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Energy efficiency of a house in Mediterranean region: insulation and glazing impact

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Abstract

The insulation of a building's envelope is critical for reducing energy consumption, enhancing indoor thermal comfort, and achieving sustainable development goals. This theoretical work focused on the energy and thermal aspect of insulators and glazing to determine the optimal thermal insulation and the best glazing for the building envelope in the Mediterranean region where the province of Ain Temouchent, Algeria, was taken in this study. This study evaluated the effectiveness of insulation materials, which are expanded polystyrene, glass wool, rock wool, and wood fiber of varying thicknesses, and glazing in the Algerian market. The TRNSYS 17 software is used to simulate the building's behavior. The study finds that wood fiber insulation with a 9 cm thickness provides the best thermal performance, resulting in a 26% reduction in energy costs compared to 3cm of expanded polystyrene. Furthermore, upgrading from single to double glazing can reduce heating and cooling costs by 23% and 10%, respectively, demonstrating the importance of proper insulation and glazing in achieving energy efficiency, and enhancing indoor thermal comfort for occupants. In conclusion, this study provides valuable findings for designing energy-efficient buildings with optimal thermal insulation and glazing. Future research should explore broader factors affecting building performance, such as the long-term performance and durability of materials in varying climates and building designs, as well as the impact of occupancy and building orientation. Although the study acknowledges its limited examination of factors and options, it still provides valuable insights into building performance with insulation and glazing.

Keywords: Energy efficiency. Energy consumption. Heat transfer. Materials of thermal insulation. Indoor thermal comfort. Glazing.

1. Introduction

In 2020, the building sector accounted for 36% of global final energy demand and 37% of energy-related CO2 emissions. However, global energy demand in buildings fell by 1% in 2020 compared to 2019 due to the COVID-19 pandemic, which significantly influenced the worldwide building and construction sector (International Energy Agency 2021). In addition, statistics indicate that new and old policies are making slow progress compared to the sector's expansion. Therefore, more actions are needed to reduce energy demand emissions and encourage clean solutions and innovations to make buildings future-proof (International Energy Agency "Global Status Report for Buildings and Construction Towards a zero-emission, efficient and resilient buildings and construction sector" 2021, 2020, 2019, International Energy Agency "Energy Efficiency 2019: Analysis and Outlooks to 2024. Paris, France: IEA" 2019).

The United Nations estimates that by 2050, the world's population will reach 9.7 billion, and two-thirds of them will live in urban areas. This rapid urbanization will significantly increase the demand for building construction, making it even more critical to adopt sustainable practices and energy-efficient technologies (United Nations 2018).

Electricity consumption in buildings represents around 55% of the total global consumption. Moreover, electricity has climbed by more than 19% since 2010. Thus, it is a crucial source of growing energy demand and emissions by the global building stock. This illustrates how critical it is to increase access to clean and renewable energy sources and adopt passive and low-energy designs in building construction (International Energy Agency "Electricity" 2021). The IEA projects that global electricity demand will increase by around 2.5% per year between 2021 and 2030, driven by population growth, urbanization, and economic development in developing countries (International Energy Agency "Electricity" 2021).

More specifically, the building sector in Algeria has seen significant growth in recent years, with an annual average growth rate of 7.1% between 2010 and 2019. The majority of buildings in Algeria are made of concrete and lack energy-efficient features, leading to high energy consumption and significant carbon emissions. However, the government has launched several initiatives to promote sustainable building practices and improve energy efficiency in the sector, including the National Program for the Promotion of Renewable Energies and Energy Efficiency in Buildings (World Bank 2021). In Algeria, people have difficulty dealing with the heat during the summer months. They use air conditioning units to regulate indoor temperature and humidity levels to create a comfortable living or working environment., resulting increasing a massive demand for energy consumption. Using air conditioning units also raises the demand for energy because people need it to ensure thermal comfort and protect against potential heat waves. As a result, the demand for electricity in the summer increases each year. In 2012, peak power consumption was 9,000 MW, which grew to 15,000 MW in July 2019, this power consumption level has never been reached before on the national grid (Medjelekh *et al.* 2016, Sonelgaz 2022, Transition Énergétique en Algérie 2020).

Despite the sector's economic significance, it faces several challenges, including the need to reduce its environmental impact, improve the quality and affordability of buildings, and ensure the safety and well-being of occupants. To address these challenges, governments, industry leaders, and civil society organizations are working together to promote sustainable building practices, increase energy efficiency, and reduce carbon emissions in the sector (United Nations Environment Programme UNEP 2022, US Environmental Protection Agency 2021, US Green Building Council 2021).

For this reason, several countries and organizations are working to innovate and implement actions to improve efficiency and reduce emissions, to address the environmental impact of the building sector. On one hand, the European Union has set targets to reduce energy consumption and greenhouse gas emissions from buildings by 32.5% and 30%, respectively, by 2030. On the other hand, the United States Environmental Protection Agency's (EPA) Energy Star program promotes energy efficiency in buildings, and the Leadership in Energy and Environmental Design (LEED) certification program encourages sustainable building practices globally (European Commission 2019, US Environmental Protection Agency 2021, US Green Building Council 2021). Moreover, Algeria, as a significant producer and exporter of oil and gas, recognizes the importance of transitioning to renewable energy sources and increasing energy efficiency in buildings, which committed to an energy transition policy based on energy efficiency and the development of renewable energies; it also gave great importance to the construction sector. In 2011, the country updated its plan and focused more on deploying renewable energy sources on a large scale through various stimulus measures. The Algerian government aims through this program to expand the use of renewable energies and diversify energy sources in the country (Transition Énergétique en Algérie 2020, International Energy Agency "Renewable Energy and Energy Efficiency Development Plan 2011-2030, Algeria" 2021). The government's National Renewable Energy and Energy Efficiency Program (NREEEP) aims to increase the share of renewable energy in the country's electricity mix to 27% by 2027, and to reduce energy consumption in the building sector by 20% by 2030. The NREEEP also includes measures to promote energy-efficient technologies and building practices, as well as financial incentives to encourage investment in renewable energy projects (International Energy Agency "Electricity" 2021).

Today's buildings are expected to achieve energy-efficient and environmentally friendly. This is performed through processing and assessment to reduce energy demand and mitigate climate change. In recent years, there has been a renaissance in building energy efficiency. In this context, there has been a renewed focus on building energy efficiency, with two main strategies being pursued: active strategies, which include heating, ventilation, and air conditioning (HVAC) and artificial lighting, and passive strategies, which focus on improving the building envelope to reduce energy demand. Passive strategies include measures such as thermal insulation and optimizing solar inputs Verbeke and Audenaert (2016).

Passive strategies for energy-efficient buildings have become an essential area of research and innovation. Recent Studies have shown that buildings designed with passive strategies can reduce energy consumption by up to 75% compared to conventional buildings (International Energy Agency "Energy Efficiency" 2019). In addition to the environmental benefits, passive building strategies can lead to cost savings for building owners and operators over the life cycle of the building. As such, improving building energy efficiency is crucial for reducing greenhouse gas emissions and mitigating climate change.

This study focuses on passive strategies for improving energy efficiency in buildings. With a particular emphasis on thermal insulation. By examining the effectiveness of thermal insulation materials with different thicknesses in the building envelope in the Mediterranean climate. Furthermore, we investigated the impact of glazing on the building envelope in terms of energy consumption and thermal indoor environment. To do this, we conducted a comprehensive analysis of various glazing options, including different types of glass. Using energy modelling analysis, we simulated the performance of each glazing option and assessed their impact on indoor temperature, and overall energy consumption.

Thermal insulation is a simple technique with a high impact on energy efficiency, reducing the energy required for cooling in summer and heating in winter. The usage of thermal insulation properly slows the heat transfer rate by conduction, convection, and radiation. Due to its high thermal resistance, effective use saves energy and reduces the size of the HVAC system during design Sadineni *et al.* (2011). There are four types of thermal insulation: organic, inorganic, metallic, and advanced materials. Each type of insulation has subcategories based on the nature of the material used. The choice of insulation material depends on various factors such as the desired thermal conductivity, compressive strength, density, durability, and cost (Papadopoulos 2005; Al-Homoud 2005; Cengel and Ghajar 2015).

Windows are the most vulnerable part of the building envelope to lose and gain heat. As a result, a significant electrical energy is consumed. However, smart, passive, and active windows are being created as glazing technology advances, significantly reducing building energy demands while enhancing the indoor environment Rezaei *et al.* (2017).

Studying the impact of glazing on the building envelope is important for several reasons. Firstly, it can help to improve the energy efficiency and thermal performance of buildings, resulting in significant long-term energy savings and reduced environmental impact. Secondly, it can improve occupant comfort by regulating the indoor temperature and reducing glare. Thirdly, it is becoming increasingly important for building owners and designers to consider the environmental impact of their buildings and strive for more sustainable design solutions. Finally, understanding the impact of glazing can help inform the selection of appropriate materials and design strategies to achieve better building performance. By studying the impact of glazing on the building envelope, we can make informed decisions to create buildings that are more energy-efficient, sustainable, and comfortable for their occupants.

The primary objective of this study is to assess the impact of insulators and window glazing on the thermal and energy performance of buildings. The study seeks to identify the most effective insulator, optimal thickness, and appropriate window glazing by analyzing the thermal behavior and energy consumption of four insulators: Expanded Polystyrene, Rock Wool, Glass Wool, and Wood Fiber, at different thicknesses of 3, 6, 9, and 12 cm. Additionally, five types of window glazing were selected, which are Single-glazing, Double-glazing, Triple-glazing, Double-glazing low-emissivity, and Double-glazing low-emissivity filled with argon gas, with an aluminum frame. TRNSYS 17 software has been used to simulate the behavior of building systems under different conditions and evaluate the impact of various factors on energy performance accurately. The house is located in Ain Temouchent, Algeria. By examining these factors, this study aims to provide valuable insights into the most effective insulation and window glazing options for enhancing the thermal and energy performance of buildings. The findings of this research will have significant implications for architects, engineers, and policymakers seeking to improve the energy efficiency of buildings and reduce their carbon footprint in the Mediterranean region.

The paper is structured to provide a comprehensive understanding of the impact of insulation and window glazing on building energy usage and the indoor environment. The introduction section provides an overview of the building sector worldwide and locally and highlights energy consumption in buildings with supporting statistics, its objectives, and the scope of the research. Section 2 provides a literature review of relevant research on building envelope improvements and their influence on building energy usage and the indoor environment. Section 3 outlines the research methodology used in the study, including data collection and analysis. Section 4 presents the study's results, including the analysis of insulation types and thicknesses, comparison of window glazing types, and determination of the optimal insulation thickness for the building envelope and best window glazing. Section 5 discusses the implications of the study's findings for building design. Finally, the conclusion section summarizes the study's findings, the limitations faced during the research, and potential future directions for research in this area.

1.1 Literature review

These studies provide valuable insights into the thermal insulation materials and glazing types used in building construction and their impact on energy efficiency. They cover a range of topics, including the sustainability characteristics of insulation materials, the thermal performance of glazing systems, and the heat transfer performance of various glazing types. The studies use a variety of research methods, including numerical simulations, experimental investigations, and comparative analyses, to provide a comprehensive understanding of thermal insulation and glazing in buildings.

Akan (2021); Eddib and Lamrani (2019) investigated the optimum insulation thickness of buildings in Turkey and Morocco. they use different insulators materials; the selection of insulators is based on the most common in that area. Akan (2021) studied life cycle cost analysis and the total annual net savings energy in the buildings. Eddib and Lamrani (2019) monitoring indoor environment changes and energy saving. As a result, we notice Rockwool and Wood fiber are the best insulators according to Turkey and Morocco's climate. Daouas (2011) used an analytical method based on Complex Finite Fourier Transform (CFFT) to calculate yearly transmission loads for a typical wall structure in Tunisian climate. The study discovered that wall orientation has a negligible impact on optimal insulation thickness but a significant impact on energy savings. The results showed that the south orientation is the most economical with an optimum insulation thickness of 10.1cm, 71.33% of energy savings and a payback period of 3.29 years. Economic parameters, such as insulation cost, energy cost, inflation, and discount rates, were also found to have a noticeable effect on optimum insulation and energy savings.

