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Testing Low Energy Residential House: Combining Different Strategies in Palestine.

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A thesis submitted in partial fulfillment of requirements of the degree
Master of Architecture- Sustainable Design

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Testing Low Energy Residential House: Combining Different Strategies in Palestine.

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Testing Low Energy Residential House: Combining Different Strategies in Palestine.

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ABSTRACT

Over the last decades, energy saving was a great challenge for engineers, especially since it enables them to achieve the principles of sustainability by reducing the use of non-renewable energy sources in attaining heating and cooling needs in buildings. The term low energy houses refer to buildings that achieve energy efficiency by integrating many strategies and thus reducing their dependence on fossil fuels. Although the building sector in Palestine lacks mechanisms for implementing sustainability, there is still hope to achieve energy efficiency and reduce carbon dioxide emissions by following specific strategies in buildings.

This study can be considered a reference for architects to design low energy buildings because of electricity supply shortage. Therefore, the study aims to identify low energy strategies that can be applied to houses in several areas with different climates in Palestine. To achieve research objectives and aims; the study relied on the descriptive-analytical approach. The descriptive part focuses on case studies that already applied low energy systems and studies their strategies. The analytical part relied on the simulation tool used for thermal analysis (DesignBuilder V6) to apply the possible scenarios to the selected building. The strategies included building orientation, shading devices, insulation, different glazing type, and landscape (tree Planting), then integrating these strategies with the solar cell system to reduce energy consumption and obtain a low energy house.

The information was analyzed by DesignBuilder and summarized by the case studies, the following results were reached: Palestine can achieve the goal of low energy houses due to its location in the Mediterranean region, solar cell system is very recommended for power production in Palestine owing to the high number of sun hours. On the other hand, the building`s orientation, glazing type, insulation material, and tree planting are passive strategies that have a notable effect on heating and cooling loads of 60 %. Furthermore, integrating passive design strategies with a PV system is the best way to achieve energy savings of 60% to 84% in energy consumption for heating and cooling loads. As mentioned, it was emphasized that the decisions taken in the design phase concerning energy efficiency are of great importance.

The study had some recommendations for specific strategies that can assist decision-makers, architects, and building owners in different climate zones in Palestine to obtain low energy buildings. These recommendations were divided into two phases; the first phase includes passive strategies to reduce energy consumption such as orienting the long side of the building on the east-west axis or near it, determining the recommended type of shading devices and glazing type for each city, using expanded Polystyrene into walls and roofs, and planting small Araucaria trees around the building in Jerusalem and high trees in Jericho and Gaza. The second phase includes combining these strategies with a PV system at 27° to produce energy for the building.

اختبار منزل سكني منخفض الطاقة: الجمع بين استراتيجيات مختلفة في فلسطين.

سجى عدنان سيد احمد

المستلخص

توفير الطاقة يعتبر تحديًا كبيرًا للمهندسين عند تصميمهم للمباني، ويمكنهم من خلاله تحقيق مبادئ الاستدامة والتقليل من استخدام موارد الطاقة غير المتجددة لأغراض التدفئة والتبريد داخل المباني. يشير مصطلح المباني منخفضة الطاقة إلى المباني التي تتميز بالترشيد في استهلاك الطاقة من خلال دمج العديد من الاستراتيجيات وتقليل اعتمادها على الوقود الأحفوري. على الرغم من أن قطاع البناء في فلسطين يفتقر إلى آليات تنفيذ الاستدامة، إلا أن هناك أملًا في تحقيق كفاءة الطاقة وتقليل انبعاثات ثاني أكسيد الكربون من خلال اتباع استراتيجيات محددة في المباني.

يمكن اعتبار هذه الدراسة بمثابة مرجعٍ للمهندسين المعماريين في ظل نقص إمدادات الكهرباء؛ من أجل ذلك كانت الرسالة تهدف إلى تحديد استراتيجيات الطاقة المنخفضة لكي يتم تطبيقها على المنازل في مناطق مختلفة في فلسطين (القدس، أريحا، غزة). اعتمدت الدراسة على المنهج الوصفي التحليلي من أجل تحقيق أهدافها، ركز الجانب الوصفي على الحالات الدراسية التي طبقت أنظمة الطاقة المنخفضة ودراسة استراتيجياتها، كما اعتمد الجانب التحليلي على استخدام أداة المحاكاة للتحليل الحراري DesignBuilder V6 وتطبيق السيناريوهات المختلفة على المبنى المقترح للدراسة، وقد تضمنت الاستراتيجيات: توجيه المبنى، وأجهزة التظليل، والمواد العازلة، وأنواع الزجاج، وتنسيق الحدائق (زراعة الأشجار)، ودمج هذه الاستراتيجيات مع نظام الخلايا الشمسية لتحسين استهلاك الطاقة والحصول على مبنى منخفض الطاقة.

تم تحليل نتائج الحالات الدراسية بالإضافة إلى نتائج المحاكاة الحرارية للمبنى بواسطة DesignBuilder، وتوصلت الدراسة إلى أن وجود فلسطين في منطقة البحر الأبيض المتوسط يجعلها موقعا مناسباً لتطبيق استراتيجيات تخفيض الطاقة في المنازل، وينصح بشدة استخدام نظام الخلايا الشمسية لتوليد الطاقة في فلسطين بسبب ساعات الشمس الطويلة، كما أن توجيه المبنى، ونوع الزجاج، والمواد العازلة المستخدمة، وزراعة الأشجار جميعها استراتيجيات سلبية ذات تأثير ملحوظ على خفض أو رفع أحمال التدفئة والتبريد بنسبة 60% ، وأن دمج الاستراتيجيات السلبية مع النظام الكهروضوئي هو الطريقة الأمثل للوصول إلى مباني منخفضة استهلاك الطاقة؛ حيث أنها تؤدي إلى توفير في الطاقة بنسبة تصل 60% الى 84% من أحمال التدفئة والتبريد.

وكما ذكرنا سابقا فإنه من المؤكد أن القرارات التي يتم اتخاذها خلال مرحلة التصميم ذات أهمية كبيرة في التأثير على كفاءة الطاقة في المباني؛ ولذلك قدمت الدراسة بعض التوصيات كرؤية مهمة للمهندسين المعماريين وأصحاب المباني في مختلف المناطق الفلسطينية بهدف الوصول إلى مباني منخفضة استهلاك الطاقة، تم تقسيم التوصيات على مرحلتين: المرحلة الأولى تضمنت تطبيق بعض الاستراتيجيات السلبية لتخفيض استهلاك الطاقة كتوجيه الضلع الأطول للمبنى على المحور الشرقي الغربي أو قريب من ذلك، وتحديد النوع المناسب من أجهزة التظليل ونوع الزجاج لكل مدينة، واستخدام مادة البوليسترين الممدد في الحوائط والسطح، بالإضافة إلى زراعة أشجار الأروكاريا الصغيرة حول المنازل في القدس والأشجار الكبيرة حول المباني في أريحا وغزة، أما المرحلة الثانية فتضمنت دمج هذه الاستراتيجيات مع خلايا طاقة شمسية على ميل 27° لإنتاج الطاقة للمبنى.

DECLARATION

I declare that the Master Thesis entitled" Testing Low Energy Residential House: Combining Different Strategies in Palestine." is my own original work, and herby certify that unless stated, all work contained within this thesis is my own independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgment is made in the text.

Student Name :Saja Adnan Saied Ahmad

Signature:——————————— Date:——————————

DEDICATION

To my parents, for all your support, encouragement, and unconditional love.

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List of Abbreviations

RE	Renewable Energy
RES	Renewable Energy sources
PH	Passive House
PVS	Photovoltaic system
NEU	Net Electricity from Utility
TOSUES	Total On-Site and Utility Electric Sources
TOSES	Total On-Site Electric Sources
ECU	Electricity Coming from Utility
SEGU	Surplus Electricity Going to Utility
NEU	Net Electricity from Utility

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Chapter 1 Introduction

1.1 Introduction

"We shape our buildings, thereafter they shape us", quoted Sir Winston Churchill. The design of a building is a process that requires great and elaborate thinking. A building is an integrated set of different systems that, when united, give its complete form to it. Therefore, these systems need specialists to be highly familiar with them to achieve the goal for which it was designed, which is to provide comfort to the occupants and not forget that the building and its contents are closely linked to the surrounding environment through an integrative relationship based on giving and taking. Therefore, environmental systems and related energy issues are considered essential parts of this design process. It is also recognized that buildings correspond to the local climate in which they are located so that the available resources are used in a highly efficient manner. Therefore, the climate and the changes associated with it significantly and noticeably affect the buildings, especially in terms of energy gain and loss, and this matter has become clear in recent times. The problem of increased energy consumption and its effects on the environment and human beings was manifested through increased reliance on fossil fuels and the resulting increase in operating costs and toxic emissions into the air. This matter is considered one of the most important issues that the whole world is trying to address.

Therefore, this study aims to analyze the impact of building orientation, glazing type, insulation material, and landscape (planning tree) on a dwelling. Moreover, to achieve the targets of low energy houses, photovoltaic modules are integrated into the building, after determining the amount of energy that will be covered by cells.

1.2 Background

As the buildings sector accounts for roughly (30-40%) of global energy consumption, buildings are responsible for roughly 30% of CO_2 emissions, which is expected to be avoided by 2030, with benefits (Bernstein et al.,2007). At the turn of the century, efforts were made to develop new policies that would improve both energy efficiency and renewable energy in the world's buildings sector, and these policies included developing thermal regulations for buildings and strengthening passive solar architecture.

As a result, evaluating energy consumption became a measure of sustainability to evaluate structures (C.A & Ding,2001). According to the Palestinian Statistics Center, the building and construction sector is one of the first and most influential on Palestine economically, socially, and environmentally, and this effect manifests itself in the quality of the environment and energy through the stages of construction and subsequent matters of operation and maintenance, in 2010, this sector grew at a rate of more than 36% of all other sectors, with a 22% increase in employment over 2009 (PCBS, 2017).

Housing is also one of the priorities in the Palestinian's life; as it faces the pressures of the "Israeli" occupation in Palestine, which in turn led to a shortage of land and what is being built on it (Arij, 2008). According to the Anshasi study, due to the limited income of the family in Palestine, they usually build and design their building without consulting specialists or certified environmental engineers, and the whole situation resulted in undesirable buildings that have a character far from the original character of Palestine (Enshassi, 2000).In the past, Palestinians built with local materials that took into account the conditions of their environment, saving themselves from the energy problems that plague our buildings today.

Today, materials that are not suitable in any way are used, both for insulation and for other purposes, such as concrete, concrete bricks, and natural stone (Al-Atawna et al., 2015). Moreover, due to the high cost of thermal insulation, Palestinians today don't pay much attention to this problem, which has led to an increased demand for energy to provide thermal comfort to the residents through the installation of air conditioners. Salameh (2012) found in his research that the practices used in Palestine raise operating and maintenance costs while also increasing the environmental burden.

Energy is necessary for economic, environmental**,** and social progress (Chaar et al, 2010), the energy sector in Palestine differs from other countries because of the pressures it faces, as it is considered a developing country under occupation, and it is unable to exploit all its resources available to it, such as water and natural gas, and the responsible for this is Israel (Basel, 2009). An estimated 100% of fossil fuels and 89% of electricity consumption are imported from this occupation (A. Tai, 2021). According to Abu Hamed et al. (2012), the general energy framework in Palestine is still politically incomplete, and its characteristics are not yet known. It also shows that political stability has a significant impact on what is commonly referred to as renewable energy, as well as how the economic situation of the population affects the energy demand. As a result of not creating this framework with clear features, it constitutes an obstacle for investors and their fear of making large investments in the field of energy and that these investments are in the long term. Therefore, here we can say that the role of renewable energy in Palestine begins in terms of trying to move to sustainable energy development and develop long-term strategies (IRENA, 2014)**,** and therefore, achieving energy security in Palestine is through affordability. Costs and labor to conserve energy produced as much as possible (PWC, 2012).

Today, renewable energy, with its different technologies, is widely recognized as one of the clean energies that continue to increase in popularity since it can be used in a variety of industries without affecting the environment (Castellano et al.,2015). This energy can also help countries achieve their goals in political stability, as it is considered stable and low-cost energy, based on the enhancements it provides in increasing development (Casanova-Pelaez et al.,2015), Due to the challenges that Palestine confronts in all areas, whether political, social, or geographical, it is moving toward this form of energy rather than fossil fuels, as Palestine has a high indicator of renewable energy sources such as solar and wind energy, despite the problems it experiences. During the year, Palestine is exposed to around 3000 hours of radiation on average (Daud et al.,2012).

In Palestine, there is a need to reduce energy consumption in buildings by taking advantage of the available renewable energy, including it in the building design process, by integrating it with passive technologies suitable for Palestine, this work requires a comprehensive study of the reality of Palestinian housing. This poses a challenge to decision-makers and architects.

1.3 Research Problem

The shortage of conventional energy supplies, increasing population growth, and growing energy prices are all vividly felt in Palestinian areas (Abualkhair,2007). As a result, Palestine would face an escalating energy crisis. Palestine's overall energy demand was roughly 5800 GWh in 2018. Meanwhile, renewable energy sources accounted for 10.2% of total demand in 2018. (PCBS, 2019). On the other hand, due to the considerable expansion of the housing sector, the residential sector accounts for a bigger portion of the rise in total final energy consumption (Basel, 2009) For the residential sector, the CoE is about 0.6215 ILS/kWh (Juaidi et al.,2009).

Due to the lack of fossil fuel resources and numerous years of occupation, Basel (2009) summarizes in his study that the use of renewable energies is one of the strongest possibilities in Palestine. Despite the country's small size (6000 km2) and low population, a large portion of the country (roughly 60%) is classified as rural, with over 100 communities living in poor socioeconomic conditions and facing ignorance and restrictions from development plans that are tailored to their specific needs and circumstances.

AlKhatib (2015) showed that because traditional energy sources are unavailable in Palestine, and the building sector has a high energy demand, a new approach to building design is required. Political and economic constraints have prevented alternative energy sources such as solar and geothermal from reaching their full potential. These renewable energy sources, as well as their incorporation into building design, are critical components of a future that is both sustainable and energy independent. The notion of low energy houses has been proposed as a way to reduce the excessive energy consumption of buildings. The concept of low energy houses falls under this term it is considered as a high-energy-performance building with on-site energy generation from renewable resources that meets the majority of the energy demand (Aelenei et al.,2019) Building typology, orientation, construction material, and HVAC systems can all be improved to reduce energy use. This need can then be met by renewable energy technologies (Solgi. E et al.,2019).

1.4 Research Question

Problem identification has raised the main research question, which can be summarized in the following:

“How the low energy houses can be achieved in Palestine, and what strategies can be employed by architects to reduce energy consumption and conserve energy?

This main question proposed more sub-questions:

1. What are the proposed scenarios of passive and renewable energy sources strategies that could be applied to low energy houses, especially in Palestine?
2. How could renewable energy sources be utilized to get the low energy houses?
3. How could low energy houses be implemented in various climate zones?

1.5 Research Aim and Objectives

The main objective of this research is to reach a low energy house in Palestine using a simulation program**,** by testing the use of passive design strategies and photovoltaic cells on the thermal performance of the house.

To achieve the main goal, several objectives should also be realized, such as:

1. Testing the impact of using passive design strategies on the energy consumption of houses in Palestine.
2. Testing the effect of using photovoltaic cells on consumption and their role in saving energy for houses.
3. To examine the energy performance of housing in Palestine.

1.6 Research Significance

In Palestine, there is a great need to study the energy performance of buildings, to solve the problem of high consumption, especially in residential buildings. This study contributes to addressing aspects of energy efficiency, in three specific climatic zones to reduce the energy consumption of annual heating and cooling loads. In addition, this study focuses on proposing a set of different design strategies in Palestine based on thermal simulation to verify the impact of these strategies on building and energy consumption and to study the impact of each strategy on the other and their effects on non-thermal aspects. Also, to take the initiative to raise awareness of the possibility of implementing this type of housing within the constraints available, by clarifying the design principles and standards that can be followed to obtain low energy houses and work on their adaptation, to correspond with the statistics available in Palestine. Finally, it will have a positive environmental impact, improve living standards and reduce carbon dioxide emissions resulting from heating, air conditioning, and lighting. Many studies have dealt with this, including:

Elgendy and Mekkawi (2015) provided simulation-based research for a home prototype in Alexandria, Egypt, to achieve the low energy aim. Changing design decisions and factors such as building orientation, window placement, roof insulation, wall construction materials, glass kinds, and shading devices can result in a reduction of 38.2% in overall site energy usage.

Serghides et al. (2015) used construction simulations to see if an existing single-family house could meet low energy standards and uncover hidden barriers and challenges. Using low-energy techniques, a variety of renovation scenarios in Cyprus were generated. The efficiency of each method and technique used to reduce energy consumption and greenhouse gas emissions was evaluated in terms of cost-effectiveness based on the analysis of the results. It accounts for 24% of the overall investment and results in a total energy consumption reduction of only 2kWh/m2 a year.

Ascione et al. (2016) presented a study entitled Concept, Design, and Energy Performance of a low energy Building in Mediterranean Climate It aims to offer concepts, design standards, and energy performance expectations for a low energy building constructed for a typical Mediterranean environment. The structure was in Italy, and the goal was to create recommendations for both new construction and restoration to increase the energy efficiency of buildings in Mediterranean climates. The study found that maximizing passive technologies is critical. A variety of architectural layouts, as well as HVAC systems, equipment, and devices for energy conversion from renewable energy sources, were examined. The research is based on a transient energy simulation or a steady-state energy description.

The study of Irfan et al. (2018) is one of the research that discussed the importance of resorting to the design of this type of building instead of traditional buildings, as it was clarified that it is one of the best ways to overcome the energy crisis in the country, through the participation of solar energy in the design process it also showed that the cost of energy will be close to zero or very low also by generating revenue by selling additional energy, in addition to a reduction in carbon emissions, which reduces the environmental pollution.

In a study entitled "Design strategies and energy performance of a low energy house based on natural philosophy", by Shi et al. (2019), The paper outlines a way of achieving the objective of low energy use in buildings by combining various strategies. The findings of the study reveal that passive and active design solutions can balance function, aesthetics, comfort, and energy in residential architectural designs.

Khakian et al. (2020) presented a study based on low energy house modeling in Balangan for sustainable development in the region. This study aimed to evaluate the energy performance of residential buildings in the area and to evaluate the impact of various factors from building orientation, window to the wall (WWR), glazing type, and fixtures. Shading, insulation, energy performance. In addition to equipping, it with photovoltaic units, in comparison to typical buildings, the results showed that 29 % energy savings might be realized.

In Palestine, Monna et al (2020), suggested the PV system as the best investment in renewable energy for residential building owners in Palestine, due to this study, the annual kWh/m2 produced by PV units installed on rooftops of houses varies between 0.5 to 6 times of its consumption depending on the selected city, building type and shape, tilt angle, spacing between arrays, building orientation and installed power.

And in another study, Monna et al (2022), suggested installing PV systems on rooftops of schools in the West Bank and Gaza Strip to fulfill its consumption of energy and use the surplus production of electricity for the surrounding buildings also it recommends providing all schools with envelope improvements.

Haj Hussein et al (2022), the concept of the approach suggested by the researchers was to show the importance of thermal insulation. It was declared in this research that the energy demanded can be reduced by 43% to 83% according to the applied scenario of thermal insulation considering the U-values for the building envelope, therefore it was recommended to update the building energy code in Palestine.

These various studies have proven that the use of different strategies in the design of residential buildings reduces the total energy consumption at the private level, and thus solves the problem of high consumption and great pressure on electricity for the region at the public level, as this is the case in Palestine. Therefore, this comprehensive study was conducted on passive and RES design strategies, so this research will constitute an introduction to the design of low energy buildings in the environment of Palestine and evaluate their performance.

1.7 Research Scope and Limitation

The obstacle that faced this research was the absence of local study cases in Palestine for this type of housing.

The scope of the study will be limited to:

1. Region and Climate Selection: Three regions in Palestine with different climates were selected.
2. Model Description: A residential house similar to a villa located in Palestine. It consists of the same building materials that are commonly used in Palestine**.**
3. Simulation Tool: In this study, DesignBuilder (V 6.0), which uses the EnergyPlus engine for energy simulations and has an advanced user interface will be used.
4. Chosen Parameters: For minimizing energy consumption, the impact of several parameters that include orientation, glazing type, shading devices, insulation materials, and landscape (planting trees) on the energy performance of the building will be studied in chapter three.

1.8 Research Structure

The research includes seven chapters related to finding low-energy house strategies by studying the effect of each of them on the energy consumption of buildings in Palestine. The first is an introduction, followed by a literature review and background material. The second, third, and fourth sections. The methodology utilized in data collecting and analysis is presented in Chapter 5, and the results and conclusion are presented in Chapters 6 and 7. Figure 1.1 below shows the research structure and the main contents of each chapter.

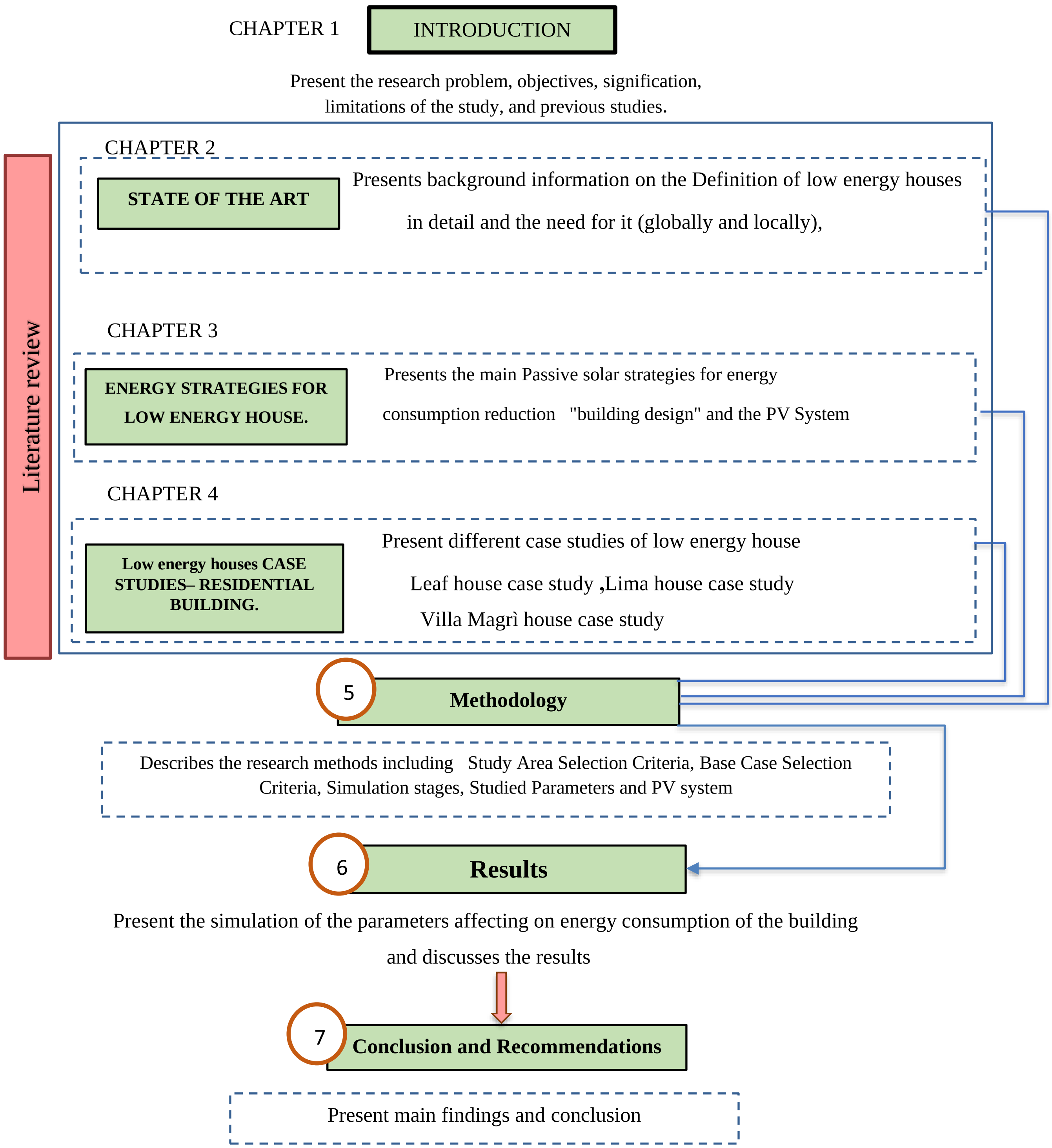


Figure 1.1: Flow Chart of the Research Structure, Source: By the Researcher

Chapter 2 State of The Art

2.1 Introduction

This chapter presents a summary of the literature that focused on the issues related to low-energy buildings. The first one is a background about low energy, it explained the need for this type (globally and locally) and its historical development of it. The second is the definitions and terms that were associated with this type of building.

2.2 Background

Population expansion in various aspects of life, particularly in the energy sector, has contributed to an increase in consumption around the world. In developing countries, this was the most obvious. During the last decade large amounts of fossil fuels have been consumed, and in turn have a major impact on the ecosystem, as represented in today's climate change. Due to this shift in climate, human beings, particularly in buildings, need to make some lifestyle changes because this sector is highly impacted. Therefore, the design of where we live had to be rethought, and all factors, whether energy consumption or production and other concerns arising from this transformation, had to be taken into account. This phase concentrates on the building's energy efficiency and looks carefully at how energy use and production might be rationalized by seeking to relate renewable energy concepts to the construction industry to achieve this (Joel Anderson,2016).

In recent times there has been great interest in the concept of energy efficiency in the building industry due to the emphasis on climate warming and increasing environmental pollution caused by the heavy consumption of fossil fuels from various sources. (Williams et al., 2015). In his study, Aksamija (2015) stated that continuing to emit carbon dioxide will have a substantial impact on the notion of energy efficiency, particularly when adopting crisis measures that minimize energy consumption. Recently, a new approach has been proposed to reduce energy consumption and pollution emissions, and this approach is called low energy buildings or zero-energy buildings (Fatima Harkous, 2018). The concept of this approach to homes is not new as Berry et al. (2014) point out that there is nothing particularly novel about mixing passive solar design ideas with efficient energy-efficient gadgets and renewable energy technologies

2.2.1 The need for low energy houses (globally and locally):

A third of the world's total energy use is consumed by the building sector due to the considerable energy demand (IEA, 2010). To attain the best energy performance in buildings of various types, certain measures are taken into consideration. These actions were referred to as the concept of low energy houses, as one of the best methods for reducing carbon emissions that significantly affect the environment, in addition to reducing the high energy use, and so reducing the global barriers of energy due to high costs and environmental changes. (Marzal et al., 2011)

Where in this approach the increasing energy demand, especially electrical, is reduced and the energy needs are met through renewable energy sources so that it replaces fuel in addition to its ability to store energy and export it when needed, the main goal of this type of buildings, or why do we need it, is not only limited to reducing consumption by using passive design but to create a building that can balance active technologies with renewable energy technologies. (Habash et al, 2014).

Al-Qadi (2018), mentioned that the high fuel prices and the dependence on non-renewable resources make the shift to this type of buildings a serious need in Palestine. It is necessary to understand the current energy consumption to develop policies and strategies for an independent sustainable energy system. Data were surveyed about the physical characteristics of the residential buildings in Hebron, socioeconomic features of the habitants, and quantity of energy used for heating. A model was developed to estimate the annual energy consumption in Hebron using Ridge Regression Analysis. And it was found that only 9.2% of houses heat their houses during winter and 3.5%-21.6% of their monthly income is spent on space heating.

Monna et al (2021), The paper has created a plan of three stages to reduce the energy consumed in residential buildings; reducing the infiltration to 0.25 air changes per hour, then adding thermal insulation (6cm extruded Polystyrene) for external walls and roof, changing the glazing to double low E (3 mm, 13 mm air gap), Replace standard fluorescent with CFL and LED lights, use inside blinds, external 50 cm overhang shading, and natural ventilation was enhanced. Finally, enhancing natural ventilation for summer and mechanical ventilation for winter, extra insulation for windows using triple glazing (3 mm, 13 air), 0.5 m overhang and internal blinds, and using new or renovated solar water heating systems. Using the three levels achieved a total saving of 71% to 73% when compared to the base case. Also, building type and climatic zones should be considered, and using a PV system in addition to previous strategies could achieve a low energy house or even an energy-positive building.

As for the local need, this type of building is in great demand, especially since Palestine is a developing country with an increasing population density in terms of the energy sector where electricity and any other source of non-renewable energy are imported from other countries. It does not have much authority over energy resources due to the occupation's control over most of them. Also, this type of building can help in the development of the region in the long term and achieve positive benefits in all respects, especially in the state economy. Solar energy and other strategies will encourage investors to think about investments in this type of building and find technologies for achieving the desired benefit. These types will also achieve efficiency in the use of energy, both in terms of gain or loss, and thus will help reduce the percentage of pollution in the environment as a result of its dependence on the use of clean sources of energy.

2.2.2 The historical development of low energy houses

Builders and building associations, as well as architects, were involved in the low energy houses' idea to achieve buildings with high energy output, because of the significant increase in energy costs, the growth in resources, and climatic changes. **(**Tabrizi, 2021). The concept of low-energy houses is considered new but the approach and dealing with homes with low emissions and energy started in the mid-twentieth century. In 1960 approximately thirteen buildings were dealing with solar energy in the United States. (Yang et al.,2008). These buildings are considered to be the first generation of low energy homes in the modern era. In 1939, the first low energy project was established and was called MIT Solar House I. The number of homes that rely on solar energy began to increase in the mid-seventies, and the common goal in all these homes was to test the performance of solar energy and work to improve it in low-cost and simple ways to have little harm to the environment. (Dutil et al.,2011). Tabrizi (2021) in his study on the importance of moving to this type, explained some of the buildings that are good examples that spread in that period, including Odeillo Residences (1974), Tyrrel House, The Hofman House, and Baer House (1972). These buildings are a good approach to homes that rely on solar energy and harvest energy from renewable sources. In 1989, a building "Nulli " was built in Germany. (Najafi, 2011).

Kapsalaki (2012) referred to the evolution of these buildings in his study on the efficient economical design of residential buildings in such a way that they are completely energy free and the structure of the buildings was arranged as follows:

- 1992 The Fraunhofer Institute for Solar Systems developed a solar-based house in Freiburg.
- In 1998 an experimental residential building was constructed in Lakeland, Florida, and it was called "PVRES".
- In 2005 another house was built on the same system and it was called "Solar Harvest" with an area of 426 square meters in the same year the University of Nevada constructed two adjacent houses with an area of 150 square meters for both of them.
- In 2006 in Austria, a "Tanno Meet Gemini" building was established, which is considered the first of its kind in this area with an area of 3294 square meters, and in Germany, a "Solar Plus Haus" was established with an area of 212 square meters.
- In 2007 a house was built in Canada with an area of 140 square meters and it was called "Eco Terra".
- In 2009 Hawkes Architecture in the United States created a 'Crossway EcoHouse' with an area of 285 m2.

2.3 Definitions of low energy houses

The notion of low energy houses has been mentioned in prior papers and studies over the years, but each time it was defined differently, therefore no consensus or unified definition was formed. As a result, the researchers were hampered by the lack of a consistent substrate, thus they proposed various models based on the following key factors: (Bajracharya & Thapa,2015)

1. What methods will be used to achieve the goals of this sort of structure?
2. How does this type of structure interact with the network?
3. What factors influence project balance?

Low energy building means a building that has a very high energy performance, the low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.

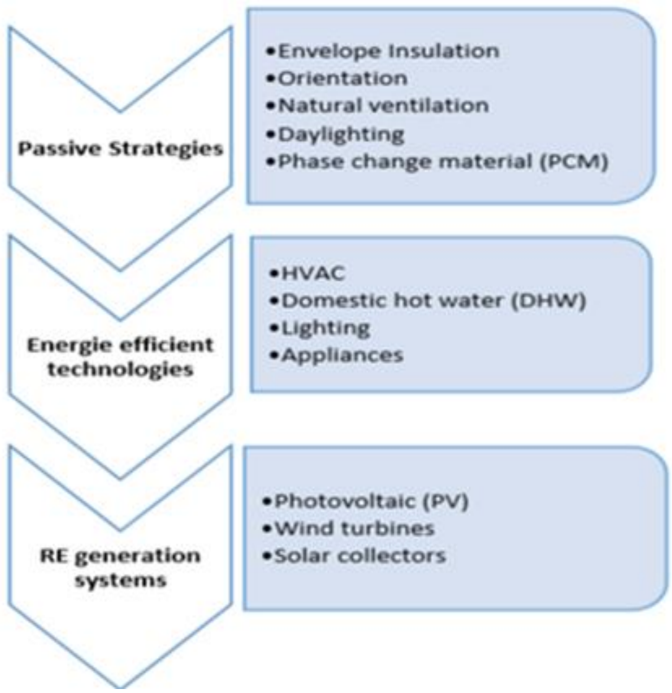


Figure 2.1: Traditional three steps to achieve low energy houses, source: (Fatima Harkouss,2018)

Through many classifications, which have been detailed in many studies, this type of house can be achieved, especially in the study of Torcellini et al. (2006). They fall into two categories, one connected to the renewable energy grid and the other not connected.

2.3.1 Classifications based on energy measurement methods.

The National Renewable Energy Laboratory of the United States (NREL) has specified four ways for measuring and describing low energy for buildings: costs, source energy, emissions, and site energy. (Hootman, 2013). Cost and pursuing metrics, as well as which type of renewable energy may be employed to achieve each requirement, are the trade-offs between these definitions. Even so, if a project team wants, both definitions can be used together. (Carmichael & Managan, 2013). Torcellini et al. (2006) in their study discussed the concepts as follows:

1. Site: when accounted for at the site, the building site produces at least as much energy as it consumes in a year.
2. Source: a building that accounts for at least as much energy as it consumes in a year. The principal energy utilized to generate and transfer energy to the site is referred to as source energy. This is critical when accounting for energy consumed from the grid when a

considerable part of the energy is lost during transmission from the generator to the site, and in losses in thermal generation efficiency.

3. Cost: the annual net paid bills between the building using renewable energy and the utility should be at least zero or in the building's favor in this area. Benefits: utility bills make it simple to perform and measure. Based on fuel availability, market forces will produce an acceptable balance between different fuel types. It's possible to control the system based on demand.
4. Emissions: this time, the balance is defined by a different metric: emissions. To counteract the emissions-intensive electricity purchased from the grid, the building produces at least as much emission-free energy. Non-energy differences between fuels, such as carbon emissions and other sources of pollution, are taken into consideration here. As a result, it is more complex to implement than the others.

