THE IMPACT OF GLAZING TYPOLOGIES IN OFFICE BUILDINGS ON ENERGY USE: THE CASE OF MEDITERRANEAN CLIMATE

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Approval sheet of the Thesis

This is to certify that we have read this thesis entitled **“The impact of glazing typologies in office buildings on energy use: The case of Mediterranean climate”** and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

THE IMPACT OF GLAZING TYPOLOGIES IN OFFICE BUILDINGS ON ENERGY USE: THE CASE OF MEDITERRANEAN CLIMATE

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Lately, achieving suitable indoor environments and minimizing energy usage and its detrimental effects on the ecosystem have emerged as two of the most crucial and vital goals in building design [1]. For this reason, figuring out how much energy building envelopes need is becoming very important. These days, a "high-performance window" is one that minimizes the quantity of non-regenerative energy used in the building while also guaranteeing the best possible thermal and visual comfort for the occupants of the building [2].

This research aims to estimate the energy performance of glazing in Mediterranean climate context. Also, it will explore the specific aspects of glazing technology, architectural design principles, and case studies to offer nuances perspective on how the role of glazing can be optimized in the pursuit of comfort and sustainability in office buildings within the Mediterranean climate, in the representative capital city of Albania, Tirana. In conducting a comprehensive analysis of the glazing overall energy performance on office buildings, a 20m x 30 m x 16m building is designed, 60 glazing scenarios are simulated and design variables such as building shape and orientation are meticulously chosen. The findings and subsequent discussions of the study reveal that across all scenarios involving double and triple glazing, the annual cooling energy demand consistently surpasses the heating energy demand. This phenomenon is attributed to the prevailing warm Mediterranean climate and the specific orientation of the building. The study's conclusion asserts that among the glazing scenarios examined, DG_1 and DG_2 exhibit the lowest energy consumption levels, contrasting with DG_9, which demonstrates the highest energy consumption, with a difference of 40%.

In conclusion, this research sheds light on the intricate interplay between glazing technology, architectural design, and energy performance in Mediterranean climate contexts, offering valuable insights for optimizing comfort and sustainability in office buildings, with implications for future design practices and energy policies.

Keywords: *Glazing technology, energy performance, simulation, Mediterranean climate, office buildings, orientation.*

ABSTRAKT

NDIKIMI I TIPOLOGJIVE TE XHAMIT NE NDERTESAT E ZYRAVE NE PERDORIMIN E ENERGJISE: RASTI I KLIMES MESDHETARE

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Kohët e fundit, arritja e mjediseve të përshtatshme të brendshme dhe minimizimi i përdorimit të energjisë dhe efektet e dëmshme të saj në ekosistem janë shfaqur si dy nga qëllimet më vendimtare dhe jetike në projektimin e ndërtesave [1]. Për këtë arsye, të kuptuarit se sa energji kanë nevojë ndërtesat po bëhet shumë e rëndësishme. Këto ditë, një "dritare me performancë të lartë" është ajo që minimizon sasinë e energjisë jo-rigjeneruese të përdorur në ndërtesë, duke garantuar gjithashtu komoditetin më të mirë të mundshëm termik dhe vizual për banorët e ndërtesës [2].

Ky hulumtim synon të vlerësojë performancën energjetike të xhamave në kontekstin klimatik mesdhetar. Gjithashtu, ky hulumtim do të eksplorojë aspektet specifike të teknologjisë së xhamit, parimet e projektimit arkitektonik dhe studimet e rasteve për të ofruar nuanca perspektive se si roli i xhamit mund të optimizohet në ndjekjen e rehatisë dhe qëndrueshmërisë në ndërtesat e zyrave brenda klimës mesdhetare, në përfaqësuesin e kryeqytetit te Shqipërisë, Tirane. Gjatë kryerjes së një analize gjithëpërfshirëse të performancës së përgjithshme të energjisë së xhamit në ndërtesat e zyrave, është projektuar një ndërtesë 20m x 30m x 16m, janë simuluar 60 skenarë xhami dhe variabla të projektimit si forma dhe orientimi i ndërtesës janë zgjedhur me përpikëri. Rezultatet dhe diskutimet pasuese të studimit zbulojnë se në të gjithë skenarët që përfshijnë xham të dyfishtë dhe të trefishtë, kërkesa vjetore për energji për ftohje e tejkalon vazhdimisht kërkesën për energji për ngrohje.

Ky fenomen i atribuohet klimës së ngrohtë mesdhetare mbizotëruese dhe orientimit specifik të ndërtesës. Përfundimi i studimit pohon se midis skenarëve të ekzaminuar të xhamit, DG_1 dhe DG_2 shfaqin nivelet më të ulëta të konsumit të energjisë, në kontrast me DG_9, i cili demonstron konsumin më të lartë të energjisë, me një diferencë prej 40%.

Si përfundim, ky hulumtim hedh dritë mbi ndërveprimin e ndërlikuar midis teknologjisë së xhamit, dizajnit arkitektonik dhe performancës së energjisë në kontekstet klimatike mesdhetare, duke ofruar njohuri të vlefshme për optimizimin e rehatisë dhe qëndrueshmërisë në ndërtesat e zyrave, me implikime për praktikat e ardhshme të projektimit dhe politikat e energjisë.

Fjalët kyçe: *Teknologjia e xhamit, performanca e energjisë, simulimi, klima mesdhetare, ndërtesat e zyrave, orientimi.*

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Thank you all.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Lately, achieving suitable indoor environments and minimizing energy usage and its detrimental effects on the ecosystem have emerged as two of the most crucial and vital goals in building design [1]. For this reason, figuring out how much energy building envelopes need is becoming very important.

These days, a "high-performance window" is one that minimizes the quantity of non-regenerative energy used in the building while also guaranteeing the best possible thermal and visual comfort for the occupants of the building [2]. Given that the window occupies a space in the building structure that divides the inside from the exterior, it is obvious that it needs to have characteristics that are suitable for the current climate, on the characteristics and applications of the structure. Requiring the least amount of energy while still achieving acceptable levels of indoor comfort is one of the main goals of building design [3]. To do this, it is first necessary to give careful thought to several construction and design characteristics, including the building's orientation, form, and envelope structure, the region's climate data. In addition to providing a view of the outside, windows are crucial construction elements because they let in light, solar heat gain, air circulation, and noise reduction [4]. Glass is a common material for building enclosures in contemporary residential and commercial structures. When glass is used extensively in building envelopes, heat gain increases and more energy is needed to keep the building pleasant [2]. Solar radiation generally enters buildings through the walls, floors, roofs, and windows; however, only window glass materials allow the majority of direct solar radiation to enter.

For such reason, selecting the most appropriate type of glazing can reduce the cooling loads in buildings. Today however, choosing windows is largely based on their thermal behavior, and the majority of research evaluating windows' effects has ignored embodied consequences in favor of operation. Modern residential and office buildings have enormous potential for energy savings, and a building's outer structures determine how energy-efficient it is. When it comes to heat transfer from the inside to the outside of a structure, windows are among the most vulnerable components of its enclosure [5]. Buildings are becoming more and more windows, as seen by shifts in architectural styles.

Consequently, obtaining precise evaluations is especially significant in terms of their thermal qualities. Large solar energy flows via windows during colder months not only minimize a building's heat loss, but warmer months also result in higher cooling demands, which lowers the building's energy performance. Lately, achieving suitable indoor environments and minimizing energy usage and its detrimental effects on the ecosystem have emerged as two of the most crucial and vital goals in building design [1]. For this reason, figuring out how much energy building envelopes need is becoming very important.

1.1 Motivation

Being a subject internationally known and studied by researchers, the glazing technology has a significant impact on quality of life, which provides the best conditions for its residents. Different factors such as energy consumption, energy transmittance, daylight, energy saving and many more contribute to the innovations and changes in relation to the quality of the glass, making this topic always suitable with the time and changes in the quality of life [6]. Being related throughout my life with windows, costumer demand and having the necessary knowledge about the quality of windows, glass facade, architectural glass systems and other certain factors that help to improve the internal conditions of buildings, I suppose that the topic addressed would help to clarify some gaps in this large scale of glass technologies.

Global energy usage in the building industry is still rising. More precisely, buildings make up one-third of today's total energy use, whereas homes make up around three-quarters [7]. This exacerbates climate change and the depletion of fossil resources, making energy consumption reduction in the building industry vital [2].

Furthermore, it is thought that this industry offers one of the best value options for cutting energy usage. It has previously been noted by certain writers that this situation may not be well served by the conventional thermal transmittance of building envelope components. Inadequate U-values for opaque and transparent components may boost the amount of energy needed for heating and/or cooling, which would be detrimental to a building's performance [2]. Compared to northern European nations, the Mediterranean area has buildings that are more likely to overheat, thereby raising the need for cooling systems - a problem that is uncommon in other regions [7].

The research is motivated by the recognition that traditional approaches to architecture in the Mediterranean may require revaluation and refinement to meet contemporary standards of sustainability. By centering the investigation on the integration of glass, the study seeks to uncover innovative design strategies, technological advancements, and sustainable practices that can be employed to enhance the comfort of occupants while minimizing the ecological footprint of residential structures.

1.2 Thesis objectives

This study aims to present the significant role of glazing in office buildings and its crucial role in balancing comfort and sustainability. Due to the lack of real scenarios of glazing models applied in Mediterranean regions to show the contribution to energy efficiency, comfort and give considerations or strategies for incorporating glass in a sustainable and comfortable manner, this research aims to fill this gap by exploring energy-based design solutions in different types of glazing models, giving a real based data information on what is the right choice of glazing for buildings located in the Mediterranean region. The models have all various type of glazing properties, and slightly differences regarding thermal, physical, construction characteristics, to compare and demonstrate how different glasses can be unique for each climate zone.

As the research unfolds, the thesis aims to contribute not only to the academic discourse but also to the practical realm of architectural design, providing insights, guidelines, and recommendations for professionals engaged in the creation of office and residential spaces tailored to the nuances of the Mediterranean climate.

It will delve into the specific aspects of glazing technology, architectural design principles, and case studies to offer nuances perspective on how the role of glass can be optimized in the pursuit of comfort and sustainability in office buildings within the Mediterranean climate.

Through this exploration, the thesis aspires to be a beacon guiding the convergence of comfort and sustainability in office architecture, with glass playing a pivotal role in this transformative journey.

1.3 Organization of the thesis

This thesis is organized into five chapters. The organization is done as follows: in chapter 1, the motivation and thesis objectives are presented. Chapter 2 describes the theoretical framework of glazing properties, authors findings and many more. Chapter 3 describes the methods used in this research, detailed review of the process and descriptive analysis. Chapter 4 presents the results and discussions for the practical implications, optimization scenarios and other review of research. In chapter 5, conclusions and recommended alternatives for future research are presented.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Numerous studies have been conducted in the literature to assess the role of energy performance of different types of windows in different areas. In this section, papers and the findings of different authors are brought into evidence to present different scenarios of window performance, glazing, energy performance, orientation and other factors.

2.2 Effect of glazing properties on energy performance of windows in buildings in Mediterranean climate

To begin with, M. Fernandes et al. examined the impact of various U-values on the design of buildings while examining the significance of thermal transmittance in the Mediterranean area. For sixteen different locations, 192 000 residential structures were created at random, and each building's energy use was evaluated. It came to light that energy consumption reduced with decreasing U-values in north Mediterranean places, but weak thermal transmittances seemed to dramatically increase energy demand in warmer climes. Larger structures tend to have worse energy performance for high U-values, while larger windows tend to have better energy performance. Larger north-facing windows were advantageous for low U-values [4].

In addition, Y. Elkhayat et al. rely on the multi-criteria selection of high-performance glazing solutions for an office building located in New Cairo, Egypt. Fully glazed office buildings have high energy consumption mostly because of the significant cooling requirements during summer. To address this issue, High-Performance Glazing Systems (HPGS) are used to minimize solar heat gain and achieve energy savings.

Nevertheless, choosing the most sustainable High-Performance Green Building (HPGS) is a complex task because of the single-criterion choice procedure. Utilizing Multi-Criteria Decision Making (MCDM) analysis may effectively address this issue and provide a hierarchical order for the available options. SuperDecisions software use the Analytic Hierarchy Process (AHP) to choose three potential HPGS solutions for an office building located in New Cairo, Egypt. The ranking findings indicate that the Photovoltaic glazing system is the most sustainable choice, with the Low-E and Electrochromic glazing systems following in second and third place, respectively. The life cycle cost criteria is the primary factor that influences the ranking outcomes, as determined by the sensitivity analysis that was conducted [8].

Also J. Santana and H. Jarimi examined the functionality of several glass technologies in their article, concentrating on the optical and physical characteristics of both advanced window technologies and conventional windows, with U-value (thermal transmittance value) being one of the most important factors in window technologies. The authors discussed about the connection between the U-value and the optical and physical characteristics of the various types of windows. One of the primary findings is that more investigation is required to create window technologies that are not only highly insulating but also capable of producing energy [9].

Moreover, J. Karlesson assessed the energy efficiency and optical performance of windows in his study. The angle-dependent optical characteristics were thoroughly analyzed by the author. A basic framework that compares the energy efficiency of various kinds of windows in numerous types of buildings and climates has been further analyzed and put into use under a number of circumstances. This model, along with other building and window simulation models, has been utilized to study the energy performance for a significant number of windows. The findings clarify that, on a broad and global scale, windows that are energy-efficient provide enormous saving energy potential [3].

An office building's heating and cooling loads were assessed by Gasparella et al. taking into account the kind of glazing, ventilation patterns, and window area. They proposed that by using low emissivity glazing and the right window areas, the thermal requirements can be maximized.

The window energy performance of a well-insulated residential building was examined in a subsequent study by the same authors in relation to the kind and amount of glazing, the orientation, and the levels of internal gain. They came to the conclusion, among other things, that using large-glazed surfaces can improve performance in the winter but could deteriorate it in the summer [10].

An interesting view has been presented by J. Wrights in his paper, where he explained and constructed a model on how to calculate the center-glass indices performance of windows, a very important aspect to be considered, given that the performance of the building envelope is greatly impacted by heat transfer through windows and solar gain and the glazing system's centre-glass area is where the majority of this energy gain or loss goes. The variables taken into consideration by the author to construct the model are the U-factor and solar heat gain coefficient (SHGC). Wrights analyzed the accuracy of other existing models and compared them, realizing about the defects they could lead at. He successfully achieved into considering a new approach of a higher accuracy and realizing a model possible to use for any user [11].

2.2.1 Thermal comfort and heat transfer

De Rubeis et al. evaluated the heating efficiency of an energy-effective residential building made of high-quality performance materials situated in central Italy. The findings demonstrated that even with optimization margins for the self-sufficient house, the low U-value materials used for the exterior walls allow for less heat loss, resulting in an elevated efficiency. Determining the most appropriate relationship among the properties of U-values and the energy consumption of buildings, along with the association between geometry-based indices and the U-values, is of interest, as these studies highlight. These indices can be helpful in establishing recommendations that lead to better construction performances and encourage designers to consider different shapes and designs when connected with energy consumptions. For Mediterranean climates in particular, it might be interesting to find the values of thermal transmittance for building components that would reduce cooling requirements without significantly increasing warming requirements [12].

K. Gorantla et al. analyzed the thermal efficiency of structures with different window panes, including clear, bronze, green, and bronze-reflective single, double, triple, and quadruple panes. The authors concluded that the number of panes glazing layers in a building minimizes the amount of heat gain. From the perspective of decreased heat gain for cooling loads, windows facing south are shown to be more energy-efficient. The bronze-reflective window glass materials with single, double, triple, and quadruple glazing are determined to be the most energy-efficient among the four glass materials studied with four pane glazing layers in four different climatic conditions of India [1].

G. Alvares et al. presented a methodology and an apparatus to evaluate the thermal transmittance of glazing in Mexico, by considering only single commercial glazing. To assess the test box's temporal responsiveness for each of the test glasses taken into consideration, a time constant test was run. The instrument's capacity to quantify and monitor the radiant heat passing through a particular glass is one of its advantages. The total heat loss coefficient is calculated by calibrating the calorimetric box. The net heat gain through a certain glazing array was calculated in order to assess the thermal performance of glazing.
The difference between the heat extracted by the heat exchanger and the heat losses resulting from variations in the outside and inside temperatures is the rate of energy flow through a glazing system. The calorimeter box calibration revealed a heat loss value of 1.7 ± 0.1 W/m2 ◦C [13].

S. Chaiyapinunt et al. discussed in their study thermal comfort and heat transfer of glass windows and glass windows with various types of film. Investigations were conducted into several glass window kinds, including low-e, reflecting, tinted, double-pane, and transparent glass. Following that, films with various spectrum optical characteristics were affixed to several kinds of glass windows and examined. The study was conducted using the exterior design weather conditions that were chosen from a 12-year archive of meteorological data from Bangkok. Research indicates that glass windows with relatively high transmittance values will make an enclosed person more uncomfortable. Conversely, more heat will be absorbed in the glass material by the reflecting glasses which have low transmittance and high absorptance values—than will be transferred through the glass windows [14].

2.2.2 Energy Efficiency

Another study from K. Tsikaloudi and K. Laskos examined how energy-efficient various window designs are in Europe's Mediterranean region. The authors determined the area weighted energy and the cooling energy index for various window types for residential and commercial buildings based on three window-related factors: orientations, geometry (frame and window fractions), and thermophysical and optical qualities. The findings demonstrated that windows' thermophysical characteristics have a major impact on how energy-efficient they are in warm areas. More specifically, especially in settings with regulated ventilation, the influence of solar transmission must be taken into account and choosing it optimally can help reduce energy use. Conversely, poor thermal transmittance created fenestration goods appear to behave disadvantageously since they prevent heat from being dissipated towards the surrounding environment, which eventually leads to higher cooling energy demands [15].

Gultekin and E. Farahbask investigates the energy efficiency of Turkish residential building windows. Twelve distinct situations were created from single low-e glass, double low-e glass, and single thermopane possibilities in order to conduct this research. The eQuest energy analysis programme was made use to analyze the scenarios in terms of energy consumption resulting from the usage of natural gas for home heating. The findings indicate that the kind of glass has an impact on energy usage [16].

Also De Rubeis et al., as explained above, evaluated the heating efficiency of an energy-effective residential building made of high-performance materials situated in central Italy. The findings demonstrated that even with optimization margins for the self-sufficient house, the low U-value materials used for the exterior walls allow for less heat loss, resulting in an elevated efficiency. For Mediterranean climates in particular, it might be interesting to find the values of thermal transmittance for building components that would reduce cooling requirements without significantly increasing warming requirements [12].

2.3 Glazing techno-economic performance

Technology and cost optimization are factors of great importance when choosing the glazing type. In the article by Konstantinos P. Tsagarakis, energy conservation strategies and technology used in office buildings are examined, with a specific emphasis on double glazing windows, central heating, and air conditioning systems. A survey was performed among 685 managers from various firms to get insights into the elements that influence their investment decisions about these technologies. The findings indicated that parameters such as ownership, awareness level, recent formation of the firm, and involvement in trade were associated with managers exhibiting a more energy-saving profile. Ownership, recent establishment, service-oriented nature, large workforce, and high electricity bill-to-turnover ratio are factors that seem to influence the willingness of companies to adopt specific energy-efficient measures for heating and cooling. The research also discovered that the inclination to install such technologies increased when a techno-economic information session was conducted. The study suggests that companies should assess the environmental consequences of their facilities and use energy-conservation strategies to reduce their carbon footprint [17].

Another research done by N. Aste with objectives to evaluate the techno-economic efficiency of glass in office buildings across three distinct European climates. The findings indicate that solar gains have a detrimental effect on the annual balance of energy in contemporary office buildings, with thermally-insulated envelopes exacerbating overheating even in colder climes. To reduce energy usage, the most logical approach is to either restrict the use of windows or utilize external sun shading devices. Solar control glazing without shade offers the highest level of cost-effectiveness. However, if the issue of glare discomfort is taken into consideration, solar shading devices become the most convenient choice [18].

An office building's heating and cooling loads were assessed by Gasparella et al. taking into account the kind of glazing, ventilation patterns, and window area. They proposed that by using low emissivity glazing and the right window areas, the thermal requirements can be maximized. The energy performance of window of a well-insulated residential building was examined in a subsequent study by the same authors in relation to the kind and amount of glazing, the orientation, and the levels of internal gain.

They came to the conclusion, among other things, that using large-glazed surfaces can improve performance in the winter but could deteriorate it in the summer [10].

The objective of a research conducted by A. Stegou-Sagia et al, at the National Technical University of Athens is to analyse the energy performance and thermal satisfaction of buildings in Greece. The research used the computer software Ener-Win to model an office and residential structure, with a specific emphasis on analysing their energy usage and assessing the comfort levels. The research also investigates the influence of glass on energy distribution and comfort, as well as the extent to which comfort conditions in typical Greek buildings adhere to international norms. The research highlights the significance of implementing energy efficiency enhancements at the first stages of building design. The research demonstrates that the use of transparent glass in office buildings leads to higher yearly energy consumption as a result of enhanced solar gains. Reducing the amount of glazing area decreases energy consumption, while using grey tinted glazing provides a well-balanced option. Climate has a negligible effect on yearly consumption. The primary applications are space heating, cooling, hot water use, illumination, and building machinery. In Greece, the main emphasis is on thermal comfort during the summer months, as a result of the temperature and little attention given to lighting and cooling. Occupant's perceived control in office buildings may cause a decrease in the use of energy. Precise and meticulous design is essential in order to attain optimal levels of both energy efficiency and comfort. The research emphasizes the significance of taking into account lighting factors and the perceived autonomy of occupants in the construction of office buildings [19].

2.3.1 Embodied impacts for framing window systems

Another study is conducted by S. Shiva et al. which suggested a method to help sustainably produced window design that is based on Pareto optimal frontier and embodied impact evaluation. An extensive examination of the environmental effects embodied in 32 window systems was put into practice. The most popular framing materials wood, PVC, fiberglass, aluminum, and others along with additional elements thermal breaks, weather stripping, spacers, and double- and triple-glazed options have all been considered. According to the embodied impacts computed for the window systems, the frame's contribution to aluminum windows is greater than that of the glazing, whereas the frame's contribution to wood-framed windows is significantly less [20].

The environmental consequences of window materials might be regarded as concealed impacts. Nevertheless, with the development in energy efficiency of buildings, the significance of windows in terms of their affects has been more acknowledged, although their analysis remains incomplete. Therefore, it is necessary to do a thorough study in order to make an informed decision when choosing energy-efficient windows that have minimal environmental implications. The article from A. Khan and G. Moeseke suggests a method that utilizes embodied effect assessment and Pareto optimum frontier to assist in the creation of ecologically friendly window designs. An extensive evaluation was conducted to analyse the environmental effects associated with a typical-sized window. This evaluation included 32 different systems, taking into account four different framing materials (polyvinyl chloride, aluminium, wood, fiberglass) and eight different glaze options (for single-, double-, and triple-glazed windows). The analysis of the impact of aluminium-framed window systems reveals that the setting has a greater impact compared to the glazing. Specifically, the frame contributes to 50-70% of the total embodied impacts. When it comes to windows with fibreglass and polyvinyl chloride (PVC) frames, the frame accounts for the majority of the embodied impacts of single-glazed windows (59–87%), double-glazed windows (45–56%), and triple-glazed windows (21-39%). The impact of a wood frame, which accounts for less than 30% of the total, is rather minor.

For various environmental effect categories, the non-dominated solutions are investigated and the Pareto optimal bounds are established for the window systems [21].

2.4 Effect of building orientation and glazing to wall ratio in buildings

For the study of J. Konteleon and D. Zenginis, an analysis has been done on building zones with different orientations and percentages of glass to wall area in Thelassoniki, Greece. The investigation of how settings of indoor temperature affect heat losses or gains through building structures has been made possible by the investigation and the variables taken into consideration are based on thermal analysis, heat flow and gain, building zone, orientation, and glazing proportion. A lumped thermal-network model has been used to conduct thermal assessments.

The main conclusions of the study explain that the amount of glazing in the wall region should be taken into consideration for design purposes. Heat gain or loss increases in tandem with an increase in the glazing area. The direction of a building zone is the primary factor determining the impact of glazing. Additionally, it is demonstrated that a comparable building zone with a variable percentage of fenestration might exhibit identical behavior The building zone typologies that have been analyzed indicate that south-oriented building zones have the maximum heat gains. On the contrary hand, building zones facing north are shown to have the greatest heat losses [22].

In order to gather comprehensive data on energy-efficient exterior configurations during the early phases of building design, Echenagucia et al. developed an integrative strategy that included a multi-objective analysis with the goal of reducing the energy required for lighting, heating, and cooling. Four open-air office buildings across Europe were the subject of the inquiry. The findings showed that the building's total WWR (window-to-wall ratio) was minimal throughout, particularly for the exposed facades in the east, west and north. When compared to the other orientations, the area of the windows’ facing south was larger and had more fluctuation [23].

Architectural consensus holds that a building's glazing system is its most vulnerable component when it comes to indoor energy performance. Because of the translucent materials, it is the only area of the structure that receives direct solar gain. As such, this area of the building exterior warrants careful study by engineers and architects, especially in areas with strong sun radiation. The author Mamdooh Alwetaishi (2017), has identified three microclimate locations in Saudi Arabia: hot, dry and humid. The purpose of the study was to examine the impact of glass to wall ratio in these areas. Based on earlier research, the study has examined the highest glazing ratios in the area, which are 5%, 10%, 20%, 30%, and 40% out of the exterior wall. The study employed TAS EDSL computer modelling, which was verified by field monitoring research. Additionally, the influence of the position of the student in relation to the system of glazing will be investigated using a globe thermometer. Lastly, a questionnaire will be used to get students' real thermal comfort while keeping the same PSBD in the chosen zones. According to the study, the worst directions for obtaining the most heat across all places are the south and east. According to the research, 10% of the wall should be made of glass in hot, dry climates as well as humid one [24].