Huang *et al*. (2020) established a whole-life-cycle assessment model to exploit the optimal economic thickness and evaluated the energy-saving rate, economic benefits, greenhouse-gas emissions. On office buildings in the Chinese zone of a humid subtropical climate, compare the super-insulated aerogel with four commonly-used insulation materials (Expanded Polystyrene, Extruded Polystyrene, Foamed Polyurethane, and Glass Fibers). Thus, aerogel insulation achieved a faster reduction in carbon emissions than other insulators.

Necib, H and Necib, B (2020) utilized analytical approaches to computing the optimal insulation thickness using a FORTRAN programmed. According to the findings, the best insulation thickness for the four East, North, West, and South orientations are 7.3, 6.2, 7.3, and 6.7 cm, respectively. An investigated study was done by Ramin *et al.* (2016) to determine the optimal insulating thickness for various wall orientations In Iran. Furthermore, the effect of the position of the insulation. According to the results, insulation in different wall designs can reduce annual loads by 70–82% compared to an uninsulated concrete wall and 31–58% for an aerated brick wall. Moreover, even though their time lag and decrement factor were not the same, insulation positions resembled yearly loads and ideal insulation thickness.

Yu, S *et al*. (2022) conducted theoretical research to investigate the link between wall insulation and thermal mass and find a balance between wall thermal performance and energy consumption. Using five different materials with varying thicknesses and climates, tracking and analyzing the effects of 4 factors: heat transfer coefficient, thermal inertia index, attenuation degree, and delay time. The result reveals that the correlation coefficient (R2) between M and building energy consumption is around 0.7736–0.8215, which is more than the heat transfer coefficient of 0.3494–0.384 and is more accurate in forecasting building energy needs. Furthermore, the appropriate wall thickness of common building materials in different climate zones is found by analyzing the thermal improvement rate and the building energy-saving rate.

Yu, J *et al*. (2009); Yu, J *et al*. (2011) devoted their study to finding the optimum insulation thicknesses of five insulation materials, namely Expanded Polystyrene, Extruded Polystyrene, Foamed Polyurethane, Perlite and Foamed Polyvinyl Chloride. For external walls and roofs in 4 different cities in China distinct by hot summer and cold winter. Based on life cycle cost, life cycle saving, payback period analysis. They are considering different orientations, surface colours, insulation materials and climates. Moreover, because of the highest life cycle savings and the lowest payback period, Expanded Polystyrene is the most cost-effective insulating material of the five.

Lamya *et al*. (2021) Their study aimed to investigate the heat transfer through the envelope of an administrative building in Errachidia City in Morocco. The authors used numerical simulation based on the finite element method to evaluate the impact of several thermal insulators, including air, hemp wool, glass wool, rock wool, and extruded polystyrene of different thicknesses, on the heat transfer through the building's envelope. The results showed that air gap is an efficient thermal insulator compared to the other insulators under study. The authors concluded that the use of an air gap as thermal insulation in buildings located in arid regions such as Errachidia City can ensure thermal comfort for occupants, reduce energy consumption, and cut down on material costs.

Evin and Ucar (2019) present a methodology for determining the optimum thermal insulation thickness for residential building envelopes. The study includes a case study comparing 4 insulation materials for 20 different energy demand scenarios for four different cities each representing a different climatic zone of Turkey. The study finds that as heating degree-day values increase, required insulation thickness increases, with Van in the cold region requiring the highest insulation thickness. The external wall insulated with rock wool (RW) at the optimum thickness has the least total energy cost among other insulation materials, while the roof insulated with Extruded Polystyrene (XPS) or RW reduces energy cost by 77% and 82%, respectively. RW insulation material in the external wall is the most eco-efficient material among other insulation materials. The study concludes that the methodology can be replicated to other kinds of buildings and different climatic conditions, and that the results will be helpful in guiding the choice of insulation type for building envelopes in different climates.

D'Agostino *et al.* (2019) conducted an analysis of the optimal thermal insulation thickness for an office building in different climates using the "cost-optimal" methodology. They used energy simulations under dynamic conditions for a case study in Palermo, Milan, and Cairo, considering various internal thermal loads and insulation thicknesses. Their findings showed that excessive insulation in buildings with high internal thermal loads or located in hot climates could lead to higher energy consumption for cooling. The optimal insulation thickness varied for each location, with Milan requiring 8-10cm of insulation, Palermo requiring 2-4cm, and Cairo not benefiting from insulation. They also proposed a modified "cost-optimal" methodology that considered thermal comfort, resulting in a different optimal solution for Milan. The study has some limitations and suggests further investigations into cool down by ventilation and insulation with low thermal mass.

Rezaei, *et al.* (2017) review conventional, advanced, and smart glazing technologies and materials to improve indoor environments and reduce energy consumption in buildings. The authors highlight the importance of windows in energy consumption and CO2 emissions and discuss the relative merits of various glazing systems. They also suggest suitable smart technologies for hot, cool, and temperate climates and emphasize the importance of high visible transmittance and low overall heat transfer coefficient in an ideal window. Hee, *et al.* (2017) studied the impact of window glazing on energy consumption and occupant comfort in buildings. The authors emphasized the importance of natural light and the challenges of selecting an appropriate glazing that meets both energy and daylighting requirements. The study concluded that optimization techniques can balance the trade-offs between energy and daylighting requirements and that techno-economic evaluation is important to determine the suitable glazing for a building. Finally, the study suggested that dynamic glazing is more suitable for commercial buildings, while static glazing requires more substantial optimization.

Almarzouq and Sakhrieh (2018) examined the impact of glazing design and infiltration rate on energy consumption and thermal comfort in residential buildings. They examined a residential building in Amman, Jordan. To identify the best alternative design to minimize energy consumption and improve the indoor environment. The results revealed that replacing a single glazing window with a double-glazing window Argon-filled with low emissivity coating may save 24.7% of the spent energy while degrading thermal comfort by 1%. In addition, a reduced infiltration rate by 50% can save 19.4% of the energy used and enhance thermal comfort by 10%.

Chen *et al.* (2019) conducted a pilot study to investigate the effects of glazing types and daylight on participants' satisfaction and performance in a full-scale office in Beijing. Five glazing systems were tested during the heating season, and research methods included lighting measurements, subjective assessments, and reaction time tests. The study found that daylight illuminance associated with glazing types and times of day played a major role in influencing participants' visual performances, alertness, physical well-being, and relaxation. The glazing type and correlated color temperature (CCT) of daylight did not significantly affect visual responses if proper daylight illuminance could be achieved. Circadian Stimulus (CS) delivered by daylight varied in times of the day and glazing types, affecting participants' alertness and relaxation. Some glazing types could improve physical comfort and reaction time under varying daylight illuminances. However, the study's conclusions were limited to specific climate conditions, one office room, and several typical glazing types, and the impact of seasonal affective disorders was not fully considered. The authors recommended a larger range of glazing types and more accurate investigation tools for future studies.

Alam and Islam's (2017) research paper investigates the effect of external shading and window glazing on energy consumption of residential buildings in Jessore, Bangladesh. The study employs EnergyPlus software to evaluate the impact of shading and glazing on the energy transferred into or lost from the room through the fenestration areas. The authors conclude that appropriate overhangs or side fins can significantly reduce the annual energy transferred into the building. They also found that shaded simple glazing can have an energetic behavior equivalent to high-performance glazing, leading to a reduction in cost. The study suggests that selecting the best window with different glazing, overhangs, and side fins based on energy evaluation is achievable.

Dutta and Samanta (2018) compared two popular building simulation models, TRNSYS and eQUEST, to assess their relative accuracy in simulating a multizone building located in a tropical climate. Both models were validated using actual and simulated annual energy consumption data, and a model-to-model comparison was performed. The results showed that TRNSYS predicted the building's total energy consumption more accurately than eQUEST. The study also investigated the energy-saving potential of five different types of single and double glazing glasses using both simulation models. The findings revealed that the solar heat gain coefficient (SHGC) was a more important factor than U-value in reducing the cooling load of the building's energy. The study concluded that both simulation models are capable of generating building models similar to the actual case building, and that the proper selection of window glazing can significantly reduce energy consumption in tropical climates.

Previous research has investigated the optimal insulation thickness using different insulation materials and various analytical approaches. This study aims to contribute to the existing knowledge by investigating the effectiveness of thermal insulation and glazing.

2. Building description

Figure 1 depicts the detailed architectural design for the studied house, which has been built on an area of 85 m² with a height of 4 m. The house is designed to provide comfortable living spaces and includes two bedrooms, a bathroom, a living room, a dining room, a kitchen that is attached to a courtyard, and a guest room. To ensure optimal functionality and maximum utilization of space, the building has been meticulously divided into nine zones. The careful consideration of these zones allows for efficient management of the different areas of the house and enhances the overall flow and functionality of the living space.

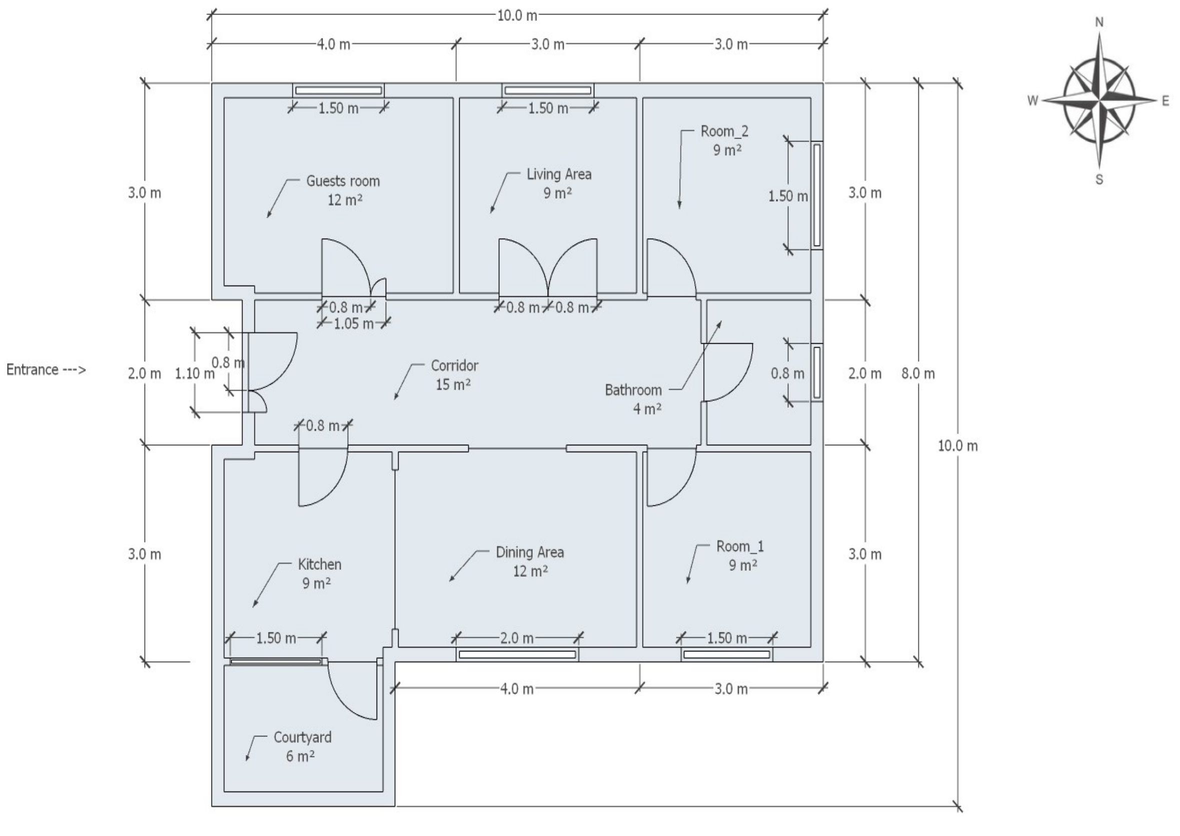


Figure 1 – House architectural design.

