Zero net energy house ZNEH (Biaoua & Bernier 2008)

Fang & Li (2013) explored the solar photovoltaic and thermal technology and applications in China. The paper illustrated the review of the solar energy resource, PV application, technology, and development. Nowadays China has become the biggest producer of SWHs and PV cells globally. In 2011, China produced about 42% of PV and the solar DHW cumulative installations constituted about 2/3 of the world's amount. It concludes that the integration of the solar DHW with PV and the building structure are the main way for solving the energy problems of the future.

2.3.4 Background and Types of the Photovoltaic

The word photovoltaic is related to the Latin word *photo,* which means light, and *voltaic* refers to energy. This system captures energy from the sun and converts it to electricity.

In 1873, British scientist Willoughby Smith recognized that selenium was sensitive to light. Smith found selenium's ability to conduct electricity increased in direct proportion to the degree of its exposure to light. Smith's conclusion about Photovoltaic technology attracted many scientists to experiment to produce electricity without consuming any material substance and with minimum heat. In the 1950s, Bell Laboratories investigated a dependable method to power remote communication systems. Bell developed a silicon-based cell that achieved six percent efficiency in 1954. However, the first practical use of photovoltaic technology was to power a telephone repeater station in rural Georgia at the end of the 1950s. Scientists of the National Aeronautics and Space Administration (NASA) found that this reliable energy source coupled with lightweight could be very suitable for outer space. PV systems were installed on the first satellite of the United States in the early 1960s. (Solar Energy International 2004)

At the same time, building PV has witnessed a high level of development globally with a growth rate of 16.8% per year while in Europe it reached 33% per year. Over the last decade, the depletion of energy resources required in building integrated PV in order to achieve the reduction in energy consumption. The applications of PV systems have been expanding while the costs have been declining. The BIPV can be part of buildings, walls, roofs, and awnings that provide electricity generation and act as a protective envelope for the building Archer & Hill (2001).

According to Harvy (2010) (BiPV) module systems can be attached or integrated with building in several ways as followings:

- Integrated into the sloped roof which displaced conventional roofing materials
- Mounted onto the slope roofs
- Horizontal models on a flat roof
- Tilted models on a flat roof which need a support structure
- P V modules on facades, which can be placed on vertical facades.
- PV modules as skylights in atria

Figure 2.12 shows several types of PV modules that have been highlighted above.

Figure 2.12 Different types of PV models (www.schueco.com)

Today Photovoltaic Panel (PV) technology can supply electricity to one million homes all over the world. In 2005, world solar photovoltaic market installations totaled 1,460 megawatts and over $7 billion in the global market (2005 Solar Buzz Inc. Report).

2.3.5 Photovoltaic Review in Previous Studies

Extensive studies have been conducted to investigate and evaluate the BiPV impact on reduction of building energy consumption and savings. Dominguez, J Kleissl, & Luvall (2011) and Bayod-Rújula, Ortego-Bielsa,& Martínez-Gracia (2011) investigated solar photovoltaic panels on roofs based on energy consideration. It found that the roof presents the largest potential area that could be suitable for installation of PV panels. Moreover, the significant advantage is the flexibility of adopting the optimal position and adjusted angles to maximize the amount of solar gain.

Dominguez, J Kleissl, & Luvall (2011) investigated a case study which partially covered a tilted PV array and a flush horizontal solar PV array. The results showed that the total annual cooling load of the PV covered roof was reduced by 38% with the greatest, which is the warm, sunny month. The daily PV array electricity production resulted in a 10% enhancement of the net energy balance of PV.

Sadineni, (2012) used a field monitoring and modeling approach to investigate the benefits occurring in July impact of roof-integrated PV orientation on the peak demand of residential electricity. The paper investigated the impact of PV orientation in the peak load of the building. In order to do that, the study developed approximately 200 homes to study substation level peak reduction strategies. Fifty homes were already built and occupied; the temperature and power measurement sensors were installed in several homes in order to determine the energy performance of the buildings. The paper focuses on monitoring the energy performance of the building due to PV direction, which mainly depends on building orientation. In addition, a model developed from samples of these houses to simulate by using ENERGY-10. It concluded that the energy efficiency methods minimized the total annual energy by 38% comparing to a code standard home while the 220 oriented-PV reduced the peak energy demand by 62% comparing to the standard building code.

Norton B. (2011) Hasan &. Sumathy (2010) investigated enhancing the performance of building integrated photovoltaic through a literature review. It concluded from the literature review that hybrid PV/T system is compatible with cold climate regions. There is a large amount of research that still needs to be undertaken in terms of design aspects to improve the PV system before implementation. On the other hand, it has found that the optimal design of PV/T systems could provide buildings with 100% renewable electricity and heat. Moreover, it concludes that the cost of the BiPV system could be less by reducing the PV module and elements of manufacturing, installation, operation, and maintenance costs. Although the maintenance and operation costs can be minimized by utilizing more reliable systems and equipment.

Taleb & Pitts (2009) and Radhi (2010) explored the potential of adopting integrated photovoltaic in the Gulf countries. The papers looked at the possibility of using BiPV systems in GCC (Gulf Cooperation Council) countries. The paper determined the current situation of using BiPV in these countries and the ability to develop this technology in the future. It also discusses and analyzes the data that was obtained from questionnaires and interviews to recommend expanding the practice in this field in order to improve the image of BiPV technology in GCC countries. It concluded that the period of achieving these objectives in the GCC area could be more than 20 years away unless the governments encourage and support the stakeholders to enhance choices in the future.

While Radhi (2010) investigated the variation of the total energy used through building integrated photovoltaic system as wall cladding in United Arab Emirates. The study focused on the ratio between the PV output comparing with saving energy due to the use of PV panels.

The research determined the embodied energy of PV façade that was defined as energy input including energy used for the production and installation of the system. The PV output examined through a select case study of office buildings that could be more correspondent to apply a PV system in the future. The case study contained three floors with an area of approximately of 4075 m2. The building is supplied with air conditioning and a constant central heating and ventilation system (HVAC). The main construction is steel frame, concrete floors, stucco cladding, and flat roof with concrete slab that is covered by roofing tiles. As mentioned in the study, the PV panel depends mainly on location. The study chose three cities in which to locate the case study: Al Ain, Abu Dhabi and Dubai, each city having longitude, latitude, and sea level with different temperatures and relative humidity. The study used Energy-10 software, which is able to model and simulate the performance of PV systems in two cases--if it stands alone or is integrated with the building. It has been concluded that the use of solar energy in the UAE can be a significant promising renewable energy source which is convenient to the regional environment. The result shows that the reduction in energy in the selected cities was in the range of 1.1 – 2.2% due to the south or north façade that the PV is located on while the cause of the reduction related to the declination in the cooling load and heat gain.

Koyunbabaa, *et a*l (2011) explored the improvements of BiPV performance and Trombe wall system of the façade through an experiment and simulations. A test room was built in the laboratory on the ground floor of Ege University Solar Energy Institute. The room was supplied with a data logger and sensor, while a PV module was integrated on the south façade in order to gain the highest level of solar radiation. A thermal mass was built 0.5m away from the PV. The thermal mass was composed of covering brick, vertical-holed brick, extrude polystyrene, and plaster from outside to inside. The ceiling was covered with extrudes polystyrene and a PV plate. All the components, floors, and ceiling of the test room were well insulated; four PV models used normal power of 27W for each one. The paper aimed to make a two dimensional simulation model of BiPV with a Trombe wall system that ventilated naturally in different conditions and locations. The results of the experiment and the simulations have been compared to increase the validity of both methods. The study concludes that the heat stored in the wall during the day transferred inside the room during the nighttime when the radiation was missing. The experiment and the simulation determined main factors that could affect the BiPV performance such as: locations, climate conditions, inner space, distance, solar cell, vent size, and thermal mass. Consequently, the BiPV system was considered a clean source of energy to provide electricity and heat that led to energy reduction.

Ho Yoo (2011) investigated a sunshade system with a semitransparent solar cell module on a vertical south façade. The simulation model assumes that no shadows were cast by surrounding buildings except the shadows that accrue by the PV panels themselves. The study determines the main factors that should be considered when calculating solar irradiance and power generation, which are:

- The accurate calculation of irradiance on the module
- The calculation of the over surface temperature of the solar cell module
- All other aspects such as: shading, reflectance of the ground, wall, and transmittance of the upper panel, which should be calculated because in some cases it affects the power generation. The main parameters that were highlighted are:
    - Azimuth angle of the building which was changed from 90 to 270, the simulating shows that the most proper orientation for the BIPV generation is south /east 50
    - Angle of solar cell modules, which changed from 15 to 85 the minimum power generated at 25 degrees while the maximum output of BIPV was generated approximately at 55 degrees
    - Albedo of the surface of the earth is changing from 0.2 to 0.6, as the albedo cannot change, while the PV's angle could adjust to amplify the reflected irradiance from the earth's surfaces.

    The paper recommended a long-term simulation in order to optimize a BIPV system. The simulation clarified that computer software could be successfully used to develop a multi function BIPV.

Eltawil & Zhao (2008) explore the grid-connected photovoltaic power systems through technical and potential problems and review. The paper investigates and highlights the importance of a grid-connected PV system and their characterization. The grid-connected solar PV system represents the fastest growing power technology; it records 55% enhancement in cumulative installing capacity. Moreover, half of this annual global increment has occurred in Germany while it increased in Japan by about 300 MW and 70 MW in United States. Figure 2.13 explains the grid-connected photovoltaic power systems. Table 2.2 shows the annual growth of grid-connected photovoltaic power systems from 1996 to 2005.

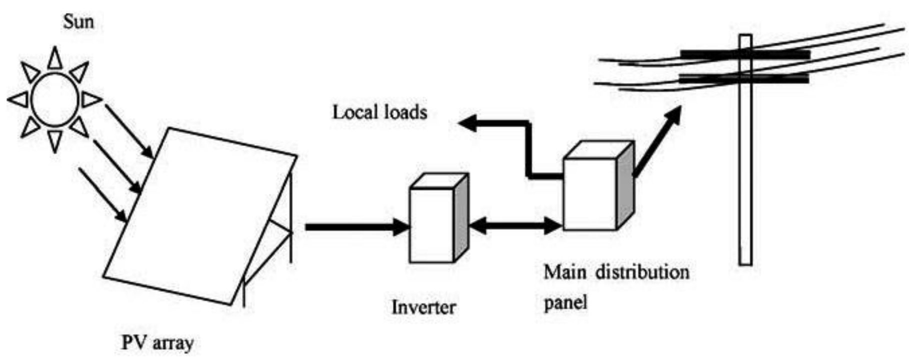

Figure 2.13 Grid-connected PV power technologies with no storage (Eltawil & Zhao 2008)

Table 2.2 The annual growth rate of grid-connecting PV power technologies (Eltawil & Zhao 2008)

Year	Annual growth rate (%)
1996	7.9
1997	21.3
1998	23.5
1999	29.9
2000	41.7
2001	50.4
2002	51.4
2003	55.5
2004	65.9
2005	~75

Penga, Huanga, and Wub (2011) investigated the building-integrated photovoltaic (BiPV) in architectural design in China. BiPV represents the most abundant, inexhaustible and clean technology of the all the available energy renewable resources. It was recommended considering the function, cost, technology, and aesthetics of BiPV systems. In addition, the BiPV should be designed for a building with a photovoltaic structure that can easily replace the components of photovoltaic and provides convenient maintenance.

Mandalaki et al (2012) assess the fixed shading devices, which are integrated with PV for efficient energy use. The study investigates the optimum-shading device that can obtain the balance between amount of daylight and the reduction of cooling and heating loads. Thirteen cases of fixed shading devices have been examined and categorized based on energy performance through physical modeling and computer simulation. The results of the study show that PV integrated with shading devices located in the south façade can efficiently produce electricity. However, shading devices can achieve double efficiency through reducing the cooling and heating loads in addition to producing electricity and controlling the daylight.

2.4 Baghdad, Iraq Climate

According to the climatic report provided by the US Air Force (USAF) to the National Climatic Data Center (NCDC), Iraq has hot, dry summers with high temperatures that sometimes exceed 100F° during summer afternoons while it often remains above 80F° during summer nights. Humidity is usually low except in areas that are closer to the Persian Gulf. Iraq has some extremes in climates, from hot summers to cold winters that usually have low temperatures often remaining above freezing. The rainfall level begins in winter with annual rains averaging 5 inch in the driest desert area. While most of the country has average rains of less than 10 inches per year. Baghdad has the highest average temperature in July of 110 F° and a minimum average temperature of 28F° in January. Winds usually continue to come from the northwest at 5-10 knots all season. Western Iraq has westerly winds. The western desert of the Tigris and

Euphrates valley has northwesterly winds and the remaining eastern part of the country has northerlies.

2.4.1 Climate Analysis by IES-VE Software

Baghdad city has no weather data adopted in the IES - VE software as a result of lack published weather data of Iraq. Kuwait will be used as the nearest referencing point. Statistical weather has been extracted from IES-VE software. The weather database illustrates the temperatures over the whole year in Baghdad. Figure 2.14 shows the hottest months are July and August when the temperature records more than 45 C° and sometimes hits 48 C°. While it can range 10-20 C° during the winter, it could be less than 10 C° on some days.

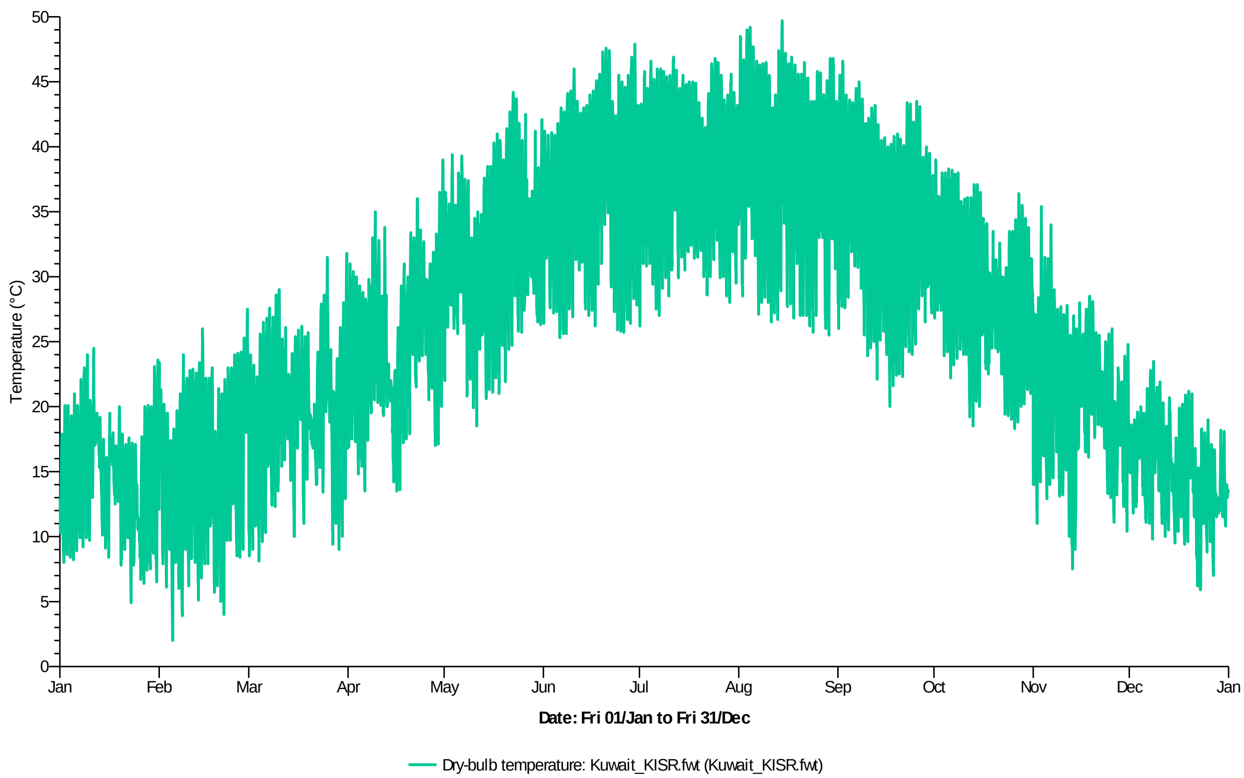

Figure 2.14 Annual temperatures of Baghdad (IES-VE weather database)

The humidity in Baghdad is low compared to closer areas in the Persian Gulf. The software adopting Kuwait as a reference point to analyze the weather data of Baghdad shows the humidity in Figure 2.15. It should be less in Baghdad since it is located in the middle of Iraq far away from the Persian Gulf. The graph shows that the humidity will be between 10 -20 % in the summer time while it will be higher in winter.

The analysis of the weather data shows that the direct solar radiation is high over the whole year. It reaches up to 950W/sqm. Figure 2.16 shows the amount of direct radiation that occurs in the area for a whole year. The diffuse radiation shown in Figure 2.17 gives an indication that it's also high and ranges between 200 - 800 W/sqm.

Wind speed and direction have been shown in Figures 2.18 and 2.19 The prevailing wind comes from the north west 5-10 knots on average over all season.
The analysis of the sky cover shows that the skies are normal everywhere in Iraq. Clear or nearly clear skies prevail over much of Iraq by mid-May. Figure 2.20 shows the cloud cover over the whole year.

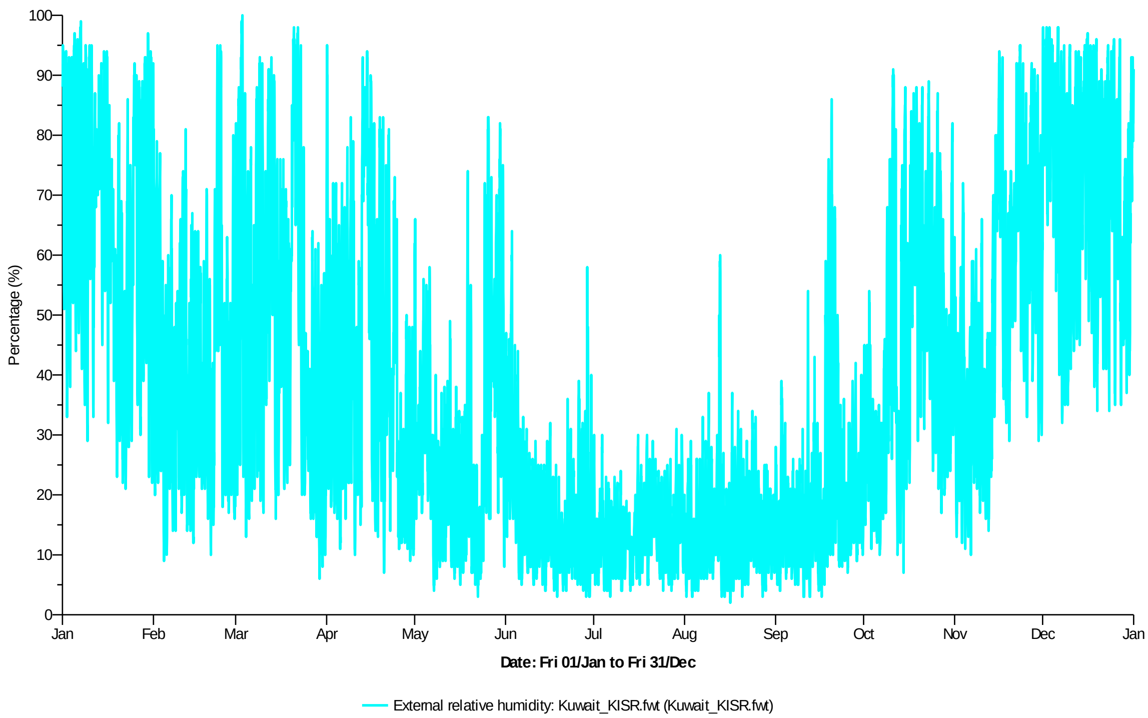

Figure 2.15 External relative humidity data (IES-VE weather database)

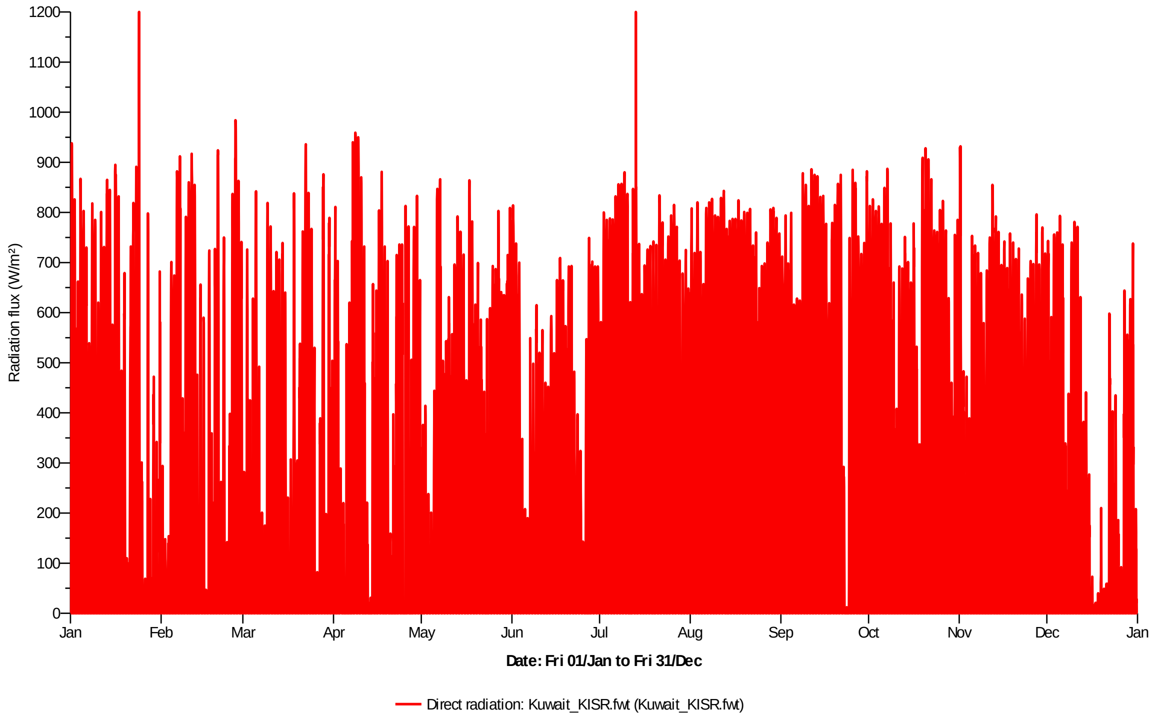

Figure 2.16 Direct radiations data (IES-VE weather database)

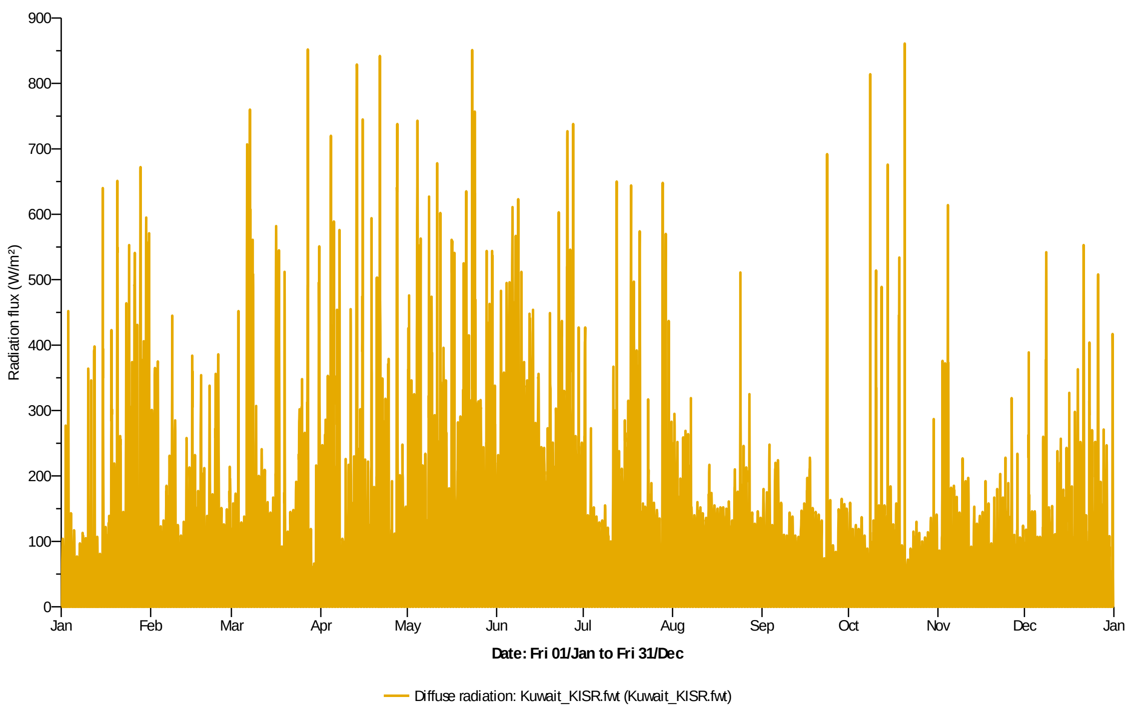

Figure 2.17 Diffuse radiation data (IES-VE weather database)

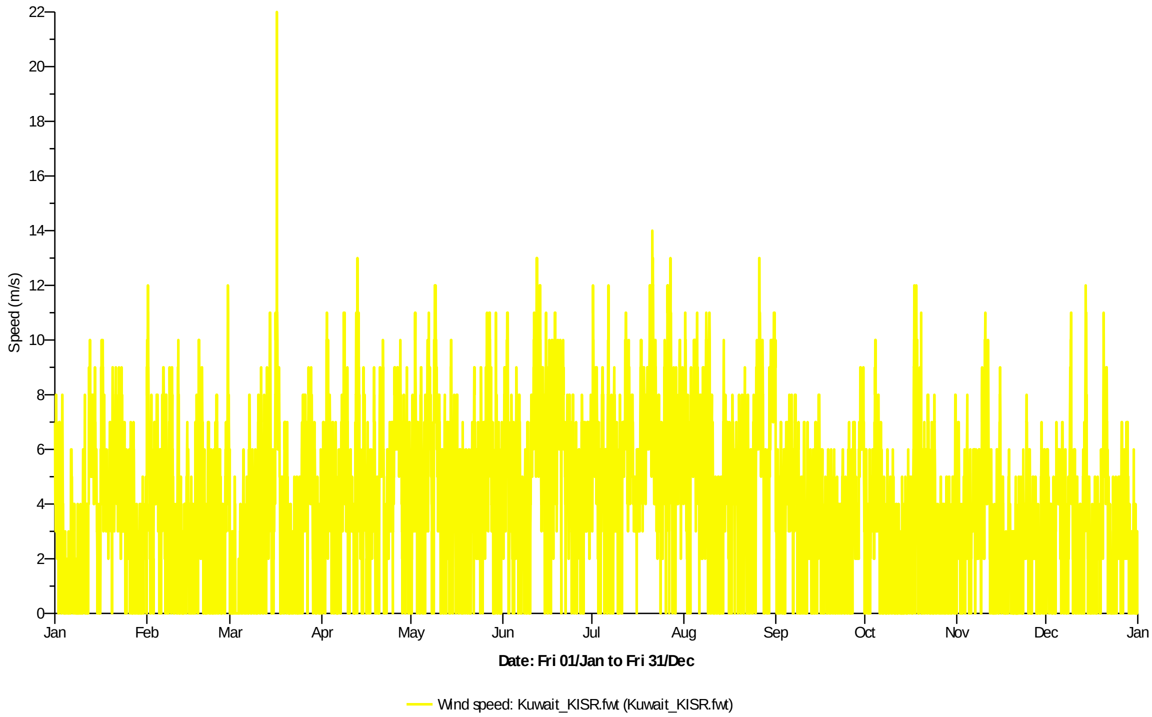

Figure 2.18 Wind speed data (IES-VE weather database)

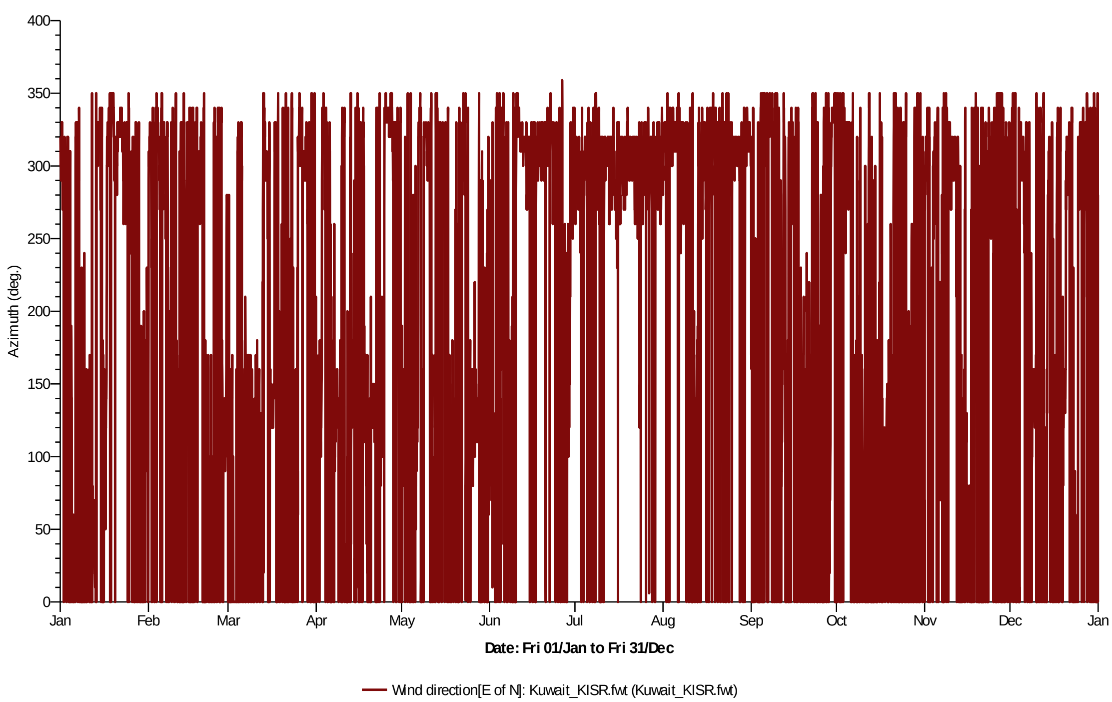

Figure 2.19 Wind direction data (IES-VE weather database)

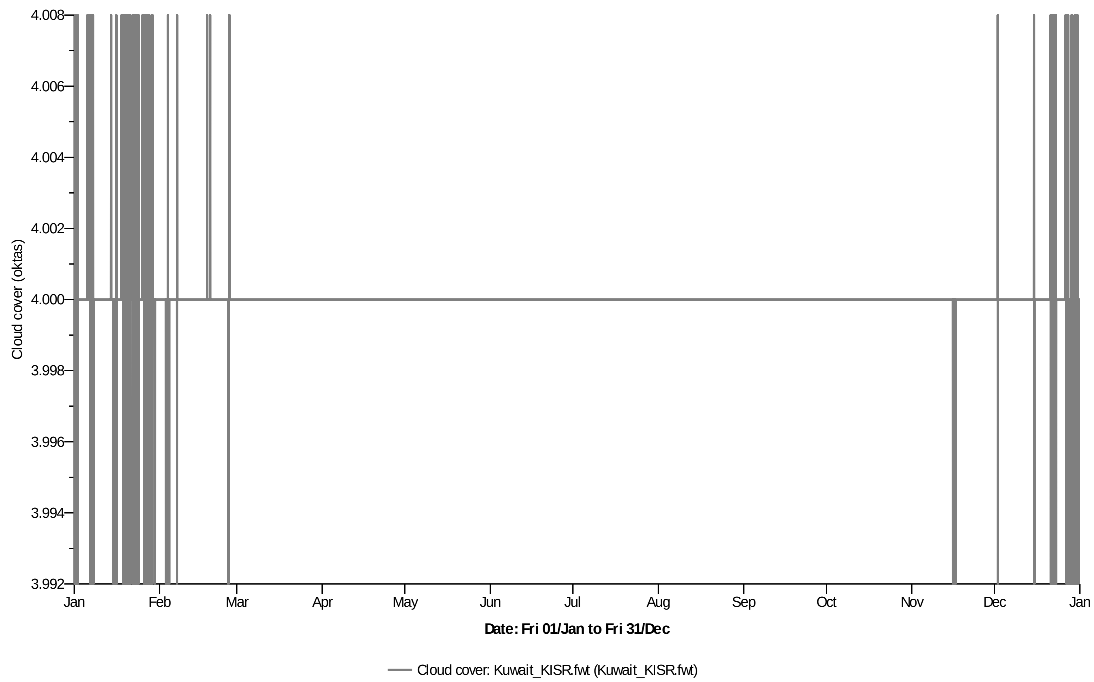

Figure 2.20 Cloud cover data (IES-VE weather database)

2.5 Energy Demand in Iraq

Although Iraq is a rich country with huge oil reserves, it still suffers a shortage of electricity. According to the United States Energy Information Agency 2013 (USEIA) since the postwar period from 2003 to 2012 Iraq has struggled to achieve its energy demand. Iraq has been importing electricity from Iran and Turkish electrical floating power plants, which are available in the Persian Gulf. In addition, privately-owned generators have been widely used especially in Baghdad City which has an additional 1GW of capacity.

The increased electricity demand is related to many reasons, such as the growing economy and the super fast purchase of electronics and appliances. The second reason is that electricity is subsidized in Iraq, which leads to an increasing demand. The lack of electricity reaches the peak in summer considering the high temperatures, which reach to more than 48C degrees in July and August. This unacceptable situation increases the morbidity and mortality in Iraqi society. For more than 20 years, the Iraqi people have been suffering due to a lack of electricity. Nowadays Iraqi people can have electricity from private generators with high cost, but they have limited power with no safety or security features. In addition, these private generators are operated by unskilled labor and without any control of a governmental authority.

2.6 Problem Statement

According to the Ministry of Electricity, Iraq has only generated 8,000 megawatts while the current required power is rising to 13-15,000 megawatts. Figure 2.21 shows the amount of demand and supply of the grid. According to the International Agency Information and Analysis Unit (IAU) in July 2010 electricity in Iraq Factsheet - UN, households were receiving just eight hours of electricity per day in 2007.

The United Nations Development Program (UNDP) noted that the electricity supply has since deteriorated in some areas, especially Baghdad. The northern part of Iraq (Kurdistan region) has achieved some improvement. Since 2003 the public approval of electricity demand has never reached over 39% even during low demand periods.

Many families are forced to support their houses with expensive communal and private generators. The electricity problems in Iraq are widespread. Figure 2.22 shows the electricity that is received from the public network and the use of a secondary electricity source in the whole country.

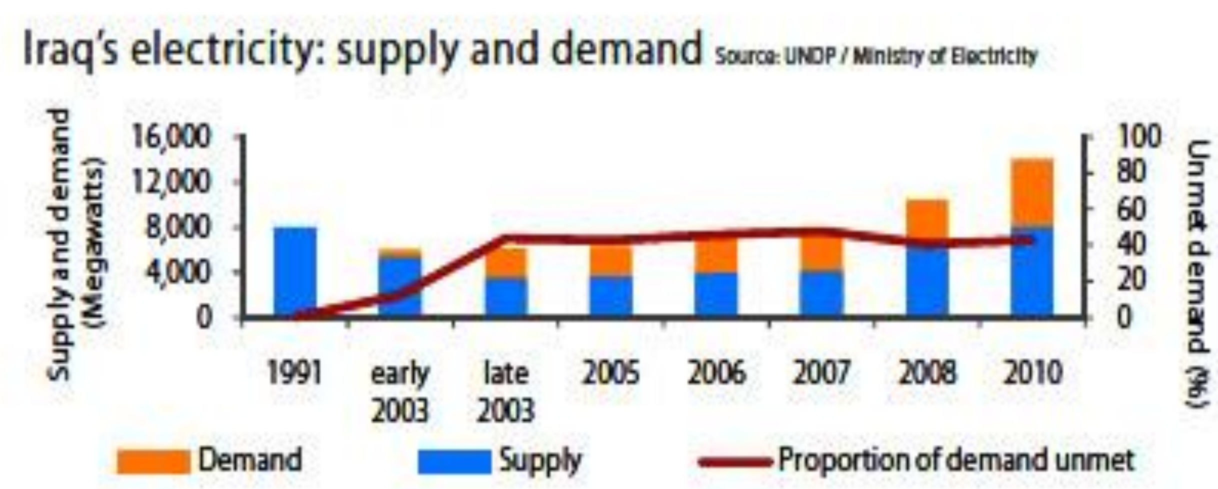

Figure 2.21 Proportion of electricity supply and demand in Iraq, United National Development Program/ Ministry of Electricity (International Agency Information and Analysis Unit (IAU) in July 2010, electricity in Iraq fact sheet)

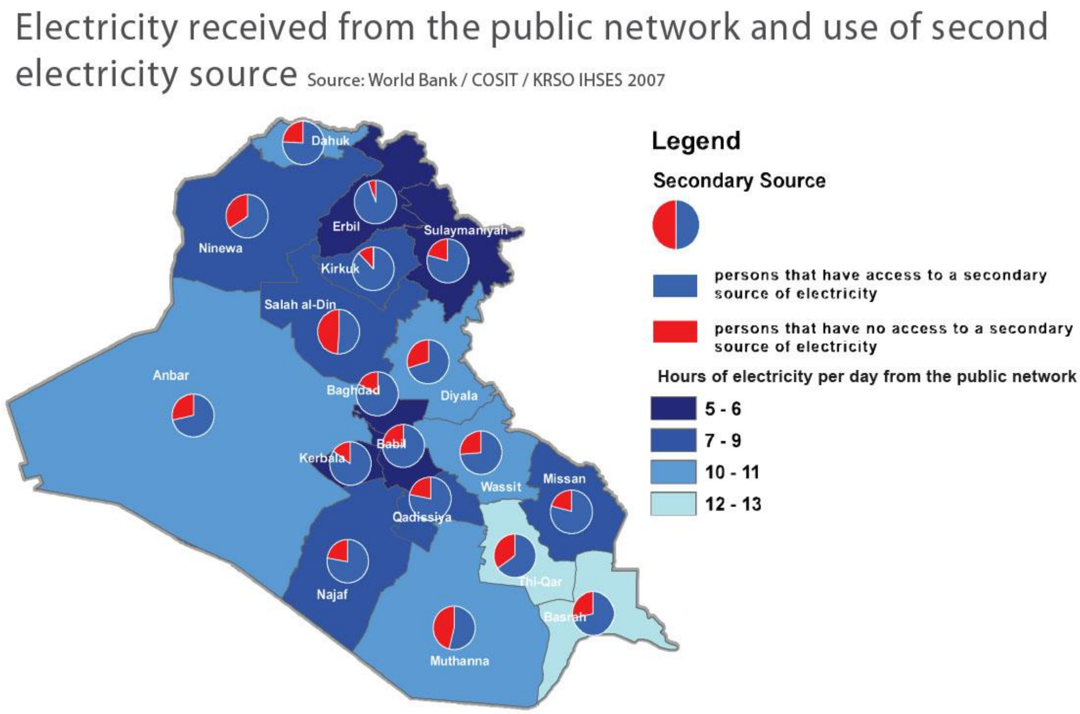

Figure 2.22 Electricity supply by the public grid and private electricity source, World Bank 2007 (International Agency Information and Analysis Unit (IAU) in July 2010, electricity in Iraq fact sheet)

Observations done by the author in July 2012 associated with the facts that have been mentioned above create the outline of the problems which are highlighted as follows:

- Electrical power disconnects for several hours daily
- Private electricity generators are located between the residential zones and operated by unprofessional laborers as shown in Figures 2.23 and 2.24
- Electricity connection cables have been added randomly without any level of safety and security as shown in Figures 2.25 and 2.26
- Although, many families depend on these private generators, the amount of energy provided is very limited and it could not cover the actual demand of each house.
- Almost every house should apply a converter in order to switch from grid electricity to private electricity. This device could be damaged continuously and should be replaced by another one which cost money and effort as shown in Figure 2.27.