In this study, the only definition used from this classification is site energy. To complete the picture of the low energy houses concept, several factors must be taken into account: climate, passive technologies, energy efficiency, and renewable energy systems.

2.3.2 Renewable Energy (RE) supply option hierarchy.

Torcellini et al. (2006) created a classification system based on the kind of renewable energy sources that a building can use. Also, Marszal et al. (2010) confirmed this in their studies and the options were as follows:

- Option 0: It tends to reduce the energy demands of buildings using energy-efficient technologies and demand-side RE systems. The passive usage of RE sources, such as solar daylighting, passive solar heating, passive cooling, and wind catching, are all examples of demand-side RE systems.

- Option 1: is a supply option that is available on-site. It tends to take advantage of renewable energy sources within the footprint of the structure. RE is directly connected to the energy distribution systems (electricity, hot water) of the building, reducing transmission and distribution losses. Due to future development plans of surrounding lands, it is not essential to displace/disassemble these systems.

- Option 2: is a supply option that is delivered on-site. It tends to take advantage of renewable energy resources that are available at the building's site's perimeter, but not on the roof or within the footprint of the building.

- Option 3: the supply option is off-site. To generate power on-site, the resources must be accessible in the construction lifespan to bring on the site renewable resources. This alternative is less advantageous than choices 1 and 2, because of the carbon traces of renewable resources production and transportation on site.

- Option 4: the supply option is off-site. It involves the acquisition of installed RE sources. Building owners negotiate superior off-site solar and wind resources with the power company to develop off-site wind turbines and solar panels. The building may own some hardware and receive electricity credits. The facility would also pay a fee for the energy supply. It is the worst categorization; it does not generally cut energy use.

From these options; the study relied on option 1. Figure 2.6 clarify the difference between the RE supply option hierarchy

Option 0	→	Building envelope improvement, efficient energy measures &demand-side RE technologies	→	Insulation, efficient equipment, lighting, passive solar heating, day-lighting, solar ventilation air pre-heaters, natural ventilation, evaporative cooling.
Option 1	→	RE within building footprint	→	Thermal solar collectors, PV located on building's roof or façade, building-mounted wind turbines.
Option 2	→	RE at boundary of building's site, not mounted on building nor within building footprint	→	Parking lot PV, ground-mounted thermal solar systems, tower-based wind turbines, on-site solar-driven chiller.
Option 3	→	RE from off-site to produce electricity on-site	→	Wood pellets, biodiesel, waste, and vegetable oil imported to the site, combined heat and power (CHP) systems, to produce electricity and heat.
Option 4	→	Purchase installed off-site certified RE source	→	PV panels installed off-site, utility-based wind turbines, RECs (e.g. Green credits certified by Green-E (2009)).

Figure 2.6: Different between the RE supply option hierarchy, Source: (Harkouss, 2018)

2.4 Summary

1. This chapter focused on the literature review of the concept of low-energy buildings, showing the different definitions of these buildings and making it clear that they do not have a specified definition.

2. This section covered the divisions of low energy houses and how it's adopted. In this study, the concept of site energy was used, and the study relied on option 1 in the RES supply option hierarchy because the common use of using RES in Palestine is to install PV models on the roof to generate a certain amount of energy without giving up using the grid.

3. It also explained the importance of low energy houses in general and Palestine in particular, as it is considered a country that contains the ingredients of these buildings, therefore, it is easy to deal with this idea.

Chapter 3 Energy Strategies to Achieve Low Energy Houses

3.1 Introduction

In this chapter, passive design strategies and Solar Energy systems will be clarified and defined through what was mentioned in previous studies which answers question number two: "What are the proposed scenarios of passive design strategies and renewable energy generation to obtain a low energy house?"

This chapter will also identify the factors and criteria that affect the depreciation performance of buildings, and thus describe the common building materials used in Palestine. The modeling of these factors will be presented in the next chapter.

3.2 Background

In most nations, the construction sector accounts for approximately 35% of overall energy use (Harish & Kumar, 2016). The demand for numerous technologies and sophisticated systems in dwellings has also raised the quantity of energy that is utilized more and more, and to manage such difficulties, strategies, and decisions must be made. The importance of energy usage in buildings cannot be overstated, and more consideration should be given to it. The interaction between design components, climate, users, shading, lighting, and HVAC system, on the other hand, is quite complicated and may be tested by assessing all elements affecting energy efficiency (Cellura, 2017).

Building energy efficiency can be increased by employing either active or passive energy-saving techniques. Energy savings of approximately 60% compared to standard structures planned following current building codes have been observed, and these savings are often attained through design solutions. (Isaac et al., 2016). Figure 3.1 shows the factors that lead to the realization of the low energy house, and they constitute the strategies that will be adopted in this regard. As these factors (location, orientation, passive design, renewable energy) have a direct connection with energy consumption, and they are linked to each other in an integrative relationship as shown in the figure below. (BigRentz, 2021)

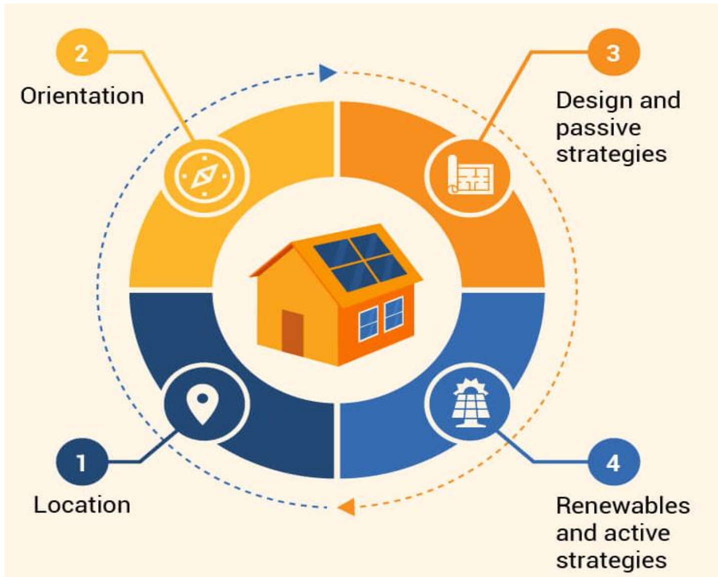


Figure 3.1: ways to achieve low energy house, Source: (BigRentz, 2021)

3.3 Passive solar strategies for energy consumption reduction "building design"

The Passive House idea is a cost-effective way to reduce energy consumption in the construction industry, where heating and cooling consume the majority of the energy. As a result, energy efficiency measures are becoming more widely applied in the residential sector, which accounts for the majority of such use. When it comes to energy-efficient structures, the necessity for professionals who deal with energy issues is critical, especially for architects in the early stages of their architectural design. As a result, architects who work on the design and construction stages of a building play a critical role in improving its energy efficiency (Fernandez-Antolin et al., 2019).

Palestine has many climatic zones, each with its own set of temperatures, demography, and environmental factors. The low energy building design faces a problem in this regard. There is a model for each climatic zone. Unfortunately, we believe that the majority of Palestinian designers and the general public do not pay enough attention to climatic zones and their impact on building eco-friendly structures. Addressing the use of strategies at the design stage will help reduce energy throughout the year and this will be clarified in the study.

Passive methods are used to reduce energy use and rationalize its consumption inside the building and thus play a major role in making design decisions. These strategies include:

3.3.1 Orientation of the building

The most significant aspect of passive solar architecture is the direction of the building. The long axis of the structure should run east-west so that the north and south sides get the most solar exposure. Assuming we are in the Northern Hemisphere, passive solar design makes use of windows on the south side of the structure. It is important to consider the uses of the southern region when choosing a site. For the best results, solar exposure requires an open view (Murphy,2016).

In some climatic zones, buildings require dominant wind direction and speed, therefore orientation can play a significant role in obtaining thermal comfort. For example, during the summer in Mediterranean regions, night ventilation is critical (Ascione et al., 2016). When studying building orientation, it is also crucial to relate building rotation to proximity to surrounding structures and other components that induce shadowing, such as topography or trees (Friess & Rakhshan, 2017). The ideal choice of building orientation should be made at the design stage, taking into account the building's specific climatic conditions. Building heating and cooling loads can be affected by choosing the optimal orientation (Al-Tamimi et al., 2011). For moderate as well as hot and humid climates, it was observed that buildings consume less energy annually if oriented north. However, in hot and humid climates, the west orientation was observed to have less annual energy consumption (Siddhartha, 2015) heat gain through different window orientations makes big difference. South-facing apertures perform best in cold regions. North orientation is preferable in hot areas. When spaces are oriented toward the south in temperate temperatures, the lowest total loads are frequently reached (Andersson et al., 1985).

3.3.2 Glazing

Glazing is one of the passive envelope parameters related to energy-efficient buildings. According to Lee et al. (2013), windows account for 20-40% of the lost energy in the building. The window is an essential component of building design that has a significant impact on the overall energy performance. The energy performance of a window is determined by its thermal transmittance, glazing solar transmittance, and air leakage due to frame and installation airtightness. (Ihara et al., 2015).

Many factors must be considered when selecting a window type, including glass thickness and color, solar control, architectural attractiveness, daylight control, safety, visual contact, sound control, thermal losses, and shading devices (Hassouneh et al., 2010). Choosing a proper window design will undoubtedly cut energy usage (Muhaisen & Dabboor, 2013). South windows are not recommended in Gaza's scorching environment. Low U-value glazing is also chosen to reduce energy use. Triple windows outperform double windows in both hot and cold regions (Bülow-Hübe, 1998). However, the qualities of the glazing vary. In hot areas, triple-reflecting glass is recommended. In cold climates, triple clear glass is suggested. Figures 3.2 show the Maine glazing type.

In Palestine, and particularly in residential buildings, double clear glazing is the most commonly used glass in windows with standard aluminum frames. (Lisa,2020) Aluminum shutters are the simplest and most widely used type of shade device. While tinted and mirrored glass are used to minimize the amount of solar radiation passed through the area. Tinted glass absorbs very little solar heat while blocking out the light it aids in decreasing glare. The reflected glass reflects solar heat. As a result, both tinted and reflected glass are excellent options for reducing cooling energy consumption. Low energy coated glass, whether double or triple low energy, is constructed with low U values but is meant to allow maximum solar heat to enter through its surface. (Lisa,2020).

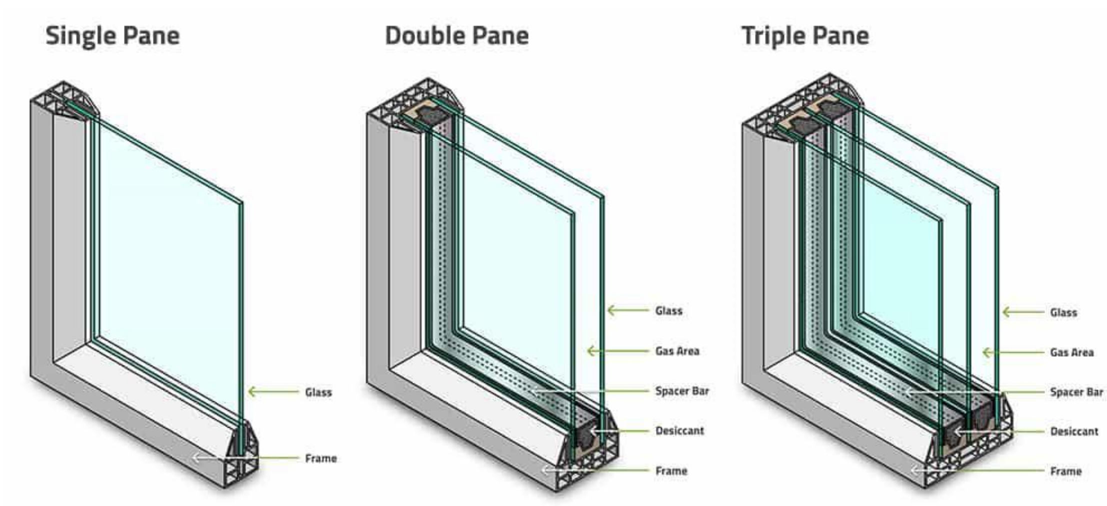


Figure 3.2: Main glazing type in the market, Source: (Padilla, 2020)

3.3.3 Shading Devices

Along with orientation, shading devices play a vital impact. They have a significant impact on limiting heat input and the amount of natural daylight that penetrates the area in rooms that have orientation issues during a certain season. The primary function of a shade system is to protect the transparent areas of a building from undesired solar radiation. Various types of shading systems are shown in Figure 3.3. By intercepting incoming daylight, shading devices can influence building energy use. (Omrany& Marsono,2016) According to Corrado et al. (2004), the appropriate external shading systems can manage the amount of solar radiation admitted into a room, which can significantly reduce cooling loads and increase interior thermal comfort. Previous research on a high-rise residential building in Taiwan by Yu et al. (2008) found that envelope shading is the best approach for reducing cooling energy consumption, resulting in an 11.3 % reduction in electric consumption. The location of shade devices is critical. Fully shaded glazed surfaces can minimize solar heat input by up to 80%When compared to those located behind the glazing surface. (Al-Yasiri, 2021)

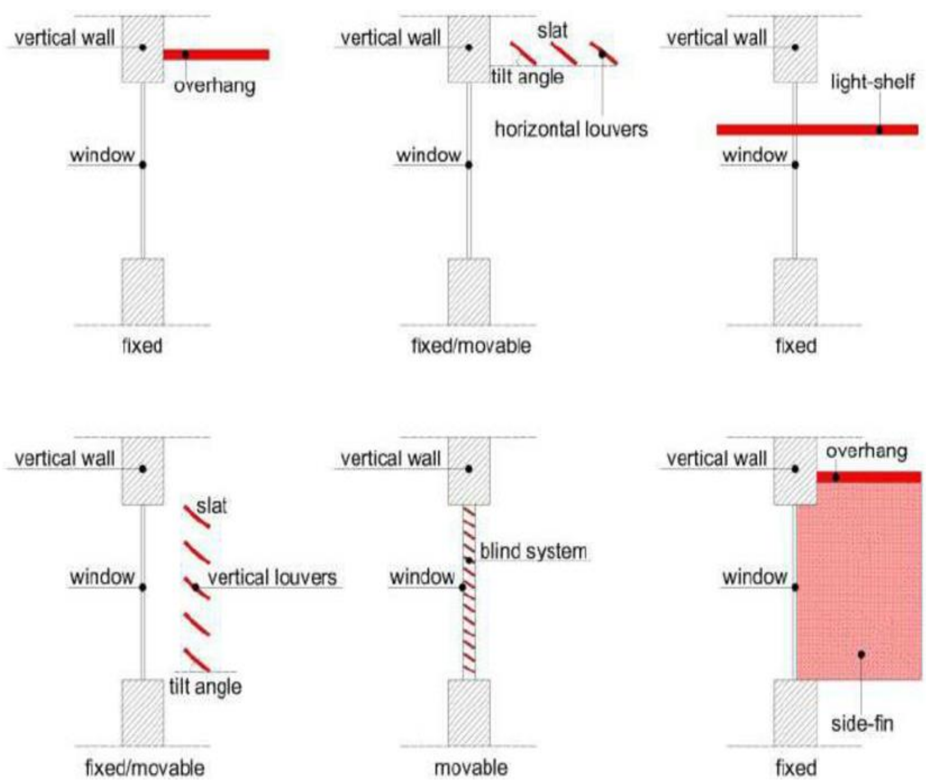


Figure 3.3: Main shading types, Source: (Omrany& Marsono,2016)

3.3.4 Thermal Insulation

Thermal insulation is a material or a mixture of materials used in the building shell to slow the rate of inward or outward heat flows via conduction, convection, and radiation. (Martinez,2001) Proper thermal insulation application in building envelopes can result in lower building energy consumption as well as fewer environmental implications. This is what many studies have shown including:

Comakli and Yuksel (2004) evaluated the environmental impact of heat insulation used to reduce heat losses in buildings. It was discovered that using the optimal thickness of insulation can result in a 27 % reduction in CO_2 emissions. (Asfour and Kandeel 2016) (Eskin and Türkmen, 2008) investigated the impact of various thicknesses of Extruded polystyrene thermal insulation on a base case office space in four different climates in Turkey. Antalya achieved a 29.2 % decrease in heating and cooling energies by installing 75mm thick insulation on the inner side of the wall, Izmir achieved a 25.43 % reduction, Istanbul achieved an 18 % reduction, and Ankara achieved a 19.02 % reduction. According to Asfour's research, using thermal insulation in the walls and ceilings of structures in Gaza City can prevent undesired heat gains and losses from the building envelope. Throughout the year, the presence of insulation in the ceilings and walls reduces human discomfort by 17%. (Asfour and Kandeel, 2014).

Thermal insulation is important in both optimizing building energy and minimizing building environmental consequences. Thermal insulation should be used in conjunction with other passive measures to improve building energy efficiency even more. Technical parameters of building insulations, such as thickness, should be carefully chosen with the environment of the building location in mind. (Salah,2021) People in Palestine shied away from adopting thermal insulation a few years ago as the cost was too expensive and people ignored the benefits. Palestinians have just become aware of the need for insulating walls. (Alsayed, 2019) In the construction sector, there are just a few forms of insulation. Insulating materials made in Palestine include polyurethane foam and polystyrene sheets, which can be expanded or extruded. Except for Rock wool, which is imported from Jordan. (Muallem,2020) Figures (3.4) (3.5) (3.6) (3.7) show the different types of insulation material.

 Figure 3.4: Extruded Polystyrene, Source: https://www.indiamart.com/proddetail/extruded-polystyrene-boards-3927729888.html	 Figure 3.5: Expanded Polystyrene, Source: https://www.nuclear-power.com/nuclear-engineering/heat-transfer/heat-losses/insulation-materials/expanded-polystyrene-eps/
 Figure 3.6: Foam Polyurethane ,Source: https://purity.designuspro.com/en/sleep/napolnitel-ppu-chto-eto.html	 Figure 3.7: Rock Wool, Source: https://www.nuclear-power.com/nuclear-engineering/heat-transfer/heat-losses/insulation-materials/expanded-polystyrene-eps/

3.3.5 landscape (tree Planting)

Landscape trees affect urban temperatures by casting shade on man-made ground covers and buildings (Chagolla et al., 2012). Strategically positioned shade trees help reduce the cooling energy use of buildings by intercepting sunlight that would otherwise heat windows, walls, and roofs (Simpson &McPherson,1998). During the winter, however, shade from misplaced trees can interfere with passive solar heating an effect known as the heating penalty of shade trees (Simpson,1998). Between 1997 and 2000, a tree-planting program in Toronto, Canada planted 577 trees in residential areas, resulting in yearly energy savings of 77,140 kWh (167 kWh per tree) in 2009. (Sawka et al.,2013). According to simulations; in cold regions, a 30% uniform increase in urban tree cover can reduce winter heating expenses by around 10% in cities and 20% in rural areas by lowering the ambient temperature and wind speed. (Akbari,2002) Abdul Aziz's study conducted in Jordan, which was about the effect of tree shading on energy consumption in the building, showed that the use of tree shade as an external shading strategy is effective in reducing electricity loads as a result of lower cooling loads by about 5.5%. (Abdel Aziz,2016)

As a result of Palestine's distinguished location and its location within the Mediterranean climate, helped to diversify its vegetation cover, and this matter greatly helps to save energy if it is used for this purpose. (Ali-shtayeh & Khalil Hamad.,1995) Figure 3.8 shows the effect of trees on the building.

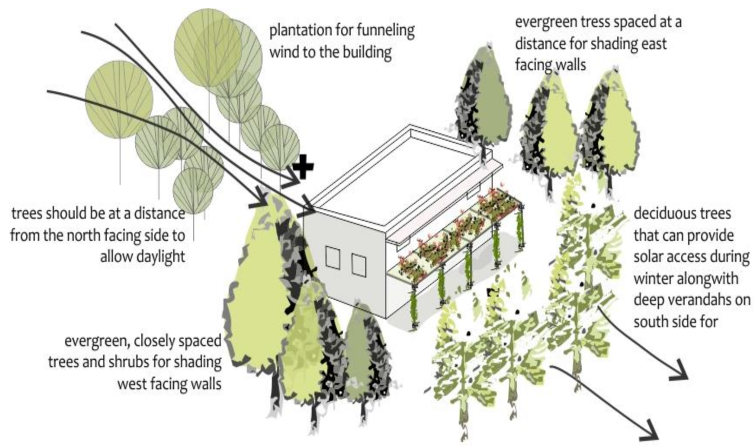


Figure 3.8: the effect of trees on buildings,

Source: https://nzebnew.pivotaldesign.biz/knowledge-centre/passive-design/vegetation/

3.4 On-Site Renewable Energy Utilization

Wind, solar, and geothermal energy are examples of renewable energy sources that generate power. Wind-powered turbines, solar arrays, and other byproducts such as digester gas, municipal solid waste, and landfill gas can all be used to generate energy. The utilization of renewable energy on a global scale is critical since it not only affects long-term economic growth but also helps to avert global climate change. (Baris and Kucukali, 2012).

3.4.1 Solar Energy

Solar energy is an inexhaustible source of clean energy, providing local energy independence and making electric power available to anybody everywhere on the planet using photovoltaic (PV) technology. (Bridgewater, 2009).

3.4.1.1 PV system

Asfour (2013) summarized in his study that Photovoltaics are devices that convert the energy gained from the sun into electrical energy. Where these devices consist of two layers of thin thickness of semiconducting materials, and when exposed to the sun, moving charged particles are formed in these layers and thus result in an electric current Figure 3.9 shows how a photovoltaics cell generates power. These cells are grouped into connected units, for ease of use in buildings. The electric energy produced is usually used in a public and private manner Private or home use involves the delivery of energy for illumination and the operation of minor load applications, whereas general use includes street lighting and public services. PV technologies come in a variety of shapes and sizes. These cells might be amorphous or crystalline. Amorphous (thin film) cells are flexible, making them useful in situations like curving roofs. Their efficiency, however, is the lowest. Monocrystalline and Polycrystalline crystalline cells are the two types of crystalline cells. The first is the most efficient and widely used in the market, whereas the latter is less efficient but less expensive. (Asfour,2013)

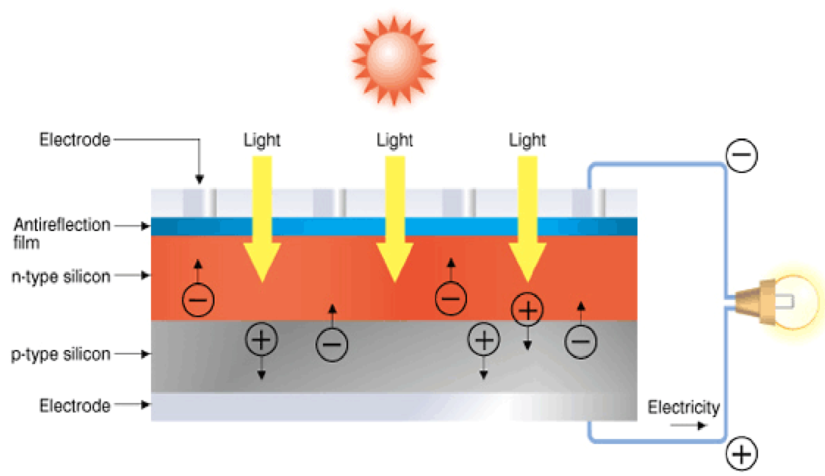


Figure 3.9: How a photovoltaic cell generates power,

Source: https://cockroach-boat.weebly.com/energy.html

3.4.1.2 Types of solar PV

PV-based power generation systems are broadly classified into two types. Grid-connected PV systems and stand-alone PV systems are the two types. This is indicated by Rathore et al. (2019) in their study, which was based on a comprehensive review of different types of solar cells, describing the standalone system as one in which PV installations are not connected to the power grid. They have a battery backup system to store the extra electricity generated throughout the day for usage at night as shown in Figure 3.10. And the other systems are linked to the local power grid. During the day, the electricity generated by the grid-connected system can be used directly or sold to any electrical supply company. When the PV system does not generate electricity owing to a lack of sunlight in the evening, power can be purchased and stored from the local network. These systems do not require any battery storage because they supply electricity straight to the load or grid as needed as shown in Figure 3.11

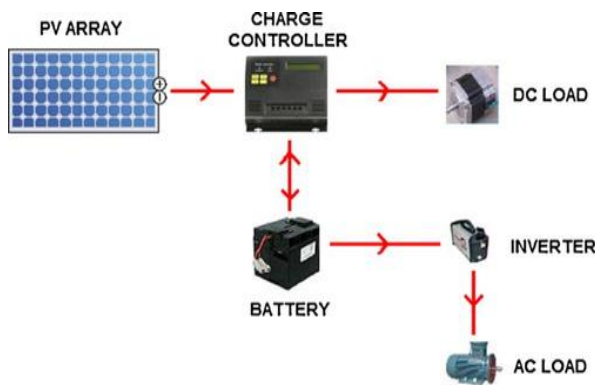


Figure 3.10: standalone system, Source: (Meral and Dincer,2011)

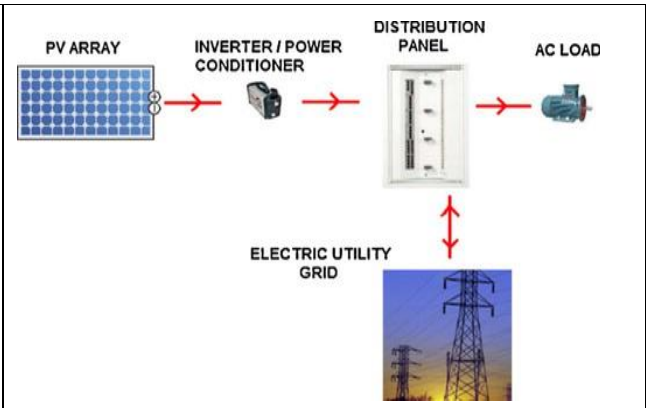


Figure 3.11: Grid-connected PV systems, Source :(Meral and Dincer,2011)

The maximum permissible peak power for grid-connected PV household systems in Palestine is 5 kWp, according to PEA regulations (PSI). This limitation is set at this figure since the yearly energy consumption of most residence houses does not equal or surpass the annual output of a 5 kWp PV generator. As a result, all interested households want to put 5 kWp on their roofs to earn the most money. Furthermore, no specific standards, policies, or specifications exist to enforce the selection of PV modules, but the majority of PV modules in the local market are polycrystalline or monocrystalline, with 60 or 72 PV cells connected in series and rated at peak power in the 260–340 Wp range. (Omar and Mahmoud,2018)

3.5 Summary

This chapter is a continuation of the literature review in the previous section. In this thesis, two main stages will be dealt with to achieve low energy houses.

- first stage: Energy reduction strategies for the building.

Passive strategies include all the strategies that do not require energy for operation. Effective employment of these strategies can provide buildings with low energy consumption. Low energy buildings typically include a high level of insulation, energy-efficient windows, and natural ventilation. Where these strategies in addition to the orientation of the building, landscape, and shading are considered the main elements of the Passive design. (Ltd.,2022)

Each of these elements works with the others to achieve comfortable temperatures and good indoor air quality. Ltd (2022) summarizes how these elements interrelate with each other. The first step is to achieve the right amount of solar access enough to provide warmth during the cooler months while preventing overheating in the summer. This is done through a combination of location and orientation, window design, and shading. Insulation helps maintain even temperatures, while ventilation provides passive cooling as well as improving indoor air quality. This study came to confirm the study of Al-Ghamry & Azmy (2017) and Farouh (2016). These studies showed that despite the presence of other techniques, these elements (orientation, glazing, shading devices, thermal insulation, and landscape) are the most important determinants of low-energy houses, as all the houses mentioned in previous studies shared only these determinants and others were dealt with or ignored.

Since this study relied on what was stated in previous studies, it depended on what was considered a basic determinant of the energy reduction process in homes and considered a basic parameter in the thermal analysis process.

- The second stage: Energy production

At this stage, the focus was on generating energy from renewable sources. It is known that these sources are multiple, the most important of which are solar cells, geothermal, and biomass. Each of these strategies has its challenge. In this study, the solar cells system was adopted because this system is characterized by ease of installation and handling in terms of maintenance and is more economical, while other systems are more complex. And this was confirmed by Ahady et al (2019)

Chapter 4 Low Energy Building’s Case Studies– Residential Building

4.1 Introduction

This chapter presents three case studies of low energy houses. Two of them are located in Italy and one in Spain, these countries were chosen based on their similarity to Palestine's climate, as well as the type of buildings so the analysis is very close and helpful to the desired conclusions.

4.2 Leaf House (LH) Case Study.

The LH in Ancona, Italy, was established using unique ecological and bioclimatic architecture concepts Figure (4.1). It is constructed following current energy rules and incorporates various renewable energy sources. The basic geographical and climatic facts, as well as some building geometric features, are shown in Table (4.1) (4.2). The LH has six units with a net conditioned floor space of 477 m^2. A single flat has an area of 85.65 m^2. The two apartments on the second floor are smaller than the first two apartments, and their area is 58.39 m^2 each, besides there is an intermediate floor of 9.35 m^2 as shown in Figure (4.2). About the south elevation, the ratio of its length to the east one was set to maximize the solar radiation gain. Further, to keep it under control overheating, the southern façade presents external fixed overhangs used as shading elements. (M. Mistretta et al., 2013).

Figure 4.1: Leaf house location, Source: (Cellura et al.,2014)

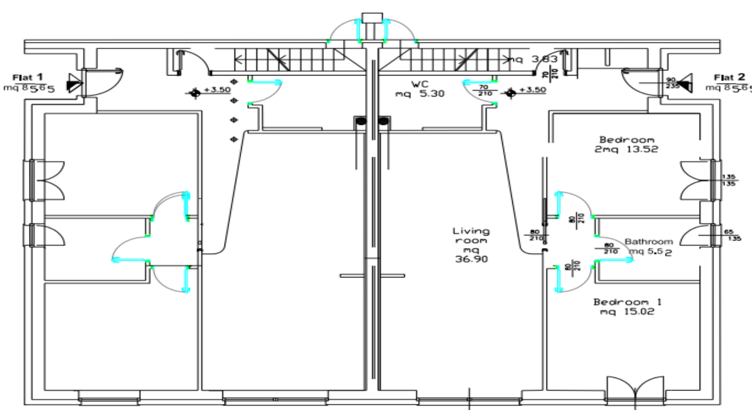


Figure 4.2: Ground floor of Leaf house, Source: (Cellura et al.,2011)

Table 4.1: Main features and climatic data of the LH

Climatic data	
Minimum and maximum temperature °C	-5, 37
Mean annual humidity (%).	0.67
Mean annual horizontal solar radiation (W/m^2)	302
Latitude	43°47'N
Longitude	13°07'E
Altitude (m)	130

(M. Mistretta et al., 2013).

Table 4.2: Construction Elements for Leaf house envelope & U value.

Structures	**Construction Elements**	**U value (W/m² ºC)**
Walls	Plaster 2 cm, Light weight brick 30 cm, Cement plastering 1,5 cm, Polystyrene 18 cm, and Plaster 2cm.	0.15
Roof	Plasterboard 3cm, Vapor barrier 0.1 cm, Wood fiber (170 kg/m3), Rock wool 10 cm, sheath 0.1 cm, Air space, and Pinewood 2 cm.	0.25
Floor	Terracotta tiles 2 cm, concrete subfloor 5 cm, polyurethane foam 4 cm, Background lean concrete 5 cm, Bitumen 0.5 cm, Concrete 20 cm, air cavity 19 cm, rock fragments11.5 cm.	0.41
windows	The windows are made of a double panel insulated glazing (U=1.1 W/(m^{2}K) with a 6 mm external glass, 14 mm gap filled with argon, and 4 mm internal glass; The Solar Heat Gain Coefficient (SHGC) is 0.6.	0.86 g-value for window =0.61

Source: (Cellura et al.,2011)

- **The ways LH dealt with reduced energy consumption.**

1. <u>Passive Approaches.</u>

Garde & Donn (2014) also described passive techniques that were used in LH and analyzed it as shown in table 4.3:

Table 4.3 : passive techniques use for heating & cooling.

Passive techniques use for heating	**Description**	**Passive techniques use for cooling**	**Description**
Thermal Mass	Walls and floors have high thermal mass	Sun shading	The roof, solar thermal panels, and balcony behave like solar shields.
Sunspaces	Wide windows on the southern facade allow solar radiation to heat the building.	Green Roof/Façade	Ventilated roof reduces the solar loads during summer.
Heat Recovery	Preconditioning in an underground duct of the fresh air.	Ground Cooling	Preconditioning in an underground duct of the fresh air.

Source: (Garde & Donn,2014)

2. Energy Efficiency Systems.

Cellura et al. (2014) in their study described the thermal plant of the LH, Garde & Donn (2014) supported what was stated in this study through their study based on analyzing the case study from their point of view and explaining the techniques that are used in LH to produce the energy as shown in Table 4.4.

Table 4.4: Energy Supply and Integration of Renewable Energy

Energy Supply and Integration of Renewable Energy	**techniques**	**description and the concluding results.**
Electricity Production	Photovoltaic (PV)	Technology: PV Monocrystalline silicon Expected generation (kWh): 25000 Measured generation (kWh):24750
Solar Water Heating	Hot Water	Technology: Flat plate collectors Production (kWh/m². year) :9 Annual % of Hot Water:6300%
Renewable Production of Heating	Geothermal	Technology: Geothermal Heat Pump, Efficiency (%): 4.6 Production (kWh/m². yr.) :27.40 Annual % of Heating :78.26086957(Produced by renewables)
Renewable Production of Cooling	Geothermal	Technology: Geothermal, Efficiency (%): 4 Production (kWh/m². yr.): 20 Annual % of Heating :100(Produced by renewables)

Source: (Garde & Donn,2014)

The Advantages and Disadvantages in LH Case:

- Advantages

The advantages of the used techniques in LH can be summarized as follows:

1. The use of geothermal technology works to provide thermal comfort by heating the house when the temperature is low and cooling it when the temperature is high. The heat recovery system has an 80%.
2. The photovoltaic panels on the south-facing roof provide the heat pump with the electric energy it requires. (The solar system is very powerful)

- Disadvantages

1. Geothermal technology needs constant, accurate, and large monitoring, in addition to its high maintenance costs.
2. It requires great effort and a large period to give the required energy.