The architectural design of the house was created using SketchUp design software and the TRNSYS 3D Plugin tool. These software tools allow for detailed and accurate 3D modelling and simulation, enabling designers to create a realistic and comprehensive visual representation of the building. Overall, the architectural design of this house aims to provide a functional, comfortable, and aesthetically pleasing living space for its inhabitants.

3. Materials and properties

The following tables provide a comprehensive overview of the thermophysical properties of various building components, including walls, roofs, insulators, windows glazing, and operational data. These tables offer detailed information on the thermal characteristics of these elements, including thermal conductivity, Thermal Capacity, Density, and other important parameters. This data is crucial for designing and constructing energy-efficient buildings that can effectively regulate indoor temperatures and reduce energy consumption.

Table 1 summarizes the thermal and physical properties of building construction materials, along with the thickness of each layer of building materials used for both walls and roofs. The information presented in the table provides a detailed overview of the layers of materials used in the construction of these building components, starting from the inside to the outside.

Table 1 – Layers and thermophysical properties of building materials.

	Thickness [cm]	Thermal Conductivity [W/m. K]	Thermal Capacity [kJ/kg. K]	Density [kg/m^3]
External walls				
Plaster	1	0.351	1	1500
Parping	20	1.053	0.65	1300
Cement mortar	2	1.15	1	1700
Concrete	2	1.755	0.65	2100
Internal walls				
Mortar	2.5	1.15	0.84	2000
Hollow Brick	10	1.15	0.878	1800
Mortar	2.5	1.15	0.84	2000
Roof				
Plaster	1	0.351	1	1500
Polystyrene	4	0.0361	1.25	25
Reinforced Concrete	4	1.755	0.92	2300
Hourdis	16	1.23	0.65	1300
Reinforced Concrete	4	1.755	0.92	2300
Cement Mortar	10	1.15	1	1700
Floor Tile	1	1.75	0.7	2300

The thermal conductivity, thermal capacity, and density of various insulation materials are listed in table 2. These properties are important for selecting the most appropriate insulation material for a building, as they determine how well the material will perform in terms of heat retention and energy efficiency.

Table 2 - Properties of insulation materials.

	Thermal Conductivity [W/m. K]	Thermal Capacity [kJ/kg. K]	Density [kg/m^3]
Expanded Polystyrene	0.0442	1.45	20
Glass Wool	0.0417	0.84	12
Rock Wool	0.0444	0.92	300
Wood Fibre	0.0383	1.95	180

Table 3 provides a detailed list of features for each glazing and frame, including the overall heat transfer coefficient and solar energy transmittance. These properties are important for selecting the most suitable glazing and frame for a building, as they determine how much heat is transmitted through the glass and frame and how much solar energy is absorbed.

Table 3 - Properties of glazing alternatives.

	U-Value [1]	g-Value [2]	Frame	Frame U-Value
Simple	5.74	0.87	Aluminium	2
Double	2.95	0.777	Aluminium	2
Triple	2	0.7	Aluminium	2
Double, Low-e	1.76	0.597	Aluminium	2
Double, Low-e, Ar	1.43	0.596	Aluminium	2

[1] *U-Value:* Overall heat transfer coefficient.
[2] *g-Value:* Solar energy transmittance of windows.

Table 4 provides detailed information regarding the orientation, length, and width of windows in a building. The table also contains the position of each window, which indicates the window's height from the ground. These factors are essential for determining the amount of natural light and ventilation that enters the building through the windows.

Table 4 - Windows orientation and dimensions.

Zones	Orientation	Height x Width [m]	Position [1] [m]
Kitchen	South	1.20 x 1.50	1.10
Dining Area	South	1.20 x 2.0	1.10
Room 01	South	1.20 x 1.50	1.10
Bathroom	East	0.8 x 0.8	2.0
Room 02	East	1.20 x 1.50	1.10
Living Area	North	1.20 x 1.50	1.10
Guests Room	North	1.20 x 1.50	1.10

Table 5 presents the operational data for the studied house and includes important details regarding the comfort temperature range for both winter and summer, as defined by ASHRAE criteria (ASHRAE Handbook of Fundamentals 2005). Additionally, the table provides information on the set temperature for heating and cooling settings, which is essential for ensuring optimal thermal performance and energy efficiency in the building.

Table 5 - The operational data.

Temperature Set Range [1]	Winter	20.3-24.3 °C
	Summer	24.3-26.7 °C
Heating Set Point	20.3°C	
Cooling Set Point	26.7°C	

[1] Comfort temperature range selected according to ASHRAE criteria.

4. Meteorological data

The Wilaya of Ain Temouchent has a Mediterranean climate, characterized by hot summers and temperate winters. Although the climatic regime is characterized by winds that generally bring little humidity (winds from the North - West, South - East direction), these winds lose a large part of their humidity during their passage over the Moroccan and Spanish reliefs. In addition, the southern reliefs (SEBAA - CHIOUKH, TESSALA, MONTS DE TLEMCEN) have a favorable influence by hindering the arrival of dry and hot continental winds from the South (SIROCCO).

Usually:

- An average annual temperature of 17.4 °C;
- The average precipitation is 485 mm;

- July is the hottest month of the year. The average temperature is 25.7 °C at this time. In January, the average temperature is 10.8 °C. January is therefore the coldest month of the year;
- A difference of 73 mm is recorded between the driest month and the wettest month. 14.9 °C variation is displayed over the whole year (Agence Nationale de développement de l'Investissement 2015).

Meteonorm program provided meteorological data of Ain Temouchent. The generated weather file presented the ambient temperature, humidity, wind speed and direction, precipitation, solar radiation, sunshine duration and soil temperature. In addition, the ambient temperature is interpolated using data from six weather stations at Beni-Saf (9 km), Oran (68 km), Tlemcen (42 km), Melilla (152 km), Taoumia (150 km), Oujda (88 km) (Meteonorm V7.1 2016).

Figure 2 illustrates the monthly variation of ambient temperature, including the monthly maximum, minimum, and average temperatures. The lowest recorded temperature was 4.85 °C in January and the highest was 29.65 °C in July, with an annual average temperature of 17.30 °C. Given these temperature extremes, we will concentrate our investigation on January and July to ensure that the building's design and systems can provide adequate heating and cooling during the coldest and hottest months, respectively.

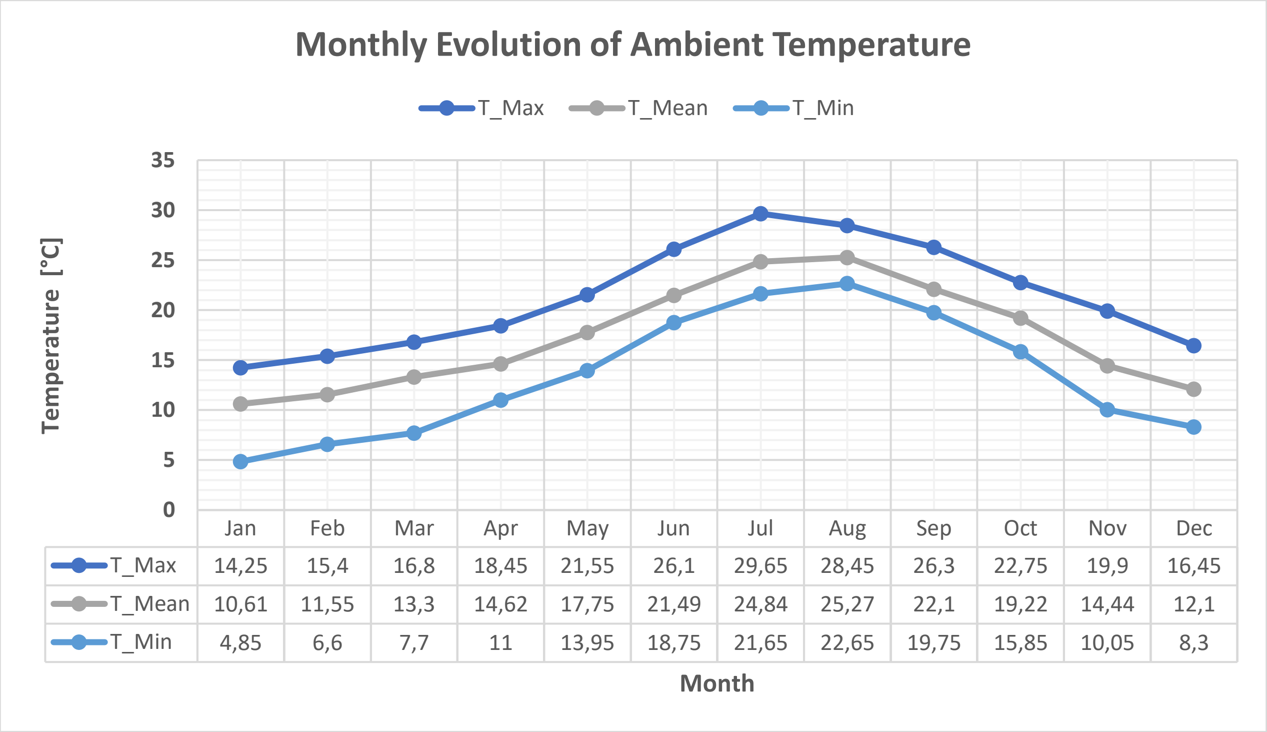


Figure 2 – Monthly variation of ambient temperature.

5. Methodology

The methodology presented in the study involves analysis and investigation of the energy efficiency and thermal comfort of a traditional house in Ain-Temouchent city. The first step is to identify major deficiencies in the house, which are then used to provide suggestions for reducing energy consumption and improving the indoor environment through the use of passive strategies. Subsequently, the methodology involved conducting simulations of various types of insulators with varying thicknesses. The simulations were aimed at assessing the effectiveness of the insulation materials and determining their impact on both the internal thermal comfort of the building and energy consumption. Additionally, the same simulation process was used to evaluate different types of glazing in order to determine the most optimal option.

To conduct the simulation, we used the TRNSYS 17 software, which is a reliable tool for modelling the behavior of buildings. This software was used to simulate the performance of different insulation materials and glazing types, with a focus on evaluating their thermal and energy performance in the Mediterranean region.

To determine the optimal insulation and thickness, we compared the results of the simulations for each insulation material and thickness, evaluating the impact on energy consumption and internal thermal comfort. We also assessed the best types of glazing based on their performance in reducing heating and cooling costs and internal thermal comfort.

To enhance the clarity of the methodology, a flowchart has been illustrated in Figure 3 which will represent the research process. This methodology allowed us to determine the most effective insulation material and thickness, as well as the best types of glazing, which can be used to design and construct energy-efficient buildings in the Mediterranean region.