- Many Iraqi families could not apply the electricity for their houses because of lower income.

Figure 2.23 Private electricity generator in the middle of the residential area which is run by unprofessional labourers in Baghdad (July 2012 taken by the author)

Figure 2.24 Private generators without any level of safety and security (Baghdad July 2012 taken by the author)

Figure2.25 Electricity connection cables have been added randomly without safety and security (Baghdad, July 2012 taken by the author)

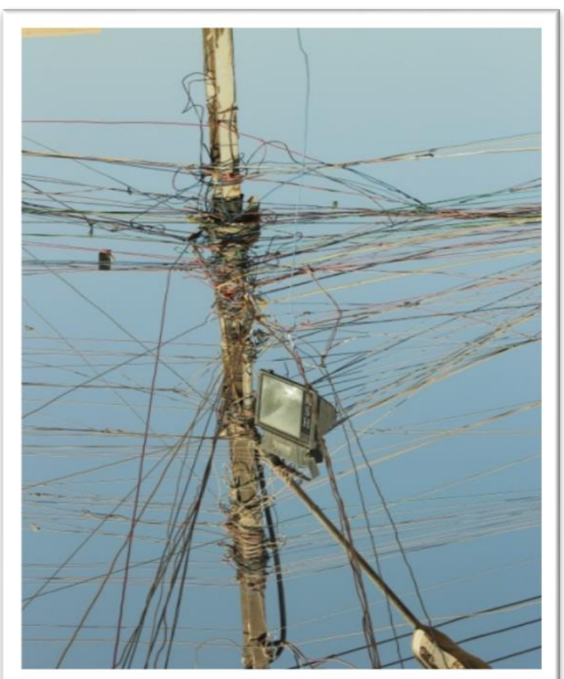

Figure 2.26 Electricity connection cables have been added randomly without safety and security (Baghdad, July 2012 taken by the author)

Figure 2.27 The converter which should be installed in each house (Baghdad July 2012 taken by the author)

2.7 Renewable Energy and PV Development in Iraq

A.Kazem and Chaichan (2012) investigated the status and future prospects of renewable energy in Iraq. It has been noted that Iraq suffered from electricity shortage for several years. This lack of electricity creates a big challenge in adopting another alternative such as renewable energy.

The population in Iraq has increased from 14 million in the 1980s to 32 million in 2010; it estimates 64 million by 2050. Although Iraq has ranked tenth in the world with regard to natural gas, it also has many other raw materials. However, it still has a big gap between the electricity demand and production as seen in Figure 2.8. After 1973, many solar researchers started to investigate the amount of solar intensity in Baghdad. The study illustrated that Iraq received more than 3,000 hours of solar radiance per year while Baghdad proper has an hourly solar intensity averaging between 416 W/ m2 in January to 833W/m2 in Jun.

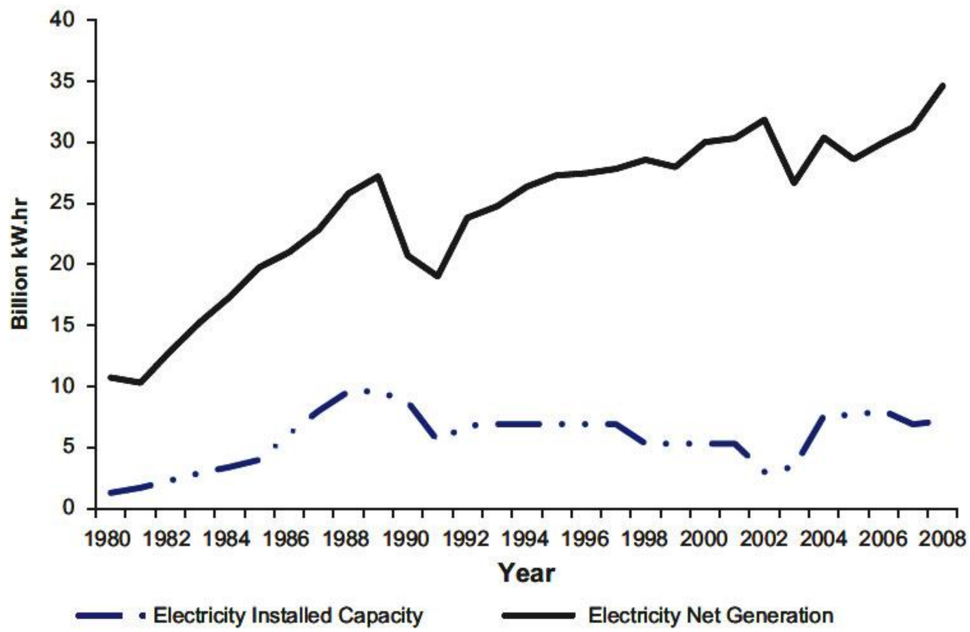

Figure 2.8 Electricity demand and production in Iraq until 2008 (Kazem and Chaichan 2012)

According to the distribution of solar radiation all over Iraq, it has been found that adopting PV technology is suitable for significantly achieving electricity production. On the other hand, the impact of high air temperatures and dust on the PV efficiency has also been considered. It has been recommended that investigating the type, the rate of accumulation, and the density of the dust is in order to provide a good solution in the future. Finally Kazem and Chaichan noted that the government should support and implant many projects of renewable energy in order to improve these technologies in the future.

Dihrab and Sopian (2010) & Karaghouli and Kazmerski (2010) explored and investigated the practical use of PV systems in rural Iraq. Dihrab and Sopian (2010)

proposed a PV and wind systems to be examined and simulated through MATLAB solver software. A hybrid system combining the solar and wind technologies was proposed and simulated in three different zones in Iraq.
It concluded that the solar and wind energy are suitable for Iraq to generate enough electricity for some villages in rural areas.

Karaghouli and Kazmerski (2010) also address the need for renewable energy to be used in Iraq. The study proposes a photovoltaic (PV) system to power a health clinic in a rural area. An estimation of the system size and its lifecycle cost has been done by computer model (HOMER). The results show that using a PV system is justified on economical, technical and humanitarian grounds.

2.8 Aim and Objectives

From the literature review, the aim of this dissertation is focused on investigating the impact of applying passive and active strategies on energy performance and savings. This study provides a valuable contribution to the academic knowledge about passive and active strategies to fill the lack of information and implementation.
. While the objectives of this research are:

1- Examine the effect of different shading devices on cooling loads and energy performance
2- Examine different U-Values for roof and walls through adding insulation materials
3- Examine different values of Glazing Solar Heat Gain Coefficient (SHGC) and its''' impact on energy performance and savings
4- Examine the impact of using different installations area for Solar Domestic Hot Water SDHW on energy performance, boiler load, and PV production
5- Estimate the proper configuration for a PV based on the highest rate of power production through the following parameters:
   - Orientation (azimuth and tilted angles)
   - Area for Installing PV
   -Type of PV cells based on level of efficiency

6- Evaluate the energy performance of each scenario based on the following:

   -Total annual energy consumption and savings

   - Chiller load reduction

   - Total annual energy production of PV and reduction of grid demand

7- Providing recommendations according to the results of the simulations

Chapter 3

Methodology

3.1 Introduction

This chapter illustrates different methodologies, which can be used to evaluate the passive and active strategies of energy consumption. The pros and cons of each methodology will be highlighted in order to justify the selection methods for this research. Extensive studies were conducted to investigate and evaluate the impact of adding different types of passive and active strategies on energy performance and savings.

3.2 Defining research parameters

This research investigated the potential reduction of electricity demand by adopting several scenarios of passive and active strategies. Energy consumption will be the major output results that will be covered in this study. Modules of typical houses that exist in Baghdad, Iraq, will be created to examine the entire research. Many variables will be explored with different configurations evaluating the energy performance and savings. Two groups will be established which are passive and active and each one has different variables as follows:

Passive strategies:

- The dimension and location of the shading devices due to facing north or south
- The U-Values of the construction element (adding insulation materials for roof and wall)
- The Glazing Solar Heat Gain Coefficient (SHGC) values

Active strategies:

- The Coefficient of Performance (COP) of air-condition systems
- Different area of solar domestic hot water (DHW) will be examine to evaluate the impact on total annual consumption and PV output power
- The orientation and the tilted angle of PV panels based on energy production
- The available area for installing PV on their output power
- The Type of PV cells based on the level of performance (Monocrystalline Silicon, Polycrystalline, Amorphous Silicon, and Thin Film)

All these parameters will be evaluated separately according to their impact on energy performance and savings over the whole year. In this part of the study various methodologies will be demonstrated in order to establish a basic understanding of the most suitable selection methods for this research.

3.3 Type of Methodologies

Enormous research has been conducted to investigate the effect of passive and active strategies. Each paper has determined different parameters according to the type of method and the topic that has been investigated. Several research methodologies have been conducted to provide similar output data that was required to achieve the goal of this study. These methodologies are: experimental method, literature review, and simulation method. Sometimes the paper used a combination of two methods in order to have results that were more accurate.

3.4 Experimental Studies

Cabeza *et al* (2010) and Al-Homoud *et al* (2009) explored the potential energy performance and savings through an experimental method investigation. Cabeza *et al* (2010) used a field experiment in which several cubicles were constructed and instrumented to assess the real thermal transmittance of a wall in two different seasons. The results show the monthly energy consumption and provide a comparison between the insulation materials according to thickness, density, thermal diffusivity, and thermal conductivity. Figure 3.1 shows cubicles built as per the typical Mediterranean building style so that strategies could be tested using different insulation materials.

Al-Homoud *et al* (2009) used a field experiment based on monitoring three selected mosques over a specific period of the year in order to assess the quality of thermal comfort and energy consumption in peak occupied time that was determined by the prayer schedule. The study investigates the acceptable level of thermal comfort and the energy consumption in terms of an HVAC system operated and its efficiency in hot, humid climates. According to the observation, the recorded data of the main parameters, which are temperature and humidity, gave an accurate assessment level of thermal comfort for each case. A total of fifteen temperature and humidity data loggers have been tested and installed in the columns or walls in each mosque. They were placed 1m from ground level in order to consider the standing or seating situation of the occupants. The data was recorded every five minutes in order to assess thermal comfort especially during prayer time and its impact on energy performance.

Figure 3.1 Cubicles built as typical Mediterranean building strategies tested different Insulation materials (Cabeza *et al* 2010)

Kumar and Suman (2013) & Stazi et al (2013) used an experimental method to evaluate the impact of insulation material in walls and roofs on energy consumption and indoor thermal comfort. Kumar and Suman (2013) focused on measuring the thermal conductivity of insulation material by Automatic Guarded Hot Plate Apparatus that is shown in Figure 3.2

Stazi *et al* (2013) used the contemporary monitoring of three residential multi-story buildings. The experimental method combined with Dynamic Parametric Analyses (EnergyPlus,CFD Fluent) were carried out in order to verify the impact of different retrofit solutions and identified the optimal thermal insulation strategies.

Sadineni *et al* (2012) investigated the impact of PV orientation at the peak load of the building through field monitoring and modeling approaches. In order to do that, the study developed approximately 200 homes to study substation level peak reduction strategies. Fifty homes are already built and occupied with temperature and power measurement sensors installed in several homes to determine the energy performance of the buildings. The paper focuses on monitoring the energy performance of buildings due to PV direction, which mainly depends on building orientation.

Figure 3.2 Automatic Guarded Hot Plate Apparatus (Kumar and Suman 2013)

Koyunbaba (2011) used an experimental method and simulation to improve the performance of BIPV Trombe wall to the façade. A test room has been built in the laboratory on the ground floor of Ege University Solar Energy Institute, the room supplied with data logger and sensor, while a PV module was integrated on the south façade in order to gain the highest level of solar radiation. A thermal mass was built 0.5 m away from the PV.

3.4.1 Pros and Cons of the Experimental Methods

It's very clear from the previous section that the experimental methods mainly depend on creating and testing a real mock-up under real conditions. These mock-ups are different according to surrounding circumstances that could be determined by using the laboratory or field experiment. The equipment that could be used in this method includes: sensors and a data logging system, which records and transfers information to the computer as in some cases the method requires the need to design and implement a model to test passive and active strategies. In many cases the experimental method coupled with other methods needs to be supported.

Thus, the advantage of the field experiment is the reality of the result and the consideration of actual weather and conditions. On the other hand, the field experiment requires an existing building or samples. Passive and active design strategies need to be evaluated during the design phase in order to make modifications or adjustments in order to achieve the purpose of passive design.

On the other hand, a field experiment needs to be constructed, instruments installed, monitored over a period of time, while consuming effort, time and cost. In addition, the monitoring systems and sensors could have some errors, which affect the accuracy of the results.

Also, the circumstances of the experiment should be similar to the required conditions in order to achieve accurate results.

3.5 Literature Review Studies

Arif Hasan and Sumathy (2010) use a literature review to investigate and cover PV/T photovoltaic thermal from different aspects, primarily electrical performance and thermal output. The study covered the development of PV. In addition, it focuses on different devices of PV such as: liquid PV/T collector, air PV/T collector, ventilated PV with heat recovery, and PV/concentrator. The study also covers the PV performance analysis that includes: theory of PV modules, analytical models of PV, modeling and simulation and experimental work.

Norton *et al* (2011) used a literature review to explore the efficient and the economical aspect of BiPV. The study focused on the range of improvements that included inverters, concentrators, and thermal management systems. It also reviewed the cost of the BIPV system that could be less by reducing the PV module and elements of manufacturing, installation, operation, and maintenance costs.

Taleb and Pitts (2009) summarise that renewable forms of energy is important throughout the world, in order to develop and promote suitable energy policies for the future it is necessary to gain an understanding of stakeholder views in all countries, including those with substantial fossil fuel reserves. The volume of construction work in the Gulf Cooperation Council (GCC) countries had recently been at unprecedented levels, with a huge environmental impact from construction and also from potential future energy demands. The outcomes of the research's questionnaires and interviews to investigate the possibility of using BiPV systems in GCC (Gulf Cooperation Council) countries. The paper determines the current situation of using BiPV in these countries and the ability to develop this technology in the future.

3.5.1 Pros and Cons of Literature Review Methods

This method depends on the previous research that investigated passive and active strategies performance and their impact on energy consumption and savings. This method could not achieve accurate data since it was not practically involved in the process of obtaining the results. Thus, it has a limitation of use, as it could not achieve all types of analysis unless it was combined with another method in order to become more credible.

3.6 Modeling and Simulation Studies

Zhai *et al* (2011) used Energy Plus to assess the accuracy and usability of simulation for natural and hybrid ventilation for real buildings and compared it with measurement data. Furthermore, the study focuses on the measurement data that are critical for an accurate validation of thermal–ventilation models which included field-measured temperature. The methodology of this paper depends on Energy Plus software, which is an energy analysis and thermal load simulation software based on physical make-up. This program is able to calculate the cooling and heating loads and simulates the operation of HVAC systems.

The study chose three different buildings with many parameters including; floor area, height, ceiling U-value, glazing specification and façade ordination, loads of lighting, equipment, and occupancy.

Al-zoubi and Al-Zoubi (2010) investigated the façade performance and energy consumption through using Lightspace software. The simulations examined the effect of shading devices positioned on the propagation of light and vision in a space.

The results from the computer simulation and logarithmic analysis showed a great instance of correlation between the locations of shading devices and the light distribution in those spaces.

Kima et al (2011) explored the thermal performance of exterior shading devices in residential buildings using Integrated Environmental Solutions-Virtual Environment (IES-VE) to assess the most appropriate shading device systems' position in order to achieve thermal performance in residential buildings. The main goal of the study was to examine the wide variation of both an experimentally designed exterior shading device and conventional one in terms of heating, cooling, and energy consumption. IES-VE is a performance analysis software that allows architects and engineers to offer quantitative feedback with an integrated collection application that can easily be linked by a single integrated data model and a common user interface. The IES program coupled with a green building concept can use 30% less energy than conventional buildings.

Ho Yoo S. (2011) theoretically studied and used a simulation of SOLCEL software to investigate the optimal application of BiPV through various parameters on a vertical south façade. The parameters that were simulated were azimuth angle and angle of solar cell modules. The paper recommends a long-term simulation in order to optimize a BiPV system, and clarify that SOLCEL could be successfully used to develop a multi function BiPV. It also found that the results of the simulations had a good record when it was compared with the experimental information.

Hamza (2008) investigated the double versus single skin facades in hot, arid areas through using simulation by IES-VE. This paper studied the impact of a double skin facade on cooling loads in an office building with a hot, arid climate. It shows a comparison between an optimized single facade and an optimized double skin facade based on a case study that was located in Cairo, Egypt, which matched a typical hot, arid climatic profile. IES-VE can generate data that are suited for thermal analysis, solar shading, HVAC systems, and natural ventilation. Many parameters affected the simulation results, such as building construction, HVAC systems, natural ventilation, and occupancy patterns. All these parameters have been tested with the ASHRAE standard. The simulation gave results that are accurate and matched the actual data.

Hammad & Abu-Hijleh (2010) investigated the impact of external dynamic louvers on energy performance and savings in an office building located in Abu Dhabi with IES-VE software. The simulation explored different configurations in order to evaluate the efficiency of dynamic louvers for the case study. The study examined the different orientation of the lovers due to south, east, and west. In addition, the research adopted the use of light-sensor light dimmers in order to be compared to the use of dynamic facades.

3.6.1 Pros and Cons of Modeling and Simulation Methods

It is clear from the discussion above that the computer simulation methodology can achieve many advantages such as: the flexibility to provide measurement at any time and any season of the year. It also can change the parameters easily with limited time. Comparisons can be done in many cases or comparing with the standards. The simulation can be run several times in order to be sure of the accurate results. In addition, the modeling of the building can easily be done with minimum time and effort under different weather data and locations. Thus, the scale and orientation can be changed at any stage of the simulation. On the other hand, the computer simulation still has validation problems and inaccurate results while applying the weather data or during the modeling stage. According to Zhai *et al* (2011), the inherent uncertainty of the program can affect the result of the research. It also seems that some studies have many parameters that cannot be controlled through computer simulation.

3.7 The Selected Methodology

Nowadays a simulation method is the most widely used in order to investigate the passive and active strategies and their impact on energy performance and savings. Different types of software can be adopted to simulate passive and active strategies that are mentioned through the previous section and summarized as follows:

Hamza (2008) investigates the double versus single skin facades in hot, arid areas using simulation by IES-VE software.

Dihrab and Sopian (2010) investigate the proposed PV system and wind to be examined and simulated through MATLAB solver software.

Karaghouli and Kazmerski (2010) used the computer modeling HOMER to study a photovoltaic (PV) system in order to power a health clinic in a rural area.

Hammad and Abu-Hijleh (2010) use IES-VE to investigate the impact of dynamic external louvers on energy savings.

Al-Zoubi and Al-Zoubi (2010) used Lightspace software to investigate façade performance and energy consumption.

Kima et al (2011) explored the thermal performance of exterior shading devices in a residential building using IES-VE to assess the most appropriate shading device systems. The study concluded that an IES program coupled with green building can use 30% less energy use than conventional buildings.

Mandalaki et al (2012) assessed fixed shading devices, which were integrated with PV for efficient energy use through physical modeling and computer simulation.

Yasar and Kalfa (2012) used DesignBuilder software to investigate the impact of glazing on energy efficiency and cooling and heating load climate.

Ballarini and Corrado (2012) used DesingBuilder software to investigate the impact of insulation materials on cooling and heating loads and energy performance.

Sadineni (2012) used field monitoring and modeling approaches to investigate the Impact of roof-integrated PV orientation on the peak demands of electricity.

Shameri (2013) used IES-VE to investigate the impact of double-skin facade to increase human comfort and decrease energy consumption.

According to the research parameters that are mentioned in section 3.2, it seems that modeling and simulation are the most suitable methods that support research to achieve its goal.

According to Attia *et.al* (2010) ten different Building Performance Simulation (BPS) tools were justified by architects, designers, educators, and students. The comparisons were done accordingly: Usability and Information Management (UIM), second; the Integration of Intelligent Design Knowledge Base (IIKB), and third, the development of Graphical User Interface (GUI).

IES-VE software has been ranked to have 85% comparing with nine other selected software programs as shown in Figure 3.2. The strength of IES-VE has been related to its user friendly GUT. Further IES have been offered creating templates, selecting default values, facilities data entry, and thermal performance analysis. All these characteristics can provide a quick consideration in the early design phase in order to increase the awareness of detailed analysis.

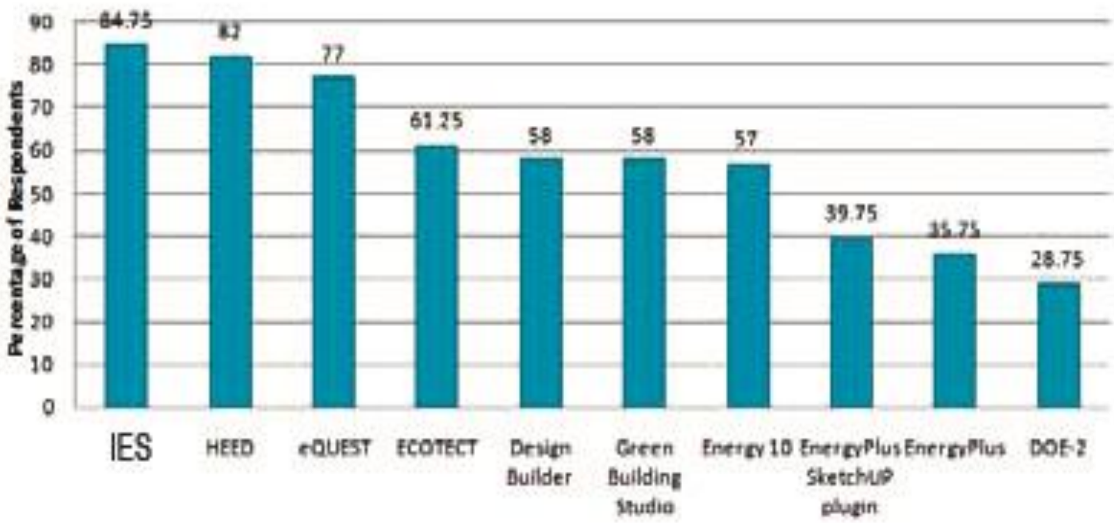

Figure 3.3 IES Ranked as the best ten software simulations (Attia *et.al* 2010)

Crawley *et al* (2008) contrasted the capabilities of building energy performance simulation programs.

Twenty major building energy simulation programs have been reviewed and compared to assess their features and capabilities. These comparisons are based on data collected by the program developer.

The evaluation of the program was based on the following categories: day lighting, solar radiation, general modeling features, zone loads, building envelope, renewable energy system, electrical systems and equipment, ventilation, HVAC system, environmental emissions, economic evaluation, climate data availability, validation, and user interface. Table 3.1 provides an assessment of twenty programs based on zone load analysis. The paper defined the IES-VE as the integrated suite applications that include the following modules:

- ModellT - used to create geometry and edit it
- ApahceSim - used to obtained thermal analysis

- ApacheCalc- used to analyze loads
- Apache HVAC - component based HVAC
- SunCast used to analyze shading and visualization
- MacroFlo - used to analyze natural ventilation
- MocoFlo- 3D computational fluid dynamics
- FlucsPro/Radiance used for lighting design
- DEFT Model optimization
- Simulex - building evacuation
- Lifecycle - life-cycle energy and cost analysis

Table 3.1 Comparison of the 20 software programs according to zone loads (Crawley *et al* 2008)

	BLAST	BSim	DeST	DOE-2.1E	ECOTECT	Ener-Win	Energy Express	Energy-10	EnergyPlus	eQUEST	ESP-r	IDA ICE	IES <VE>	HAP	HEED	PowerDomus	SUNREL	Tas	TRACE	TRNSYS
Interior surface convection																				
• Dependent on temperature	X	X					P		X		X	X	X		X	X	X	X		X
• Dependent on air flow	X						X		P		X		X		X			X		E
• Dependent on surface heat coefficient from CFD									E		E		X							
• User-defined coefficients (constants, equations or correlations)		X	X	X	X				X		E	R	X		X	X	X	X		X
Internal thermal mass	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
Automatic design day calculations for sizing																				
• Dry bulb temperature	X	X	X	X	X	X	X	X	X	X		X	X	X	X	P		X	X	
• Dew point temperature or relative humidity			X	X		X	X		X	X		X	X	X				X	X	
• User-specified minimum and maximum			X	X		X	X		X	X		X	X	X	X			X	X	
• User-specified steady-state, steady-periodic or fully dynamic design conditions			X									X	X	X				X	X	X

X feature or capability available and in common use; P feature or capability partially implemented; O optional feature or capability; R optional feature or capability for research use; E feature or capability requires domain expertise; I feature or capability with difficult to obtain input.

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According to the Table below IES-VE provides many features that can analyze loads of the zones. Table 3.2 shows the evolution of IES-VE according to the renewable energy system analysis.

Jenkins *et al* (2013) defined IES-VE as a dynamic simulation software that is widely used in the construction sector. The advantage of IES-VE is that the calculations can be performed hourly, which provide more accurate data. The modeling phase can be applied using different shapes of buildings with CAD-compliant user-interface.

Table 3.2 Comparison of the 20 software programs according the HVAC system and renewable energy (Crawley *et al* 2008)

	BLAST	BSim	DeST	DOE-2.1E	ECOTECT	Ener-Win	Energy Express	Energy-10	EnergyPlus	eQUEST	ESP-r	IDA ICE	IES (VE)	HAP	HEED	PowerDomus	SUNREL	Tas	TRACE	TRNSYS
Renewable Energy Systems (12 identified, X+O)	1	2	2	1	4	0	0	2	4	2	7	1	3	0	0	1	2	2	0	12
Idealized HVAC systems	X		X		X	X			X		X	X	X				X			X
User-configurable HVAC systems		X	X				P		X		X	X	X	X	X	X	R	X	X	X
Pre-configured systems (among 34 identified, X+O)	14	14	20	16	0	16	5	7	28	34	23	32	28	28	10	8	1	23	26	20
Discrete HVAC components (98 identified, X+O)	51	24	34	39	0	24	8	15	66	61	40	52	38	43	7	15	3	26	63	82

X feature or capability available and in common use; P feature or capability partially implemented; O optional feature or capability; R optional feature or capability for research use; E feature or capability requires domain expertise; I feature or capability with difficult to obtain input.

It is seen from research papers that adopting IES-VE software, simulation can achieve the purpose of the research at different rates depending on the data and the simulation modeling in order to provide realistic results. The efficiency of the program depends on the ability of this program to have fully integrated modeling and analysis to provide accurate results. Passive and active design strategies need to be simulated several times before it is confirmed and implemented. It also can cover all the parameters that determine building performance and energy consumption.

3.8 Integrated Environmental Solutions- Virtual Environment (IES-VE)

The IES Virtual Environment software is a performance analysis software that allows architects and engineers to offer quantitative feedback. It provides an integrated collection application that can easily be linked by a single integrated data model and a common user interface. According Kima et al (2011) the IES program coupled with a green building concept can use 30% less energy than conventional buildings. In addition, it assists in showing the LEED and BREEAM regulation and producing a UK Energy Performance Certificate.

IES simulation: Model IT is the main phase of the IES which offers a simple way to build a model with a high level of dimension control and locating the opening in professional ways by determining the ratio of the opening. In order to be sure that your model works properly, the 3D model could be checked and modified during the modeling period. On the other hand, the project template can determine all the building details such as the rhythm of occupants, construction materials, type of HVAC, and ventilation. Changing this setting will create different scenarios to be simulated.

SinCast provides different kinds of shading analysis through images, movies, and shading calculations that are used during Apache thermal software analysis. The images that are generated by SunCast give full information about the sun's path and the impact of shading on the building during specific days and times. This is done in order to assess the most appropriate shading device system's position to achieve optimal thermal performance of the building. The results from the simulation provide specific calculations and graphs to determine the external shading device that has the highest level of efficiency.

The IES modeling used to generate data for statistical analysis used Apache Sim to simulate all thermal performance aspects such as solar shading, HVAC systems, and natural ventilation. Apache–Sim simulation generally depends on the shape of the building and the real weather data. The simulation will run for two building models; one without shading and the other with shading to compare the results through the total energy result.

The software IES-VE can obtain results categorized according to each scenario and parametric as follows:

- Cooling load: evaluate the thermal cooling load performance through the results of the simulation for variable parameters such as: location, orientation, the U-Values of constructions elements, the ratio of glazing, and the variation during seasons and daytime. It can also simulate and calculate the sunshade system.

- Energy Consumption: evaluated the total energy of the building, which includes the outcome of electricity for cooling, heating, artificial lighting, and equipment. This evaluation will provide a full image about the most efficient scenario.

- Electricity produced by PV: evaluated and analyzed in terms of the impact of each parameter on the total amount of electricity production and in terms of savings compared with the total energy results. It compares the PV output and energy savings, examines different locations, angles, and types to determine the proper one based on PV electricity production.

More information about IES - VE with details can be obtained from:
http://www.iesve.com/

3.9 IES-VE Software Validation

The computer simulation still has validation problems and inaccurate results when applying weather data or during the modeling stage. According to Zhai (2011), the inherent uncertainty of the program can affect the results of the research. It also seems that some programs have many parameters that cannot be controlled through computer simulation that required it to be coupled with other methods.

Schwartz and Raslan (2013) investigated the variation results of the most popular building energy simulation tools. This data was based on the impact of the software on

BREEAM and LEED rating systems. A case study was selected to examine three of the most widely used that are (EnergyPlus, IES, and Tas) in order to evaluate their influence on BREEAM and LEED rates. The IES-VE software was considered the most popular simulation software that was used as follows:

- Used in 18 out of top 20 consultancy firms
- Used in 19 out of top 20 engineering firms
- Used in 15 of the top 20 architectural design firms in the UK
- Used in more than 80 countries

Enormous researchers have used IES-VE simulations for the investigation of the effect of passive and active strategies on energy consumption and savings such as:

- Hamza (2008) investigated the double versus single skin facades in hot, arid areas through using simulation by IES-VE
- Kima (2011) used IES- Virtual Environment software to investigate the most appropriate configuration of shading device systems in order to achieve thermal performance in a building.
- Shameri (2013) used IES-VE to investigate the impact of Double-skin facade to increase human comfort and decrease energy consumption.
- Katanbafnasab and Abu-Hijleh (2013) used IES -VE to investigate the assessment of energy mpact of using building integrated photovoltaic and electrochromic glazing in an office building in the UAE.
- Hammad and Abu-Hijleh (2010) increased the validity of the IES-VE software by establishing the same basic case by software that is (HAP 4.41). The other model was established by a mechanical engineer in Atkins who adopted the exact same measurement and descriptions. The cooling loads of the basic case during the peak hours in June and December obtained from IES-VE have been compared with the same result that was obtained from (HAP 4.41). The result of the comparison shows that cooling loads obtained by both software programs follow the same trend that increases the validity of the software. This is vital to conduct in similar researches.

- Al Awadhi *et.al* (2013) used IES-VE to investigate the impact of reducing the U-Values on the total energy consumption and savings in five houses that were built from 1974-2012 in the United Arab Emirates.

A comparison was conducted between Case1 (basic case) of the study and the first case (B74) that was investigated by Al Awadhi, *et al*. (2013). It was found that whenever the two cases had a difference in the number of floors and the total floor area, the annual energy consumption per square meter remained similar since both were built in the same period of time and with similar climate conditions.

The energy consumption of Case1 is about 467 kWh/ m2 while the consumption of the basic case for the Al Awadhi, *et al*. (2013) is 480 KWh/m2. Both results, which were obtained by IES-VE, have almost the same value which increases the confidence of the use of the software by the author.

Generally IES-VE validity can be highlighted through the level of reality and the capability of the author to use the software properly. Since the software has been approved by communities and used to evaluate several governmental projects, its validity has been decreased. The capability of another to use the IES-VE has been improved through the following:

-The author attended a training course and seminars that were conducted by IES representatives.

- The software was used to investigate previous research since 2012.
- The author spent more than six month practicing with the software before starting this study.
- The modeling process has been reviewed by an IES-VE technical advisor to assure the input data affects the output results.
- The software templates and input data have been verified by a technical advisor.
- A student's copy has been re-activated on 5th of January 2013, in order to be the main methodology for supporting the topic of this dissertation.

Finally, the results of the simulations have been compared with the results of previous studies that have similar conditions. These were simulated by other software to be sure that the author used the software properly. Each scenario will be justified separately to increase the level of validity as will be illustrated in the next chapter.

Chapter 4

Building the Simulation Model

4.1 Case Study Description

Passive and active strategy studies should consider many aspects, such as: type, location, orientation, number of occupants, and occupancy profile of buildings in addition to weather data and site consideration. Overall these strategies should be taken into consideration during the design and construction phases. While in other cases it rehabilitates buildings, worldwide needs for these solutions are necessary to enhance energy performance.

A typical house located in a popular area of Baghdad has been selected to be a case study for this research. The model was established to examine several parameters that affected passive and active strategies. Common elements and construction materials in Iraq have been adopted to build up the model thus increasing the validation of the results.

This chapter includes the modeling description, occupancy profiles, and simulation parameters. Generally all data include: dimensions, information, and photos that were collected from the site visit. The area of the plot is about 780 m2 which is occupied by two floors. The built up area of the ground floor is about 259 m2 and the second floor is 166.7 m2, as shown in Table 4.1. It is occupied by an Iraqi family containing five people.

There is no definite design for housing in Iraq. Rather, it varies depending on the income of the family. This house was built in the 1980s and adopted the technique and materials that were prevalent in those days. In fact, most houses were built by contractors with limited consulting or governmental regulations. The house is located in the middle of the plot with car parking and a garden in front while the remaining area is designed to be a backyard.

Table 4.1 Case study descriptions (typical house in Baghdad, Iraq)

Base Case Building Descriptions	
Building type	Residential
Plot area	780 m2
Height	Two storey
Ground Floor Descriptions	
Floor area	259.7 m2
Volume	779.2 m3
Wall area	240.6 m2
Open area	35 m2
Window/Wall Ratio	14.5 % of the total walls
First Floor Descriptions	
Floor area	166.8 m2
Volume	500.5 m3
Wall area	178.1 m2
Open area	16.1 m2
Window/Wall Ratio	8.9% of the total walls

This base case represents the prevalent practices of construction in Baghdad in the 1980s. The software has the ability to consider the same type of construction, insulation and finishing materials, shading devices, and glazing performance. A basic case is established as existing. The results of this case will be compared with other cases adopting passive or active strategies to recognize the impact of each one on energy demand reduction.

4.2 Modeling Process

The modeling process was done by the ModelIT which is the model building component of IES-Virtual Environment. The ModelIt allows the user to create 3D models required by other components and enable appropriate levels of complexity to be incorporated within a model across the entire design. This model consists of subjectively shaped spaces with doors and windows connecting both internally and externally. However spaces may be created graphically or by manual input.

The main drawing has been created by the AutoCAD software in order to export it as a DXF file as an underlay for zone creation. In order to be sure that the model is working properly, the 3D model is checked and modify during the modeling period.