Implementing appropriate design methods throughout the architectural phase of building development offers enhanced possibilities for energy conservation. This study by Mahmood Sh. Suwaed aims to examine the impact of several aspects on window design, including the window-to-wall ratio (WWR), window orientation, and different glazing materials. The investigation was conducted in Kirkuk, Iraq, with the goal of potentially reducing energy consumption. The study analyses a typical office block in the area using simulation. It assesses four different window-to-wall ratios, four orientations, and three types of glazing materials: transparent, theoretical, and gray. Additionally, it examines the performance of both double and single-glazed windows. The findings suggest that the lowest amount of heat consumption may be attained by using double clear glass for windows facing south, assuming a window-to-wall ratio of 100%. To minimize cooling usage for north-facing windows, it is recommended to use double theoretical-197 glass with a 25% WWR. Architects and construction managers might apply these techniques to effectively convey information to clients and make informed judgments regarding window design [25].

In addition, Cappelletti et al. evaluated the energy requirements for heating and cooling an open-plan office with varying glass features within managed indoor comfort conditions while taking into account the climates of Milan, Rome, and Paris. They discovered that the ideal window attributes vary depending on the building's location, the time of year, and the orientation of the facade. In southern areas, a low-g-value double-glazed window is favored, whereas a triple-glazed window would function better in northern latitudes [10].

Marino et al. implemented a parametric analysis to determine how the window-to-wall ratio affected the building energy usage in Italy. The authors came to the conclusion that while the facade configurations, presence of shading devices, insulation properties of the building, and climate conditions all had a significant impact on energy consumption, the optimal WWR did not significantly change when the effects of each factor were considered separately. Conversely, the ideal WWR can be increased for the combined benefit of enhancing the installed electric power illumination and improving the envelope features, irrespective of the temperature [26].

Amaral et al. conducted a parametric study to examine window size, direction, and shadowing for three glass types of a reference room in Coimbra, Portugal.

The conclusions showed that the smaller U-values of the windows leaded to having lower window-oriented east, west, and south, and larger windows-oriented north [27].

2.5 Importance of occupant well-being

E. Magri outlined the importance of occupant well-being rather to focus only on the construction of energy-efficient buildings. Research indicates a direct correlation between occupant well-being and many environmental parameters, specifically daylight distribution, glare, and indoor air temperature. occupant comfort, external shading devices and, more frequently, internal blinds are used; nevertheless, this is frequently done at the expense of views. The goal of adaptive facades is to address the issue of finding a way to balance energy efficiency and occupant comfort. In order to investigate the possibilities of electrochromic glass in a functioning office building situated in a central Mediterranean setting, a field test research project is presented in this study. The purpose of the study is to gain a better understanding of the advantages that this form of glazing offers to occupants. Electrochromic glazing allows for active dynamic control of light and heat transmission, reflection, and absorption since it is composed of a thin-film coating consisting of numerous minuscule conductive layers. These elements' characteristics alter as a result of mobile ions entering or leaving the EC layer. For dynamic daylight and solar energy uses in buildings, electrochromic glass appears to be rather promising [28].

G. Tibi and A. Mokhtar identified the main factors and circumstances impacting the decision rules of architects regarding buildings in UAE by concentrating on the correlation between the price of glass and its thermal properties. It makes use of a standard 30-story residential structure that is oriented north-south and has a WWR of 50%. The effects of various varieties of glass on the cooling load and, consequently, the energy consumption, are modelled using an energy simulation tool. The price and heat characteristics of the used glass varieties are those found in the UAE market. The analysis considers the variations in energy prices across the nation. The ideal glass thermal characteristics are determined by applying both the life cycle cost reduction and the easy payback time methodologies. According to the study, among three emirates in the United Arab Emirates (Dubai, Abu Dhabi, Sharjah), glass type G has the lowest Life Cycle Cost and one of the quickest payback periods.

As a result, the study suggests that high-rise residential structures in the UAE that have an approximately north-south orientation and a WWR of 50% use this type of glass. This advice takes into account the unique climate conditions of the United Arab Emirates, the glass kinds that are now accessible, their current pricing in the nation, and the existing energy price structure [29].

S. Jaber and S.Ajib examined the optimal sizes of windows, construction orientation, and thermal insulation thickness for a common Mediterranean-region residential building from an energy, economic, and environmental standpoint. They concluded that it is possible to save around 27.59% of yearly energy usage by selecting the ideal orientation, windows and shading devices that are the right size, and the right amount of insulation. Also, a 11.94% reduction in Life Cycle Cost (LCC) is achieved, and the specific energy consumption per square meter is 65 kWh/m2 [30].

2.5.1 Investigation on thermal breakage and heat transfer of glazing under the fire conditions

Fire conditions are used to examine thermal breakdown and heat transmission in single, insulated, and laminated glazing. Insulated and laminated glass last longer and reduce vent development, according to a study from Y. Wang et al. The research also analyzed three glasses' heat transmission mechanisms and made fire-resistant glass design recommendations.
Coated, insulated, and laminated glass facades are popular for energy efficiency, beauty, and lighting.

Glass is fragile and may shatter under severe circumstances, increasing fire risk and compliance with national fire rules. Single glazing, insulated glazing, and laminated glass are compared for heat resistance. Single glazing has less heat resistance than laminated glass owing to its flat surface and low contact resistance. Insulated glazing offers the highest thermal resistance owing to its thicker gap and reduced heat transmission. The numerical findings support the theoretical argument that insulated glazing is more fire-resistant.

The investigation demonstrates that severe thermal stress deriving from changes in temperature among covered and exposed regions causes most glass fracture. There is little research on single, insulated, and layered glazing under similar conduction, making thermal breakage behaviour and heat transfer mechanisms critical [31].

2.6 Aim and Originality

No previous study performed a comprehensive building simulation model, which addressed the detailed input variable such as: indoor air temperature, building location, economic aspects, energy loads, geometry, HVAC operations, simulation-assisted study that has an occupancy schedule in accordance to the current need and aim to create a spread network of offices or commercial buildings, construction materials and glazing properties and analysis. The high complexity of morphology-based energy performance optimisation of various buildings due to the impact of numerous variables makes the study a valuable contribution to the existing literature as it discusses the knowledge gaps discovered as follows. Despite the fact that there are few studies on optimising energy consumption on a building, each study has its own specific analysis. Neither of the researched are developed concerning the Mediterranean climate, constructing summer and winter simulations, specifically for glazing.

This work proposes a new comprehensive framework to evaluate the energy performance of glazing on building envelopes analytically and quantitatively. It does this by completing the gaps left by previous studies and providing an overall assessment for the Mediterranean region. Tirana, the capital city of Albania was taken as a reference point, as one of the representative cities of Mediterranean climate in Europe. This paper is constructed considering energy performance, analyzing the geometry, orientation, glazing properties with different U-values, direct and total solar transmittance, reflectance, light transmission, different properties and also the economical aspect.

Table 1. Data available in scientific literature for window and glazing performance in buildings.

Authors	Year	Climate	Aspects of comfort studied	Variables	Method/Program	Case study model	Location
Helen Rose Wilson	2004	Different climatic zones of EU	High performance windows	Selection of appropriate window and glazing types	Softwares, parameters	EU buildings	Freiburg,DE
Saboor Shaik, Kirankunar, Asok	2009	Climatic zone of India	Thermal transmittance, energy performance, solar radiation	Types of glazing to use in Green Energy Buildings, Orientation, light control, window size, glazing, roof insulation, wall insulation	The Perkin-Elmer lambida 950 Spectrophotometer	5x5x5 prototype building (Green energy building)	India
K.J. Kontaleon & D.G. Zangino	2017	C’ climatic zone of Greece (Thessaloniki)	Analysis heat flow through building zone, in aspects of orientation and glazing properties	Thermal analysis, Heat flow & gain, building zone, orientation, glazing proportion	(thermal - network modelling methodology)	Vacant square space 10x10 and height of 3m (cubical shape)	Thessaloniki, Greece
Consiglia Mocerino Arch Ph.D	2020	All climates	High performance and intelligence of glass technologies in architecture	Glass efficiency, technological innovations, new models, bipv	BIM methodology, Real data collection	BIPV building	France
John L. Wright Eng Ph.D	2015	-	Center-glass performance indices of windows calculation	orientation, WWR, space organization, sun shading, and building shape	Cws ,Linear matrix reduction methods, real data collection	Glazing layers	USA
G. Alvarez, M. J. Palacios J. J. Flores	2000	-	Test method to evaluate the thermal performance of window glazing	Building, glazing, thermal performance, comparative test data	Solar simulator test lamp, Calorimeter apparatus box, test method	Apparatus/ test box	Mexico
Silvana Flores Larsen, Luis, Celina	2015	Mediterranean Climates Sub-Tropical	Double skin glazed facades in sunny Mediterranean climates	Double skin façade, glazed façade, ventilated façade, energy efficiency, office building	Field measurements, data collection	Office building DGF	Argentina
J. Karlsson & A. Ross	2001	3 different climates Stockholm, San Francisco and Miami	Energy window performance, glazing	Coatings, glazing thermal emittance , energy	Data collection	Glazing units & residential buildings in Sweden	Sweden

Authors	Year	Climate	Aspects of comfort studied	Variables	Method/Program	Case study model	Location
Jorge Luis, Hasila Jarimi, Mariana	2019	-	Window glazing technologies and future prospects	Glazing technologies, vacuum glazing, u- value, optical properties	Data collection, software & parameters	Glazing units	Nottingham, UK
K. G. Tsikaloudaki, Laskos, Bikas	2015	Mediterranean climate	Energy performance of windows in Mediterranean regions	Window energy performance, energy needs	Meteonorm, energyplus, Vba & excel & r package	Reference room Office & residential	Greece
Shiva Saadatian, Fusto Freire	2021	-	Embodied impact of vindow systems n a comparative assessment of framing and glazing alternatives	Window system, embodied impact, cradle to site, glazing, framing	Cradle-to-site analysis.	Vacant square space 10x10 and height of 3m (cubical shape)	Portugal

CHAPTER 3

METHODOLOGY

3.1 Overview

Even though office building optimization has been the subject of several studies, further research is still required. Therefore, this work explores optimization scenarios in office buildings in a Mediterranean environment using a theoretical method and computer simulation. To obtain more complete data for each alternative of the retrofitting scenarios and to better compare them, 30 scenarios of double glazing and 30 scenarios of triple glazing are proposed, each analyzed in all orientations, east, south, west and north. The computer evaluation's findings will show how each retrofitting scenario improves the comfort and energy efficiency of the building envelope.

3.2 Climate Characteristics

Albania has a varied topography due to its proximity to the sea and mountains. The Albanian region is impacted by two primary climates, namely the Mediterranean and Continental climates [32]. The building model of this study is located in Tirana, as the capital city of Albania, is one of the representative cities of Mediterranean climate in the country.

3.2.1. Mediterranean Climate

In the places where it predominates, the Mediterranean climate has an impact on both the indoor and outdoor temperatures. Mediterranean climates are found on the western side of continents between roughly 30° and 40° latitude [32]. The warm, dry summers and moderate, rainy winters that define the Mediterranean region are well-known for their beneficial weather. Summer in the Mediterranean region is hot and dry, distinguished by warm to high temperatures, plenty of sunshine, and clear skies, and during this season, there is typically relatively little rainfall. Winter in the Mediterranean region is moderate and rainy. Despite being colder, the season's temperatures almost never go below zero.

Although there are numerous advantages to reside in this climate for outdoor living, there are also many difficulties in keeping a comfortable indoor environment. The Mediterranean climate's impacts on humidity, temperature, and air quality necessitate careful design of building techniques and the usage of suitable room air conditioners. It can be challenging to establish a cool and comfortable ambiance in homes and other indoor places during the summer because of the tremendous heat that can seep indoors and raise temperatures, and also due to the fact that evenings are often colder in a Mediterranean environment.

The Mediterranean region's interior climate is influenced by several factors, including architecture, natural ventilation, and air conditioning use having an overall impact on construction and architecture [33]. In the Mediterranean region, traditional architecture is shaped by the climate. To keep heat out and the interior cool, houses are frequently constructed with thick walls and little windows. These modifications contribute to the creation of a cozy and comfortable living space where people may fully take advantage of the advantages of the Mediterranean climate [33].

3.2.2 Climate in Albania

With a land area of 28,748 km2, Albania is a small, mountainous nation in Southeast Europe, positioned on the western side of the Balkans [32]. Albania has a varied topography due to its proximity to the sea and mountains. The vast majority of the nation’s western border is made up of an extensive area of coastline that runs along the Adriatic Sea, the majority of Albania is made up of mountains, with an average elevation of 700 meters above the sea level. As a result, Albania's area is impacted by both the continental and Mediterranean climates.

About half of Albania's land is covered by a Mediterranean climate, which mostly impacts the country's western, central, and southern regions [34]. Albania experiences hot, dry summers and moderate, humid winters due to its Mediterranean climate. The second part of the year is when the country receives the most rainfall, yet the agro-ecological zones have very different climates. There is a gradient of colder temperatures and less precipitation eastward from the coast due to strong maritime influences on the coastal plains.

At 100 metres above sea level, Tirana is situated at 41.32° latitude north and 19.82° longitude east. The average annual temperature is 16.3℃, and varies from 6.3℃ in January to 23.7℃ in July, reaching the highest, 234 Kwh/m^2 [35]. The average temperature during the year in Tirana is shown in *Figure 1* below. Other information regarding the monthly temperature is shown in *Figure 2, Figure 3 and Table 2.*

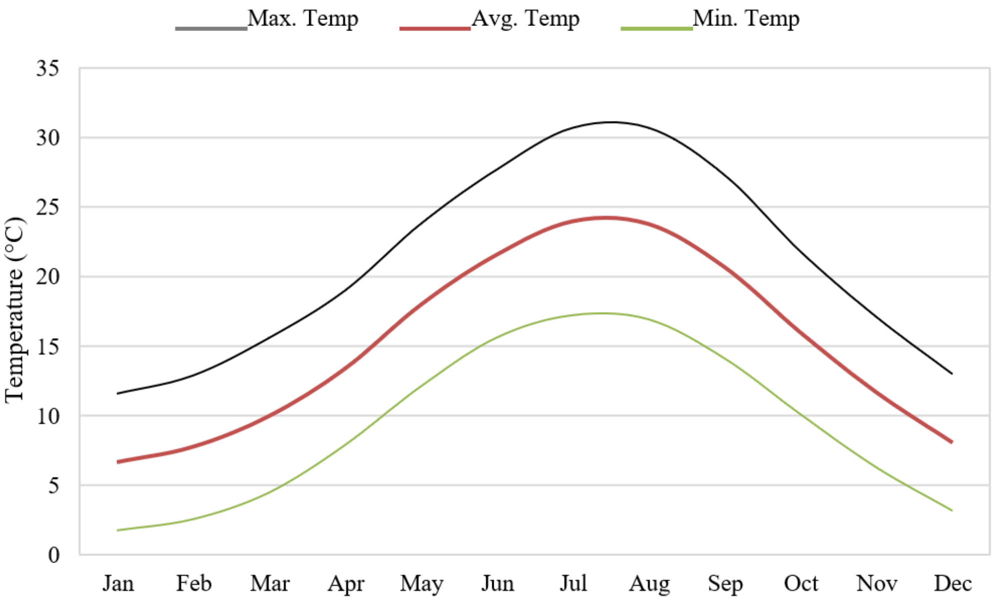


Figure 1. Annual temperatures for the city of Tirana.

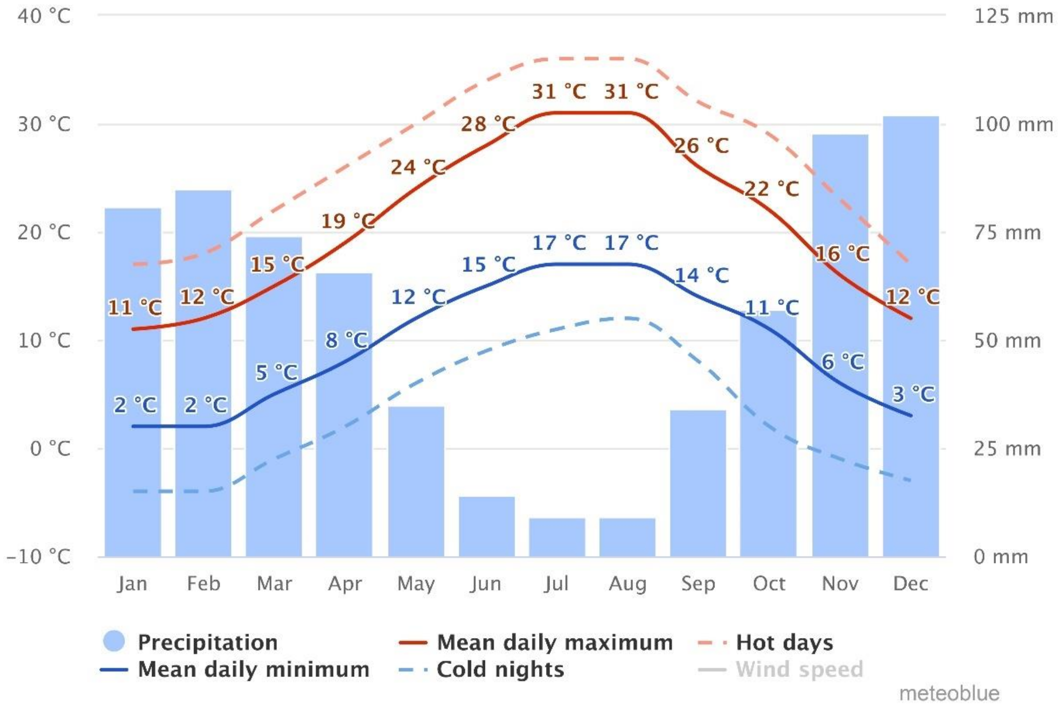


Figure 2. Tirana's climate monthly temperature [32].

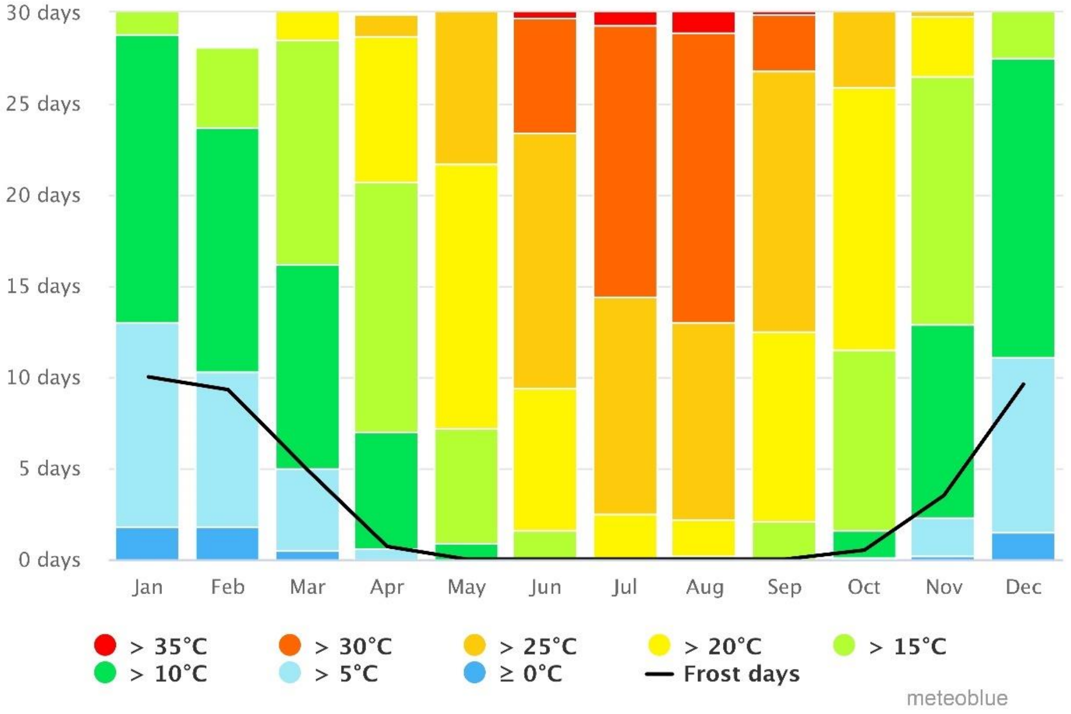
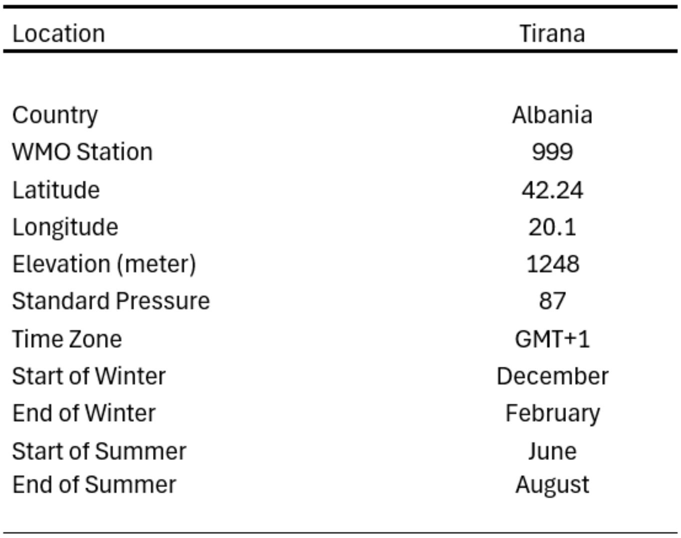


Figure 3. Data on the highest outdoor temperature in Tirana Monthly [32].

Table 2. Tirana Weather [32].



Location	Tirana
Country	Albania
WMO Station	999
Latitude	42.24
Longitude	20.1
Elevation (meter)	1248
Standard Pressure	87
Time Zone	GMT+1
Start of Winter	December
End of Winter	February
Start of Summer	June
End of Summer	August

3.3 Case Study Description

This study aims to present the significant role of glazing in office buildings and its crucial role in balancing comfort and sustainability. Given the lack of real scenarios of glazing models applied in Mediterranean regions to show the contribution to energy efficiency, comfort and give considerations or strategies for incorporating glass in a sustainable and comfortable manner, this paper aims to fill this gap by achieving energy-based design solutions in different types of glazing models, giving a real based data information on what is the right choice of glazing for buildings located in the mediterranean region. The models are designed to compare and show the various glasses might be different for each climate zone. They have slightly varying glazing properties as well as modest variations in physical, thermal, and construction properties.

Thus, to investigate the energy performance and optimization scenarios, a building model of 20 m x 30 m x 16 m is designed as shown in *Figure 4,* with reference location in Tirana, Albania. It is an office building separated in three floors, with one side constructed in curtain wall (glass façade), while the three other sides are constructed by brick wall. It has a total gross area of 1800m2, 1713m2 net. The total area for each floor is 600m2, 571 m2 net. The building model has different orientation, east-south-west-north, by giving real solution when it comes to building orientation. Various optimization scenarios are constructed to make a comparison and prove that alternatives can be unique for each glazing properties and orientation of the building.

Figure 4. 3D Building design model.

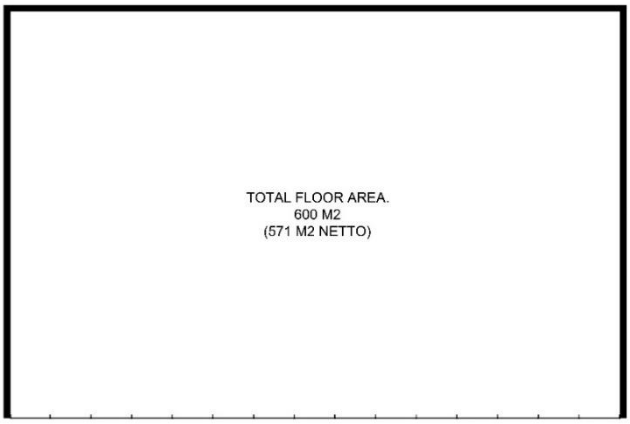


Figure 5. Typical ground, first and second floor plan (offices area).

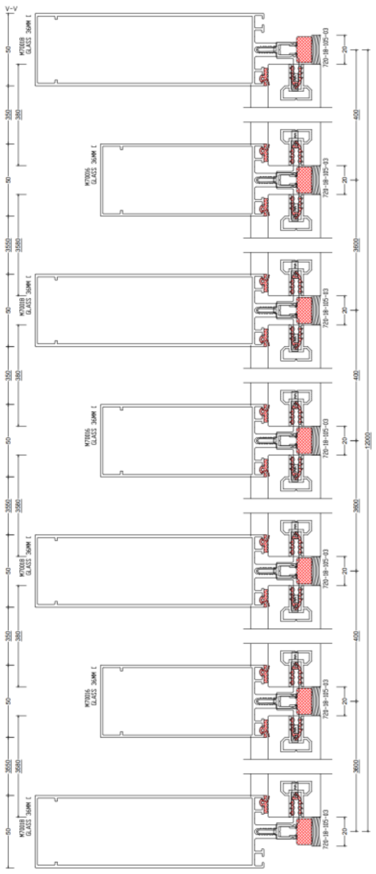


Figure 6. Section drawing detail of curtain wall used in 3D modelling (horizontal aluminum profiles).