4.3 Lima House Case Study.

The Lima house prototype is located in Barcelona (Spain) Figure (4.3), Forty companies from the sustainable construction and energy efficiency sectors participated in the development of the LIMA prototype, which was led by SaAS – Sabaté Associates Architecture and Sustainability. It is based on a series of earlier studies aimed at dramatically decreasing the worldwide environmental effect of buildings in warm climates and giving a reference for future constructions in the Mediterranean area. (Sabaté & Peters, 2011). The basic geographical and climatic facts, as well as some building geometric features, are shown in Table (4.5) (4.6). the Conditioned Floor Area = 45 $m^{2,}$ as shown in Figure (4.4).

Figure 4.3: Lima house location, Source: (ARCHITECTS,2013) (Espanha mapa livre)-edit by researcher

Figure 4.4**:** LIMA HOUSE PLAN, Source: (LIMA.CAT)

Table 4.5 Main features and climatic data of the Lima House

Climatic data	
Minimum and maximum temperature °C	4, 28
Mean annual humidity (%).	0.72
Average sunshine	3185.21 hours in the year
Latitude	41° 23' 6.2304" N
Longitude	2° 10' 24.2508" E
Altitude (m)	47

(CLIMATE-DATA)

Table 4.6: Construction Elements for LIMA HOUSE envelope & U value

structures	Construction Elements	U value (W/m² ºC)
Walls	Horizontal timber cladding, ventilated cavity, semi-permeable polypropylene membrane, wood fiber insulation, cross-laminated timber panels, cavity, and plasterboard.	0.19
Roof	soil for an extensive green roof, 70mm - Geotextile felt, polyester, and PP Drainage and water retention, EP Filtering blanket, PP fibers Impermeable sheet, EPDM Geotextile felt, polyester, and PP Wood fiber insulation, 120mm A vapor barrier of PP cross-laminated timber structural panel, 125mm plasterboard, timber substructure (50x50), 15mm	0.17
Floor	floating bamboo flooring:15mm, wood-fiber insulation:100mm, structural cross-laminated timber panel:125mm	0.18
windows	Frames Fustiland. Glazing Saint-Gobain Climalite Plus	1.35 in all the windows except the west the U value =1.57
		g-value for window =0.42

Source:(Sabaté & Peters ,2011), (Garde & Donn ,2014)

- **The ways LIMA house dealt with reducing energy consumption**

1. <u>Passive Approaches.</u>

Garde & Donn (2014) also described passive techniques used in LIMA HOUSE and analyzed it as shown in table 4.7:

Table 4.7: passive techniques use for heating & cooling

passive techniques use for heating	description	passive techniques use for cooling	description
Heat Recovery	The current Spanish building code requires large amounts of fresh air. A heat recovery unit largely reduces the energy used for heating the ventilation air	Natural Ventilation	Ventilated façade - to reduce heat transfer through the wall in summer.
		Green Roof/Façade	To increase the thermal inertia - reduce the peak load.
		Sun shading	Automatically controlled Venetian blinds.

Source: (Garde & Donn,2014)

2. <u>Energy Efficiency Systems.</u>

Garde & Donn (2014) explain the techniques that are used in LIMA HOUSE to produce the energy as shown in Table 4.8.

Table 4.8: Energy Supply and Integration of Renewable Energy

Energy Supply and Integration of Renewable Energy	**techniques**	**description and the concluding results.**
Electricity Production	Photovoltaic (PV)	Technology: (PV) Polycrystalline Expected generation (kWh): 1100 Measured generation (kWh):1100
Solar Water Heating	Hot Water	Technology: Flat plate collectors Position: On the roof Area (m²):4 Production (kWh/m². year) :49 Annual % of Hot Water:100%
Renewable Production of Heating	Geothermal Heat Pump	Heat Pump, Efficiency (%):140 Production (kWh/m². yr.) :9.80 Annual % of Heating:28% (2.8 kWh/m². year heat from the ground) (Produced by renewables)
Renewable Production of d Cooling	Geothermal Heat Pump	Heat Pump, Efficiency (%): 4 Production (kWh/m². yr.): 39 Annual % of Heating:101% (39.5 kWh/m². year cool from the ground) (Produced by renewables)

Source: (Garde & Donn,2014)

The Advantages and Disadvantages of LIMA House Case Study:

▪ <u>Advantages</u>

1. A (relatively) compact design, excellent insulation levels, thermal mass (green roof), vented façade, and sun protections are among the features that help save heating and cooling costs (Venetian blinds with automatic control).
2. Sabaté & Peters (2011), (LIMA.CAT) explained that the prototype has several advantages as follows:

- MATERIALS: 3.7% of the building materials used are less detrimental to the environment as a result of the utilization of renewable or recycled resources. Wood and bamboo make up more than two-thirds of the products 63%, while recycled materials make up 20.7 % (compost, gravel, etc.).
- ENERGY:99.4% reduction in CO2eq emissions during a 60-year lifespan the use of plant-based materials in place of concrete, steel, and aluminum is intended to reduce energy consumption associated with construction materials (wood or bamboo). Heat recovery and

occupancy-controlled ventilation, high-efficiency central heating and cooling, and solar thermal collectors for hot water heating are just a few of the features that LIMA offers to reduce energy consumption during the building's use period.

- WATER: The use of water-efficient appliances and fixtures, rainwater collecting for plant watering and laundry, and the use of shower gray water for toilet flushing all contributed to a 52.9% reduction in water consumption.

▪ <u>Disadvantages</u>

1. It requires high construction costs, due to the great need to link the housing units among each other as they are residential complexes, and to high control and maintenance.
2. Some systems have a high start-up cost and it’s difficult to install.

4.4 Villa Magrì case study.

An Italian single-family home, Villa Magri is located near Brindisi's small hamlet of Mesagne, Figure 4.5. Passive House and low energy building standards were used in its construction. It has a total area of 309 m^2 spread over two stories. The first floor is 225,71 m^2 and the second floor is 84,40 m^2. (Stasi et al.,2019) The basic geographical and climatic facts, as well as some building geometric features, are shown in Table 4.9 & Figure 4.7. A lowered surface-to-volume ratio was found to be an effective passive strategy for climate management. It also created a high-efficiency plant system with air pretreatment by an earth-to-air heat exchanger paired with heat, and a high-performance envelope made of environmentally acceptable materials. The window-to-wall ratio is 16.05 %, and the surface-to-volume ratio is 0.73 m. (Stasi et al.,2020) Figure 4.6 shows the Villa Magrì from the outside.

Figure 4.5: Villa Magrì location, Source:(Rhorer,2014) (PHI Italia ,2019)-edit by researcher

Figure 4.6: Villa Magrì, Source:(archives,2015)

Table 4.9 Main features and climatic data of the Villa Magrì

Climatic data	
Minimum and maximum temperature °C	6, 32
Mean annual humidity (%).	0.74
Average sunshine	3388.77 hours in the year
Latitude	40°33'30.64" N
Longitude	17°48'27.86"E
Altitude (m)	71

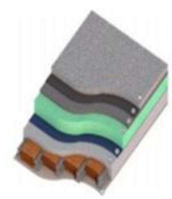
(CLIMAT-DATA)

External Wall

	Material	Thickness [m]	Thermal conductivity λ [W/m K]	Density ρ [kg/m³]	Specific heat capacity c [J/Kg K]	Water vapour resistance μ [-]
1	Gypsum plaster	0.02	0.70	1340	840	150
2	Tufa block	0.10	0.55	1400	950	4
3	Mixture of hemp and hydraulic lime	0.40	0.064	200	1500	5
4	Blocks of hemp and lime	0.12	0.096	330	1870	5
5	Cement plaster	0.005	0.900	1860	840	20
	Total thickness	**0.645 m**	**U = 0.127 [W/m² K]**			

Flat roof

	Material	Thickness [m]	Thermal conductivity λ [W/m K]	Density ρ [kg/m³]	Specific heat capacity c [J/Kg K]	Water vapour resistance μ [-]
1	Gypsum plaster	0.02	0.70	1340	840	150
2	Brick and concrete floor	0.250	0.80	1841	900	150
3	Vapour barrier	0.001	0.005	–	–	10,000
4	XPS panel	0.26	0.040	35	1400	130
5	Concrete screed	0.07	1.200	1950	1000	10
6	Waterproofing	0.005	0.500	1100	1400	33
7	Gravel	0.10	2.00	881	1674	50
	Total thickness	**0.705 m**	**U = 0.136 [W/m² K]**			



Ground floor

	Material	Thickness [m]	Thermal conductivity λ [W/m K]	Density ρ [kg/m³]	Specific heat capacity c [J/Kg K]	Water vapour resistance μ [-]
1	Porcelain stoneware	0.015	0.900	1860	840	20
2	Cement mortar	0.05	1.200	1950	1000	10
3	EPS panels	0.03	0.040	35	1400	35
4	Concrete screed	0.06	1.200	1950	1000	10
5	Concrete slab	0.50	2.300	2300	1000	130
6	Lean concrete	0.07	0.900	1800	2100	150
7	PE paper	0.001	0.500	980	1800	100,000
8	Cellular glass gravel	0.30	0.096	100	1090	2
9	Geotextile TNT	0.005	0.25	1150	1000	6000
	Total thickness	**1.03 m**	**U = 0.223 [W/m² K]**			

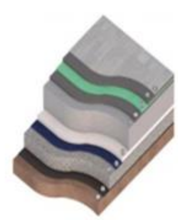


Figure 4.7: features of the material envelope of Villa Magrì, Source:(Stasi et al.,2020)

- **The ways Villa Magrì dealt with reducing energy consumption**

1. <u>Passive approaches.</u>

Stasi et al. (2019) summarized in their study the passive design strategies as well as other systems that supported these methods and in the next year, they made another study related to the same topic but wider. The strategies were as follows:

- Orientation and solar load control

The building's general orientation is the east-west axis, with broad south-facing walls to maximize solar gain in the winter. window exposed surface is determined by its orientation. When it comes to heat transfer, the southern region's windows have a surface area of 40.98 m^2 whereas the northern region's window area is 15.47 m^2. This is in addition to the use of sun breakers and shading devices. To improve interior comfort, the northern part was used for bathrooms, storage, entrance, and vertical connection, while for the southern part, the bedrooms, the kitchen, and the living were placed to take advantage of the sun. A schematization of the solar screens planned to control the summer solar loads is shown in Figure 4.8. (Stasi et al.,2019) A high amount of albedo has been employed on the exterior walls and roof to prevent overheating in the summer. White paint is used on the exterior wall, white stone is utilized on the exterior floor, and white gravel is used on the top roof of the building (Stasi et al.,2020).

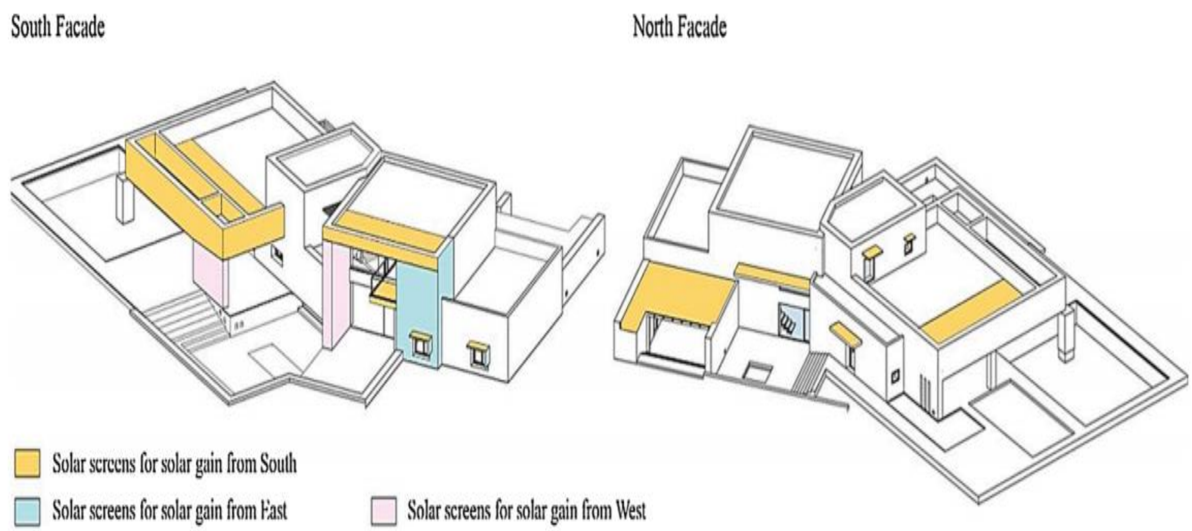


Figure 4.8: Fixed solar screens provided in the case study, Source:(Stasi et al.,2020)

2. <u>Energy Efficiency Systems.</u>

There is a heat pump in Villa Magri that connects to a heat exchanger located 1.50 meters below ground. An exterior air suction tower is connected to a polypropylene tube exchanger with DN 200 mm. With an efficiency of 0.86, double heat recovery technology was used and connected to the air handling unit. To power the building, photovoltaic monocrystalline silicon panels were used to harness renewable energy (Stasi et al.,2019). Table 4.10 shows the result of using heat recovery with an HVAC system in the summer and winter seasons:

Table 4.7: The result of using heat recovery with the HVAC system of Villa Magrì

season	thermal /cooling power of the heat pump	energy efficiency rating	outside air temperature	outlet water temperature
winter	13.30 kW	3.54	7 ° C	45 ° C
summer	10.70 kW	3.44	7 ° C	35 ° C

Source: (Stasi et al.,2019)

The Advantages and Disadvantages of Villa Magrì Case Study:

- Advantages

1. By using the building-plant system, it is possible to maintain the setpoint temperature within acceptable ranges for interior comfort. Summer temperatures rarely exceed 26 °C, and winter temperatures rarely get under 20 °C.
2. Electricity usage is about 40.68 kWh/m^{2}y, and the PV system generates about 40.74 kWh/ m^{2}y.
3. Total end-use consumption is 5.30 kWh/m^{2}y for heating, 1.16 kWh/m2y for cooling, 12.51 kWh/m^{2}y for mechanical ventilation, 4.72 kWh/m2y for domestic hot water production, 8.23 kWh/m^{2}y for internal equipment, and 7.19 kWh/m2y and 1.53 kWh/m^{2}y for interior and outdoor lighting, respectively.

- Disadvantages

1. Heat pump systems have a high start-up cost and it's difficult to install, especially since research must be done to understand local heat movement and geology as well as the heating and cooling requirements of a home.
2. The more energy to be produced, the more solar panels are needed, in which case as much sunlight as possible must be collected, solar PV panels require a lot of space, and some roofs are not large enough to fit the number of solar panels to have.

4.5 Summary

Case studies for low energy houses, particularly in the Mediterranean region, were presented in this chapter. Three instances were chosen, two of them are in Italy and the third is in

Spain. The three cases all have the same goal: to create a low energy building in the Mediterranean region by integrating different solutions and strategies. Every case has its advantages and disadvantages as mentioned on pages 30,33,34,37. These advantages and disadvantages were studied in light of the Palestinian situation and explained as follows:

Challenges:

- Political and economic Palestinian situations have strongly affected the renewable energy market and have inhibited investors from making investments in this sector.
- Absence of regulations to control the market, Heavy tax system, and high cost of RE technologies.
- Weak technological capability in both humans and institutions, lack of professional training on new applications and designs, and absence of pilot projects in types of RE in Palestine.
- Renewable resources are limited to solar energy using the photovoltaic system, thermal applications (mainly for water heating), wind energy is limited in Palestine and not commonly utilized yet.
- Geothermal technology approved that it gives the thermal comfort of a building, and it has started in Ramallah city in one of the ITEHAD subdivision villas, it approved a worst-case efficiency rating of 450%, and it achieved savings of about 70%(Yaseen,2009), but this mechanism requires difficult techniques and a long time to give the desired energy in addition to its high maintenance cost, so it was not considered in this study.
- Heat recovery is not considered in this study because it is not common in Palestine also because:
  1- It works efficiently in well-insulated and airtight buildings only.
  2- It is needing important initial investment.
  3- Filters need to be cleaned every 3 months (or replaced).
  4- Larger encumbrance of the insulated air supply/exhaust pipes, and air distribution ducts.

Potential:

- The previous three cases focused on the efficiency of the Mediterranean region in achieving this type of housing, especially since Palestine is located within this climate and is characterized by a high number of sun hours.

- The outcomes of this topic were favorable in each of the three examples, as passive techniques combined with renewable energy proved to be effective in reaching this goal, and the climate of the region played a significant role in this.
- After analyzing the case studies, the solar cell system will be adopted in this thesis, as it will be in great agreement with the study objectives, dealing with it will be easy, and the climate of Palestine is suitable for the solar cell system owing to the average sunshine which is estimated at 3400 hours/year. This helps greatly to exploit the strategies of passive and active design and employ them together to get low-energy houses, which will be explained in further detail in the next chapter.

Chapter 5 Research Methodology

5.1 Introduction

This chapter explains the methodology used in this research to achieve its objectives. The descriptive-analytical approach was used in this research. This chapter first presents an overview of the research method used in each phase of the study. Second, it discusses the methodology used in this thesis which includes the identification of the parameters affecting building performance. Finally, it presents the simulation process proposed for this research.

5.2 Study Area Selection Criteria

There are seven climatic zones in the West Bank and Gaza strip. Three of them were selected for the simulation. The reasons for selecting these three climatic zones were because:

- These climatic zones cover the largest cities in Palestine.
- They have the highest population densities.
- They have the highest number of existing buildings.
- They hold the potential for the highest growth in future residential building construction.

The other climatic zones were not considered in this study because they are either non-populated areas or have climatic conditions that are close to the selected zones.

5.3 Base Case Selection Criteria

Residential buildings in Palestine consist of single houses**,** villas, and apartment buildings. (Haj Hussein et al.,2022). According to the Palestinian Central Bureau of Statistics. Single houses represent the first rank of the common type in the West Bank and the second rank in the Gaza Strip, with a rate of 45.3%. This study focused on the residential building sector for the following reasons:

- The residential buildings represent the majority of buildings in Palestine.
- They are responsible for the largest part of energy consumption about 60% of electricity consumption.

The base case is A 2-story building, as depicted in Figure 5.3. Figure (5.4) (5.5) demonstrates the 2D plan of the building. It can be seen that the ground floor comprises a kitchen, a store, a WC, a guest room, and a dining room. There are three bedrooms on the first floor, a bathroom, and a living room.

It was chosen because:

- It represents the majority of household units in Palestinian cities in terms of services.
- It assumes a 5cm stone building envelope, 15cm concrete, 7cm block, and 2cm plaster, which is the common scenario in the study.
- Windows are clear double-glazed with 81% visible transmittance and 76% Solar Heat Gain Coefficient and the frames are standard aluminum frames.
- The thermal characteristics of construction materials and their availability were determined using the Energy Codes for Buildings and their publication "Construction Techniques Survey in Palestinian Territories" (Khammash, 2002).

Table 5.1 describes the physical and Climate characteristics of buildings in the study context. The residential space is considered to be occupied daily. The set point of room temperature is 25°C for cooling and 22°C for heating. The occupancy density equals 0.0215 people/m². The lighting target was set to 300 Lux and the type fluorescent in the simulation program. The minimum fresh air for one person equals 2.36 l/s-person.

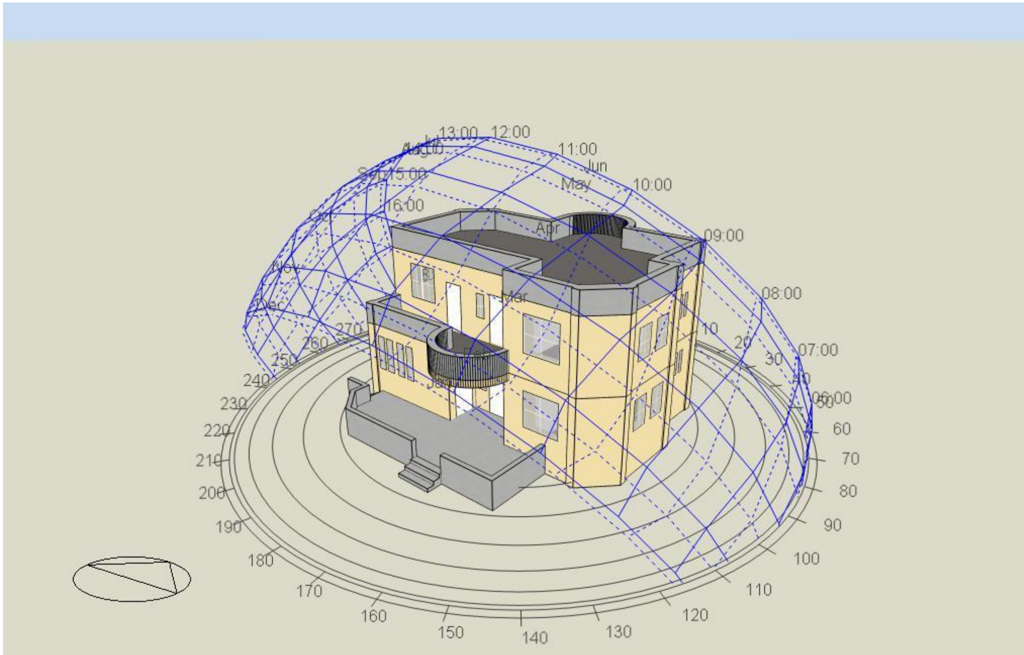


Figure 5.1: The building 3D model with sun path, Source: researcher

Figure 5.2: The ground floor of the house, Source: (Al Herbawe et al.,2003)

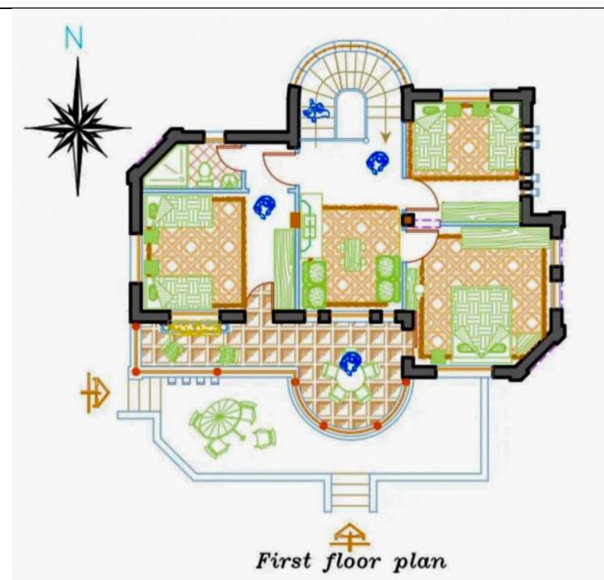


Figure 5.3: The first floor of the house, Source: (Al Herbawe et al.,2003)

Table 5.1: Physical Characteristics of the case study and Climate selected zones (Jerusalem) Characteristics

Climate-specific characteristics	
City	Jerusalem
Latitude and Longitude	31.77°-35.22°
Altitude	750 M
Temperature Average Min(°C)	8.9 °C
Temperature Average Max(°C)	26.1 °C
ASHRAE Zone	3C
Physical Characteristics	
Building configuration	200 m^2 (floor with 120 m^2 & roof with 80 m^2)· single-family
Floor Height	3.00 meter
Number of floors	two-floors (floor &roof)
Glazing type	clear double glazed-6mm
Window to wall%	30%
Construction method	
Exterior walls	5cm Stone 15 cm Concrete 7cm Block **U-Value =2.645 w/m^2-k** 2 cm Plaster
Roof	Roof Construction method 26 cm Concrete slab **U-Value = 2.684 w/m^2-k** Asphalt layer
Floor Construction	26cm reinforced concrete 15cm Sand and cement mortar **U-Value = 1.334 w/m^2-k** 2-3 cm thick Tile
Finishing Materials	
Floor	Porcelain tiles
Internal Partitions	Painted 10cm Block

5.4 Simulation Process

The descriptive analytical approach was followed in this research. The theoretical and analytical phases were separated. The theoretical Phase included identifying issues related to the subject of the study. Furthermore, in addition to identifying the tools used worldwide to evaluate the thermal performance of buildings. The descriptive technique was used to determine the approved concepts, materials, and tools by gathering information from new international researchers and following their strategies- in similar previous case studies- for obtaining low-energy houses. The study covers the analytical approach by using the DesignBuilder simulation tool to apply several scenarios in achieving low-energy principles.

First, the study starts by determining the annual rate of electricity consumption in kilowatt-hours for the building. Then, the impact of different passive strategies on thermal performance and energy consumption is analyzed. After that, DesignBuilder is used to determine the value of heating and cooling loads. Later, building and environment data should be inserted into DesignBuilder such as:

- Complete climatic data for the building area.
- General information about the building, including layers of materials used in exterior walls, windows, doors, and roofs.

Through this process, the study reaches a starting point for comparing the power output of different systems. After that, the building is simulated when each strategy of passive design is used individually and with applying different scenarios, then the best scenario is applied to the tested model. After that, it is linked to the RES to achieve low energy consumption. Strategies include orientation, glazing type, shading devices, insulation materials, tree planting, and photovoltaic cells. The results help to outline strategies that may benefit architects and decision-makers in Palestine to achieve energy efficiency in buildings. Later on, the results will be discussed to come up with recommendations. Figure 5.4 shows the research methodology phases.

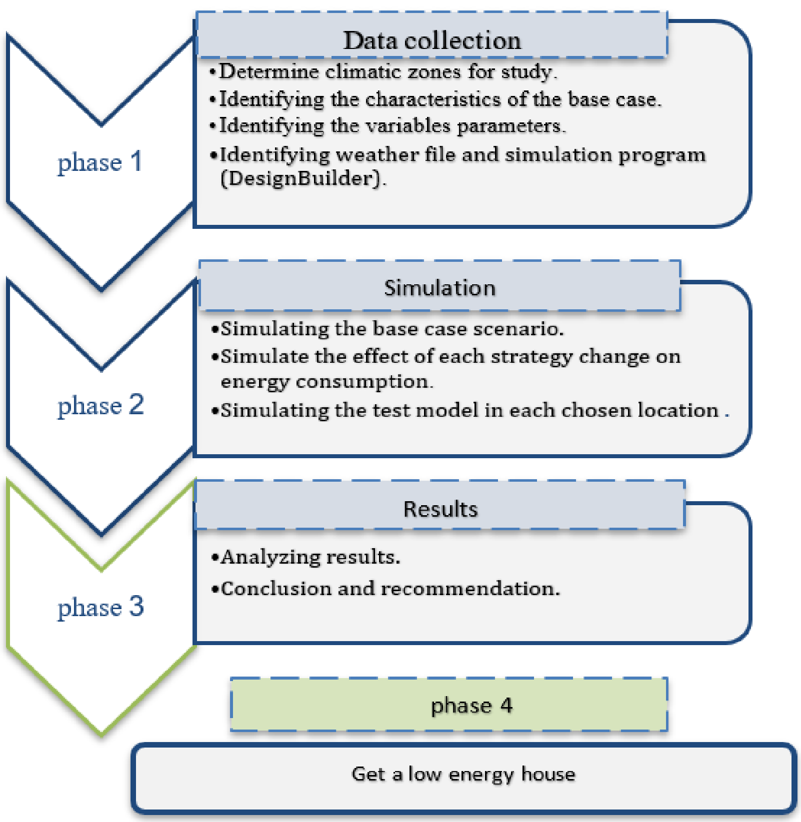


Figure 5.4: Research Methodology phases, Source: By the Researcher

5.4.1 Categorizing Parameters

All parameters pointed out previously in the literature review in chapter three were categorized into three categories for this study. Those categories are the design parameters (variables), constant parameters, and confounding variables.

1- Design variables (Input parameters):

Design Parameters are the elements that are allowed to vary during the analysis process to get the best results, which are: Orientation, insulation type, glazing type, shading devices type and projection, tree height, and PV. These parameters are going to be studied individually in chapter 6.

2- Constant parameters:

A residential building's design is unsuccessful if it doesn't consider the occupants (Ardda et al., 2018). This is very true when studying residential buildings in Palestine. Sociocultural values are never ignored in this type of building and constant parameters are related to common design practices:

- Wall configuration: In Palestine, it was found that the wall configuration was common to be: 5cm stone, 15 cm concrete, 7cm blocks, and 2 cm plaster as mentioned in table 5.1
- Window-to-wall ratio: Privacy is highly needed. Large window-to-wall ratios or completely glazing facades are never found or accepted in Palestine. Social values are given greater attention in residential buildings than environmental or economic values.
- Insulation thickness: It is common to be from 3 to 5cm. In the study, it was fixed to 5cm as it is more efficient in power saving and it was not more than 5cm due to economic issues as the insulation material is expensive.
- Tree type: A certain type of tree was found to be the most commonly used in the study region as mentioned in the Palestinian statics center which is the Araucaria tree.

3- Confounding variables:

They are factors that can't be controlled by the user but may still influence the building performance such as occupancy, lighting, building schedule, residential appliances…etc.

Table 5.2: Categorizing Parameters

Design variables (Input parameters)	Constant parameters	Confounding variables
Orientation Insulation type Glazing type shading devices type and their projection tree height PV	Wall configuration Window-to-wall ratio Insulation thickness Tree type	Occupancy Lighting Appliances

5.4.2 Simulation stages

The simulation process consists of two stages. The first stage is inserting the variable parameters related to the passive strategies and simulating the scenarios of each strategy then choosing the best scenario for each case and simulating the basic case and analyzing the energy loads resulting. The second stage is RES when both the tested model and the basic model are connected with the solar cell system simulated and compared, RES's effect on annual energy loads will be determined.

1. Testing and identifying passive design parameters and input values (first stage):

The effect of the passive design variables' values on the decision-making of the low energy design was studied using parametric analysis. The passive parameters will first be considered separately to see how they affect the cooling and heating requirements for each zone, then the best result for each parameter will be determined and then linked to the RES parameters to finally get a low energy house.

- <u>Orientation</u>

To determine the best orientation of the building, the case reference scenario was first estimated and then the same case was simulated every 15° starting from 0 to 360°, as shown in Figure 5.5. The number of scenarios is 24.

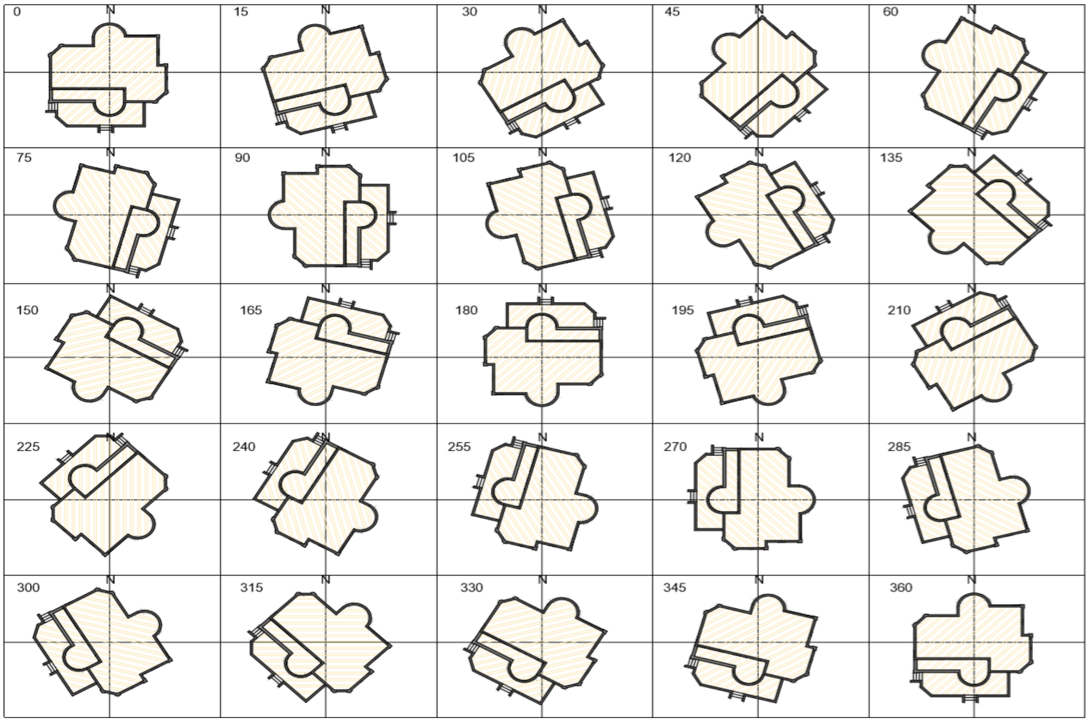


Figure 5.5: Orientation, Source: researcher

- <u>Glazing Type</u>

For this study, and since glazing is the main source of heat gain and heat loss (Hassouna et al., 2012), and because it is affected by various factors and cannot be generalized to a specific case (Rathi**,** 2012), Table 5.3 shows that all types of windows in Palestine will be taken into consideration so that a simulation will be made for each of the mentioned types and see their impact on heating and cooling loads. The number of scenarios 6.

Table 5.3: shows Glazing types and their properties Available in the Palestinian Market

glazing type parameters	**Visible Transmittance**	**Glazing Thickness (mm)**	**Air Gap Thickness (mm)**	**Solar Heat Gain Coefficient**	**U-Value**
Clear – double glass	81 %	6	13	76%	2.73
Tinted – double glass	61%	6	13	63%	2.70
Reflective – double glass	8%	6	6	63%	2.73
Double – High Solar Gain - Low E Glass	78%	6	13	26%	1.99
Double – Low Solar Gain - Low E Glass	64%	6	13	26%	1.7
Triple – High Solar Gain - Low E Glass	69%	3	13	55%	1.42
Triple – Low Solar Gain - Low E Glass	63%	3	13	38%	1.02

Source: (Hadid, 2002b)

- <u>Shading Devices</u>

Exterior window shadings are regarded as a viable alternative for passive cooling. The building was designed with and without shading devices to see how it affects energy efficiency. Table 5.4 shows the different shaders used in the simulation and their specifications. First, the building is simulated without shading devices, and then the different types are tested. Each type has from 2 to 3 cases in the simulation. Figure 5.6 (a) (b) (c) shows the dimensions of the shading devices. The number of scenarios is 11.

Table 5.4: different shading devices and their Simulation specification.

shading devices parameters	**Simulation Specifications**
blinds (BLs)	- Blinds were examined inside and outside of the windows. - Blinds should be made up of low-reflective material i.e., aluminum.
overhang (OHs)	- Two options were implemented: 0.5m and 1m. - the overhang should be made up of low-reflective material i.e., aluminum
Louvers (LOs)	- one option was implemented: 0.5m. - the angle of lovers' blades which were assumed to be 10^{o}, 45^{o}, and 60^{o}. - Louvers should be made up of low-reflective material i.e., aluminum
Overhang (OHs)+ Sidefins (SFs)	- Two options for the Combinations of OHs and SFs were implemented: 0.5m and 1m. - Sidefins should be made up of low-reflective material i.e., aluminum
Overhang (OHs)+ Sidefins (SFs) + Louvers (LOs)	- Two options for the Combinations of OHs, SFs, and LOs were implemented: 0.5m and 1m.