Figure 4.1 shows plans of the ground, first floor, and roof while figure 4.2 shows the front elevation of the case study that acts as an underlay for the window and opening locations. ModelIT is also able to add the shading devices that appear within the green color to be estimated through the simulations as shown in figure 4.3

Figure 4.1 Plans of the case study, ground floor, first floor, and roof by CAD (author)

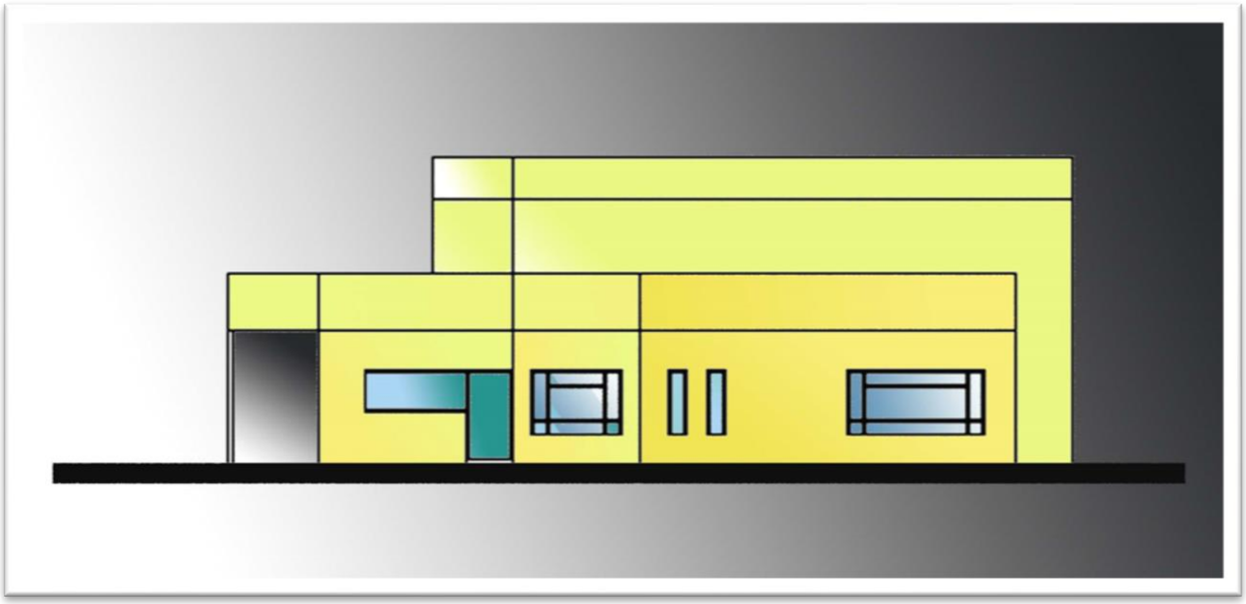

Figure 4.2 Front elevation of the selected case study by CAD (author)

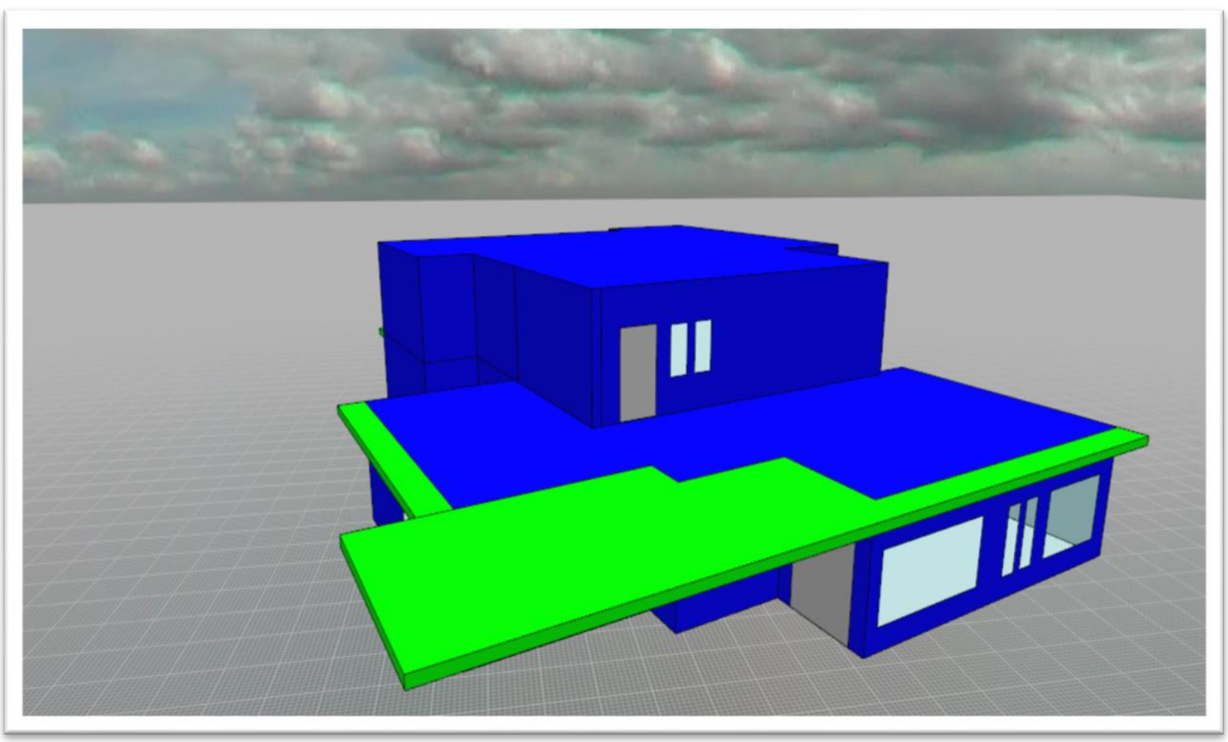

Figure 4.3 Front view of the house by IES (author)

4.3 Weather Data

One of the significant features in IES software is the (AP) located database that contains weather files for different cities in the world. As mentioned in section 4.1 the case study is located in Baghdad. Thus, the weather data in Baghdad city is required for the simulated process. Baghdad has no weather data so a Kuwait weather file was considered as the nearest point of weather measurements.

The weather data file for each city includes hourly values of dry bulb, wet bulb temperature, wind speed and direction, cloud cover, direct and diffuse solar radiations, azimuth and solar altitude.

Baghdad is located at Latitude 33.3° N and Longitude 44.40°E as shown in Figure 4.5.

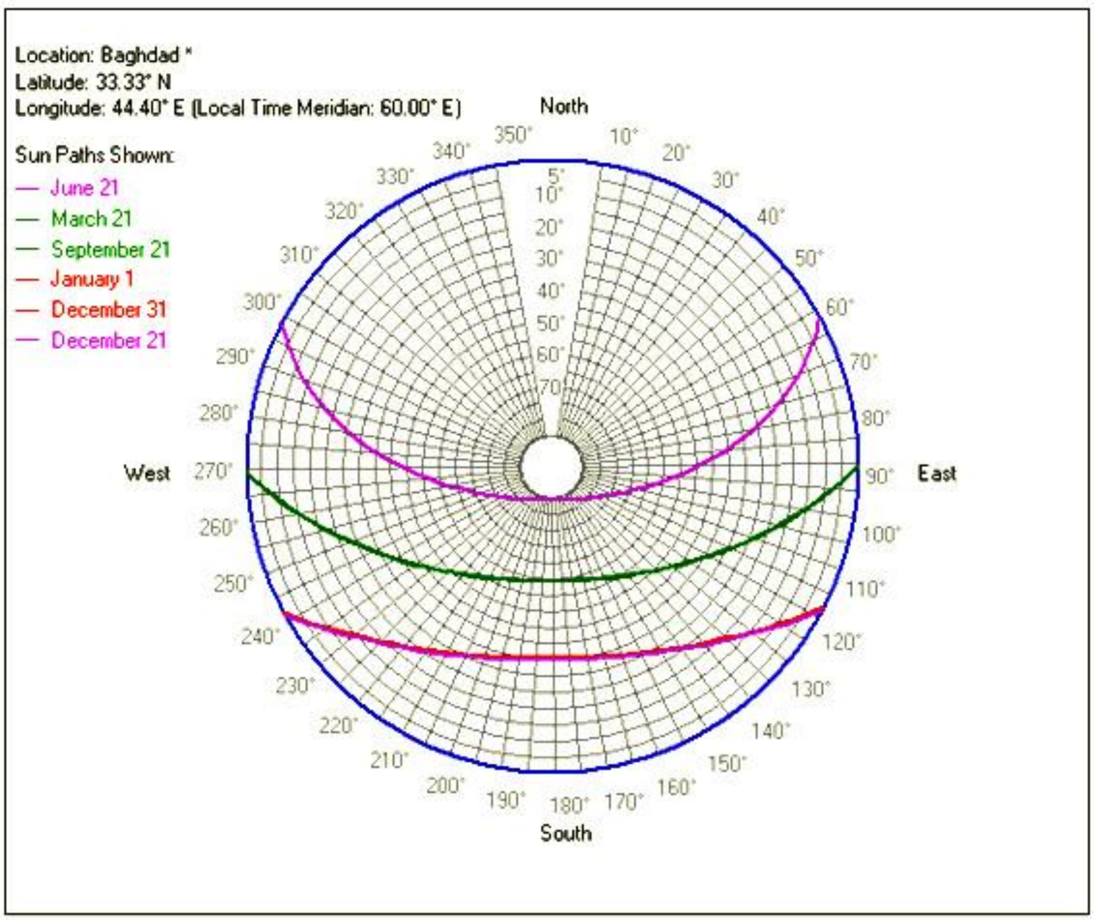

Figure 4.4 Baghdad Sun path diagram (IES Database)

4.4 Times of Simulations

Simulations were conducted for the whole year to determine the peak months of total energy consumption. Iraq weather varies from dry, hot in the summer and cold in the winter. The hottest month is August when the cooling loads could reach higher rates. The peak date for highest temperature was the 14th of August as shown in figure 4.6. This shows the dry–bulb temperature, wet-bulb temperature, direct radiation and the diffuse radiation for Baghdad generated by IES-VE software (weather data).

In spite of cold weather in winter, the radiation is still high as shown in figure 4.7. The data records on 27th of January when the temperature was less than 10-20C in the middle of the day, the radiation reached to more than 800 (W/m2).

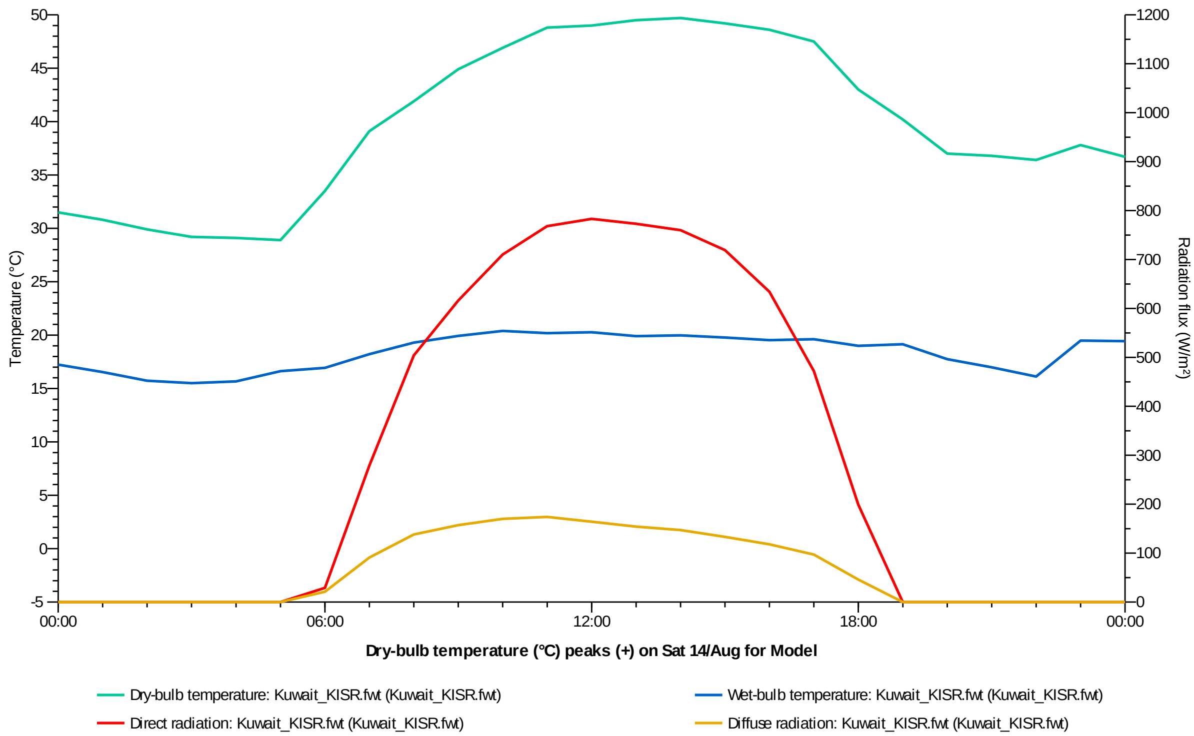

Figure 4.5 Baghdad weather data on August 14th (IES –VE weather database)

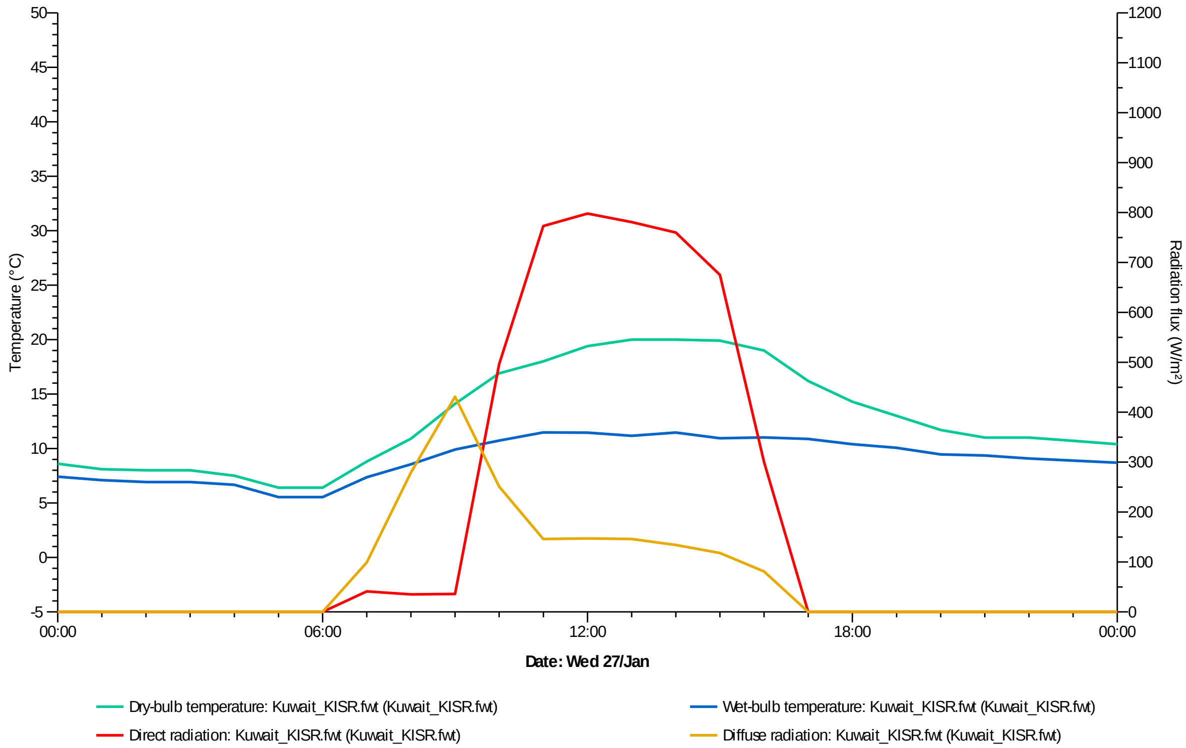

Figure 4.6 Baghdad weather data on January 27th (IES –VE weather database)

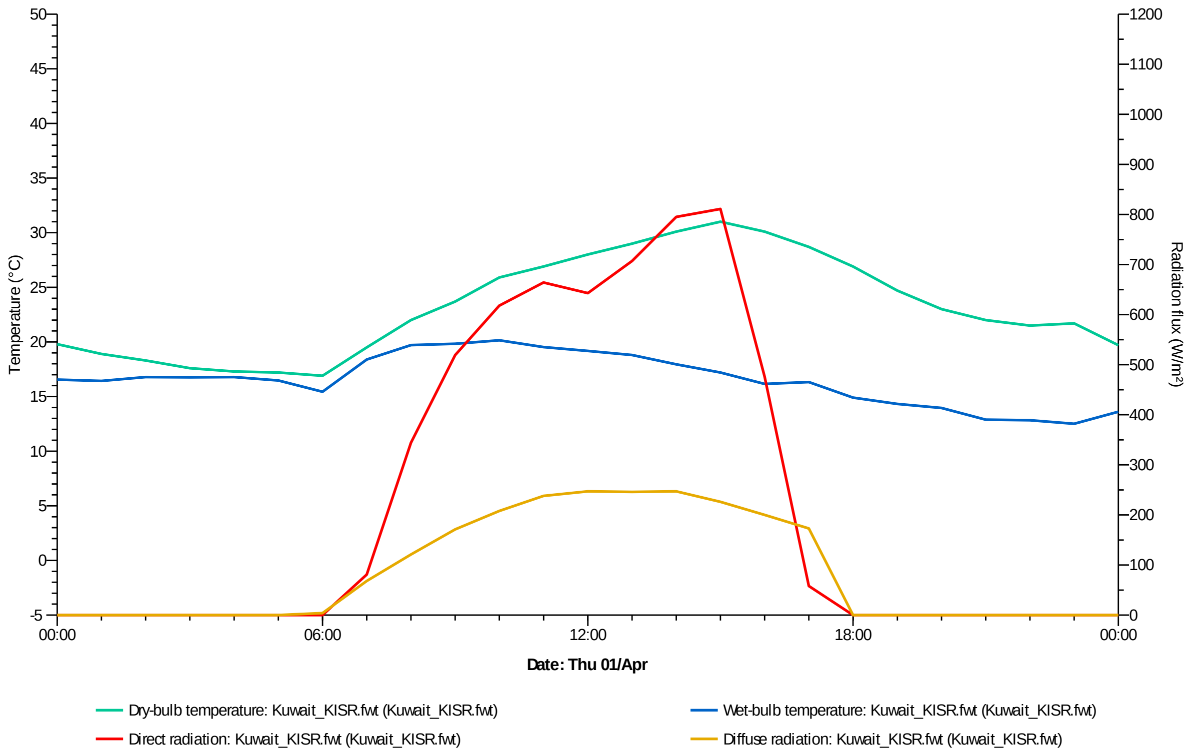

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Figure 4.7 Baghdad weather data on April 1st (IES –VE weather database)

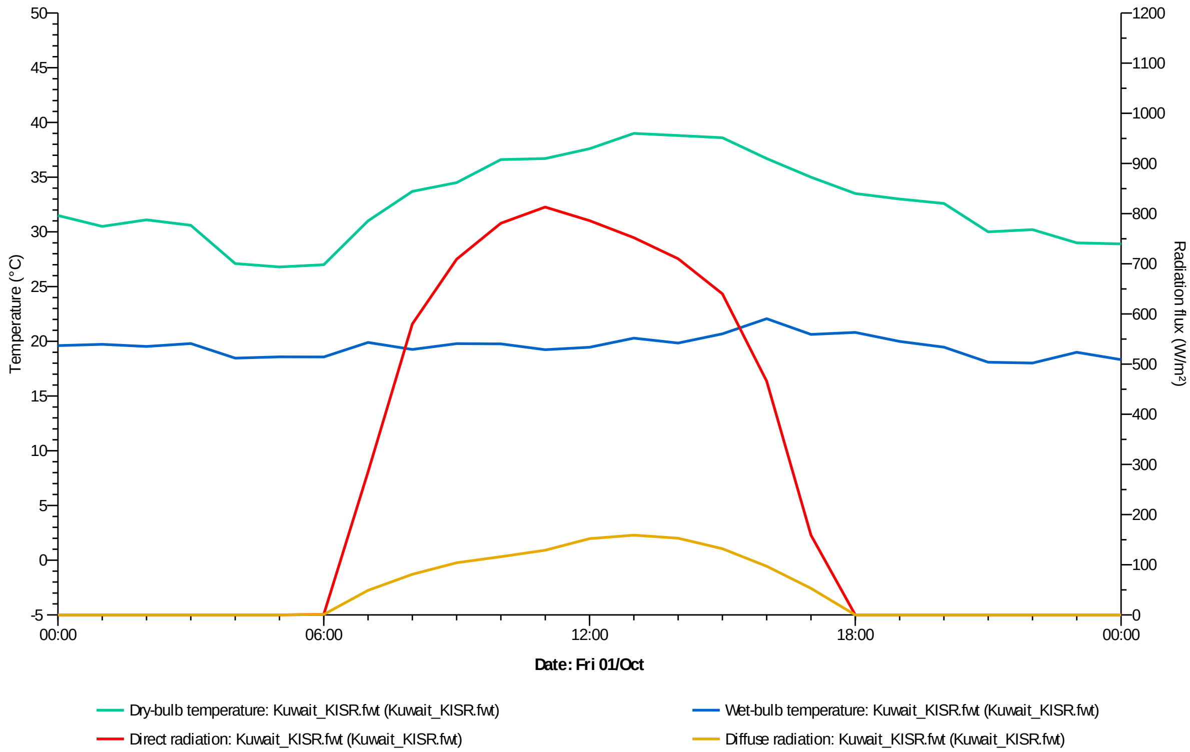


Figure 4.8 Baghdad Weather data on October 1st (IES –VE weather database)

However, even in spring and autumn, the amount of direct radiation records high levels. Figure 4.8 shows the 1st of April and figure 4.9 shows the 1st of October. All these figures give a full indication of the direct radiation even when temperatures are moderate. Thus, this enormous amount of radiation should be used to generate electricity through solar systems.

4.5 Simulation Profiles

The IE –VE software offers the ability to create different types of profiles for the same project. It is usually used to scheduled occupancy, HVAC system, lighting, and equipment used according to the variation of a year. The operation profile of this study is based on the typical lifestyle of an Iraqi family. Three types of profiles have been set up which are: daily profile, weekly profile, and annual profile to provide accurate input data to obtain results with a high degree of validity. The main profile is the daily profile while the weekly profile depends on the weekend days to determine occupancy and the use of the HVAC system. Further, the annually profile depends generally on both daily and weekly profiles to specify time variation over a year when the cooling, heating, and boiler are on or off according to the season.

4.5.1 Daily Profile

The daily profile is created in order to consider the lifestyle of Iraqi families, society, and the timetable of their work and schools. The profile relates to people occupancy and the HVAC system operated.

This profile assumes that from 8 am to 2 pm people will be out for work and education. Consciously the occupancy and the use of HVAC will be zero while it will be 1 unit when people will be back. (1 means 100% used in the software consideration). The use of HVAC is linked to the occupancy profile as shown in Figure 4.10. The daily profile has a significant importance and that is to highlight the peak hours and provide more accurate data to the software to increase the validity of the results.

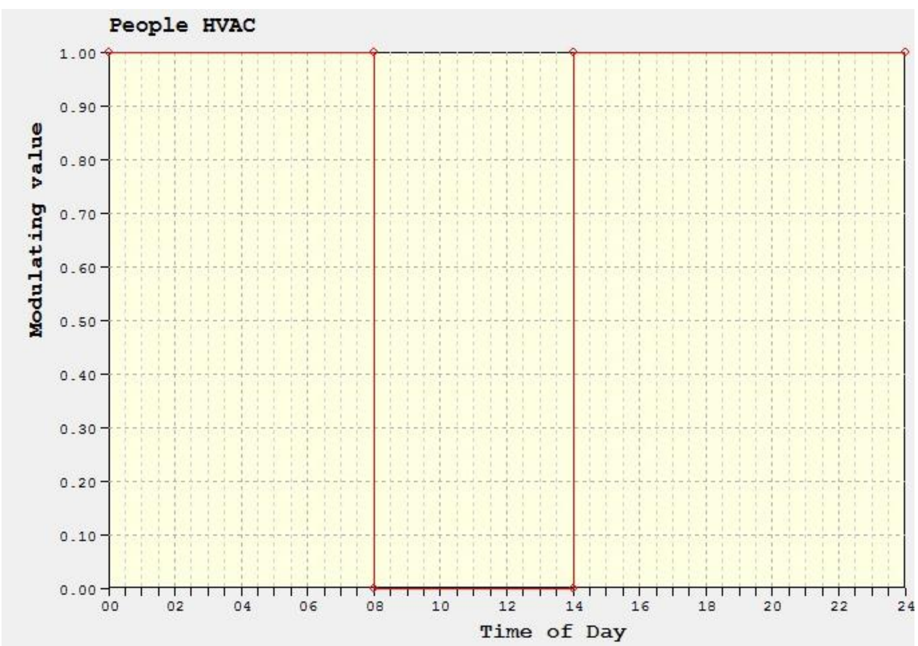


Figure 4.9 Daily profiles for occupancy and HVAC used, IES,

4.5.2 Weekly Profile

The weekly profile adopts the daily profile that I mentioned before. Meanwhile, the weekend days have been assumed as full day occupancy and used. (Iraqi families usually spend the weekend mainly at home.) Thus it assumes the occupancy profile and HVAC system will be on continuously during the weekend days (Friday and Saturday). While it then returns back to use the daily profile for the rest of the week as shown in Figure 4.11.

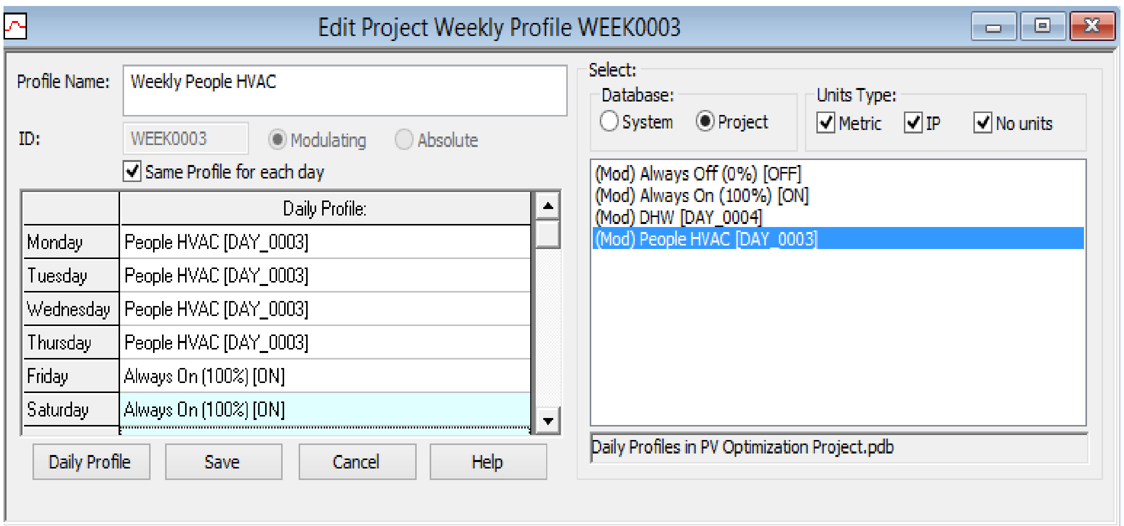


Figure 4.10 Weekly occupancy profile (people and HVAC) IES, Building Template Manager.

4.5.3 Annual Profile

The annual profile is a frequent repetition of the weekly profiles. As exceptions, it has adopted two types of profiles for summer and winter. Weather in Iraq varies from hot to cold which needs the Domestic Hot Water (DHW). This profile was created to give accurate data of solar domestic hot water operating time during the whole year. It assumes that the DHW will be off between April and October while it will be on for the rest of the year as shown in Figure 4.12. All these profiles have been considered for each simulation to increase the reliability of the results.

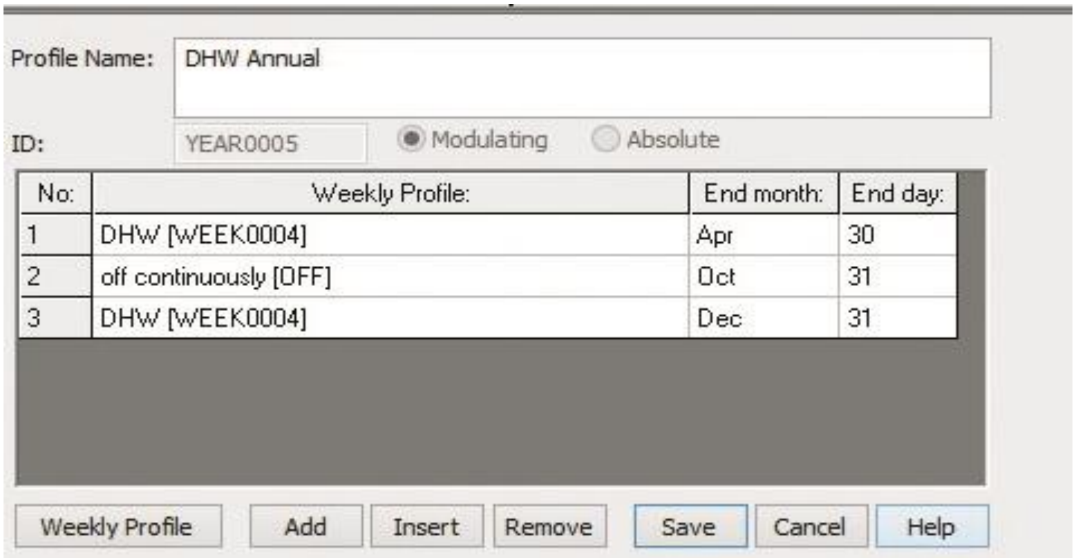


Figure 4.11 DHW annual profiles, IES Building Template Manager

4.6 Constructions Template of the Basic Case

The IES-VE software provides the ability to create different layers of constructions and finishing materials according to the scenario of the simulation. This template includes the thermal properties of each construction elements such as: roof, ceiling, wall, and windows to be applied in the module of simulations. The major purpose of the construction database is to set up materials for projects and the possibility of modifying these materials to evaluate their impact for different scenarios.

The basic case (Case1) has common materials that are used for construction in Iraq, in order to be realistic. Meanwhile, it will be essential to be compared with other cases basing their impact on energy performance.

Materials Constructions that have been adopted in the basic case and are highlighted in Table 4.2.   This includes the specifications of the roof, wall, floor, and glazing system. A description of each material was determined through thickness, density, conductivity and the total U-Value to be examined during the simulations.

The significance of this table is to recognize the U-Value of each parameter as existing. Glazing properties are highlighted through the value of Solar Heat Gain Coefficient (SHGC) referred to as the solar energy Permeability of glazing.

Table 4.2 Materials properties that were used for Case1 (Basic Case)

	Materials	Thickness(M)	Density (kgm2)	Conductivity W/(m.k)	ASHRAE U- Value W/m2 K
Roof	Concrete tiles	0.025	2100	1100	2.0896
	Sand	0.05	0.2080	0.3500	
	Concrete undried aggregate	0.2	2243	1.7300	
	Plaster	0.03	1300	0.5000	
Wall	Cement plaster aggregate	0.030	0.7200	1860	1.7197
	Common brick	0.24	0.7270	1922	
	plaster	0.0300	0.5000	1300	
Floor	Concrete tiles	0.025	1.100	2.1000	2.7322
	Concrete un dried aggregate	0.2000	1.7300	22430	
	Tile bedding	0.0500	1.4000	2.100	
	Materials	Thickness(M)	SHGC	Conductivity (W/m.k)	ASHRAE U-Value including frame W/m2 K
Glazing	Windows (single)	0.0040	0.811	1.0600	5.8744

Since Iraq and the U.A.E are located in the same zone with similar hot climate conditions, the study used ESTIDAMA regulations that are establish by the Abu Dhabi Urban Planning Console (UPC). ESTIDAMA has five certification levels ranging from 1-5 Pearls. The study selected two values of them to be applied in the model: 1Pearl and 2Pearls.

According to Awadhi *et al* (2013) these values are used to examine the impact of low U-Values on energy consumption in existing buildings in the U.A.E.

The constructions database has significant importance due to its ability to recognize the most effected parameters in order to improve energy performance much more than the others. The database also shows which Pearl has the most energy savings.

4.7 Simulations Process

Different scenarios have been adopted to examine the effect of each strategy on energy performance. The variations of these cases can be highlighted through two groups as follows:

- Passive strategies: that affects the energy consumption and reductions through adding shading or insulation materials to reduce the U -Values. The SHGC values are used to examine the performance of glazing and its impact on energy consumption.

The ranges of U-Values have been adopted from ESTIDAMA regulations as mentioned before which are 1Pearl and 2Pearls. The simulations will run for each parameter separately in order to recognize the effect of each one on energy consumption and to evaluate the worth of using this parameter.

The main various parameters for this group of scenarios are as follows:

- Shading coefficient
- Roof insulation
- Wall insulation
- Solar Heat Gain Coefficient (SHGC) of Glazing

Table 4.2 defines all the passive strategies and their simulations. A final simulation for the optimal scenarios will be run to evaluate the parameters together for best energy savings.

Active strategies: this group of simulations contains various cases that investigate the impact of increasing the Coefficient of Performance (COP) on energy demand reduction. Also, it investigates the effect of solar Domestic Hot Water (DHW) on energy consumption. This simulation will examine the proper area for this system. A comparison between solar DHW and PV production will estimate the benefit of each one due to energy production and savings.

It will also examine the effect of adopting the photovoltaic Panels (PV) on grid electricity demand reduction by investigating the most optimized angle, area and efficiency base on the energy production.

The matrix of the active strategies is clarified in the cases and the parameters as shown in Table 4.3 while the main parameters for active strategies are as follows:

- Angles and orientation of PV
- Area of installation of PV and Solar DHW
- PV performance efficiency

4.8 Simulations Consideration

-The study used the simulations to recognize the results of energy consumption and savings for the whole year. Also the simulations were used to highlight peak months for energy performance and their effect on the total electricity demand reduction.

- The model was built up without considering any high-rise building as surrounding. Typical Iraqi housing is constructed almost horizontally. Consequently, any shadow profile was ignored during the simulations, except the one that may be caused by part of the building. Each house has a setback, two meters from each side. This consideration has significance especially for simulating the PV production due to location and performance.

- An optimized case of passive strategies will be adopted to supplement simulations of the active strategies. The results will be evaluated due to energy consumption and savings. Finally, a simulation will be run to examine the most proper passive and active strategies based on energy performance and savings.

Table 4.3 Matrix simulation for passive strategies

			Passive strategies									Optimize shading with U-Value 1Pearl	Optimized case with U-Value 2Pearsl
			Shading		Roof and walls				Glazing				
	Cases	Case 1 As existing	Case2 Roof Shading (Pergola)	Case 3 window shading	Case4 Roof1Pearleused Polyurethane Board	Case5 Roof12Pearl 2 used Polyurethane Board	Case6 wall ins. Pearl 1	Case 7 wall ins. Pearl 2	Case 8 Glazing Pearl 1	Case9 Glazing Pear 2	Case 10 Practical Optimize Case	Case 11 Efficient Optimized Case
U- Values	**Roof**	2.0069	2.0069	2.0069	0.1401	0.119	0.4417	0.4417	0.4417	0.4417	0.14	0.12
	External Wall	1.6424	1.6424	1.6424	1.6424	1.6424	0.3196	0.29	0.337	0.224	0.32	0.29
SHG	**External glazing**	4.8678	4.8678	4.8678	4.8678	4.8678		4.8678	2.2057	1.9069	2.2	1.9

Table 4.4 Matrix for the active strategies and simulations

Active strategies				
Coefficient of Performance (COP)	Solar (DHW)	Photovoltaic (PV)		
Case 12	Cases (13-17)	Cases (18-22)	Cases (23- 25)	PV cell performance
Changing COP form 2.3 to 3.5	Examine 2,4,6,8, and 10 m2 area of SDHW	Different PV tilted angles 41,57,65,73,80 degree	Different PV area	Monocrystallin, Polycrystalline, Amorphous, and Thin film

4.9 Modeling Validation

The validation of the software has been clarified in chapter 3 under section 9. The main approach of using IES–VE is to investigate the most appropriate configurations of passive and active strategies to achieve thermal performance of the building. All the results of simulations will be compared to Case 1 (basic case) to evaluate the impact on energy consumption and savings.

The validation of the basic case was conducted to verify the level of accuracy through comparing and adopting much previous research. Part of these studies considered the IES-VE while others used other software to investigate passive and active strategies.

Meanwhile the comparison will approve the accuracy and validity of the software user when comparing the results that were obtained from different simulation programs. In addition, comparing the results of energy consumption with actual electricity bills that were obtained from governmental authorities could be impossible for these reasons:

- Electricity shortage in Iraq provides an accurate data of actual consumption hours
- Relying on the private sector in supplying the energy to supplement the demand for electricity

Chapter 5

Results and Discussion

5.1 Introduction

This chapter describes the results that were obtained from the simulation processes according to the configurations outlined in the previous section. The simulations are grouped as passive and active strategies, and the results are discussed under every variable parameter for each group individually. Illustrations, graphs, and tables are provided wherever needed to understand and support the outputs for each case.

The sub-cases of the same scenarios are often integrated in one section in order to be easily compared. The findings of each scenario will compare the results of the basic case to energy performance and consumption. Also, it's compared with other scenarios whenever useful.

The value of information is supported with each case, while detailed data and tables of simulations have been moved to the Appendices.