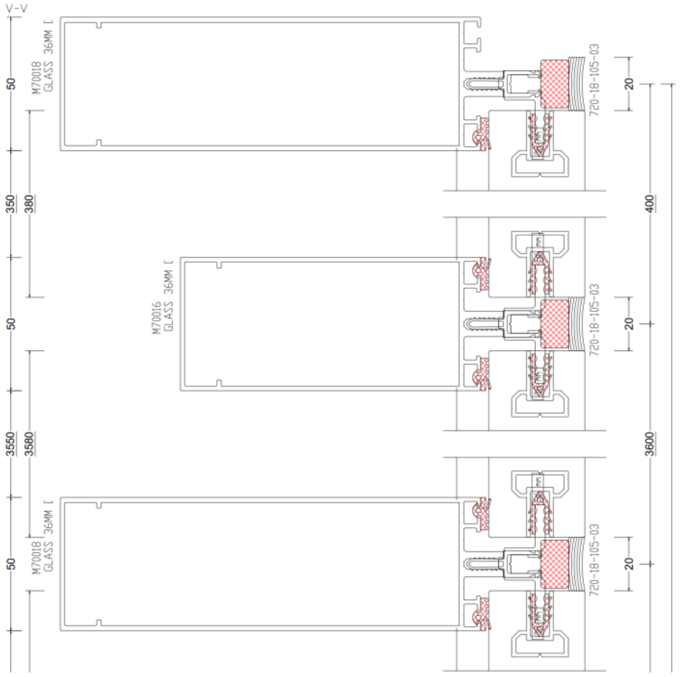


Figure 7. Section drawing detail of curtain wall used in 3D modelling (closer image).

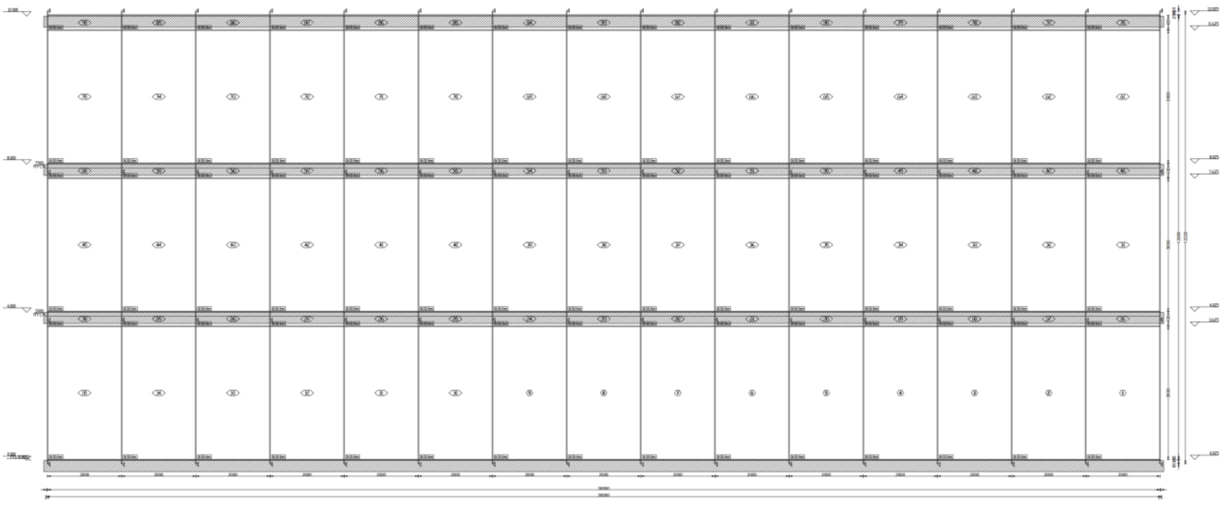


Figure 8. Technical elevation drawing on curtain wall (glass facade).

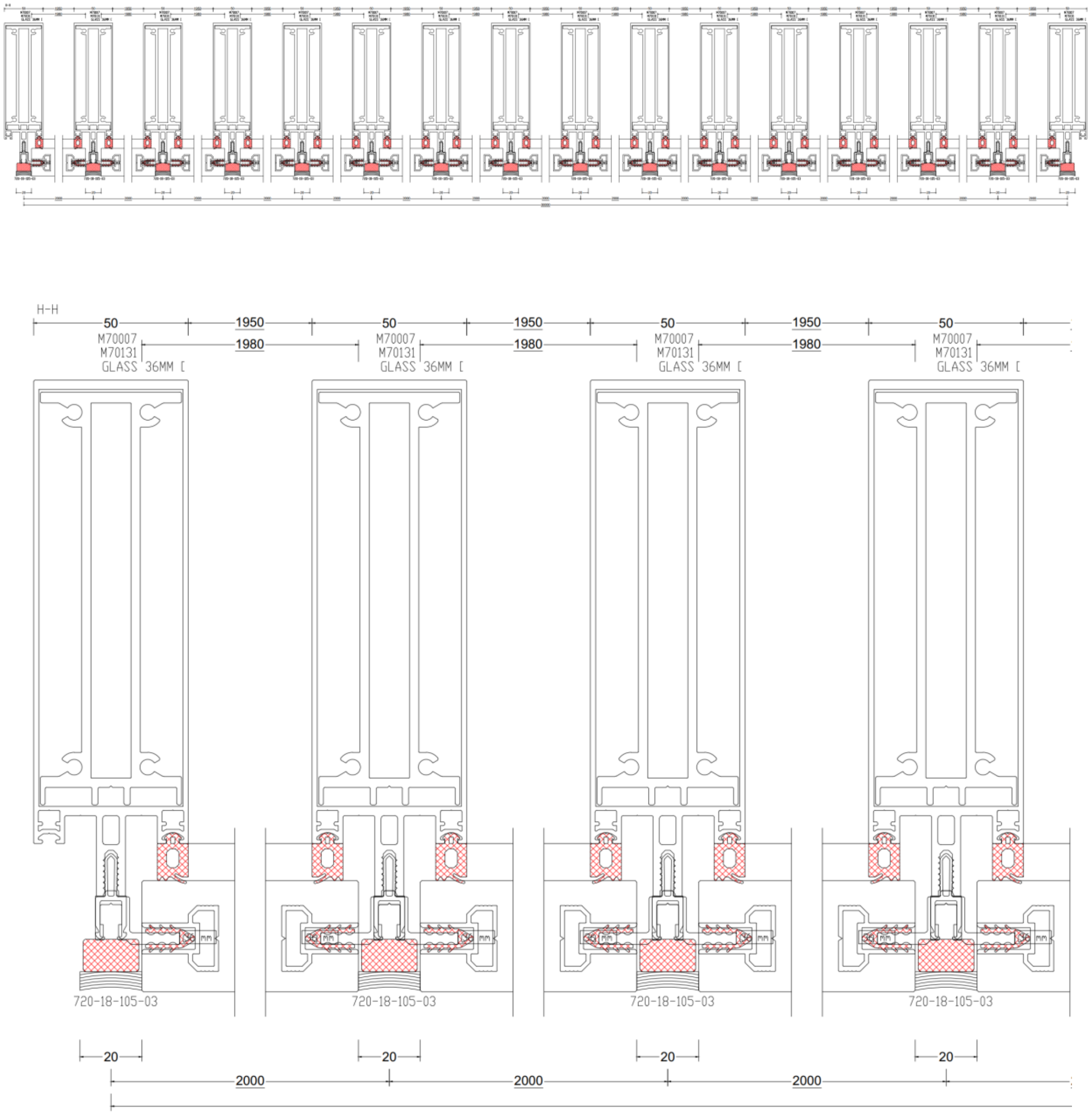


Figure 9. Section Drawing detail of curtain wall used in 3D modelling (vertical aluminum profiles).

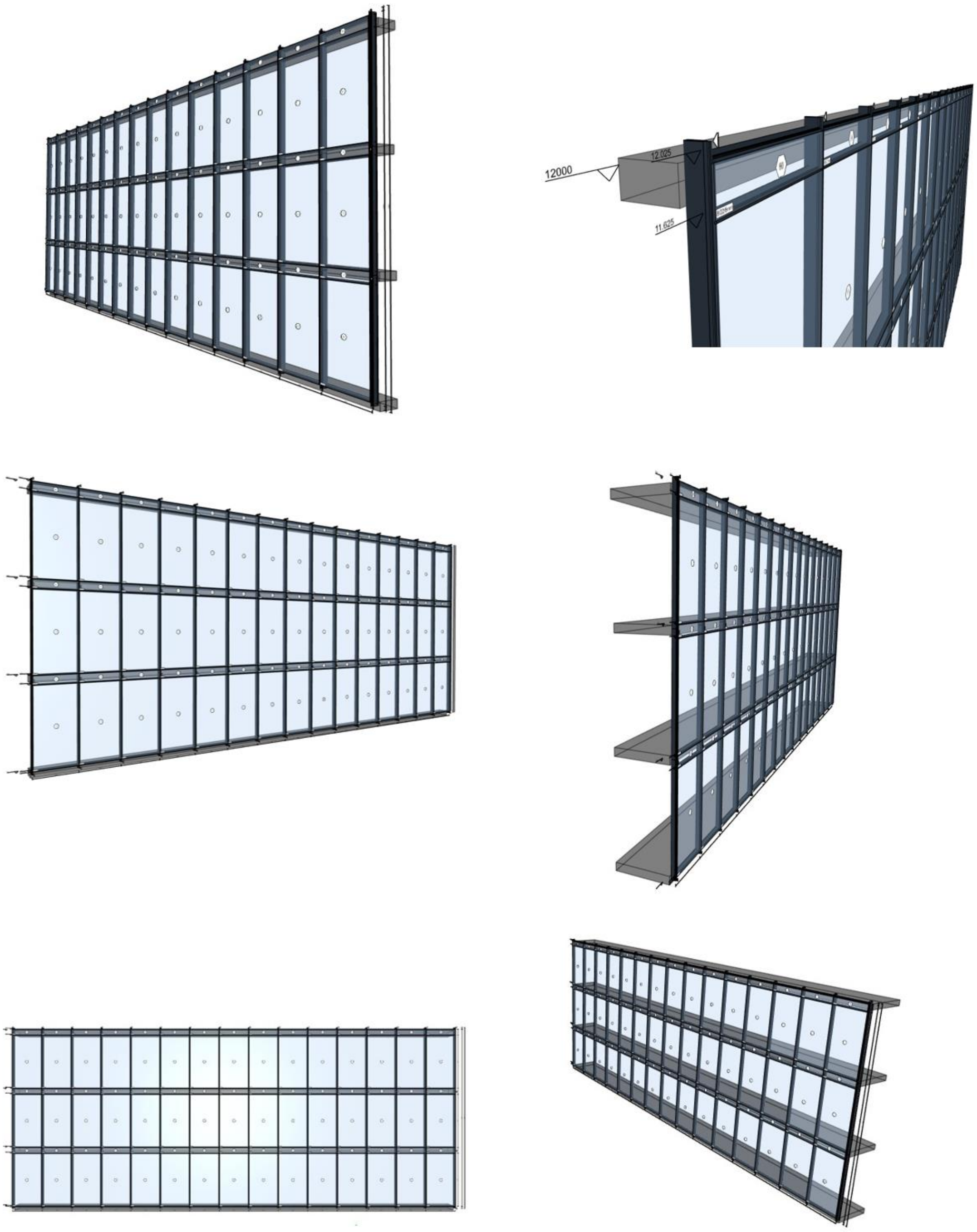


Figure 10. 3D constructed model of the curtain wall (glazing).

3.3.1 Glazing Description

Aluminum façade profiles were used to construct the curtain wall as shown in *Figure 5, 6, 7, 8, 9 and 10*. Since the main focus of the research is the glazing, simulation was only based on glazing effectiveness. The laminated glass, which is used almost in all scenarios due to its importance in safety reasons, also called triplex glass, is a composite material consisting of several layers of glass that are bonded together using heat and pressure, with the addition of one or more polymer interlayers. The glass and interlayers are offered in a range of colors and thicknesses to achieve the required aesthetic and functionality, in compliance with applicable building code regulations and client preferences. Laminated glass offers superior mechanical strength and enhanced security advantages [39]. The increasing demand for greater natural light in buildings is leading to a growing preference for larger windows that are energy-efficient. Additionally, both national and municipal regulations now mandate the use of safety glass in a wider range of architectural projects. Laminated glass is considered one of the most effective solutions to meet these requirements [39].

The Planitherm 4s Evolution or Low-E glass is used in all scenarios, on the outdoor glass. This glass has dual functionality to enhance occupant comfort: solar control and thermal insulation. The glass coatings used are regularly attached on the second surface of the insulating glazing. The advantage of utilizing the Low-E glass to regulate interior temperature effectively results in reduced energy consumption by minimizing the need for air conditioning. The occupant may experience optimal temperature and appropriate lighting regardless of the season. The summer-winter comfort function ensures a pleasant environment throughout the year, while the reflexivity feature ensures a suitable amount of privacy. It is a vital key to having a comfort indoor temperature due to its thermal properties [39].

Moreover, the tempered glass is used in all scenarios in indoor glass, also called as safety glass. Being an office building, it is important that the properties of glazing meet the safety regulations. Since tempered glass is mostly used in areas where strength, safety, and thermal resistant properties are needed, this glass will increase strength, thermal shock resistance, and safety of the glass itself.

In double and triple glazing scenarios, all indoor glass panes are transparent glass, also called as annealed or float glass, providing good transmittance of daylight. The option of tinted glass was not considered due to the lack of daylight transmittance, which is a key point in office areas, making the environment calmer and more interesting for the occupants. On the triple glazing scenarios, the middle glass in all scenarios is transparent glass since it is not vulnerable to external factors such as wind, birds, blows etc.

Argon gas is used in all glazing scenarios (Argon Gas 90%), as an inert and colorless gas that is found naturally and does not pose any damage. By introducing Argon gas between the glass panes, the thermal insulation of the double or triple glazing is enhanced. Being denser than air, it enhances thermal insulation effectiveness when introduced into the air space between the two panes. When a glazing unit incorporates Low E glass with Argon Gas, it reduces the temperature difference between the window and the room, bringing them closer to the same temperature [40]. This combination effectively minimizes the presence of air currents and drafts that arise from the convergence of dissimilar temperatures [40].

Similar to the gas fill, glass spacers have a significant effect on the thermal efficiency of an insulating glass unit. Hence, it is crucial to ensure that the spacer technology is both efficient and sustainable. Spacers determine the width of the gap between the glass panes [41]. The primary role of the spacer is to ensure a fixed gap between the layers of the glass. Spacers regulate the transfer of heat and cold between glass panes, making them a crucial element in maintaining the performance of the glass [41]. Different thicknesses of spacers are used in the analyzed scenarios.

More detailed information about the glazing can be found on the figures and tables on the following pages.

3.4 Computational Simulation Analysis

This study seeks to explore the effect of glazing in buildings energy performance, occupancy pattern, air conditioning systems and building energy performance analysis. As a result, the study's parameters are based on actual situations, by taking real data about the parameters and construction of building model and its patterns. A comprehensive account of the building envelope is completed, encompassing plan drawings, construction details, glazing, HVAC system, and occupancy schedule.

The goal of these analyses is to gain a comprehensive understanding of the building and its behaviour through simulations conducted using DesignBuilder software, using both passive and active approaches.

3.4.1 Simulation Software Description

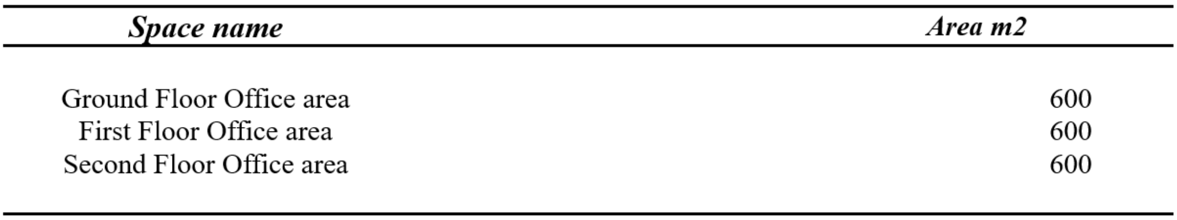
Nowadays, computer software is mostly used to evaluate a building's energy. In relation with the Energyplus software, the DesignBuilder provides a multitude of criteria to take into account. Determining the ideal values is crucial to the study's efficacy. A special software as DesignBuilder makes it possible to assess energy use by simulating an environment [36]. Mechanical, natural, and HVAC ventilation, as well as lighting systems, are assessed using corresponding retrofitting techniques. It can be applied to various tasks, such as daylight level computation, thermal loads and comfort forecast, building energy assessment, thorough HVAC modelling, and estimation of natural ventilation. Additionally, it contains a computational fluid dynamics (CFD) module for sophisticated heat and air flow analysis. The programme needs input data for location, weather, and several building envelope factors in order to function properly. Meteonorm 8 software was used to generate local weather files for different climatic situations in the Mediterranean region of Europe.

Concerns about global warming have made energy challenges a crucial research area in recent years [37]. The building envelope's thermal performance has an impact on the building's energy usage. Because they directly affect the building's thermal performance, glazing, façade, and structural materials receive a lot of attention [38].

3.4.2 Model Inputs Description

The building envelope is thoroughly described, complete with plan drawings, a construction description, glazing details, HVAC system details, and an occupancy timetable. This evaluation uses simulations performed in Design Builder software to aim for a broad spectrum understanding of the structure itself and how it behaves. *Table 3* shows the total area for each floor.

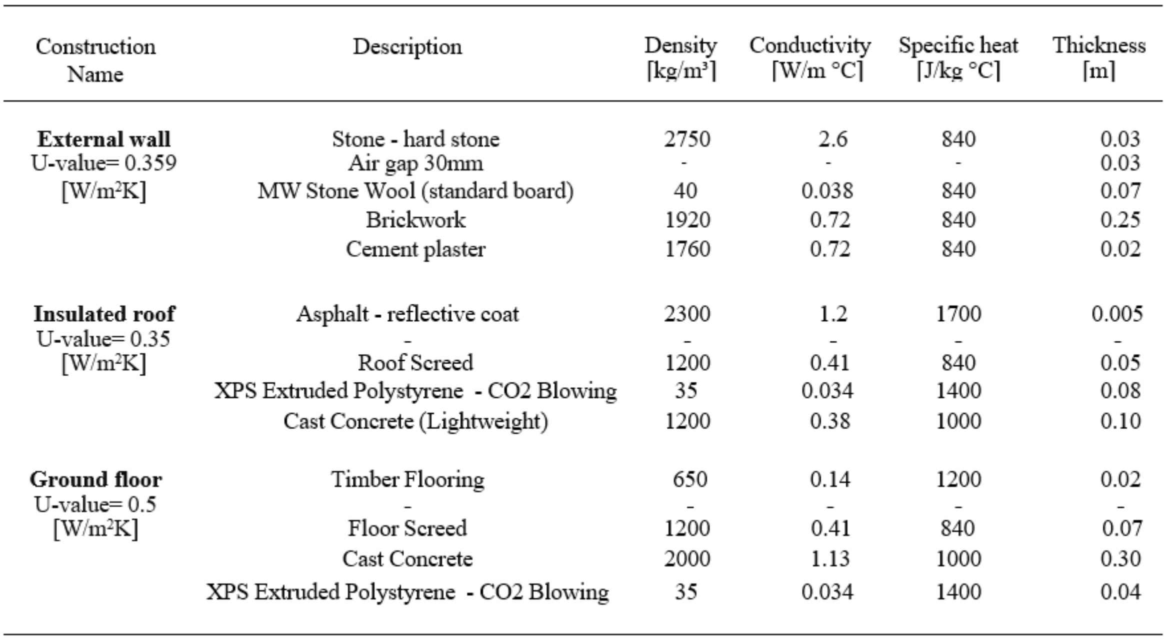
Table 3. Total area of each floor.



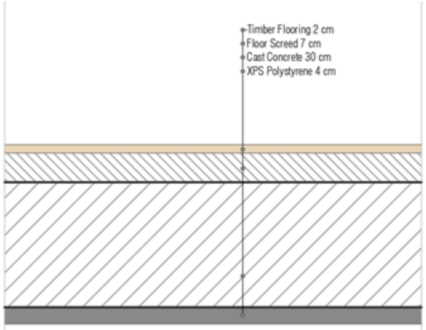
Space name	***Area m2***
Ground Floor Office area	600
First Floor Office area	600
Second Floor Office area	600

Since the key factor of this study is the glazing and all the simulation is done based on the glazing, the construction properties were base scenarios. Important was the external wall U-value to adjust the balance between the thermal efficiency of the glass facade but also the side walls since they cover three sides of the building, so it has a U-value of 0.36 [W/m^{2}K] as shown in *Table 4* and *Figure 11*. The gross wall area is 1200 m2, above ground wall area is 1200 m2, the window opening area is around 346 m2. Thus, we have a WWR (gross Window-Wall Ratio %) of 28.85 %. The gross roof area is 600 m2, same as the floor plans.

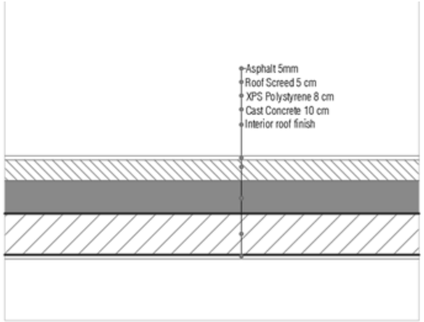
Table 4. Wall description.



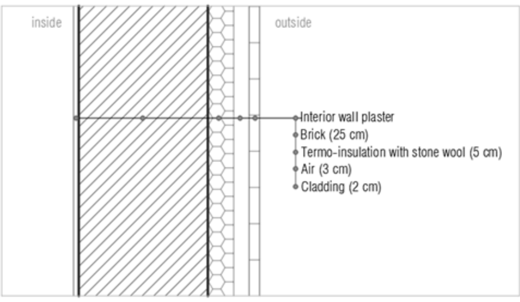
Construction Name	Description	Density [kg/m³]	Conductivity [W/m °C]	Specific heat [J/kg °C]	Thickness [m]
External wall	Stone - hard stone	2750	2.6	840	0.03
U-value= 0.359	Air gap 30mm	-	-	-	0.03
[W/m²K]	MW Stone Wool (standard board)	40	0.038	840	0.07
	Brickwork	1920	0.72	840	0.25
	Cement plaster	1760	0.72	840	0.02
Insulated roof	Asphalt - reflective coat	2300	1.2	1700	0.005
U-value= 0.35	-	-	-	-	-
[W/m²K]	Roof Screed	1200	0.41	840	0.05
	XPS Extruded Polystyrene - CO2 Blowing	35	0.034	1400	0.08
	Cast Concrete (Lightweight)	1200	0.38	1000	0.10
Ground floor	Timber Flooring	650	0.14	1200	0.02
U-value= 0.5	-	-	-	-	-
[W/m²K]	Floor Screed	1200	0.41	840	0.07
	Cast Concrete	2000	1.13	1000	0.30
	XPS Extruded Polystyrene - CO2 Blowing	35	0.034	1400	0.04



Ground Floor



Roof section



Exterior Wall Section

Figure 11. Section drawing details based on simulation.

3.4.3 Activity

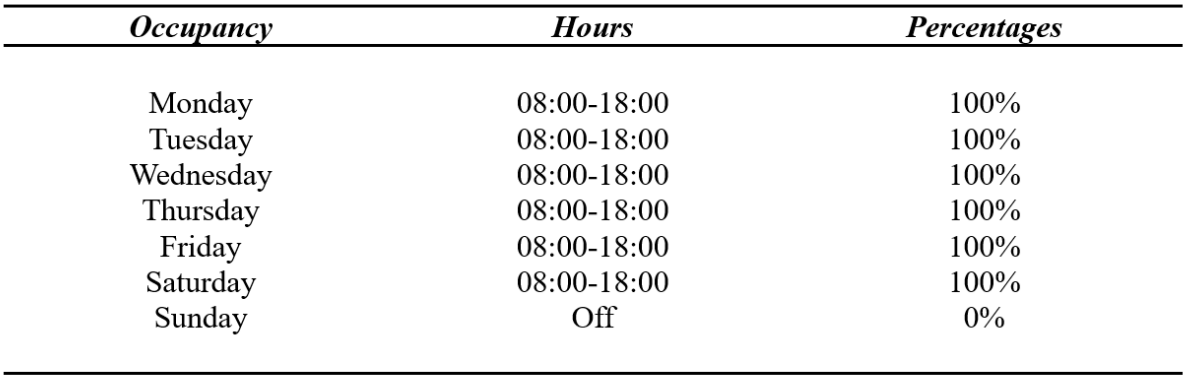
Albania, especially its capital city Tirana, has had a huge rate of office areas and buildings built during these last 20 years. Not only in Tirana, but also for the other cities of other mediterranean countries, this study seeks to fill the gap in the use of the glazing. There are multiple templates on the Design Builder simulation programme that show office activity. Specific attributes are assigned to each of them based on actual case studies from offices that operate in Albania and other Mediterranean nations.

A. **Occupancy**

The occupancy specifies how many individuals are occupying the floor space and how long they stay there. Office Buildings or areas offer almost the same activity in each space, for this reason the occupancy schedule is the same for each floor.