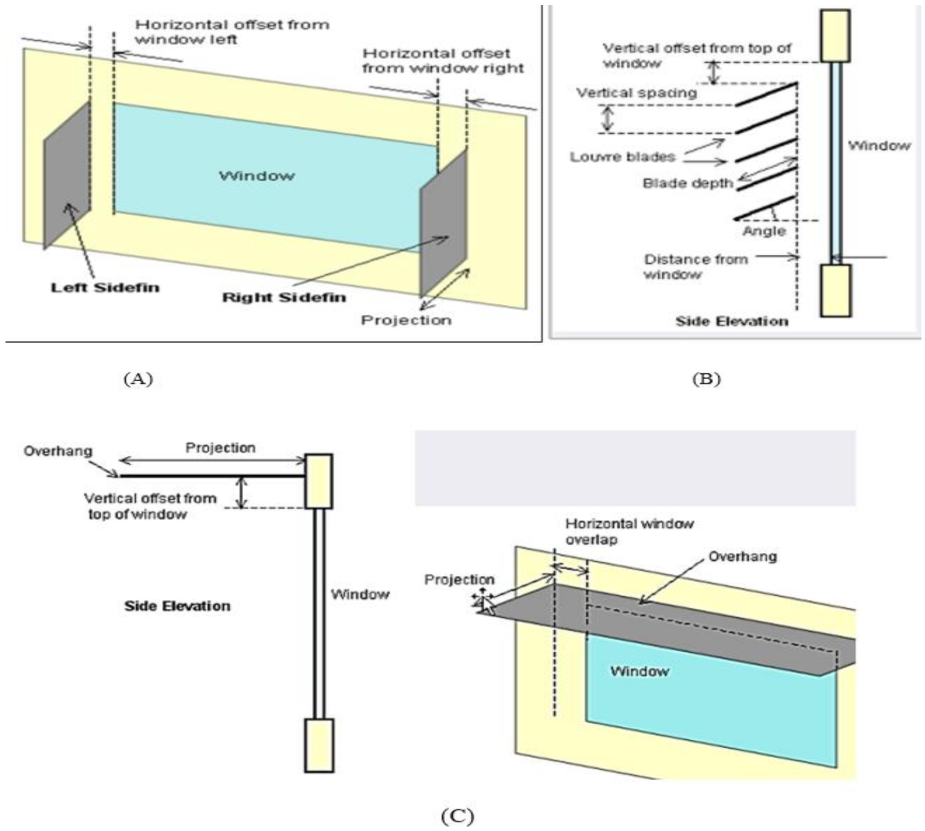


Figure 5.6: Shading Devices Dimensions on DesignBuilder: (a) Dimensions of Sidefins, (b) Dimensions of Louvers, (c) Dimensions of overhang Source: https://designbuilder.co.uk/

- <u>Insulation Material</u>

One of the most important energy-saving solutions was the installation of insulating materials in the exterior walls. Several insulation materials were evaluated, and the one with the best performance was proposed. Table 5.5 displays the common materials in Palestine that were considered. The number of scenarios is 5

Table 5.5: Thermal Properties of Different Insulating Materials

insulation parameters	**Density (Kg/m^3)**	**Conductivity (W/mK)**	**Specific Heat (J/kg·K)**	**Thickness (m)**
Thermal air gap	1000	0.28	1000	0.05
Expanded Polystyrene	30	0.022	1400	0.05
Extruded Polystyrene	27	0.025	1400	0.05
Foam Polyurethane	30	0.026	1470	0.05
Rock Wool	80	0.032	710	0.05

Source: (Hadid, 2002b)

- <u>landscape (tree Planting)</u>

In this study, the Araucaria tree was used as shown in Figure 5.7, which is an evergreen tree used in all Palestinian areas, especially around dwellings. This study focused on the tree height and its effect on energy consumption in the selected areas, the northern building side has no trees as it receives almost no direct sunlight. The following table 5.6 shows the characteristics more clearly **.**The number of scenarios is 3

Table 5.6: characteristics Simulation of Araucaria tree

Tree parameters	**Simulation Specifications**
Tree height	4m,6m,10 m
Distance from building	3m
Rate of Growth	slow
Use	Shade, decoration

Figure 5.7: Araucaria tree, Source: https://info.wafa.ps/ar_page.aspx?id=8131.

2. Renewable Energy Sources generation (second stage)

Palestine has a high solar energy potential all year, with an average solar radiation of 5.46 kWh/m^2.day. Thus, PVs have the potential to be a very effective energy-producing characteristic in the region; Palestine receives reasonably good quality solar energy all year. The purpose of incorporating PVs into the roof is to investigate how far we can plan for solar energy as a reliable source of electricity in the future.

- Photovoltaic system

To realize the advantages of a low-energy house, the test model in each region was linked to photovoltaics by estimating what energy is required after simulating the energy consumed on-site. The base case model was also linked to the solar cell system to make a comparison with the test model associated with the same system to show the amount of difference in terms of energy. The characteristics of the system will be determined in the next section of the study, after obtaining the best passive strategies after simulation.

5.5 Evaluation Criteria

The evaluation was based on a comparative approach between the different cases. The comparative process was performed separately for each phase. Different variables of the case were compared with each other and then compared with the other case's variables. The effect of changing the orientation, glazing type, insulation type, shading devices, and tree on the performance of the building was evaluated, with the result that gives better performance and lowers energy consumption being preferred and recommended with the PV system.

5.6 Summary

In this chapter, the study methodology and simulations that will be carried out for the selected passive strategies & RES have been clarified, in Figure 5.8. The main steps that were clarified:

1. The criteria for the study area selection were explained.
2. The criteria for the base case study selection were demonstrated.
3. Phases of the simulation process, constant parameters, and variables were clarified.

4. The process of testing parameters was explained, the properties of used parameters were defined and the characteristics of selected variables have been clarified based on what is available and common in Palestine.

5. This chapter is considered a general framework for low energy houses.

    - These steps were explained to achieve the desired results.

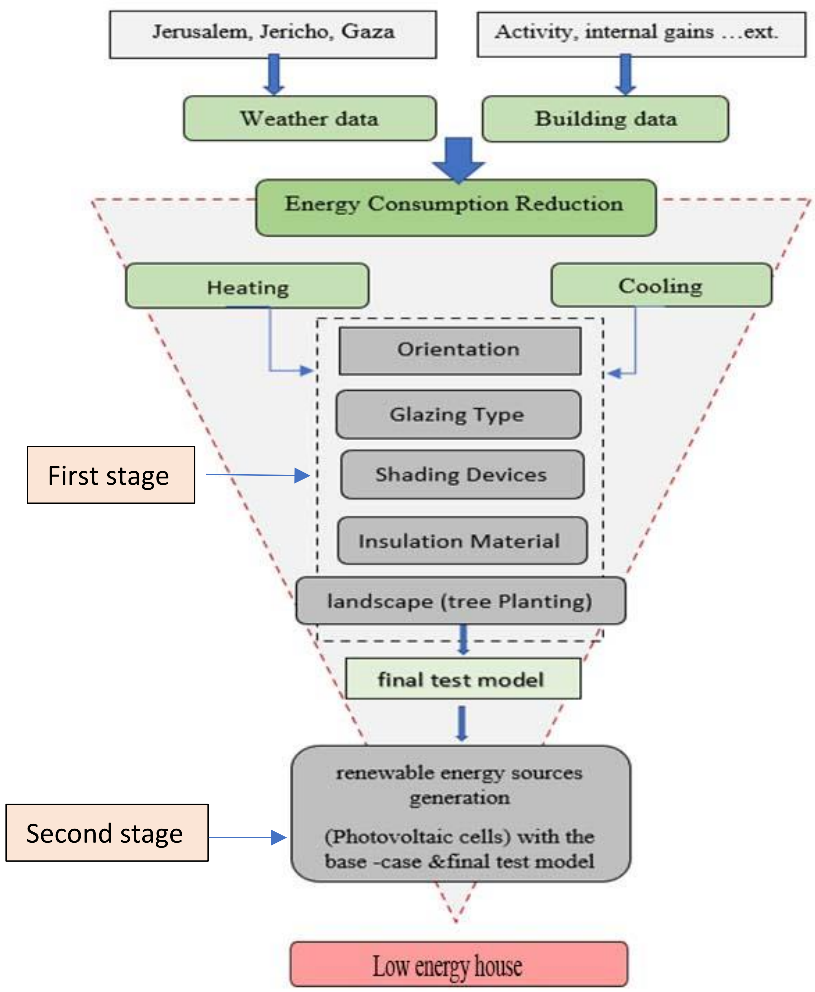


Figure 5.8: Proposed guideline Simulation methodology, Source: By the Researcher

Chapter 6 Research Results

6.1 Introduction

The main issue in this chapter is how to achieve energy efficiency for the base case building via the chosen strategies as the first step for obtaining a low energy house as mentioned before in the previous chapter. In this context, this chapter answers questions no. one & two: "What are the proposed scenarios of passive and RES strategies that could be applied for low energy houses, especially in Palestine?" "How could the RES generation help to get a low energy house?"

Simulation results are presented in the section below, using the parameters given in the tables mentioned in the previous section. A comparison was made on the DesignBuilder program to reach the best values.

6.2 Case Study Area: Jerusalem

The selected climatic zones reflect places with large population densities and cover the main climatic conditions. The city of Jerusalem represents the main climatic zone (zone 4), which is 3C according to ASHRAE climate zones and a Csa according to Koppen's climate classification. It is located at an elevation of 750 meters above sea level and experiences hot summers and very cold winters. The city of Jericho is located in the second climatic zone (zone1), which is 3A in ASHRAE climate zones and a Csa (C) Temperate, (s) Dry summer, (a) Hot summer in Koppen's climate classification. It is 300 meters below sea level and experiences hot, dry summers and warm winters. The city of Gaza is a 3A according to ASHRAE.

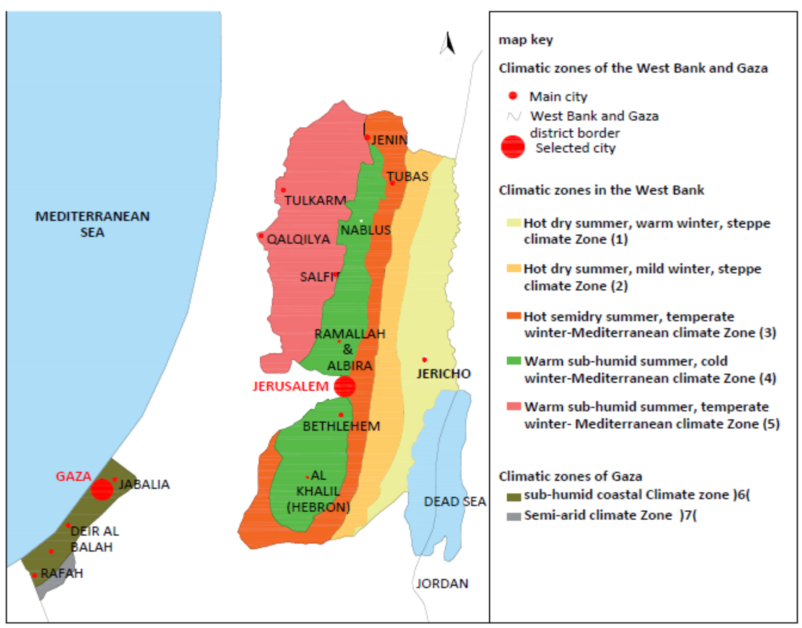


Figure 6.1: Climatic zones in the West Bank and Gaza strip. source (Monna et al, 2022)

climate zones represent the third climatic zone (zone 6). It is located 5 meters above sea level and experiences hot, humid summers and mild winters, classified Csa (Monna et al.,2021), and classified BSh according to Koppen's climate classification. (Ajjur & AL-Ghamdi,2021). the BSh classification used in the study context. As shown in Figure 6.1.

The study concentrates on Jerusalem as a base case. Jericho and Gaza cases were added to the appendix (for more details see appendix C).

6.3 First Stage Result

6.3.1 Orientation result & discussion

The base case in Jerusalem was simulated using its weather file on the Design Builder program, then the variable parameters were successively tested and the best option was determined in each case to obtain the final tested model at the end. The results were as follows:

- It has been observed that orientation has a great effect on energy consumption. Table 6.1 explained that by showing all the values of the heating and cooling loads yearly, as well as the annual consumption of the building when changing the orientation angle. The difference in results was noted as follows:
- The largest annual total site consumption was 141.05 kWh/m^2 when the building was oriented at an angle of 225.
- The lowest annual total site consumption was 135.82 kWh/m^2 at an angle of 345 as shown in Figure 6.2 and if looking back to Figure 5.5 it will be noted that the longest side of the building is still close to the imposition direction of the base case (along the east-west axis) with a slight deflection of the axis.
- As for the effect of changing the orientation on the amount of energy conservation, Figure 6.3 shows this effect throughout the year, as it is clear that 0.5% energy can be saved when making the right orientation which is at an angle of 354 so it was considered for the design, and energy consumption can be increased by 3.3% if the building is oriented incorrectly. Figure 6.4 shows how annual heating and cooling loads are distributed in a year and how different orientation affects them. The lowest total heating and cooling loads were 118.26 kWh/m2 with energy savings equal to 0.5%, which is represented by the red column, and the largest total load was

123.58 kWh/m^2 with an increase in energy consumption of 3.5%, which is represented by the blue column.

Table 6.1: Simulation results of the orientation on total sit energy, annual heating, cooling loads, and annual energy saving for Jerusalem city.

Case/Angle	Total sit energy (kWh/m^2)	Heating (kWh/m^2)	Cooling (kWh/m^2)	Energy saving%
Baseline-case 0	136.53	99.44	20.53	-
15	137.04	98.76	20.72	0.40%
30	138.37	99.24	21.57	1.35%
45	139.24	99.34	22.35	-2%
60	138.73	98.69	22.48	-1.60%
75	137.98	98.13	22.28	-1.10%
90	138.04	98.38	22.11	-1.11%
105	138.64	98.89	22.21	-1.50%
120	139.15	99.43	22.18	-2%
135	139.02	99.71	21.76	-2%
150	137.99	99.36	21.07	-1%
165	137.20	99.17	21.48	-0.66%
180	137.44	99.57	20.32	-0.66%
195	138.01	99.43	21.06	-1.10%
210	139.54	99.58	22.46	-2.20%
225	141.05	99.93	23.65	-3.30%
240	140.55	99.18	24	-3%
255	140.15	98.92	23.88	-2.70
270	140.56	99.34	23.80	-3%
285	139.92	98.30	24.17	-2.50%
300	139.32	97.75	24.10	-2%
315	138.38	97.61	23.26	-1.40%
330	136.55	96.96	22.04	-0.01%
345	135.82	97.2	21.06	0.5%
360	136.53	99.44	20.53	-

Best value of the orientation in this case. Worst value of the orientation in this case.

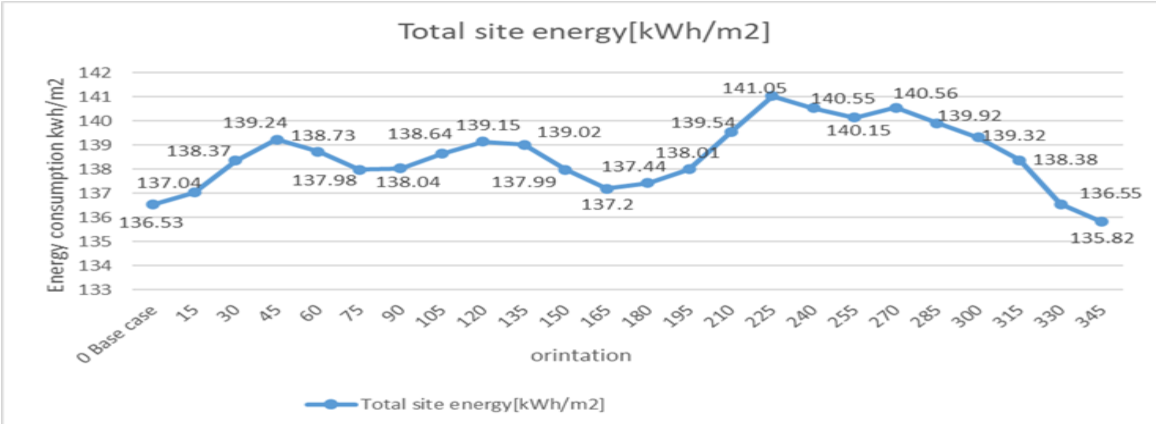


Figure 6.2 Annual simulation results site energy consumption (kWh/m^2) for the orientation parameters (Jerusalem)

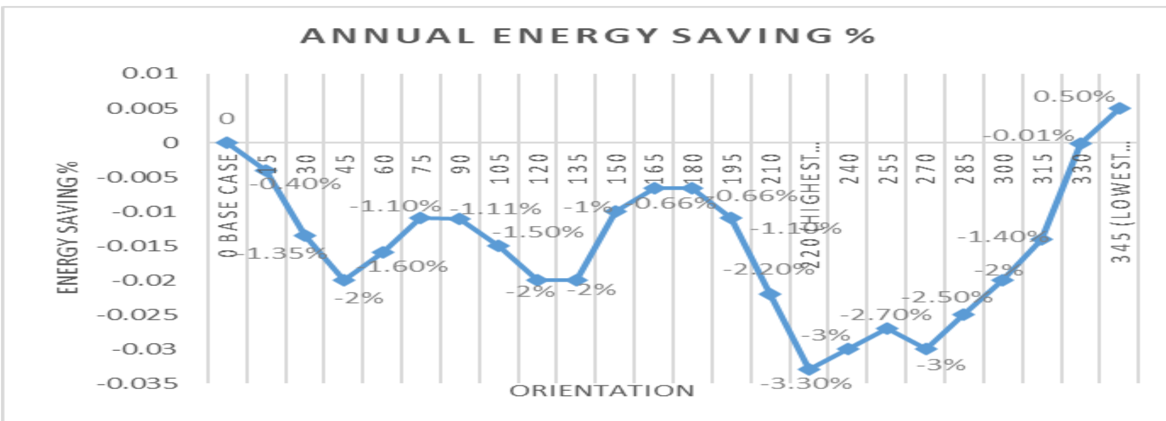


Figure 6.3: Annual simulation results of the site energy saving % for the orientation parameters (Jerusalem)

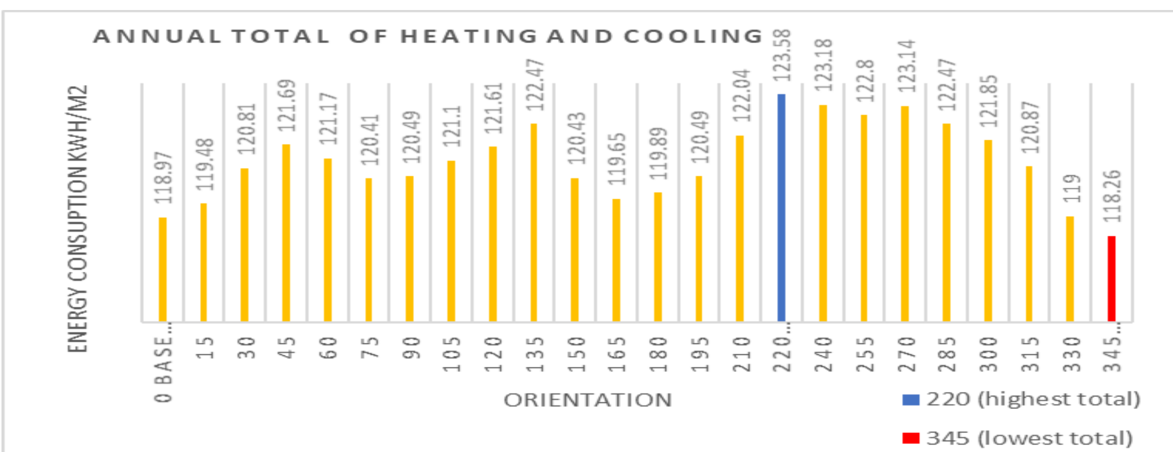


Figure 6.4: Annual simulation results of total heating and cooling loads (kWh/m^2) for the orientation parameters (Jerusalem)

6.3.2 Glazing Type

The result of the simulation shows how much the glazing type affects the total energy consumption. According to the simulation results shown in Figure 6.11, Triple – High Solar Gain - Low E Glass has a much higher reduction impact on total net site energy with a value equal to 135.55 kWh/m^2 with energy consumption equal to 0.7% and can be considered effective for the design. On the other hand, Reflective – double glass has much higher energy consumption on-site energy if compared to the base case which equals 4.5%, as it gives an estimated consumption equal to 142.65 kWh/m^2.

To study the effect of changing the type of glass on heating and cooling loads, Figure 6.12 illustrates this effect as it shows the simulation results for the loads and how they are distributed throughout the year. Where two different columns appear, each representing the exact value of the load. The red column represents the cooling load and the blue column represents the heating load. The results showed that the lowest total heating and cooling loads were equal to 117.97 kWh/m^2 when Triple – High Solar Gain - Low E Glass was used, while Double – High Solar Gain - Low E Glass gives a total load equal to 118.39 kWh/m^2, then in the third place Triple – Low Solar Gain - Low E Glass with a total load equal to 118.41 kWh/m2 and followed by Clear – double glass that was used in the base case with a total load equal to 118.97 kWh / m^2, then Tinted – double glass gives total load equal to120.07 kWh/m^2. The largest total loads were estimated at 124.33 kWh/m^2 if Reflective – double glass was used.

While Figure 6.13 shows the amount of saved energy when changing the type of glass, it is clear that energy can be saved by 1% when using Triple - High gain solar - low emissivity glass, and the energy consumption can be increased by 4.5% if Reflective - Double glazing was used in the building. The reason that Reflective glass consumes this amount of energy is due to the increase in cooling loads due to heat return.

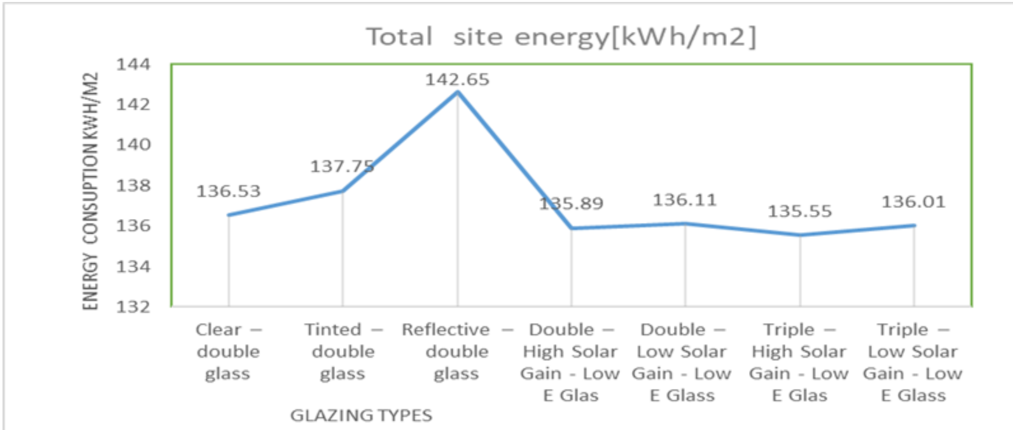


Figure 6.11: Annual total site energy consumption (kWh/m^2) for the glazing type parameters (Jerusalem)

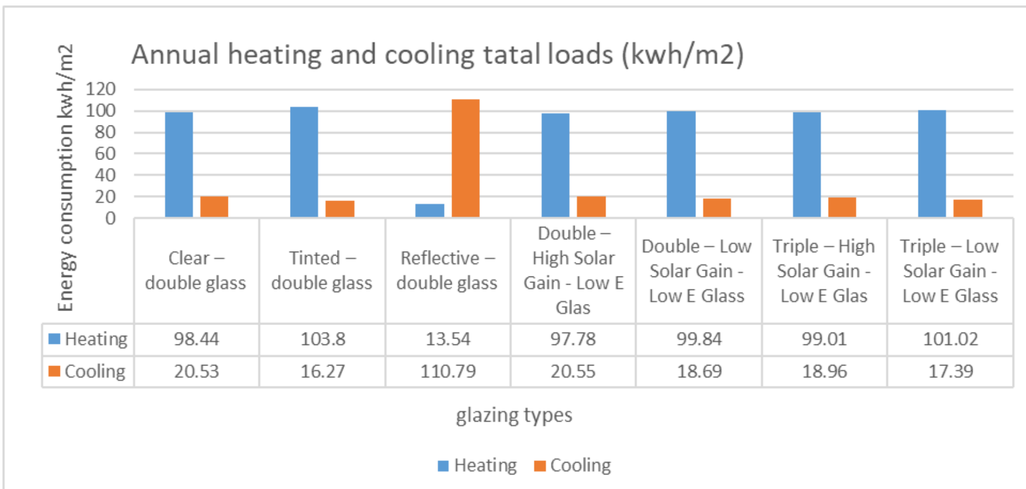


Figure 6.12: Annual total heating and cooling loads (kWh/m^2) for the glazing type parameters (Jerusalem)

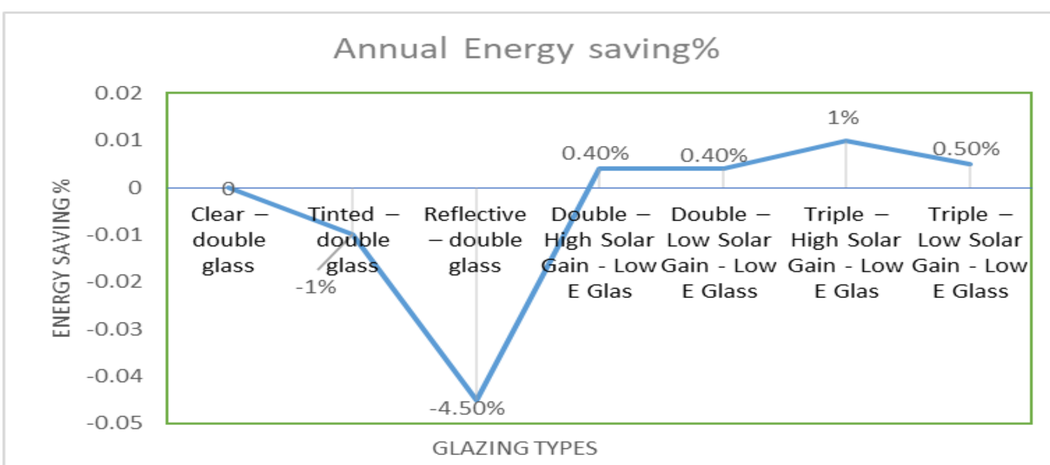


Figure 6.19: Annual Simulation results of energy saving loads % for the glazing type parameters (Jerusalem)

6.3.3 Shading Devices

For shading simulation, 11 cases were simulated and compared to the base case, the results are shown in Figures (6.20) (6.21). As shown, all types reduce annual heating and cooling loads. The overhang with a projection of 0.5 m has a much higher reduction effect on the total energy consumption by a value of 118.95 kWh/m^2 with energy savings of 15%, so it was considered in the design. This was represented by the red column. On the other hand, the decrease in consumption was similar to the rest of the shading types. In terms of achieving the largest total of cooling and heating loads, it is the combination of three types with a 1m projection which represents the yellow column that gave Consumption equal to 125.66 kWh/m^2, with energy savings of 10%.

In conclusion, the utilization of shading devices can minimize electricity consumption, and on the other hand, increase total site energy. As shown in Figure 6.22, the total site energy can reach 144.23 kWh/m^2 in the case of the combinations of three types with a 1m projection, and that means consuming more energy by about 5.6%.

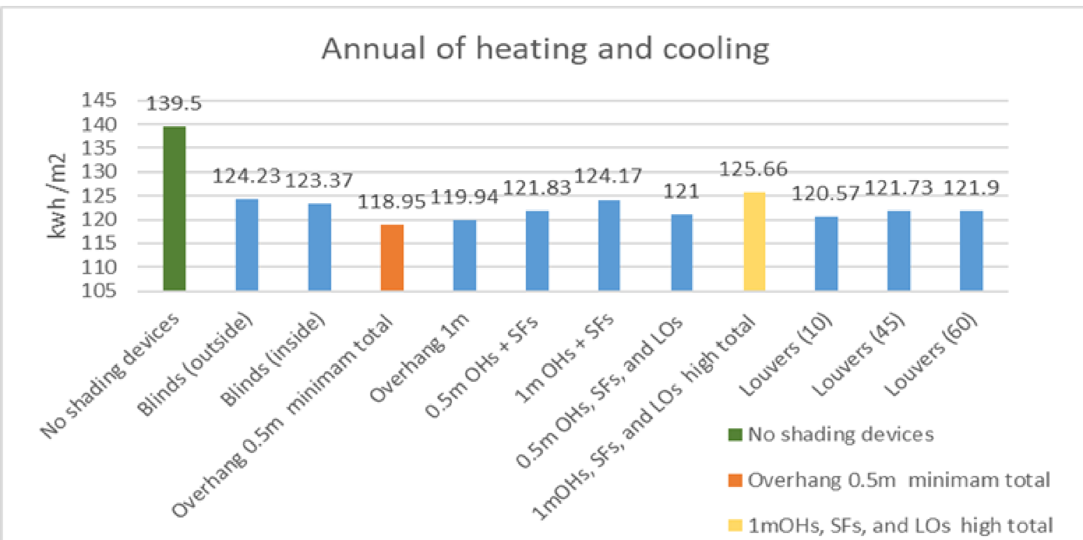


Figure 6.20: Annual simulation results of total heating and cooling loads (kWh/m^2) for shading devices parameters (Jerusalem)

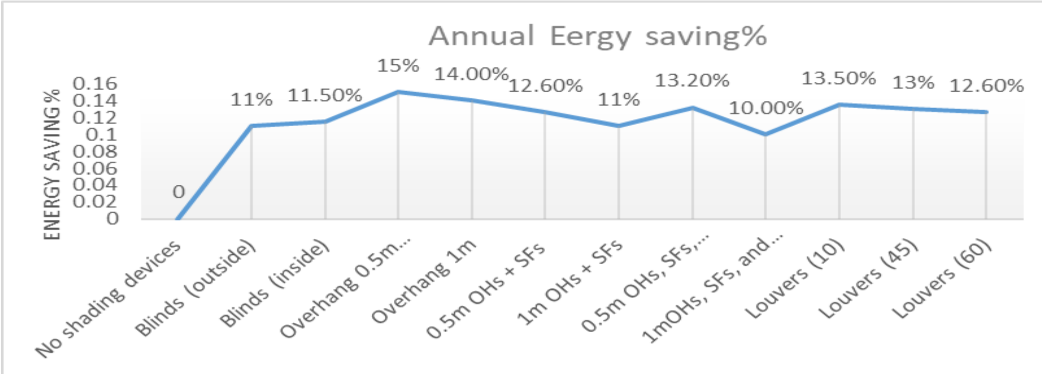


Figure 6.21: Annual Simulation results of energy saving loads % for the shading type parameters (Jerusalem)

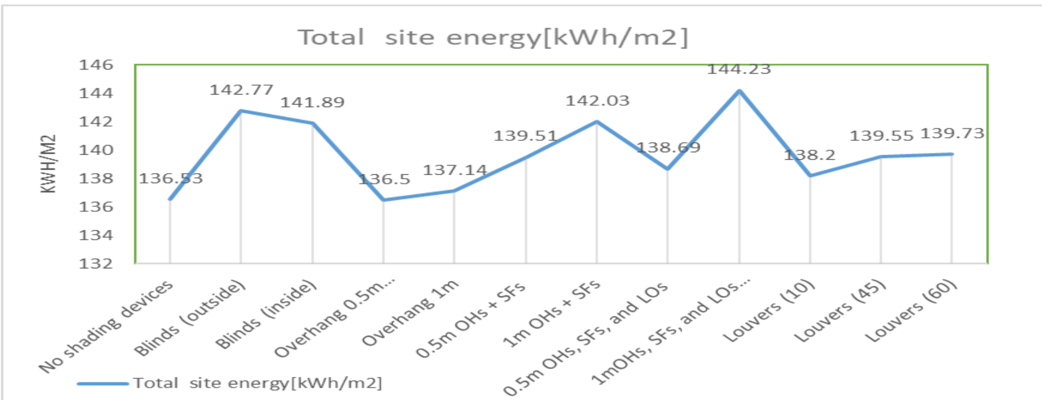


Figure 6.22: Annual simulation results of site energy consumption (kWh/m^2) for shading devices parameters (Jerusalem)

6.3.4 Insulation Material

Five cases of insulation materials were compared to the base case, and the results were shown in Figure 6.29. It can be observed from the simulation results that the inclusion of insulation materials of all kinds can significantly reduce the total net energy at the site. Energy consumption decreased from 136.53 kWh/m^2 to 65.43 kWh/m^2 when Expanded Polystyrene was used. This means energy savings by half. It was followed by Extruded Polystyrene with an energy saving of 50.7% with a total site equal to 67.27 kWh/m^2. Foam Polyurethane saves 50.3% of energy with a total site equal to 67.85 kWh/m^2. Rock Wool saves 48% of energy with a total site equal to 71.2 kWh/m^2, while Thermal air gap gave the highest consumption in the site energy, however, it reduced the consumption for the basic case and saved energy by 17.6% with a total site equal to

112.43 kWh/m^2. These results show the importance of including insulation in buildings and its benefit in the long term.

All types of insulation used in the simulation reduce the amount of consumption for heating and cooling loads throughout the year, especially expanded polystyrene, which reduces the total loads from 118.97 kWh/m^2 to 47.91 kWh/m^2, where the amount of energy saving is about 60%. Therefore, it was taken into consideration in the design. Then comes the polystyrene extruded, which gives a consumption of 49.75 kWh/m^2 with energy savings equal to 20.58 %. The thermal air gap with a 0.05 meters thickness gives the largest energy consumption for cooling and heating which is equal to 94.92 kWh/m^2 with an energy saving of about 20.2% as shown in Figure (6.30) (6.31).