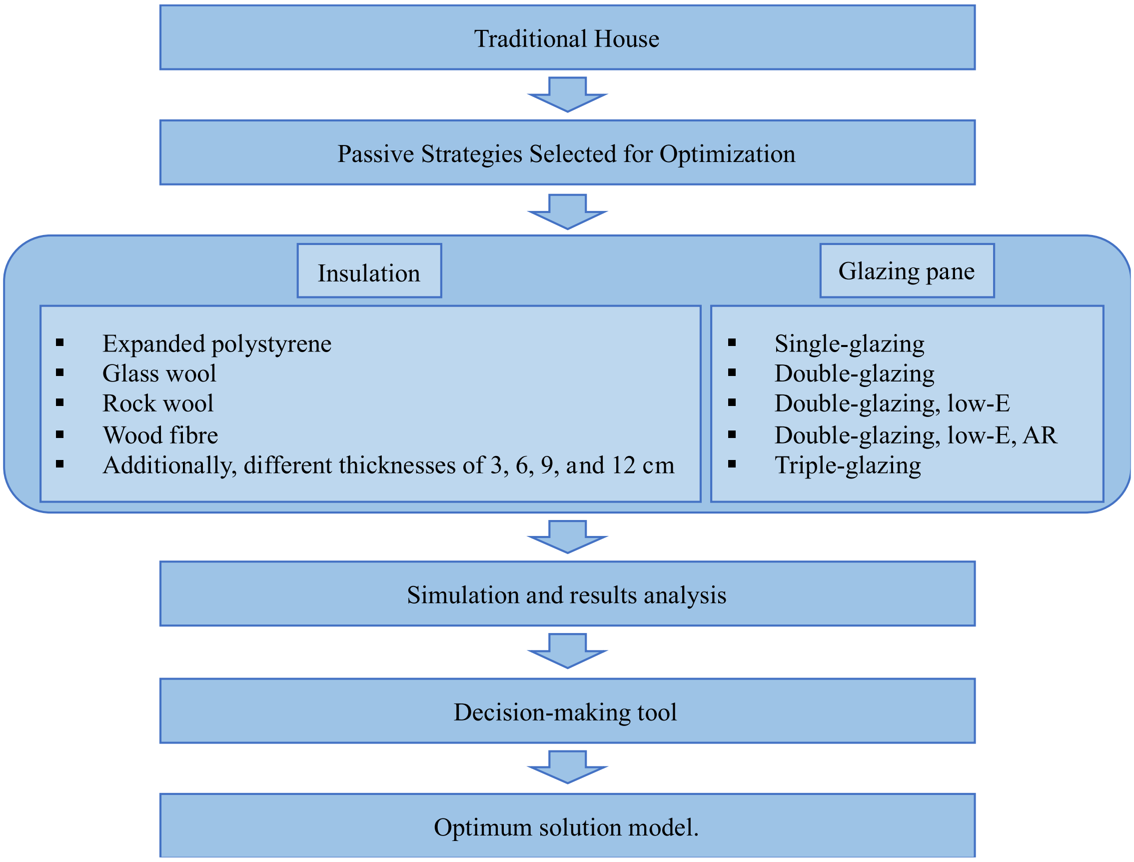


Figure 3 – Flowchart of the research methodology.

5.1 Hypotheses

- The investigated house has four outside facades, and the roof is exposed outside;
- The thermophysical properties of the materials used are obtained entirely from the TRNSYS 17 library and used research papers in the literature review;
- Meteorological data of the city of Ain Temouchent was provided from the Meteonorm program (Meteonorm V7.1 2016);
- The infiltration rate is calculated via the computed empirical relation used in various research publications. the infiltration rate equation is

$$Infiltration = 0.07 \,.\, V_{Wind} + 0.4 \quad [ACH] \tag{9}$$

Where V_{Wind} expresses the wind velocity [m/s];

- The temperature of the soil is obtained from the Ain Temouchent meteorological file generated from the Meteonorm program (Meteonorm V7.1 2016);
- The internal gains (Equipment, Lights and People) is zero (unoccupied house);

- Thermal bridges are not taken into account;
- The simulation time step is one hour.

6. Results and discussion

To conduct the simulation, TRNSYS 17 simulation program was used. The house was divided into nine zones, as shown in Figure 1, with the courtyard zone assumed to be a shaded group during the architectural design modelling process in SketchUp software using the TRNSYS 3D-Plugin.

Figure 4 displays the yearly ambient temperature variations in Ain Temouchent. The ASHRAE Standard-55 criteria (ASHRAE Handbook of Fundamentals 2005) divides the temperature readings into two comfort zones for winter and summer, illustrated in Figure 4. The range for winter comfort is 20.3-24.3°C, while that for summer is 24.3-26.7°C. Winter comfort spans December 21 to June 21, which encompasses the winter and spring seasons, while summer comfort ranges from June 21 to December 21, comprising summer and fall seasons. Within a year, 30% of the hours achieved thermal comfort, which amounts to 590 hours for winter and 744 hours for summer. These results provide valuable insights into the amount of time during which residents could expect to experience comfortable indoor temperatures in Ain Temouchent.

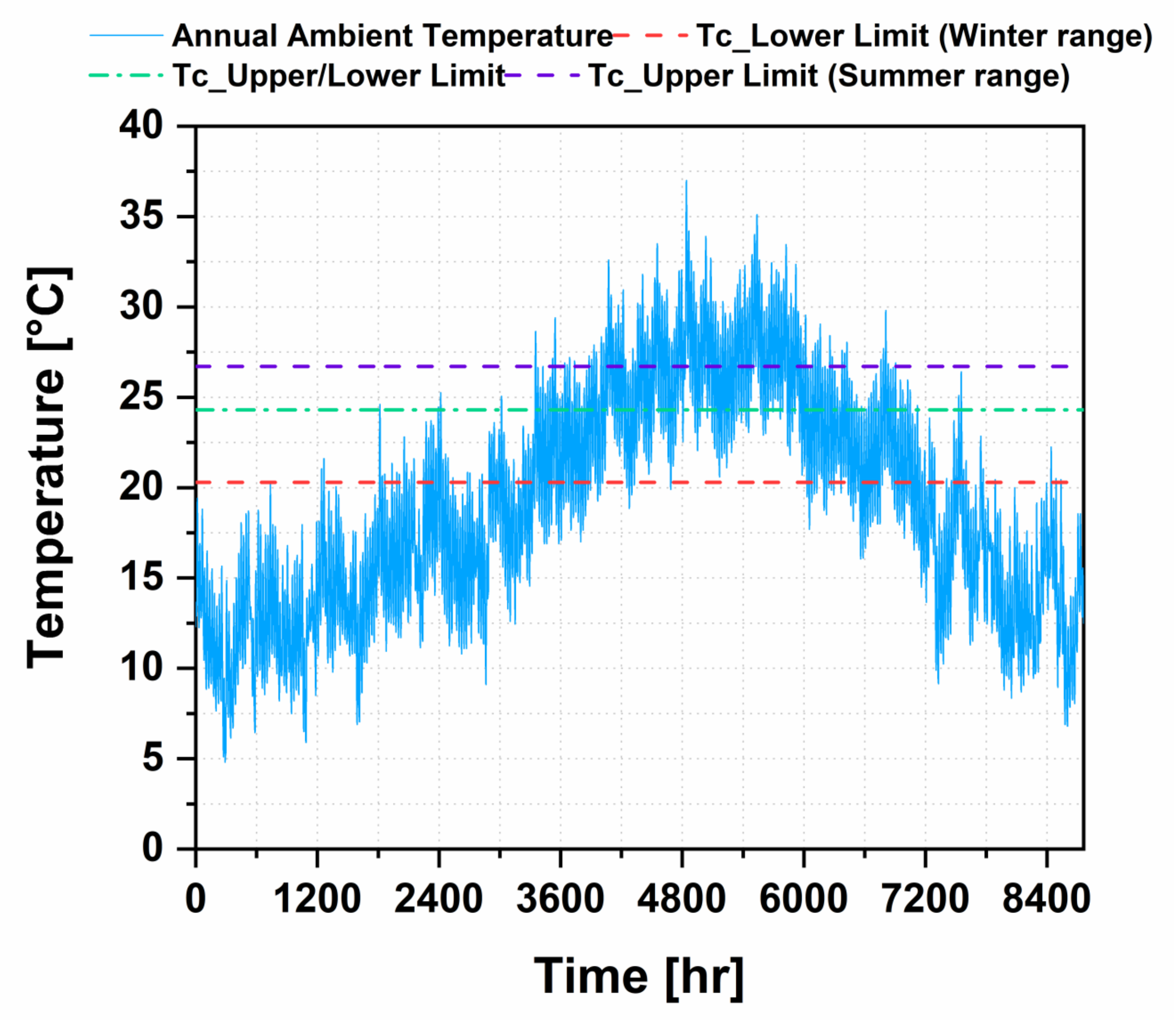


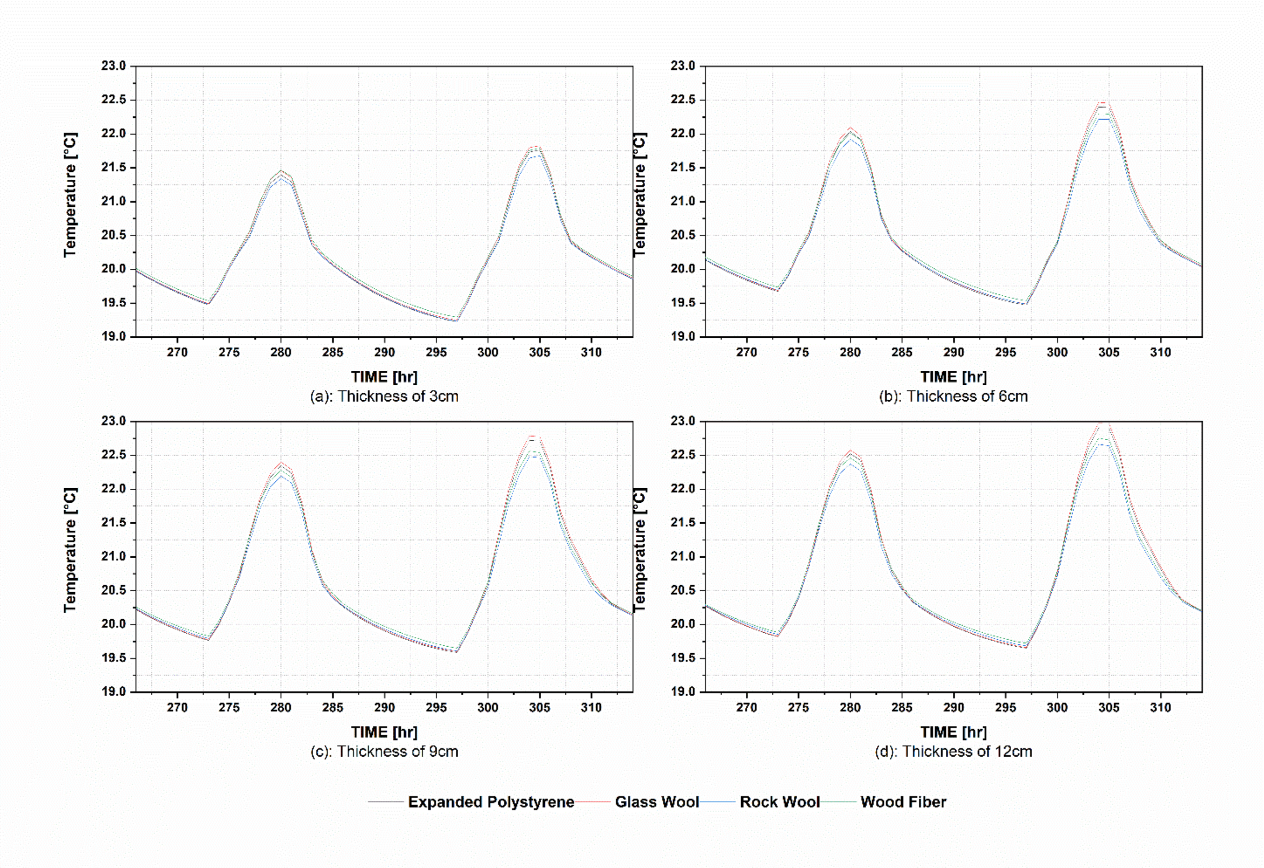
Figure 4 – Temperature evolution of the city of Ain Temouchent over a year.