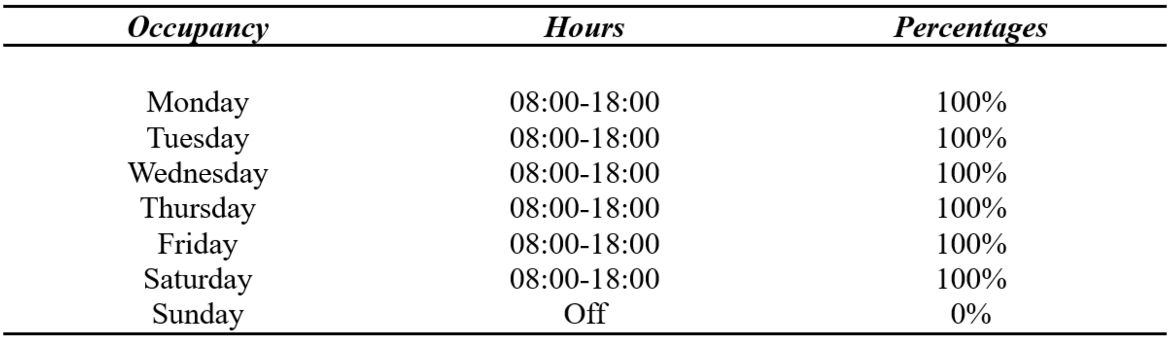
For the analyzed office building, there are a total of three floors, each of them serving as a working office space. Below, there are *Table 5, 6 and 7* showing the occupancy schedule for each floor.

Table 5. Ground floor occupancy schedule



Occupancy	***Hours***	***Percentages***
Monday	08:00-18:00	100%
Tuesday	08:00-18:00	100%
Wednesday	08:00-18:00	100%
Thursday	08:00-18:00	100%
Friday	08:00-18:00	100%
Saturday	08:00-18:00	100%
Sunday	Off	0%

Table 6. First floor occupancy schedule.



Occupancy	***Hours***	***Percentages***
Monday	08:00-18:00	100%
Tuesday	08:00-18:00	100%
Wednesday	08:00-18:00	100%
Thursday	08:00-18:00	100%
Friday	08:00-18:00	100%
Saturday	08:00-18:00	100%
Sunday	Off	0%

Table 7. Second floor occupancy schedule.

Occupancy	***Hours***	***Percentages***
Monday	08:00-18:00	100%
Tuesday	08:00-18:00	100%
Wednesday	08:00-18:00	100%
Thursday	08:00-18:00	100%
Friday	08:00-18:00	100%
Saturday	08:00-18:00	100%
Sunday	Off	0%

B. Metabolic Rate

The quantity of heat gain per person in the space under the design parameters is determined by the metabolic rate. The rate is different for each size: 1.00 for males, 0.85 for women, and 0.75 for kids. In summer, the clothing factor is at a minimum of 0.5 and reaches a maximum of 1 in winter [36].

C. Environmental Control

Environmental control includes minimum fresh air requirements per person, set points for heating and cooling, and lighting specifications. The ideal temperature in a particular space when heating is needed is defined by the heating set points temperature. Likewise, the optimal temperature at which cooling is necessary is determined by the cooling set point temperature. [36].

Table 8. Set points temperatures table.

Heating temperature set points	**°C**
Heating	22
Heating set back	12
Cooling temperature set points	***°C***
Cooling	24
Cooling set back	28

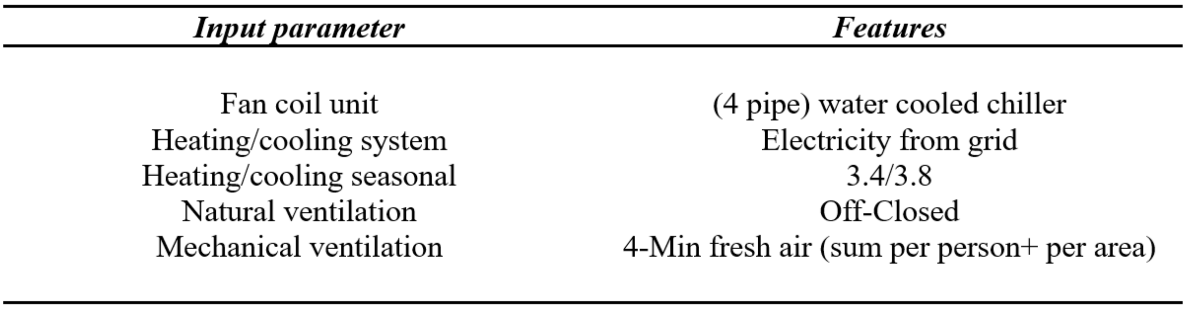
Since the Building has no openings throughout the façade, mechanical ventilation has been used to generate appropriate mechanical air circulation. *Table 8* above shows the set point temperatures for heating and cooling.

3.4.4 HVAC

Focusing on the scenarios, Fan Coil templates are powered by the electric grid and function as the HVAC system. To match the demand for heating and cooling, the unit is managed. The fan coil unit simulates a four-pipe fan coil unit that includes an outside air mixer, a chilled water-cooling coil, and a hot water heating coil (64). The HVAC schedule is the same for all the three floors.

There is no natural ventilation throughout the building so mechanical ventilation is used in the three floors where there are 0% opening glazing. *Table 9* shows the input parameters for HVAC, while *Table 10* outlines the HVAC operation time schedule for each floor. *Table 11* shows the schedule of mechanical ventilation.

Table 9. Input parameter for HVAC operation.



Input parameter	*Features*
Fan coil unit	(4 pipe) water cooled chiller
Heating/cooling system	Electricity from grid
Heating/cooling seasonal	3.4/3.8
Natural ventilation	Off-Closed
Mechanical ventilation	4-Min fresh air (sum per person+ per area)

Table 10. HVAC operation time schedule.

Floor	*Hours*
Ground Floor	07:30-18:00
First Floor	07:30-18:00
Second Floor	07:30-18:00

Table 11. Natural and mechanical ventilation schedule.

Ventilation	*Summer*	*Intensity(%)*	*Winter*	*Intensity(%)*
Mechanical	08:00-18:00	20%	08:00-18:00	20%

3.5 Scenarios for the proposed design strategies

Detailed description of the glazing and their properties are shown in the tables on the following pages. In every three scenarios we can see on the tables, for ex. DG_1, DG_1.1 and DG_1.2 they have the same glass, but only the spacing is changing. The code DG means double glazing and the code TG means triple glazing. There are 30 glazing scenarios for double glazing (DG) and 30 glazing scenarios for triple glazing (TG).

Since it has a major impact on the overall energy demand of the building, they were separated into three scenarios to show the importance of the spacing and its relation with energy consumption of the building. 16mm, 20mm and 24mm spacing was used in all double glazing simulations. No smaller spacer was used because in most of the glazing being produced in the today's times 16mm is the most common use of spacing, since it has a very positive impact on energy of the building compared to smaller spacers. Also, when compared to bigger spacers such as 20-24 mm, 16mm tends to be a better choice. More detailed information can be found on the properties table of each glazing and in the results of the simulations on the following pages.

For the triple glazing, 12mm, 14mm and 16 mm spacing was used. No bigger spacer was used because the thickness of the glazing exceeds the normal parameters of the aluminum, pvc or other material profiles, making it ineffective compared to the used spacers in this study when it comes to energy efficiency. Detailed information can be found on the glazing properties *Table 12, 13, 14 and 15* where the thickness of each scenario is shown.

Table 12. Description of the proposed double glazing scenarios.

Code	***Scenario***	***Description***
DG_1	33.1 (16 Argon 90) 6 Ft	Double Glazing Laminated 33.1 Low-E Planitherm 4S Evolution Coating with 16mm Spacing filled with Argon Gas 90% & 6mm Tempered Transparent Inside Glass
DG_1.1	33.1 (20 Argon 90) 6 Ft	Double Glazing Laminated 33.1 Low-E Planitherm 4S Evolution Coating with 20mm Spacing filled with Argon Gas 90% & 6mm Tempered Transparent Inside Glass
DG_1.2	33.1 (24 Argon 90) 6 Ft	Double Glazing Laminated 33.1 Low-E Planitherm 4S Evolution Coating with 24mm Spacing filled with Argon Gas 90% & 6mm Tempered Transparent Inside Glass
DG_2	33.1 (16 Argon 90) 33.1	Double Glazing Laminated 33.1 Low-E Planitherm 4S Evolution Coating with 16mm Spacing filled with Argon Gas 90% & 33.1 Laminated Transparent Inside Glass
DG_2.1	33.1 (20 Argon 90) 33.1	Double Glazing Laminated 33.1 Low-E Planitherm 4S Evolution Coating with 20mm Spacing filled with Argon Gas 90% & 33.1 Laminated Transparent Inside Glass
DG_2.2	33.1 (24 Argon 90) 33.1	Double Glazing Laminated 33.1 Low-E Planitherm 4S Evolution Coating with 24mm Spacing filled with Argon Gas 90% & 33.1 Laminated Transparent Inside Glass
DG_3	33.1 (16 Argon 90) 8Ft	Double Glazing Laminated 33.1 Low-E Planitherm 4S Evolution Coating with 16mm Spacing filled with Argon Gas 90% & 8mm Tempered Transparent Inside Glass
DG_3.1	33.1 (20 Argon 90) 8Ft	Double Glazing Laminated 33.1 Low-E Planitherm 4S Evolution Coating with 20mm Spacing filled with Argon Gas 90% & 8mm Tempered Transparent Inside Glass
DG_3.2	33.1 (24 Argon 90) 8Ft	Double Glazing Laminated 33.1 Low-E Planitherm 4S Evolution Coating with 24mm Spacing filled with Argon Gas 90% & 8mm Tempered Transparent Inside Glass

DG_4	44.1 (16 Argon 90) 6 Ft	Double Glazing Laminated 44.1 Low-E Planitherm 4S Evolution Coating with 16mm Spacing filled with Argon Gas 90% & 6mm Tempered Transparent Inside Glass
DG_4.1	44.1 (20 Argon 90) 6 Ft	Double Glazing Laminated 44.1 Low-E Planitherm 4S Evolution Coating with 20mm Spacing filled with Argon Gas 90% & 6mm Tempered Transparent Inside Glass
DG_4.2	44.1 (24 Argon 90) 6 Ft	Double Glazing Laminated 44.1 Low-E Planitherm 4S Evolution Coating with 24mm Spacing filled with Argon Gas 90% & 6mm Tempered Transparent Inside Glass
DG_5	44.1 (16 Argon 90) 8 Ft	Double Glazing Laminated 44.1 Low-E Planitherm 4S Evolution Coating with 16mm Spacing filled with Argon Gas 90% & 8mm Tempered Transparent Inside Glass
DG_5.1	44.1 (20 Argon 90) 8 Ft	Double Glazing Laminated 44.1 Low-E Planitherm 4S Evolution Coating with 20mm Spacing filled with Argon Gas 90% & 8mm Tempered Transparent Inside Glass
DG_5.2	44.1 (24 Argon 90) 8 Ft	Double Glazing Laminated 44.1 Low-E Planitherm 4S Evolution Coating with 24mm Spacing filled with Argon Gas 90% & 8mm Tempered Transparent Inside Glass
DG_6	44.1 (16 Argon 90) 44.1	Double Glazing Laminated 44.1 Low-E Planitherm 4S Evolution Coating with 16mm Spacing filled with Argon Gas 90% & 44.1 Laminated Transparent Inside Glass
DG_6.1	44.1 (20 Argon 90) 44.1	Double Glazing Laminated 44.1 Low-E Planitherm 4S Evolution Coating with 20mm Spacing filled with Argon Gas 90% & 44.1 Laminated Transparent Inside Glass
DG_6.2	44.1 (24 Argon 90) 44.1	Double Glazing Laminated 44.1 Low-E Planitherm 4S Evolution Coating with 24mm Spacing filled with Argon Gas 90% & 44.1 Laminated Transparent Inside Glass
DG_7	55.1 (16 Argon 90) 55.1	Double Glazing Laminated 55.1 Low-E Planitherm 4S Evolution Coating with 16mm Spacing filled with Argon Gas 90% & 55.1 Laminated Transparent Inside Glass
DG_7.1	55.1 (20 Argon 90) 55.1	Double Glazing Laminated 55.1 Low-E Planitherm 4S Evolution Coating with 20mm Spacing filled with Argon Gas 90% & 55.1 Laminated Transparent Inside Glass
DG_7.2	55.1 (24 Argon 90) 55.1	Double Glazing Laminated 55.1 Low-E Planitherm 4S Evolution Coating with 24mm Spacing filled with Argon Gas 90% & 55.1 Laminated Transparent Inside Glass

DG_8	55.1 (16 Argon 90) 10 Ft	Double Glazing Laminated 55.1 Low-E Planitherm 4S Evolution Coating with 16mm Spacing filled with Argon Gas 90% & 10mm Tempered Transparent Inside Glass
DG_8.1	55.1 (20 Argon 90) 10 Ft	Double Glazing Laminated 55.1 Low-E Planitherm 4S Evolution Coating with 20mm Spacing filled with Argon Gas 90% & 10mm Tempered Transparent Inside Glass
DG_8.2	55.1 (24 Argon 90) 10 Ft	Double Glazing Laminated 55.1 Low-E Planitherm 4S Evolution Coating with 24mm Spacing filled with Argon Gas 90% & 10mm Tempered Transparent Inside Glass
DG_9	12 Ft (16 Argon 90) 12 Ft	Double Glazing 12mm Tempered Transparent with 16mm Spacing filled with Argon Gas 90% & 16 mm Tempered Transparent Inside Glass (Air Albania Stadium Case)
DG_9.1	12 Ft (20 Argon 90) 12 Ft	Double Glazing 12mm Tempered Transparent with 16mm Spacing filled with Argon Gas 90% & 20 mm Tempered Transparent Inside Glass (Air Albania Stadium Case)
DG_9.2	12 Ft (24 Argon 90) 12 Ft	Double Glazing 12mm Tempered Transparent with 16mm Spacing filled with Argon Gas 90% & 24 mm Tempered Transparent Inside Glass (Air Albania Stadium Case)
DG_10	66.1 (16 Argon 90) 12 Ft	Double Glazing Laminated 66.1 Low-E Planitherm 4S Evolution Coating with 16mm Spacing filled with Argon Gas 90% & 12mm Tempered Transparent Inside Glass
DG_10.1	66.1 (20 Argon 90) 12 Ft	Double Glazing Laminated 66.1 Low-E Planitherm 4S Evolution Coating with 20mm Spacing filled with Argon Gas 90% & 12mm Tempered Transparent Inside Glass
DG_10.2	66.1 (24 Argon 90) 12 Ft	Double Glazing Laminated 66.1 Low-E Planitherm 4S Evolution Coating with 24mm Spacing filled with Argon Gas 90% & 12mm Tempered Transparent Inside Glass

Table 13. Description of the proposed triple glazing scenarios.

Code	*Scenario*	*Description*
TG_1	6 Ft (16 Argon 90) 4 (16 Argon 90) 6 Ft	Triple Glazing 6mm Tempered Low-E Planitherm 4S Evolution Coating + 16mm Spacing filled with Argon Gas 90% + 4mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_1.1	6 Ft (12 Argon 90) 4 (16 Argon 90) 6 Ft	Triple Glazing 6mm Tempered Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 4mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_1.2	6 Ft (12 Argon 90) 4 (12 Argon 90) 6 Ft	Triple Glazing 6mm Tempered Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 4mm Transparent Glass + 12mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_2	6 Ft (16 Argon 90) 6 (16 Argon 90) 6 Ft	Triple Glazing 6mm Tempered Low-E Planitherm 4S Evolution Coating + 16mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_2.1	6 Ft (12 Argon 90) 6 (16 Argon 90) 6 Ft	Triple Glazing 6mm Tempered Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_2.2	6 Ft (12 Argon 90) 6 (12 Argon 90) 6 Ft	Triple Glazing 6mm Tempered Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 12mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_3	33.1 (16 Argon 90) 4 (16 Argon 90) 6 Ft	Triple Glazing 33.1 Laminated Low-E Planitherm 4S Evolution Coating + 16mm Spacing filled with Argon Gas 90% + 4mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_3.1	33.1 (12 Argon 90) 4 (16 Argon 90) 6 Ft	Triple Glazing 33.1 Laminated Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 4mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside

TG_3.2	33.1 (12 Argon 90) 4 (12 Argon 90) 6 Ft	Triple Glazing 33.1 Laminated Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 4mm Transparent Glass + 12mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_4	33.1 (16 Argon 90) 6 (16 Argon 90) 6 Ft	Triple Glazing 33.1 Laminated Low-E Planitherm 4S Evolution Coating + 16mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_4.1	33.1 (12 Argon 90) 6 (16 Argon 90) 6 Ft	Triple Glazing 33.1 Laminated Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_4.2	33.1 (12 Argon 90) 6 (12 Argon 90) 6 Ft	Triple Glazing 33.1 Laminated Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 12mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_5	33.1 (16 Argon 90) 6 (16 Argon 90) 33.1	Triple Glazing 33.1 Laminated Low-E Planitherm 4S Evolution Coating + 16mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 33.1 Laminated Transparent Inside
TG_5.1	33.1 (12 Argon 90) 6 (16 Argon 90) 33.1	Triple Glazing 33.1 Laminated Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 33.1 Laminated Transparent Inside
TG_5.2	33.1 (12 Argon 90) 6 (12 Argon 90) 33.1	Triple Glazing 33.1 Laminated Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 12mm Spacing filled with Argon Gas 90% + 33.1 Laminated Transparent Inside
TG_6	44.1 (16 Argon 90) 6 (16 Argon 90) 6 Ft	Triple Glazing 44.1 Laminated Low-E Planitherm 4S Evolution Coating + 16mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_6.1	44.1 (12 Argon 90) 6 (16 Argon 90) 6 Ft	Triple Glazing 44.1 Laminated Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside

TG_6.2	44.1 (12 Argon 90) 6 (12 Argon 90) 6 Ft	Triple Glazing 44.1 Laminated Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 12mm Spacing filled with Argon Gas 90% + 6mm Tempered Transparent Inside
TG_7	44.1 (12 Argon 90) 6 (16 Argon 90) 44.1	Triple Glazing 44.1 Laminated Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 44.1 Laminated Transparent Inside
TG_7.1	44.1 (12 Argon 90) 6 (12 Argon 90) 44.1	Triple Glazing 44.1 Laminated Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 12mm Spacing filled with Argon Gas 90% + 44.1 Laminated Transparent Inside
TG_7.2	44.1 (14 Argon 90) 6 (16 Argon 90) 44.1	Triple Glazing 44.1 Laminated Low-E Planitherm 4S Evolution Coating + 14mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 44.1 Laminated Transparent Inside
TG_8	44.1 (12 Argon 90) 6 (16 Argon 90) 8 Ft	Triple Glazing 44.1 Laminated Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 8mm Tempered Transparent Inside
TG_8.1	44.1 (12 Argon 90) 6 (12 Argon 90) 8 Ft	Triple Glazing 44.1 Laminated Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 12mm Spacing filled with Argon Gas 90% + 8mm Tempered Transparent Inside
TG_8.2	44.1 (14 Argon 90) 6 (16 Argon 90) 8 Ft	Triple Glazing 44.1 Laminated Low-E Planitherm 4S Evolution Coating + 14mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 8mm Tempered Transparent Inside
TG_9	8 Ft (16 Argon 90) 6 (16 Argon 90) 33.1	Triple Glazing 8mm Tempered Low-E Planitherm 4S Evolution Coating + 16mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 33.1 Laminated Transparent Inside
TG_9.1	8 Ft (12 Argon 90) 6 (16 Argon 90) 33.1	Triple Glazing 8mm Tempered Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 33.1 Laminated Transparent Inside

TG_9.2	8 Ft (12 Argon 90) 6 (12 Argon 90) 33.1	Triple Glazing 8mm Tempered Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 12mm Spacing filled with Argon Gas 90% + 33.1 Laminated Transparent Inside
TG_10	8 Ft (16 Argon 90) 6 (16 Argon 90) 8 Ft	Triple Glazing 8mm Tempered Low-E Planitherm 4S Evolution Coating + 16mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 8mm Tempered Transparent Inside
TG_10.1	8 Ft (12 Argon 90) 6 (16 Argon 90) 6 Ft	Triple Glazing 8mm Tempered Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 16mm Spacing filled with Argon Gas 90% + 8mm Tempered Transparent Inside
TG_10.2	8 Ft (12 Argon 90) 6 (12 Argon 90) 6 Ft	Triple Glazing 8mm Tempered Low-E Planitherm 4S Evolution Coating + 12mm Spacing filled with Argon Gas 90% + 6mm Transparent Glass + 12mm Spacing filled with Argon Gas 90% + 8mm Tempered Transparent Inside

Table 14. Double glazing properties**.**

Code	Glazing	Thickness (mm)	Total solar Transition % (SHGC)	Direct Solar Transmission	Light transmission %	U value (w/m-K)	Price/m2 in Euro
DG_1	33.1 (16 Argon 90) 6 ft	28.4	35	0.38	60	1.0	65
DG_1.1	33.1 (20 Argon 90) 6 ft	32.4	35	0.38	60	1.1	66
DG_1.2	33.1 (24 Argon 90) 6 ft	36.4	35	0.38	60	1.1	67
DG_2	33.1 (16 Argon 90) 33.1	28.8	35	0.38	60	1.0	75

DG_2.1	33.1 (20 Argon 90) 33.1	32.8	35	0.38	60	1.1	76
DG_2.2	33.1 (20 Argon 90) 33.1	36.8	35	0.38	60	1.1	77
DG_3	33.1 (16 Argon 90) 8ft	30.4	34	0.38	60	1.0	90
DG_3.1	33.1 (20 Argon 90) 8ft	34.4	34	0.38	60	1.1	92
DG_3.2	33.1 (24 Argon 90) 8ft	38.4	34	0.38	60	1.1	95
DG_4	44.1(16 Argon 90) 6ft	30.4	34	0.37	60	1.0	90
DG_4.1	44.1(20 Argon 90) 6ft	34.4	34	0.37	60	1.1	92
DG_4.2	44.1(24 Argon 90) 6ft	34.4	34	0.37	60	1.1	95
DG_5	44.1(16 Argon 90) 8ft	32.4	34	0.37	59	1.0	95
DG_5.1	44.1(20 Argon 90) 8ft	36.4	34	0.37	59	1.1	97
DG_5.2	44.1(24 Argon 90) 8ft	40.4	34	0.37	59	1.1	98
DG_6	44.1(16 Argon 90) 44.1	32.8	33	0.37	59	1.0	100
DG_6.1	44.1(20 Argon 90) 44.1	36.8	33	0.37	59	1.1	102
DG_6.2	44.1(24 Argon 90) 44.1	40.8	33	0.37	59	1.1	105
DG_7	55.1(16 Argon 90) 55.1	36.8	32	0.37	58	1.0	110
DG_7.1	55.1(20 Argon 90) 55.1	40.8	32	0.37	58	1.0	112

DG_7.1	55.1(24 Argon 90) 55.1	40.8	32	0.37	58	1.1	115
DG_8	55.1(16 Argon 90)10ft	36.4	33	0.37	59	1.0	120
DG_8.1	55.1(20 Argon 90)10ft	40.4	33	0.37	59	1.1	125
DG_8.2	55.1(24 Argon 90)10ft	44.4	33	0.37	59	1.1	130
DG_9	12ft (16 Argon 90)12ft	40.0	64	0.72	78	2.5	140
DG_9.1	12ft (20 Argon 90)12ft	44.0	64	0.72	78	2.5	145
DG_9.2	12ft (24 Argon 90)12ft	48.0	64	0.72	78	2.5	150
DG_10	66.1 (16 Argon 90)12ft	40.4	32	0.36	58	1.0	155
DG_10.1	66.1 (20 Argon 90)12ft	44.4	32	0.36	58	1.0	150
DG_10.2	66.1 (24 Argon 90)12ft	48.4	32	0.36	58	1.1	165

Table 15. Triple glazing properties.