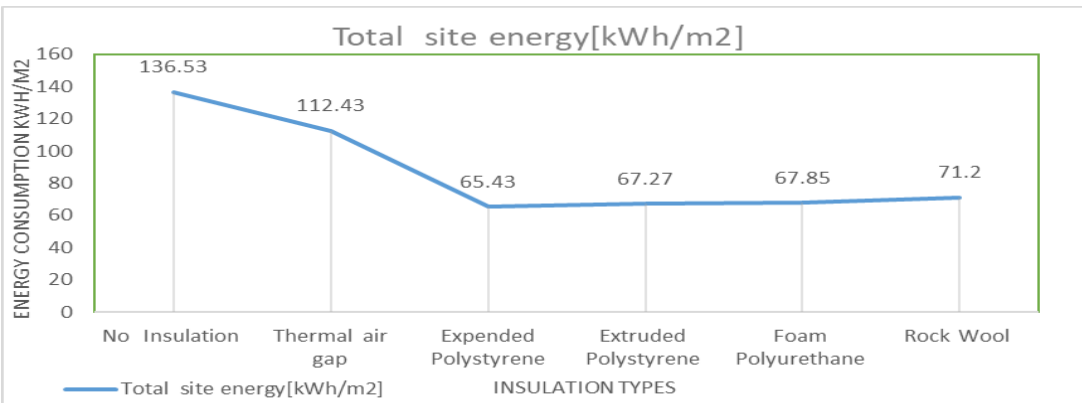


Figure 6.29: Annual site energy consumption (kWh/m^2) for insulation material parameters (Jerusalem)

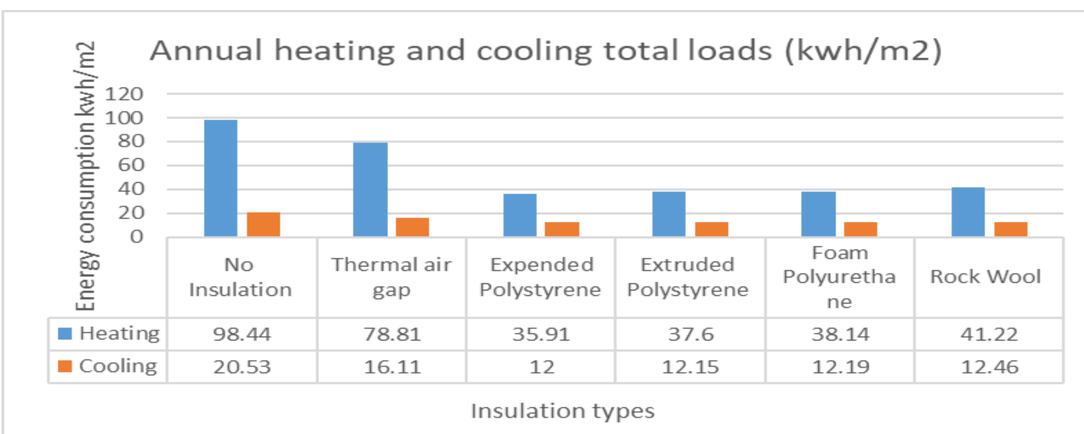


Figure 6.30: Annual total heating and cooling loads (kWh/m^2) for insulation material parameters (Jerusalem)

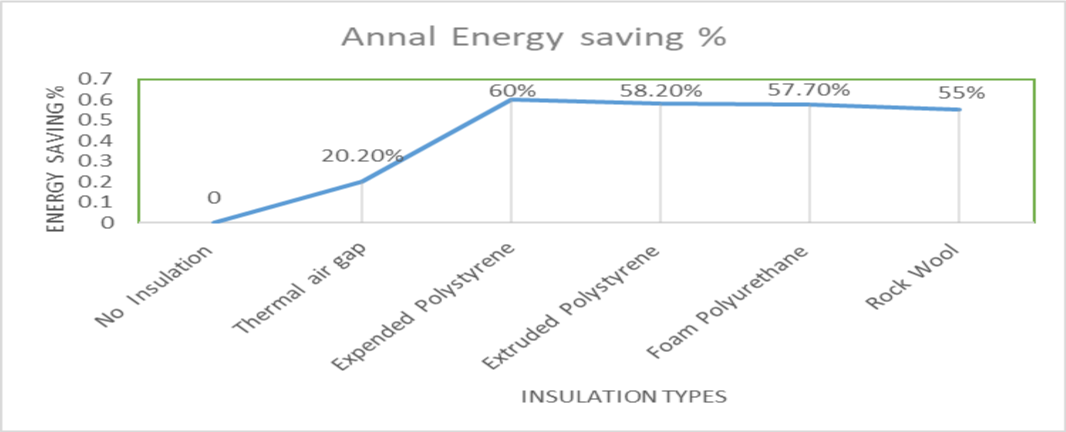


Figure 6.31: Annual energy saving loads % for the insulation material parameters (Jerusalem)

6.3.5 Landscape (Tree Planting)

Initially, a simulation of the building was carried out without the presence of trees. When trees were added to the simulation of the annual consumption of the building (January to December), the great effect of the trees on energy performance in terms of gain and loss was noted. The local climate is an important factor that influences energy consumption (Livingston & Cort, 2011). As a result of cooling and heating hours differentiation in each region, it was found that planting trees may lead to an increase in energy consumption in the site calculations for the city of Jerusalem. This is because it is an area with a moderate climate, so the energy increases for heating or cooling. As can be seen in Figure 6.38, the tree with a small height gave the best results in simulation, as it reduced energy consumption from 136.53 kWh/m^2 to 135.85 kWh/m^2, with an energy conservation rate of 0.5%. If this result is compared with other options of different lengths, it was found that the large height as well as the average height of the tree both gave an increase in energy consumption with values equal to 1.60% and 0.25%, respectively.

Regarding the annual heating and cooling loads, the presence of small-sized trees near the house reduced the consumption of these loads to 118.2 kWh/m^2 with an energy conservation amount equal to 0.6% as shown in Figure (6.39) (6.40), unlike other heights. High Araucaria trees increased energy consumption by 2% with a total load of heating and cooling equal to 121.01 kWh/m^2 and Araucaria trees of medium length by 0**.** 25% with a total load of heating and cooling equal to 119.27 kWh/m^2, so the small size of the tree will be considered in the design of the city of Jerusalem.

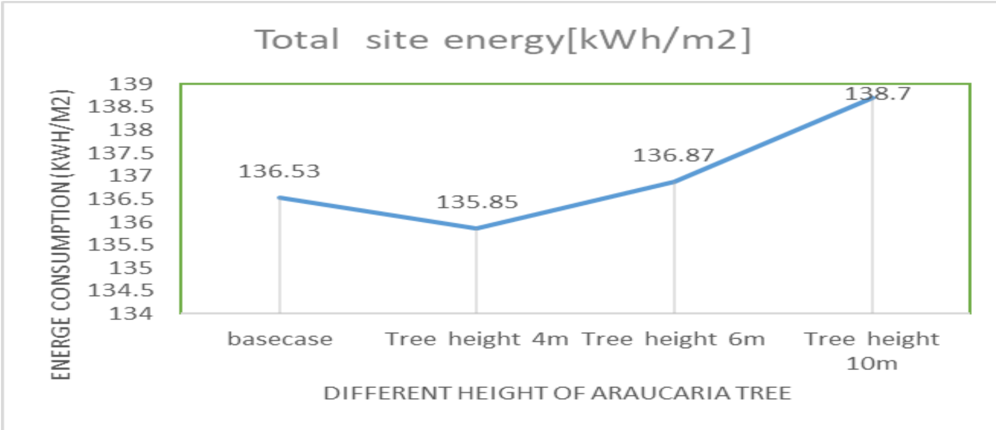
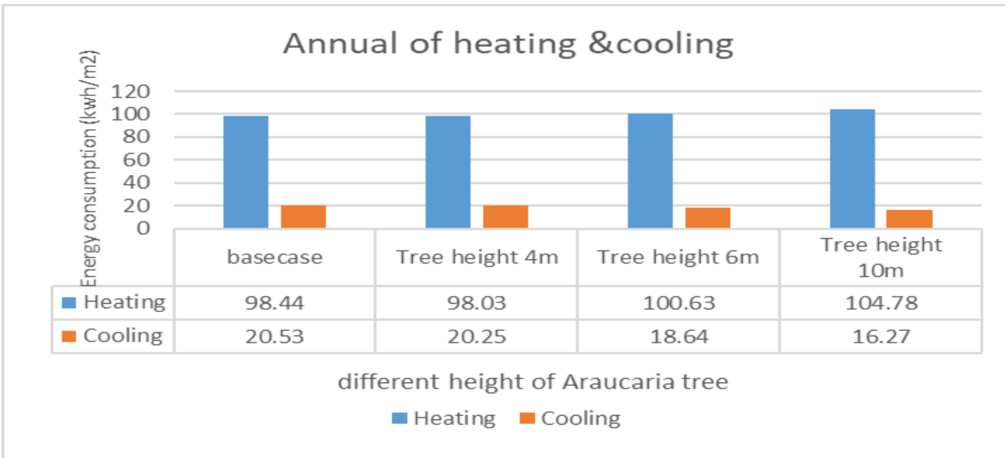


Figure 6.38: Annual site energy consumption (kWh/m^2) for landscape parameters (Jerusalem)



	basecase	Tree height 4m	Tree height 6m	Tree height 10m
Heating	98.44	98.03	100.63	104.78
Cooling	20.53	20.25	18.64	16.27

Figure 6.39: Annual total of heating and cooling loads (kWh/m^2) for landscape parameters (Jerusalem)

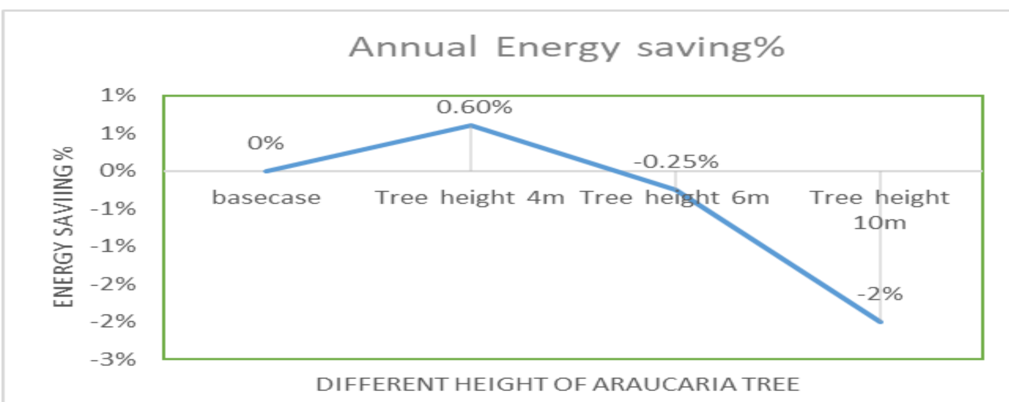


Figure 6.40: Annual Simulation results of energy saving loads % for the landscape parameters (Jerusalem)

6.3.6 Final result for the tested model:

Table 6.4 shows the best parameter values reached by the simulation of the Jerusalem case at the first stage.

Table 6.4: best choices of the passive parameter for the Jerusalem case.

passive parameter	Jerusalem case
Orientation	345
Glazing type	Triple – High Solar Gain - Low E Glass
Shading devices	Overhung 0.5m projection
Insulation Material	Expanded polystyrene
landscape (tree Planting)	Small Araucaria tree 4m in height

A model was made with the values of the new parameters and simulated by the Design-Builder program to determine the amount of change in energy consumption and the final energy conservation resulting from the first stage before moving to the second stage. Table 6.5 shows the difference in annual energy consumption between the base case and the newly tested model.

Table 6.5: Comparative between the base case and the tested model.

Study Case	Total sit energy for base case (kWh/m^2)	Total sit energy for tested model (kWh/m2)	Total of annual heating and cooling for base case (kWh/m2)	Total of annual heating and cooling for tested model (kWh/m2)
Jerusalem	136.56 kWh/m^2	65.04 kWh/m^2	119 kWh/m^2	47.41 kWh/m^2

It was found that the amount of energy consumption on site was reduced by 65.04 kWh/m^2 with energy saving equal to 52% as Figure 6.47 shows. This means that the reduction is approximately half of the total energy. Also, the total heating and cooling loads were reduced from 119 kWh/m^2 to 47.41 kWh/m^2 with energy saving equal to 60% if compared to the basic case Figure (6.47) (6.48).

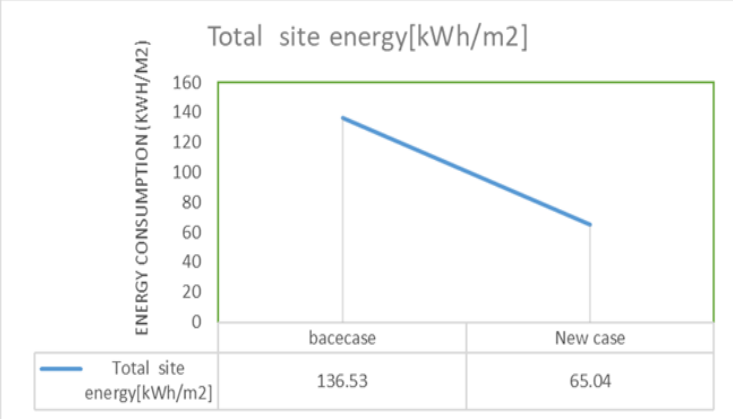


Figure 6.47: Annual simulation results of site energy consumption (kWh/m^2) for final test model (Jerusalem)

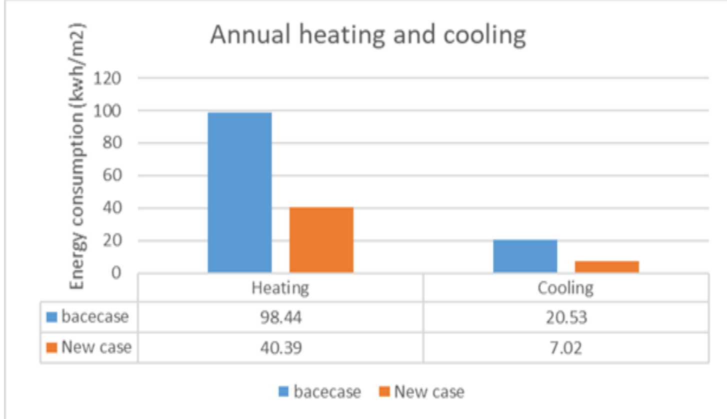


Figure 6.48: Annual simulation results of total heating and cooling loads (kWh/m^2) for the final test model (Jerusalem)

6.3.7 Validation

To validate our results in this stage, it was found that the energy savings that were reached from decreasing the heating and cooling loads equal 60%, which is close to that reached by Albadaineh (2022) in her study titled "Energy-passive residential building design in Amman, Jordan", where the heating and cooling loads in the virtual building were annually decreased from 56.57 kWh/m^2 to 15.25 kWh/m^2, with a savings rate equal 63%. Also, the result obtained is close to the ratio reached by Elgendy & Mekkawi (2015) in their study, where heating and cooling loads were reduced using passive strategies from 9535 kWh/m^2 to 3472.99 kWh/m^2 with a savings rate of 63.5%.

6.4 The second stage:

6.4.1 The way to get a low energy house with RES

Low-energy houses must generate power utilizing renewable energy sources (RES). They depend on transforming the building into a power plant to generate electricity. After getting the optimal model by applying previous passive strategies, it has been noted that the average energy saved equals 60%. Figure 6.53 below shows the way to size the PV needed.

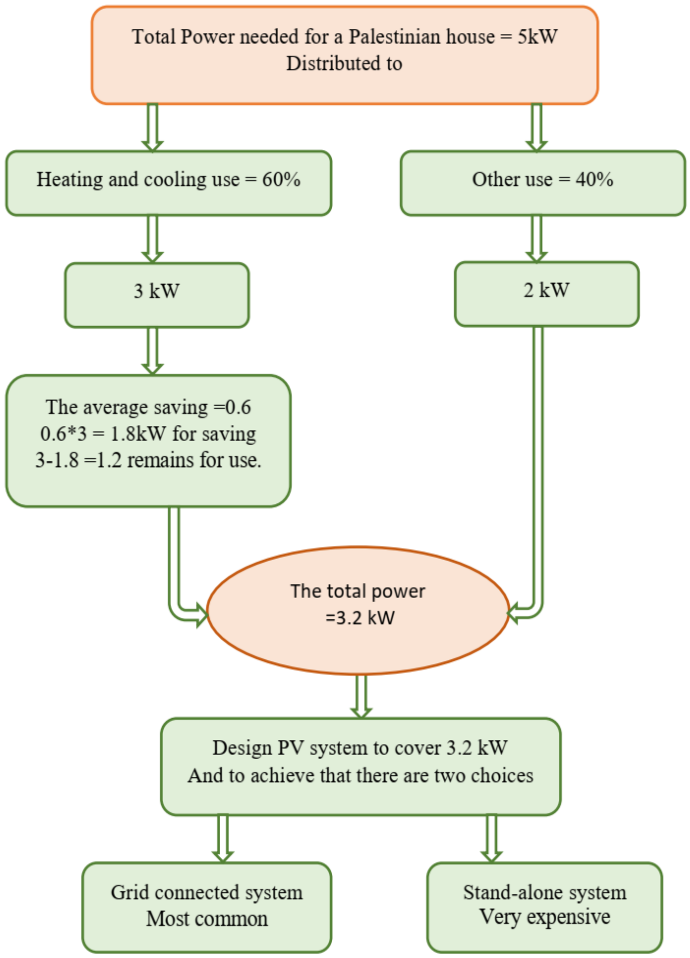


Figure 6.53: the way to get low energy house with RES

In this section ,to cover 3.2 kilowatts, 12 solar panels are used. The area required for a 1 kW Poly-crystalline array is 5.5 m^2. The exact dimensions of the Poly-crystalline unit used are 2.108 m × 1.048 m (length × width). This requires at least 20m^2 of roof space. The cells are installed at an angle of 27 towards the south to obtain the maximum amount of solar radiation.

6.4.2 The RES (PV system) results & discussion

Solar radiation is one of many renewable energy sources available in Palestine. As a result, this section will exclusively analyze the use of Photovoltaic (PV) in energy generation in comparison to the main reference scenario.

In the beginning, the base case model was connected with the solar cell system, and then energy calculations were made to see the impact of the system on it as shown in Figure 6.54. Secondly, the tested model was connected and calculations were made in the same way as shown in Figure 6.55. Finally, the results of the two models were compared to notice the differences in energy.

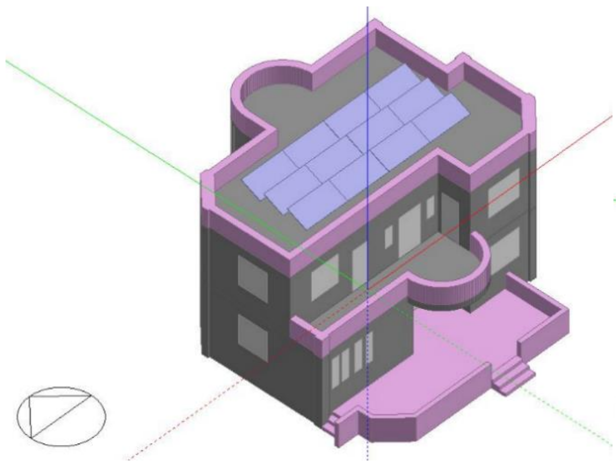


Figure 6.54: The baseline case with PV

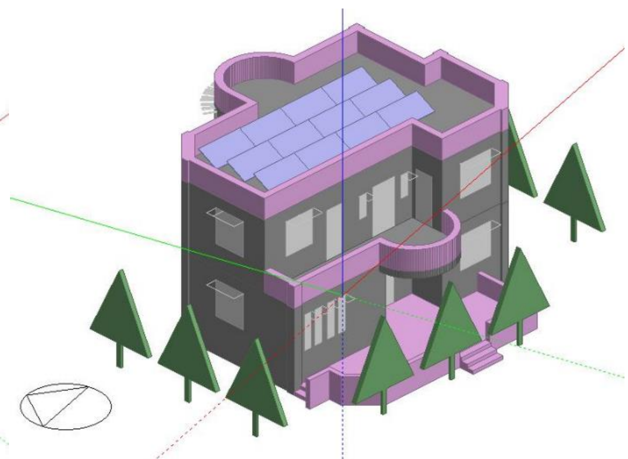


Figure 6.55: The tested model with PV

Generally, when studying energy consumption, the total electricity demands were reduced in the two scenarios, as shown in Figure 6.57. The reference case consumed 19288.58 kWh. While applying scenario 2 (Base case + PV) the total energy consumed in the building was 17449.46 kWh, and in the third Case (tested model + PV) the total energy consumed in the building was 9056.91 kWh as shown in Figure 6.56. Two columns appeared. The blue column represents the total quantity of the building`s electricity demands if the utility is used for supply, as previously determined. While red columns represent the amount of energy generated by photovoltaic models. In truth, DesignBuilder is used to divide the quantity of energy generated on-site into two sections. One is used to afford the building`s electricity needs. Electricity demands would be provided by on-site generating and the remaining needs would be fulfilled by the utility. The other section of the on-site generated energy is the use of surplus energy in the grid. Referring to Figure 6.56, the on-site generated electricity of Base case + PV has covered 37.6% of electricity demands and the tested model + PV has covered 75.4%. On the other hand, Table 6.6 and Figure 6.57 explained that electric loads were provided for the two examined generation cases by the total on-site and utility electric sources. The value was calculated to be 2390.086 kWh per year which correspondent with the total Electricity used in the reference case. Also, the total On-Site electric sources of the investigated cases were estimated as follows:

- Base case + PV has generated 6590.985 kWh which represents 277.76 % of TOSUES.
- tested model + PV has generated 6827.574 kWh which represents 288.34 % of TOSUES.

The Net Electricity from Utility, according to Table 6.6, can be calculated by Equation (6.1):

NEU = TOSUES – TOSES…..…EQ (6.1)

Where,

NEU: Net Electricity from Utility.

TOSUES: Total On-Site and Utility Electric Sources.

TOSES: Total On-Site Electric Sources.

Also, the Surplus Electricity Going to the Utility was calculated briefly in Table 6.7 and Table (appx B.1), Figure 6.57. Surplus Electricity Going to Utility was 6546.79 kWh for Base Case + PV which represents about 275.89 % of TOSUES and it was 6769.557 kWh for tested model + PV which represents about 285.89 % of TOSUES.

The Electricity Coming from Utility has been calculated in Table 6.7 as shown in Equation 6.2

ECU = SEGU –NEU……………………………….………..…...…EQ (6.2)

Where,

ECU: Electricity Coming from Utility.

SEGU: Surplus Electricity Going to Utility.

NEU: Net Electricity from Utility.

Thus, Electricity Coming from the Utility was 2390.086 kWh in the reference case at Jerusalem. It was 2328.747 kWh in Base Case + PV and 2309.839 kWh in tested model + PV.

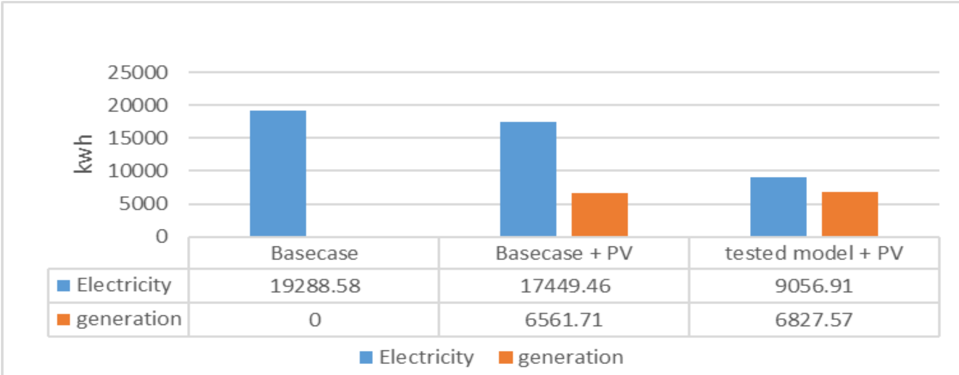


Figure 6.56: PV generation results in Jerusalem Case

Table 6.6: Electric loads satisfied of the examined generation cases in Jerusalem

Electric loads satisfied	Base Case	Base Case + PV	Tested model + PV
Total On-Site Electric Sources	0.00	6590.985	6827.574
Electricity Coming from Utility	2390.086	2328.747	2309.839
Surplus Electricity Going to the Utility	0.00	6546.79	6769.557
Net Electricity from Utility	2390.086	-4218.04	-4459.72
Total On-Site and Utility Electric Sources	2390.086	2372.942	2367.855

The negative sign in the table means that the power is transferred to the grid

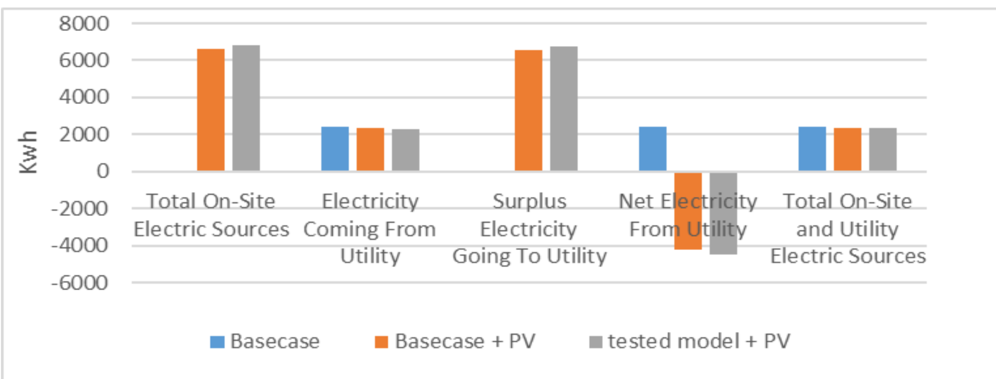


Figure 6.57: Electric loads satisfied of the examined generation cases in Jerusalem

The results showed that the tested model + PV achieved the higher value of on-site electricity generation and followed by the base case + PV. The total site energy and net site energy are shown in Figure 6.58. Total site energy is the total energy consumed on site. Also, net site energy is the net energy consumed on-site “total site fuel consumption minus any on-site generated energy” (DesignBuilder V6).

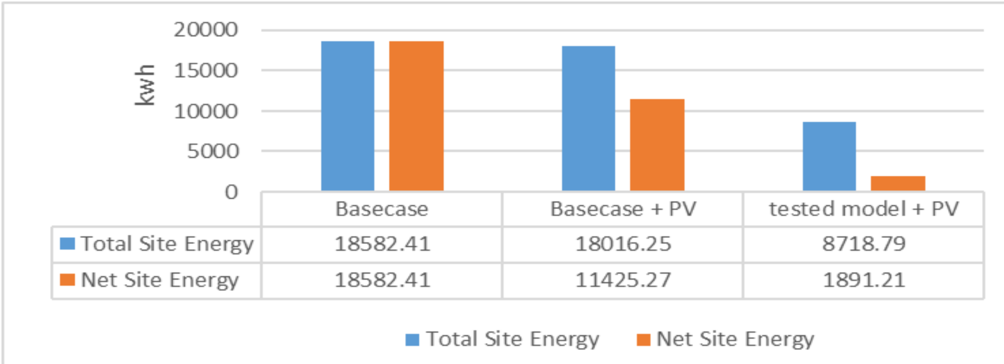


Figure 6.58: Total site energy and net site energy of the examined generation cases in Jerusalem

From figure (6.58) (6.57) it is noted that the tested model with PV case achieves a large amount of on-site energy. It annually produces 6827.574 kWh which accounts for 78% of the total site energy and net site energy was 1891.21 kWh. While in the case of applying base case with PV, net site energy was 11425.27 kWh, and the on-site energy covered about 36% of the total site energy.

6.4.3 Final result for Jerusalem case with RES:

The building in the case of the tested model with PV can save energy by about 90% compared to the base case, so this is considered a new way to save energy in the future. Figure 6.69 shows that the final saving of heating and Cooling Reaches 84%.

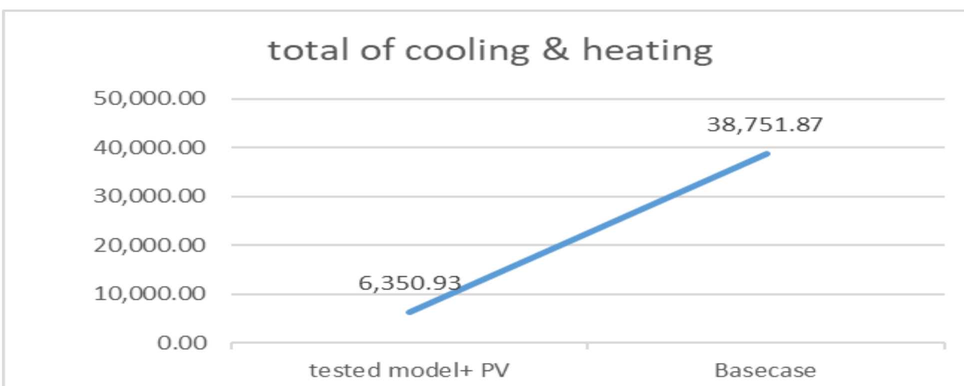


Figure 6.69: The comparative of total heating and cooling between the tested model with PV & Base case in Jerusalem

As shown in figure 6.69, there is a strong negative correlation between the PV system and the total heating and cooling loads, when a PV system is used the total heating and cooling loads reduce until it reaches 16% of the total before using the PV system.

6.4.4 Validation:

Many researchers have verified and validated the DesignBuilder software such as Khakian et al (2020), to be assured of the reliability of our results, a two-story residential building located in the mountains village of Palangan in Iran was selected and simulated using DesignBuilder. The findings indicated that an energy saving of 29% can be achieved compared to conventional buildings, and over 22 MWh of electricity can be produced annually.

Also, the previous case studies in chapter 4 validate the reduction of energy consumption when both passive and active techniques were used in a building; Leaf House, Lima House, and Villa Magri achieved good results in terms of energy consumption due to using a combination of passive techniques and RES system.

6.5 Conclusion

This chapter has covered how to obtain a low-energy house in Jerusalem, Palestine (two similar studies of Jericho and Gaza were added to appendix C due to a lack of accurate weather data for these two cities). The city of Jerusalem represents the mountainous areas. By testing various passive strategies (Orientation, glazing type, insulation materials, landscaping, and shading devices), determining the best options for each strategy, and then connecting it to the solar cell system using DesignBuilder.

Through the results, the importance of investigating design requirements before starting the implementation process was clarified, as each of the strategies demonstrated its importance in reducing annual heating and cooling loads. Also, integrating these strategies with the solar system is one of the best ways to attain a low-energy house design.

In this study, the impact of the use of passive design strategies and the solar cell system on the thermal aspect of the building in terms of energy consumption was addressed. This effect is not limited to this aspect, as there are other aspects such as privacy and visual comfort. These aspects combined are among the basic needs for home design. This includes the following :

Passive design strategies:

- Orientation: The building`s orientation affects other strategies like shading devices, glazing type, and color. It also determines the amount of received solar radiation. During winter, the south façade is the source of passive heating in winter and natural daylight, but in summer the heat gain should be controlled by the use of shading devices, tree planting, and the type of glass. From the visual aspect, orientation and daylighting are very much linked. Good orientation will provide adequate daylight without glare or excessive solar gain, designing to a suitable orientation is limited by roads and urban design context.
- Glazing type: The type of glass influences the visual communication between indoors and outdoors, the shape of the building, and the privacy of the habitants. The color of the glass is also important as it affects the shape of the building and the quantity of daylight entering the building. The glazing type should be consistent with the shading devices as they both control the daylight and privacy in the building. The big size of windows causes problems in privacy and thermal comfort, as windows are weak points in the thermal insulation system. Finally, high-performance glass requires high capital cost, and the window-to-wall ratio affects shading and thermal insulation and is affected by orientation and landscaping.
- Shading devices: There is a strong relation between shading devices and glazing type; any change in one of them affects the performance of the other. As previously mentioned, composite shading devices provide more privacy than vertical or horizontal ones, and this requires being careful in determining the color and type of glass to allow more daylight to enter the space. Also, it is affected by the building`s orientation and the seasonal changing angle of the sun. It controls the amount of daylight entering the building to avoid discomfort glare. This effect is greater in the Composite types of these devices other than the horizontal or vertical. Alzoubi (2010) mentioned that vertical elements providing shading have the advantage of not obstructing the outdoor view and at the same time providing appropriate shading, which enriches the benefits of the device. In conclusion, balance is needed between blocking direct solar gain in summer and solar heat gain`s benefits in winter, also designers should consider practical issues such as window washing in the design.

- Insulation material: Good insulation with a suitable thickness prevents external noise from reaching the inner space of a building, and it provides privacy for the habitants due to sound insulation. It reduces heat transfer which affects the space temperature. It is largely affected by the window-to-wall ratio. The thermal bridging should be reduced to achieve the efficiency of the insulation on energy performance. Economically, Good insulation is very expensive but it gives good returns in thermal comfort in the long term.
- Landscape (tree planting): It can help in reducing the temperature around the building, thus reducing the cooling load. trees provide cooling shades in the summer which assists mechanical ventilation and a pre-cooling system, and in winter its leaves fall which allows the warm sun to enter the building and facilitate passive heating. Also, it helps to control daylighting through windows and reduces glare. Trees, in addition, provide privacy for the habitants of the building and indicates that the building is private, not public. But the landscape is limited by the available space, and it requires maintenance and irrigation.

<u>Solar cell system:</u>

- PV: The solar system clarified its effect on energy reduction and generation when it is linked with passive design strategies. Its impact does not stop at this limit but also includes several aspects represented in the aesthetic aspect of the building, so it has been found that the external shape of the building is affected, especially the roof on which the solar cells will be placed. Here, it is taken into account that the design of the external surface is compatible with the surrounding buildings, so the effect will be positive from the visual aspect.

Chapter 7 Conclusion and Recommendations

7.1 Introduction:

This chapter is a conclusion to the study results that have been found through the case studies and the analytical part using the DesignBuilder simulation tool. This study investigates the influence of several factors such as orientation, thermal insulation, shading devices, glazing types, and landscaping (tree planting) on the energy performance of a two-story house in Jerusalem as a case study (Jericho and Gaza in appendix C). After that, the building is equipped with PV modules, and this chapter can be considered the outcome of the research technique mentioned above. Finally, recommendations are presented in light of these results to decision-makers, architects, and owners for achieving low-energy house strategies in Palestine.

7.2 Findings:

The results of the simulation process showed what strategies to be followed in terms of building orientation, glazing type, shading devices, insulation materials, and tree planting, then integrate them with PV systems for the three tested models: Jerusalem as a main case, Jericho and Gaza as additional case for more information (see appendix C).