5.2 Basic Case (Case 1)

The results of the simulations show the main energy consumption caused by cooling loads. The total annual energy consumption of this case is (152.1MWh), 49.1% cooling energy, 0.3% boiler energy, 30.2% equipment energy and 20% lighting energy. This percentage shows the major part of energy consumption is related to the energy system that includes cooling and heating energy consumption as shown in Table 5.1. The system's energy consumption is 75.29 MWh representing approximately half of the total energy utilization as highlighted in Figure 5.1. The detailed table is available in the Appendices.

The total annual light energy is 30.7 MWh while the total annual equipment energy is approximately 46 MWh. Energy consumed by lighting or equipment is not affected by the seasons or differences in temperature. Consequently, both of them have very little difference in value for the whole year.

Due to the large forecasted demand for electricity during the summer, the results show that the maximum energy consumption occurred in July and August which represent the peak months for high temperatures. Figure 5.1 shows increased system energy consumption (heating and cooling system) compared with the total lighting energy and total equipment energy.

Table 5.1 Total energy consumptions and system loads of the basic case

Date	*Total system energy MWh	Total light energy MWh	Total equip energy MWh	Total energy MWh
Jan	2.0485	2.6365	3.9548	8.6397
Feb	1.791	2.3549	3.5324	7.6783
Mar	2.3352	2.5853	3.878	8.7985
Apr	4.7065	2.5341	3.8012	11.0418
May	8.8178	2.6109	3.9164	15.345
Jun	10.7645	2.5085	3.7628	17.0358
Jul	11.9607	2.6365	3.9548	18.5519
Aug	11.8052	2.5853	3.878	18.2684
Sep	9.2955	2.5085	3.7628	15.5668
Oct	7.0459	2.6365	3.9548	13.6371
Nov	2.6965	2.5085	3.7628	8.9678
Dec	2.0258	2.6109	3.9164	8.553
Summed total	**75.2933**	**30.716**	**46.0753**	**152.0841**

* Total system energy is included (Boiler energy and Air conditioning system energy

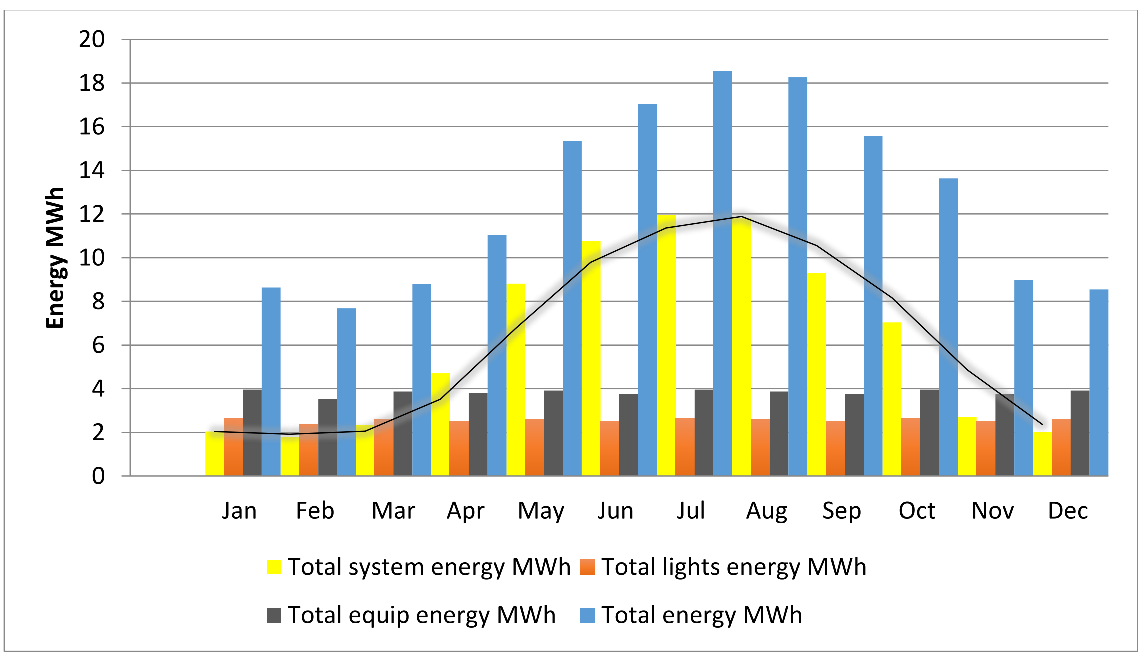


Figure 5.1 The total energy consumption over a whole year

Figure 5.1 shows the system energy, as expected, consumes the maximum energy for the whole year. The total light energy has less consumption while the equipment energy consumed a little more than lighting energy consumption. The study was carried out for Case1 (basic case) to be considered as a reference of energy consumption as shown in Table 5.1. Furthermore it is to be compared with subsequent simulations due to energy demand reduction and savings.

Al-Ragom (2002) found in Kuwait that the annual electricity consumption for air conditioning systems represents 50% of the total electricity, while it represents 70% of the total produced electrical energy at peak times. By using modeling and simulation, the paper investigates the annual consumption of typical two-story residential houses in Kuwait that use an estimated 166.53 MWh.

The paper examines the properties of the construction materials through adding wall insulation, roof insulation, or changing the glazing system and their effect on total energy consumption. The house has been compared with Case1 (basic case) to increase the validity of the results. The comparison shows that the annual energy consumption of Case1 (basic case) is within the range of annual energy consumption of the Kuwait basic house. Both houses have been built in the same time period. The slight difference in the results relate to the U-Values variation and the different types of construction.

Table 5.2 Comparison between Case1 (basic case) and the case study in Kuwait that is investigated by Al-Ragom (2002) based on the U-Values

Cases	Storey	Total area m2	External walls U-Value w/m2k	Roof U-Value w/m2k	Floor U-Value w/m2k	Annual energy consumption MWh	Annual energy consumption KWh/m2
Kuwaiti house	2	344	2.5	1.1	3.6	166.5	542.4
Case 1(Basic case) of Iraq	2	325	1.7	2	2.7	152.1	467

Al Awadhi, *et al*. (2013) investigated the energy performance of several public housing cases through simulations in order to evaluate the refurbishment requirements. These cases were built between 1974–2012. The cases represent building in each decade and different construction techniques used. The study estimated the energy consumption and reduction for each case through using an Integrated Environmental Solution-Virtual Environment (IES-VE) simulation. The basic case establishes them as they were built, while the other cases adopted different refurbishment practices such as insulation and changing the type of glazing. The results of these cases in the U.A.E have been compared with the results that were obtained from Case1 (basic case) to increase the level of credibility.

Table 5.3 shows a comparison between the four cases located in the U.A.E and Case 1(basic case) located in Iraq including: the build up period, total floor area, number of floors, annual total energy, and annual total energy per square meter. The table clarifies that the results of annual total energy consumption of Case1 (basic case) are located between the ranges of the other cases when considering the differences in total floor area and numbers of floors.

A comparison between the first case (B74) and Case1 (basic case) shows that both cases were built during the same period, in the 1980s. According to Table 5.3 there are differences in the number of floors and the total floor area, thus it's better to compare the annual energy consumption per square meter. It was found that case (B74) which was investigated by Al Awadhi, *et al*. (2013) is 480 KWh/m2 while the annual energy consumption for Case1 (basic case) is 467 kWh/me. This comparison indicates that the total energy consumption of Case1 is within the range of total actual consumption.

Table 5.3 Comparison between four cases studied in the U.A.E and Case1 (basic case) in Iraq using IES-VE simulation due to energy consumption

Model Number (basic case)	Decade	Total floor area (m2)	No. of storey	Annual total energy MWh	Annual total energy KWh/m2
B74	1980s	114	1	54.7	480
679	1990s	351	1	188.5	537
717	2000s	394	2	237.2	602
762	2010s	742	2	174.9	371
Case 1(Basic case)	1980s	325	2	152.1	467

Case1 (the basic case) in Iraq has been compared with cases that have similar features and climatic conditions of those located in Kuwait and the United Arab Emirates to assure the level of accuracy and validity of the results. It is very important for the energy consumption value to be accurate because it will be the reference point to evaluate all other cases.

5.3 Passive Strategies Scenarios

This scenario, as mentioned in chapter 4 under section 7 contains several types of passive strategies. The scenario will examine and evaluate the case that can most significantly reduce electricity demand.

The Passive strategies will examine adding shading to the roof and windows; reducing the U-Values through adding insulation materials in the roof and walls, while adopting these (SHGC) values of glazing to examine the impact on total energy consumption. Each scenario will examine different configurations to evaluate the best case for energy savings.

5.3.1 Shading Strategies

The existing case study has many shading devices. The main one covers the entrance of the house on the North side as shown in Figure 5.2, while another example is shading the windows located on the South as shown in figure 5.3.

This section examines two types of shading. The first one extends the roof of the ground floor (known as pergola Case2). The pergola provides more shade and increases the space for installing the photovoltaic panels that relate to the active strategies. The other type is the horizontal louvers that shade the windows represented in Case3.

The expected impact of this scenario will be limited (as shown in Figure 5.2 and 5.3) because of the existing shading devices. However, passive strategies should be integrated. Improved energy performance and savings will be achieved when each strategy is combined.

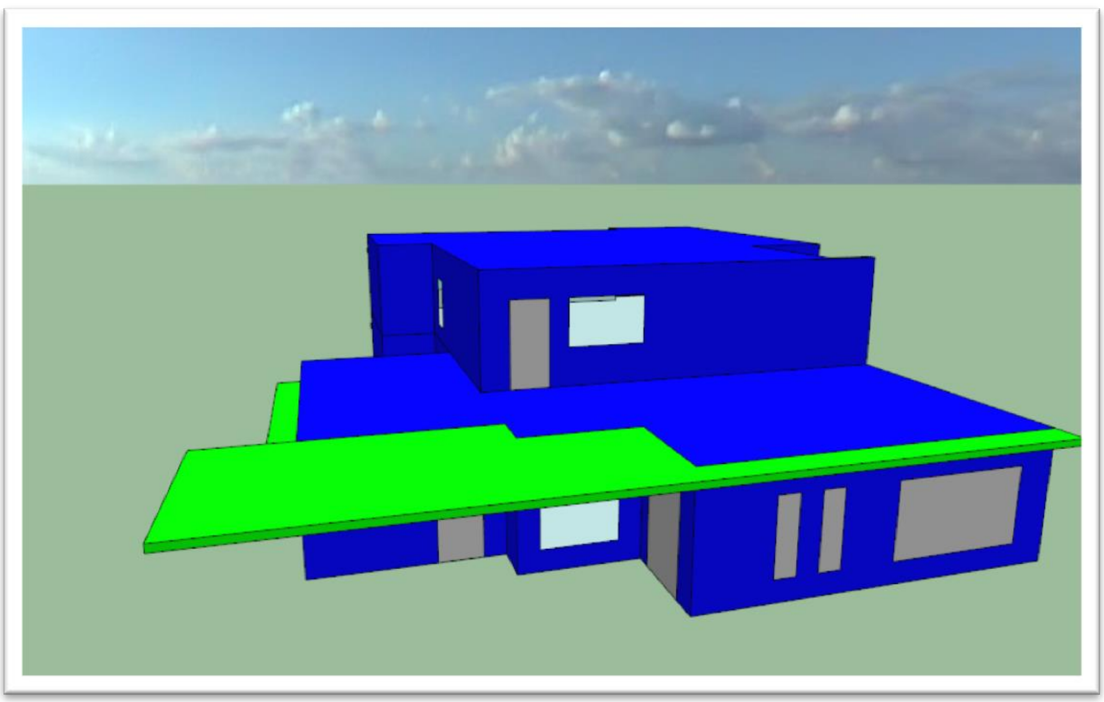


Figure 5.2 Case 1 shading device of the entrance at the North (IES-VE) ModelIt

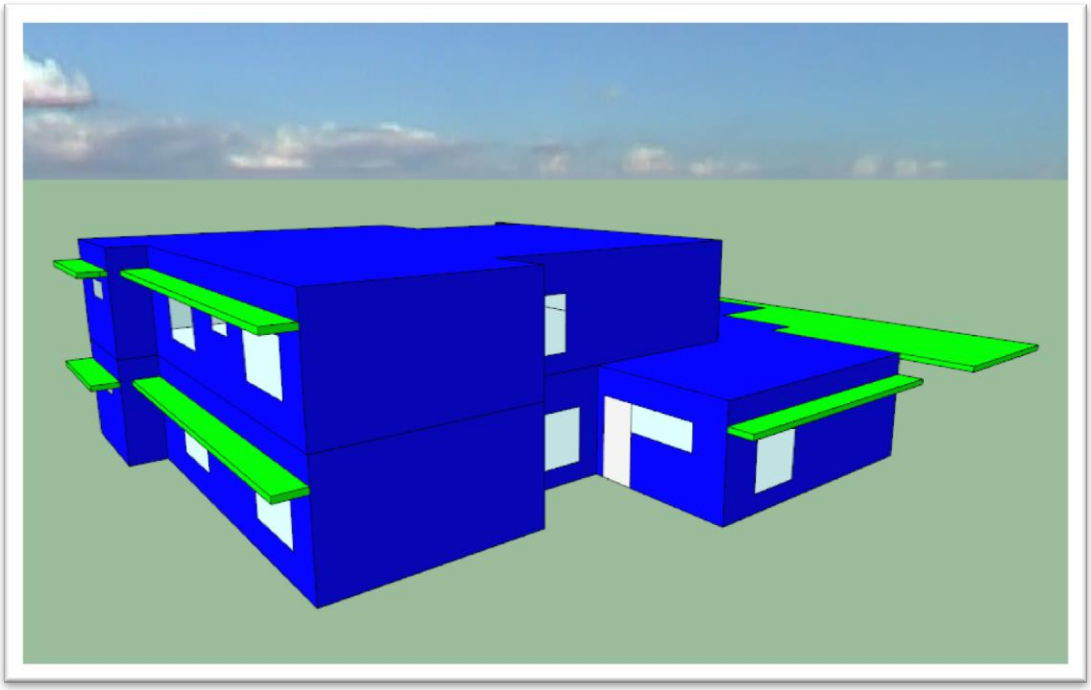


Figure 5.3 Case1 shading devices of rear façade at the South (IES-VE) Modellt

5.3.2 Shading Devices (Cases 2 and 3)

According to Marrero (2010) the impact of shading devices on building energy consumption depends on many factors such as: window area, the location of the louvers due to being north or south facing, and inclination angles.

The location of the pergola in Case 2 has been chosen according to the available space in the case study, which is located on the north side. This extension (pergola) has been added to cover the roof of the ground floor and to reduce the solar radiation which has significant impact on the cooling loads as shown in Figure 5.4

Additionally, it will be used to examine the active strategies through installing photovoltaic panels (PV) in the next section. Each case has been simulated separately to understand and evaluate the impact of each strategy on energy consumption. The result of this scenario in Case 2 shows that the total annual energy was reduced from 152.1 MWh to 151.6 MWh representing a 0.29% difference. This ratio of reduction can increase if shading devices have more area and are installed in different locations due to north or south placement.

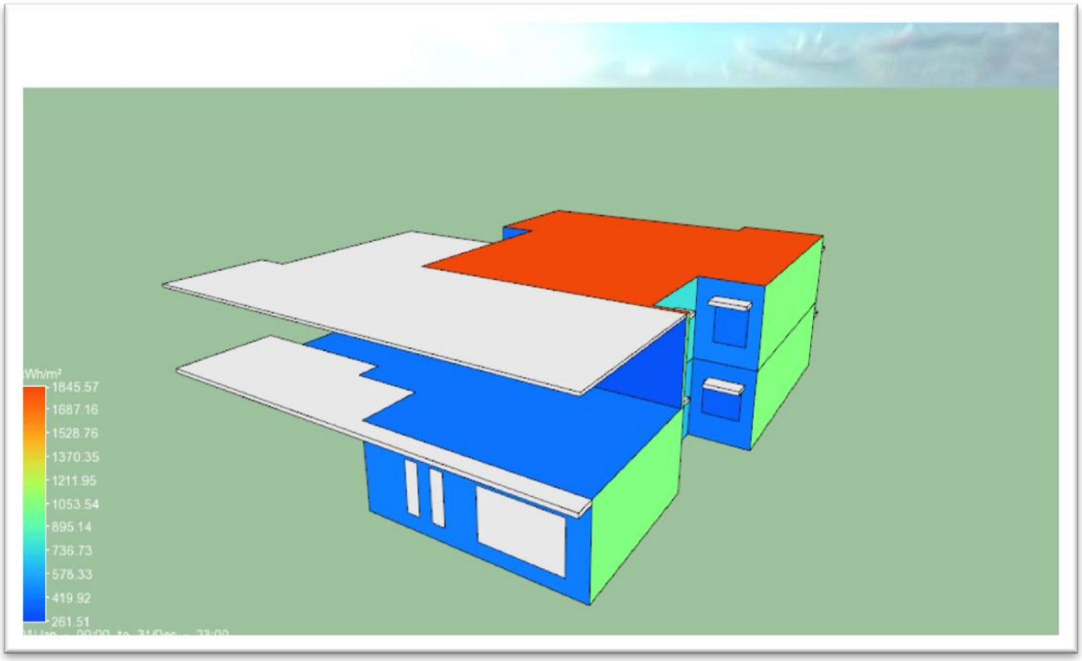


Figure 5.4 Sun Cast analysis of the roof extensions as a pergola on the north side (IES-VE)

This strategy should be considered carefully to provide the right balance between shading and the amount of daylight to avoid darkness that could lead to increased consumption of energy. The result of Case 3 that examines the shading of windows, shows that the total energy consumption has been reduced from 152.1 MWh to 151.9 MWh. This reduction represents 0.11% which is less than the reduction of Case1. Table 5.4 compares Cases 1 and 2 with the basic case also shown below.

Table 5.4 Comparison between Case1, and Cases 2, 3

Cases	Total Annual Energy (MWh)	% Energy reduction
Case 1 (Base Case)	152.1	0
Case 2 (Pergola)	151.6	0.29
Case 3 (Windows shading)	151.9	0.11
Total energy reduction		0.4

Radhi (2009) found that the savings in energy due to shading devices are not significant compared with other passive strategies such as insulation materials.

This reduction is expected according to the window/wall ratio that is 14.5% for the ground floor, and 8.9% for the first floor as mentioned in section 4.1 in addition to the location of the shaded elements. The rate of energy reduction is very limited; the combination of different passive strategies can achieve a high level of energy performance and energy demand reduction. In addition, the obtainable space for adding shading devices is located on the north as shown in figure 5.5 while the south façades have no extra space to extend the roof and it has already been shaded.

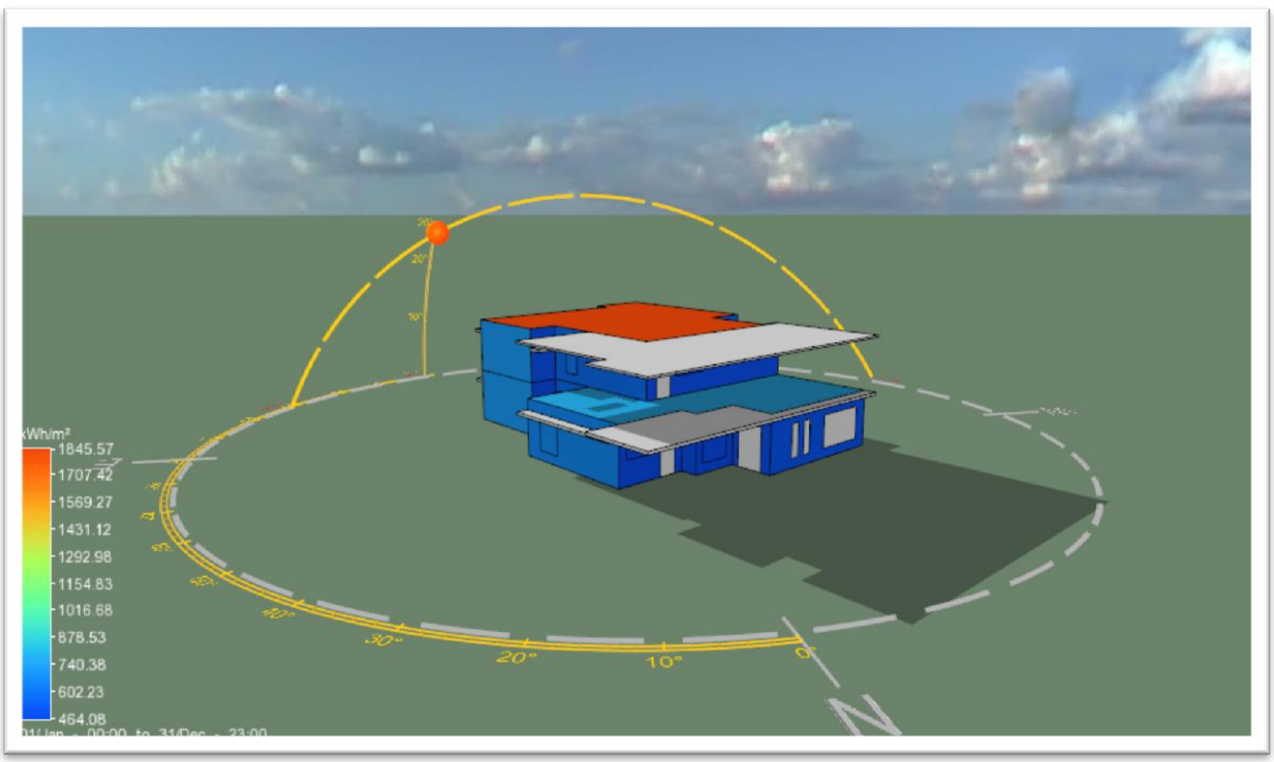


Figure 5.5 Location of shading device due to the North by Sun Cast analysis (IES-VE)

As Kim (2011) mentioned, the style and the shape of the shading devices could also contribute positively to reduce the cooling load. The simulations evaluate the energy consumption and the chiller load to recognize the impact of each scenario on both of them.

Case 2 used the pergola shading to reduce the chiller load from 106.5 MWh to 105.6 MWh representing 0.8% of reduction. The reduction of window shading devices in Case 3 has much less of a reduction which is from 106.5 MWh to 106.1 MWh. It represents only 0.3% as seen in Figure 5.6. Both cases have been compared with the basic case to evaluate the impact of each strategy on energy performance and savings.

A slight reduction in total energy and chiller load is expected due to the location of the shading devices as mentioned before. Meanwhile the majority of the research is to combine different passive strategies to achieve an overall reduction of electrical demand.

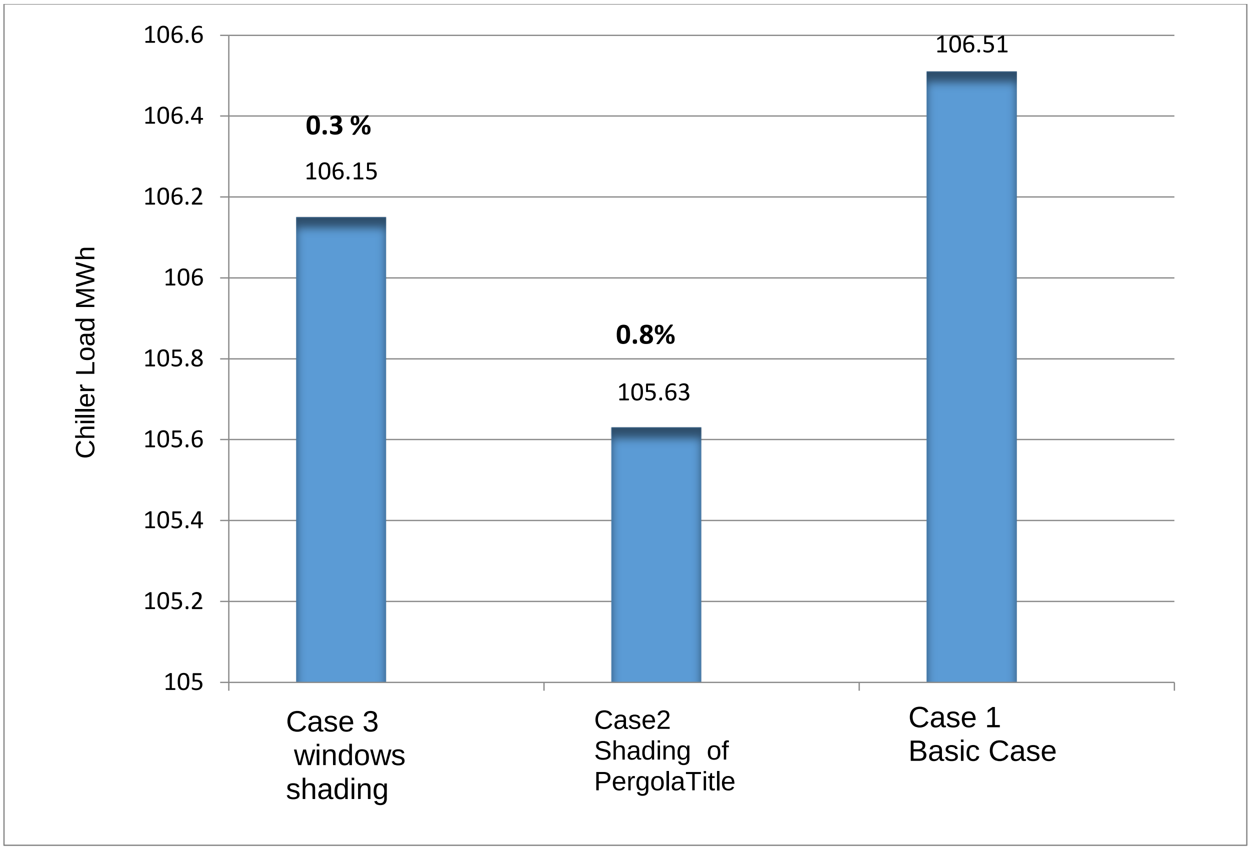
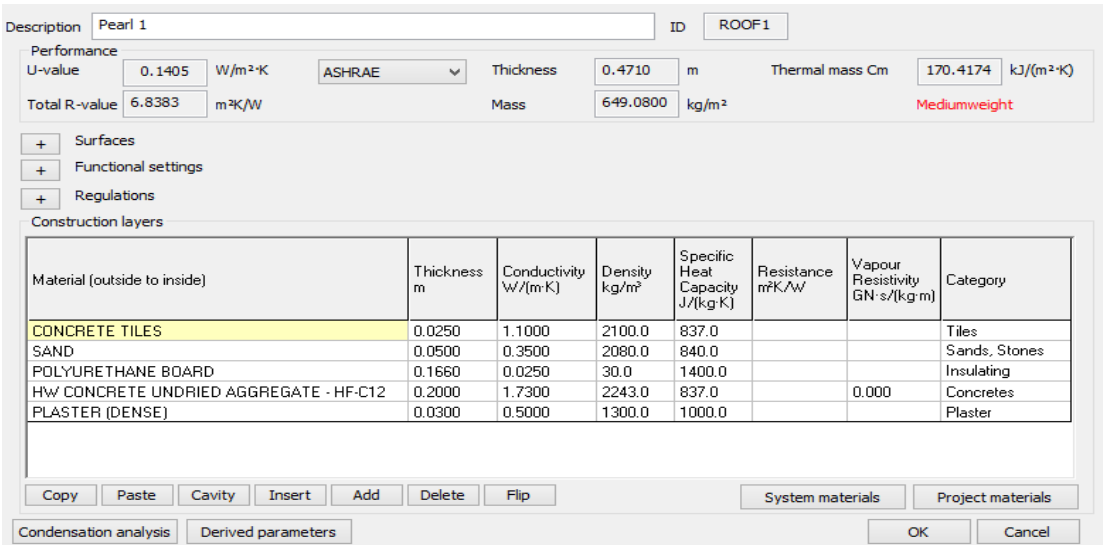


Figure 5.6 Cases 2 and 3 comparisons with Case 1 (basic case) due to the chiller load reduction

5.3.3 Adding Insulation Materials in the Roof (Cases 4 and 5)

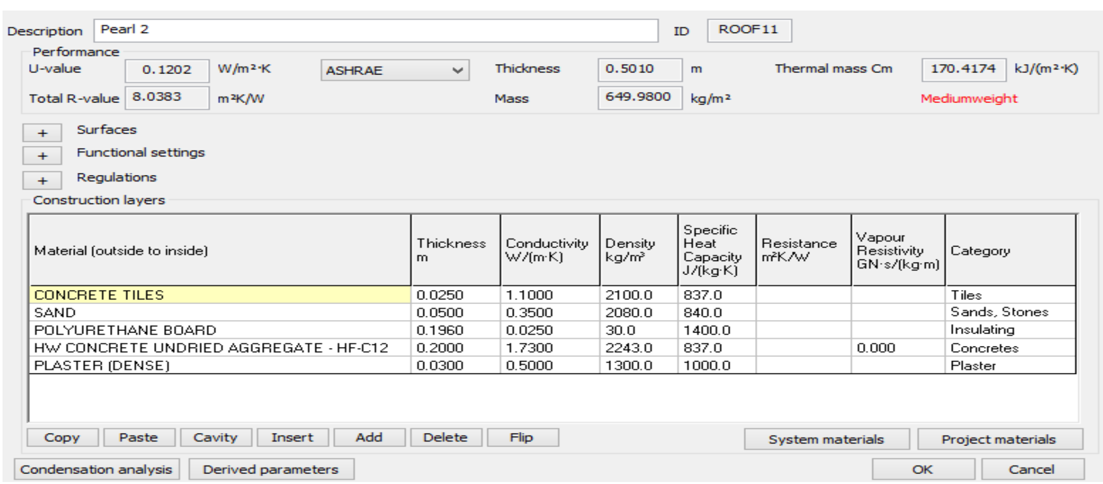
This scenario, considered the Polyurethane Board, uses insulation materials added to the conventional layers of the roof. Case 4 examines the U-Value of 1Pearl that is

0.1405 W/m2 K while Case 5 examines 0.1205 W/m2 K as U-Value of 2Pearls. The construction template of IES-VE software illustrates the properties of each case as shown in Figures 5.7 and 5.8.



Material (outside to inside)	Thickness m	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
CONCRETE TILES	0.0250	1.1000	2100.0	837.0			Tiles
SAND	0.0500	0.3500	2080.0	840.0			Sands, Stones
POLYURETHANE BOARD	0.1660	0.0250	30.0	1400.0			Insulating
HW CONCRETE UNDRIED AGGREGATE - HF-C12	0.2000	1.7300	2243.0	837.0		0.000	Concretes
PLASTER (DENSE)	0.0300	0.5000	1300.0	1000.0			Plaster

Figure 5.7 Case 4 Roof layers -1Pearl (IES-VE constructions template)



Material (outside to inside)	Thickness m	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
CONCRETE TILES	0.0250	1.1000	2100.0	837.0			Tiles
SAND	0.0500	0.3500	2080.0	840.0			Sands, Stones
POLYURETHANE BOARD	0.1960	0.0250	30.0	1400.0			Insulating
HW CONCRETE UNDRIED AGGREGATE - HF-C12	0.2000	1.7300	2243.0	837.0		0.000	Concretes
PLASTER (DENSE)	0.0300	0.5000	1300.0	1000.0			Plaster

Figure 5.8 Case 5 Roof layers - 2Pearls (IES-VE constructions template)

The result of Case 4 shows that the total annual energy has been reduced from 152.1 MWh to 145.5 MWh representing 4.33%. While the total energy of Case 5 achieved 145.4 MWh providing a 4.4% reduction. The difference between Cases 4 and 5 are due to energy demand reduction and as Figure 5.9 shows, it is not significant.

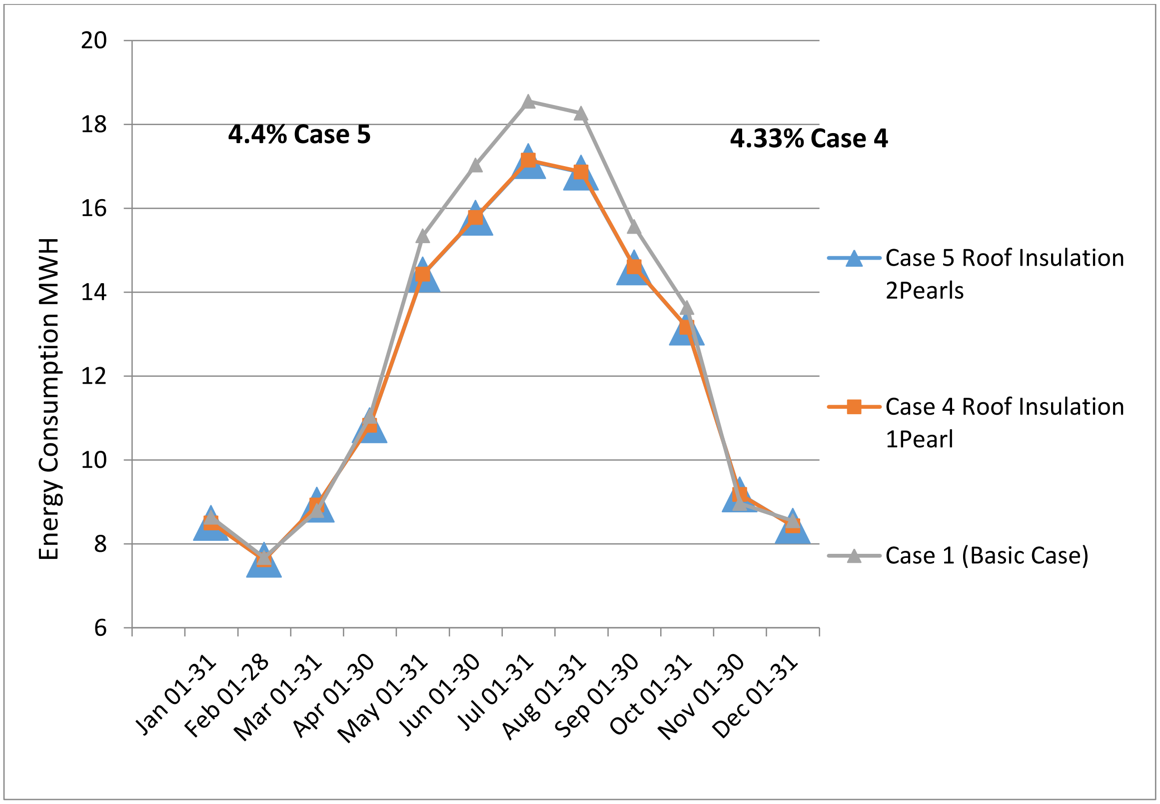


Figure 5.9 Cases 4, 5 and the impact of adopting insulation materials in the roof (1Pearl and 2Pearls)

The graphs show the greatest improvement in energy occurs during the hottest months. This means using insulation will be very useful in hot climate zones. Furthermore, the difference between 1Pearl and 2Pearls is limited. The cost of the insulation materials and the benefit rendered should be considered.

Consequently, the chiller load of Case 4 has been reduced from 106.5 MWh to 94 MWh, 11.7% of the total annual consumption. The chiller loads were reduced from 106.5 MWh to 93.8 MWh in Case 5, a reduction of 11.9%. According to Al-Ragom (2002) the use of roof insulation reduced the cooling load by only 2% while the results of Cases 4 and 5 achieved a more significant reduction.

Kumar (2012) found that the insulation in roofs and walls reduced unwanted heat gain and loss. Therefore, it minimized the dependence on air conditioning systems by extending the period of thermal comfort, especially during the inter-seasons. Sixty percent of thermal transfer occurs through the roof. In other words, improved insulation in the roof will be highly effective in reducing the cooling load and lowering energy consumption. Figure 5.10 provides a comparison between Case1 and Cases 4 and 5 based on the chiller load reduction.