Code	Glazing	Thickness (mm)	Total solar Transition % (SHGC)	Direct Solar Transmission	Light transmission %	U value (w/m-K)	Price/M2 in Euro
TG_1	6ft (16 Argon 90) 4 (16 Argon 90) 6	48.0	31	0.34	64	0.8	80
TG_1.1	6ft (12 Argon 90) 4 (16 Argon 90) 6	44.0	31	0.34	64	1.0	82

TG_1.2	6ft (12 Argon 90) 4 (12 Argon 90) 6	40.0	31	0.34	64	1.1	85
TG_2	6ft (16 Argon 90) 6 (16 Argon 90) 6	50.0	32	0.36	55	0.8	85
TG_2.1	6ft (12 Argon 90) 6 (16 Argon 90) 6	46.0	32	0.36	55	1.0	87
TG_2.2	6ft (12 Argon 90) 6 (12 Argon 90) 6	42.0	32	0.36	55	1.0	89
TG_3	33.1 (16 Argon 90) 4 (16 Argon 90) 6ft	48.4	32	0.35	56	0.8	100
TG_3.1	33.1 (12 Argon 90) 4 (16 Argon 90) 6ft	44.4	32	0.35	56	1.0	105
TG_3.2	33.1 (12 Argon 90) 4 (12 Argon 90) 6ft	40.4	32	0.35	56	1.0	105
TG_4	33.1 (16 Argon 90) 6 (16 Argon 90) 6ft	50.4	31	0.35	55	0.8	110
TG_4.1	33.1 (12 Argon 90) 6 (16 Argon 90) 6ft	46.4	31	0.35	55	1.0	115
TG_4.2	33.1 (12 Argon 90) 6 (12 Argon 90) 6ft	42.4	31	0.35	55	1.0	115
TG_5	33.1 (16 Argon 90) 6 (16 Argon 90) 33.1	50.8	31	0.35	55	0.8	115
TG_5.1	33.1 (12 Argon 90) 6 (16 Argon 90) 33.1	46.8	31	0.35	55	1.0	120

TG_5.2	33.1 (12 Argon 90) 6 (12 Argon 90) 33.1	42.8	31	0.35	55	1.0	122
TG_6	44.1 (16 Argon 90) 6 (16 Argon 90) 6ft	52.4	31	0.35	55	0.8	125
TG_6.1	44.1 (12 Argon 90) 6 (16 Argon 90) 6ft	48.4	31	0.35	55	1.0	130
TG_6.2	44.1 (12 Argon 90) 6 (12 Argon 90) 6ft	44.4	31	0.35	55	1.0	132
TG_7	44.1 (12 Argon 90) 6 (16 Argon 90) 44.1	50.8	30	0.35	54	0.9	135
TG_7.1	44.1 (12 Argon 90) 6 (12 Argon 90) 44.1	46.8	30	0.35	54	1.0	140
TG_7.2	44.1 (14 Argon 90) 6 (16 Argon 90) 44.1	52.8	30	0.35	54	0.9	142
TG_8	44.1 (12 Argon 90) 6 (16 Argon 90) 8ft	50.4	30	0.35	54	0.9	145
TG_8.1	44.1 (12 Argon 90) 6 (12 Argon 90) 8ft	46.4	30	0.35	54	1.0	150
TG_8.2	44.1 (14 Argon 90) 6 (16 Argon 90) 8ft	52.4	30	0.35	54	0.9	155
TG_9	8 (16 Argon 90) 6 (16 Argon 90) 33.1	52.4	31	0.36	55	0.8	150
TG_9.1	8 (12 Argon 90) 6 (16 Argon 90) 33.1	48.4	31	0.36	55	1.0	155

TG_9.2	8 (12 Argon 90) 6 (12 Argon 90) 33.1	44.4	31	0.36	55	1.0	155
TG_10	8 (16 Argon 90) 6 (16 Argon 90) 8	54.0	31	0.36	55	0.8	150
TG_10.1	8 (12 Argon 90) 6 (16 Argon 90) 8	50.0	31	0.36	55	0.9	155
TG_10.2	8 (12 Argon 90) 6 (12 Argon 90) 8	46.0	31	0.36	55	1.0	160

The above tables show different glazing properties such as direct and total solar transmittance, glazing thickness, light transmittance, U- value and also the prices for the double and triple glazing scenarios. It is important to mention that the prices are average prices that may be slightly higher or lower, but are based on glass manufacturers. *Figure 12 to Figure 71* on the following pages illustrate a conceptual section drawing or configuration of each scenario, showing how the glass and its coatings are used in glazing. Descriptions are given below the drawings, showing the outdoor glass, spacing and indoor glass type and their thickness. Each scenario has its own specific thickness and properties.

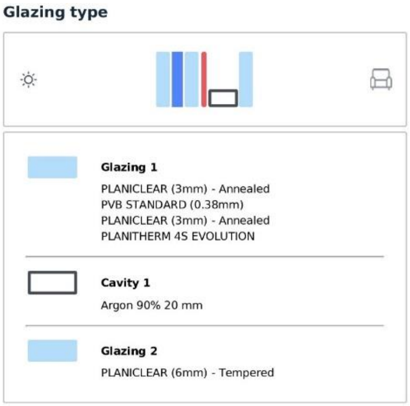

Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (6mm) - Tempered

Figure 12. Double Glazing configuration DG_1.


Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 20 mm

Glazing 2
PLANICLEAR (6mm) - Tempered

Figure 13. Double Glazing configuration DG_1.1.

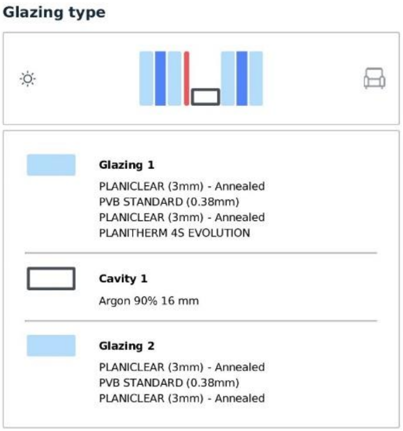

Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 24 mm

Glazing 2
PLANICLEAR (6mm) - Tempered

Figure 14. Double Glazing configuration DG_1.2.

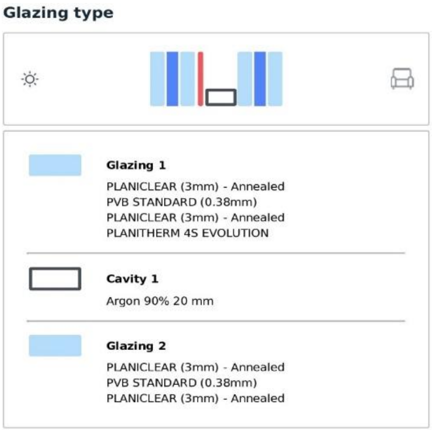

Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed

Figure 15. Double Glazing configuration DG_2.


Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 20 mm

Glazing 2
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed

Figure 16. Double Glazing configuration DG_2.1.


Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 24 mm

Glazing 2
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed

Figure 17. Double Glazing configuration DG_2.2.

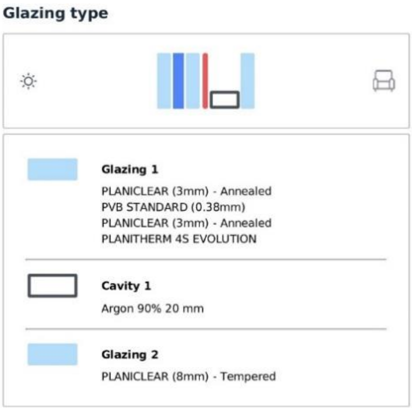

Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (8mm) - Tempered

Figure 18. Double Glazing configuration DG_3.

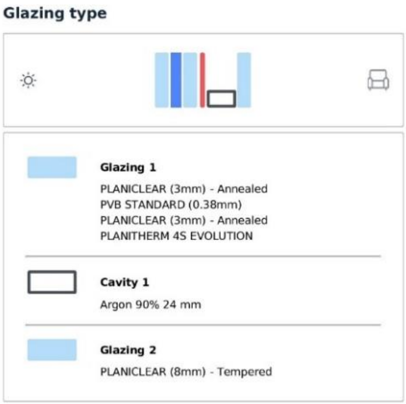

Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 20 mm

Glazing 2
PLANICLEAR (8mm) - Tempered

Figure 19. Double Glazing configuration DG_3.1.


Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 24 mm

Glazing 2
PLANICLEAR (8mm) - Tempered

Figure 20. Double Glazing configuration DG_3.2.


Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (6mm) - Tempered

Figure 21. Double Glazing configuration DG_4.


Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 20 mm

Glazing 2
PLANICLEAR (6mm) - Tempered

Figure 22. Double Glazing configuration DG_4.1.

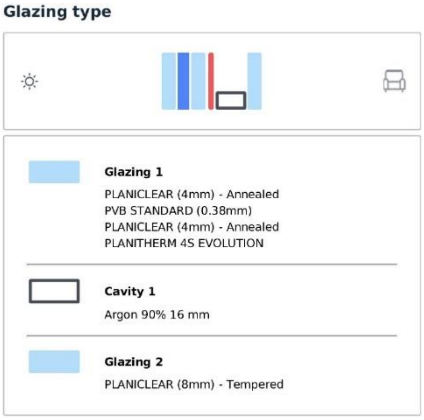

Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 24 mm

Glazing 2
PLANICLEAR (6mm) - Tempered

Figure 23. Double Glazing configuration DG_4.2.

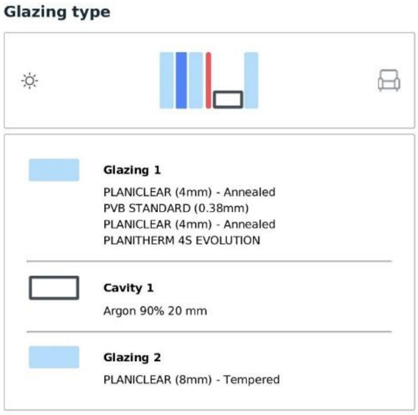

Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (8mm) - Tempered

Figure 24. Double Glazing configuration DG_5.

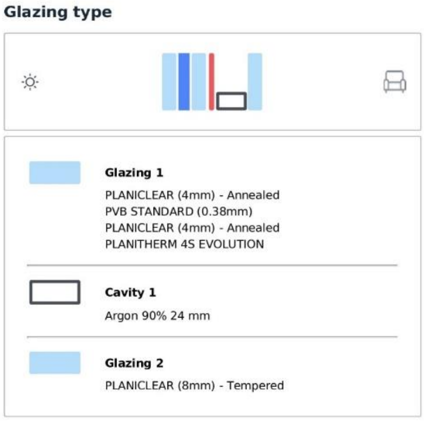

Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 20 mm

Glazing 2
PLANICLEAR (8mm) - Tempered

Figure 25. Double Glazing configuration DG_5.1.

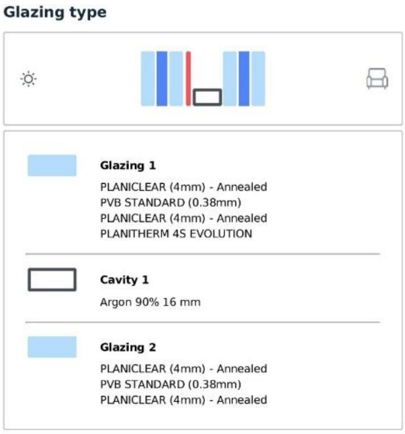

Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 24 mm

Glazing 2
PLANICLEAR (8mm) - Tempered

Figure 26. Double Glazing configuration DG_5.2.

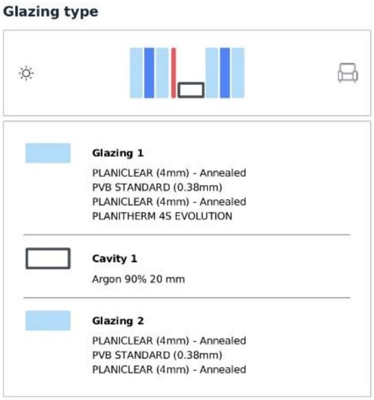

Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed

Figure 27. Double Glazing configuration DG_6.

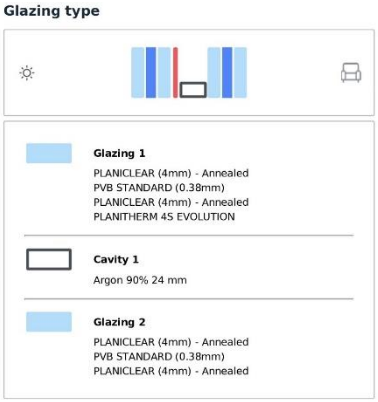

Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 20 mm

Glazing 2
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed

Figure 28. Double Glazing configuration DG_6.1.

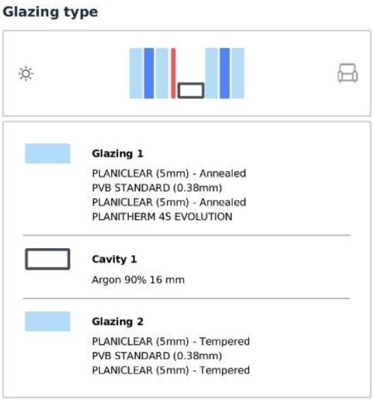

Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 24 mm

Glazing 2
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed

Figure 29. Double Glazing configuration DG_6.2.

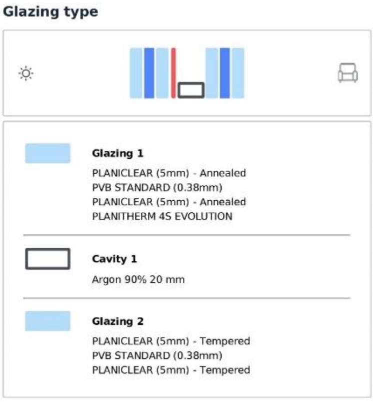

Glazing type

Glazing 1
PLANICLEAR (5mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (5mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (5mm) - Tempered
PVB STANDARD (0.38mm)
PLANICLEAR (5mm) - Tempered

Figure 30. Double Glazing configuration DG_7.

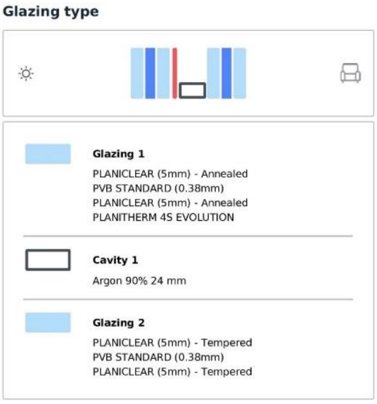

Glazing type

Glazing 1
PLANICLEAR (5mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (5mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 20 mm

Glazing 2
PLANICLEAR (5mm) - Tempered
PVB STANDARD (0.38mm)
PLANICLEAR (5mm) - Tempered

Figure 31. Double Glazing configuration DG_7.1.

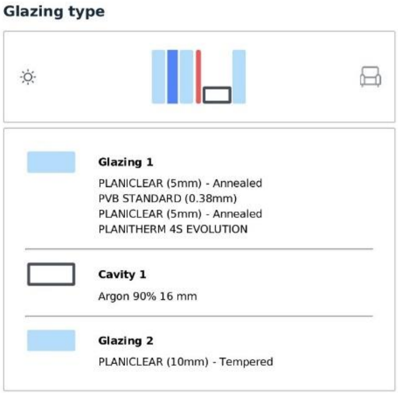

Glazing type

Glazing 1
PLANICLEAR (5mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (5mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 24 mm

Glazing 2
PLANICLEAR (5mm) - Tempered
PVB STANDARD (0.38mm)
PLANICLEAR (5mm) - Tempered

Figure 32. Double Glazing configuration DG_7.2.

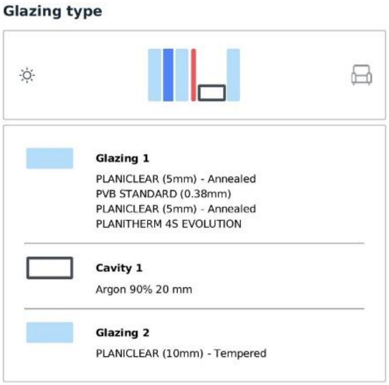

Glazing type

Glazing 1
PLANICLEAR (5mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (5mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (10mm) - Tempered

Figure 33. Double Glazing configuration DG_8.

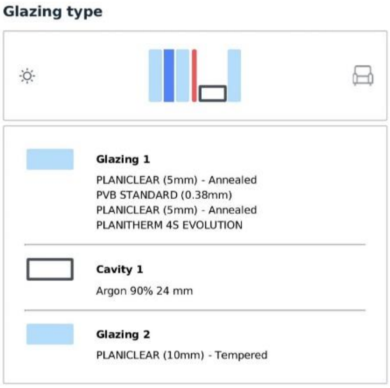

Glazing type

Glazing 1
PLANICLEAR (5mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (5mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 20 mm

Glazing 2
PLANICLEAR (10mm) - Tempered

Figure 34. Double Glazing Configuration DG_8.1.


Glazing type

Glazing 1
PLANICLEAR (5mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (5mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 24 mm

Glazing 2
PLANICLEAR (10mm) - Tempered

Figure 35. Double Glazing configuration DG_8.2.


Glazing type

Glazing 1
PLANICLEAR (12mm) - Tempered

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (12mm) - Tempered

Figure 36. Double Glazing configuration DG_9 (Air Albania Stadium case).


Glazing type

Glazing 1
PLANICLEAR (12mm) - Tempered

Cavity 1
Argon 90% 20 mm

Glazing 2
PLANICLEAR (12mm) - Tempered

Figure 37. Double Glazing configuration DG_9.1.

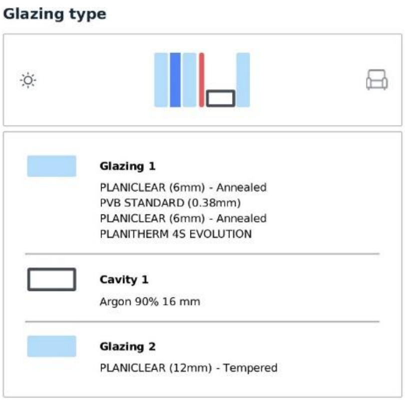

Glazing type

Glazing 1
PLANICLEAR (12mm) - Tempered

Cavity 1
Argon 90% 24 mm

Glazing 2
PLANICLEAR (12mm) - Tempered

Figure 38. Double Glazing configuration DG_9.2.


Glazing type

Glazing 1
PLANICLEAR (6mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (6mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (12mm) - Tempered

Figure 39. Double Glazing configuration DG_10.


Glazing type

Glazing 1
PLANICLEAR (6mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (6mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 20 mm

Glazing 2
PLANICLEAR (12mm) - Tempered

Figure 40. Double Glazing configuration DG_10.1.


Glazing type

Glazing 1
PLANICLEAR (6mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (6mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 24 mm

Glazing 2
PLANICLEAR (12mm) - Tempered

Figure 41. Double Glazing configuration DG_10.2.


Glazing type

Glazing 1
PLANICLEAR (6mm) - Tempered
PLANISTAR SUN PLUS II

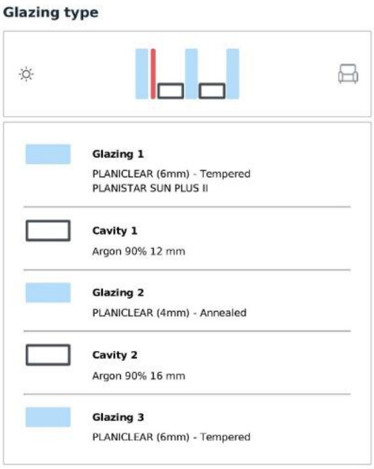
Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (4mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 43. Triple Glazing configuration TG_1.


Glazing type

Glazing 1
PLANICLEAR (6mm) - Tempered
PLANISTAR SUN PLUS II

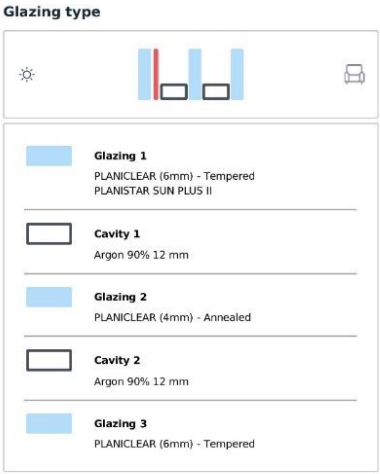
Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (4mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 42. Triple Glazing configuration TG_1.2.


Glazing type

Glazing 1
PLANICLEAR (6mm) - Tempered
PLANISTAR SUN PLUS II

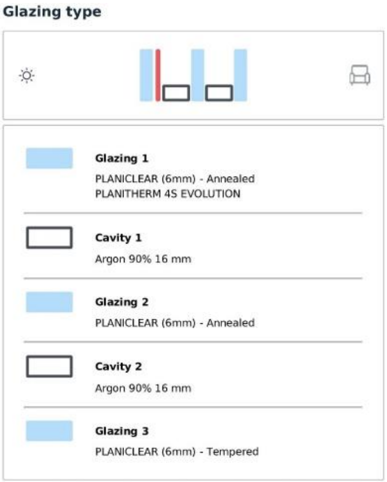
Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (4mm) - Annealed

Cavity 2
Argon 90% 12 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 44. Triple Glazing configuration TG_1.2.


Glazing type

Glazing 1
PLANICLEAR (6mm) - Annealed
PLANITHERM 4S EVOLUTION

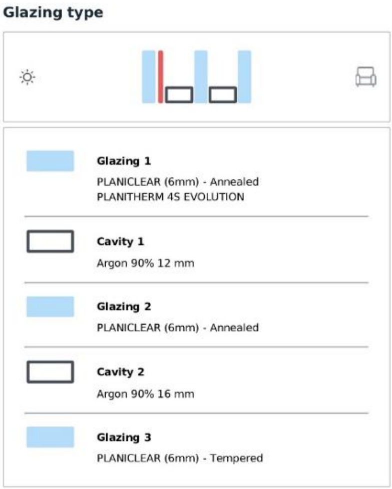
Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 45. Triple Glazing configuration TG_2.


Glazing type

Glazing 1
PLANICLEAR (6mm) - Annealed
PLANITHERM 4S EVOLUTION

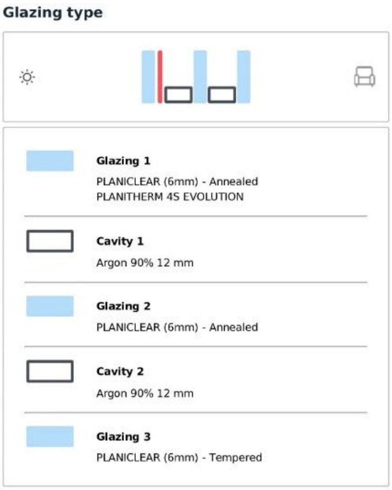
Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 46. Triple Glazing configuration TG_2.1.


Glazing type

Glazing 1
PLANICLEAR (6mm) - Annealed
PLANITHERM 4S EVOLUTION

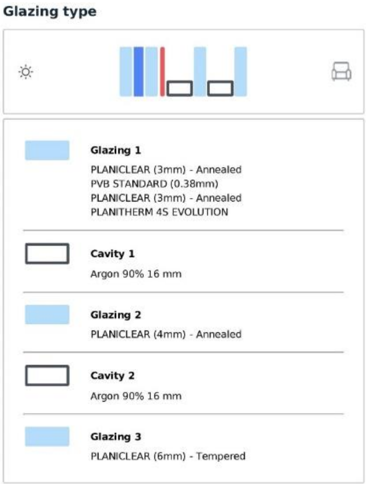
Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 12 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 47. Triple Glazing configuration TG_2.2.


Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

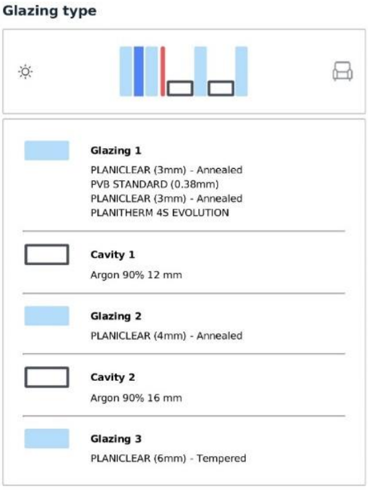
Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (4mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 48. Triple Glazing configuration TG_3.


Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (4mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 49. Triple Glazing configuration TG_3.1.


Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

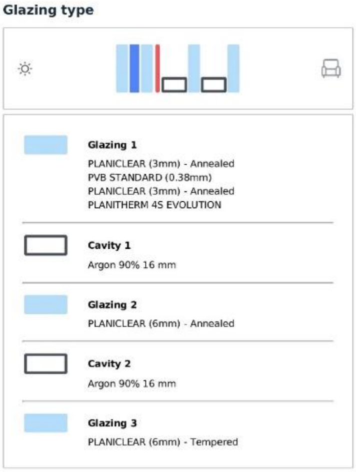
Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (4mm) - Annealed

Cavity 2
Argon 90% 12 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 50. Triple Glazing configuration TG_3.2.


Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 51. Triple Glazing configuration TG_4.


Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

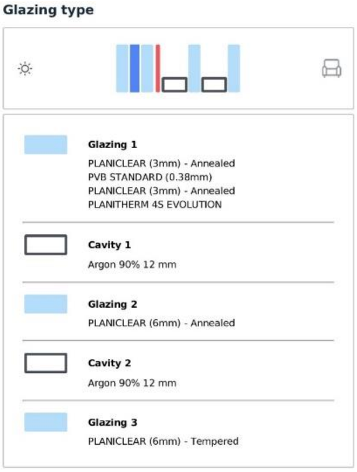
Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 52. Triple Glazing configuration TG_4.1.


Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

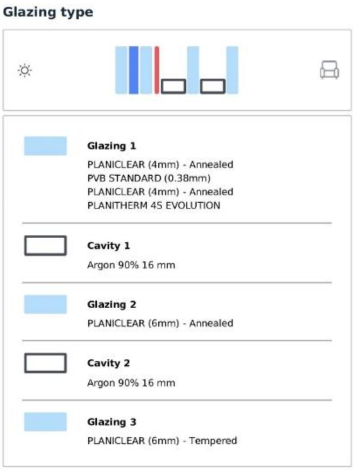
Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 12 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 53. Triple Glazing configuration TG_4.2.


Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

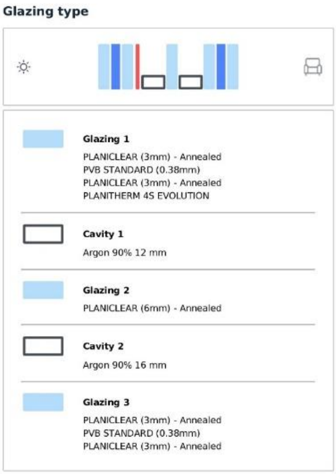
Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 54. Triple Glazing configuration TG_5.


Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

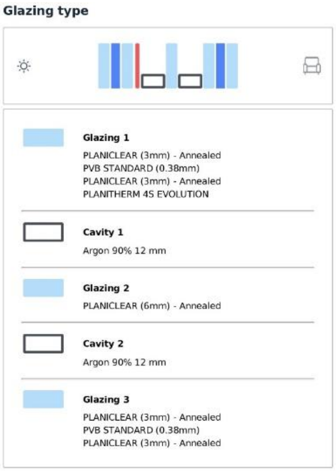
Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed

Figure 55. Triple Glazing configuration TG_5.1.


Glazing type

Glazing 1
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 12 mm

Glazing 3
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed

Figure 56. Triple Glazing configuration TG_5.2.


Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 57. Triple Glazing configuration TG_6.


Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 58. Triple Glazing configuration TG_6.1.


Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

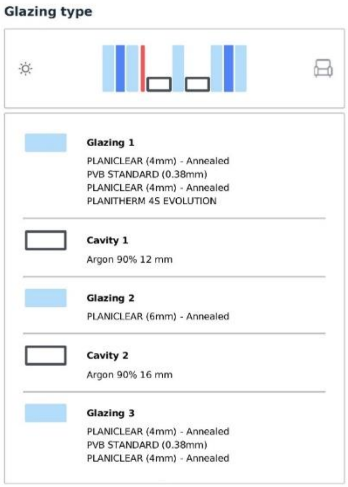
Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 12 mm

Glazing 3
PLANICLEAR (6mm) - Tempered

Figure 59. Triple Gazing configuration TG_6.2.



Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

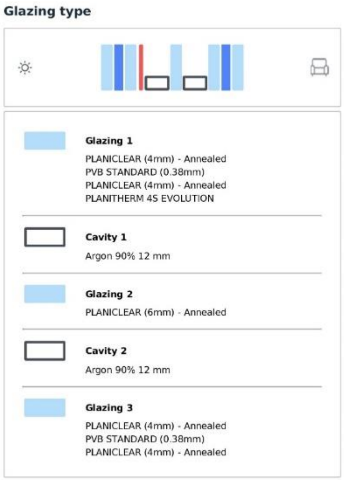
Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed

Figure 60. Triple Glazing configuration TG_7.



Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

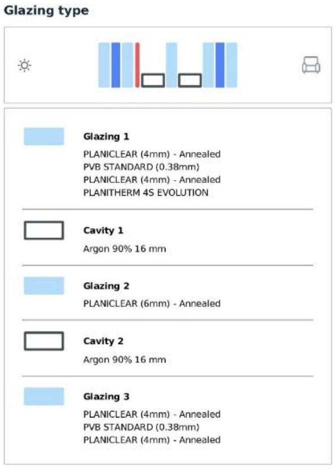
Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 12 mm

Glazing 3
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed

Figure 61. Triple Glazing configuration TG_7.1.



Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

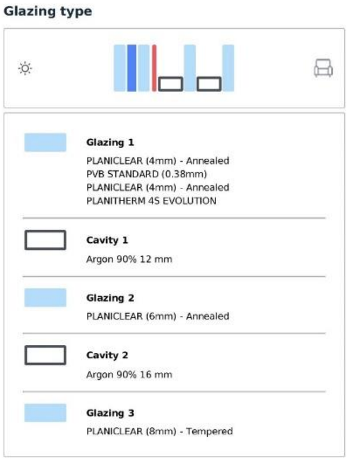
Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed

Figure 62. Triple Glazing configuration TG_7.2.



Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (8mm) - Tempered

Figure 63. Triple Glazing configuration TG_8.

Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 12 mm

Glazing 3
PLANICLEAR (8mm) - Tempered

Figure 64. Triple Glazing configuration TG_8.1.

Glazing type

Glazing 1
PLANICLEAR (4mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (4mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (8mm) - Tempered

Figure 65. Triple Glazing configuration TG_8.2.


Glazing type

Glazing 1
PLANICLEAR (8mm) - Annealed
PLANITHERM 4S EVOLUTION

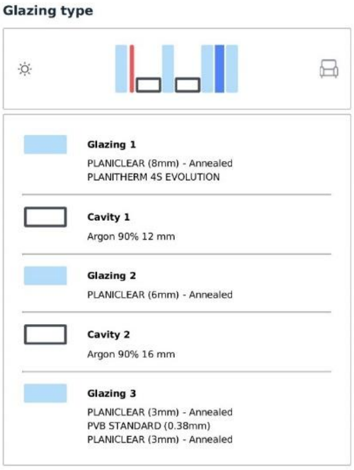
Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed

Figure 66. Triple Glazing configuration TG_9.


Glazing type

Glazing 1
PLANICLEAR (8mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed

Figure 67. Triple Glazing configuration TG_9.1.


Glazing type

Glazing 1
PLANICLEAR (8mm) - Annealed
PLANITHERM 4S EVOLUTION

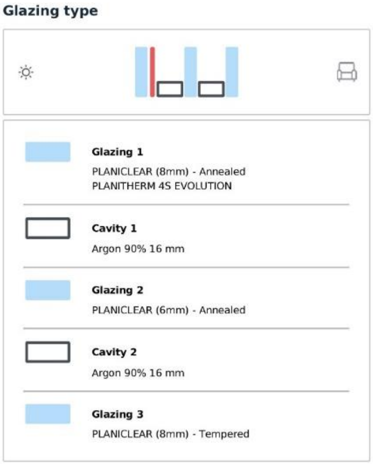
Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 12 mm

Glazing 3
PLANICLEAR (3mm) - Annealed
PVB STANDARD (0.38mm)
PLANICLEAR (3mm) - Annealed

Figure 68. Triple Glazing configuration TG_9.2.


Glazing type

Glazing 1
PLANICLEAR (8mm) - Annealed
PLANITHERM 4S EVOLUTION

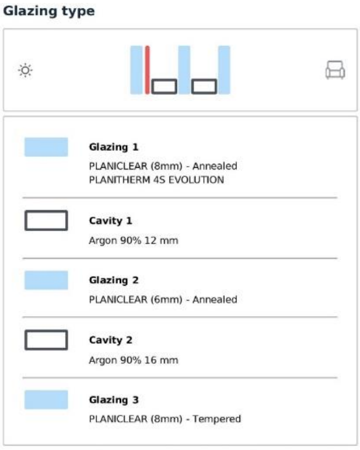
Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (8mm) - Tempered

Figure 69. Triple Glazing configuration TG_10.


Glazing type

Glazing 1
PLANICLEAR (8mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 16 mm

Glazing 3
PLANICLEAR (8mm) - Tempered

Figure 70. Triple Glazing configuration TG_10.1.


Glazing type

Glazing 1
PLANICLEAR (8mm) - Annealed
PLANITHERM 4S EVOLUTION

Cavity 1
Argon 90% 12 mm

Glazing 2
PLANICLEAR (6mm) - Annealed

Cavity 2
Argon 90% 12 mm

Glazing 3
PLANICLEAR (8mm) - Tempered

Figure 71. Triple Glazing configuration TG_10.2.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Overview

As illustrated in the figures below, in all scenarios of double and triple glazing, annual cooling energy demand is quite greater in comparison to heating one. One main reason is the climate, condition of the weather, building orientation and the greenhouse effect created by glazing. The mild climate of the Mediterranean means that more energy is needed for cooling than for heating the envelopes. Additionally, a crucial factor in raising the energy cooling need is the south-west direction. Each glazing scenario has some specific properties, and due to that the results explanation will be analyzed one by one.

4.2 Double glazing

There are a total of 30 double glazing scenarios simulations done for each orientation. For each orientation, there are five figures consisting of six glazing scenarios (two glazing types with three different spacing thickness) showing the yearly energy demand (kWh.m^{-2}a$^{-1)}$. Further detailed information is given on the following pages at the end of each orientation, showing the minimum and maximum heating, cooling and total demand.

4.2.1 DG East Orientation

Figure 72-76 shows the yearly consumption of energy for heating, cooling and the total for the scenarios of double glazing typology with east orientation. Specifically, *Figure 72* illustrates the yearly consumption for heating, cooling and total for the scenarios: (DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2). *Figure 73* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_3, DG_3.1, DG_3.2, DG_4, DG_4.1, DG_4.2). *Figure 74* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_5, DG_5.1, DG_5.2, DG_6, DG_6.1, DG_6.2). *Figure 75* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_7, DG_7.1, DG_7.2, DG_8, DG_8.1, DG_8.2). *Figure 76* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_9, DG_9.1, DG_9.2, DG_10, DG_10.1, DG_10.2).

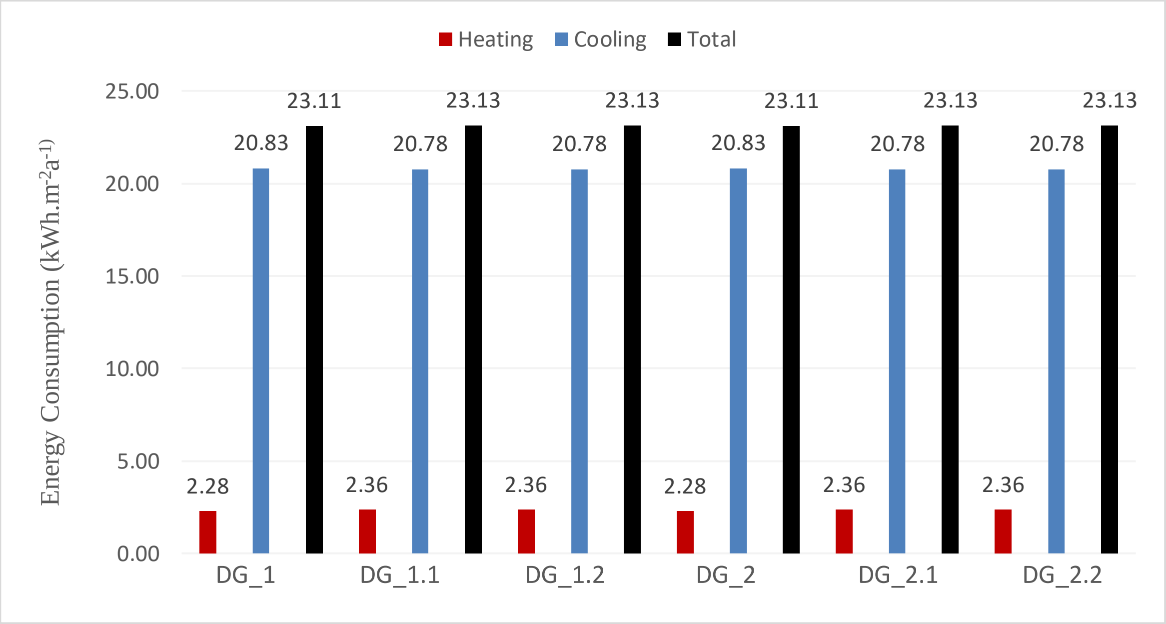


Figure 72. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios east oriented (DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2).

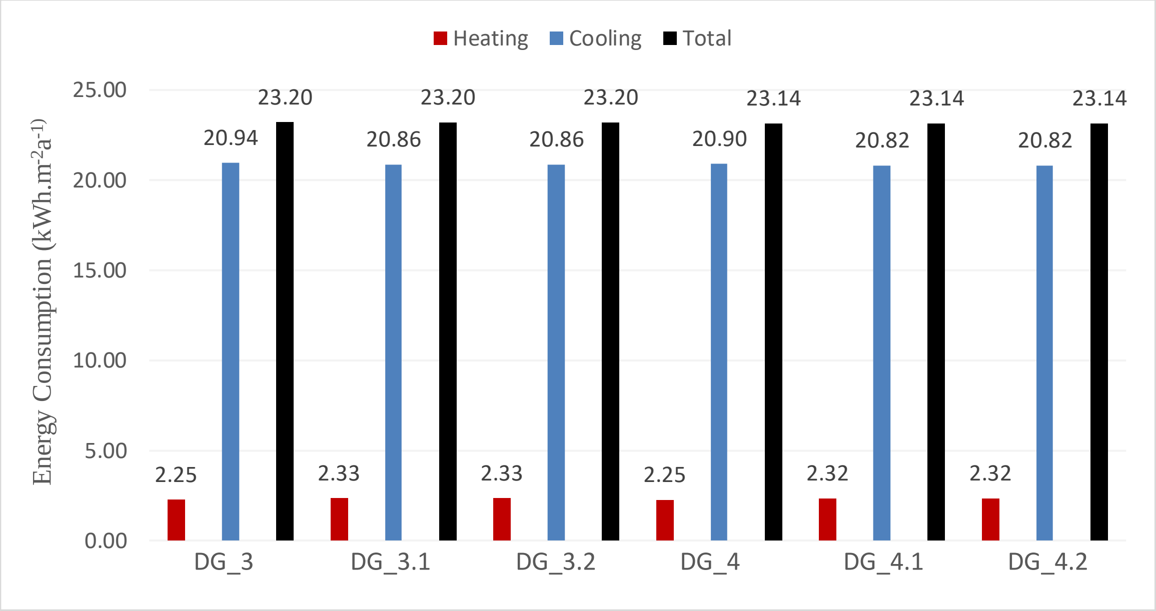


Figure 73. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios east oriented (DG_3, DG_3.1, DG_3.2, DG_4, DG_4.1, DG_4.2).

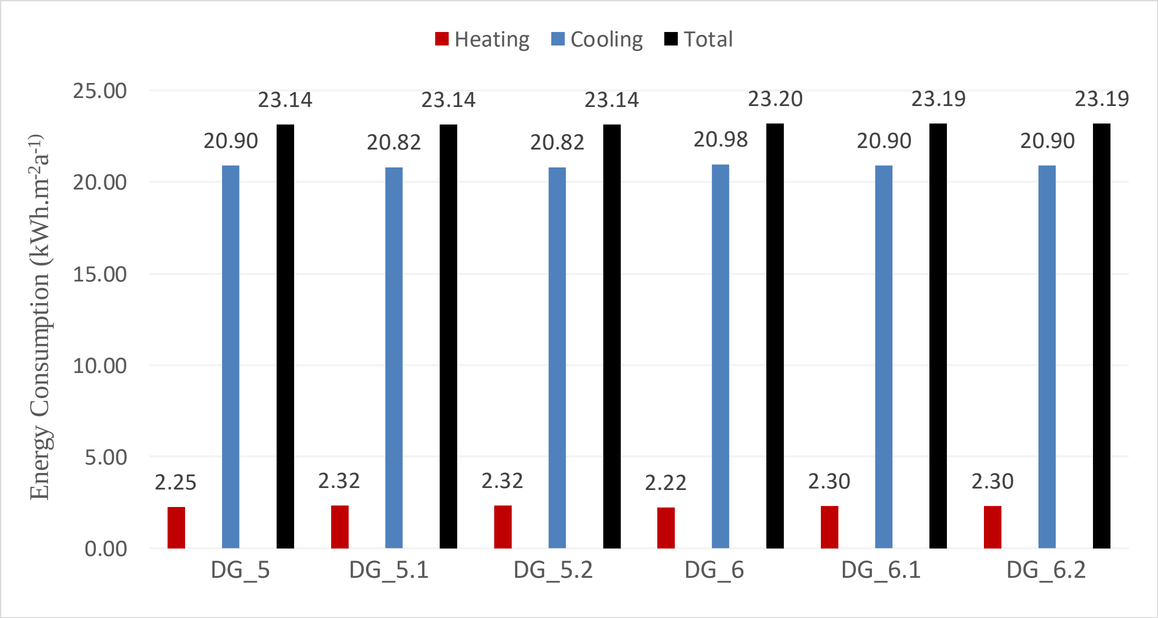


Figure 74. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios east oriented (DG_5, DG_5.1, DG_5.2, DG_6, DG_6.1, DG_6.2).

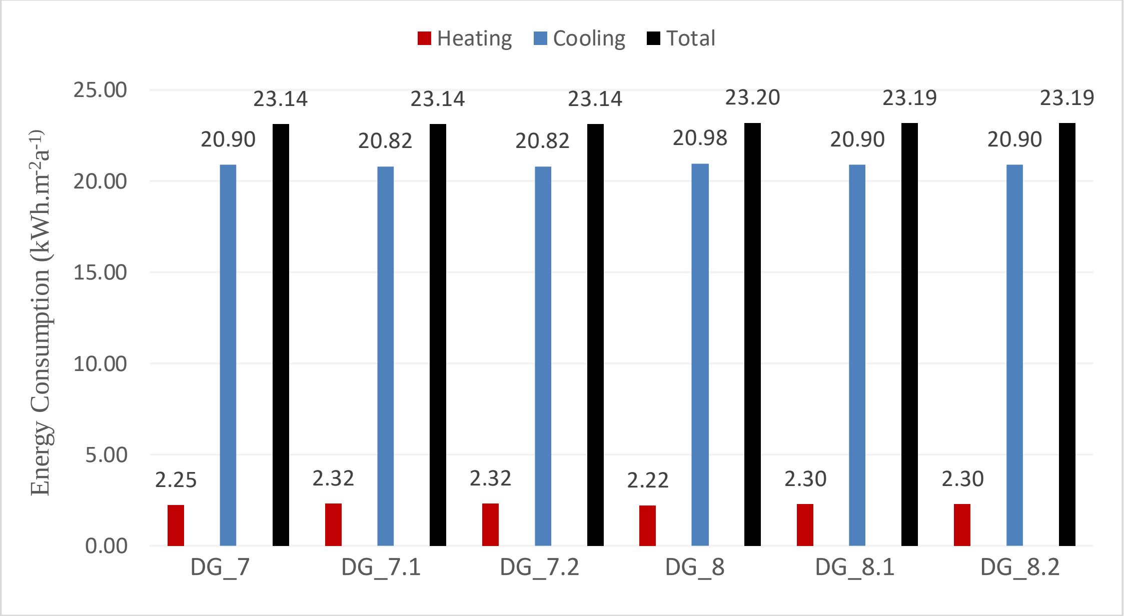


Figure 75. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios east oriented (DG_7, DG_7.1, DG_7.2, DG_8, DG_8.1, DG_8.2).

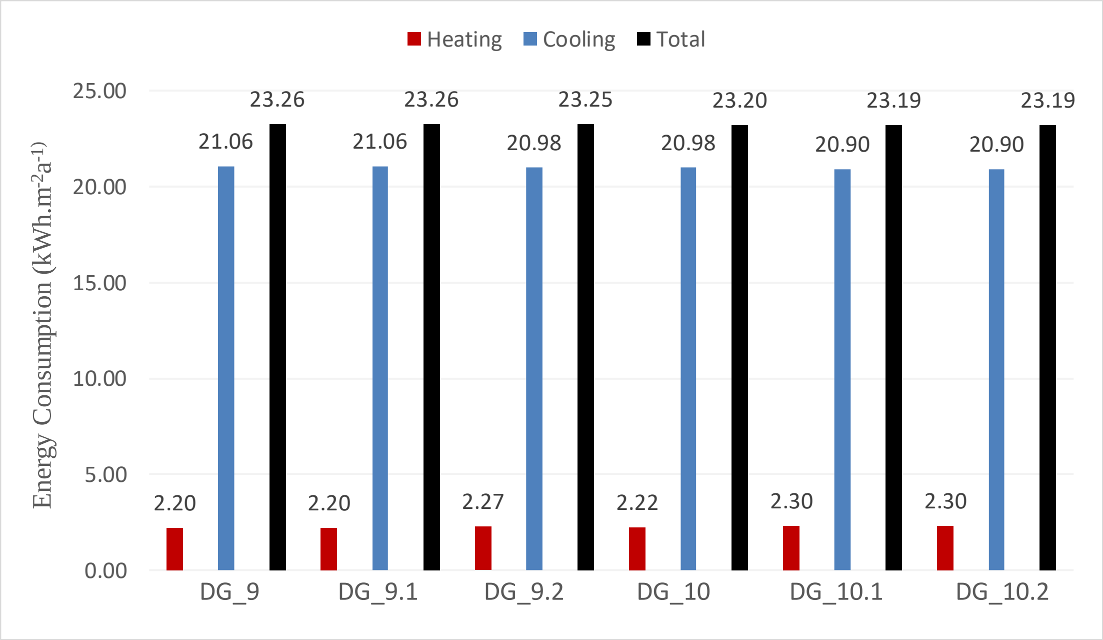


Figure 76. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios east oriented (DG_9, DG_9.1, DG_9.2, DG_10, DG_10.1, DG_10.2).

As figures show, the heating load for double glazing scenarios east oriented ranges from minimum 2.20 (kwh/ m^2) for scenarios DG_9 and DG_9.1 and maximum 2.36 (kWh.$m^{-2}a^{-1)}$ for scenarios DG_1.1, DG_1.2, DG 2.1, DG_2.2., thus giving ± 7% difference in value among minimum and maximum heating energy consumption. For the cooling load, the trend shows a higher energy consumption as for this, the cooling load ranges from minimum 20.78 (kWh.$m^{-2}a^{-1)}$ for scenarios DG_1.1, DG_1.2, DG 2.1, DG_2.2 and maximum 21.06 (kWh.$m^{-2}a^{-1)}$ for scenarios DG_9 and DG_9.1, with ± 1.3% difference between minimum and maximum cooling energy consumption. The total shows that the minimum energy consumption is 23.11 (kWh.$m^{-2}a^{-1)}$ from scenario DG_1 and DG_2, and the maximum is 23.26 (kWh.$m^{-2}a^{-1)}$ from scenario DG_9 and DG_9.1, with ± 1% difference in energy consumption.

4.2.1 DG South Orientation

Figure 77-81 illustrates the yearly energy consumption for heating, cooling and the total for the scenarios of double glazing typology with south orientation. Specifically, *Figure 77* illustrates the yearly demand for heating, cooling and total for the scenarios: (DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2). *Figure 78* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_3, DG_3.1, DG_3.2, DG_4, DG_4.1, DG_4.2) . *Figure 79* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_5, DG_5.1, DG_5.2, DG_6, DG_6.1, DG_6.2). *Figure 80* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_7, DG_7.1, DG_7.2, DG_8, DG_8.1, DG_8.2). *Figure 81* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_9, DG_9.1, DG_9.2, DG_10, DG_10.1, DG_10.2).

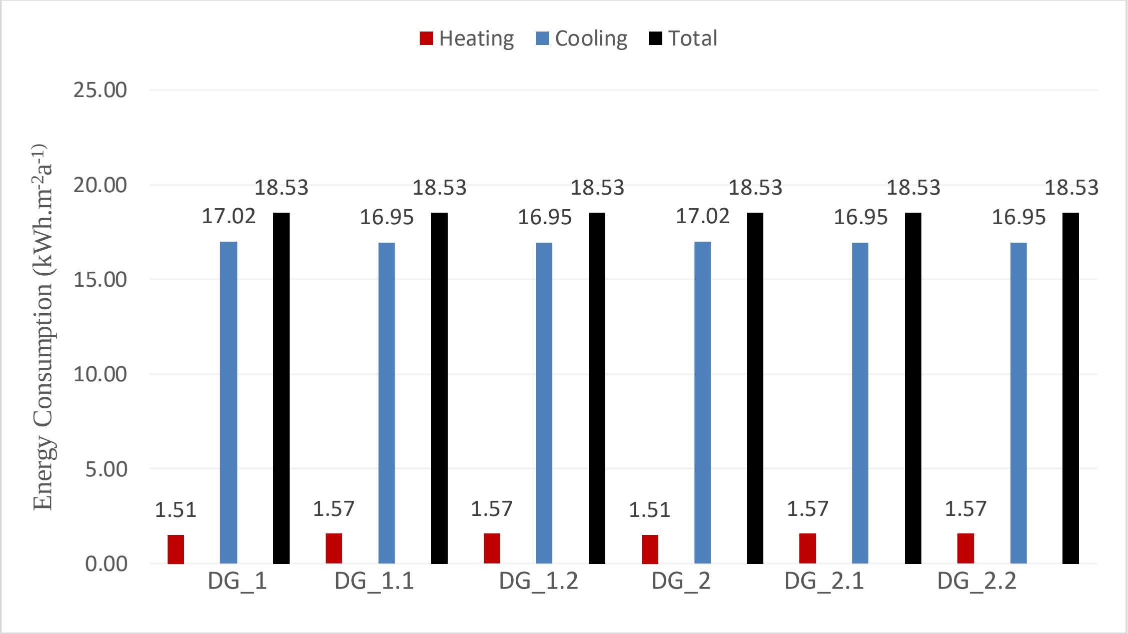


Figure 77. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios south oriented (DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2).

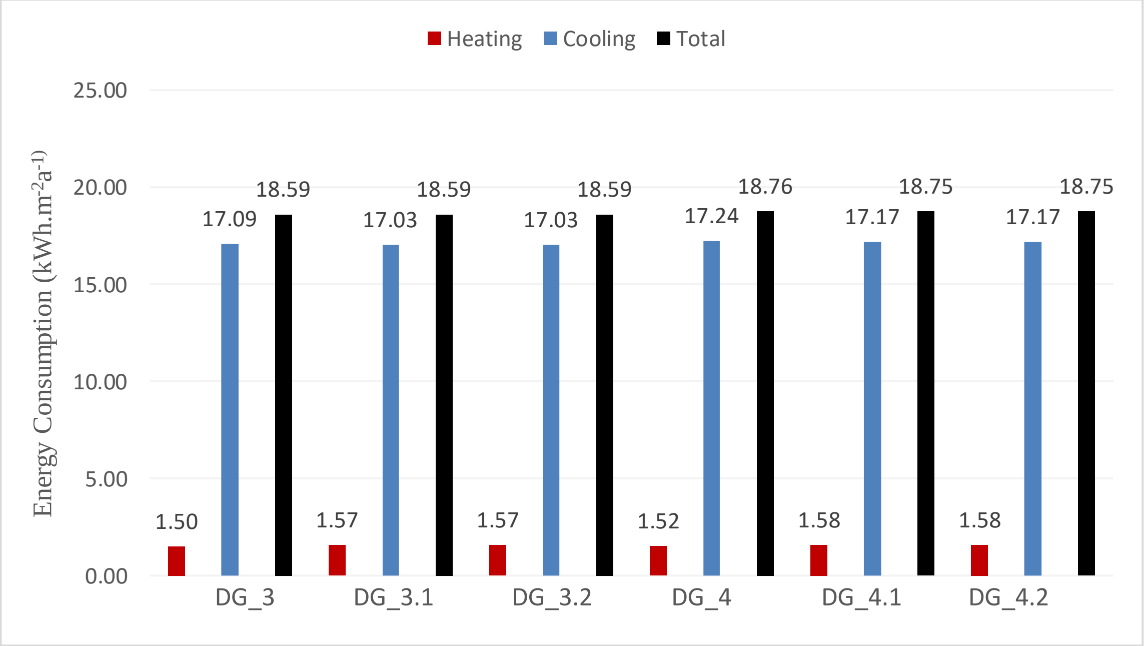


Figure 78. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios south oriented (DG_3, DG_3.1, DG_3.2, DG_4, DG_4.1, DG_4.2).