The following is a brief calculation of the findings:

- **The First stage:**

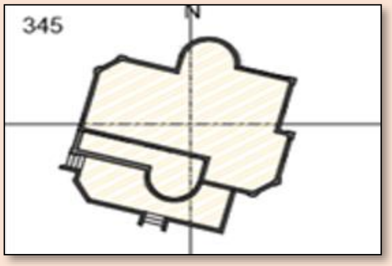
1. <u>Orientation</u>:

Orientation has a major role in energy conservation. In this study, the orientation was imposed for the reference situation along the east-west axis, but with a slight deflection of the angle by 15 degrees, so that the largest facade is facing south. The worst orientation degree was 225 with a loss rate of up to (3%-8%) as shown in table 7.1(For more information about Jericho and Gaza see appendix C).

Table 7.1: the concluded result of the orientation simulation in all scenarios

Cases	Jerusalem
Best orientation degree	345
Worst orientation degree	225
Lowest Energy consumption annually (kWh/m²)	135.82
Highest Energy consumption annually (kWh/m²)	141.05
Lowest Heating and cooling annually(kWh/m²)	118.26
Highest Heating and cooling annually(kWh/m²)	123.58
Energy saving annually (%)	0.5%
The amount of increase in energy consumption (%)	-3.30%

Jerusalem



2. Glazing types:

The type of glass has a significant impact on annual energy consumption. As shown in Table 7.2. Each region is different in the type of glass chosen to achieve the goal. Triple-high Solar Gain - Low E Glass was the best in Jerusalem. (For more information about Jericho and Gaza see appendix C).

Table 7.2: the concluded result of the glazing types simulation in all scenarios

Cases	Jerusalem
Best glazing type	Triple – High Solar Gain - Low E Glass
Worst glazing type	Reflective – double glass
Lowest Energy consumption annually (kWh/m²)	135.55
Highest Energy consumption annually (kWh/m²)	142.65
Lowest Heating and cooling annually(kWh/m²)	117.97
Highest Heating and cooling annually(kWh/m²)	124.33
Energy saving annually (%)	0.7%
The amount of increase in energy consumption (%)	-4.5%

3. <u>Shading devices:</u>

As for shading devices, they differed from one region to another. The best thing in Jerusalem was an overhang with a projection of 0.5 m, reducing heating and cooling loads by up to 15%.

Table 7.2: the concluded result of the shading devices simulation in all scenarios

Cases	**Jerusalem**
Best shading devices type	0.5m projection of overhang
Worst shading devices type	1m projection of OHs, SFs, and LOs
Lowest Energy consumption annually (kWh/m^2)	136.5
Highest Energy consumption annually (kWh/m^2)	144.23
Lowest Heating and cooling annually(kWh/m^2)	118.95
Highest Heating and cooling annually(kWh/m^2)	139.5
Energy saving annually(%)	16.3%
The amount of increase in energy consumption (%)	-
Jerusalem	

4. <u>Insulating materials</u>

Insulating materials of all kinds were characterized by a significant reduction in annual energy consumption, and the best option was Expanded Polystyrene, at a rate of up to 54%.

Table 7.3: the concluded result of the insulating materials simulation in Jerusalem

Cases	**Jerusalem**
Best insulating materials type	Expanded Polystyrene
Worst insulating materials type	Thermal air gap
Lowest Energy consumption annually (kWh/m^2)	65.43
Highest Energy consumption annually (kWh/m^2)	112.43
Lowest Heating and cooling annually(kWh/m^2)	47.91
Highest Heating and cooling annually(kWh/m^2)	94.92
Energy saving annually (%)	60%
The amount of increase in energy consumption (%)	-

5. <u>landscape (tree Planting)</u>

Planting trees around the building is important in terms of energy consumption, as it reduces the consumption rate of heating and cooling by up to 2%. Trees of 4m in height gave the best results with the lowest annual energy consumption 135.58 kWh/m^2. Also, the landscape design has a strong positive effect on the buildings' shape and use.

Table 7.4: the concluded result of the tree simulation in all scenarios

Cases	**Jerusalem**
The best height for the tree	4m
Worst height for the tree	10m
Lowest Energy consumption annually (kWh/m^2)	135.58
Highest Energy consumption annually (kWh/m^2)	138.7
Lowest Heating and cooling annually(kWh/m^2)	118.28
Highest Heating and cooling annually(kWh/m^2)	121.05
Energy saving annually (%)	0.6%
The amount of increase in energy consumption (%)	-2%

The conclusion of the first stage calculations:

The application of the best strategies in each region and obtaining the tested models worked to reduce the annual energy consumption on the site by more than half in Jerusalem (and the same for Jericho and Gaza as shown in appendix C), as the reduction rate reached 52% in general and about 60% for heating and cooling loads in particular.

Table 7.5: the concluded result of the tested model's simulation in all scenarios

Cases	**Jerusalem**
Total sit energy for test model (kWh/m2)	65.04
Total of annual heating and cooling for tested models (kWh/m2)	47.41
Energy saving annually (%)	52%

- **The second stage**

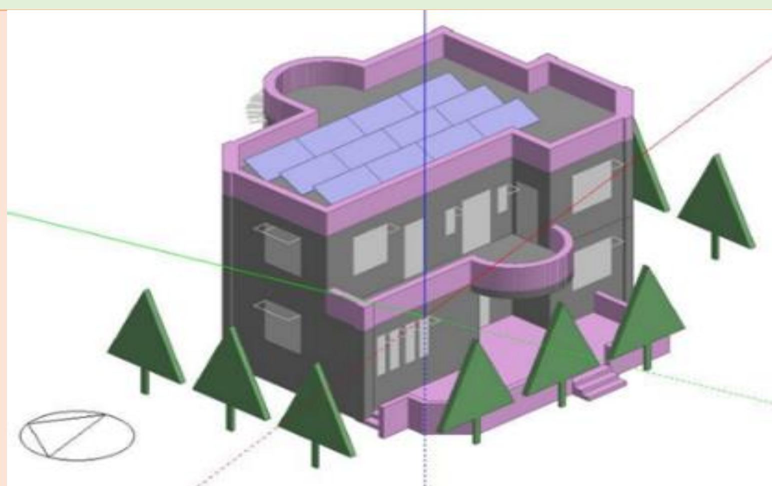
The use of a photovoltaic system works to cover the building's electricity needs through what is generated on the site, after connecting it to the tested models for each region. Where the system connected to the network was used as it is better in terms of maintenance and costs.

The installation of a PV system should be taken into consideration in the building`s design and the area needed on the roof of a building should be initially accounted for.

Table 7.6: the concluded result of the tested models with PV in all scenarios

Cases	**Jerusalem**
PV generation (kWh)	6827.574
The amount of covered electricity demand	75.4%
Total of annual heating and cooling for tested model +PV (kWh)	6350.93
annual Energy saving of heating and cooling (%)	83%

Jerusalem



7.3 Recommendations:

The recommendations are intended to serve as strategies for achieving low-energy principles in residential buildings. These recommendations were divided into two phases. It is recommended to consider the region's climate characteristics in the designing process as every climate region requires making specific procedures to successfully establish a low-energy house. The first phase includes the passive design to reduce the heating and cooling loads and take into consideration some important determinants like the climate zone. The passive strategies include the following:

1. It is recommended to orient the building at 345° when the long side of the building is on the east-west axis with a slight deflection in Jerusalem, 225° for Jericho, and 240° for Gaza.
2. Triple - high Solar Gain - Low E Glass is recommended for Jerusalem and Reflective - double glass is recommended for Jericho and Gaza, and carefully choose its color as it has a great role in determining the quantity of daylight entering the building.
3. The best recommended shading device in Jerusalem was overhang with a projection of 0.5 m. The Combinations of OHs, SFs, and LOs with 1m projection were the best in Jericho city. As for Gaza City, the Combinations of OHs, and SFs with 1m projection were the best. Visual, practical, and privacy issues should be considered in this strategy.
4. Insulation materials are very recommended for walls and roofs. Expanded Polystyrene is recommended in Jerusalem, Jericho, and Gaza. The thicker the insulation material, the more effective it is in saving energy. It can reduce about half of the energy consumed for heating and cooling.
5. Small Araucaria trees 4m in height are recommended to surround residential buildings in Jerusalem, and big Araucaria trees 10m in height are recommended in Jericho and Gaza.

The second phase includes integrating the passive techniques with the RES system to produce energy. This phase includes the following:

1. PV installation is the recommended renewable source of energy in Palestine, as it is the less expensive source and can be easily maintained.
2. The cells are recommended to be installed at an angle of 27 towards the south to obtain the maximum amount of solar radiation.

3. Installing the PV cells requires at least $20m^2$ of roof space with 12 panels at least to get 60-84 % of energy saving.

7.4 Limitations:

The previously mentioned strategies assumed their capacity in saving energy, but there are some limitations for this study, such as the following:

1. It should be recognized the results of this study are limited to the houses only with the materials typically used in the residential construction sector in Palestine.
2. The passive strategies studied in this research are not the only ones affecting strategies on energy performance, and if other additional strategies were studied such as natural ventilation, there would be different results in energy consumption.
3. This study focused on the thermal efficiency of the strategies, and there are more factors to be studied for every strategy such as visual comfort especially daylight and privacy. These factors can be studied in future studies.
4. The PV system is studied in this research as it is most common in Palestine. Other RES systems can be studied in the future.

7.5 Recommendations for future research:

Furthermore, it is recommended for future researchers extend their studies in this field as there are many topics to cover such as:

1. Geothermal technology and its impact on the energy performance of homes.
2. Advanced building materials such as phase change materials and their role in improving energy performance.
3. Simulating strategies and investigating the energy performance of multi-story residential buildings.
4. Simulation of walls with different compositions and arrangement of materials to obtain the best installation in terms of reducing energy consumption.

الله ولي التوفيق

﴿تم بحمد الله﴾

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Appendixes

Appendix A

Table A.1: Most Common Envelope Components and their Material Arrangement in Palestine. Source: Guidelines for Energy Efficient Building Design (Chapter 6) – Ministry of Local Government (Ministry of Local Government, 2004)

Layers	**Density Kg/m3**	**Specific heat J/kg. K**	**Thermal conductivity W/m. K**	**Thickness m**	**U value**
Walls					
Stone	2250	1000	1.70	0.05	3.2
Concrete	2300	1000	1.75	0.20	
Roofs					
Plaster	2000	1000	1.20	0.03	2.8
Reinforced Concrete Layer	2500	1000	1.75	0.26	
Inclined concrete layer	2300	1000	1.75	0.07	
Rainwater insulation	2300	1000	1.10	0.03	
Floors					
Porcelain Tiles	1900	1000	1.05	0.02	1.17
Sand	1750	1000	0.42	0.15	
Reinforced concrete	2500	1000	1.75	0.26	
Plaster	2000	1000	1.20	0.02	

Appendix B

Table B.1: Electric loads satisfied of the examined cases in Jerusalem

Electric loads satisfied	Baseline Case		Baseline Case + PV		Optimal + PV	
	Electricity [kWh]	Percent Electricity [%]	Electricity [kWh]	Percent Electricity [%]	Electricity [kWh]	Percent Electricity [%]
Photovoltaic Power	0.00	0.00	6937.879	292.37	7186.920	303.52
Power Conversion	0.00	0.00	-346.89	-14.6	-359.35	-15.2
Total On-Site Electric Sources	0.00	0.00	6590.985	277.76	6827.574	288.34
Electricity Coming from Utility	2390.086	100.00	2328.747	98.14	2309.839	97.55
Surplus Electricity Going to Utility	0.00	0.00	6546.79	275.89	6769.557	285.89
Net Electricity from Utility	2390.086	100.00	-4218.04	-177.8	-4459.72	-188.3
Total On-Site and Utility Electric Sources	2390.086	100.00	2372.942	100.00	2367.855	100.00
Total Electricity End Uses	2390.086	100.00	2372.942	100.00	2367.855	100.00

Table B.2: Electric loads satisfied of the examined cases in Jericho

Electric loads satisfied	Baseline Case		Baseline Case + PV		Optimal + PV	
	Electricity [kWh]	Percent Electricity [%]	Electricity [kWh]	Percent Electricity [%]	Electricity [kWh]	Percent Electricity [%]
Photovoltaic Power	0.00	0.00	6868.519	272.33	7012.828	280.49
Power Conversion	0.00	0.00	-343.43	-13.6	-350.64	-14.0
Total On-Site Electric Sources	0	0.00	6525.093	258.71	6662.187	266.47
Electricity Coming from Utility	2509.05	100.00	2516.589	99.78	2494.563	99.77
Surplus Electricity Going to Utility	0	0.00	6519.559	258.49	6656.54	266.24
Net Electricity from Utility	2509.05	100.00	-4002.97	-158.7	-4161.98	-166.5
Total On-Site and Utility Electric Sources	2509.05	100.00	2522.123	100.00	2500.209	100.00
Total Electricity End Uses	2509.05	100.00	2522.123	100.00	2500.209	100.00

Table B.3: Electric loads satisfied of the examined cases in Gaza

Electric loads satisfied	Baseline Case		Baseline Case + PV		Optimal + PV	
	Electricity [kWh]	Percent Electricity [%]	Electricity [kWh]	Percent Electricity [%]	Electricity [kWh]	Percent Electricity [%]
Photovoltaic Power	0.00	0.00	6071.191	238.39	6331.195	253.22
Power Conversion	0.00	0.00	-303.56	-11.9	-316.56	-12.7
Total On-Site Electric Sources	0.00	0.00	5767.631	226.47	6662.187	240.56
Electricity Coming from Utility	2533.574	100.00	2546.785	100.00	2494.563	100.00
Surplus Electricity Going to Utility	0.00	0.00	5767.631	226.47	6656.54	240.56
Net Electricity from Utility	2533.574	100.00	-3220.85	-126.5	-4161.98	-140.6
Total On-Site and Utility Electric Sources	2533.574	100.00	2546.785	100.00	2500.209	100.00
Total Electricity End Uses	2533.574	100.00	2546.785	100.00	2500.209	100.00

Appendix C

Table C.1: Physical Characteristics of the case study and Climate selected zones Characteristics.

Climate-specific characteristics		
City	Jericho	Gaza
Latitude and Longitude	31.87°-35.45°	31.5°-34.47°
Altitude	-300 M	5 M
Temperature Average Min(°C)	11 °C	14 °C
Temperature Average Max(°C)	31 °C	28 °C
ASHRAE Zone	3A	3A
Physical Characteristics		
Building configuration	200 m^2 (floor with 120 m^2 & roof with 80 m^2) ، single-family	
Floor Height	3.00 meter	
Number of floors	two-floors (floor &roof)	
Glazing type	clear double glazed-6mm	
Window to wall%	30%	
Construction method		
Exterior walls	5cm Stone 15cm Concrete 7cm Blocks **U-Value =2.645 w/m^2-k** 2 cm Plaster	
Roof	Roof Construction method 26 cm Concrete slab **U-Value = 2.684 w/m^2-k** Asphalt layer	
Floor Construction	26cm reinforced concrete 15cm Sand and cement mortar **U-Value = 1.334 w/m^2-k** 2-3 cm thick Tile	
Finishing Materials		
Floor	Porcelain tiles	
Internal Partitions	Painted 10cm Block	

First Stage Result

- Orientation result & discussion

In Jericho, the simulation was carried out by using Beersheba weather data which has nearly the same weather as Jericho on the Design-Builder program, and in Gaza, the simulation was carried out by using Al Arish weather data. The results were as follows:

Jericho:

The lowest annual total consumption on the site was 135.36 kWh/m^2 as suggested in the base case (along the east-west axis) as shown in Figure C.1, and the lowest total heating and cooling loads were 116.92 kWh/m^2 with the same building orientation represented by the green column.

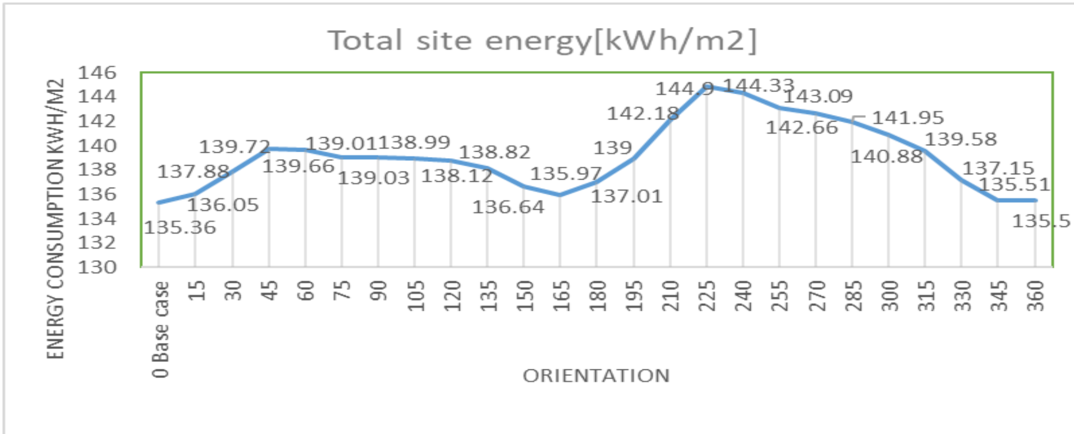


Figure C.1**:** Annual site energy consumption (kWh/m^2) for the Orientation parameters (Jericho)

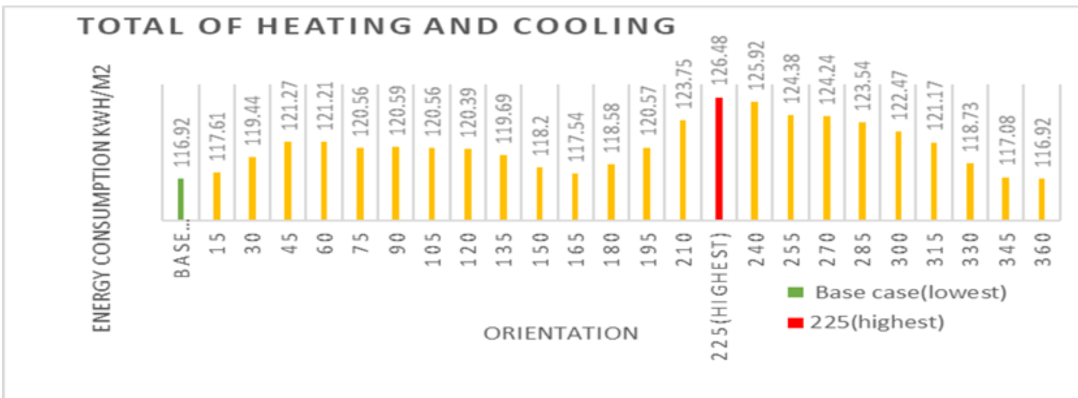


Figure C.2: Annual total heating and cooling loads (kWh/m^2) for the Orientation parameters (Jericho)

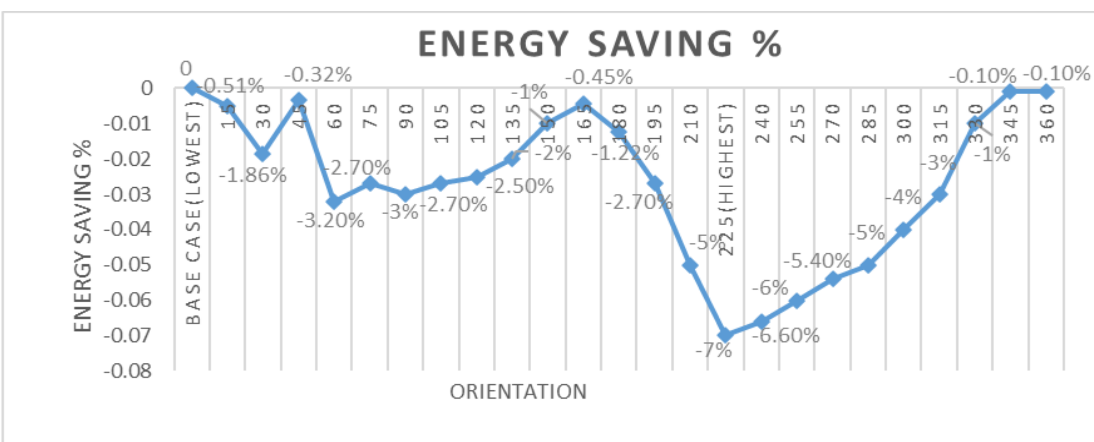


Figure C.3: Annual energy saving % for the Orientation parameters (Jericho)

Table C.2: Simulation results of the orientation on total site energy, annual heating, cooling loads and annual energy saving for Jericho city.

Case/Angle	***Total sit energy (kWh/m²)***	***Heating (kWh/m²)***	***Cooling (kWh/m²)***	***Energy saving%***
Baseline-case 0	135.36	52.73	64.19	-
15	136.05	53.24	64.37	-0.51%
30	137.88	53.81	65.63	-1.86%
45	139.72	54.06	67.21	-0.32%
60	139.66	53.68	67.53	-3.20%
75	139.01	53.28	67.28	-2.70%
90	139.03	53.26	67.33	-3%
105	138.99	53.23	67.33	-2.70%
120	138.82	53.21	67.18	-2.50%
135	138.12	53.04	66.65	2%
150	136.64	52.69	65.51	-1%
165	135.97	52.55	64.99	-0.45%
180	137.01	52.97	65.61	-1.22%
195	139	53.4	67.17	-2.70%
210	142.18	54	69.75	-5%
225	144.9	54.21	72.27	-7%
240	144.33	53.55	72.37	-6.60%
255	143.09	52.91	71.76	-6%
270	142.66	52.77	71.47	-5.40%
285	141.95	52.63	70.91	-5%
300	140.88	52.68	69.79	-4%
315	139.58	52.71	68.46	-3%
330	139.58	52.71	68.46	-1%
345	135.51	52.24	64.84	-0.10%
360	135.36	52.73	64.19	-

Best value of the orientation in this case **Worst value of the orientation in this case.**

1. <u>Gaza</u>:

The lowest annual total consumption of the site was 118.57 kWh/m^2 as suggested in the base case (along the east-west axis) as shown in Figure C.4, and the lowest total for heating and cooling loads was equal to 99.95 kWh/m^2 as appeared in the red column.

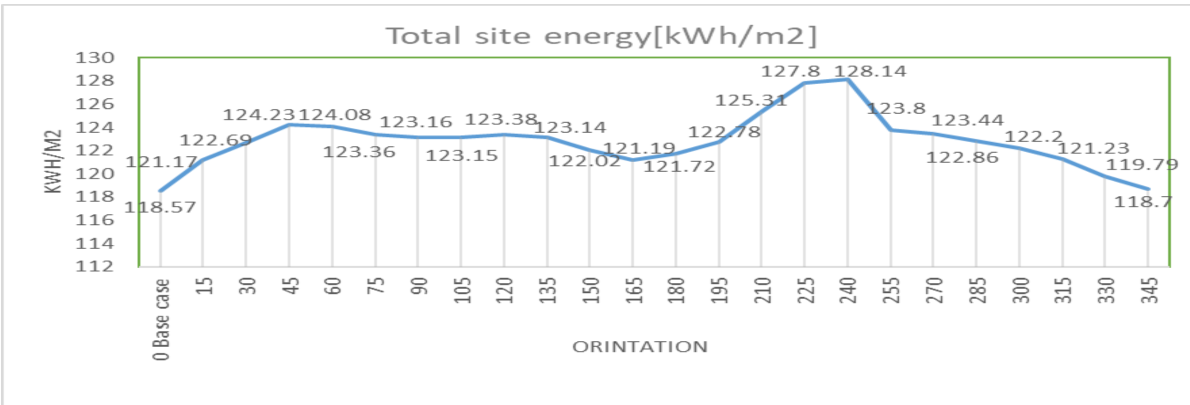


Figure (C.4): Annual site energy consumption (kWh/m^2) for the Orientation parameters (Gaza)

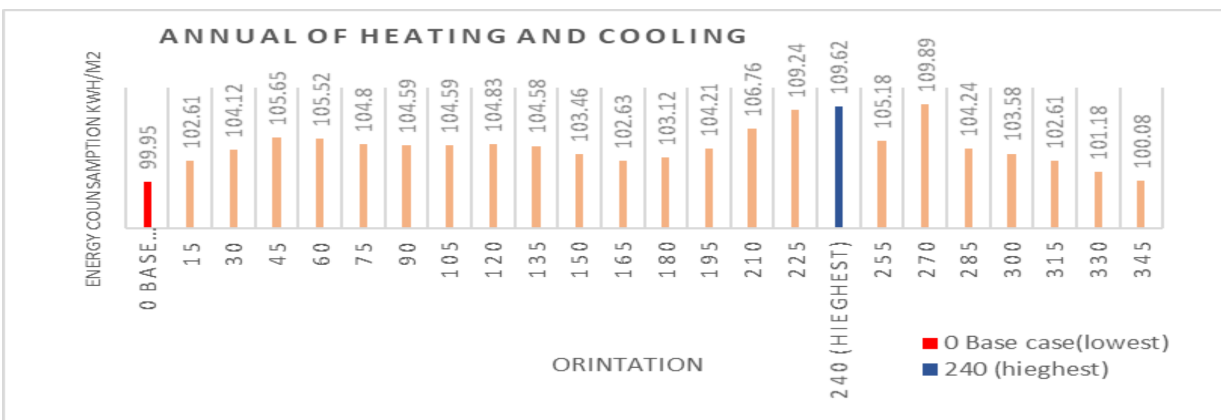


Figure C.5: Annual total heating and cooling loads (kWh/m^2) for the Orientation parameters (Gaza)

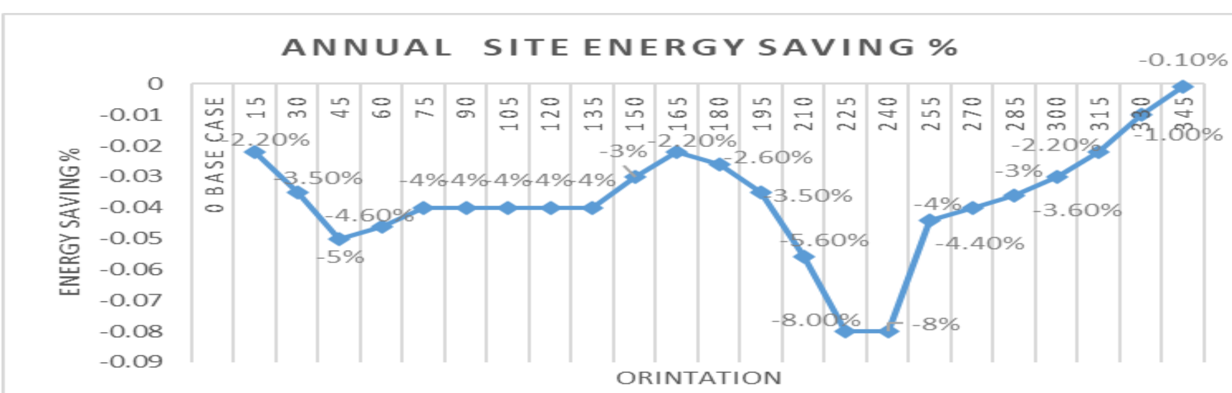


Figure C.6: Annual Simulation results in energy saving % for the Orientation parameters (Gaza)

Table C.3: Simulation results of the orientation on total sit energy, annual heating, Cooling loads, and annual energy saving for Gaza city.

Case/Angle	*Total sit energy (kWh/m²)*	*Heating (kWh/m²)*	*Cooling (kWh/m²)*	*Energy saving%*
Baseline-case 0	118.57	31.38	68.57	-
15	121.17	49.4	53.21	-2.20%
30	122.69	49.9	54.22	-3.50%
45	124.23	50.27	55.38	-5%
60	124.08	55.44	50.08	-4.60%
7	123.36	49.75	55.05	-4%
90	123.16	49.65	54.94	-4%
105	123.15	49.68	54.91	-4%
120	123.38	49.76	55.07	-4%
135	123.14	49.75	54.83	-4%
150	122.02	49.47	53.99	-3%
165	121.19	49.25	53.38	-2.20%
180	121.72	49.39	53.76	-2.60%
195	122.78	49.63	54.58	-3.50%
210	125.31	50.1	56.66	-5.60%
225	127.8	50.42	58.82	-8.00%
240	128.14	50.13	59.49	-8%
255	123.8	32.2	72.98	-4.40%
270	123.44	32.1	72.72	-4%
285	122.86	31.87	72.37	-3.60%
300	122.2	31.73	71.85	-3%
315	121.23	31.57	71.04	-2.20%
330	119.79	31.21	69.97	-1.00%
345	118.7	30.96	69.12	-0.10%
360	118.57	31.38	68.57	-

Best value of the orientation in this case **Worst value of the orientation in this case.**

- Glazing Type:

1. <u>Jericho</u>:

According to the simulation results shown in Figure C.7, the Reflective - double glass reduced the total net site energy to 131.73 kWh/m^2 with an energy saving of 2.7%, and gives the lowest total heating and cooling loads equal to 113.14 kWh/m^2 with energy savings equal to 3.2%

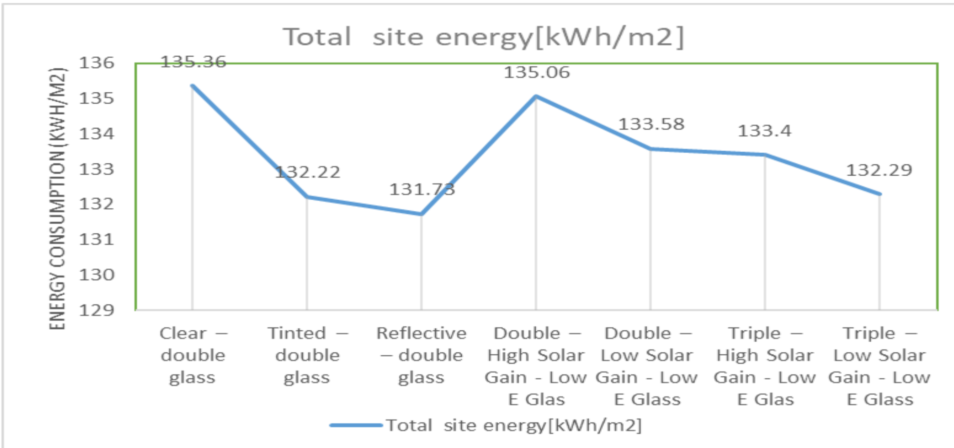
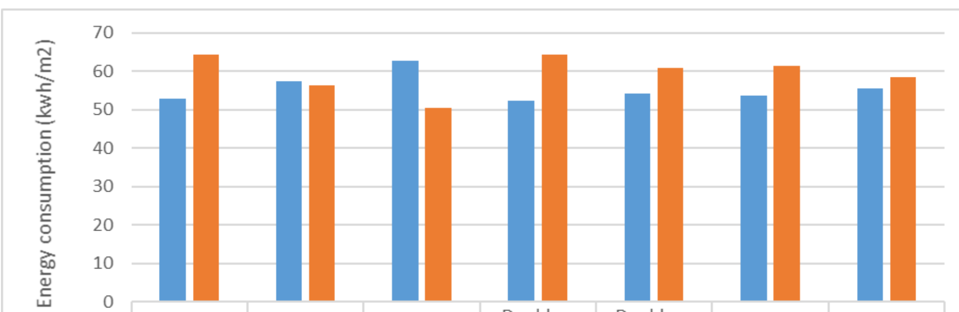


Figure C.7: Annual total site energy consumption (kWh/m^2) for the glazing type parameters (Jericho)



	Clear – double glass	Tinted – double glass	Reflective – double glass	Double – High Solar Gain - Low E Glas	Double – Low Solar Gain - Low E Glass	Triple – High Solar Gain - Low E Glas	Triple – Low Solar Gain - Low E Glass
Heating	52.73	57.38	62.67	52.36	54.21	53.65	55.39
Cooling	64.19	56.34	50.47	64.26	60.92	61.31	58.45

Figure C.8: Annual total heating and cooling loads (kWh/m^2) for the glazing type parameters (Jericho)

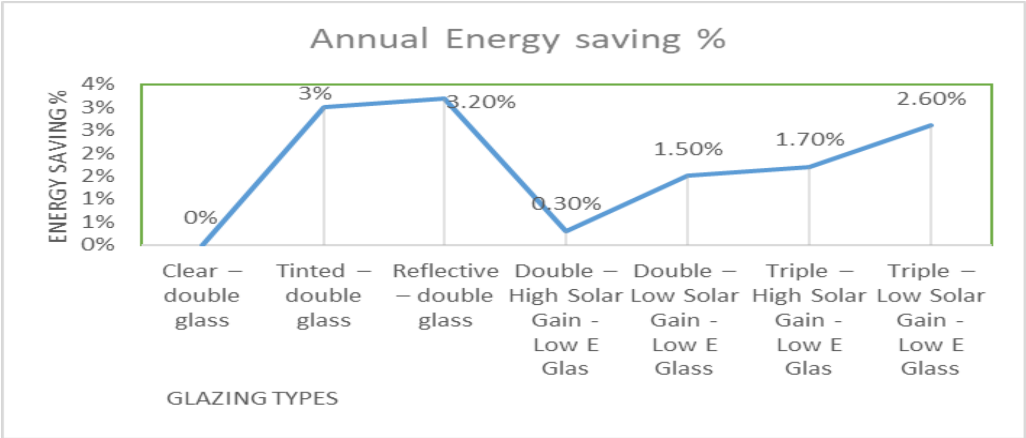


Figure C.9: Annual Simulation results of energy saving loads % for the glazing type parameters (Jericho)

2. Gaza:

According to the simulation results shown in Figure C.10, Reflective – double glass reduced total net site energy up to 113.83 kWh/m^2 with an energy saving of 4% and can be considered for the design, and Reflective - double glass gives the lowest total heating and cooling loads equal to 95.21 kWh/m^2 with energy savings equal to 5%

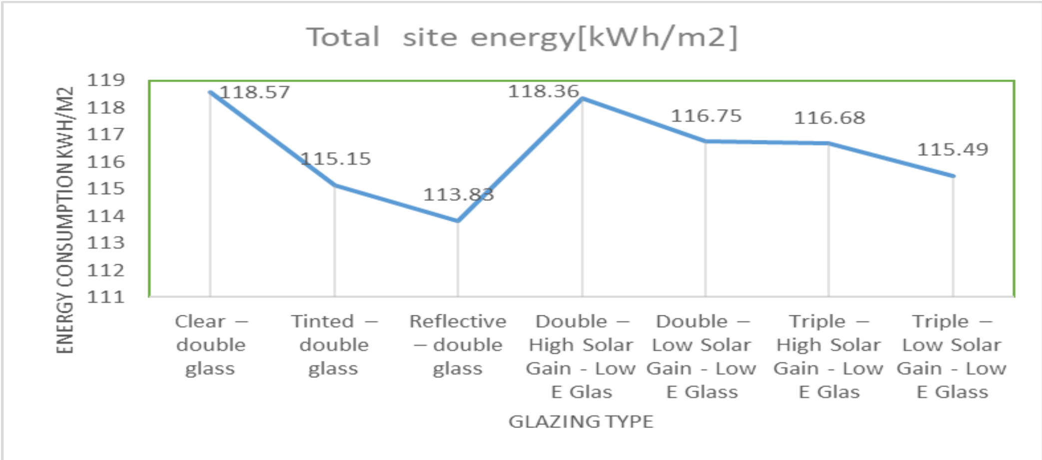


Figure C.10: Annual total site energy consumption (kWh/m2) for the glazing type parameters (Gaza)

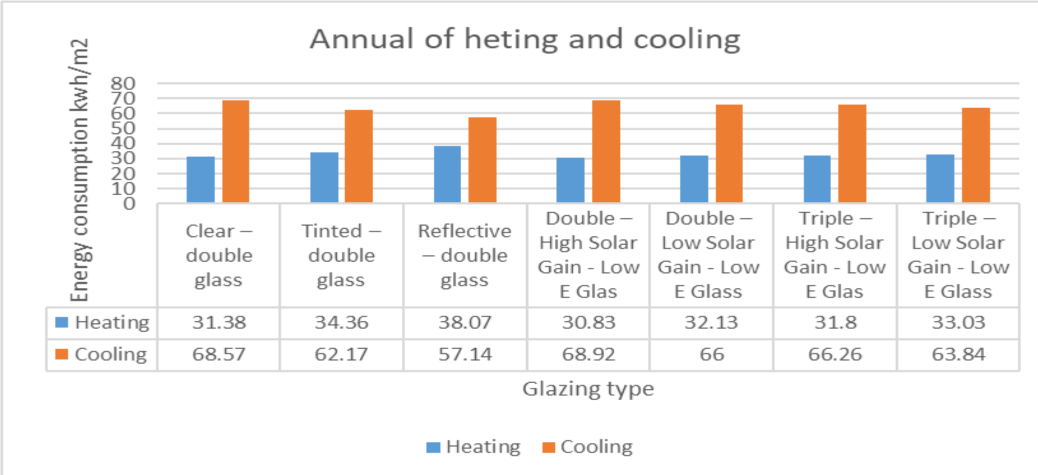


Figure C.11: Annual total heating and cooling loads (kWh/M^2) for the glazing type parameters (Gaza)

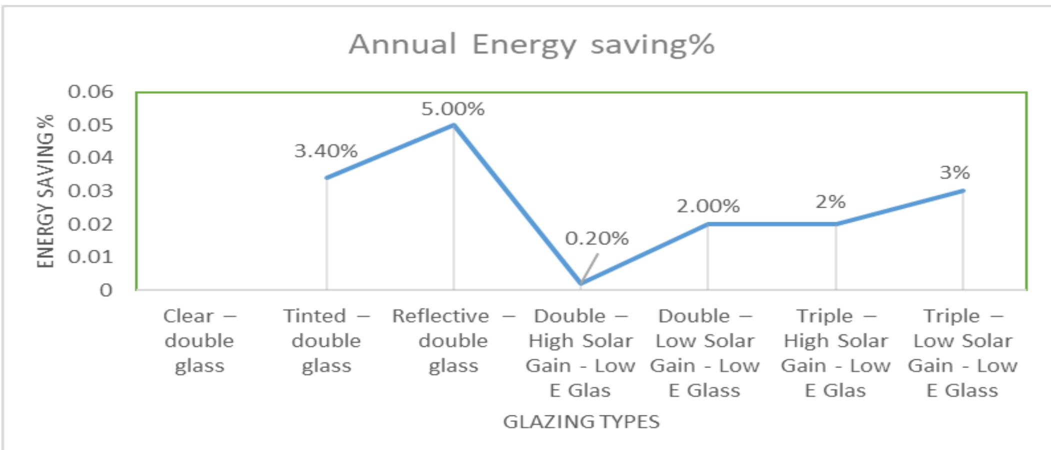


Figure C.12: Annual simulation results of energy saving loads % for the glazing type parameters (Gaza)

- Shading Devices

4. <u>Jericho</u>:

In general, the use of shading devices can reduce the total net energy of a site as shown in Figure C.13. The combinations of Ohs, SFs, and Los with 1m projection has a much higher reduction impact on total energy consumption equal to 112.41 kWh/m^2 with energy-saving reached 4%, so it is considered for the design.