6.1 The effect of insulators of varied thicknesses on the indoor environment and energy consumption

The simulation was carried out assuming that the window design contains a single pane of glass, as shown in the glass type in Table 3.

Thermal behavior: After conducting the simulation, the results were presented for a 48-hour timeframe, highlighting the most extreme temperatures: the lowest temperatures in January and the highest temperatures in July. This section focuses on presenting the findings of our study, which aimed to track the fluctuations in the indoor temperature of Room 1. As the temperature is one of the critical factors that affect the indoor environment's thermal comfort, we aimed to investigate the changes in Room 1's temperature over time. By monitoring these variations, we can gain insights into the effectiveness of insulators with different thicknesses in maintaining a comfortable indoor environment. Therefore, in this section, we provide a detailed analysis of the indoor temperature fluctuations in Room 1 and the impact of various insulators on thermal comfort.

Figures 5 and 6 illustrate the fluctuations in the internal temperature of room 1 with types of insulation of various thicknesses. Specifically highlight the maximum and minimum temperatures observed during the year, which correspond to the months of January and July.



(a): Thickness of 3cm

(b): Thickness of 6cm

(c): Thickness of 9cm

(d): Thickness of 12cm

Figure 5 – January temperatures with varying thicknesses of insulating materials where: (a) 3 cm; (b) 6 cm; (c) 9 cm; (d) 12 cm.

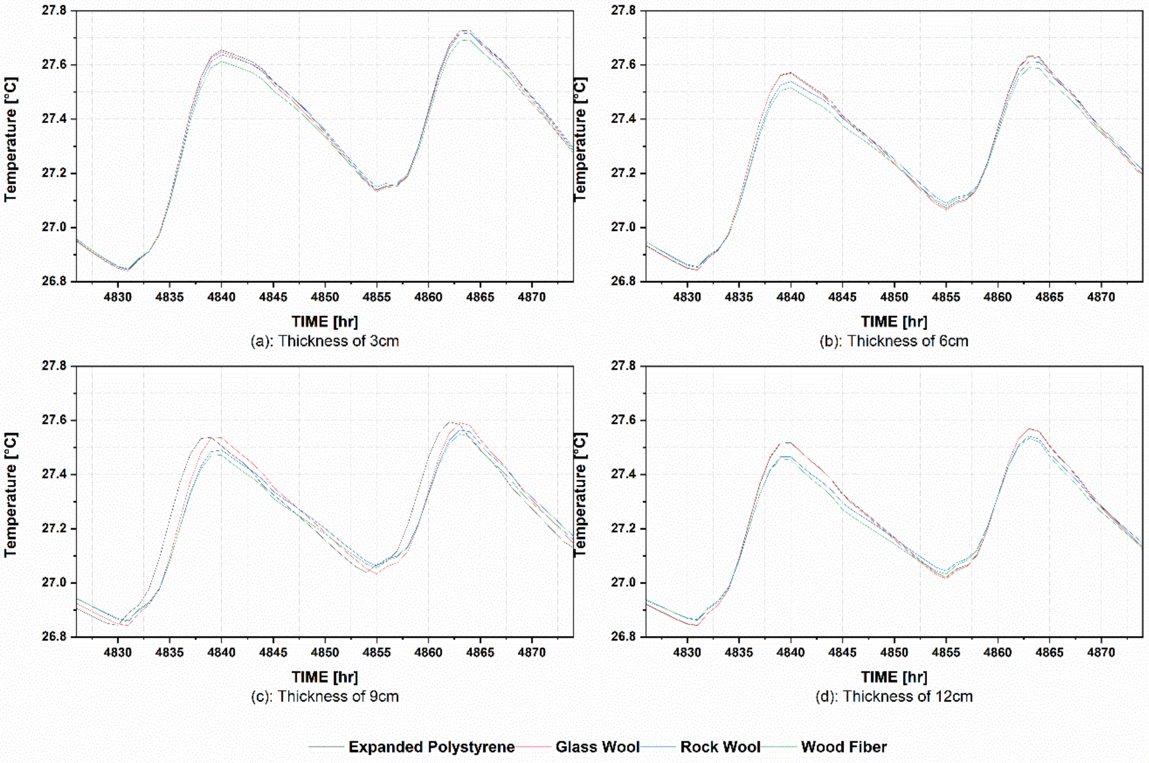
Figure 5 presents an analysis of the internal temperature variations in January for different types of insulation materials of varying thicknesses. The figure is divided into four subfigures, where each subfigure shows the temperature readings for a particular insulation thickness.

Upon examining Figure 5a, it is clear that when the insulation thickness is 3 cm, the wood fiber insulation material exhibits the highest temperature of 0.05°C compared to the other insulation materials. Thus, in this case, wood fiber can be regarded as the best insulator among the other materials. Moving on to Figure 5b, which represents the temperature readings for a thickness of 6 cm, both wood fiber and glass wool insulation materials recorded the highest temperature, with a difference of 0.04°C compared to expanded polystyrene and rock wool insulation materials. As a result, both wood fiber and glass wool are deemed to offer the best insulation in this particular case.

Figure 5c shows the temperature readings for an insulation thickness of 9 cm. In this case, wood fiber insulation material recorded a temperature that is 0.02°C higher than glass wool insulation material, and 0.04°C and 0.06°C higher than expanded polystyrene and rock wool insulation materials, respectively. Thus, in comparison, wood fiber insulation material offers the best temperature among the other insulation materials for this particular insulation thickness.

Finally, Figure 5d represents the temperature readings for an insulation thickness of 12 cm. In this case, wood fiber insulation material recorded the best results with a temperature that is 0.02 °C, 0.03°C and 0.06°C higher than glass wool, polystyrene and rock wool insulation materials, respectively. Therefore, from Figure 5, we can conclude that in the case of an insulation thickness of 3 cm, 6, 9, and 12 cm, wood fiber is the best insulator and exhibits the highest temperature compared to other insulation materials.

Figure 6 illustrates the fluctuations in internal temperature during the hottest month of the year, which is July. As we can see from Figure 6a, wood fiber has recorded the lowest temperature compared to other insulators, which indicates that it performs better in preventing heat from entering the room. This could be because of the unique structure of wood fiber insulation, which offers high thermal resistance, making it an excellent insulator for hot temperatures.



(a): Thickness of 3cm

(b): Thickness of 6cm

(c): Thickness of 9cm

(d): Thickness of 12cm

Figure 6 – July temperatures with varying thicknesses of insulating materials where: (a) 3 cm; (b) 6 cm; (c) 9 cm; (d) 12 cm.

Moreover, Figures 6b and 6c show that when the thickness of the insulation is 6 cm and 9 cm, wood fiber provided the best insulation performance, resulting in a lower temperature of 0.01°C compared to each insulator, glass wool, and rock wool, and 0.02°C compared to expanded polystyrene. This is a significant result as it indicates that wood fiber is an excellent insulator for different thicknesses and can maintain the internal temperature at the lowest point compared to other insulators. The lower the internal temperature, the less the need for air conditioning and cooling systems, which reduces energy consumption and costs.

Furthermore, Figure 6d highlights that when the insulation thickness is 12 cm, wood fiber performs the best as an insulator, offering a lower temperature of 0.01°C compared to glass wool and 0.02°C compared to expanded polystyrene and rock wool. This indicates that wood fiber is the most effective insulation material in preventing heat transfer, which can be beneficial in reducing energy consumption and costs associated with cooling systems in the summer months.

In conclusion, these results demonstrate that wood fiber is the most efficient insulation material for reducing heat transfer and maintaining a lower temperature inside the room during the hottest months of the year. By choosing the right insulation material and thickness, we can reduce energy consumption and costs associated with cooling systems, and contribute to a more sustainable and energy-efficient future.

Based on the analysis presented in Figures 5 and 6, it can be concluded that the selection of insulation materials and their thicknesses can have a significant impact on the internal temperature of indoor environments, particularly in extreme weather conditions such as in the winter and summer months. Wood fiber insulation material is found to be the best among the other insulation materials, and it performs better when the outside temperature is low, and it offers the best insulation performance for different thicknesses, resulting in a lower temperature compared to other insulators. On the other hand. By selecting the right insulation material and thickness, we can reduce energy consumption and costs associated with heating and cooling systems, which contributes to a more sustainable and energy-efficient future.

Energy behavior: In this particular section, the main emphasis is on the computation of the yearly heating and cooling requirements for each insulation material and thickness, as shown in Figures 7 and 8. The primary objective is to determine which of these insulators has the potential to offer the most effective energy-saving. The results of this analysis have been compiled in the form of annual heating and cooling load data for each insulation material and thickness.

These figures provide a clear visual representation of the energy consumption required to maintain a desired temperature within a given space throughout the year. By comparing the data for different insulation materials and thicknesses, it becomes possible to identify which materials offer the most efficient thermal insulation and which thicknesses provide the optimal balance between insulation performance and cost-effectiveness.

Ultimately, the aim of this analysis is to provide valuable insights into the most effective ways of reducing energy consumption and lowering heating and cooling costs also reduces the environmental impact of energy consumption. By choosing the appropriate insulation material and thickness.

Figure 7 depicts the annual heating demands associated with different insulators and thicknesses. The results show that there are significant differences in energy usage depending on the type of insulator and thickness chosen.

When the insulation thickness is either 3 cm or 6 cm, we observe that significant energy savings of 4% compared to glass wool and 6% compared to both expanded polystyrene and rock wool can be achieved. This indicates that at these thicknesses, certain insulators are more effective in reducing heating demands and offer better energy savings compared to others.

Additionally, when the insulation thickness is increased to 9 cm and 12 cm, the results show that using wood fiber insulation can lead to considerable energy savings. Specifically, when compared to glass wool, rock wool, and expanded polystyrene, using wood fiber insulation can result in savings of 4%, 5%, and 6% respectively. This suggests that at higher insulation thicknesses, wood fiber insulation is a more efficient option for reducing heating demands and improving energy efficiency.

It is worth noting that the thickness of the insulation material is also a critical factor in determining its effectiveness. The thicker the insulation material, the better its performance at reducing heating demands. This is illustrated in Figure 7, where thicker insulation materials consistently require less heating compared to thinner ones.

In fact, when comparing the performance of wood fiber insulation to other insulation materials across all thicknesses tested, wood fiber consistently outperforms other materials by saving more than 4% in heating load reduction. This reinforces the idea that wood fiber insulation is a reliable and effective choice for energy-efficient building design.