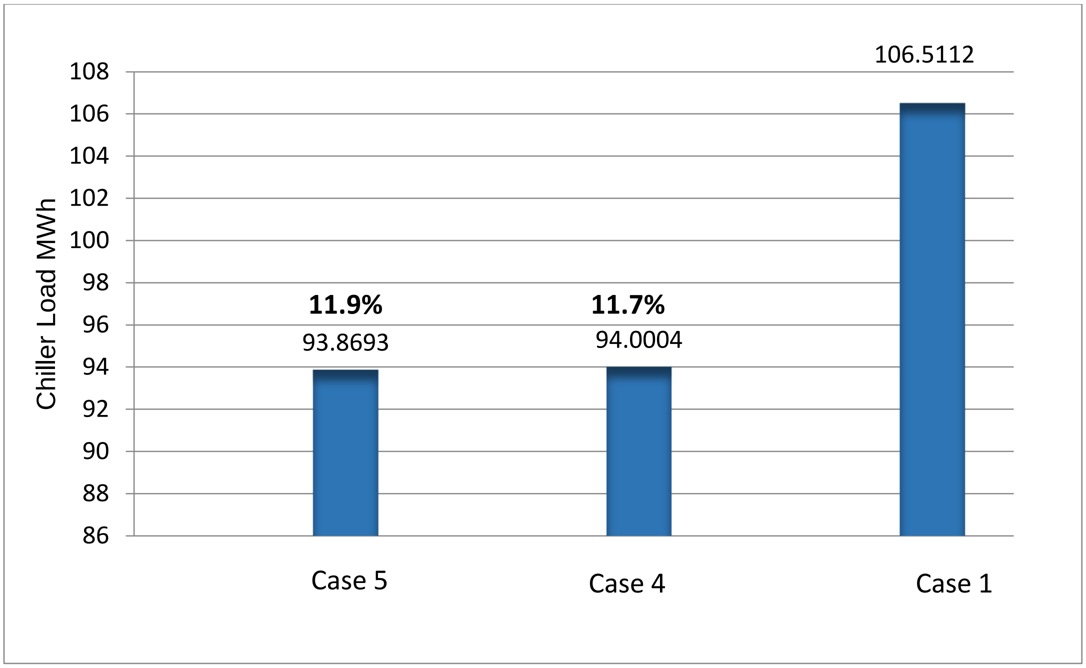


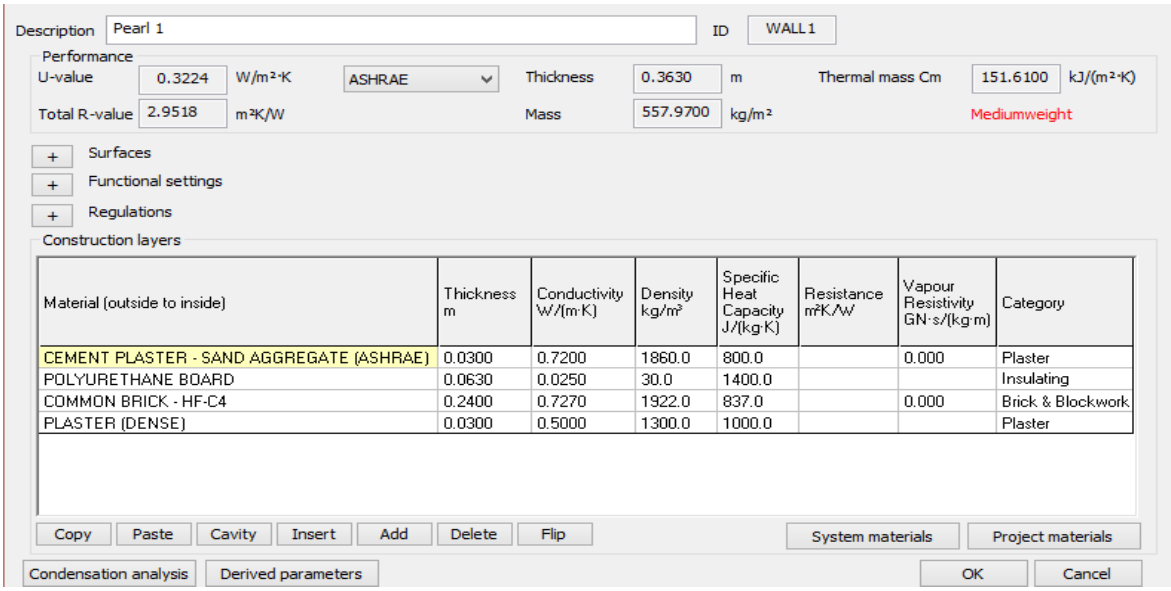
Figure 5.10 Cases 4, 5 compared with Case 1 (Basic Case) based on chiller load reduction

According to Taleb and Sharples (2011), the U-Values measured the amount of heating conveyed through the elements of the building. Thus, the use of sufficient insulation can achieve low U-Values reducing the energy consumption and increasing savings. It has been found that the difference of percentages between Cases 4 and 5 is only 0.2%. The selection between 1Pearl and 2Pearls should take into account economic considerations in order to achieve balance between cost and value.

5.3.4 Adding Insulation Materials in the Walls (Cases 6 and 7)

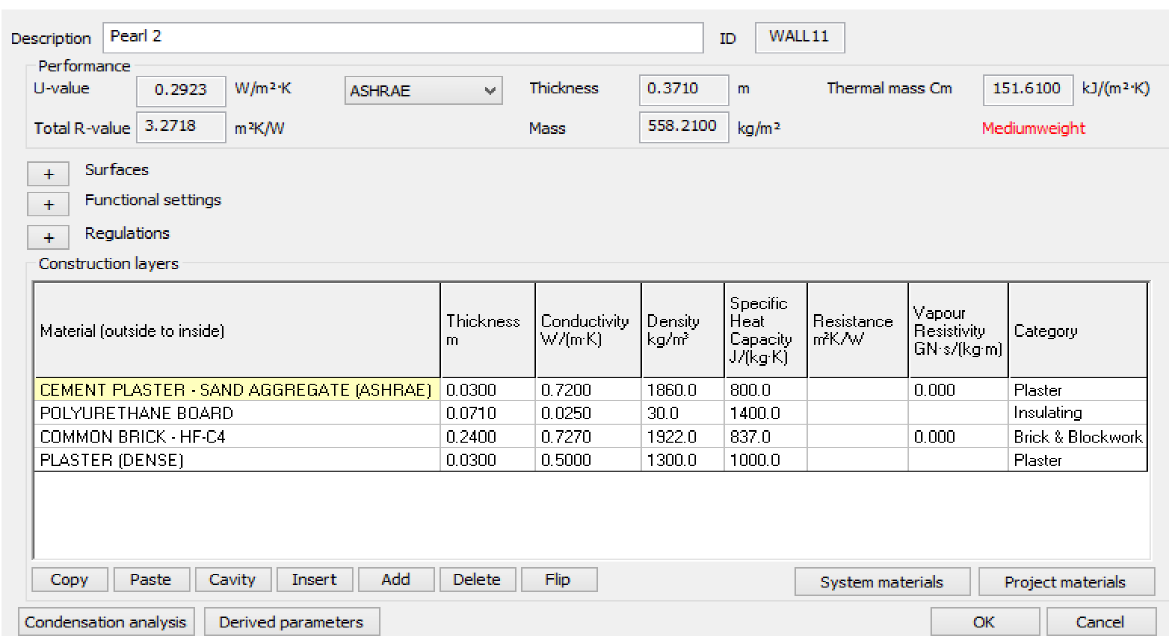
This scenario examines the impact of wall insulations such as Polyurethane Board on total energy performance. The U-Values were reduced from 1.7197 W/m2 K to 0.3224 W/m2 and refers to ESTIDAMA 1Pearl.

Characteristics of 1Pearl and 2 Pearls U-Values have been highlighted in Figure 5.11 and Figure 5.12.



Material (outside to inside)	Thickness m	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
CEMENT PLASTER - SAND AGGREGATE (ASHRAE)	0.0300	0.7200	1860.0	800.0		0.000	Plaster
POLYURETHANE BOARD	0.0630	0.0250	30.0	1400.0			Insulating
COMMON BRICK - HF-C4	0.2400	0.7270	1922.0	837.0		0.000	Brick & Blockwork
PLASTER (DENSE)	0.0300	0.5000	1300.0	1000.0			Plaster

Figure 5.11 Case 6 walls layers- 1 Pearl (IES-VE constructions template)



Material (outside to inside)	Thickness m	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
CEMENT PLASTER - SAND AGGREGATE (ASHRAE)	0.0300	0.7200	1860.0	800.0		0.000	Plaster
POLYURETHANE BOARD	0.0710	0.0250	30.0	1400.0			Insulating
COMMON BRICK - HF-C4	0.2400	0.7270	1922.0	837.0		0.000	Brick & Blockwork
PLASTER (DENSE)	0.0300	0.5000	1300.0	1000.0			Plaster

Figure 5.12 Case 7 Walls layers - 2Pearls (IES-VE constructions template)

The use of the Polyurethane Board in Case 6 that adopted 1Pearl reduced the total annual energy consumption from 152.1 MWh to 146.4 MWh representing a 3.74% decrease. Case 7 used 0.2923 W/m2 K as the U-Value of 2Pearls and reduced the energy to 146.3 MWh. This reduction is equivalent to 3.82% from the annual total energy usage as shown in Figure 5.13.

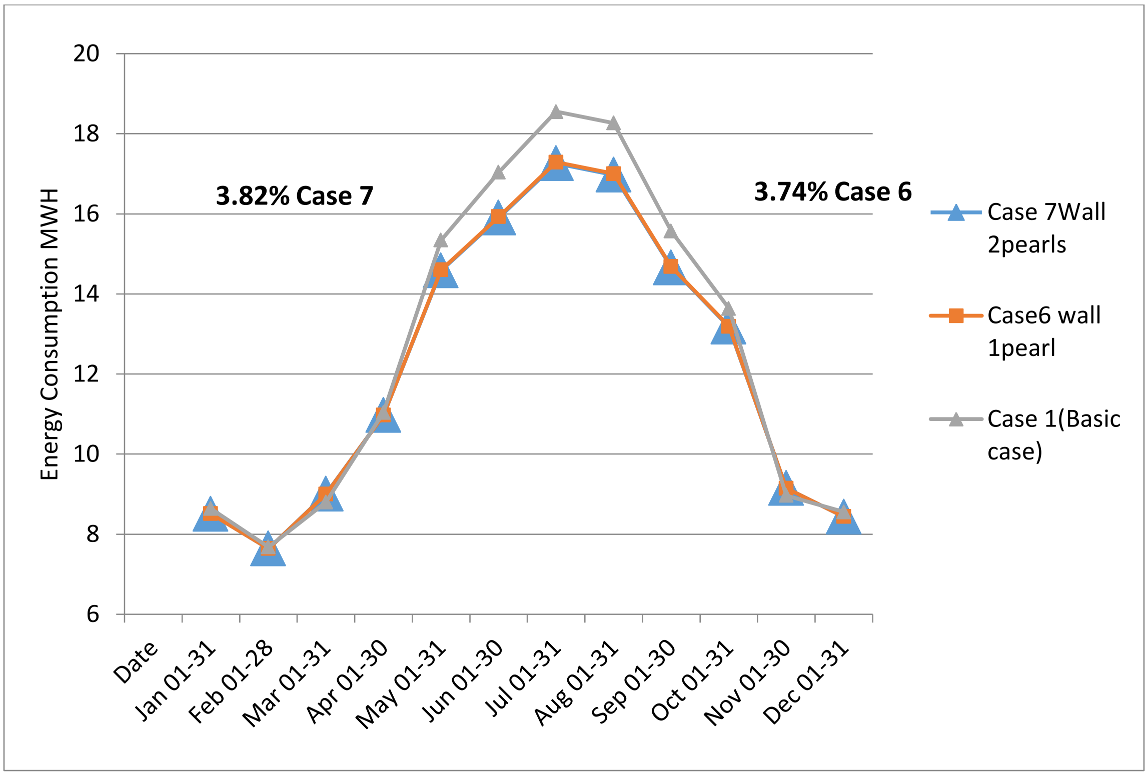


Figure 5.13 Cases 6, 7 and Case 1: the impact of adopting insulation materials in walls (1Pearl and 2Pearls)

Figure 5.14 clarifies the difference between Cases 6, 7 and Case 1 (Basic Case) due to a chiller load reduction. The graph shows that when the insulation was added to the walls, the chiller load dropped between 10.1 - 10.3 % either adopting 1Pearl or 2Pearls. Meanwhile, adding insulation to the walls had less impact on chiller load than adding insulation to the roof. Overall Friess *et al.* (2012) found that even poor insulation materials approached a 20% reduction of total energy consumption. This reduction varies depending on the insulating characteristics of these materials.

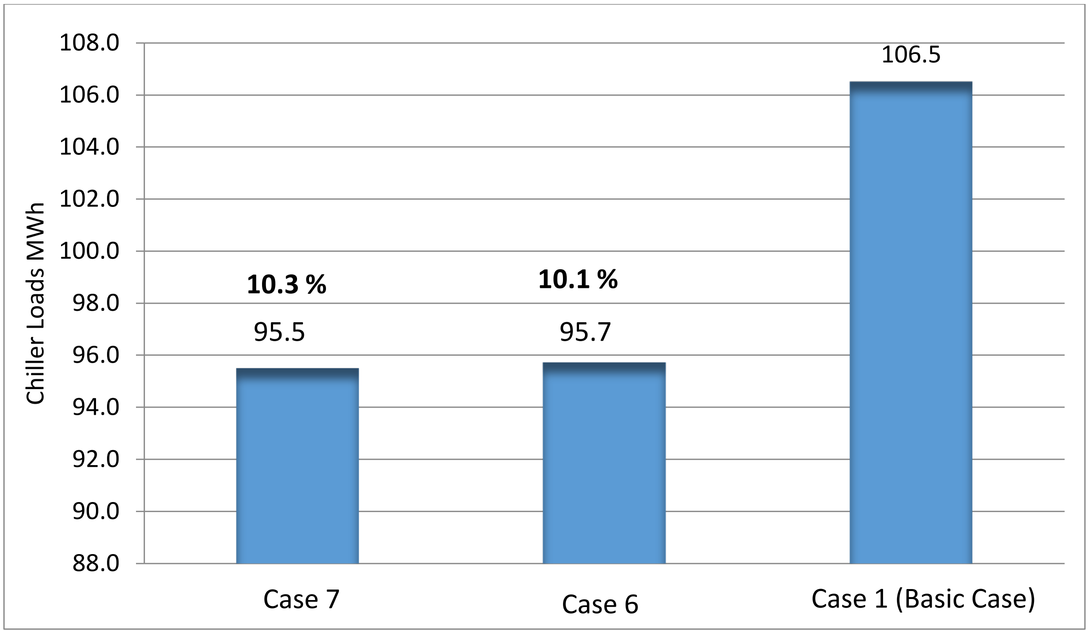


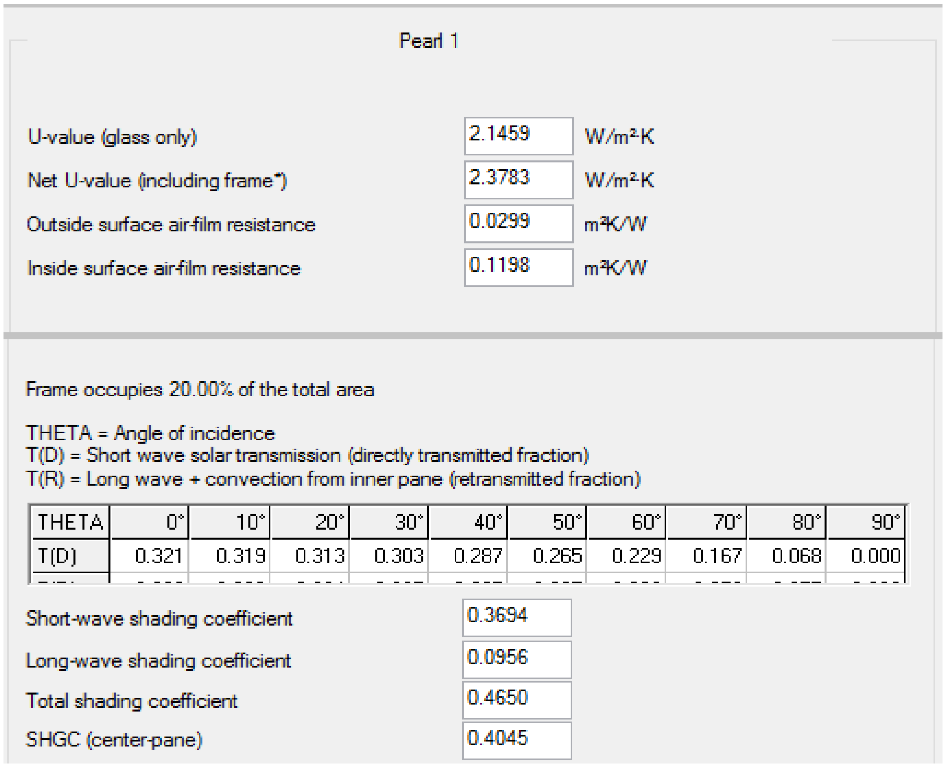
Figure 5.14 Cases 6, 7 compared with Case1 (Basic case) based on chiller load reduction

The incorporated insulation improvements allowed the chiller loads to be reduced from 106.5 MWh to 95.7 MWh which represented 10.1% in Case 6. In Case 7, it was reduced to 95.5 MWh providing a 10.3% reduction as shown in Figure 5.14.

According to Kumar (2012,) the conventional walls and roofs have the highest ratio of thermal transmittance that can be reduced through adding insulation. Thus, adapting insulation materials with low U-Values leads to achieving low cooling loads depending on the type and thickness of insulation materials used.

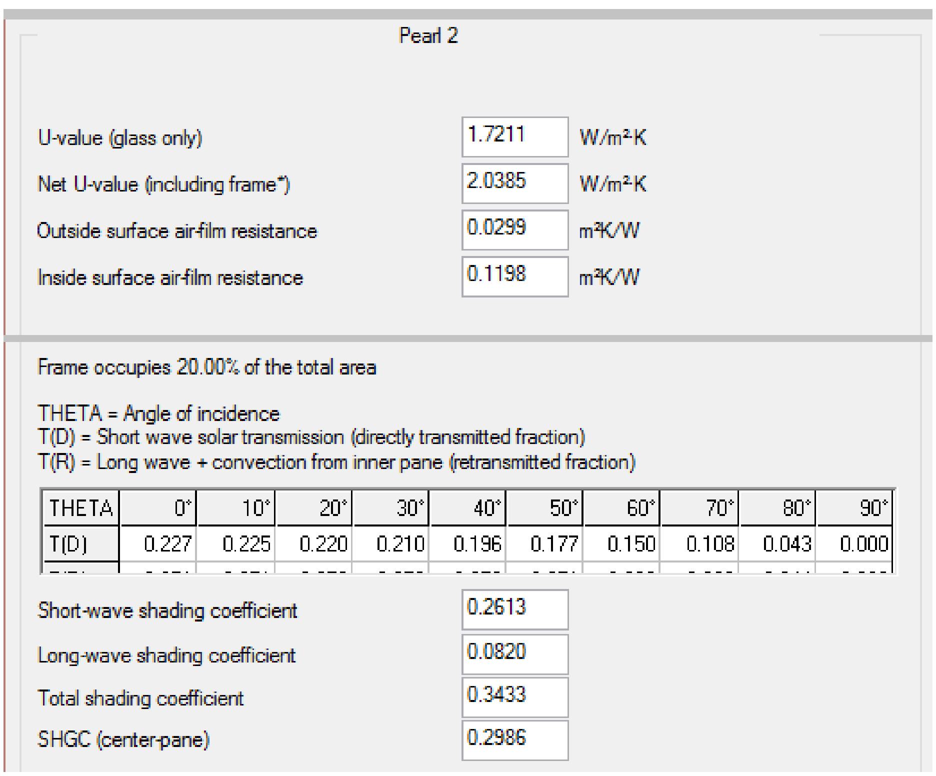
5.3.5 Changing Solar Heating Gain Coefficient of Glazing (Cases 8 and 9)

This scenario examines the impact of glazing coefficient on energy consumption through adopting two values of Minimum ESTIDAMA thermal requirements. Solar Heating Gain Coefficient of 1Pearl is 0.4 (SHGC) represented in Case 8 whereas Case 9 adopted 2Pearls 0.3 (SHGC). The glazing configuration of SHGC is highlighted according to the ASHRAE Standard in Figures 5.15 and 5.16.



THETA	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
T(D)	0.321	0.319	0.313	0.303	0.287	0.265	0.229	0.167	0.068	0.000

Figure 5.15 Case 8 - SHGC of glazing - 1Pearl (IES-VE constructions template)



THETA	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
T(D)	0.227	0.225	0.220	0.210	0.196	0.177	0.150	0.108	0.043	0.000

Figure 5.16 Case 9 - SHGC of glazing - 1Pearl (IES-VE constructions template)

The external wall area of the ground floor is approximately 259.7 m2 and the window ratio is 35 m2 which means only 13.5% is exposed to direct solar gain through the glazing. The external wall area of the first floor is almost 166.8 m2 and the window area is only about 16.1 m2 which provides a 9.6% window-to-wall ratio. According to the ratio of opening area, the expected energy demand reduction through glazing scenario seems to be less compared to the insulation scenario.

The results of Case 8 adopting 1Pearl show that the total energy consumption was reduced from 152.1 MWh to 150.2 MWh. This was a 1.2% reduction. In Case 9 the energy decrease was 149.9 achieving a 1.4% energy reduction. The graph shows that in spite of adopting low SHGC of glazing the energy improvement is very little. This passive strategy should consider the window-wall ratio before being applyed to the building.

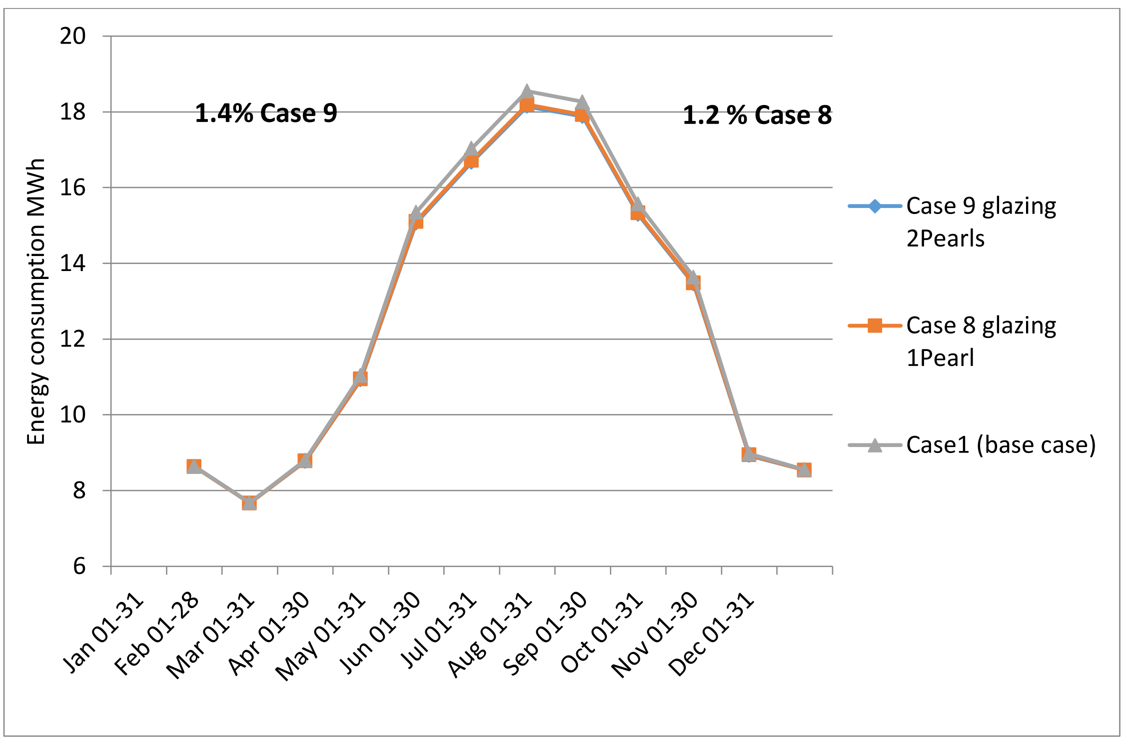


Figure 5.17 Cases 8 and 9 the impact of adopting insulation materials in the wall (1Pearl and 2Pearls)

Although the chiller load in Case 8 was reduced from 106.5 MWh to 102.9 MWh representing a 3.4% reduction, it records a slight difference in Case 9. The reduction was documented at 102.2 MWh which is equivalent to 4%. This means that the difference between adopting 1Pearl and 2Pearls is only a 0.6% load reduction. Figure 5.18 shows a comparison between Cases 8 and 9 with Case1 (Basic Case) to show the impact of using a glazing coefficient on chiller loads.

Maximum reduction of energy consumption is noticed in Case 9 which adopted 2Pearls considering that the open area is only about 11.9% of the entire building while the whole wall area is approximately 425.8 m2.

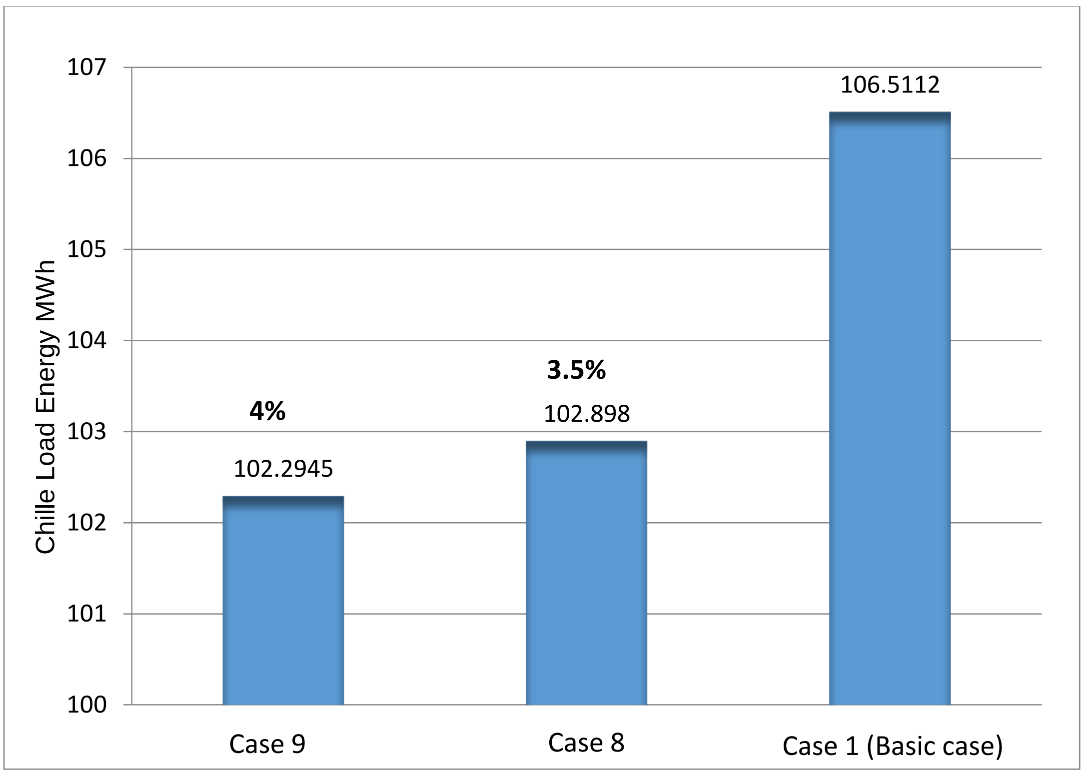


Figure 5.18 Cases 8, 9 compared with Case1 (Basic Case) based on chiller reduction

According to Al Awadhi, et al. (2013) the maximum window-wall ratio should be in the range of 15% for 1Pearl and 10% for 2Pearls. The ratio of the open area already matches ESTIDAMA thermal requirements.

Al-Ragom (2002) noted that the impact of an enhancing glazing system could achieve about a 9.1% reduction of the electrical load whereas the minimized opening ratio further reduced the electrical load by approximately 10% depending on the characteristics of the glazing. Thus, the impact of glazing will be limited according to the ratio of the opening area. The chiller loads have a 3.5% reduction for 1Pearl and 4% reduction for 2Pearls.

5.4 Annual Energy Consumption of all Passive Configurations

Results of the nine cases are highlighted in Figure 5.19. The bars show the amount of energy reduction for each passive strategy. It's very clear that the most affected scenario is the roof insulation while insulation in the wall becomes second. The shading strategy has the least effective energy reduction.

This is also clarified in Table 5.5 that summarized the nine cases and their consumptions. The data shows the consumption of each case that included lighting, equipment, boiler, chiller energy, and the amount of their reduction reductions.

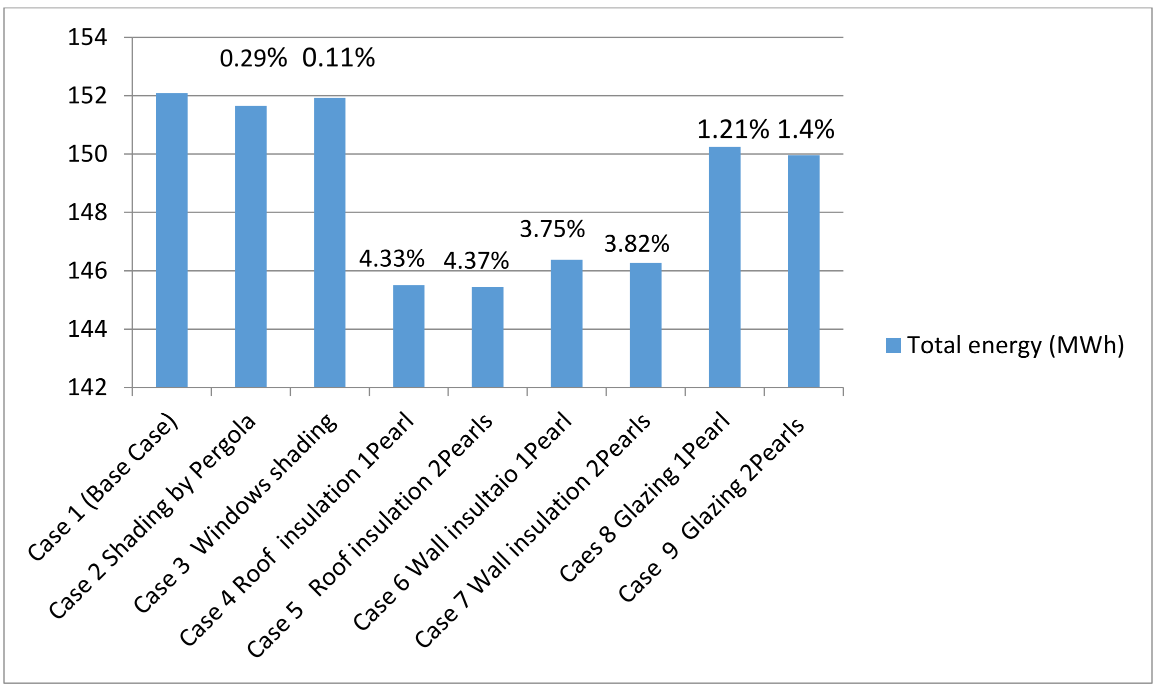


Figure 5.19 Nine passive cases compared with Case1 (Basic Case) based on energy reduction

Table 5.5 Nine cases are highlighted: energy consumption and savings

Case	Boilers energy MWh	Total chiller energy MW h	Reduction % of chiller energy	Total system energy MWh	Total light energy MWh	Equip electricity MWh	Total energy MWh	Save % of total energy
Case 1 (Base Case)	0.54	74.76	0.00	75.29	30.72	46.08	152.1	0
Case 2 (Pergola)	0.54	74.32	0.59	74.86	30.72	46.08	151.6	0.29
Case 3 (Windows shading)	0.55	74.58	0.24	75.13	30.72	46.08	151.9	0.11
Case 4 (Roof 1P)	0.21	68.50	8.37	68.71	30.72	46.08	145.5	4.33
Case 5 ((Roof 2P)	0.21	68.44	8.46	68.65	30.72	46.08	145.4	4.37
Case 6 (Wall 1P)	0.23	69.37	7.21	69.59	30.72	46.08	146.4	3.75
Case 7 (Wall 2P)	0.22	69.25	7.36	69.48	30.72	46.08	146.3	3.82
Case 8 (Glazing 1P)	0.51	72.95	2.42	73.46	30.72	46.08	150.2	1.21
Case 9 (Glazing 2P)	0.52	72.65	2.82	73.17	30.72	46.08	150.0	1.4

The data illustrated the difference between 1Pearl and 2Pearls for each scenario. The comparisons between passive cases are based on the percentage of energy reduction and savings.

Overall energy consumption is limited to the total system's energy that includes boiler energy plus cooling energy. The main variable parameters including: shading devices, insulation materials, and coefficient of glazing systems cannot affect total energy of lighting and equipment. The energy that is consumed by lighting and equipment have the same values in the nine cases. Consequently, the reduction of the total chiller energy is justified due to the impact of the variable parameters of the cooling load as shown in Table 5.6.

Table 5.6 shows the pattern of chiller load reduction according to each case. Regarding the incorporated insulation improvements, the highest energy reduction was achieved in Case 5 representing 11.9% whereas Case 3 observed the lowest ratio of chiller load reduction at about 0.33%

Table 5.6 Chiller load reduction of nine cases compared to the Basic Case

Cases	Chiller load (MWh)	Percentage of reduction %
Case 1 (Base Case)	106.5	0
Case 2 (Shading by Pergola)	105.6	0.82
Case 3 (Windows shading)	106.2	0.33
Case 4 (Roof insulation 1Pearl)	94.0	11.7
Case 5 (Roof insulation 2Pearls)	93.9	11.9
Case 6 (Wall insulation 1Pearl)	95.7	10.1
Case 7 (Wall insulation 2Pearls)	95.5	10.3
Case 8 (Glazing 1Pearl)	102.9	3.39
Case 9 (Glazing 2Pearls)	102.3	3.96

The percentages of chiller load reduction show the optimal U-Values of each scenario in order to realize if it's worth adopting or not.

Actually, the difference between 1Pearl and 2Pearls is very little due to the energy performance and chiller load reduction. Adopting 1Pearl will be more practical considering the cost issues, while adopting 2Pearls will achieve a higher level of energy consumption and savings while neglecting the cost.

Consequently, the next section will examine two cases: one more practical with a low cost which is Case 10, and the other considering the higher level of energy performance which is Case 11. The data that was obtained from the nine simulations has been moved to the Appendix.

5.4.1 Economically Optimized Case and Efficient Optimized Case (Cases 10 & 11)

Economically Optimized Case10 examines the U-Values of 1Pearl for the variable parameters that are: roof, walls, and glazing system performance in order to evaluate the passive strategies together.

The results of the simulation of Case10 show the total energy usage was reduced from 152.1MWh in the basic case to 139.6 MWh as shown in Table 5.7. This means that combining the passive strategies can achieve an 8.2% energy reduction and savings.

Figure 5.20 clarifies the economically optimized case that adopted 1Pearl also achieved a significant energy reduction.

On the other hand, the chiller load was reduced from 106.5 MWh to 76.4 MWh which is approximately 28.3% as shown in Figure 5.21. The detailed tabulation of this simulation can be found in the Appendix.

The analysis of the results clarifies that the reduction of total energy consumption and chiller loads occurred in the peak months of June, July, and August. This energy improvement can be achieved by using passive strategies matched with peak energy demand. Thus, the decrease of the U-Values of construction elements by adding insulation materials can easily enhance the energy performance of a building.

Table 5.7 Comparison between the practical optimized Case10 and Case1 (Basic Case)

Date	Total system energy (MWh) Practical optimized Case10	Total system energy (MWh) Basic Case	Boilers energy (MWh) Practical optimized Case10	Boilers energy (MWh) Basic Case	Total Energy (MWh) Practical optimized (Case 10)	Total Energy (MWh) Basic Case
Jan 01-31	2.2778	2.0096	0.0222	0.0939	8.869	8.6008
Feb 01-28	2.1343	1.7799	0.0201	0.0542	8.0216	7.6672
Mar 01-31	3.085	2.5571	0.0222	0.0222	9.5482	9.0204
Apr 01-30	4.4555	4.8112	0.0215	0.0215	10.7908	11.1464
May 01-31	6.6158	8.7097	0	0	13.1431	15.237
Jun 01-30	7.5998	10.6675	0	0	13.8711	16.9387
Jul 01-31	8.3557	11.8349	0	0	14.947	18.4261
Aug 01-31	8.2238	11.6993	0	0	14.687	18.1625
Sep 01-30	6.8942	9.2968	0	0	13.1655	15.5681
Oct 01-31	5.8439	7.0312	0	0	12.4351	13.6224
Nov 01-30	3.4014	2.9548	0.0215	0.0215	9.6726	9.226
Dec 01-31	2.3325	1.9884	0.0222	0.078	8.8597	8.5157
Summed total	61.2197	75.3404	0.1299	0.2914	139.6106	152.1313
Percentage of reduction	18.7%		0.58%		8.2%	

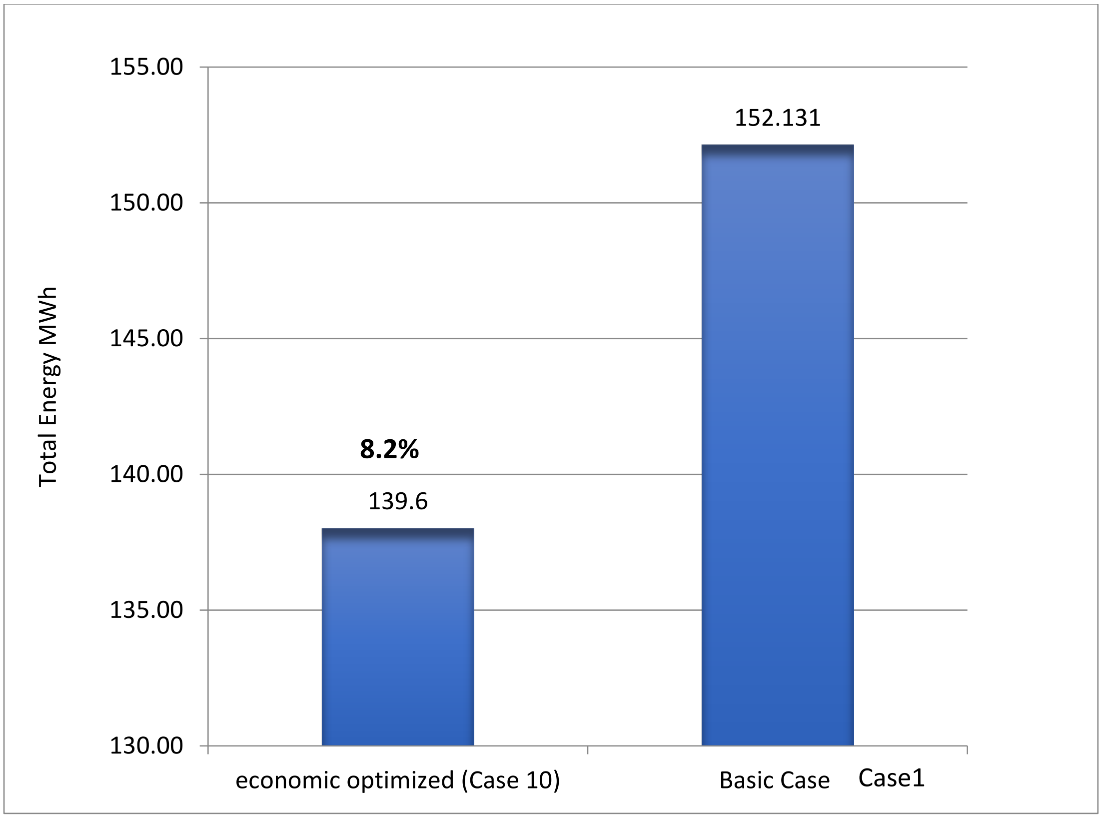


Figure 5.20 Case10 compared with Case 1 (Basic Case) based on total energy consumption

Extensive research has been done to assess the most important components for direct solar gain, which significantly affects the total cooling and heating load in a building. Several studies concluded that two–thirds of the discomfort felt was eliminated by the non-wise decisions of simple passive options. Ralegaonkar (2010)

The shading device scenarios have been already adopted in the economic and coefficient cases to be evaluated during the simulations. The energy demand reduction has a slight difference when going from 1Pearl to 2Pearls thermal requirements. The energy consumption was reduced from 139.6 MWh in the practical optimized case to 139 MWh for efficient optimized case representing a 0.42% decrease.