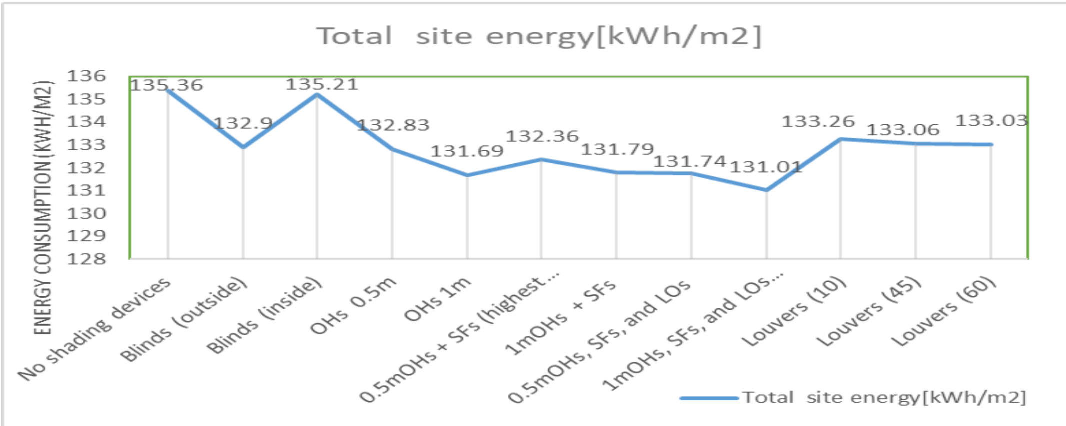


Figure C.13: Annual simulation results of site energy consumption (kWh/m^2) for shading devices parameters (Jericho)

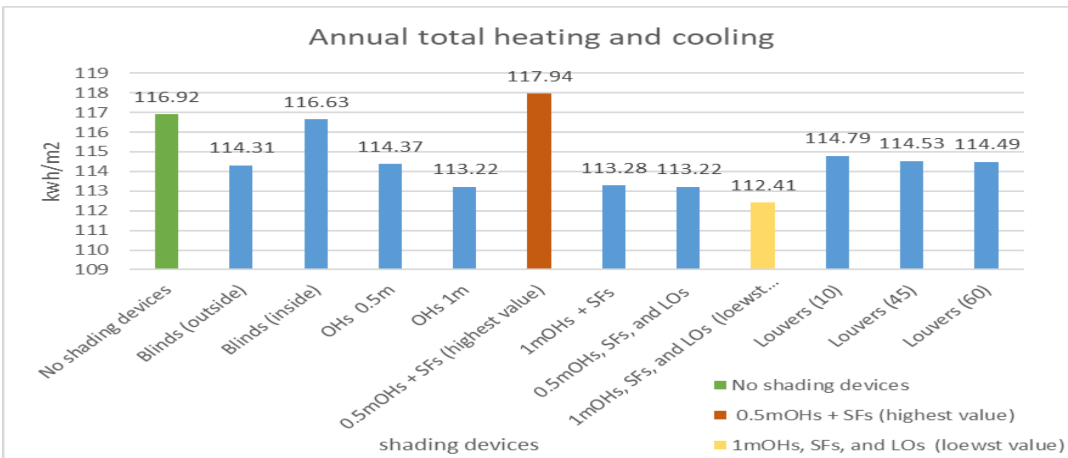


Figure C.14: Annual Simulation results of total heating and cooling loads (kWh/m^2) for shading devices parameters (Jericho)

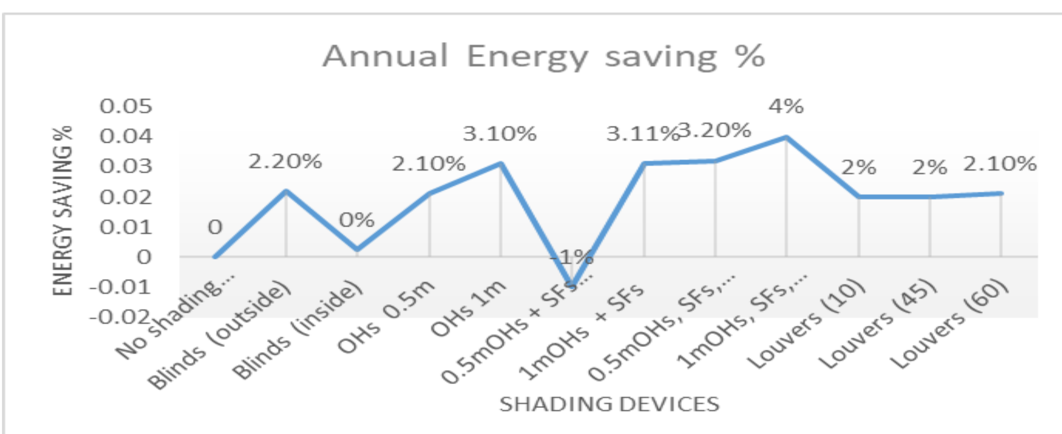


Figure C.15: Annual simulation results of energy saving loads % for the glazing type parameters (Jericho)

5. <u>Gaza</u>:

- The results as shown in Figure C.16, show the effect of the use shading device on heating and cooling loads, the Combinations of OHs, and SFs with 1m projection have a much higher reduction impact on total energy consumption with a value equal to 94.37 kWh/m^2 with energy-saving reached 6%, on the other hand, the blinds (inside)have much higher consumption on energy consumption, gives an estimated consumption equal 100.82 kWh/m^2 with an increase in consumption up to 1%, as shown in Figure C.17
- The simulation shows that the use of shading devices can reduce the total net energy of a site. As shown in Figure C.18, where the simulation of Gaza city, in this case, showed that the energy can be reduced to 112.98 kWh/m^2 with energy savings of about 5% when using 1m OHs+ SFs, while Blinds gives (inside) The highest total in terms of the total net consumption of the site, with an amount equal to 119.44 kWh/m^2.

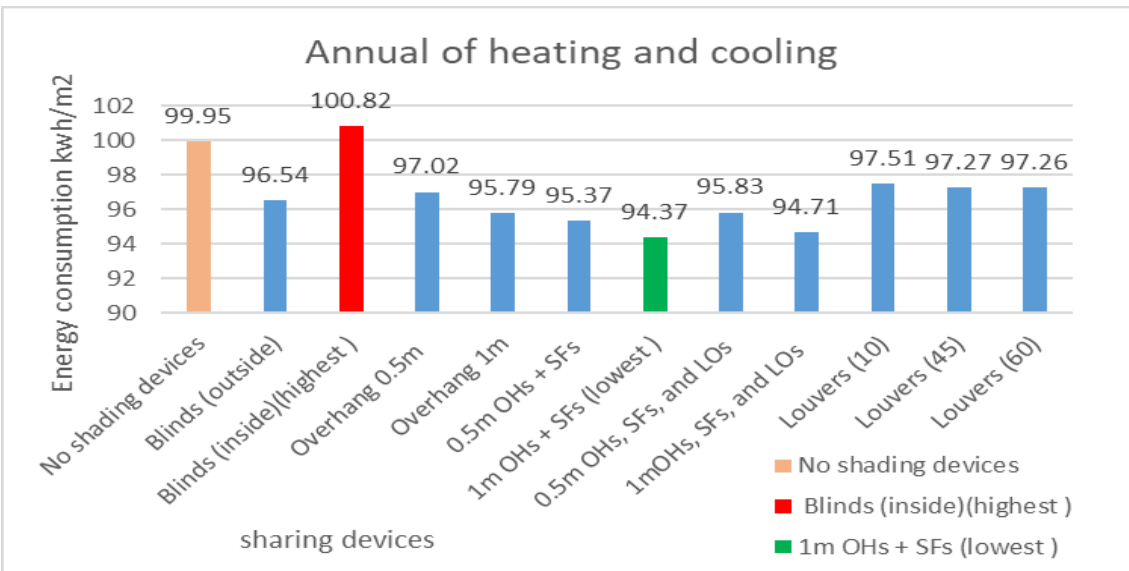


Figure C.16: Annual simulation results of total heating and cooling loads (kWh/m^2) for shading devices parameters (Gaza)

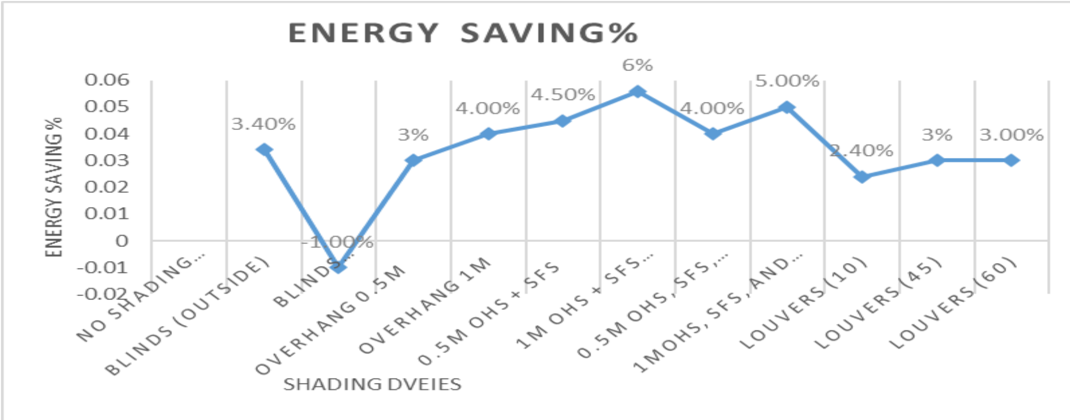


Figure C.17: Annual simulation of energy saving loads % for the shading devices parameters (Gaza)

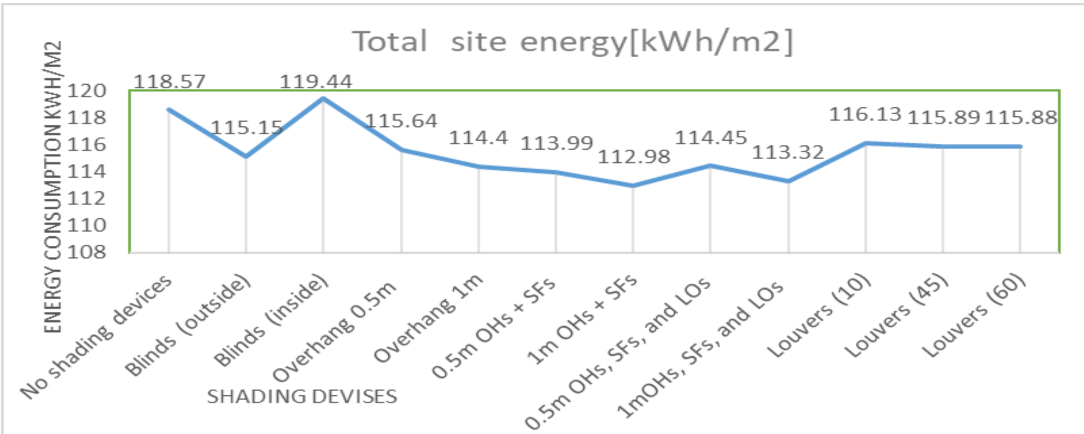


Figure C.18: Annual simulation of site energy consumption (kWh/m^2) for shading devices parameters (Gaza)

- Insulation materials:

1. <u>Jericho:</u>

All the insulation materials can significantly reduce the total site energy, when the expanded polystyrene is used, it can save energy about 46.4% with a total site equal to 72.58 kWh/m^2 as shown in Figure C.19, it gives annual loads with a value equal 54.15 kWh/m^2 where the amount of energy saving is about 53.60%, so it is considered for the design.

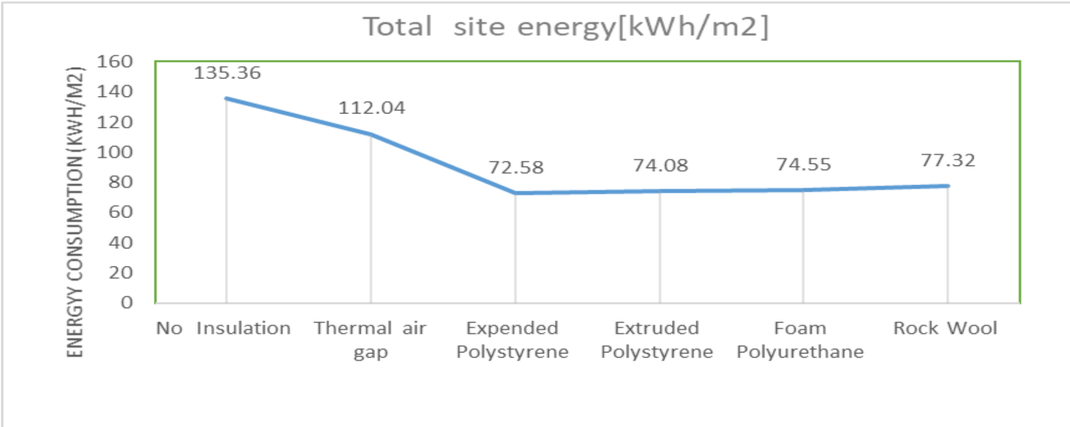


Figure C.19: Annual site energy consumption (kWh/m^2) for insulation material parameters (Jericho)

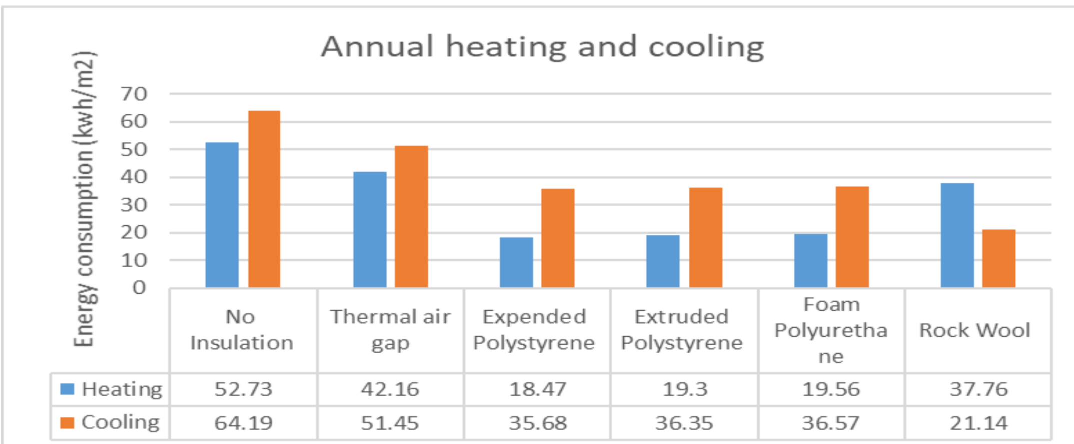


Figure C.20: Annual total of heating and cooling loads (kWh/m^2) for insulation material parameters (Jericho)

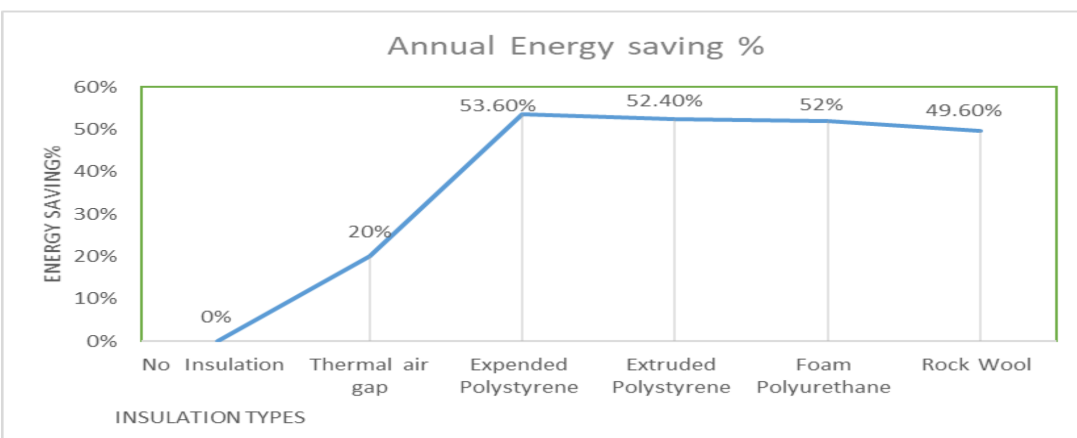


Figure C.21: Annual energy saving loads % for the insulation material parameters (Jericho)

2. <u>Gaza:</u>

when the expanded polystyrene is used, it can save energy about 42 % with a total site equal to 68.81 kWh/m^2 as shown in Figure C.22, it gives annual loads with a value equal to 54.15 kWh/m^2 where the amount of energy saving is about 50%, so it is considered for the design.

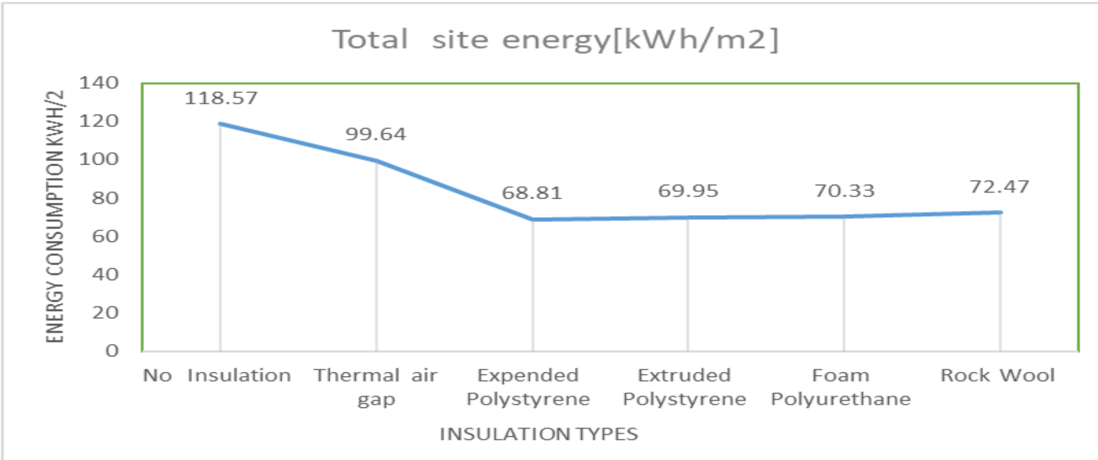


Figure C.22: Annual Simulation results of site energy consumption (kWh/m^2)

for insulation material parameters (Gaza)

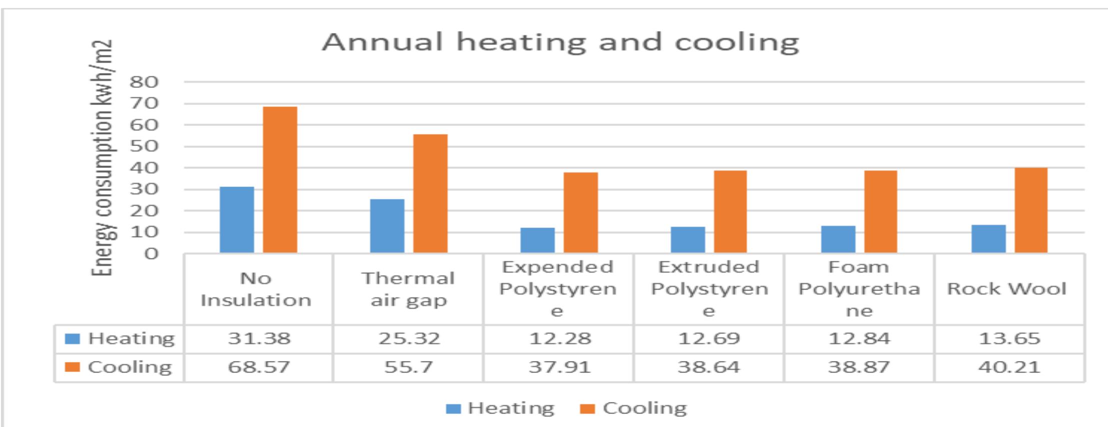


Figure C.23: Annual total of heating and cooling loads (kWh/m^2) for insulation material

parameters (Gaza)

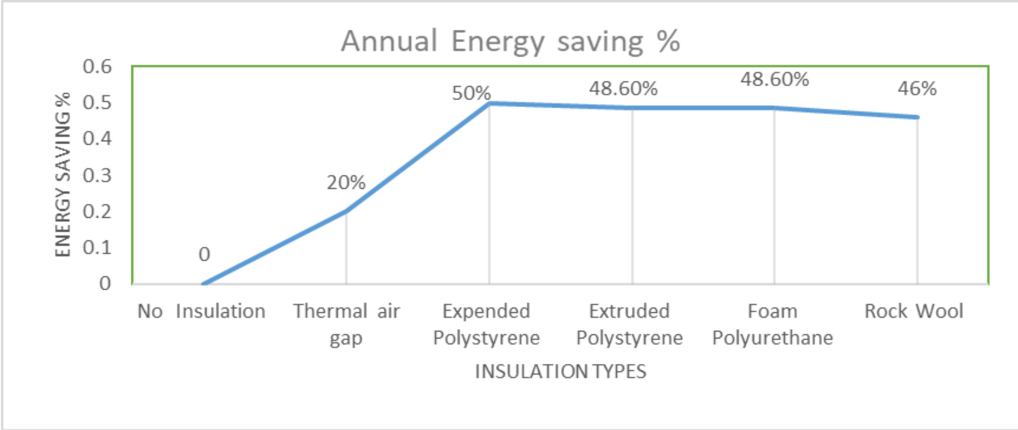


Figure C.24: Annual Simulation results of energy saving loads % for the insulation material parameters (Gaza)

- Landscape (tree planting):

1. <u>Jericho</u>:

The results showed that all the different heights of the Araucaria tree reduce the annual energy consumption as shown in figure C.25. The tree with a large height reduced the consumption from 135.36 kWh/m^2 to 132.14 kWh/m^2, which means that it worked to save energy by 2.4%, a total load of cooling and heating consumption decreased from 119.92 kWh/m^2 to 113.65 kWh/m^2 with energy savings of 3%

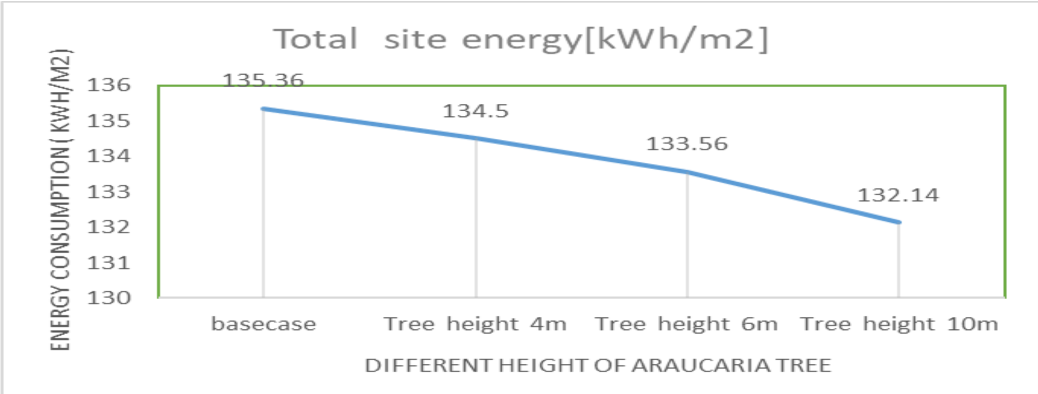


Figure C.25: Annual Simulation results of site energy consumption (kWh/m^2) for landscape parameters (Jericho)

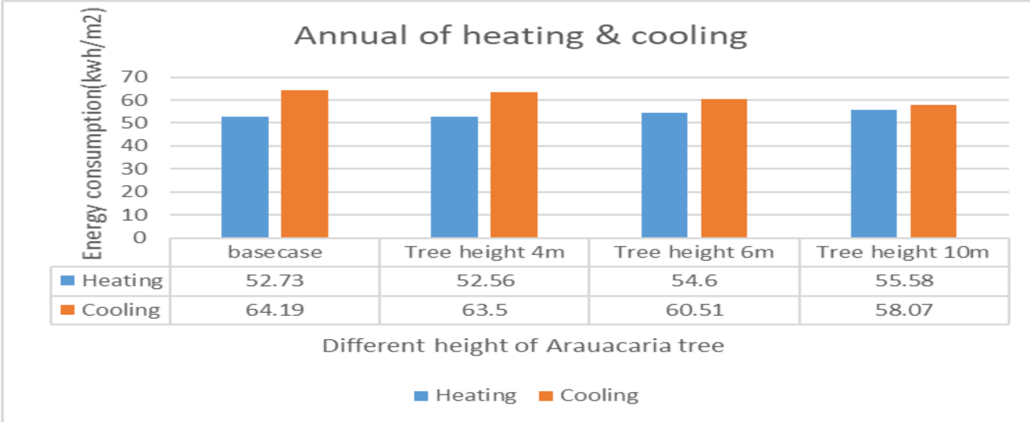


Figure C.26: Annual Simulation results of total heating and cooling loads (kWh/m^2) for landscape parameters (Jericho)

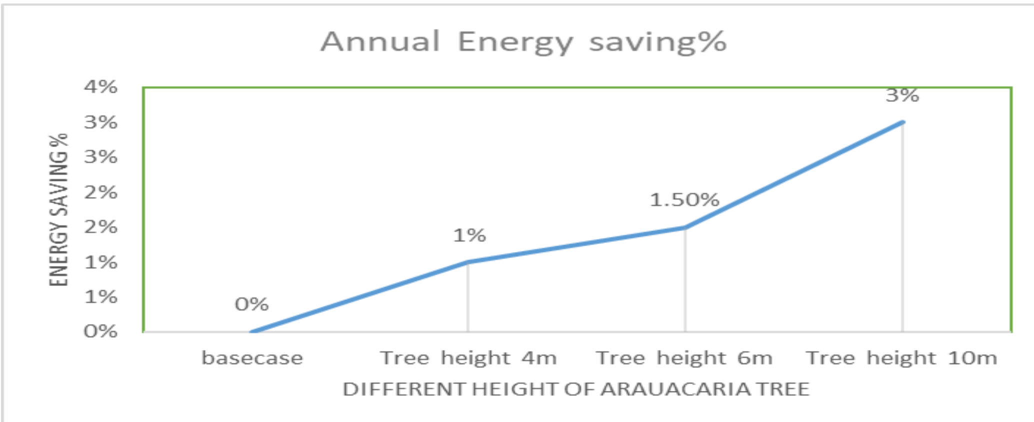


Figure C.27: Annual Simulation results of energy saving loads % for the landscape parameters (Jericho)

2. <u>Gaza</u>:

The simulation results in Gaza City were similar to Jericho, as the consumption decreased from 118.57 kWh/m^2 to 115.77 kWh/m^2 when using tall Araucaria trees with energy savings of 4.20% as shown in Figure (C.28), and it was found that a total load of cooling and heating consumption decreased from 99.95 kWh/m2 to 97.15 kWh/m^2 with energy savings of 3%

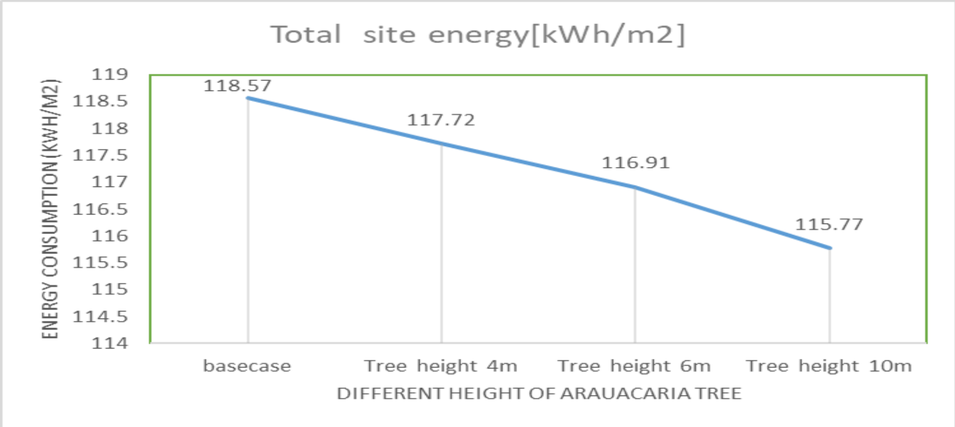
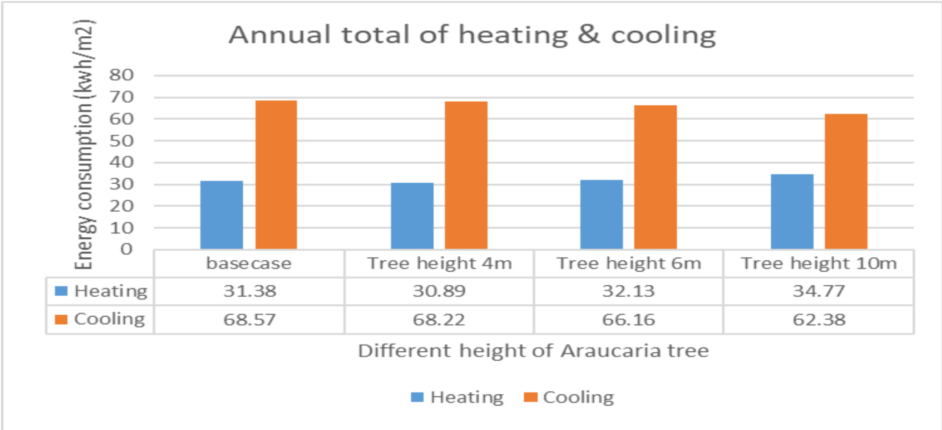


Figure C.28: Annual site energy consumption (kWh/m^2) for landscape parameters (Gaza)



	basecase	Tree height 4m	Tree height 6m	Tree height 10m
Heating	31.38	30.89	32.13	34.77
Cooling	68.57	68.22	66.16	62.38

Figure C.29: Annual total of heating and cooling loads (kWh/m^2) for landscape parameters (Gaza)

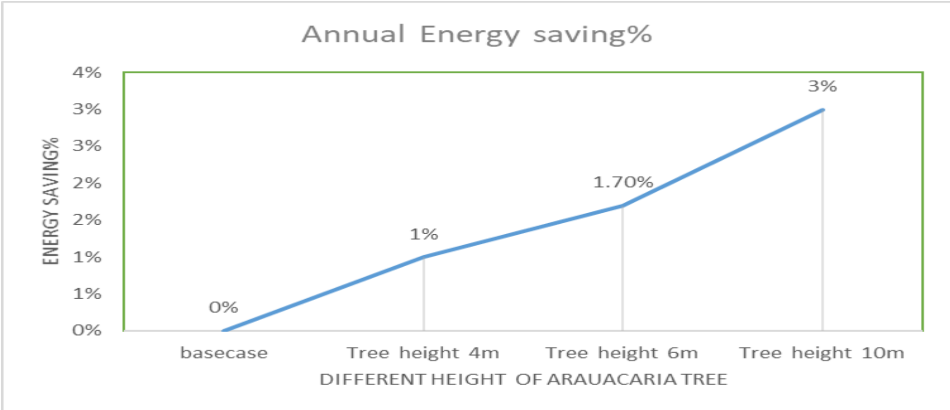


Figure C.30: Annual Simulation results of energy saving loads % for the landscape parameters (Gaza)

- Final result for the tested models:

Table C.4: best choices of the passive parameter for the Jerusalem case.

passive parameter	Jericho case	Gaza case
Orientation	The base case orientation is 0	The base case orientation is 0
Glazing type	Reflective – double glass	Reflective – double glass
Shading devices	Combinations of 1m projection OHs, SFs, and LOs	Combinations of 1m projection OHs, SFs
Insulation Material	Expanded polystyrene	Expanded polystyrene
landscape (tree Planting)	Big Araucaria tree 10m height	Big Araucaria tree 10m height

Table C.5: comparative between the base case and the tested model.