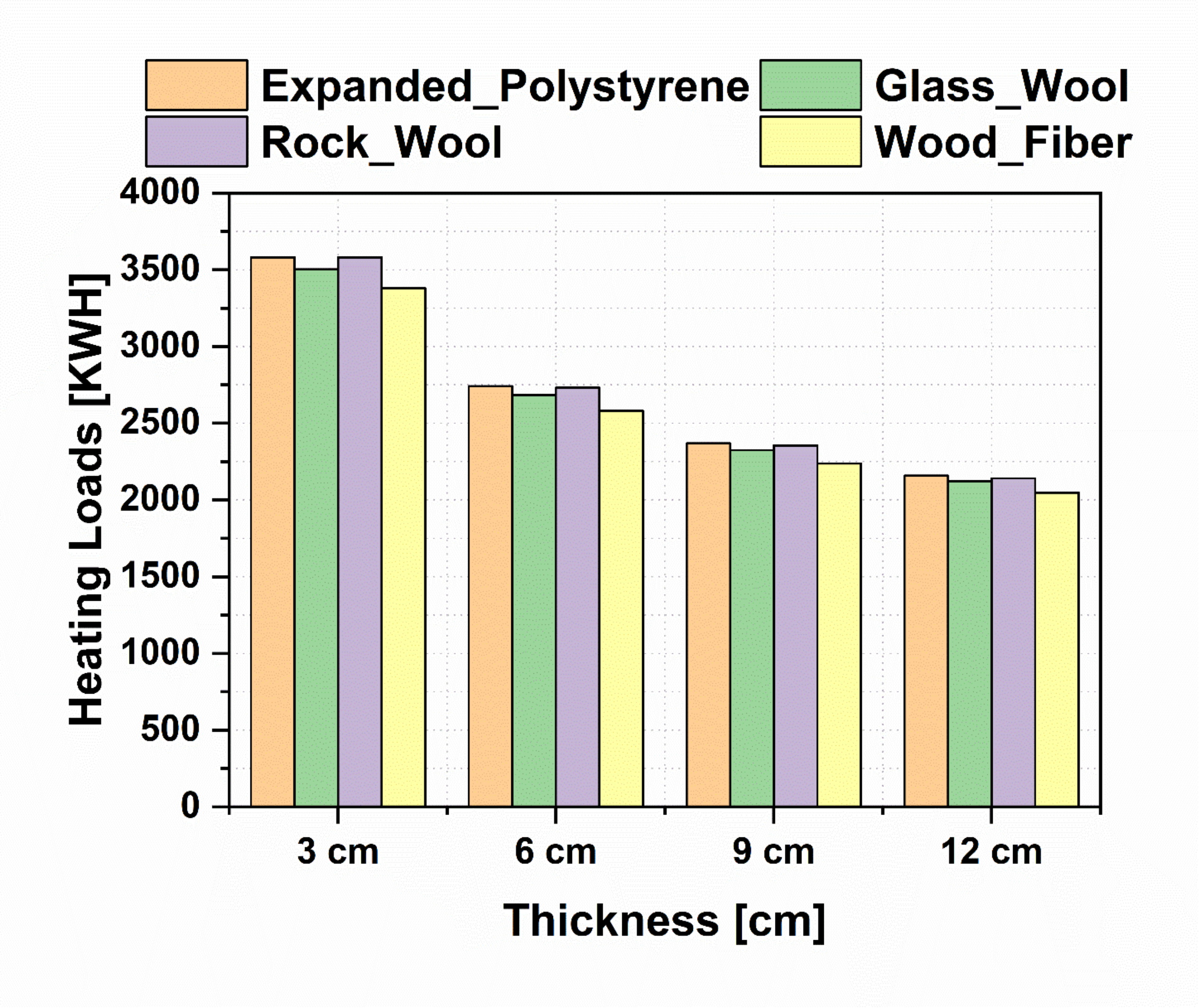


Figure 7 – Heating loads for the insulators with various thicknesses.

Turning to Figure 8, we can see that wood fiber insulation also offers some savings in terms of cooling load reduction, with reductions of 1% to 2% across all thicknesses and compared to other insulation materials. While these savings may not be as significant as those associated with heating load reduction, they are still notable and can contribute to overall energy efficiency and cost savings in a building.

These results highlight the effectiveness of wood fiber insulation as a choice for reducing both heating and cooling loads. By selecting an insulation material and thickness that offer the best performance in terms of reducing both heating and cooling demands, significant energy savings can be achieved, resulting in cost savings and environmental benefits.

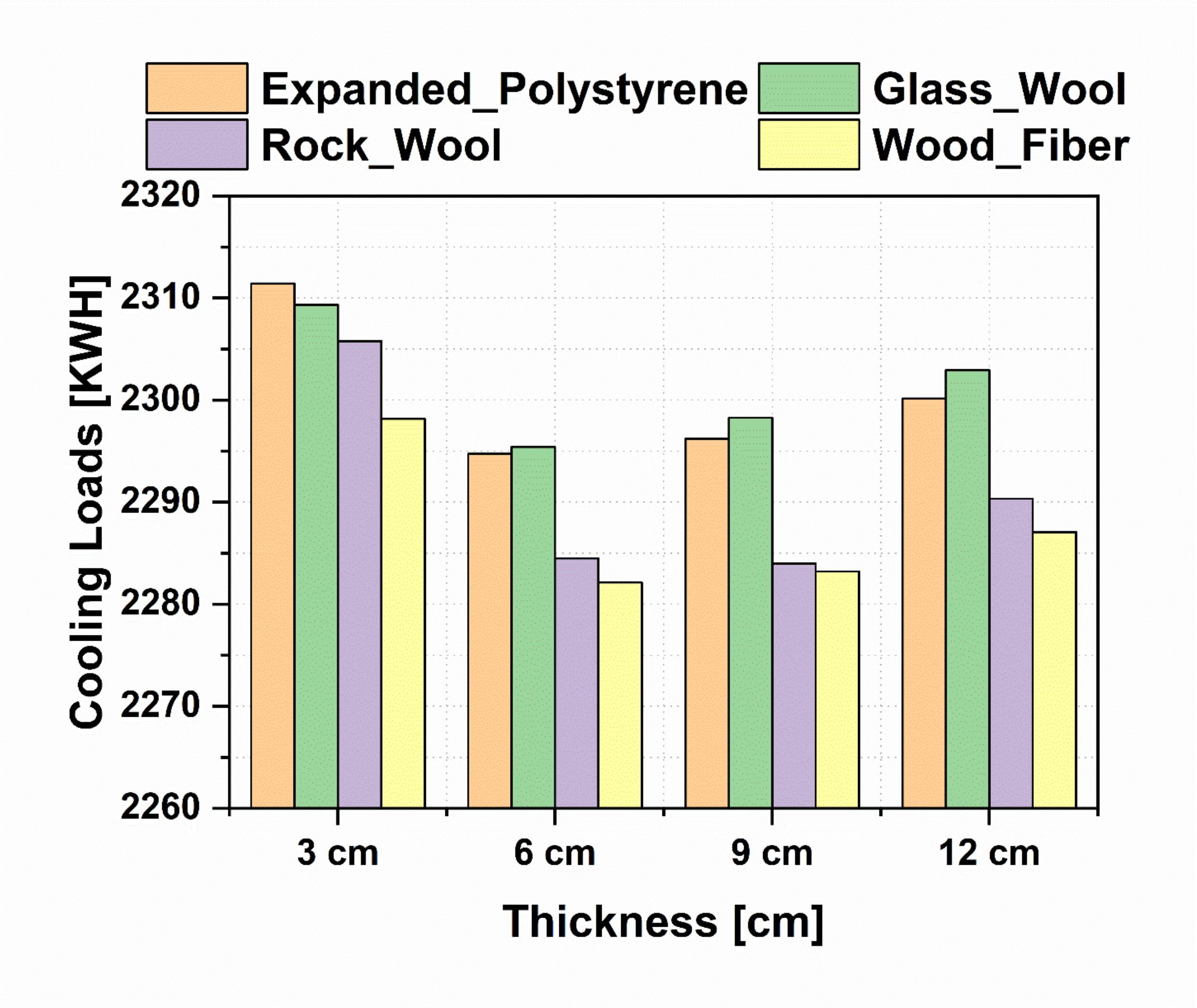


Figure 8 – Cooling loads for the insulators with various thicknesses.

We can conclude that the selection of insulation material and thickness plays a critical role in reducing energy consumption and achieving cost savings in a building. The study indicates that wood fiber insulation consistently outperforms other insulation materials across different thicknesses tested in terms of reducing heating load. Furthermore, wood fiber insulation also offers some savings in terms of cooling load reduction, contributing to overall energy efficiency and cost savings. The study suggests that selecting an insulation material and thickness that offer the best performance in reducing both heating and cooling demands can lead to significant energy savings, resulting in cost savings and environmental benefits. However, it is essential to consider various factors such as climate, building design, construction materials, and intended use when selecting insulation materials and thicknesses. We can conclude that the selection of insulation material and thickness plays a critical role in reducing energy consumption and achieving cost savings in a building. The study indicates that wood fiber insulation consistently outperforms other insulation materials across different thicknesses tested in terms of reducing heating load. Furthermore, wood fiber insulation also offers some savings in terms of cooling load reduction, contributing to overall energy efficiency and cost savings. The study suggests that selecting an insulation material and thickness that offer the best performance in reducing both heating and cooling demands can lead to significant energy savings, resulting in cost savings and environmental benefits. However, it is essential to consider various factors such as climate, building design, construction materials, and intended use when selecting insulation materials and thicknesses.

In this context, it was observed that increasing insulation thickness beyond a certain limit does not lead to significant improvements in energy savings. Thus, to optimize the balance between insulation performance and cost-effectiveness, insulation with a thickness of 9 cm was selected.

The analysis also compared the effectiveness of different insulation materials in terms of reducing heating and cooling loads. Based on the results obtained, wood fiber insulation was found to be the best insulator. This conclusion was drawn by monitoring the internal temperature of room 1 and analyzing the annual heating and cooling loads for each insulation material and thickness.

Figures 9 and 10 demonstrate the changes in indoor thermal fluctuations and the resulting energy savings achieved through the modification of wood fiber insulation thickness. The study revealed that adjusting the thickness of wood fiber insulation from 3 cm to 9 cm resulted in a savings of over 23% of the heating and cooling loads.

The results obtained from this analysis provide strong justifications for using wood fiber insulation with a thickness of 9 cm. This choice can help to achieve significant energy savings, reduce heating and cooling costs, and minimize the environmental impact of energy consumption.

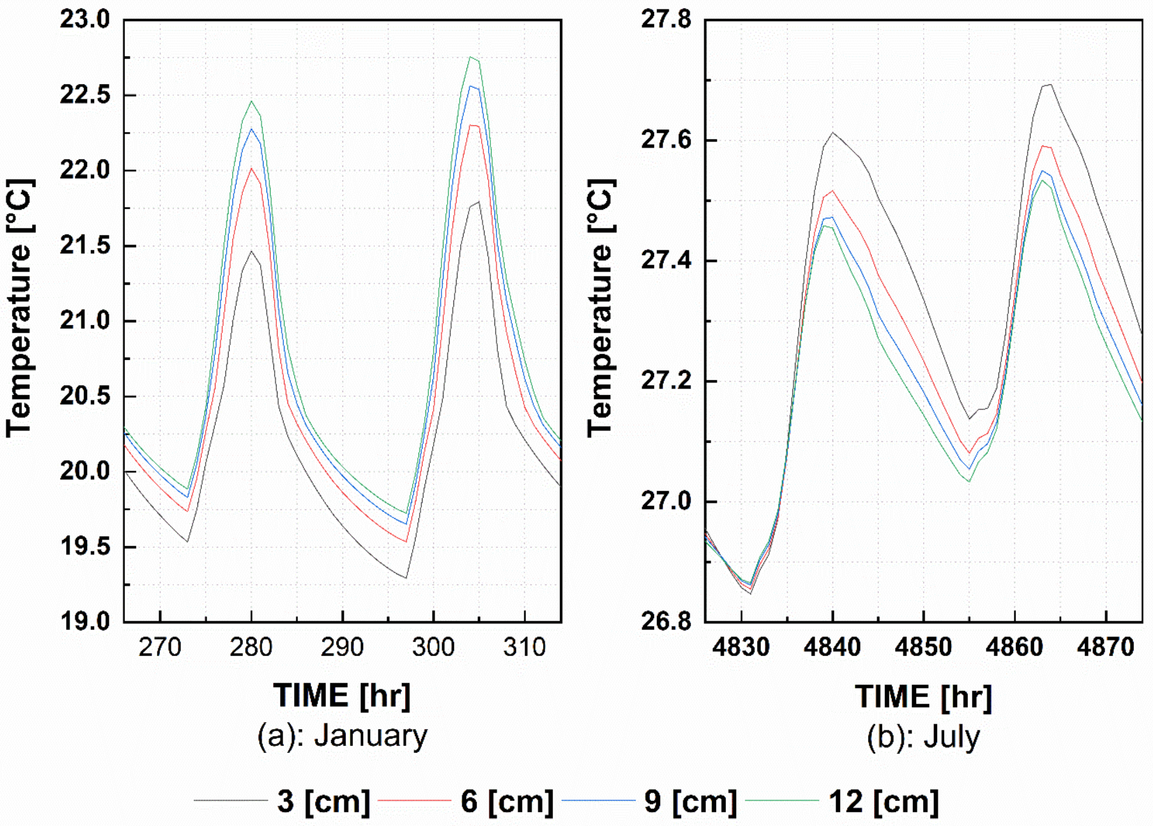


Figure 9 – Distribution of the insulator wood fiber temperature where: (a) January; (b) July.