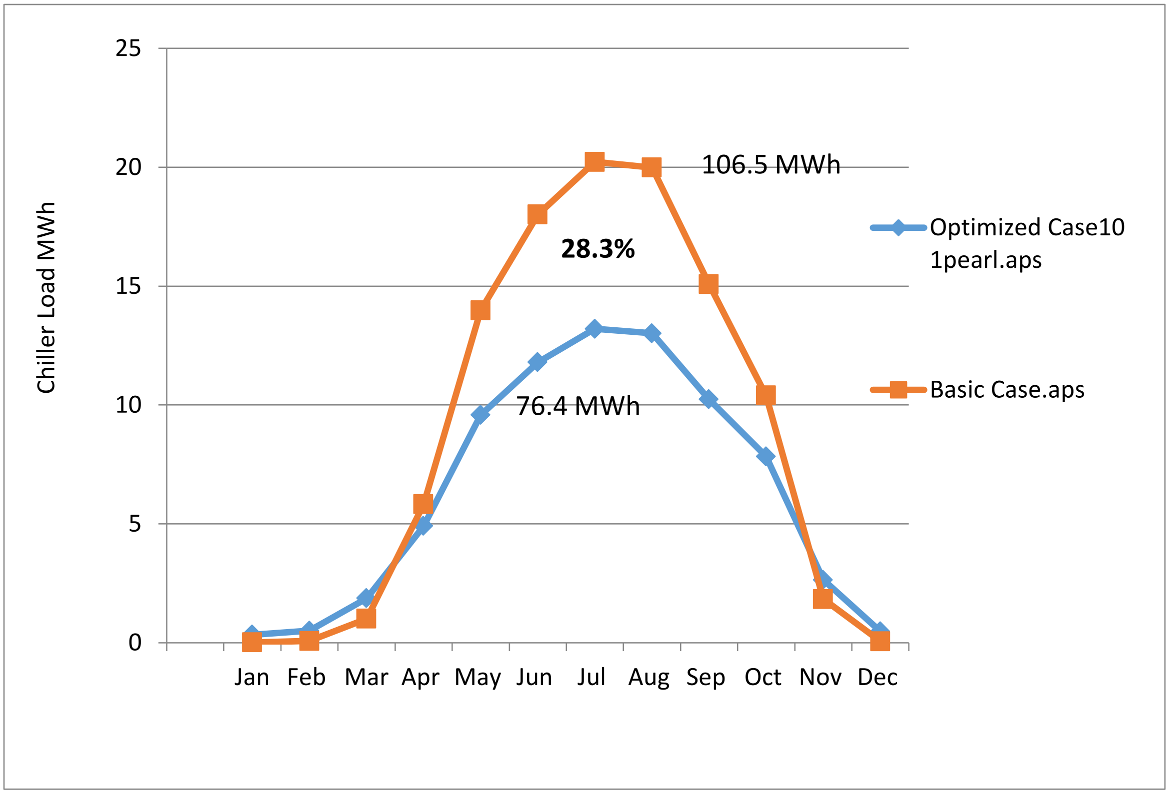


Figure 5.21 Case10 compared with Case1 (Basic Case) based on chiller load

According to Al Awadhi, et al. (2013) there is little benefit when going from a 1Pearl to a 2 Pearls refurbishment level. Thus, 1 Pearl was evaluated to be more practical.

Figure 5.20 shows a comparison between both economic cases and the basic one in order to recognize the worthiness of using 1Pearl or 2 Pearls.

Figure 5.22 shows a comparison between Efficient, Practical Cases and the Basic Case in order to evaluate the impact of both cases on chiller load reduction to see if it is worth adopting or not.

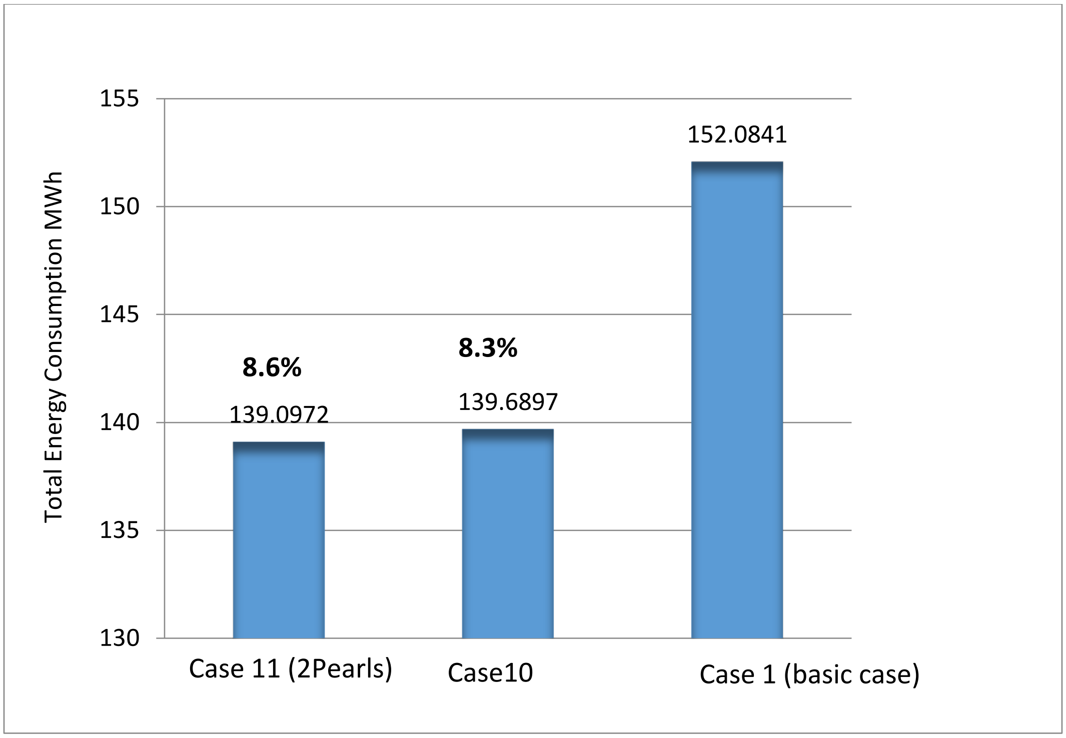


Figure 5.22 Cases 10 & 11 compared with Case1 (Basic Case) based on energy consumption

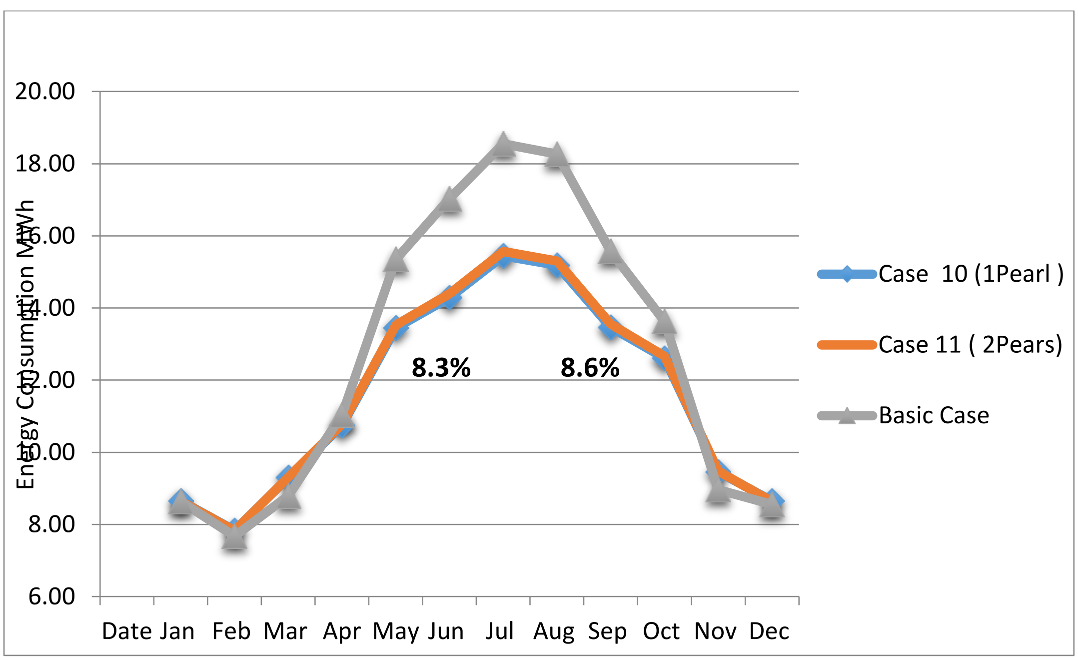


Figure 5.23 Cases 10 & 11 compared with Case1 (Basic Case) based on monthly energy consumption

According to the slight difference in energy reduction between 1Pearl and 2Pearls, it appears that 1Pearl is the optimal case when considering the benefit and cost issues.

Overall, the energy demand reduction due to the use of the passive strategies achieved 8.2% for 1Pearl and 8.6% for 2Pearls. Meanwhile, the chiller load achieved 28.3% for 1Pearl and 29.3% for 2Pearls. Adopting more efficient insulation materials in order to reduce the U-Values of the construction elements can increase this percentage of reduction.

The passive strategies can reduce the demand of energy by 8.2-8.5% in a typical house in Iraq. By adopting these solutions as regulations for housing in Baghdad, we can achieve higher levels of electricity demand reduction. In addition, insulation materials are available in Iraq and can be added to the roof and wall easily enough to enhance the energy performance of the buildings.

The U-Values of 1Pearl will be adopted for the active scenario in order to achieve the goal of electricity demand reduction through both passive and active strategies. The next section will consider the results of the economically optimized case, Case10, which was simulated for active strategies.

5.5 Active Strategies

This scenario, as mentioned in chapter 4, contains several types of active strategies. The scenario will examine and evaluate the activated case that has the most potential to significantly reduce the electricity demand.

The active strategies will examine chiller efficiency through changing Coefficient of Performance (COP), adding solar domestic hot water (DHW), and installing photovoltaic panels (PV). Each scenario will examine different configurations in order to evaluate the most appropriate optimized case of energy savings.

5.5.1 Coefficient of Performance (COP) of Air Conditioning System (Case12)

This scenario addresses the impact of chiller efficiency on total energy demand reduction through using another type of air-conditioning system. Many countries still neglect the significant importance of this strategy in order to achieve energy savings very easily within a limited time. According to Kreider *et al* (2013) The Coefficient of

Performance (COP) has been defined as the measurement of input power to the output power of a system which means that:

$$COP = \frac{Power\ Output}{Power\ Input} \quad \text{..................................} \quad (1)$$

Whenever the value of the COP is higher, the system will be more efficient. However, the other way of measuring system efficiency is the Energy Efficiency Ratio (EER) which is defined in the following equation:

$$\text{EER} = \frac{\text{Output Cooling Energy (BTU)}}{\text{Input Electrical Energy (WH)}} \quad \text{...} \quad (2)$$

While the relation between EER and COP is:

$$\text{EER} = \text{COP} \times 3.41 \quad \text{(3.41 is a constant value)..............................} \quad (3)$$

The Seasonal Energy Efficiency Ratio (SEER) is defined as the measurement of how a system behaves over a season considering the outdoor temperature variables.

$$SEER = \frac{Outpt\ Cooling\ Energy\ (BTU)\ over\ a\ season}{Input\ Electical\ Energy\ (WH)\ over\ the\ same\ season} \quad \text{..................} \quad (4)$$

According to the ASHRAE/IES Standard 90.1 (2010) the efficiency of air conditioning systems have improved over the years in order to reduce energy consumption.

The Coefficient of Performance (COP) of split units has improved from 1.7 in (1977-1997) to be 3.8 in 2006. The table of COP ASHRAE Standards has been moved to the Appendix chapter.

As stated in “ENERGY.GV” (2013) air conditioning today produces the same amount of cooling with 30%-50% less energy than in the 1970s. Air conditioner standards have achieved a SEER of 13 (equal to 3.8 COP) which is 30% more efficient than the SEER of 10 (equal to 2.9COP)

As mentioned in chapter 2 under section 2.3.1, the COP has been developed for less than 0.5 in the 1970s to be more than 3.5 after 2006. The average COP from 1998 till 2001 ranges from 2.5–3, while after 2006 it ranged from 3.5 -3.8. The COP that was used in the Basic case, 2.5, represents the average whereas it could be increased to 3 to enhance energy performance.

This scenario increased the COP from 2.5 to 3.5 in order to examine the impact of the air conditioning efficiency on energy demand reduction and savings. The results of this simulation show that the total energy was reduced from 139.6 MWh in economical optimized Case10 to be 127.8 MWh representing approximately 8.5% in reductions. This energy reduction was compared with the economical Case 10 that adopted 1Pearl and Case1 (basic case) as shown in Figure 5.24. It also shows the use of Coefficient of Performance (COP) has almost the same impact of adopting the passive strategies together.

The percentage of energy reduction for Case 10 is 8.2 % while the percentage of Case 12 is about 8.5%. This comparison gives an indication of the significant impact of this active strategy on energy savings. Thus, the results have shown that the chiller load was reduced from 76.4 MWh to 71.1 MWh representing a 4.9% reduction through changing the COP of the air conditioning system.

This scenario can be achieved quickly and easily by choosing an air conditioning system with more Coefficient of Performance (COP). This achieves about an 8.5% energy reduction immediately, neglecting the cost issues compared to the energy savings. Figures 5.24 and 5.25 have illustrated the energy reduction in Case 10 by using passive strategies while Case 12 adopts the highest COP air conditioning system.

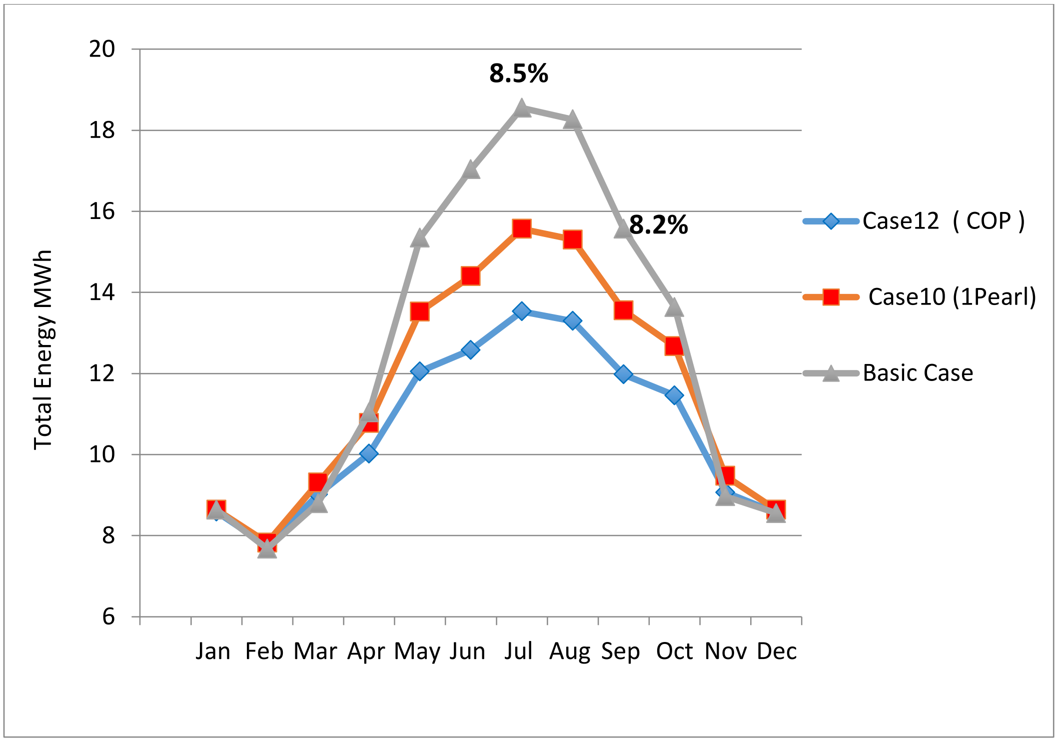


Figure 5.24 Case12 adopting (COP) and Case 10, compared with Case1 based on energy consumption

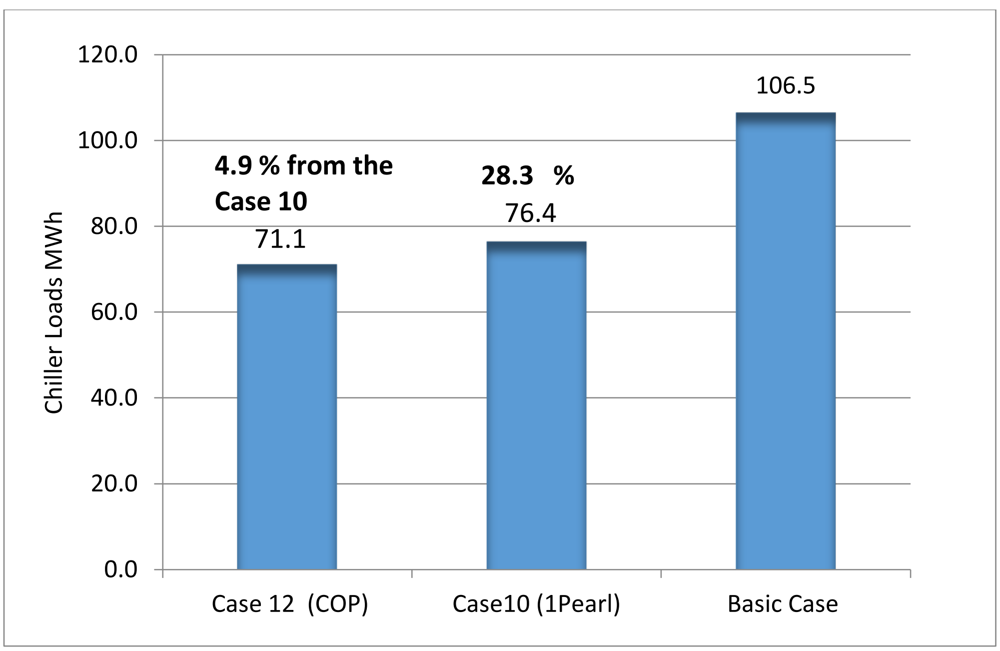


Figure 5.25 Chiller load reduction through changing (COP) represented by Case12

5.5.2 Solar Domestic Water Hot (SDWH) (Cases: 13-17)

This scenario examined one of the most effective ways for generating hot water for domestic requirements. Many simulations have been run to investigate the best area to reduce the boiler load.

According to Laughton (2010) before installation of a solar energy system one should consider the position of the sun as it keeps changing during the day and throughout the year (azimuth and altitude angles). It is important to tilt the solar collector towards the equator facing south in the northern hemisphere while in the southern hemisphere it should face north. A tilt angle variable between 10 to 50 percent from the horizontal is an acceptable compromise. However, in the tropics and equatorial areas where the sun is overhead during the day with very slight differences over the seasons the importance of the tilt angle is reduced.

According to solarelectricityhandbook.com (2013) the most suitable angle of the sun in Baghdad, especially in coldest month such as January, is 41 percent from vertical.
In order to face south, the simulation adopting azimuth angle is 180 clockwise from the north and the solar collector tilted toward 49 percent from the horizontal as offered through IES-VE simulations. While the area varied as (2, 4, 6, 8 and 10) meters square to select the optimized case that reduced the boiler energy and did not affect the photovoltaic panel production.

Regarding the previous results of the annual total energy consumption, boiler energy has the smallest part of the consumption, which means that the results of this scenario will not affect the total energy consumption as expected. The major impact will appear on the boiler load.

The results show that the boiler load was been reduced from 0.1163 MWh in Case10 to be 0.016 MWh in Case 13. This represents a 96.6% reduction as shown in Figure (5.26). The results of five simulations show that the boiler load dipped significantly when using the Solar DHW. Even when less area was used it had only a slight difference between the remaining simulations.

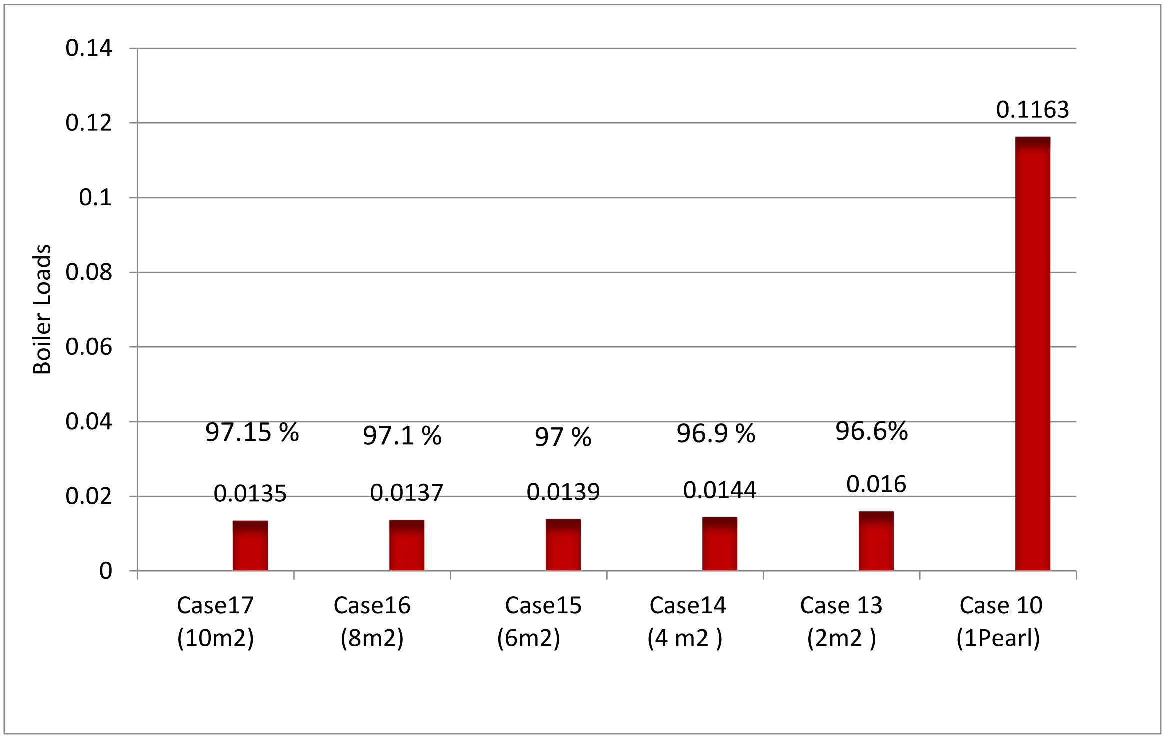


Figure 5.26 Boiler load reduction based on the use of Solar DHW system

Laughton (2010) estimated the size of the active collector area was about 0.40-0.70 meter square per person. This estimation considered the climate region that was for tropical / sunbelt equals to (>1800 annual horizontal irradiation KWh/m2). Thus, the average of the area should be multiplied by the number of occupants in order to select the installation of the solar area. The case study was occupied by five people as mentioned in the modeling chapter, so (5 people x 0.70 = 3.5 meter square), which means that 4 meters is the most suitable area that provides the house with the required domestic hot water. The results of the simulations show that once the solar DHW runs, the load has been strongly dropped while for the other cases in remains at the same level with only a slight change as shown very clearly in Figure 5.19.

Table 5.9 shows the results of simulations according to the varied area compared with the economically optimized Case 10 in order to understand the amount of boiler load reduction using this strategy.

Table 5.8 Results of boiler loads of variable solar installing areas

		Solar area				
	Practical optimized (Case10)	2 m2 Case13	4 m2 Case14	6 m2 Case15	8 m2 Case16	10 m2 Case17
Boiler load (MWh)	0.4773	0.0160	0.0144	0.0139	0.0137	0.0135

By selecting an area of 4 m2, this gives enough space for the PV to be installed. Meanwhile, the balance between both strategies will achieve a significant increase in energy production while having a demand reduction. These simulations have been done separately in order to investigate the proper configuration for each one.

5.5.3 SunCast analysis

This scenario will examine several parameters in order to achieve the most efficient case as discussed in section 4.7. There is a significant analysis that should be considered before installing photovoltaic panels which is the site assessment focusing on the amount of solar radiation.

According to Stapleton and Neill (2012) who conducted a site assessment, any potential source of shading, such as trees, other buildings, TV aerials, and any other section of roof could provide shading during the daytime and can significantly reduce photovoltaic panel energy production. Any shading decreased the PV power output while it could lead to damage of the modules over their lifetime. There are several tools to estimate shading on-site for the entire physical area including manually or through software.

IES-VE software offers a solar calculation through SunCast analysis providing a mathematical and visual indication about the amount of solar radiations for a whole year as shown in Figure 5.27 and Figure 5.28.

As mentioned in chapter 5.2, the existing house has two roofs, and it has been suggested to extend the second one to be used as a pergola to provide shade and to be used for the installation of PV.

SunCast simulations show the upper roof received about (1845 kWh/m2) of solar radiation yearly. Part of the downstairs roof received the same amount with the exception of the shaded area that gained between (1521 - 1359 kWh/m2). The figures below highlighted the shaded area that was caused by part of the building and can affect the PV output power negatively.

Thus, this analysis aims to determine the best location of the PV, the roof specifications, shading profile, and the available area to achieve the highest level of efficiency.

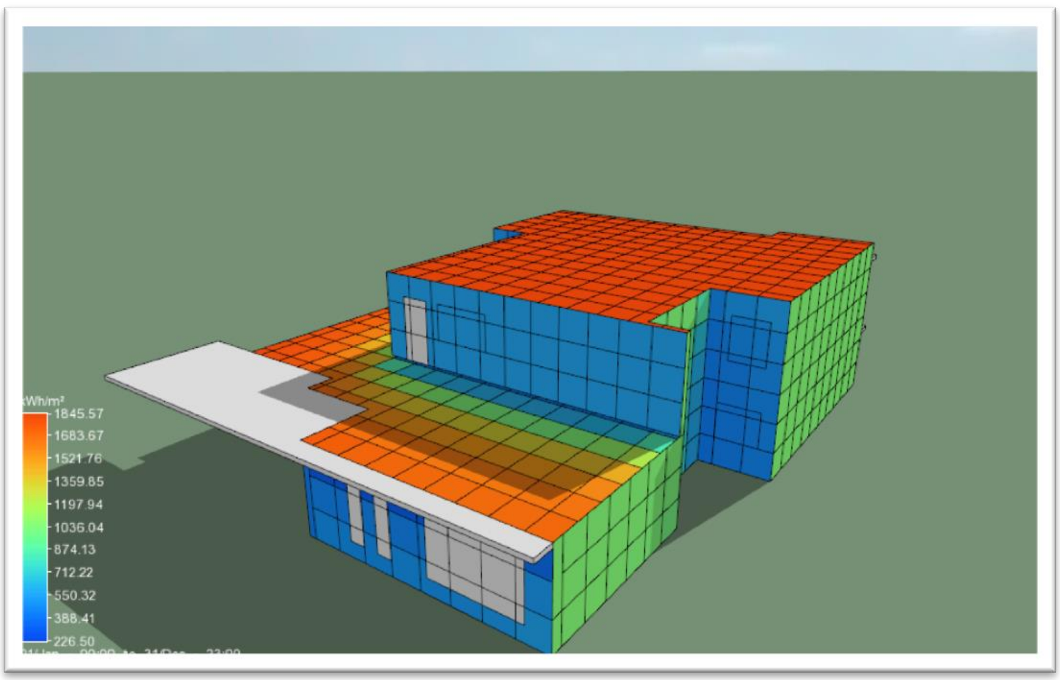


Figure 5.27 Analysis of the shading area of the roof and the amount of solar radiation by SunCast analysis (IES-VE)

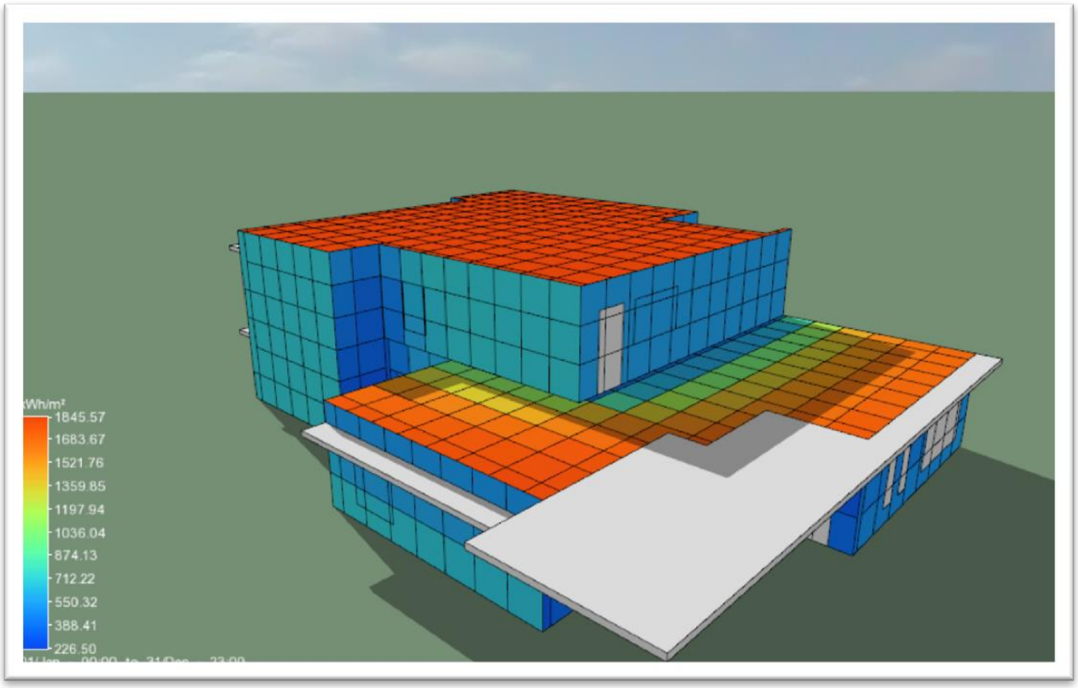


Figure 5.28 Analysis of the shading area of the roof and the amount of solar radiation by SunCast analysis (IES-VE)

This simulation gives evidence that it is important to add the pergola in order to provide a suitable place for installing the PV and to avoid any shading factors that could reduce the output power of the PV system. The pergola was a part of the passive strategies as mentioned in chapter 5.2.1, and it also offered shaded area services for the house.
The cost of the additional pergola could be negligible once the benefits of installing PV and long-term energy savings have been considered.

5.5.4 Optimized Angle of PV Panels (Cases 18 - 22)

The first simulation of this scenario will adopt a 166.8 m2 area (second roof only) to be occupied by PV ignoring the first floor roof. This scenario assumed that the first floor roof will be used to apply the outdoor air conditioning system.
Solarelectricityhandbook.com (2013) provides the optimized monthly tilt angle in Baghdad, Iraq, throughout the year in order to achieve the greatest performance from the system.

Table 5.9 Optimum tilt angle for solar panels in degrees from vertical in Baghdad (solarelectricityhandbook.com 2013)

Jan	Feb	Mar	Apr	May	Jun
41°	49°	57°	65°	73°	80°
Jul	Aug	Sep	Oct	Nov	Dec
73°	65°	57°	49°	41°	34°

Five different angles have been selected from Table 5.9 to examine the most efficient one that could enhance PV production. The selection has been done according to peak radiation and the hottest months: June, July, and August. The other angles selected were in January and March. The angle for January was 49 degrees from the horizontal (90-41) while the azimuth was 180. In order to maximize the opportunity of facing south, consideration is given to the existing orientation of the case study.

The simulations of each angle have been highlighted in Table 5.11 to understand the proper angle for energy production. According to Table 5.10, 25° from the horizontal (equal to 65°) was considered suitable for August.

The total annual production of PV increased through the changing of the tilt angles from 28.79 MWh to 30.76 MWh. Table 5.10 shows the difference between Cases 20, 21 and 22 and compared them with Cases 18 and 19. As discussed in chapter 4 under section 4.4, the peak electricity demand occurred on the 14th of August. Thus, the most optimized angles should be considered for the PV production according to this angle.

Table 5.10 PV production power of different tilted angles

	Case 18	Case 19	Case 20	Case 21	Case 22
Angles from horizontal	49	33	10	17	25
Month	January	March	June	July	August
Total annual PV productions (MWh)	28.7959	30.5884	29.8057	30.468	30.7698

This simulation gives evidence that adding the pergola to provide a suitable place for installing PV and avoiding any shading factors could reduce the PV output power. Meanwhile, the pergola is considered to be part of the passive strategies as mentioned in chapter 5.2.1 as shading devices. The cost of the additional pergola is not a significant expense when PV production and energy savings for long term planning are taken into consideration.

Figure 5.29 shows the electricity demand reduction due to the PV production using a 166meter square without adopting solar DHW. Case 22 is compared with Case 12 to evaluate the PV production with the minimum available area.

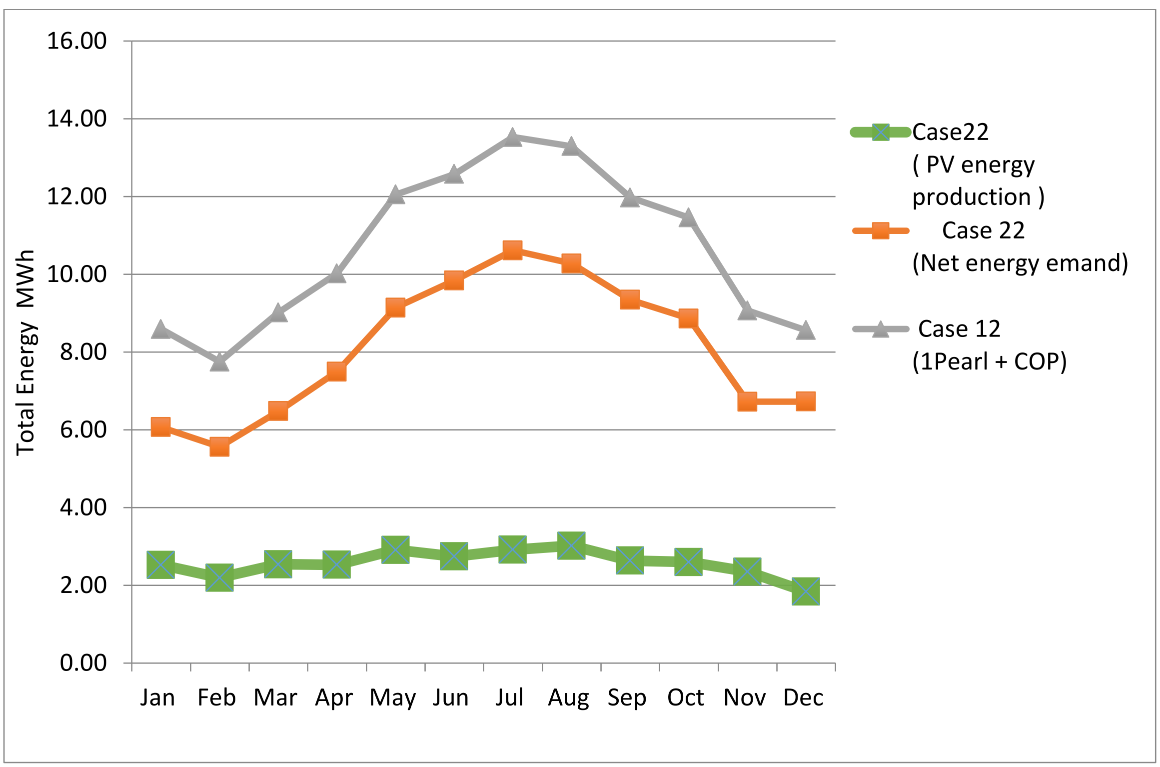


Figure 5.29 Energy demand reduction through using PV

The chart shows that PV can generate power continuously even in the coldest month. This means that adopting this strategy will actively provide energy for the whole year. The percentage of energy reduction achieved 24% of the total net electricity demand with the minimum available area.

Consequently, all of the following simulations will adopt the most optimized tilt angle, which is 25 degrees from horizontal with 180 as the azimuth angle to enhance PV energy production. The next section will examine the impact of increasing the installing area to achieve more energy demand reduction.

5.5.5 Optimized Area of PV Panels (Cases 23 and 24)

This scenario examines the extended roof as pergola with the shading devices over the windows. The area of the roof, including the extension, is 300 m2.