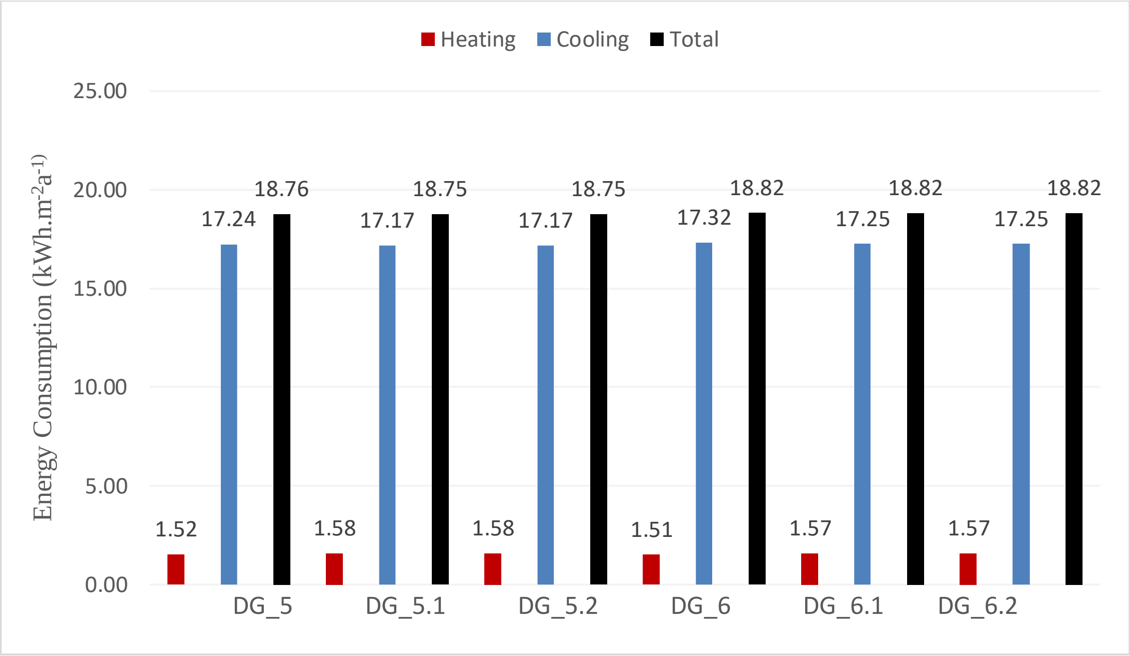


Figure 79. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios south oriented (DG_5, DG_5.1, DG_5.2, DG_6, DG_6.1, DG_6.2).

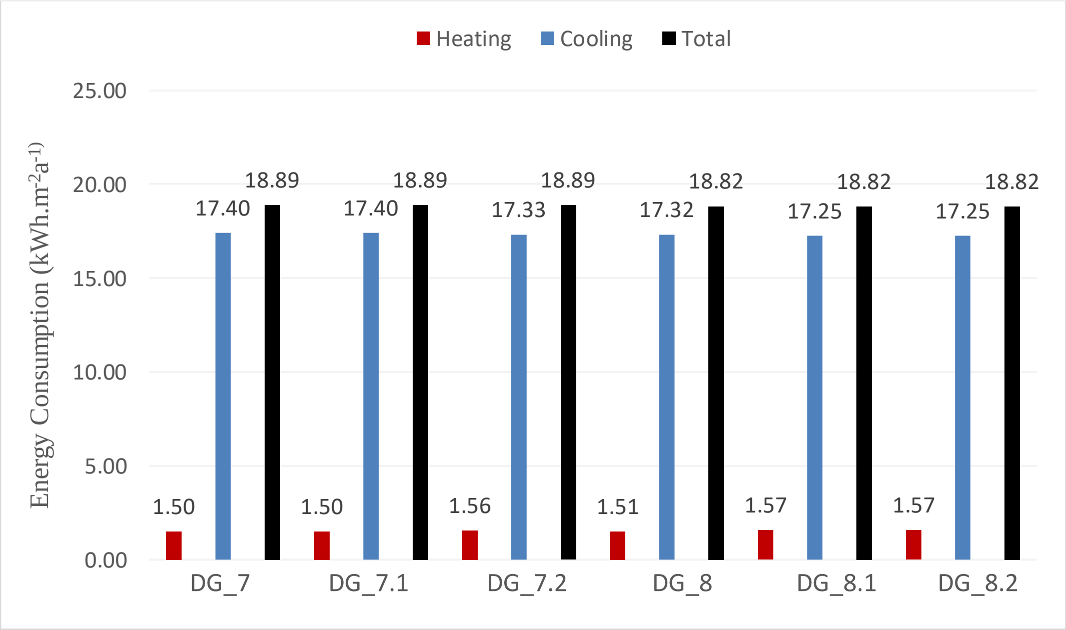


Figure 80. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios south oriented (DG_7, DG_7.1, DG_7.2, DG_8, DG_8.1, DG_8.2).

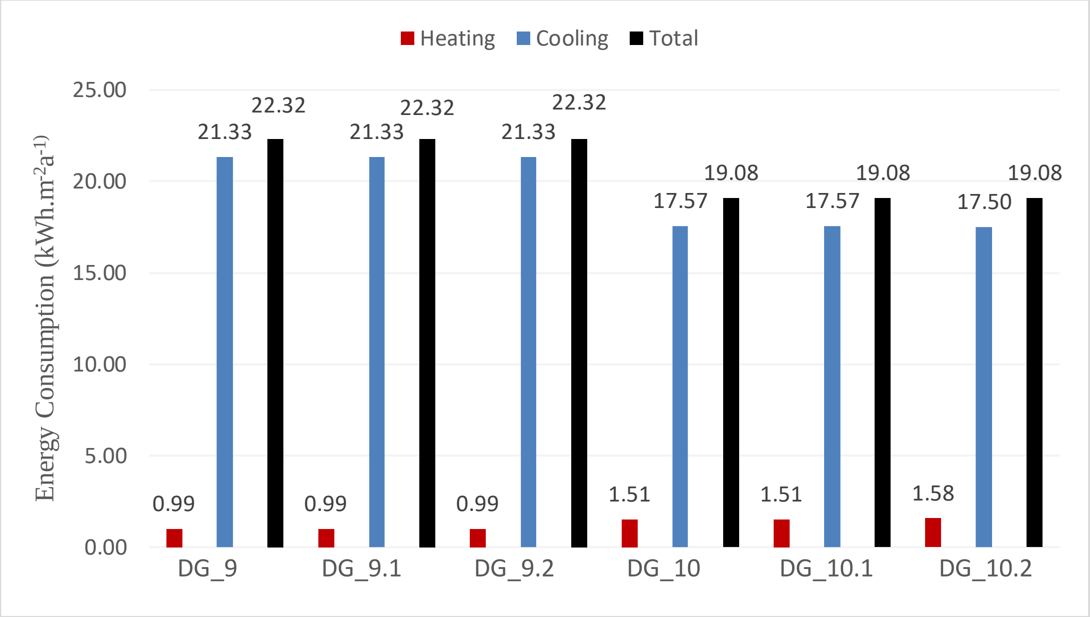


Figure 81. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios south oriented (DG_9, DG_9.1, DG_9.2, DG_10, DG_10.1, DG_10.2).

As figures show, the heating load for double glazing scenarios south oriented ranges from minimum 0.99 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_9, DG_9.1 and DG_9.2 and maximum 1.58 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_4.1, DG_4.2, DG_5.1, DG_5.2 and DG_10.2, thus giving ± 45% difference between minimum and maximum heating energy consumption. For the cooling load, the trend shows a higher energy consumption as for this, the cooling load ranges from minimum 16.95 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_1.1 and DG_1.2, and maximum 21.33 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_9, DG_9.1 and DG_9.2 with ± 22% difference between minimum and maximum cooling energy consumption. The total shows that the minimum energy consumption is 18.53 (kWh.m^{-2}a$^{-1)}$ from scenario DG_1, DG_1.1, DG_1.2 and DG_2, DG_2.1, DG_2.2, and the maximum is 22.32 (kWh.m^{-2}a$^{-1)}$ from scenario DG_9, DG_9.1 and DG_9.2, with ± 18 % difference in energy consumption.

4.2.2 DG West Orientation

Figure 82-86 illustrates the yearly energy consumption for heating, cooling and the total for the scenarios of double glazing typology with west orientation. Specifically, *Figure 82* illustrates the yearly demand for heating, cooling and total for the scenarios: (DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2). *Figure 83* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_3, DG_3.1, DG_3.2, DG_4, DG_4.1, DG_4.2) . *Figure 84* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_5, DG_5.1, DG_5.2, DG_6, DG_6.1, DG_6.2). *Figure 85* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_7, DG_7.1, DG_7.2, DG_8, DG_8.1, DG_8.2). *Figure 86* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_9, DG_9.1, DG_9.2, DG_10, DG_10.1, DG_10.2).

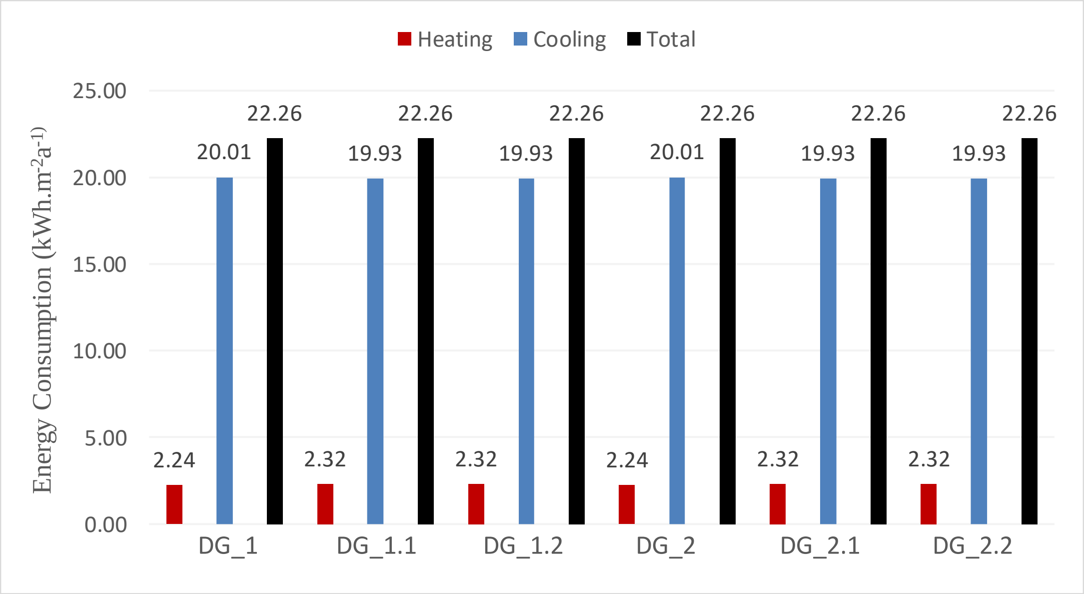


Figure 82. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios west oriented (DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2).

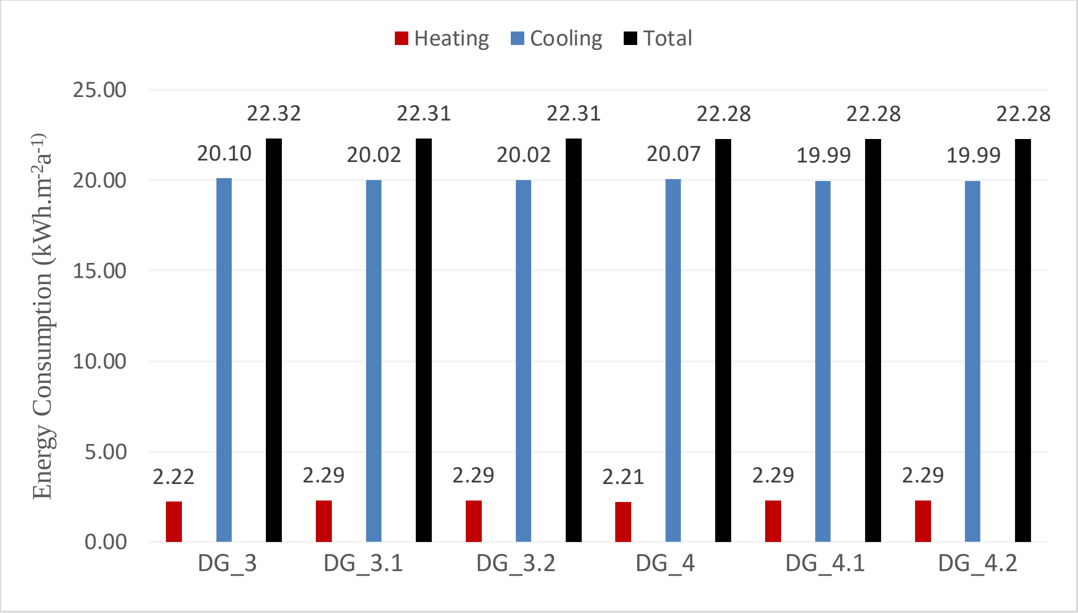


Figure 83. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios west oriented (DG_3, DG_3.1, DG_3.2, DG_4, DG_4.1, DG_4.2).

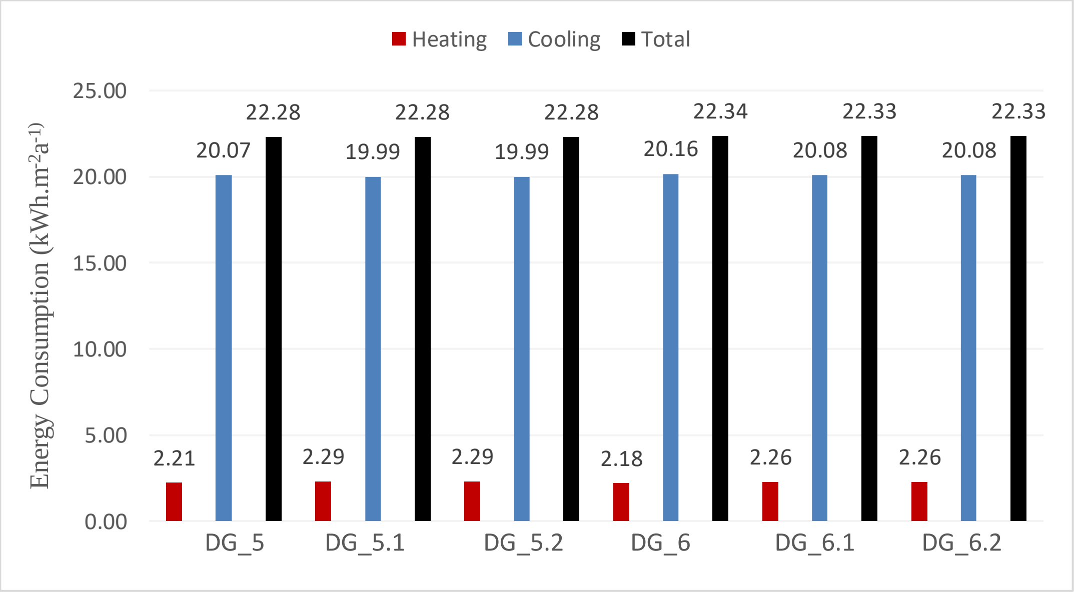


Figure 84. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios west oriented (DG_5, DG_5.1, DG_5.2, DG_6, DG_6.1, DG_6.2).

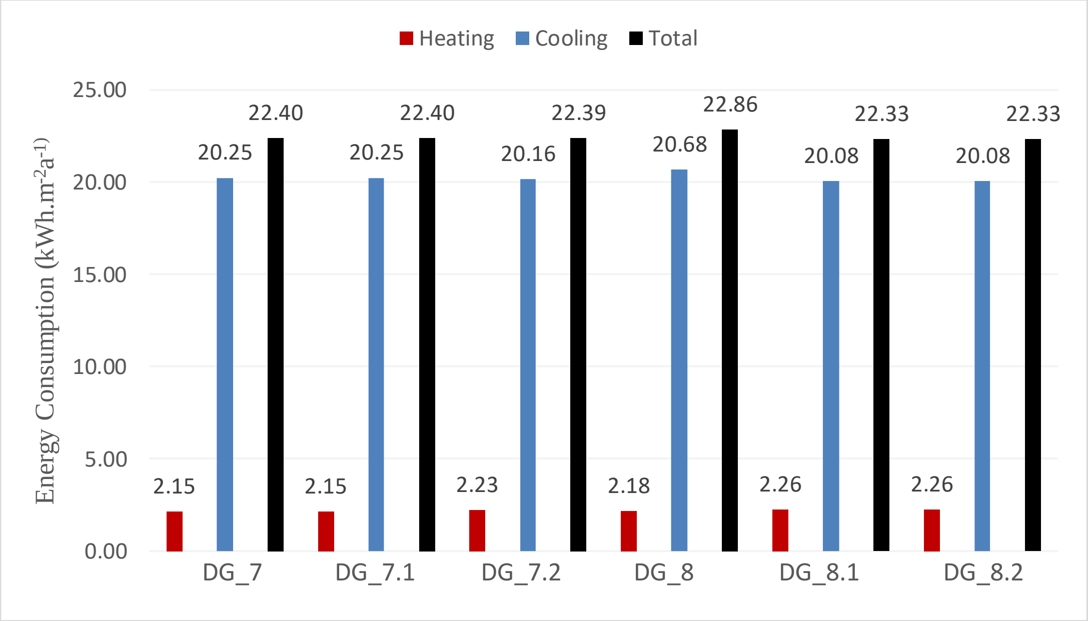


Figure 85. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios west oriented (DG_7, DG_7.1, DG_7.2, DG_8, DG_8.1, DG_8.2).

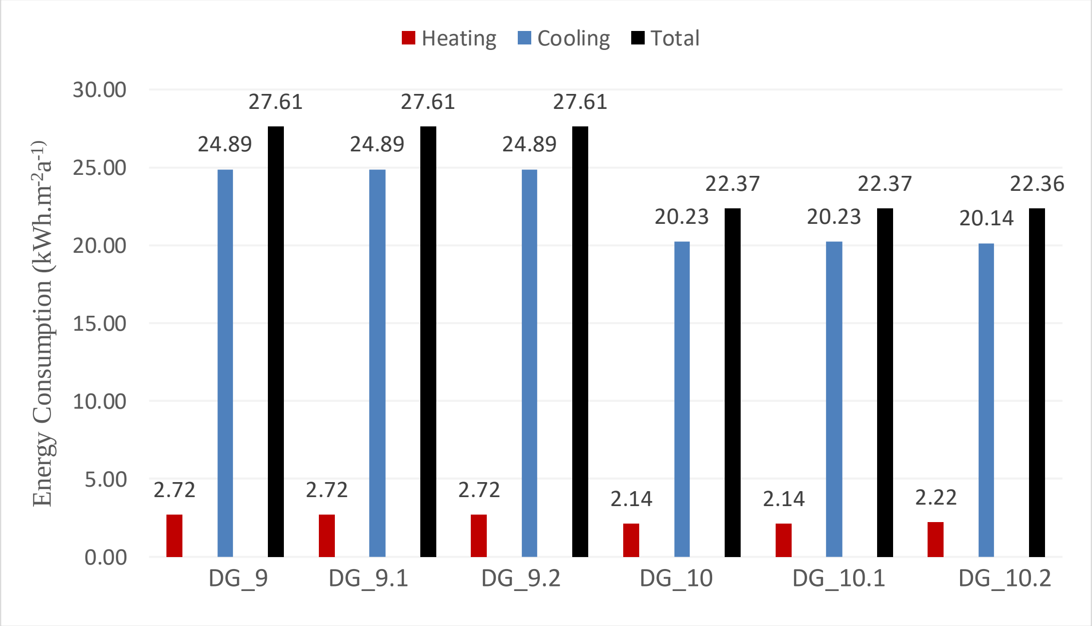


Figure 86. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios west oriented (DG_9, DG_9.1, DG_9.2, DG_10, DG_10.1, DG_10.2).

As figures show, the heating load for double glazing scenarios west oriented ranges from minimum 2.14 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_10, DG_10.1 and maximum 2.72 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_9, DG_9.1, DG_9.2, thus giving ± 24% difference between minimum and maximum heating energy consumption. For the cooling load, the trend shows a higher energy consumption as for this, the cooling load ranges from minimum 19.93 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_1.1, DG_1.2, DG_2.1, DG_2.2 and maximum 24.89 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_9, DG_9.1 and DG_9.2 with ± 22% difference between minimum and maximum cooling energy consumption. The total shows that the minimum energy consumption is 22.26 (kWh.m^{-2}a$^{-1)}$ from scenario DG_1, DG_1.1, DG_1.2 and DG_2, DG_2.1, DG_2.2, and the maximum is 27.61 (kWh.m^{-2}a$^{-1)}$ from scenario DG_9, DG_9.1 and DG_9.2, with ± 21 % difference in energy consumption.

4.2.3 DG North Orientation

Figure 87-92 illustrates the yearly energy consumption for heating, cooling and the total for the scenarios of double-glazing typology with north orientation. Specifically, *Figure 87* illustrates the yearly demand for heating, cooling and total for the scenarios: (DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2). *Figure 88* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_3, DG_3.1, DG_3.2, DG_4, DG_4.1, DG_4.2). *Figure 89* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_5, DG_5.1, DG_5.2, DG_6, DG_6.1, DG_6.2). *Figure 90* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_7, DG_7.1, DG_7.2, DG_8, DG_8.1, DG_8.2). *Figure 91* illustrates the yearly demand for heating, cooling and total for the scenarios (DG_9, DG_9.1, DG_9.2, DG_10, DG_10.1, DG_10.2).

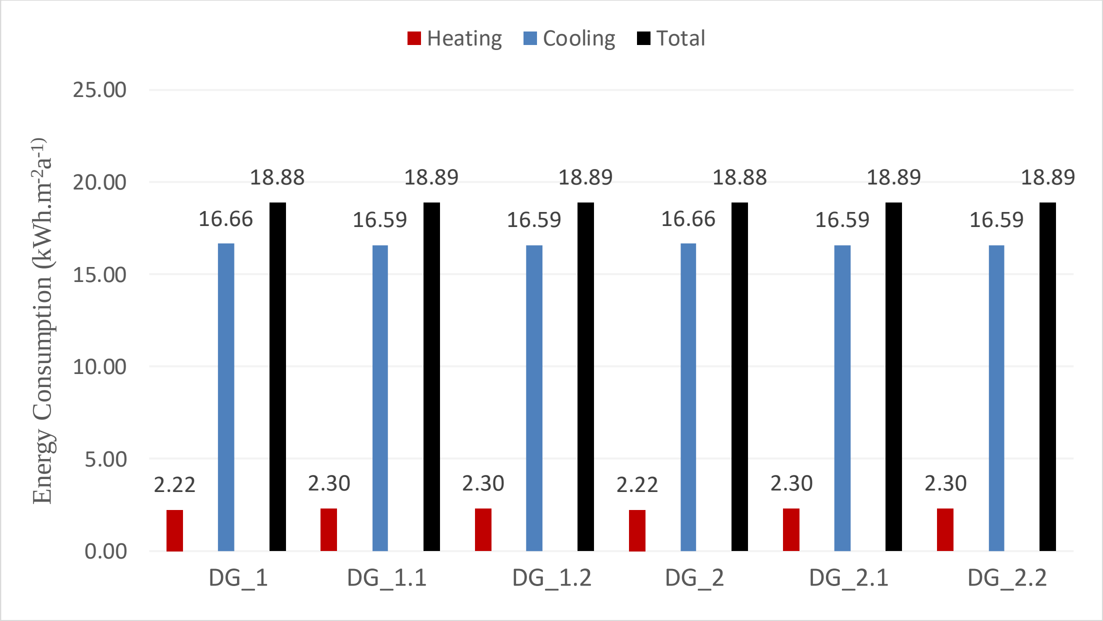


Figure 87. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios north oriented (DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2).

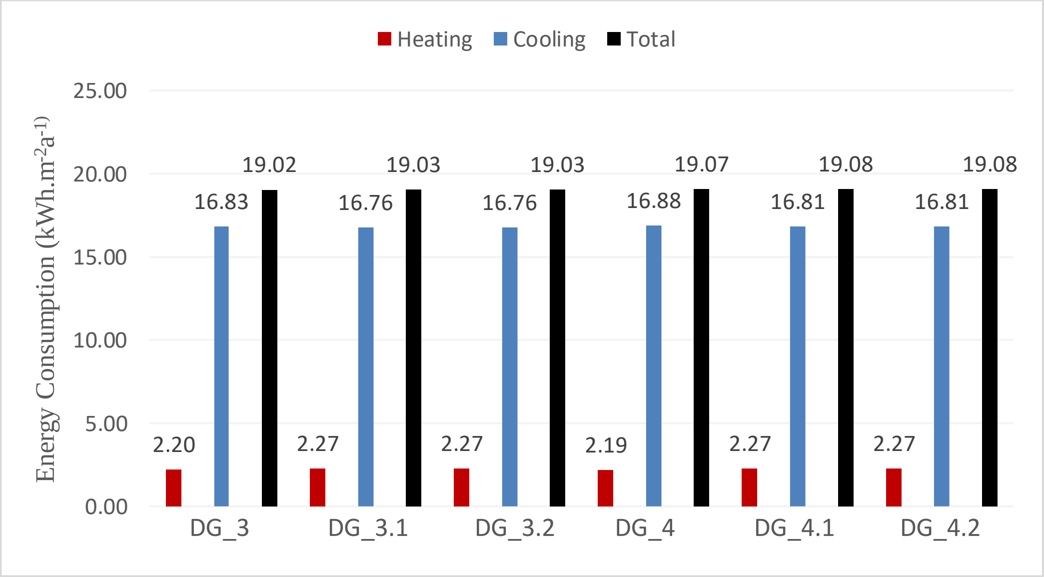


Figure 88. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios north oriented (DG_3, DG_3.1, DG_3.2, DG_4, DG_4.1, DG_4.2).