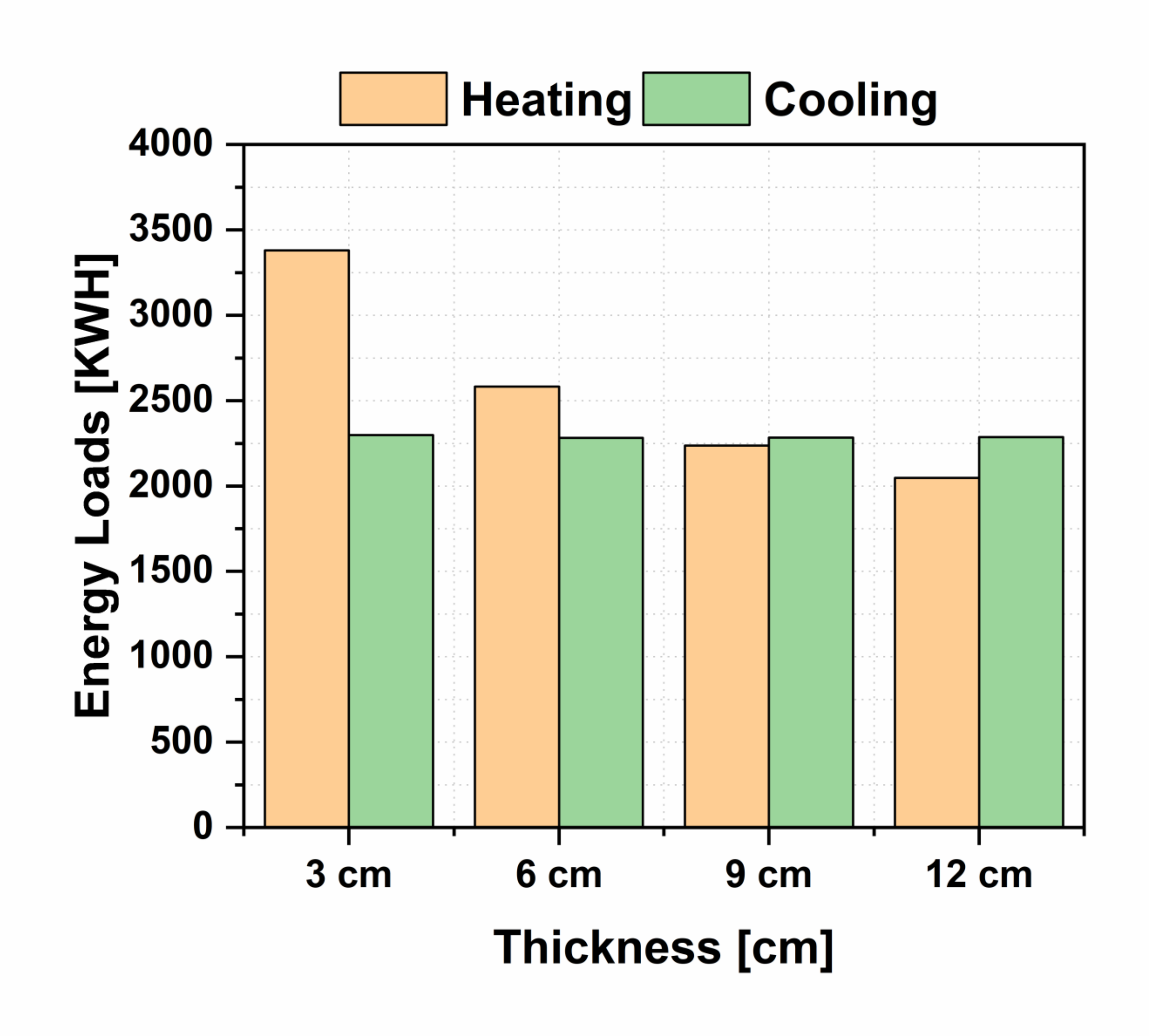


Figure 10 – Heating and cooling requirements for the insulator wood fiber.

Based on the results obtained from the analysis of the annual heating and cooling requirements for different insulation materials and thicknesses, using wood fiber insulation with a thickness of 9 cm can provide the most effective energy-saving. The results of this analysis, as depicted in Figures 7, 8, 9, and 10, indicate that the insulation thickness is a critical factor in determining the efficiency of the insulation material, and thicker insulation materials generally perform better at reducing heating and cooling demands.

Moreover, the results show that wood fiber insulation outperforms other insulation materials across all thicknesses tested, by offering energy savings of more than 4% in heating load reduction compared to other insulators. Specifically, when the insulation thickness is 9 cm, using wood fiber insulation can result in energy savings of 4% compared to glass wool, 5% compared to rock wool, and 6% compared to expanded polystyrene.

Based on these findings, it can be concluded that using wood fiber insulation with a thickness of 9 cm can provide a balance between insulation performance and cost-effectiveness, resulting in significant energy savings and cost reductions for heating and cooling loads. Therefore, if the objective is to reduce energy consumption and lower heating and cooling costs while reducing the environmental impact of energy consumption, then using wood fiber insulation with a thickness of 9 cm can be a suitable choice.

Comparison of present results with previous studies: In this section, some previous studies (Eddib and Lamrani 2019; Lamya *et al*. 2021) have been compared with our investigation. In terms of similarities, the studies aim to investigate the impact of different insulation materials and thicknesses on the energy efficiency and thermal comfort of buildings under different climatic conditions. They use numerical simulations to evaluate the performance of different insulation materials and thicknesses and provide recommendations for the most suitable materials and thicknesses for specific climates. Additionally, all studies emphasize the importance of proper insulation for reducing energy consumption, improving indoor comfort, and achieving sustainable building designs.

In terms of differences, the studies differ in their geographic scope, insulation materials and thicknesses evaluated, and specific findings. Eddib and Lamrani 2019, studied the impact of different insulation materials, including expanded Polystyrene, glass wool, rock wool, and wood fiber of different thicknesses (2 cm, 4 cm, 6 cm, and 8 cm) on the thermal and energetic performance of the envelope of a house located in Marrakesh City, Morocco. On the other hand. Lamya *et al*. 2021, studied the impact of arid climate on indoor thermal comfort in the South-East of Morocco and focuses on evaluating the impact of different insulation materials, including air gap, hemp wool, glass wool, rock wool, and extruded polystyrene of different thicknesses (5 cm, 10 cm, and 15 cm) on the heat transfer through an administrative building's envelope in Errachidia City, Morocco.

Similarly, the study on evaluating the impact of insulation and glazing on the energy efficiency of houses in the Mediterranean climate focuses on determining the optimal thermal insulation and the best glazing for the building envelope in the Mediterranean region where the province of Ain Temouchent, Algeria, was taken in this study.

In terms of results, both studies found that wood fiber insulation provided the best thermal performance. Eddib and Lamrani (2019) found that an 8 cm thickness of wood fiber insulation was the most effective, resulting in a 7% reduction for heating and 14% for cooling loads. The current study found that wood fiber insulation with a 9 cm thickness provided the best thermal performance, resulting in a 26% reduction in energy costs compared to 3cm of expanded polystyrene. Regarding temperature changes, Eddib and Lamrani (2019) found that in January, temperatures were higher by 0.26°C, and in July, temperatures were lower by 0.49°C. The current study found that in January, temperatures were higher by 0.47°C, and in July, temperatures dropped by 0.13°C. Overall, both studies provide valuable insights into the effectiveness of different insulation types and optimal thicknesses in their respective regions.

As a conclusion for this section, it can be mentioned that all studies provide valuable insights into the importance of proper insulation and glazing for reducing energy consumption, improving indoor comfort, and achieving sustainable building designs under different climatic conditions. They demonstrate the significance of choosing the right insulation materials and thicknesses for specific climates and building designs and emphasize the need for further research and experimentation to validate the numerical results found.

Table 6 - Comparison with previous studies.

Researchers	Location	Climate zones (Köppen climate classification)	Optimum Insulators	Optimum insulation thickness (cm)	Results
Present study	Ain Temouchent, Algeria	Mediterranean climate	Wood fibre	9	Energy saving 26%
Eddib and Lamrani 2019	Marrakesh, Morocco	Semi-arid climate	Wood fibre	8	Energy saving 21%
Lamya *et al*. 2021	Errachidia, Morocco	Arid Climate	Air gap	5	Heat transfer

6.2 The influence of glazing on the interior environment and energy loads

This section deals with the investigation of how glazing affects the indoor environment of room 1 and the heating and cooling loads of the entire building. Glazing refers to the transparent part of a building's façade that allows natural light into the interior spaces. The amount and type of glazing used in a building can have a significant impact on the building's energy consumption and indoor environment.

The investigation involved monitoring the indoor environment of room 1 and the heating and cooling loads of the entire building under different glazing conditions. By measuring the temperature and humidity levels in room 1 and the energy consumption of the building's heating and cooling systems, the impact of glazing on the building's energy performance and the indoor environment was assessed.

The findings of this investigation are critical for building designers and owners as they determine the optimal glazing conditions that balance energy efficiency and occupant comfort. By understanding how glazing affects the building's energy consumption and indoor environment, it is possible to make informed decisions about the design and construction of a building's façade.

Thermal behavior: This part of the study aimed to investigate the influence of glazing on the indoor environment of the building. Glazing is a critical element in the building envelope that can affect the thermal comfort of occupants. Therefore, this study explored the impact of various types of glazing on the indoor environment.

The types of glazing studied in this research included triple, double, and simple glazing, with different levels of emissivity and Argon filling. Figure 11 summarizes the results of the study, showing the indoor temperature during the winter and summer seasons for January and July, respectively.