According to Stapleton and Neill (2012) installing PV should take into consideration the edge zone, which is defined as the area around that should be left to assure that the PV is mounted safely and easily. Generally the size of this edge zone should be determined by local codes. In Australia the edge zone is regulated to be 20 per cent of the available area. While energysavingtrust.org (2013) assumed that the installation of PV panels on a flat roof should leave one meter from the edges to provide an area for maintenance. Since the location has no local codes, consequently, 10% of the total area will be reduced to provide edge zone, which is enough to provide an area for cleaning and maintaining the PV system safely.

The total roof area will be 270 m2 to install the PV panels. The simulation examines the Monocrystallin Silicon type of PV. The other type of PV cells will be tested in the next section. The results of the simulations show that the PV production was increased from 30.76 MWh in Case 22 to 50 MWh in Case 23 representing 66.6%. Furthermore, the net energy demand was reduced from 127.8 MWh to 77.8 MWh giving a percentage reduction of 39.1%.

Sharples and Radhi (2013) investigated the technical performance of residential building integrated photovoltaic in GCC countries and found that the PV of Crystalline cells with 202 meters square installed in the roof generated approximately 30.63 mu. The PV production was calculated using the Energy-10 simulation software. Comparing both results provides an indication of the PV production considering the slight difference in types, area, and location.

A comparison between Case 22 and Case 23 has been shown in Figure 5.30. Clearly the PV energy production has exceeded more than half of the energy demand achieving the aim of this research.

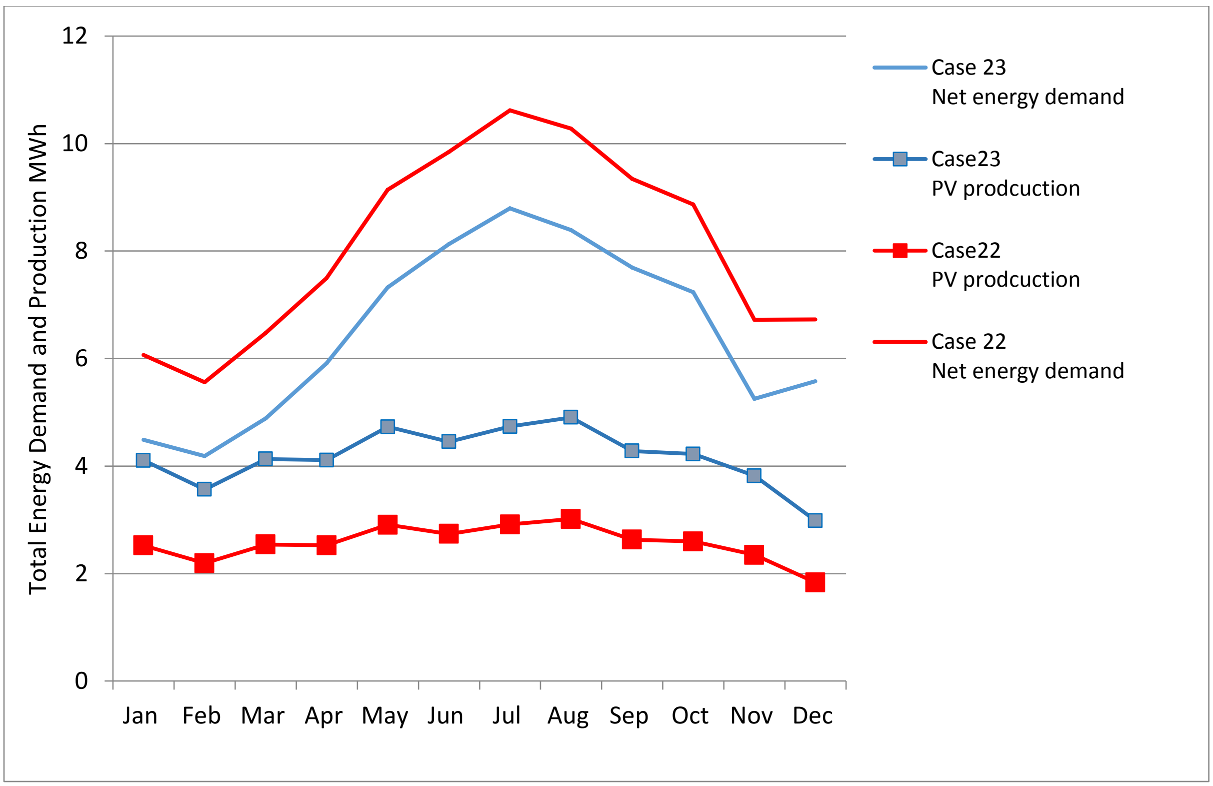


Figure 5.30 Difference between PV energy production and energy demand reduction is due to the different areas in Cases 22 and 23

The next simulation considers the solar DHW that is occupied with 4 m2 as mentioned in section 5.10 to evaluate the impact of minimizing the area for PV installation. The total area will be 266 m2 with a 10% maintenance area and a 4 m2 solar DHW.

The simulation of Case 24 shows that the PV energy production dropped from 50 MWh to 49.3 MWh. Meanwhile the boiler load improved to 0.0135 MWh. It shows that installing solar DHW will not be worthwhile because of the lack of PV production. The little improvement of the boiler load reduction will not compensate for the shortage of PV output power, which leads to increased total electricity demand.

Figure 5.31 shows Case 24 which adopts solar DHW has a reduction in the PV energy production leading to increased net electricity demand.

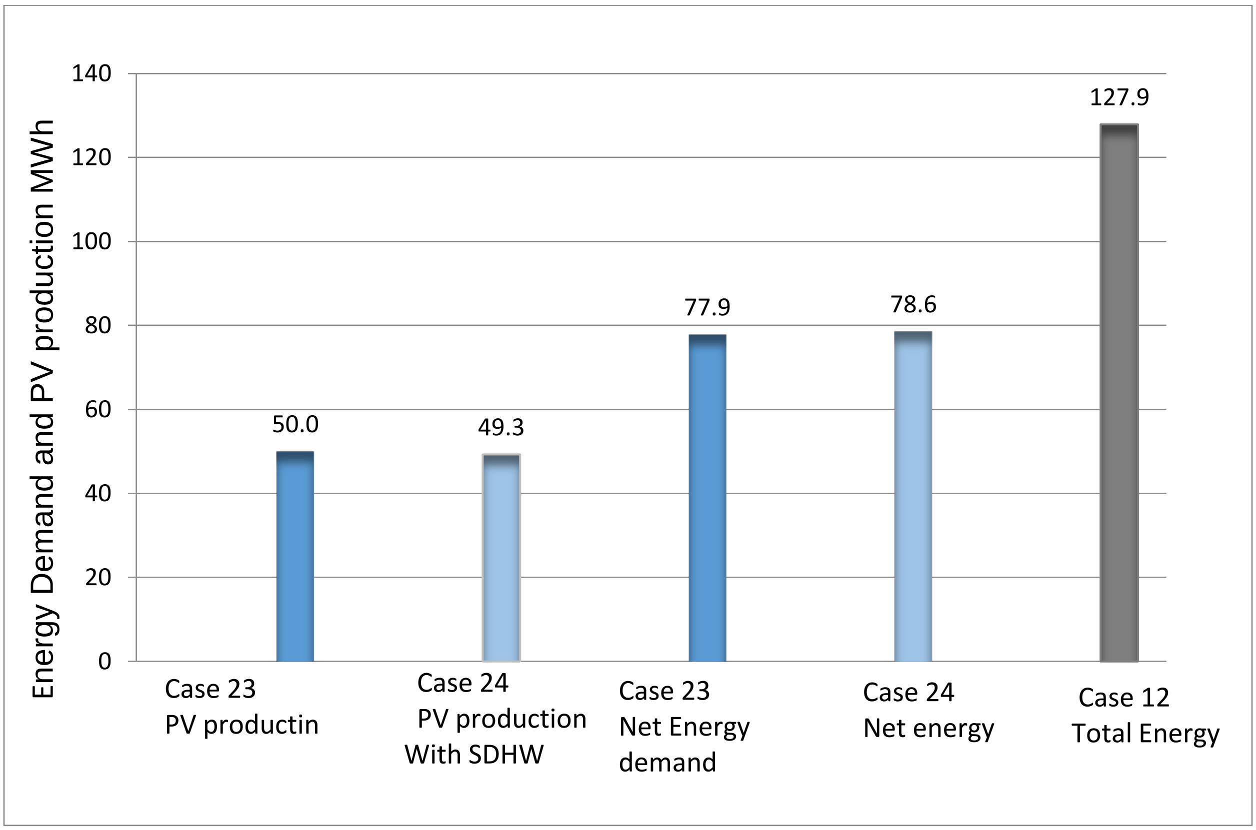


Figure 5.31 Energy demand and PV energy production for two cases: Case 23 without solar DHW and Case 24 with installed solar DHW.

As the main goal of this research is reducing the electricity demand, the solar DHW strategy should not be adopted because it increases the total PV output power. Since the weather in Iraq is usually hot, it is better to keep the area for installing PV instead of using it for solar DHW, which peaks only for a limited time of the year.

5.5.6 Installing PV on the windows shading devices (Case 25)

The SunCast analysis has been run to assess the shadow profile of the building. The analysis shows that the best location is the south façade. The other facade is shaded either by part of the building or with shading devices as shown in Figure 5.32 and Figure 5.33. Thus, the shading devices of the south facade have been highlighted to determine their area as shown in Figure 5.34.

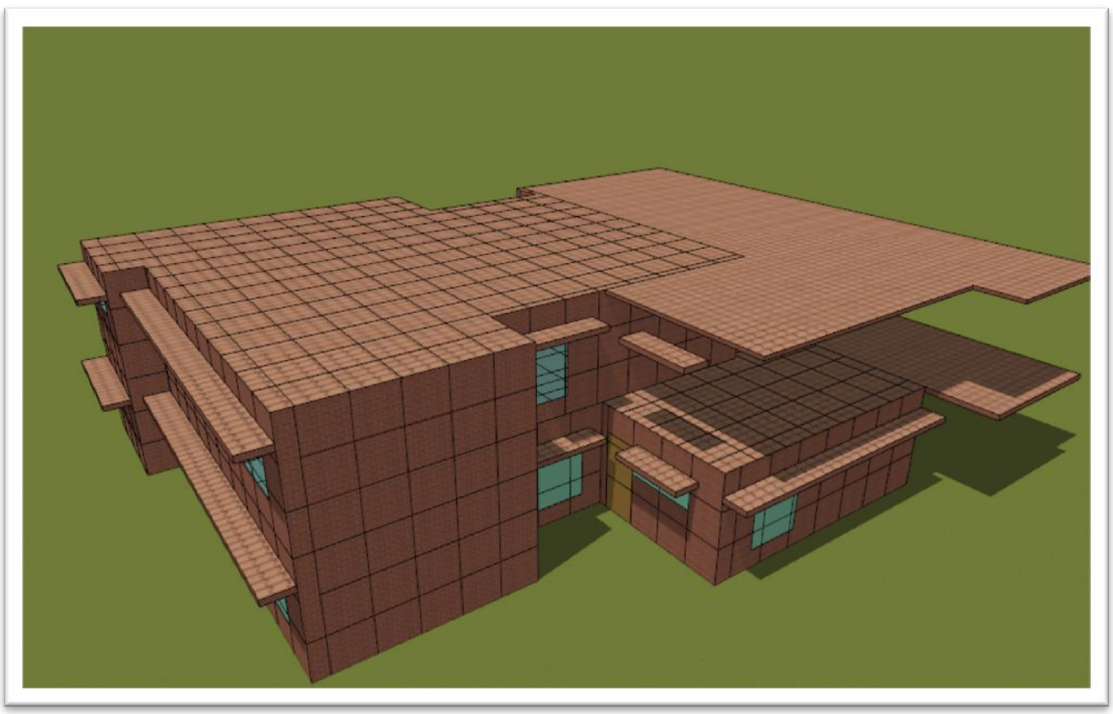


Figure 5.32 Shaded area analyzed by SunCast analysis (IES-VE)

Figure 5.33 Shaded area analyzed by SunCast analysis (IES-VE)

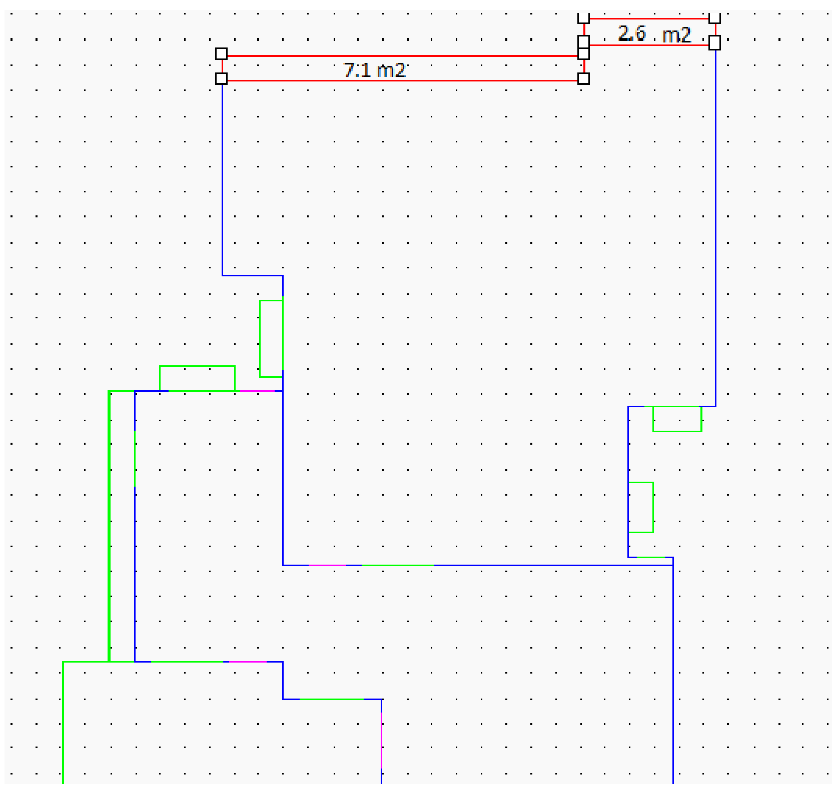


Figure 5.34 Shading devices on the south installed with PV (IES-VE)

Case 25 adopted two types of shading devices located on the south as shown in Figure 2.26. The first one is about 2.6 m2 and the other is 7.1 m2. It is located on the ground and first floors, so the area will be doubled.

The simulation added PV panels to the shading devices of the windows to increase the PV production from 49.3 MWh to 52.6 MWh as shown in Figure 2.35.

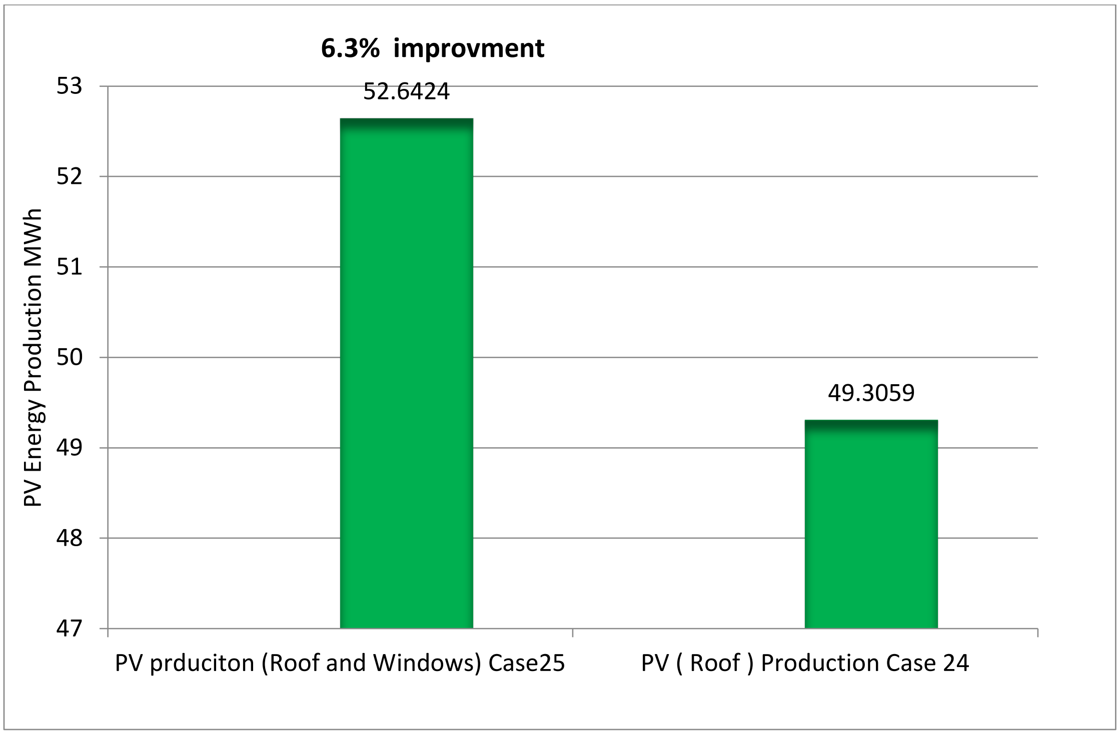


Figure 5.35 shows the PV production of two cases: 24 (PV on roof) and 25 (PV on roof and windows)

Figure 5.35 shows the additional PV panels have achieved a 6.3% improvement. This scenario depends on many factors, such as the availability of the space, the location in the south, and the shading profile. By increasing the area of the PV, the overall PV energy performance is enhanced.

5.5.7 Photovoltaic Panels Performance

This scenario will examine the major differences in the types of solar cells between Moncrystalline Silicon, Polycrystalline, Amorphous Silicon, and Thin Film. According to Stapleton and Neill (2012) the most efficient type is the Moncrystalline because it offers considerable performance when compared with other types of technologies. This higher level of performance, however, has the highest rate of cost. The utilization of these types varies from one project to another according to the available space, requirements, and preliminary cost. Monocrystalline silicon has been adopted for all previous simulations through IES-VE configurations. Stapleton and Neill (2012) highlighted the major types of PV cells and their efficiency as shown in Table 5.11.

Table 5.11 Comparison of different cells of PV Stapleton and Neill (2012) Source IEA

Cell materials	Module efficiency
Monocrystalline Silicon	14-20%
Polycrystalline	13-15%
Amorphous Silicon (thin film)	5-6 %
Thin film	9-12%

According to the efficiency classifications for each material, the Moncrystalline Silicon has the highest performance. Therefore, the simulations have already considered the most coefficient technology compared to the other types. The simulations in this scenario will not be expected to exceed the previous results of PV performance. They could, however, give an indication of the impact of selecting more efficient PV cells.
The PV types have been considered during simulations of IES-VE. Table 5.12 summarizes the module efficiency under specific cell temperatures that were used in IES-VE simulations.

Table 5.12 shows the PV cell types due to their efficiency and the normal cell temperatures according to IES-VE configuration.

Type of PV cells	Module Normal Efficiency	Normal Cell Temperature
Monocrystalline Silicon	13%	45
Polycrystalline Silicon	11%	45
Amorphous Silicon	5%	50
Thin Film	7%	46

Three simulations have been run to assure that previous simulations adopted the most efficient types of PV cells. The results of this scenario will increase the validity of the results.

Table 5.12 provides a comparison between the types of PV cells and energy production. The data show that Monocrystalline Silicon produced 52.6 MWh while Polycrystalline dropped to 44.5 MWh representing the second most efficient type. Thin film technology provides 29.6 MWh. Amorphous Silicon provides the least production at 21.9 MWh.

Table 5.13 Comparison between PV cells type and production

Type of PV cells	Amorphous Silicon	Thin Film	Polycrystalline Silicon	Monocrystalline Silicon
PV Production MWh	21.91	29.65	44.54	52.64

Due to the results of this scenario, the most efficient type of PV cells is Monocrystalline if one does not take into consideration the set up costs.

5.6 PV Production and Peak Demand

This section investigates the peak time of PV production and the actual electricity demand to find out the net electricity demand that is obtained from the following equation:

$$Net\ Total\ Energy\ Demand\ = Acutal\ Energy\ Demand - PV\ Energy\ Production \quad .... (5)$$

The occupied daily profile, determined in chapter 4 under section 4.5.2, assumes that people will be out from 8am until 2pm. Therefore, the use of energy drops to zero during this time period. On the other hand, the production of PV will peak during the daytime. Figure 5.36 shows that the peak production of PV occurred during normal work hours due to the absence of need.

The selected day is Wednesday, 18 August, which represents a normal workday during the hottest month. The graph indicates the gap between the energy producing times and the net electricity demand during the day. In addition, the actual demand has been dropped to zero from 8 am to 2pm according to the occupancy profile. Meanwhile, the net energy demands are shown as a negative value because the amount of energy production is more than the energy consumption.

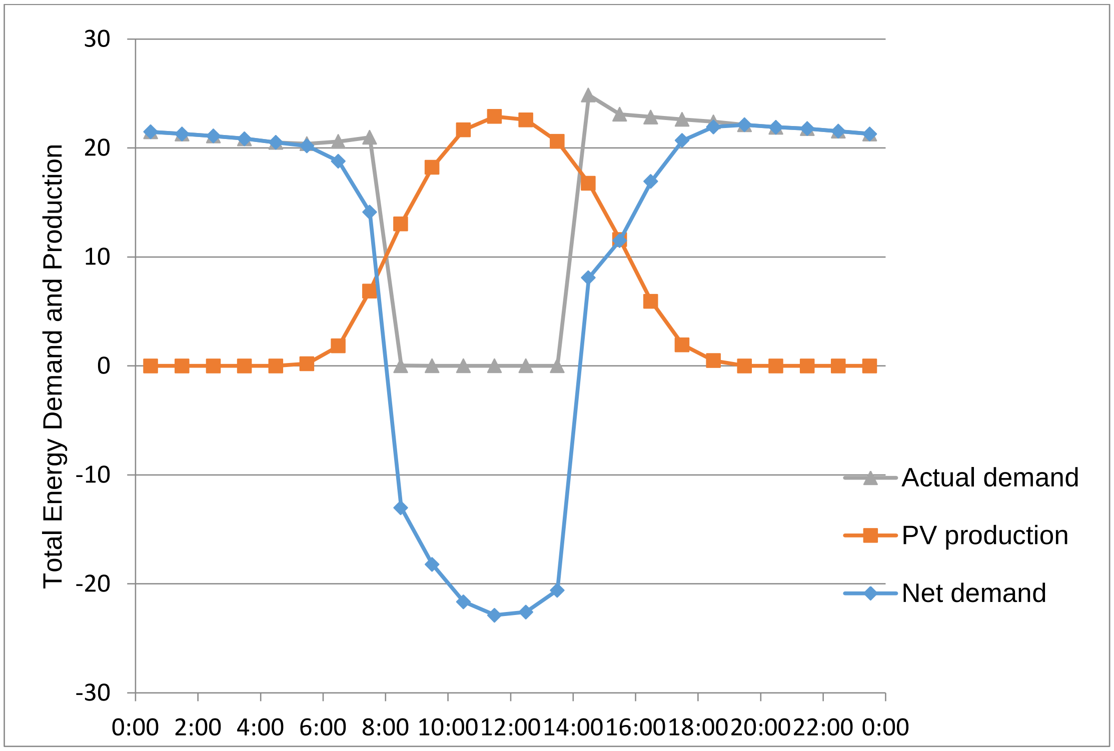


Figure 5.36 Peak time of PV production and net energy demand due to occupancy (22 of August, week day)

Figure 5.37 shows the weekend of Saturday, 14 August. The graph demonstrates the parallels between the demand for energy and PV energy production. The graph highlights that PV production is equivalent to the demand on the weekend. Compatibility between the timing of PV energy production and energy demand has a significant importance due to the reduced needs of grid electricity.

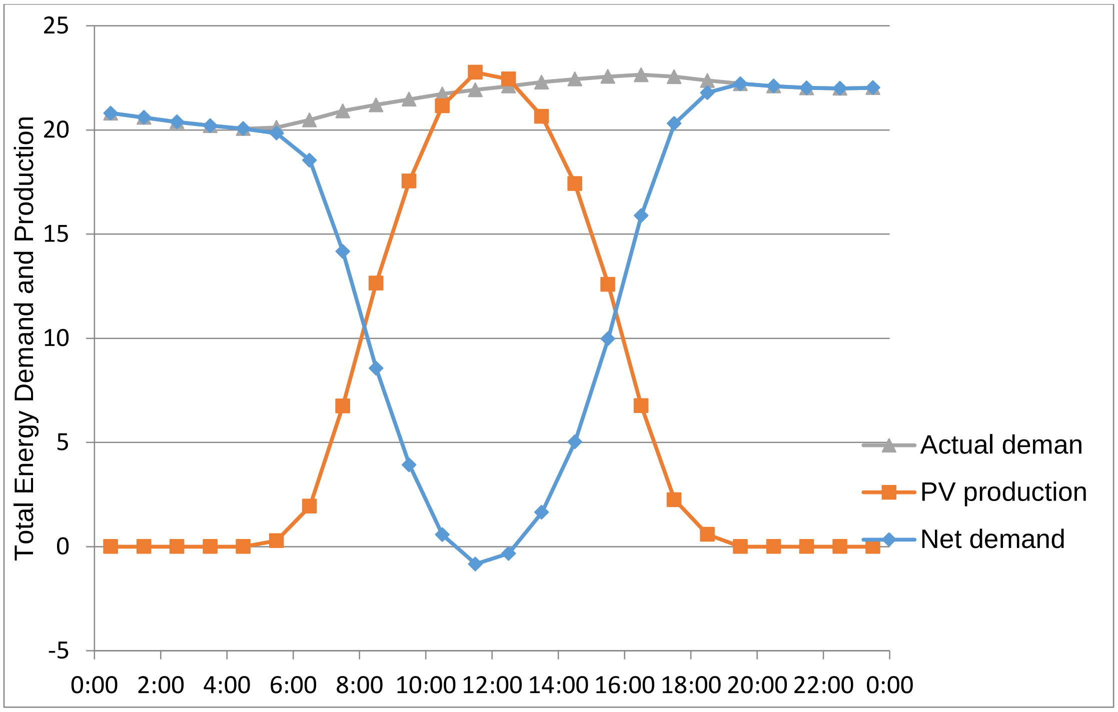


Figure 5.37 Peak time of PV production and the net energy demand due to occupancy (14 August, weekend)

Overall, the energy produced should be stored until the demand time. Two solutions for this problem are:

- Stand-alone systems add a battery to the PV system. According to Stapleton and Neill (2012) this type of system is most commonly used in remote areas. Solar power is used to charge batteries and then stores the power until the required time. The power of the battery is used to directly operate the appliances, or inverters can convert the battery voltage for use in regular AC equipment. The major disadvantage to this solution is the cost of the battery, which is not considered in this research.
- Grid connected systems feed the electricity generated by the PV back to the grid, instead of storing it in a battery. It can then be imported from the grid when the power is needed. This type of PV system avoids the cost of a battery and uses a connection between the PV system and the electricity grid. The extra power that is generated by the PV is exported to the grid, and in many countries the system owner pays for the exported power.

Ultimately, the PV system industry is aiming to achieve grid parity. This is accomplished when the cost of electricity obtained from the grid equals the cost of electricity that is produced by the PV system. This parity generally depends on local factors such as: the amount of local solar radiation, the cost of the PV systems and installation, and the local electricity prices, which vary from one country to another. However, the PV implementation is expected to be applied and improved in many developing nations within the next decade. (Stapleton and Neill 2012)

Generally, the disadvantages of the stand-alone solution are the initial setup costs and the maintenance costs of the battery. Meanwhile, connecting the PV system to the grid could support and enhance the energy performance on the public level. In my opinion, the grid connected solar electric system needs to be adopted by governmental authorities to help legislate future regulations managing the system.

Chapter 6

Conclusions and Recommendations

One of the most important things of this century is electricity; every aspect of modern life depends on it. Meanwhile, many environmental phenomena such as global warming and climate change have highlighted the importance for the need for renewable energy.

Due to the rapid growth of economies and populations, energy consumption has increased globally. GCC countries had the fastest rate of increase at 12.4% during 2005 -2009 representing 3.15% annually. The average consumption watt per person in the GCC countries reached 1149. This figure is dramatically higher than the world average (297 W per person). Many countries in the region are realizing that depending on sustainability and renewable energy will be the primary solution due to a depletion of natural resources and environmental impact. Al -Naser (2013) Therefore, sustainability and renewable energy are needed to meet the increased demand for energy.

Since the 1980s, Iraq's electricity grid has suffered from shortage and neglect, while the demand over the last decades has tripled. In this research, passive and active strategies were adopted to evaluate their impact on overall energy consumption. Since Iraq has similar climate conditions to the GCC countries, the final data of the research can also be implemented in the Gulf region.

A literature review was conducted to setup and identify the objectives of this research. Furthermore, a simulation model was configured to examine the variables. The results of the simulations used to evaluate each scenario examined the potential energy savings and compared it to the Basic Case. Passive and active strategies were evaluated separately to estimate the impact of each one.

Ultimately, the optimized configurations of passive and active strategies were combined to provide an overall estimate of energy performance and savings.

6.1 Conclusions

The dissertation discussed two groups of strategies. The first one included several scenarios of passive strategies while the second one adopted many active strategies.

The results of these simulations showed that the most effective parameter is roof insulations (1Pearl and 2Pearls), which achieved a significant energy reduction among other passive scenarios. Adopting 1Pearl provided a 4.33% energy reduction while 2 Pearls achieved a 4.37% decrease. Thus, roof insulation should be the priority when considering passive solutions for energy savings. The second most effective solution is wall insulation, which can achieve a 3.75% savings for 1 Pearl and 3.82% for 2Pearls. Meanwhile, the glazing system had the least amount of energy reduction at 1.2% for 1Pearl and 1.4% for 2Pearls. The results of adopting high performance glazing varied from one project to another in regard to the ratio of the opening to the walls.

It also found that the shading devices scenario had minimum impact on energy consumption savings (0.29 - 0.11 %) depending on the locations and size of the shaded elements. Overall, the passive strategies using 1Pearl represented in the economic case achieved an 8.2% energy demand reduction. The efficient case that was adopted in 2Pearls had little improvement over the 1Pearl as it recorded an 8.6% energy reduction. The study concludes that little benefit occurs when going from a 1Pearl to a 2 Pearls refurbishment level. Therefore, it was concluded that 1 Pearl is the most practical and economic option.

The simulations of the active strategies found that changing the Coefficient of Performance (COP) affected the energy consumption significantly. The COP values improved from 1.7 in the 1970s to 3.8 in 2006. To look for its impact on energy savings, the simulation of the Basic Case used 2.5 COP and it increased to 3.5. The increase of the COP value recorded an 8.5 % decrease in energy demand.

The results show that this scenario is the most effective active strategy and can be achieved quickly and easily by choosing an air conditioning system with more Coefficient of Performance (COP). This allows immediate energy reduction if cost issues are compared with energy savings. This conclusion provides the strongest impact of chiller efficiency on energy consumption and savings.

The research found that adding Solar DHW is not worth comparing with a lack of PV energy production, especially in hot climates. The minimal improvement of the boiler load reduction does not compensate the shortage of PV output power, which leads to an increase in the total electricity demand.

The simulations of five different angles found the best angle for installing PV is at 25 degrees tilted angle from the horizontal and 180 degrees azimuth angle. PV generates power even during the cold months, which means adopting this strategy will provide energy for the whole year. The percentage of energy reduction achieved 24% of the total net electricity demand within the minimum available area. It was found that increasing the installing area of PV increases the PV production from 62.6% to 66.6%.

In addition, the additional PV panels on window shading devices achieved 6.3% extra production. This scenario depends on many factors, such as the availability of space, location being to the south, and shading profile. Thus, whenever the installing area for the PV increases, the energy production will be enhanced accordingly.

Different types of PV cells were tested in the study to examine the level of performance for each model. The Monocrystalline is the most efficient type of PV cell, which provided the highest rate of energy production at 52.6 MWh. While the Polycrystalline Silicon reduced the energy production to 44.5 MWh, using Thin Film, energy production dropped to 29 MWh. The output power of adopting Amorphous Silicon was the least efficient dropping the amount of energy production to 21.91 MWh.

Although the initial cost of Monocrystalline is high, it is justified when compared to the output power. Polycrystalline has a lower price but lower efficiency, and Amorphous Thin Film needs more space to achieve the same comparative rate of energy production.

Finally, the production time of the PV needs to correspond with the demand time in order to avoid losing energy. The energy should be stored until the demand time, either though using a stand-alone system that utilizes a battery to PV system, or by using a grid-connected system, which feeds the electricity generated back to the grid.

Overall, it was concluded that adopting passive strategies as shading devices, roof insulations, wall insulations, and glazing systems could reduce the electricity demand by 8.2% for 1Pearl and 8.6% for 2Pearls. Increasing the Coefficient of Performance of the air-conditioning system could achieve an 8.5% energy reduction. The integration of both the passive and active strategies can achieve a 50.6% energy demand reduction.

Ultimately, the impact of each strategy will contribute to enhancing energy performance and savings. The study concluded that the integration of passive and active strategies significantly reduces electricity demand.

6.2 Recommendations and Future research

At this stage, the results have achieved the main purpose of this investigation, which was to clarify the impact of passive and active strategies on the energy demand reduction. Many other opportunities for future studies are highlighted as follows:

-There is a big gap between research related to passive and active strategies and their implementation in the Middle East, especially in the Gulf countries.

-It was noticed that there is a lack of data for Iraq related to passive and active strategy effects on energy consumption and savings. Thus, it is highly recommended to conduct research with different methodologies to investigate other alternative solutions to compensate for the lack of electrical demand.

-The proposed shading devices strategy should be based on the location, size, and the ratio of opening. The results of additional shading can be further studied in the context of the amount of daylight and visual quality.

- The impact of insulation materials on energy consumption can provide a broad area of study. The type, thickness, and integration between the different types might show more benefit to enhancing energy performance and savings.

-A study should be conducted using Solar Domestic Hot Water (DHW) with Photovoltaic panel systems, especially in hot climates. In hot climates, the energy required for the boiler is minimal compared with the energy needed for air-conditioning systems. Thus, adopting a solar DHW system can influence the PV production and reduce energy enhancement.

- Shading profiles are a very important factor to be considered during the design and installation of PV systems. The excessive rate of shaded spaces highly affected the PV performance and reduced energy production. Site assessments or sun-shading simulations are recommended to recognize the shading factors and the amount of radiation generated. Generally, wherever the area of installation of PV increased, the output power also increased. It is recommended to provide a larger area by adding or extending the roof to provide maximum PV production.

- It has been proved that Monocrystalline is the most efficient type of PV cell and provides the highest amount of energy production; however, it is also the most expensive kind. It is recommended to estimate the initial cost in order to select the most appropriate type of Photovoltaic cells.

-Finally, the time of day for highest PV energy production needs to be observed to discover if it corresponds with the time of energy needs. However, the produced energy can be stored either in a battery or connected to the main grid.

-In general, adopting passive and active strategies can be followed and applied by the private sector. Meanwhile, both of these strategies need to be supported by governmental authorities. It is recommended that the government legislate regulations and permissions, as well as give financial incentives in order to motivate the private sector to contribute to improving and enhancing energy performance of both the private and public sectors.

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Appendix A

Passive Strategies - Shading Devices

Table A.1 Monthly energy consumption and the chiller load of Case1 (basic case), Case2 (adding pergola) and Case3 (adding shading devices for windows)

Date	Total energy (MWh)	Total energy (MWh)	Total energy (MWh)	Chiller Load (MWh)	Chiller Load (MWh)	Chiller Load (MWh)
	Case 3 (windows shading)	Case 2 (Pergola)	Case 1 (Basic case)	Case 3 (windows shading)	Case 2 (Pergola)	Case 1 (Basic case)
Jan 01-31	8.644	8.6419	8.6397	0.0136	0.013	0.0134
Feb 01-28	7.6797	7.6773	7.6783	0.0688	0.0717	0.0701
Mar 01-31	8.7874	8.7801	8.7985	0.9845	0.9699	1.0066
Apr 01-30	11.0199	10.9758	11.0418	5.7786	5.6903	5.8223
May 01-31	15.3198	15.2563	15.345	13.9298	13.803	13.9803
Jun 01-30	17.0126	16.9537	17.0358	17.9707	17.853	18.0171
Jul 01-31	18.526	18.4717	18.5519	20.1784	20.07	20.2303
Aug 01-31	18.2421	18.2015	18.2684	19.9384	19.8572	19.9909
Sep 01-30	15.5449	15.5241	15.5668	15.0355	14.9937	15.0792
Oct 01-31	13.6225	13.6311	13.6371	10.3715	10.3887	10.4007
Nov 01-30	8.9616	8.9807	8.9678	1.8257	1.864	1.8381
Dec 01-31	8.5561	8.5521	8.553	0.0627	0.061	0.062
Summed total	151.9165	151.6464	152.0841	106.1582	105.6355	106.5112
% Energy reduction	0.11	0.29	0			

The maximum energy reduction

The minimum energy reduction

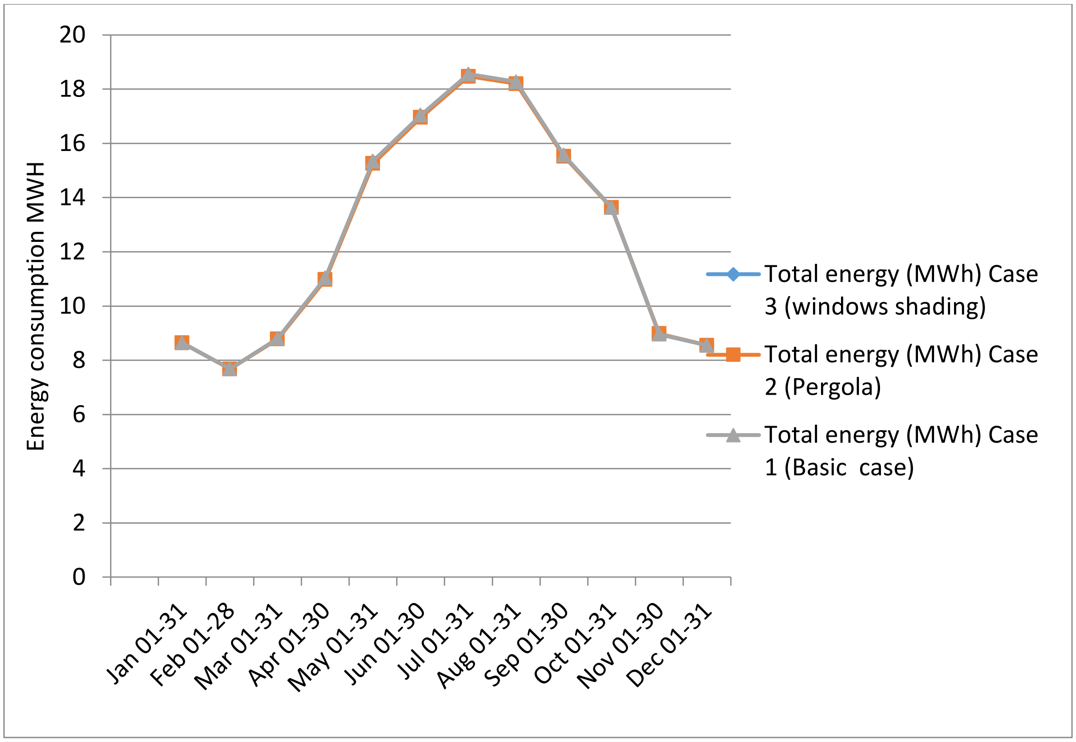

Figure A.1 The total energy consumption of adopting shading devices scenario shows that the reduction is very little.