Study Case	Total site energy for base case (kWh/m^2)	Total site energy for tested model (kWh/m2)	Total of annual heating and cooling for base case (kWh/m2)	Total of annual heating and cooling for tested model (kWh/m2)
Jericho	135.36	66.04	117	47.43
Gaza	118.57	58.57	100	40

- <u>As for Jericho</u>: shows that the amount of energy consumption on the site was reduced by up to 66.04 kWh/m^2 with energy saving equal to 51% This means that the reduction is approximately in half. Also, the total heating and cooling loads were reduced from 117 kWh/m^2 to 47.43 kWh/m^2 with energy saving equal to 59% if compared to the basic case as shown in Figure (C.31) (C.32).
- <u>As for Gaza</u>: Figure (C.33) (C.34) shows that the amount of energy consumption on the site was reduced by up to 58.57 kWh/m^2 with energy saving equal to 57% This means that the reduction is approximately more than half**.** Also, the total heating and cooling loads were reduced from 99.95 kWh/m^2 to 39.96 kWh/m^2 with energy saving equal to 60% if compared to the basic case.

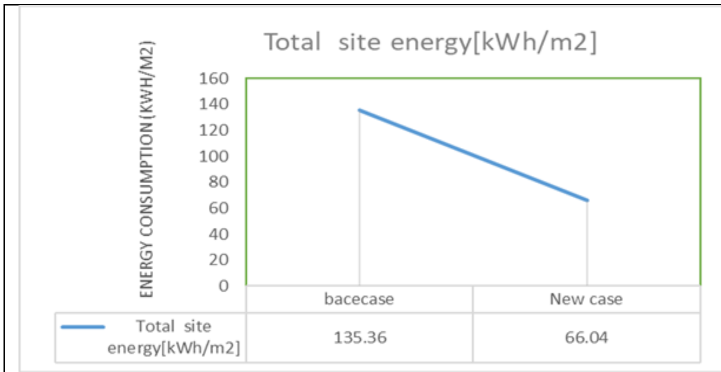


Figure C.31: Annual Simulation results of site energy consumption (kWh/m^2) for final test model (Jericho)

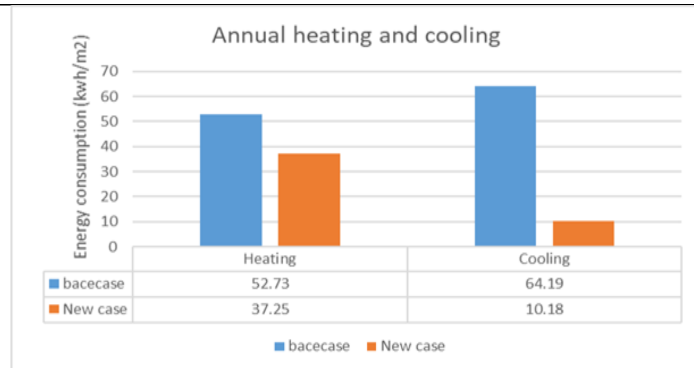


Figure C.32: Annual Simulation of total heating and cooling loads (kWh/m^2) for final test model (Jericho)

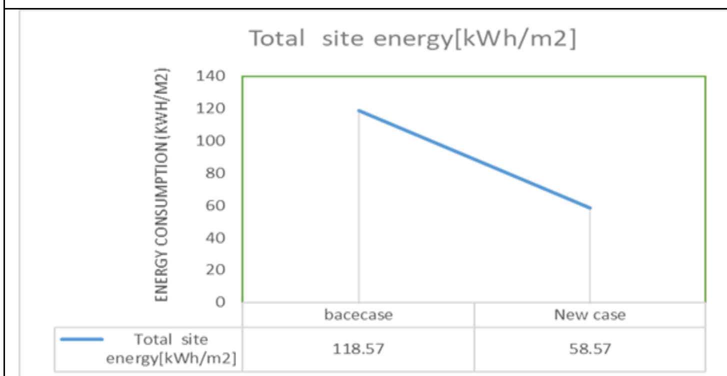


Figure C.33: Annual simulation results of site energy consumption (kWh/m^2) for optimal model (Gaza)

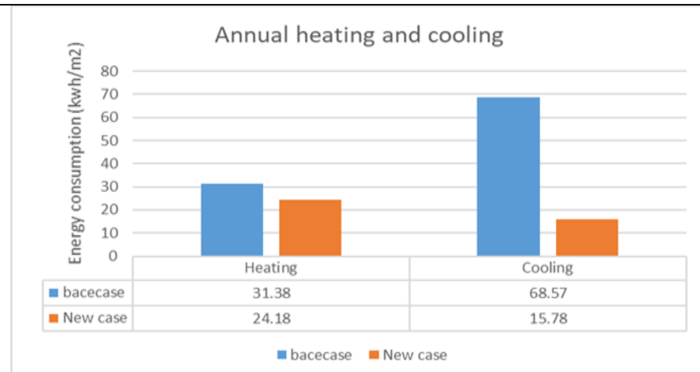


Figure C.34: Annual simulation results of total heating and cooling loads (kWh/m^2) for optimal model (Gaza)

- The RES (PV system) results & discussion

1. <u>Jericho:</u>

Figures C.35 and C.36 show the two scenarios that will be compared with the Base case.

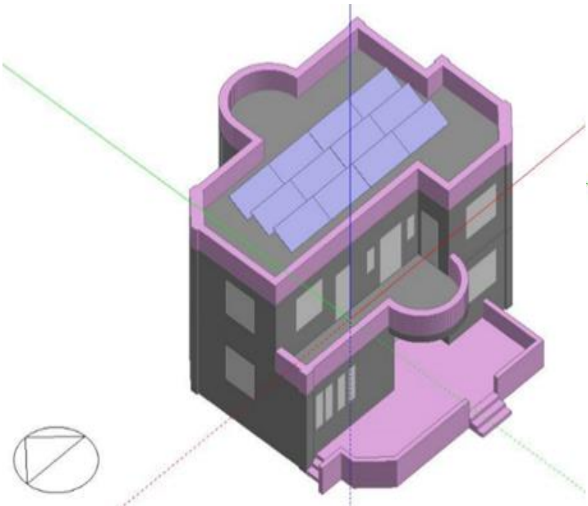


Figure C.35: The base case with PV in Jericho

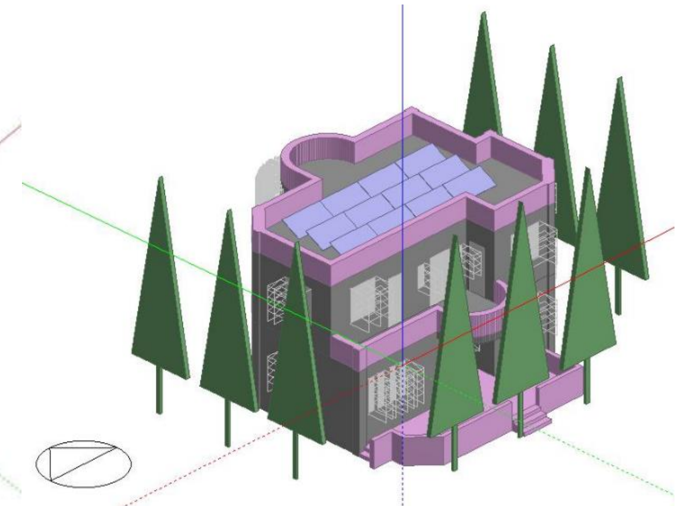


Figure C.36: The tested model with PV in Jericho

Generally, the total electricity demands declined in the two scenarios, as shown in Figure C.38. In reality, the reference case consumed 13198.4 kWh. While applying (Base case + PV) the total energy consumed in the building was 12153 kWh, and (tested model + PV) the total energy consumed in the building was 8784.64 kWh as shown in Figure C.37, two columns appeared. The blue columns represent the total quantity of electricity demanded at the building level if the utility is used for supply, as previously specified. While red columns represent the amount of energy generated by photovoltaic models. Referring to Figure C.37, the on-site generated electricity of Base case + PV has covered 54% of electricity demands and the tested model + PV has covered 76 %. On the other hand, Table C.6 and Figure C.38 explained the electric loads satisfied for the two examined generation cases. The total on-site and utility electric sources value was calculated to be 2509.05 kWh per year which corresponded to the Total Electricity End Uses in the reference case. Also, the total On-Site electric sources of the investigated cases were estimated as follows:

- Base case + PV has generated 6525.093 kWh which represents 258.71% of TOSUES.
- The tested model + PV has generated 6662.187 kWh which represents 266.47% of TOSUES.

Also, the Surplus Electricity Going to the Utility was calculated briefly in Table C.6 and Table (appx B.2), Figure C.38, Surplus Electricity Going to the Utility was 6519.559 kWh for Base Case + PV which represents about 258.49 % of TOSUES, it was 6656.54 kWh for tested model + PV which represents about 266.24% of TOSUES.

The Electricity Coming from Utility has been calculated in Table C.6 as shown in Equation 6.2 which was explained previously. Thus, Electricity Coming from the Utility was 2509.05 kWh in the reference case at Jericho. It was 2516.589 kWh in Base case + PV, it was 2494.563 kWh in the tested model + PV.

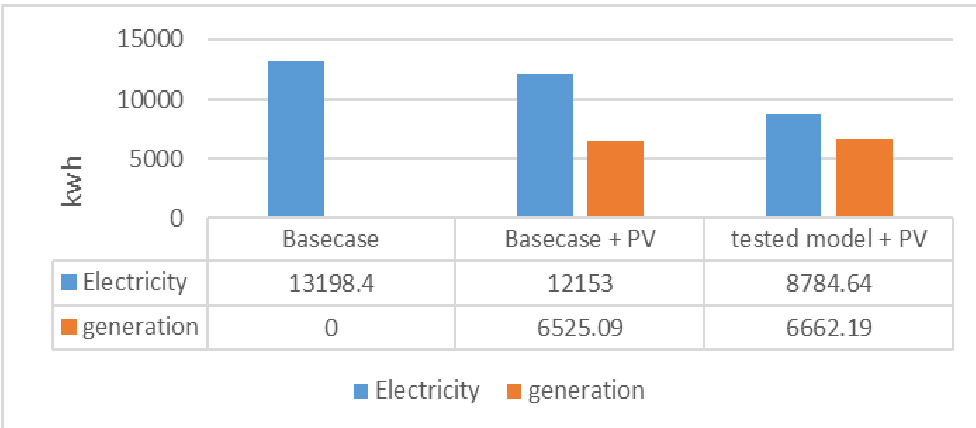


Figure C.37: PV generation results in Jericho Case

Table C.6: Electric loads satisfied of the examined generation cases in Jericho

Electric loads satisfied	Base Case	Base Case + PV	tested model + PV
Total On-Site Electric Sources	0	6525.093	6662.187
Electricity Coming from Utility	2509.05	2516.589	2494.563
Surplus Electricity Going to the Utility	0	6519.559	6656.54
Net Electricity from Utility	2509.05	-4002.97	-4161.98
Total On-Site and Utility Electric Sources	2509.05	2522.123	2500.209

The negative sign in the table means that the power is transferred to the grid

The results showed that the tested model + PV achieved a higher value of on-site electricity generation, than the base case + PV.

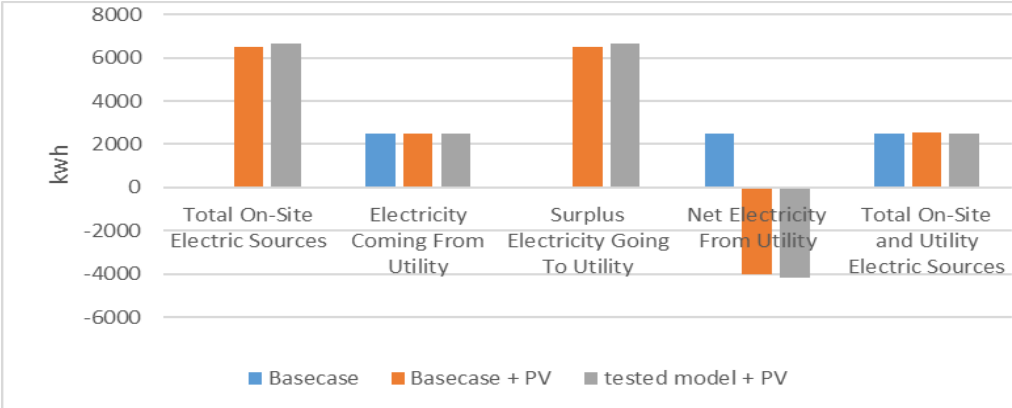


Figure C.38: Electric loads satisfied of the examined generation cases in Jericho

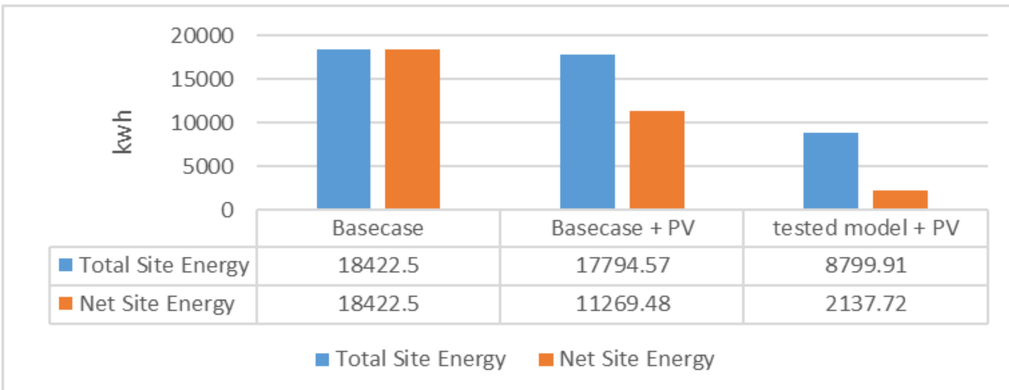


Figure C.39: Total site energy and net site energy of the examined generation cases in Jericho

From figure (C.38) (C.39) it is noted that the tested model with PV case achieved a large amount of on-site energy. It annually produced 6662.187 kWh which accounts for 76% of the total site energy. In turn, net site energy was 2137.72 kWh. While in the case of applying Base Case with PV, net site energy was 11269.48 kWh, and the on-site energy covered about 36% of the total site energy.

2. <u>Gaza:</u>

The same previous steps were repeated in the Gaza area and analyzed in the same way as the city of Jerusalem and Jericho, and it was as follows:

Figures C.40 and C.41 show the two scenarios that will be compared with the base- case.

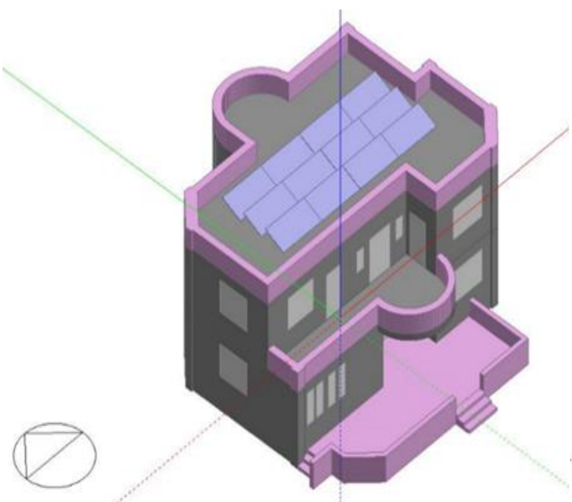


Figure C.40: the base case with PV in Gaza

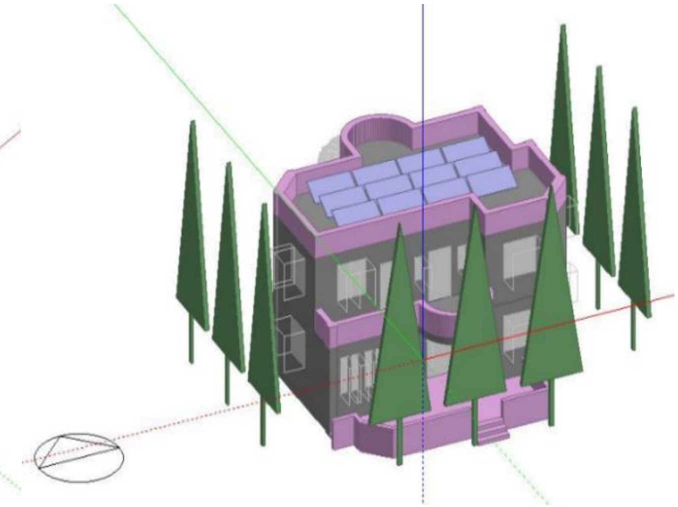


Figure C.41: the tested low-energy house with PV in Gaza

Generally, from point of view of energy consumption, the total electricity demands declined in the two scenarios, as shown in Figure C.43. In reality, the reference case consumed 9208.04 kWh. While applying (Base Case + PV) the total energy consumed in the building was 9762.36 kWh, and with the (tested model + PV) the total energy consumed in the building was 6866.82 kWh as shown in Figure C.42, two columns appeared. The blue columns represent the total quantity of electricity demanded at the building level if the utility is used for supply, as previously specified. While red columns represent the amount of energy generated by photovoltaic models. In truth, referring to Figure C.42, the on-site generated electricity of Base Case + PV has covered 59% of electricity demands and the tested model + PV has covered 87.5%. On the other hand, table C.7 and figure C.43 explained the electric loads satisfied for the two examined generation cases. The total on-site and utility electric sources value was calculated to be 2533.574 kWh per year which corresponded to the total electricity end uses in the reference case. Also, the total on-site electric sources of the investigated cases were estimated as follows:

- Base case + PV has generated 5767.631 kWh which represents 240.56 % of TOSUES.
- Optimal + PV has generated 6014.635 kWh which represents 226.47 % of TOSUES.

Also, the surplus electricity going to the utility was calculated briefly in table C.7 and table (appendix B.3), figure C.43, surplus electricity going to the utility was 5767.631 kWh for Baseline Case + PV which represents about 240.56 % of TOSUES, it was 6014.635 kWh for Optimal + PV which represents about 226.47 % of TOSUES. In this case, the result was the same total On-Site electric sources.

The electricity coming from the utility has been calculated in table C.6 as shown in equation 6.2 which was cleared previously.

Thus, electricity coming from the utility was 2533.574 kWh in the reference case at Gaza. It was 2546.785 kWh in baseline case + PV, it was 2500.268 kWh in optimal + PV.

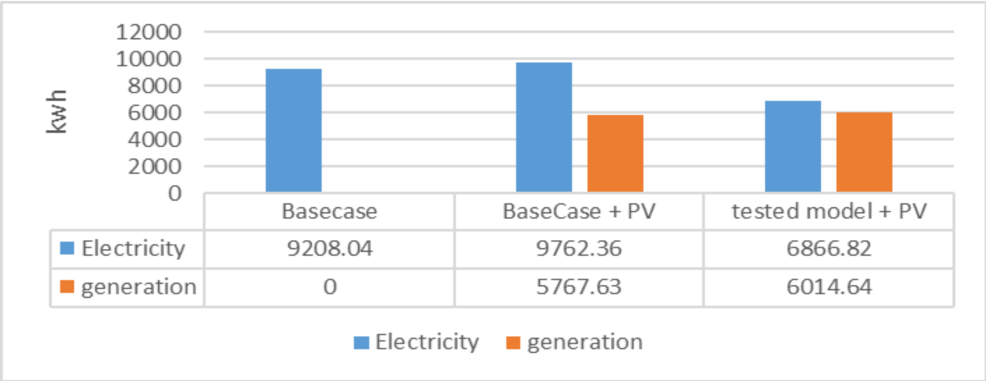


Figure C.42: PV generation results in Gaza Case

Table C.7: Electric loads satisfied of the examined generation cases in Gaza

Electric loads satisfied	Baseline Case	Baseline Case + PV	tested model + PV
Total On-Site Electric Sources	0	5767.631	6014.635
Electricity Coming from Utility	2533.574	2546.785	2500.268
Surplus Electricity Going to the Utility	0	5767.631	6014.635
Net Electricity from Utility	2533.574	-3220.85	-3514.37
Total On-Site and Utility Electric Sources	2533.574	2546.785	2500.268

The negative sign in the table means that the power is transferred to the grid

The results showed that the Optimal + PV achieved a higher value of on-site electricity generating, Then the Baseline Case + PV.

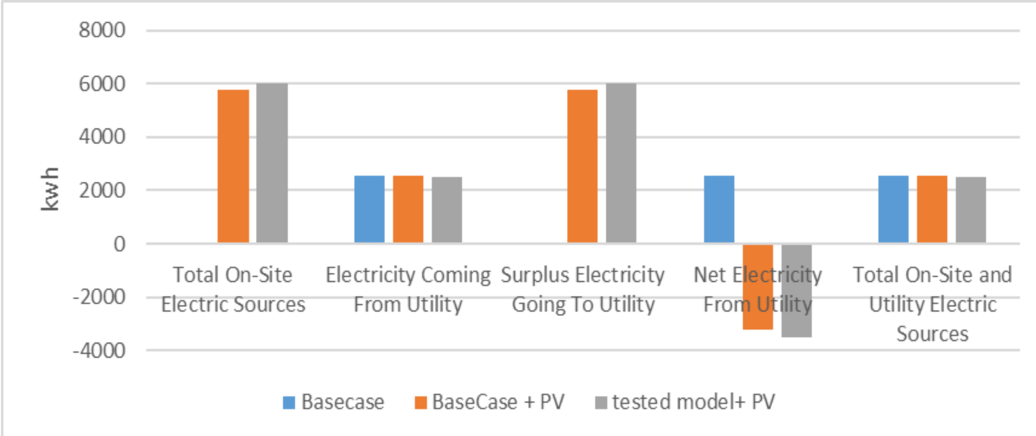
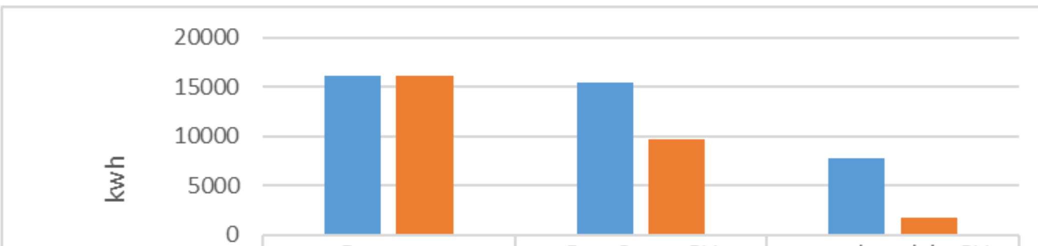


Figure C.43: Electric loads satisfied of the examined generation cases in Gaza



	Basecase	BaseCase + PV	tested model + PV
Total Site Energy	16119.19	15404.55	7778.82
Net Site Energy	16119.19	9636.92	1764.19

Figure C.44: Total site energy and net site energy of the examined generation cases in Gaza

From figure (C.43) (C.44) it is noted that the optimal PV case achieved a large amount of on-site energy. It annually produced 6014.635 kWh which accounts for 77% of the total site energy. In turn, net site energy was 1764.19 kWh. While in the case of applying Baseline Case with PV, net site energy was 9636.92 kWh, and the on-site energy covered about 37% of the total site energy.

Second stage final results with RES

<u>As for Jericho</u>: the building can save energy by up to 88% in the case of the tested model with PV if it is compared with the base case. And the final save of heating and cooling reached 60% as shown in figure C.45

As for Gaza: the building can save energy up to 52% in the case of the tested model with PV if compared with the base case. In the future. And the final save of heating and cooling reached 61% as shown in figure C.46

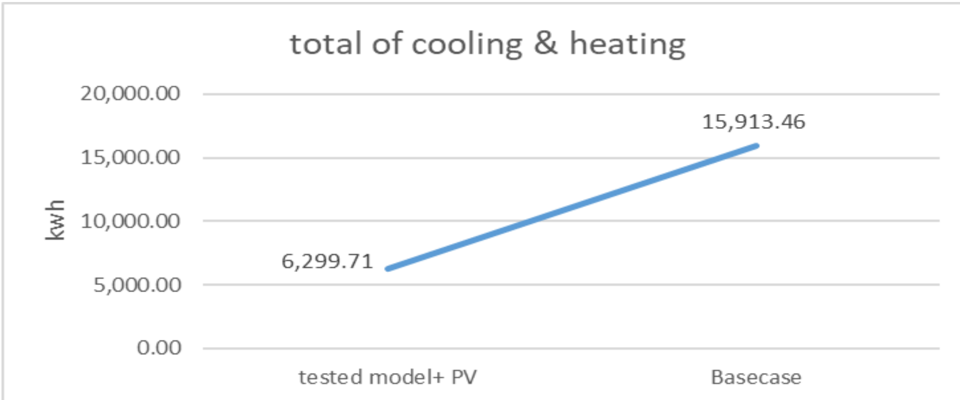


Figure C.45: The comparative of total heating and cooling between the tested model with PV & base case in Jericho

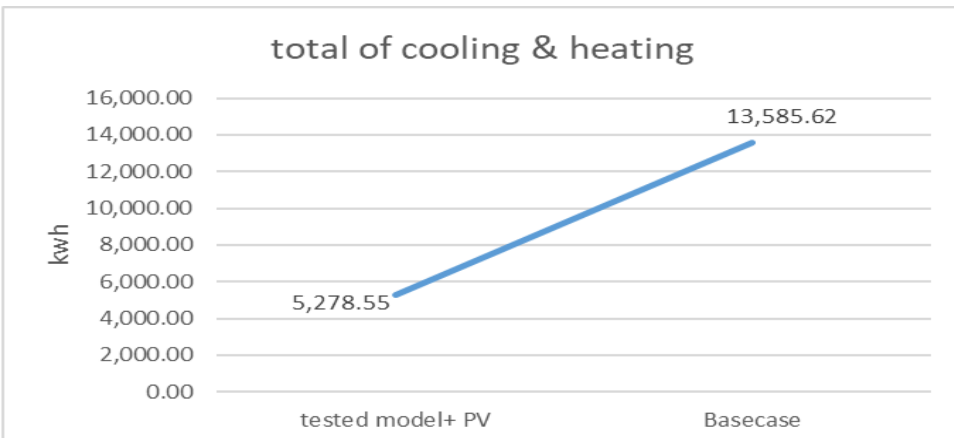


Figure C.46: the comparative of total heating and cooling between the tested model with PV & baseline case in Gaza

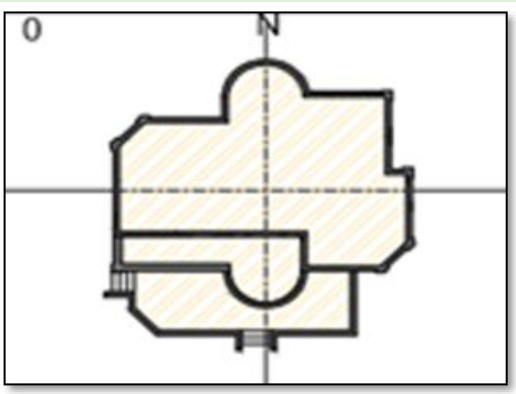
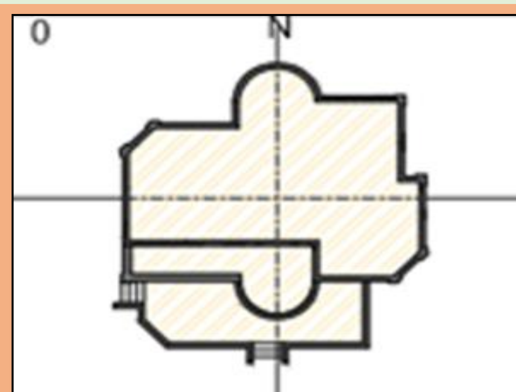
Conclusion:

The coastal climate was represented by Gaza City and the Jordan Valley climate was represented by Jericho. After studying the passive strategies, choosing the best options for every strategy, and connecting the model to the solar cell system, it was found that these strategies have a great effect on the annual heating and cooling loads.

1. Orientation

Table C.8: The concluded result of the orientation simulation in all cases

Cases	Jericho	Gaza
Best orientation degree	Base case 0	Base case 0
Worst orientation degree	225	240
Lowest Energy consumption annually (kWh/m^2)	135.36	118.57
Highest Energy consumption annually (kWh/m^2)	144.9	128.14
Lowest Heating and cooling annually (kWh/m^2)	116.92	99.95
Highest Heating and cooling annually (kWh/m^2)	126.48	109.62
Energy saving annually (%)	-	-
The amount of increase in energy consumption (%)	-7%	-8%

Jericho	Gaza
	

2. Glazing Types:

Table C.9: The concluded result of the glazing types simulation in all cases

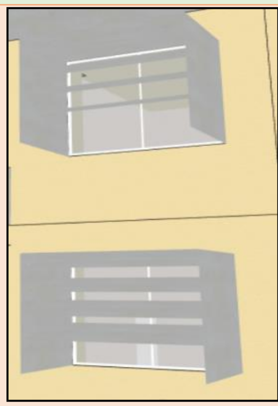
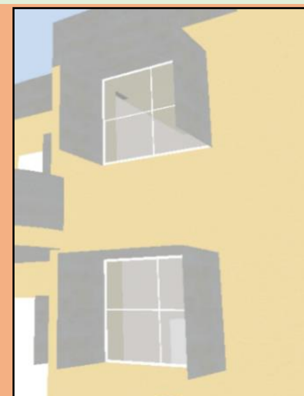
Cases	Jericho	Gaza
Best glazing type	Reflective – double glass	Reflective – double glass
Worst glazing type	Clear – double glass	Clear – double glass
Lowest Energy consumption annually (kWh /m^2)	131.73	113.83
Highest Energy consumption annually (kWh /m^2)	135.36	118.57
Lowest Heating and cooling annually(kWh /m^2)	113.14	96.53
Highest Heating and cooling annually(kWh /m^2)	116.92	99.95
Energy saving annually (%)	3.2%	5%
The amount of increase in energy consumption (%)	-	-

3. Shading Devices:

The Combinations of OHs, SFs, and LOs with 1m projection were the best in Jericho city with a load reduction of up to 4%. As for Gaza City, the Combination of OHs, and SFs with a 1m projection was the best with energy savings of up to 6%.

Table 7.2: The concluded result of the shading devices simulation in all cases

Cases	**Jericho**	**Gaza**
Best shading devices type	1m projection of OHs, SFs, and LOs	1m projection of OHs, SFs
Worst shading devices type	0.5m projection of OHs, SFs, and LOs	Blinds (inside)
Lowest Energy consumption annually (kWh/m^2)	131.01	112.98
Highest Energy consumption annually (kWh/m^2)	135.36	119.44
Lowest Heating and cooling annually (kWh/m^2)	112.41	94.37
Highest Heating and cooling annually (kWh/m^2)	117.94	100.82
Energy saving annually(%)	4%	5%
The amount of increase in energy consumption (%)	-	-

Jericho	**Gaza**
	

4. Insulating Materials:

Table C.10: The concluded result of the insulating materials simulation in all cases

Cases	Jericho	Gaza
Best insulating materials type	Expanded Polystyrene	Expanded Polystyrene
Worst insulating materials type	Thermal air gap	Thermal air gap
Lowest Energy consumption annually (kWh/m^2)	65.43	67.08
Highest Energy consumption annually (kWh/m^2)	72.58	101.49
Lowest Heating and cooling annually (kWh/m^2)	54.15	50.19
Highest Heating and cooling annually (kWh/m^2)	93.61	81.02
Energy saving annually (%)	53.6%	50%
The amount of increase in energy consumption (%)	-	-

5. Landscape (tree planting):

Table C.11: The concluded result of the tree simulation in all cases

Cases	Jericho	Gaza
The best height for the tree	10m	10m
Worst height for the tree	4m	4m
Lowest Energy consumption annually (kWh/m^2)	132.14	117.72
Highest Energy consumption annually (kWh/m^2)	134.5	115.77
Lowest Heating and cooling annually(kWh/m^2)	113.65	97.15
Highest Heating and cooling annually(kWh/m^2)	116.06	99.11
Energy saving annually (%)	3%	3%
The amount of increase in energy consumption (%)	-	-

6. Tested models:

The application of the best strategies in Jericho and Gaza and obtaining the tested models worked to reduce the annual energy consumption on the site by more than half, as the reduction rate reached 51% and 57% for Jericho and Gaza respectively, as for the heating and cooling loads in particular, it reached 60%.

Table C.12: The concluded result of the tested model's simulation in all cases

Cases	Jericho	Gaza
Total sit energy for test model (kWh/m2)	66.04	58.57
Total of annual heating and cooling for tested models (kWh/m2)	47.43	40
Energy saving annually (%)	51%	57%

Table C.13: The concluded result of the tested models with PV in all cases

Cases	Jericho	Gaza
PV generation (kWh)	6662.187	6014.635
The amount of covered electricity demand	76 %	87.5%
Total of annual heating and cooling for tested model +PV (kWh)	6299.71	5278.55
annual Energy saving of heating and cooling (%)	60%	61%
Jericho	**Gaza**