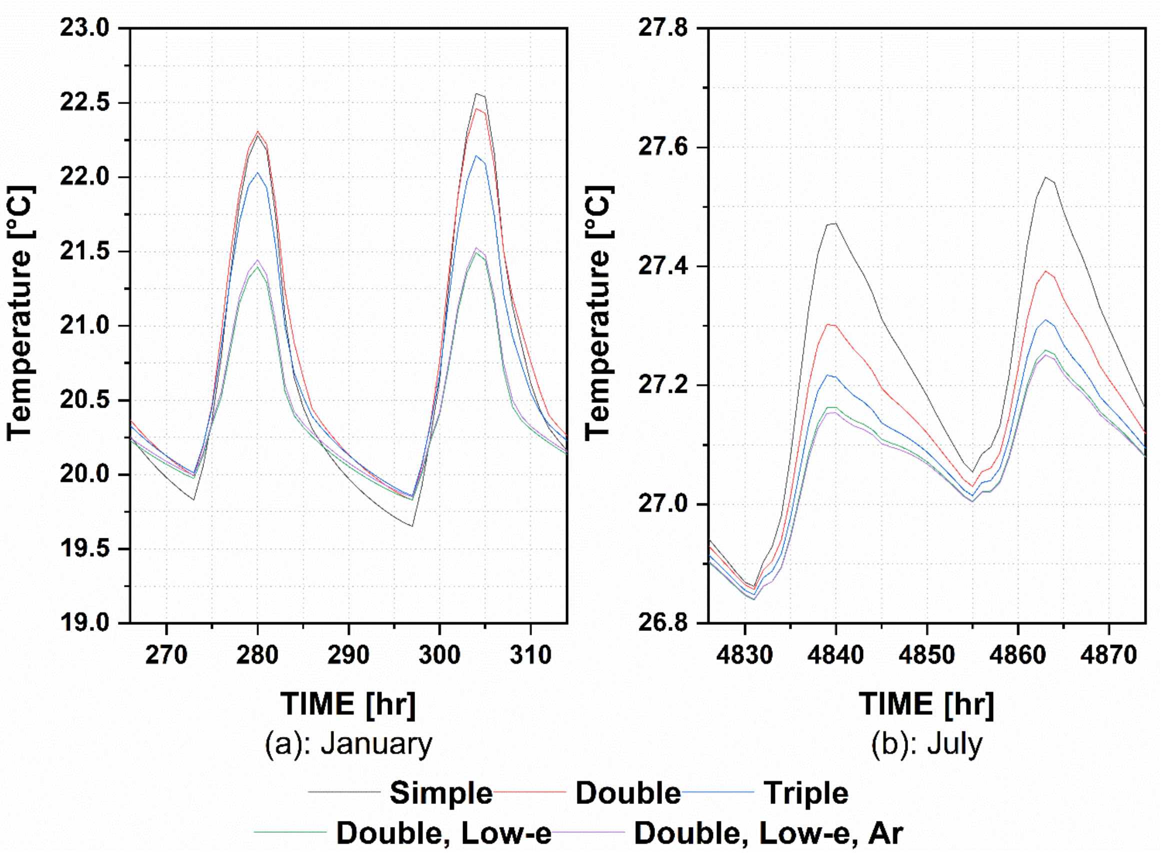


Figure 11 – Window glazing impact on the interior environment: (a) January; (b) July.

Figure 11a indicates that double-glazing provided the best internal temperature, with a difference of 0.11°C when compared to simple glazing and triple glazing. Moreover, the double-glazing low emissivity and double-glazing low emissivity filled Argon showed the lowest temperature compared to the other forms of glazing. The comparative ratios were 0.03, 0.07, and 0.15°C for each of the triple, double, and simple glazing, respectively. This suggests that double-glazing is the most efficient option for maintaining a comfortable indoor temperature in the coldest months.

Figure 11b demonstrates that the double-glazing low emissivity and double glazing low emissivity filled Argon types of glazing provided the lowest temperature compared to the other types of glazing. The comparison ratios were 0.03, 0.07, and 0.15°C for each of the triple, double, and simple glazing, respectively. This shows that double-glazing low-emissivity filled Argon is the most efficient option for maintaining a comfortable indoor temperature in the hottest months. Therefore, these types of glazing are highly efficient and suitable options for maintaining a comfortable indoor temperature throughout the year.

Energy behavior: This section of the study aimed to investigate the energy-saving potential of different types of glazing. The results showed that double glazing was the most energy-efficient option, providing the lowest heating loads when compared to other types of glazing. In fact, double glazing can save up to 23% of heating loads when compared to single glazing, as shown in Figure 12. In terms of cooling loads, adopting double glazing instead of single glazing can save more than 10%.

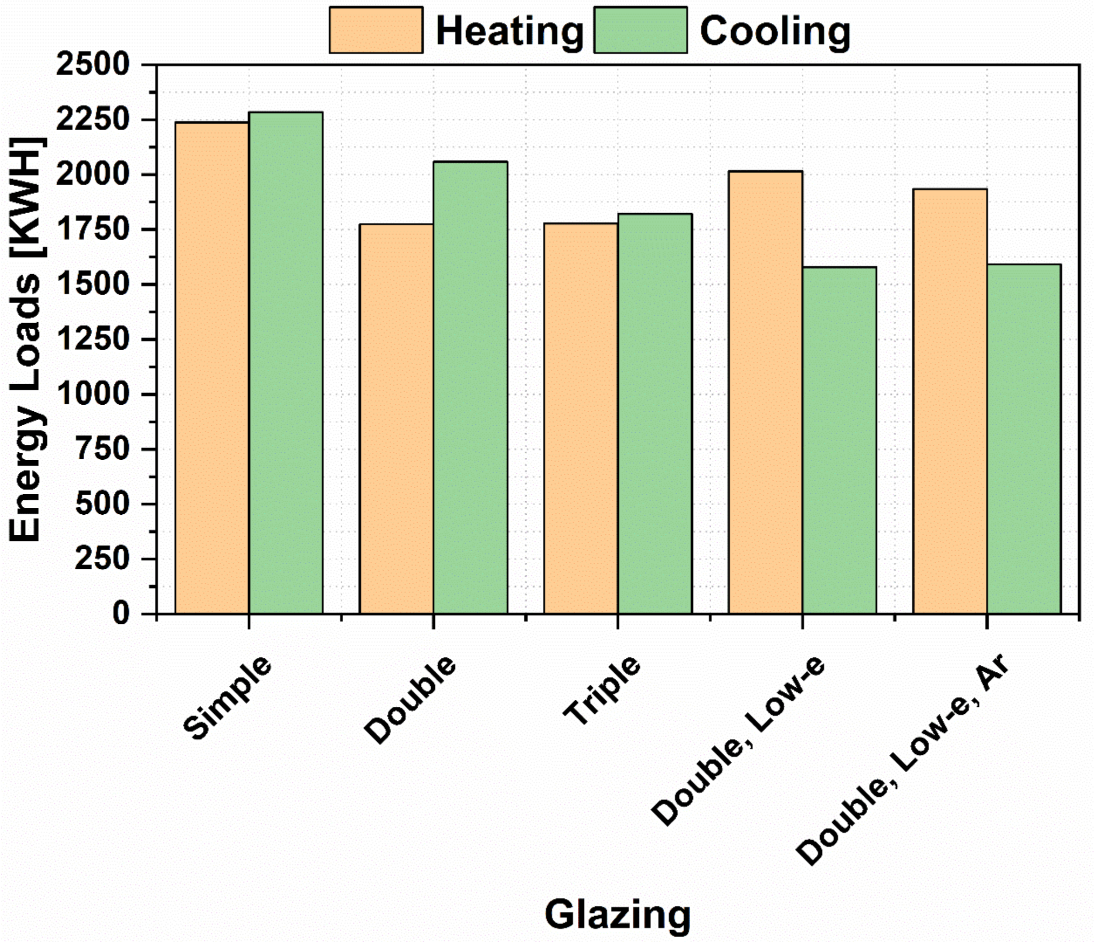


Figure 12 – Heating and cooling demands of different glazing types.

One of the significant advantages of double glazing is that it is a practical option that comes with comparable costs to single glazing. As such, it is highly recommended for the eastern, northern, and western sides of buildings. For the southern side, double glazing with low emissivity is the best choice.

These findings highlight the importance of choosing the right type of glazing for buildings to achieve energy efficiency and cost-effectiveness. Double glazing is a practical and cost-effective option that can provide significant energy savings, making it an excellent choice for the majority of building orientations. However, for the southern side of buildings, double glazing with low emissivity is the most suitable option for achieving optimal energy efficiency.

It can be concluded that glazing has a significant impact on both the thermal indoor environment and the energy consumption of a building. The study found that double glazing is the most efficient option for maintaining a comfortable indoor temperature in both the hottest and coldest months, with double glazing low emissivity filled Argon being the most energy-efficient option.

In terms of energy consumption, double glazing was found to be the most energy-efficient option, providing significant savings in heating and cooling loads when compared to single glazing. The study also showed that double glazing is a practical and cost-effective option, making it an excellent choice for the majority of building orientations, particularly for the eastern, northern, and western sides.

Overall, the findings of the study highlight the importance of considering the type of glazing used in buildings and how it can impact energy consumption and efficiency. Selecting the appropriate glazing for the building's orientation and location can result in substantial energy savings and cost reduction.

Comparison of present results with previous studies: Almarzouq and Sakhrieh (2018) conducted a study on a residential building in Amman, Jordan to investigate the effects of replacing single glazing with double glazing filled with Argon gas and low emissivity coating on energy consumption and thermal comfort. In contrast, our study focused on a house located in the Mediterranean region, specifically in the province of Ain Temouchent, Algeria, to evaluate the effectiveness of various glazing types for reducing heating and cooling costs.

Both studies share a similarity in finding double glazing to be more energy-efficient than single glazing. Almarzouq and Sakhrieh (2018) discovered that replacing single glazing with double glazing with low emissivity coating can save 24.7% of consumed energy, while our study found that upgrading from single to double glazing can reduce heating and cooling costs by 23% and 10%, respectively. Additionally, both studies recommend using double glazing as a practical and cost-effective option for most building orientations. However, our study adds the suggestion that double glazing with low emissivity is the best choice for the southern side of the building to achieve optimal energy efficiency, resulting in energy savings of more than 4% for heating and cooling loads compared to double and single glazing.

Both studies emphasize the importance of choosing appropriate glazing materials and insulation in building design to achieve optimal indoor comfort and energy efficiency.

Conclusion

In conclusion, this study evaluated the effectiveness of insulation materials and glazing for building design in the Mediterranean region, specifically in Ain Temouchent, Algeria. It focused on common insulators and glazing types, assessing their impact on indoor comfort, energy efficiency, and greenhouse gas reduction, considering climate conditions and building use. The findings stress the importance of appropriate choices for insulation and glazing to improve indoor comfort, reduce energy consumption and costs, and minimize greenhouse gas emissions. The theoretical analysis provides valuable guidance for informed decision-making in building design.

The simulations conducted using TRNSYS 17 software for the thermal and energy behavior of the building showed that wood fiber insulation is the most suitable option for providing a comfortable indoor environment for the residents. A thickness of 9 cm of wood fiber insulation was found to be optimal for maintaining comfortable indoor temperatures during both hot and cold periods. Resulting in energy savings ranging between 4-6% for heating and 1-2% for air conditioning when compared to other types of insulation such as Expanded Polystyrene, Glass Wool, and Rock Wool. Additionally, for the indoor temperatures in January, the temperatures are higher by 0.47°C, and in July, the temperatures drop by 0.13°C.

Furthermore, the study found that double glazing was the most effective option for maintaining a comfortable indoor temperature throughout the year, particularly in the coldest and hottest months. The study highlights the energy-saving potential of double glazing, which can save up to 23% and 10% of heating and cooling loads when compared to single glazing. In Summary double glazing is a practical and cost-effective option for most building orientations, while double glazing with low emissivity is recommended for the southern side of buildings to achieve optimal energy efficiency.

Overall, this study emphasizes the importance of selecting the appropriate insulation and glazing materials in building design to ensure optimal indoor comfort and energy efficiency. It is recommended to use wood fiber insulation for its superior thermal properties and to use double glazing for its energy-saving potential. The authors aim for these findings to provide a compelling reason for the Algerian government to incorporate thermal insulation into new building construction. Additionally, considering the impact of different glazing types on the energy efficiency of buildings.

The study's limitation is that it only focused on insulation and glazing's impact on the indoor environment and energy, neglecting factors like humidity and air movement. Also, the study had a limited number of glazing options and configurations. Future research should consider more glazing options to guide building designers better. Nonetheless, the study offers useful insights into building performance with insulation and glazing.

For future work, more extensive research could be conducted to examine the long-term performance and durability of the chosen materials in different climates and building designs. Additionally, the impact of other factors such as occupancy, building orientation, and shading devices could also be investigated to further optimize the thermal and energy performance of buildings.

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