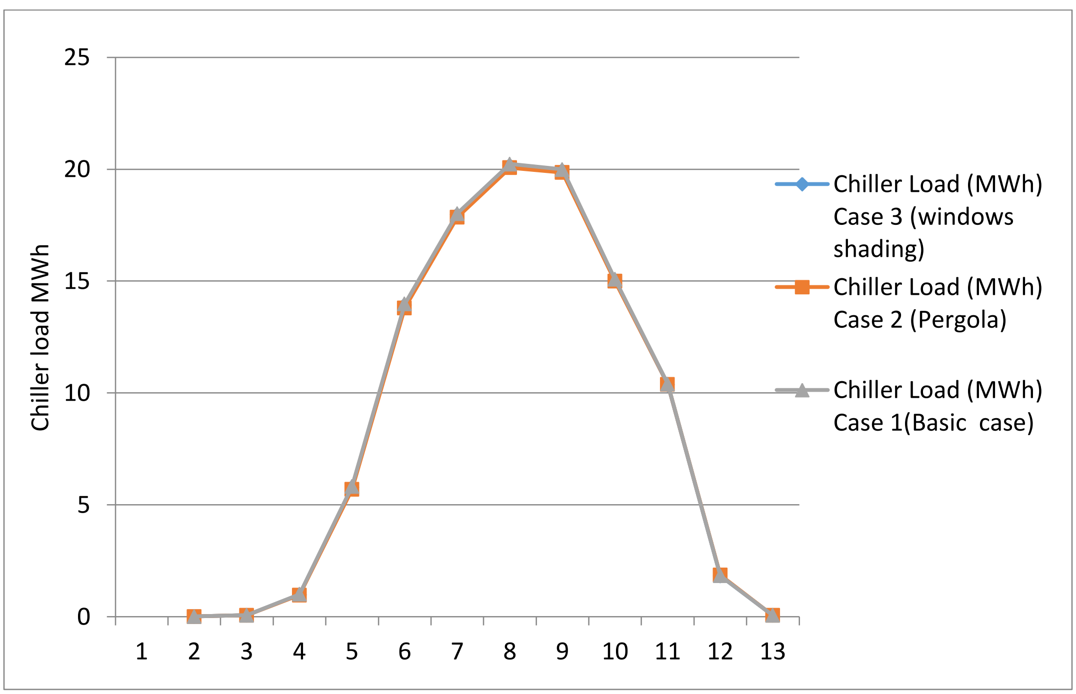

Figure A.2 Chiller loads of adopting shading devices scenario shows that the reduction is very little.

Appendix B
Passive Strategies - Adding Insulation in Roof and Walls (1Pearl & 2Pearls)

Table B.1 Monthly energy consumption and the chiller load of Case1 (basic case), Case4 roof insulation (1Pearl) and Case 5 roof insulation (2Pearls)

Date	energy consumption MWh	energy consumption MWh	energy consumption MWh	Chillers load (MWh)	Chillers load (MWh)	Chillers load (MWh)
	Case 5Roof Insulation 2Pearls	Case 4 Roof Insulation 1Pearl	Case 1 (Basic Case)	Case 5 Roof Insulation 2Pearls	Case 4 Roof Insulation 1Pearl	Case 1 (Basic Case)
Jan 01-31	8.5054	8.5062	8.6397	0.0091	0.0088	0.0134
Feb 01-28	7.6217	7.6218	7.6783	0.1003	0.0996	0.0701
Mar 01-31	8.9363	8.9336	8.7985	1.2823	1.2769	1.0066
Apr 01-30	10.8317	10.8335	11.0418	5.4022	5.4057	5.8223
May 01-31	14.4219	14.4318	15.345	12.1342	12.1539	13.9803
Jun 01-30	15.772	15.7859	17.0358	15.4896	15.5174	18.0171
Jul 01-31	17.1294	17.1451	18.5519	17.3852	17.4167	20.2303
Aug 01-31	16.851	16.8666	18.2684	17.1562	17.1874	19.9909
Sep 01-30	14.5936	14.6045	15.5668	13.1329	13.1545	15.0792
Oct 01-31	13.1595	13.1647	13.6371	9.4455	9.4559	10.4007
Nov 01-30	9.1817	9.1787	8.9678	2.266	2.2599	1.8381
Dec 01-31	8.4331	8.4328	8.553	0.0657	0.0639	0.062
Summed total	145.4	145.5	152.08	93.8693	94.0004	106.5112
% Energy reduction	4.37	4.33	0			

The maximum energy reduction

The minimum energy reduction

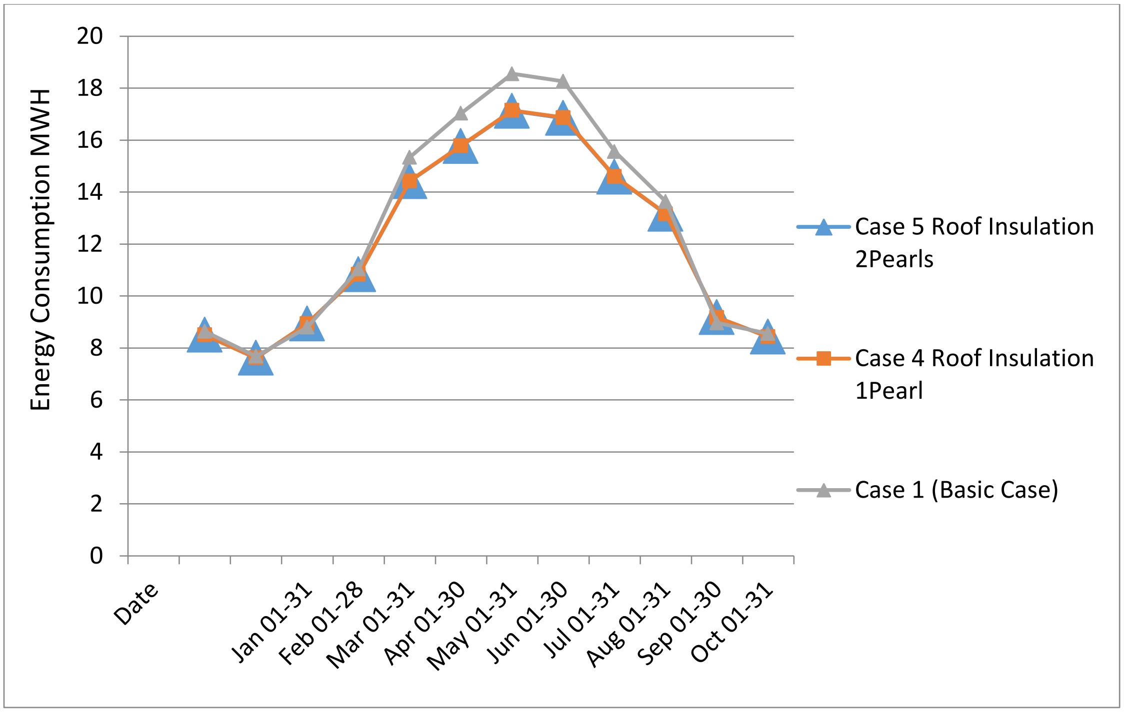

Figure B.1 Total energy consumption of adding insulation materials in roof (1Pearl and 2Pearls)

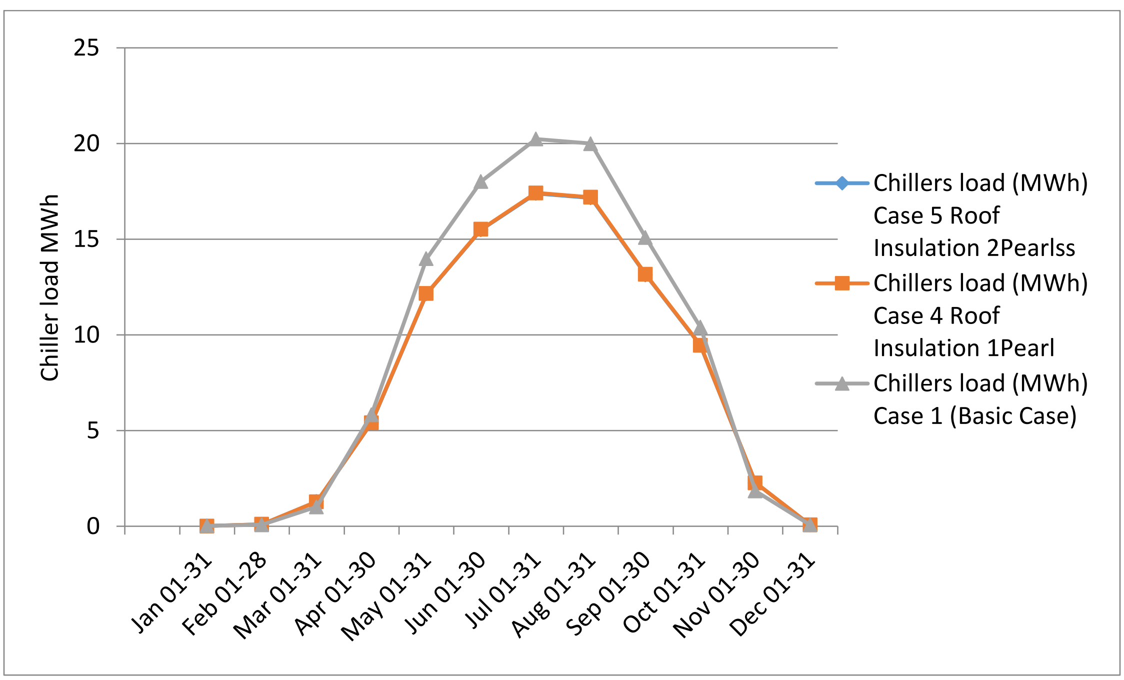

Figure B.2 Chiller load of adding insulation materials in roof (1Pearl and 2Pearls)

Table B.2 Energy consumption and the chiller load of Case1 (Basic Case), Case 6 wall insulation (1Pearl) and Case 7 wall insulation (2Pearls)

Date	Total energy (MWh)	Total energy (MWh)	Total energy (MWh)	Chillers load (MWh)	Chillers load (MWh)	Chillers load (MWh)
	Case 7 wall 2Pearls	Case 6 wall 1Pearl	Case1 (base case)	Case 7 wall 2Pearls	Case 6 wall 1Pearl	Case1 (base case)
Date						
Jan 01-31	8.5081	8.5095	8.6397	0.0131	0.0123	0.0134
Feb 01-28	7.6384	7.6384	7.6783	0.1268	0.1248	0.0701
Mar 01-31	9.005	8.9989	8.7985	1.4196	1.4075	1.0066
Apr 01-30	10.9701	10.9708	11.0418	5.6789	5.6802	5.8223
May 01-31	14.5856	14.6015	15.345	12.4616	12.4933	13.9803
Jun 01-30	15.9028	15.927	17.0358	15.7512	15.7997	18.0171
Jul 01-31	17.2595	17.2873	18.5519	17.6455	17.7011	20.2303
Aug 01-31	16.9714	16.9994	18.2684	17.397	17.453	19.9909
Sep 01-30	14.6615	14.6812	15.5668	13.2686	13.308	15.0792
Oct 01-31	13.1785	13.1884	13.6371	9.4835	9.5033	10.4007
Nov 01-30	9.1502	9.1454	8.9678	2.2029	2.1933	1.8381
Dec 01-31	8.4364	8.437	8.553	0.0542	0.0531	0.062
Summed total	146.2676	146.3849	152.0841	95.5029	95.7295	106.5112
% Energy reduction	3.82	3.75	0			

The maximum energy reduction

The minimum energy reduction

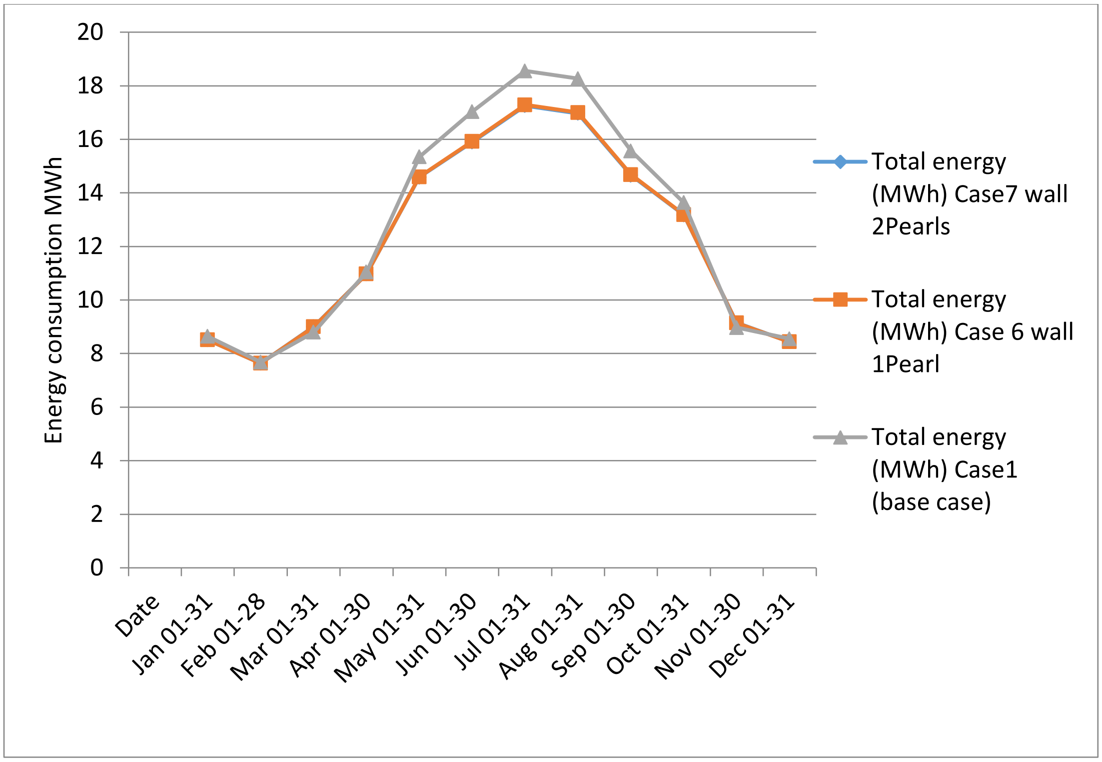

Figure B.3 Energy consumption of adding insulation materials in wall (1Pearl and 2 Pearls)

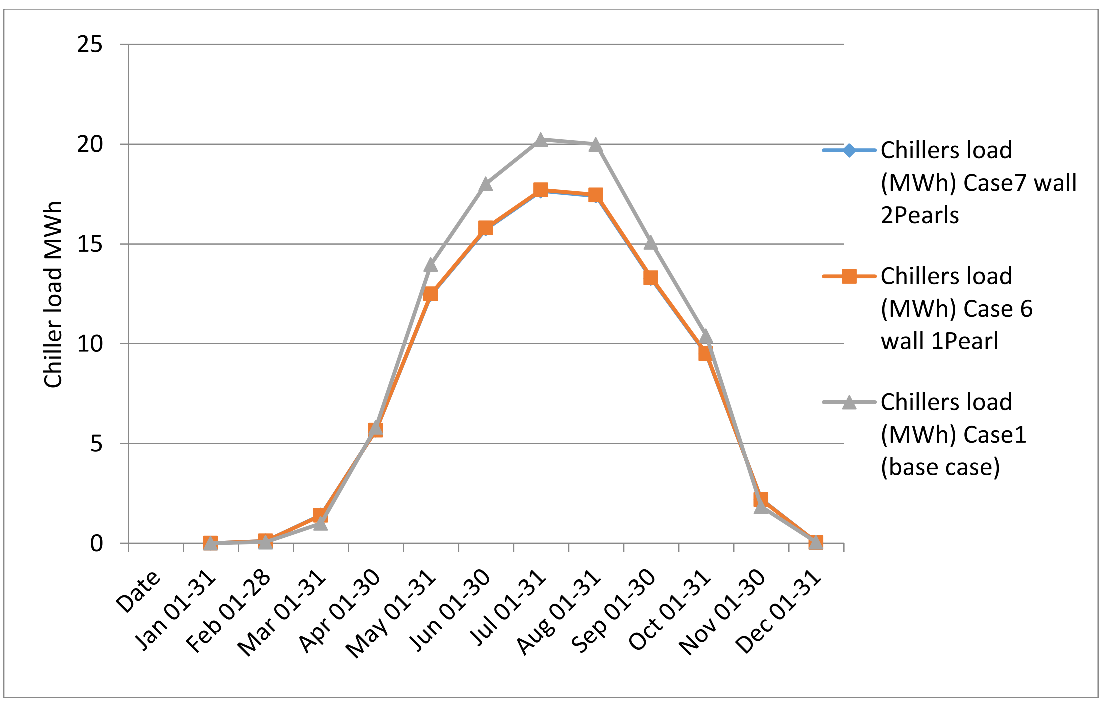

Figure B.4 Chiller load of adding insulation materials in wall (1Pearl and 2Pearls)

Appendix C

Passive Strategies - Solar Heating Coefficient Gain (SHCG) of Glazing

&

The Practical and the Economical Cases

Table C.1 Energy consumption and the chiller load of Case1 (Basic Case), Case 8 (SHCG) (1Pearl) and Case 9 (SHCG) (2Pearls)

Date	Total energy (MWh)	Total energy (MWh)	Total energy (MWh)	Chillers load (MWh)	Chillers load (MWh)	Chillers load (MWh)
	Case 9 glazing 2Pearls	Case 8 glazing 1Pearl	Case1 (base case)	Case 9 glazing 2Pearls	Case 8 glazing 1Pearl	Case1 (base case)
Jan 01-31	8.6384	8.6321	8.6397	0.0137	0.0133	0.0134
Feb 01-28	7.6675	7.6662	7.6783	0.0617	0.0641	0.0701
Mar 01-31	8.7671	8.7777	8.7985	0.9438	0.965	1.0066
Apr 01-30	10.9209	10.9435	11.0418	5.5806	5.6256	5.8223
May 01-31	15.0644	15.1043	15.345	13.4191	13.4989	13.9803
Jun 01-30	16.6673	16.7156	17.0358	17.2803	17.3767	18.0171
Jul 01-31	18.1443	18.1946	18.5519	19.4152	19.5156	20.2303
Aug 01-31	17.8763	17.9245	18.2684	19.2068	19.303	19.9909
Sep 01-30	15.2919	15.3286	15.5668	14.5293	14.6027	15.0792
Oct 01-31	13.452	13.4825	13.6371	10.0304	10.0914	10.4007
Nov 01-30	8.9248	8.9393	8.9678	1.7522	1.7811	1.8381
Dec 01-31	8.5422	8.5385	8.553	0.0614	0.0604	0.062
Summed total	149.9572	150.2471	152.0841	102.2945	102.898	106.5112
% Energy reduction	1.4	1.21	0			

The maximum energy reduction

The minimum energy reduction

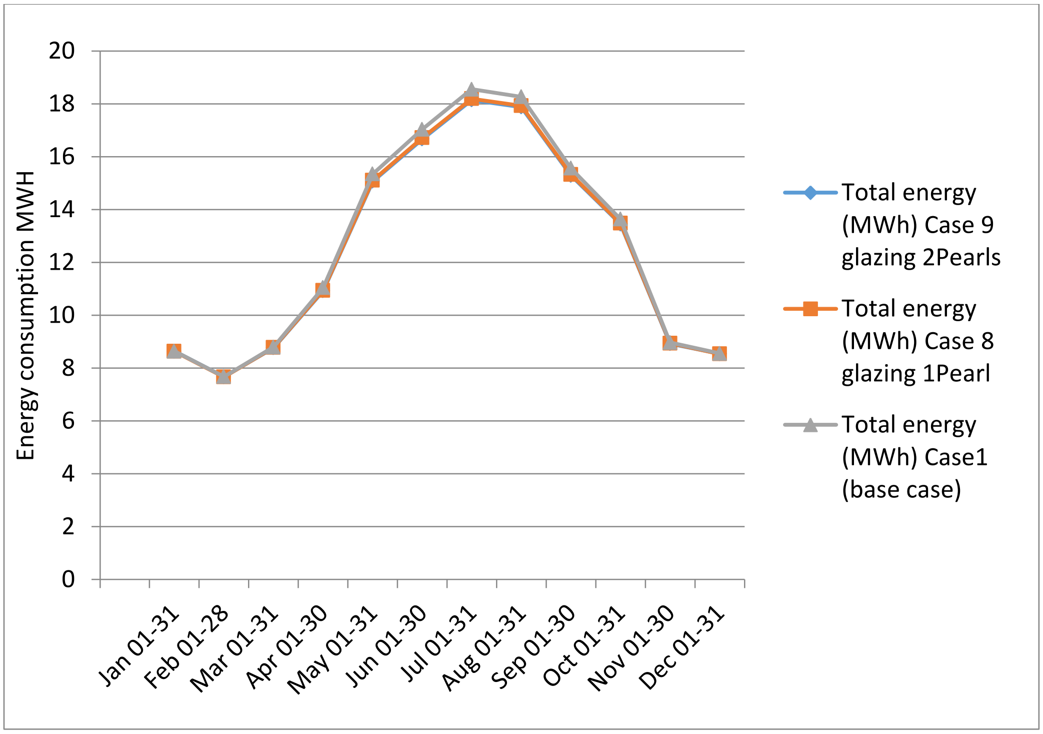

Figure C.1 Energy consumption of adopting (SHCG) (1Pearl and 2Pearls)

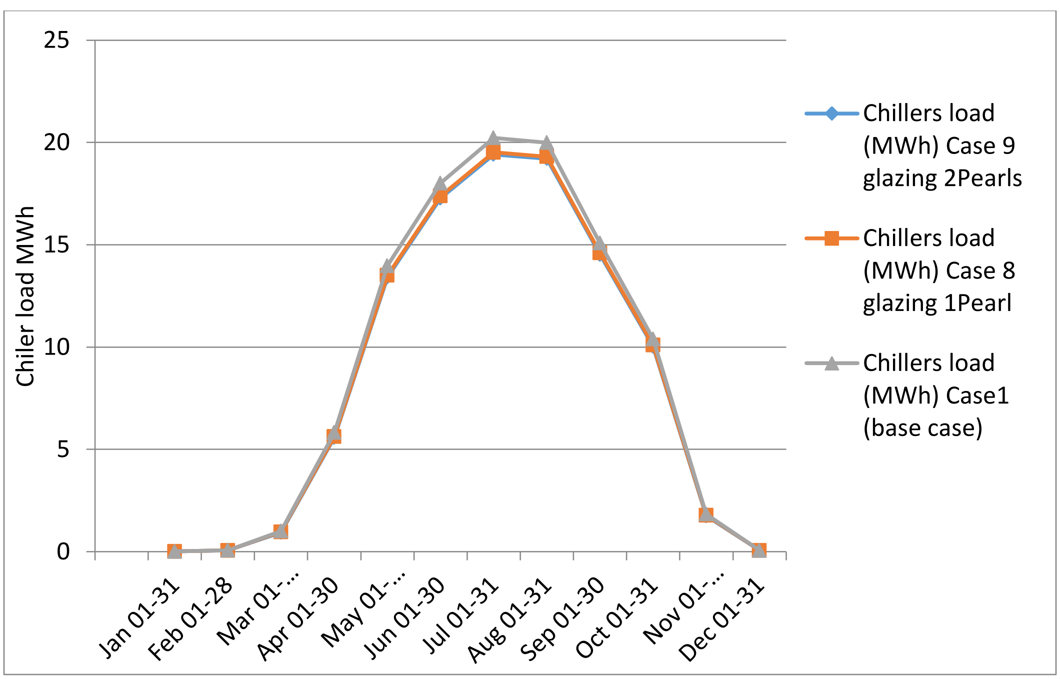

Figure C.2 Chiller load of adopting (SHCG) (1Pearl and 2Pearls)

Table C.1 Energy consumption of Case1 (Basic Case), Case 10 economical case (1Pearl) and Case 11 efficient case (2Pearls)

Date	Total energy (MWh)	Total energy (MWh)	Total energy (MWh)	Chillers load (MWh)	Chillers load (MWh)	Chillers load (MWh)
	Case11 2Pearls	Case10 1Pearl	Case1 (base case)	Case11 2Pearls	Case10 1Pearl	Case1 (base case)
	Efficient	Practical				
Jan 01-31	8.6533	8.6416	8.6397	0.3593	0.3376	0.0134
Feb 01-28	7.8382	7.8289	7.6783	0.5228	0.5057	0.0701
Mar 01-31	9.303	9.3063	8.7985	1.8663	1.8725	1.0066
Apr 01-30	10.7498	10.781	11.0418	4.8503	4.9081	5.8223
May 01-31	13.4448	13.5284	15.345	9.4258	9.5807	13.9803
Jun 01-30	14.2881	14.3995	17.0358	11.5942	11.8005	18.0171
Jul 01-31	15.4461	15.5671	18.5519	12.9802	13.2043	20.2303
Aug 01-31	15.1827	15.3018	18.2684	12.7959	13.0164	19.9909
Sep 01-30	13.4674	13.5546	15.5668	10.0744	10.2359	15.0792
Oct 01-31	12.6096	12.6695	13.6371	7.7275	7.8384	10.4007
Nov 01-30	9.4619	9.4747	8.9678	2.6169	2.6406	1.8381
Dec 01-31	8.6524	8.6364	8.553	0.5089	0.4792	0.062
Summed total	139.0972	139.6897	152.0841	75.3226	76.42	106.5112
%Energy reduction	8.6	8.2				

The maximum energy reduction (yellow)

The minimum energy reduction (light orange)

Table C.1 Practical optimized case and efficient optimized case due to U-Values and energy percentage reduction.

U-Values w/m2k	Case 1(Basic Case)	(Cases 10) 1 Pearl	(Case 11) 2 Pears
Roof	2.0069	0.14	0.119
Walls	1.6424	0.3196	0.29
Glazing SHGC	4.8678	0.4	0.3
Energy reduction percentage	0	8.2%	8.6%

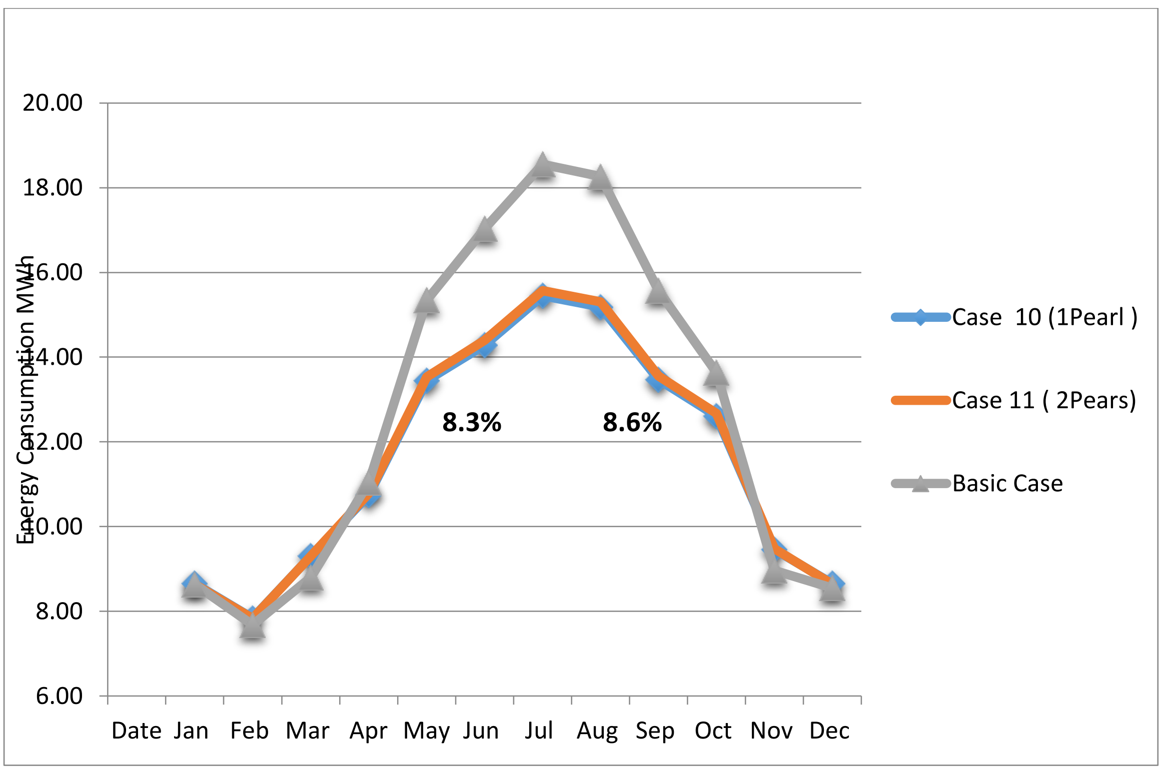

Figure C.1 Cases 10 (the economical case- 1Pearl), Case11 (the optimized case) compared with Case 1 (Basic Case) based on energy consumption

Appendix D

Active Strategies - Coefficient of Performance (COP) of Air Conditioning System & Solar Domestic Hot Water (SDHW)& Photovoltaic (PV)

Table D.1 Energy consumption of Case1 (Basic Case), Case 12, changing (COP), Case 11 efficient case (2Pearls) and economical case (1Pearl)

Date	Total energy (MWh)	Total energy (MWh)	Total energy (MWh)	Total energy (MWh)	Chiller load	Chiller load	Chiller load
	Case12 (COP)	Case 11 (2Pears)	Case10 (1Pearl)	Basic Case	Case 12 (COP)	Case10 (1Pearl)	Basic Case
Jan	8.5895	8.6533	8.6416	8.6397	0.31	0.34	0.01
Feb	7.7509	7.8382	7.8289	7.6783	0.47	0.51	0.07
Mar	9.0174	9.303	9.3063	8.7985	1.74	1.87	1.01
Apr	10.0238	10.7498	10.781	11.0418	4.57	4.91	5.82
May	12.0503	13.4448	13.5284	15.345	8.92	9.58	13.98
Jun	12.5788	14.2881	14.3995	17.0358	10.99	11.80	18.02
Jul	13.5299	15.4461	15.5671	18.5519	12.29	13.20	20.23
Aug	13.2935	15.1827	15.3018	18.2684	12.12	13.02	19.99
Sep	11.9753	13.4674	13.5546	15.5668	9.53	10.24	15.08
Oct	11.4601	12.6096	12.6695	13.6371	7.30	7.84	10.40
Nov	9.0672	9.4619	9.4747	8.9678	2.46	2.64	1.84
Dec	8.5624	8.6524	8.6364	8.553	0.45	0.48	0.06
Summed total	127.8992	139.0972	139.6897	152.0841	71.1	76.4	106.5
% Energy reduction	8.5	8.6	8.2	0			

Energy reduction by applying all passive strategies adopting 2Pearls

Energy reduction by applying all passive strategies adopting 1Pearls

Energy reduction by changing Coefficient of Performance (COP) of the air-conditioning system as active strategies

Table D.2 Boiler energy consumption of Case1 (Basic Case), Case 12, changing (COP), Cases 13.14.15.16.and 17 which examine different area of Solar Domestic Hot Water (SDHW)

Date	Case 17 Boilers load (MWh)	Case 16 Boilers load (MWh)	Case 15 Boilers load (MWh)	Case 14 Boilers load (MWh)	Case 13 Boilers load (MWh)	Case 12 Boilers load (MWh)	Case 1 Boilers load (MWh)
	solar10m	solar8m	solar 6m	solar 4m	solar 2m	(COP)	(base case)
Date							
Jan 01-31	0.0022	0.0022	0.0022	0.0023	0.0024	0.02	0.1747
Feb 01-28	0.0019	0.0019	0.0019	0.0021	0.0024	0.0179	0.0957
Mar 01-31	0.0022	0.0022	0.0022	0.0023	0.0023	0.0198	0.0198
Apr 01-30	0.0018	0.0018	0.0018	0.0018	0.0019	0.0192	0.0192
May 01-31	0	0	0	0	0	0	0
Jun 01-30	0	0	0	0	0	0	0
Jul 01-31	0	0	0	0	0	0	0
Aug 01-31	0	0	0	0	0	0	0
Sep 01-30	0	0	0	0	0	0	0
Oct 01-31	0	0	0	0	0	0	0
Nov 01-30	0.0019	0.0019	0.0019	0.0019	0.0019	0.0192	0.0192
Dec 01-31	0.0035	0.0036	0.0038	0.0041	0.005	0.0202	0.1488
Summed total	0.0135	0.0137	0.0139	0.0144	0.016	0.1163	0.4773

The boiler energy becomes zero in the cold months.

Different area of SDHW 2, 4, 6,8,10 with 180 azimuth angel and 25 tilted angle

Table E.1 PV energy production and the net grid energy based on different areas

	PV Production MWh	Net grid electricity MWh	PV Production MWh	Net grid electricity MWh	PV Production MWh	Net grid electricity MWh	PV Production MWh	Net grid electricity MWh	PV Production MWh	Net grid electricity MWh
	PV156 m2	PV156 m2	PV 158 m2	PV 158 m2	PV 160 m2	PV 160 m2	PV 166m2	PV 166m2	PV 290 m2	PV 290 m2
Date										
Jan 01-31	-2.3715	6.201	-2.4019	6.1714	-2.4323	6.1423	-2.5235	6.066	-4.4085	4.164
Feb 01-28	-2.06	5.6756	-2.0865	5.6499	-2.1129	5.6246	-2.1921	5.5588	-3.8296	3.9061
Mar 01-31	-2.387	6.6137	-2.4176	6.5838	-2.4482	6.5545	-2.54	6.4774	-4.4374	4.5633
Apr 01-30	-2.3749	7.6323	-2.4053	7.6026	-2.4358	7.5734	-2.5271	7.4967	-4.4148	5.5924
May 01-31	-2.7328	9.3193	-2.7678	9.2847	-2.8028	9.2504	-2.9079	9.1423	-5.0801	6.9719
Jun 01-30	-2.5736	10.0069	-2.6066	9.9743	-2.6396	9.9421	-2.7386	9.8402	-4.7842	7.7963
Jul 01-31	-2.7372	10.7944	-2.7723	10.7598	-2.8074	10.7254	-2.9127	10.6172	-5.0884	8.4432
Aug 01-31	-2.8338	10.4615	-2.8701	10.4256	-2.9064	10.39	-3.0154	10.2781	-5.2679	8.0274
Sep 01-30	-2.4733	9.5037	-2.505	9.4725	-2.5367	9.4414	-2.6318	9.3435	-4.5978	7.3792
Oct 01-31	-2.4408	9.0211	-2.4721	8.9903	-2.5034	8.9597	-2.5972	8.8629	-4.5373	6.9246
Nov 01-30	-2.2067	6.8441	-2.235	6.8165	-2.2633	6.7894	-2.3482	6.7191	-4.1022	4.9486
Dec 01-31	-1.7248	6.8217	-1.7469	6.8004	-1.769	6.7795	-1.8353	6.7271	-3.2063	5.3402
Summed total	-28.9162	98.8954	-29.287	98.5318	-29.6577	98.1728	-30.7698	97.1294	-53.7545	74.057

The higher production of PV with 290 m2 area of installing

Production of PV with 166 m2 area of installing

Production of PV with 160 m2 area of installing

Production of PV with 158 m2 area of installing

The least production with 156 m2 area of installing

Table E. 2 PV energy production and configuration of Cases 23 and 24

	PV production without SDHW Case 23	PV production with SDHW Case 24
PV Installing area	270 m2	266
Edge zone	10%	10%
Type	Monocrystallin Silicon	Monocrystallin Silicon
Azimuth angle	180	180
Tilt angle	25	25
Location	Roof and Pergola	Roof and Pergola
PV production	(50.MWh)	49.3 MWh),
Energy demand reduction %	39.1%.	38.50%
Total energy consumption	77.8 MWh	78.5 MWh
Boiler Loads	0.1163 MWh	0.0135 (MWh