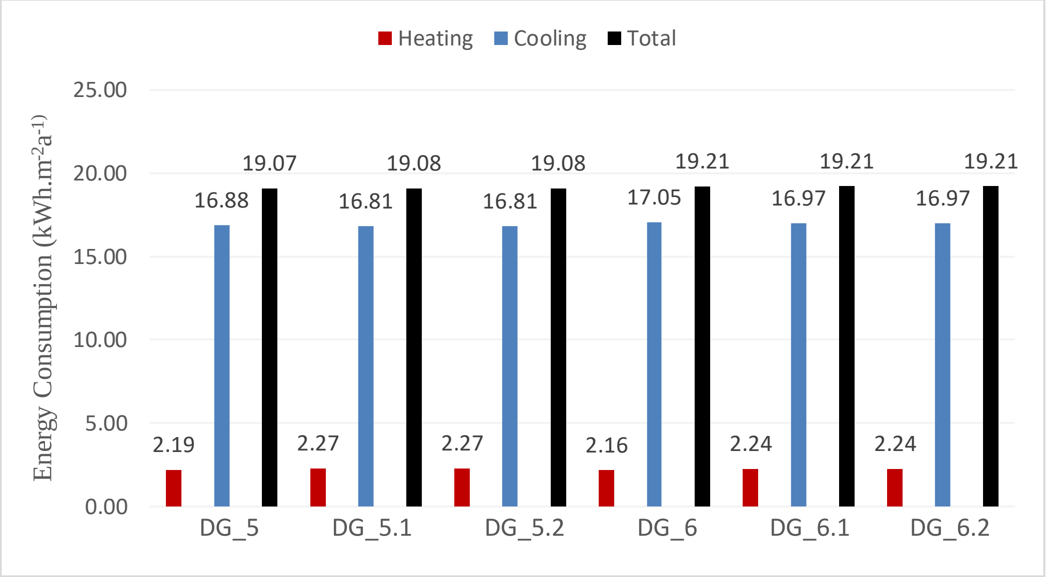


Figure 89. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios north oriented (DG_5, DG_5.1, DG_5.2, DG_6, DG_6.1, DG_6.2).

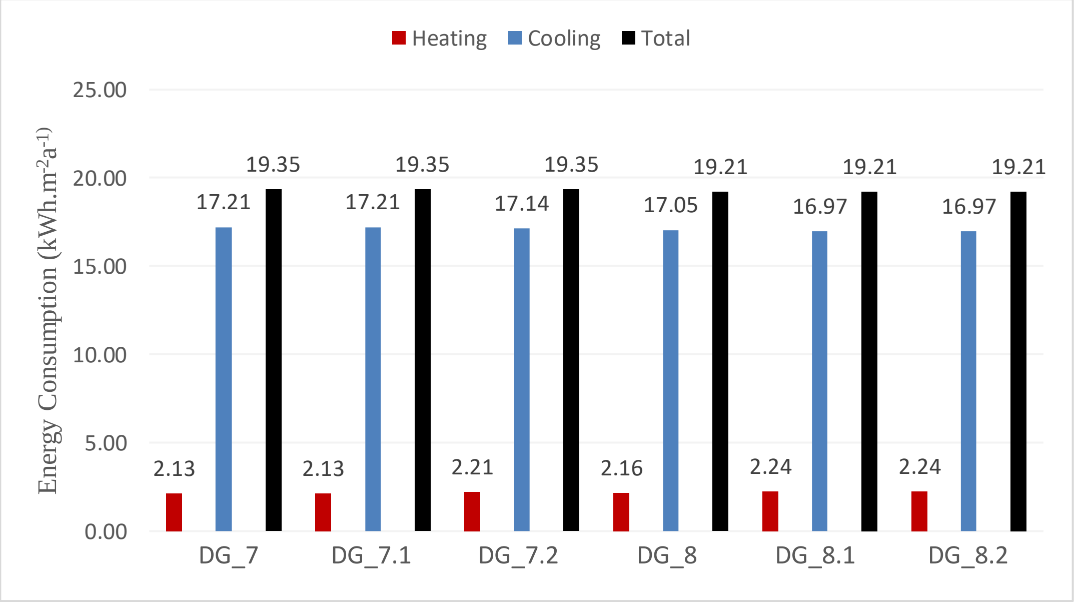


Figure 90. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios north oriented (DG_7, DG_7.1, DG_7.2, DG_8, DG_8.1, DG_8.2).

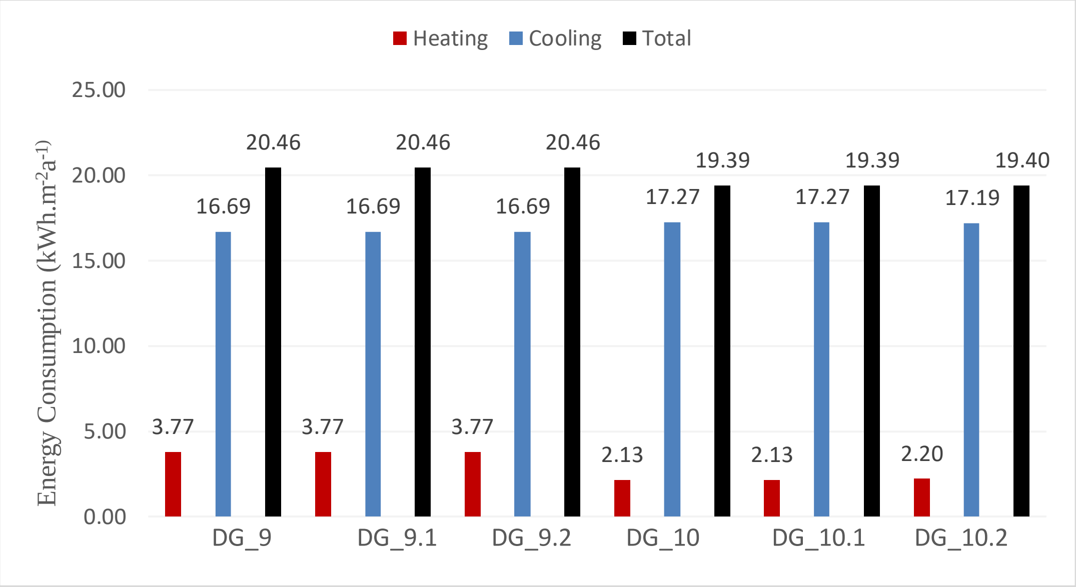


Figure 91. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios north oriented (DG_9, DG_9.1, DG_9.2, DG_10, DG_10.1, DG_10.2).

As figures show, the heating load for double glazing scenarios north oriented ranges from minimum 2.13 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_7, DG_7.1, DG_10, DG_10.1 and maximum 3.77 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_9, DG_9.1, DG_9.2, thus giving ± 55% difference between minimum and maximum heating energy consumption. For the cooling load, the trend shows a higher energy consumption as for this, the cooling load ranges from minimum 16.59 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_1.1, DG_1.2, DG_2.1, DG_2.2 and maximum 17.27 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_10 and DG_10.1 with ± 4% difference between minimum and maximum cooling energy consumption. The total shows that the minimum energy consumption is 18.88 (kWh.m^{-2}a$^{-1)}$ from scenario DG_1 and DG_2, and the maximum is 20.46 (kWh.m^{-2}a$^{-1)}$ from scenario DG_9, DG_9.1 and DG_9.2, with ± 8 % difference in energy consumption.

4.3 Tripe Glazing

Same as the double glazing, 30 triple glazing scenarios simulations are done for each orientation. For each orientation, there are five figures consisting of six glazing scenarios (two glazing types with three different spacing thickness) showing the yearly energy consumption (kWh.m^{-2}a$^{-1)}$. Further detailed information is given on the following pages at the end of each orientation, showing the minimum and maximum heating, cooling and total demand.

4.3.1 TG East Orientation

Figure 92-96 illustrates the yearly energy consumption for heating, cooling and the total for the scenarios of triple glazing typology with east orientation. Specifically, *Figure 92* illustrates the yearly demand for heating, cooling and total for the scenarios: (TG_1, TG_1.1, TG_1.2, TG_2, TG_2.1, TG_2.2). *Figure 93* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_3, TG_3.1, TG_3.2, TG_4, TG_4.1, TG_4.2). *Figure 94* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_5, TG_5.1, TG_5.2, TG_6, TG_6.1, TG_6.2). *Figure 95* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_7, TG_7.1, TG_7.2, TG_8, TG_8.1, TG_8.2). *Figure 96* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_9, TG_9.1, TG_9.2, TG_10, TG_10.1, TG_10.2).

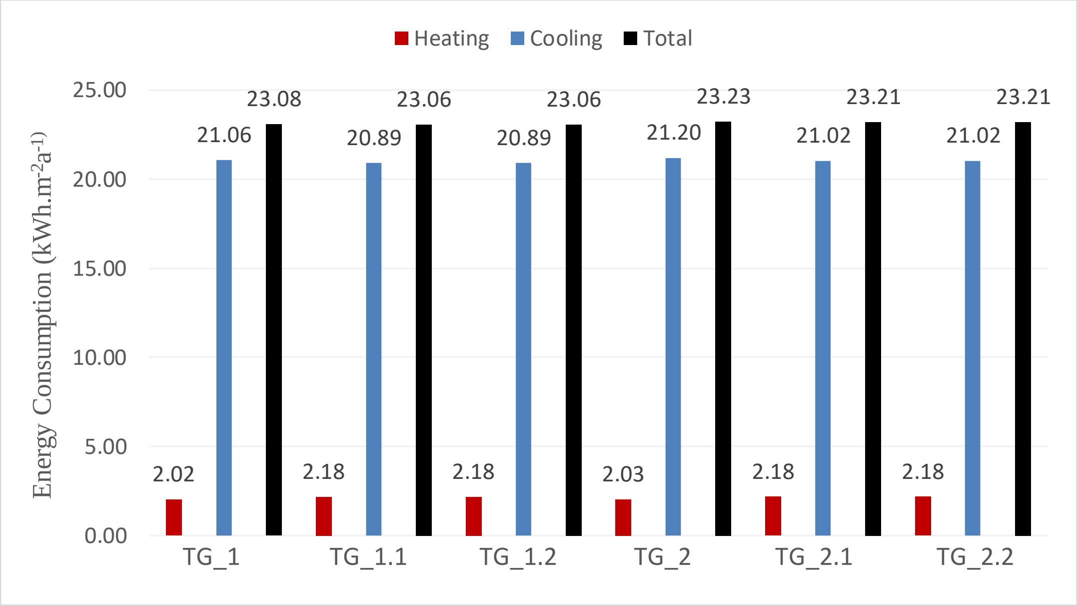


Figure 92. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios east orientated (TG_1, TG_1.1, TG_1.2, TG_2, TG_2.1, TG_2.2).

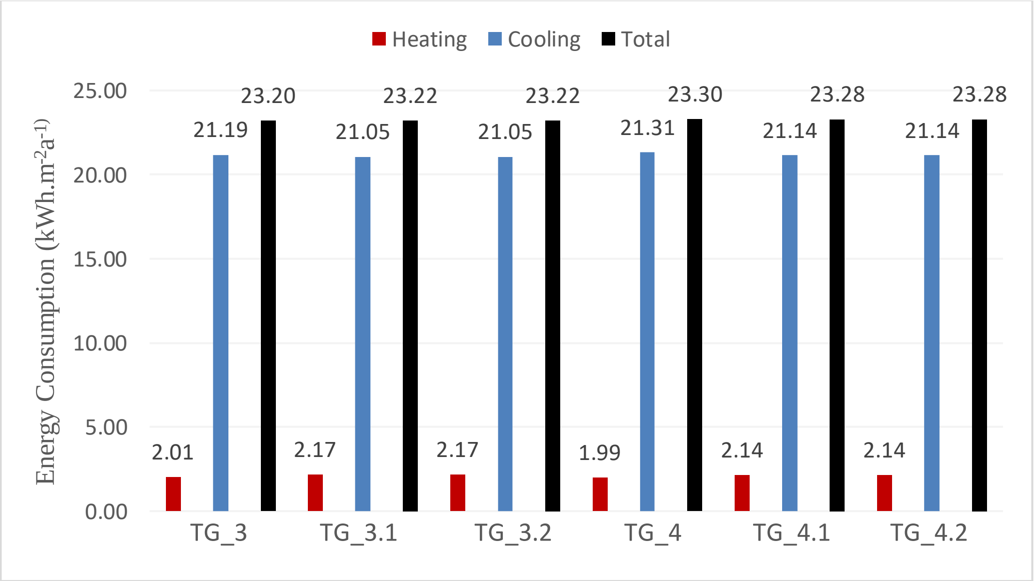


Figure 93. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios east orientated (TG_3, TG_3.1, TG_3.2, TG_4, TG_4.1, TG_4.2).

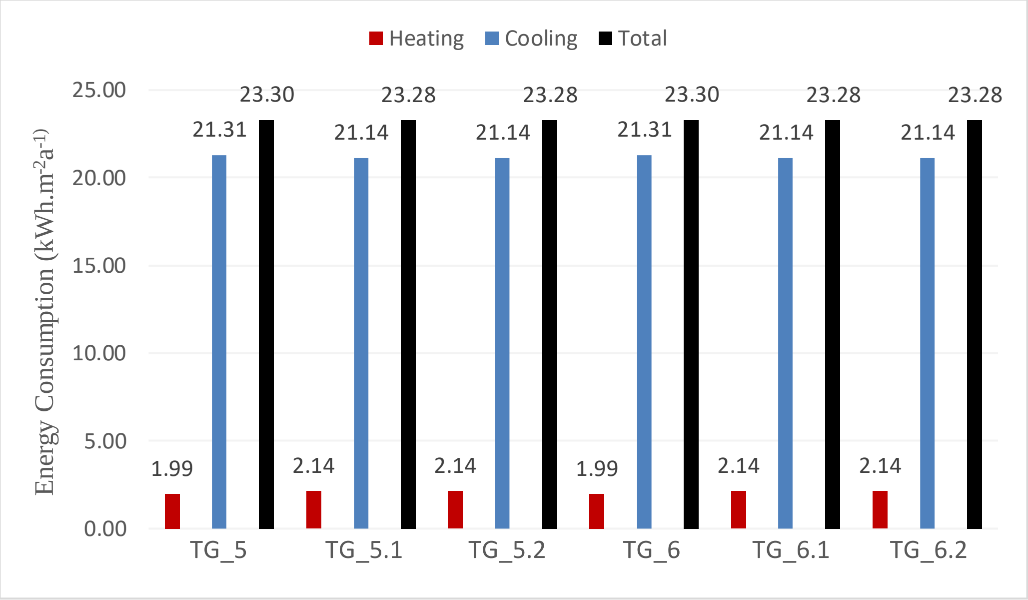


Figure 94. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios east orientated (TG_5, TG_5.1, TG_5.2, TG_6, TG_6.1, TG_6.2).

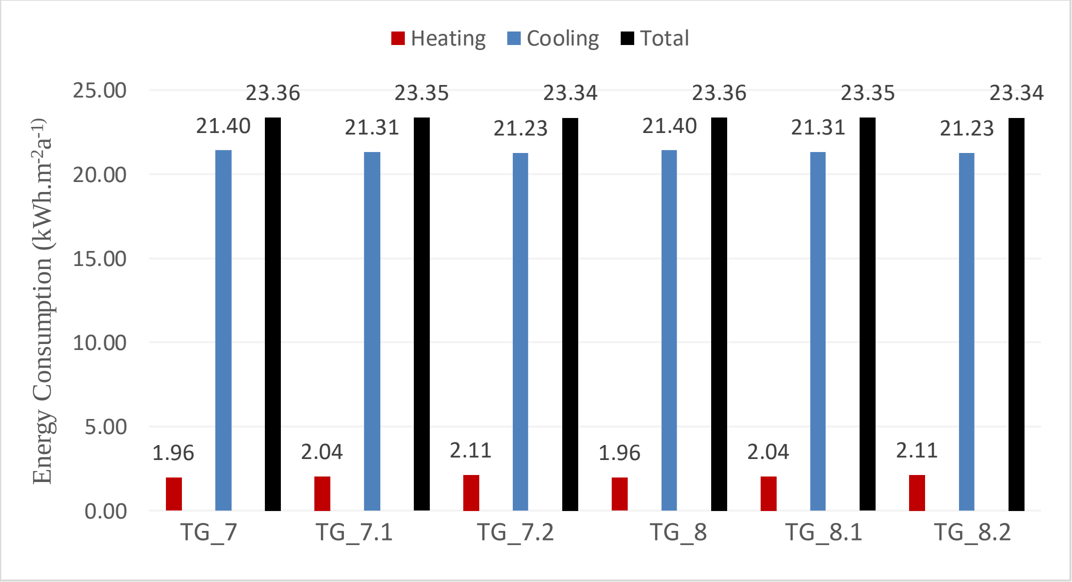


Figure 95. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios east orientated (TG_7, TG_7.1, TG_7.2, TG_8, TG_8.1, TG_8.2).

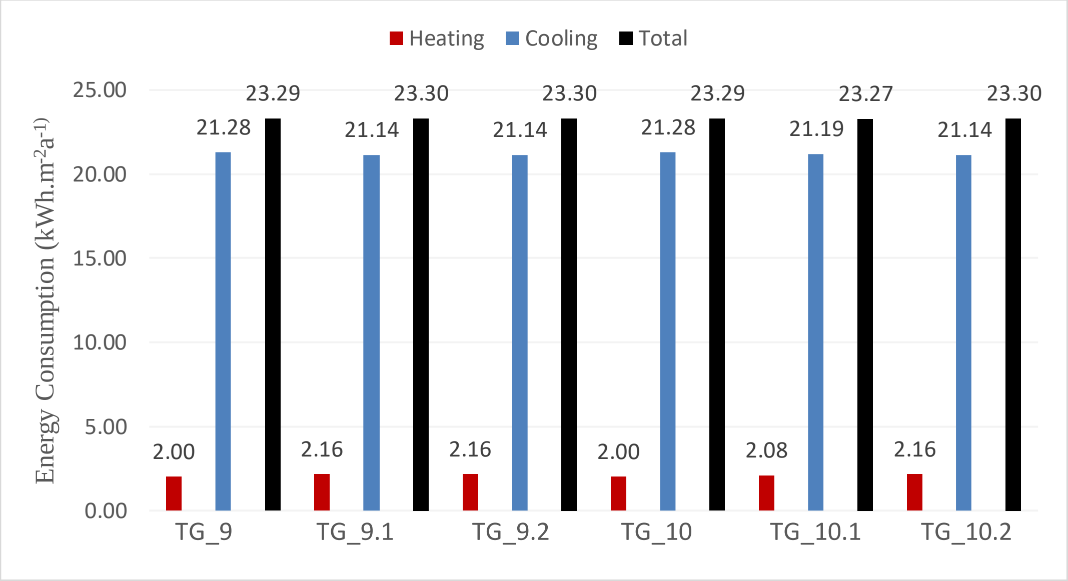


Figure 96. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios east orientated (TG_9, TG_9.1, TG_9.2, TG_10, TG_10.1, TG_10.2).

As figures show, the heating load for triple glazing scenarios east oriented ranges from minimum 1.96 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_7 and TG_8, and maximum 2.18 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_1.1, TG_1.2, TG_2.1, TG_2.2, thus giving ± 10% difference between minimum and maximum heating energy consumption. For the cooling load, the trend shows a higher energy consumption as for this, the cooling load ranges from minimum 20.89 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_1.1 and TG_1.2, and maximum 21.40 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_7 and TG_8, with ± 2% difference between minimum and maximum cooling energy consumption. The total shows that the minimum energy consumption is 23.06 (kWh.m^{-2}a$^{-1)}$ from scenario TG_1 and TG_1.2, and the maximum is 23.36 (kWh.m^{-2}a$^{-1)}$ from scenario TG_7 and TG_8, with ± 1 % difference in energy consumption.

4.3.2 TG South Orientation

Figure 97-101 illustrates the yearly energy consumption for heating, cooling and the total for the scenarios of triple glazing typology with south orientation. Specifically, *Figure 97* illustrates the yearly demand for heating, cooling and total for the scenarios: (TG_1, TG_1.1, TG_1.2, TG_2, TG_2.1, TG_2.2). *Figure 98* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_3, TG_3.1, TG_3.2, TG_4, TG_4.1, TG_4.2). *Figure 99* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_5, TG_5.1, TG_5.2, TG_6, TG_6.1, TG_6.2). *Figure 100* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_7, TG_7.1, TG_7.2, TG_8, TG_8.1, TG_8.2). *Figure 101* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_9, TG_9.1, TG_9.2, TG_10, TG_10.1, TG_10.2).

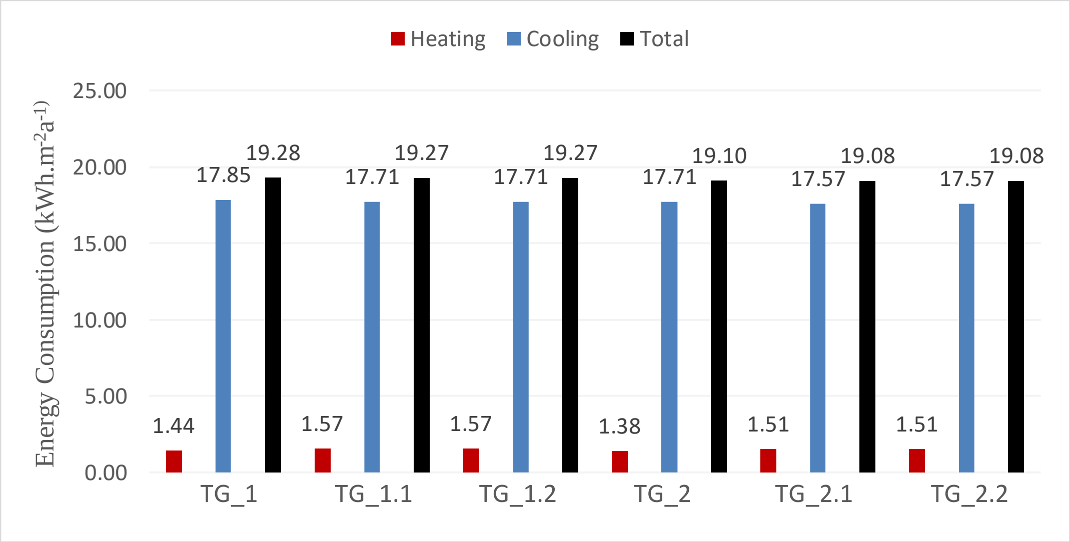


Figure 97. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios south orientated (TG_1, TG_1.1, TG_1.2, TG_2, TG_2.1, TG_2.2).

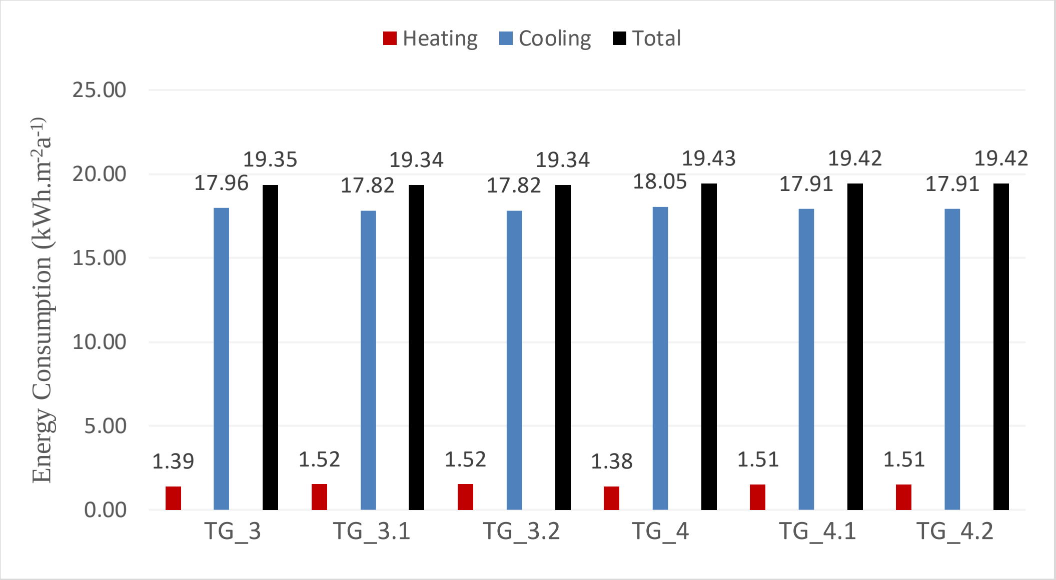


Figure 98. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios south orientated (TG_3, TG_3.1, TG_3.2, TG_4, TG_4.1, TG_4.2).

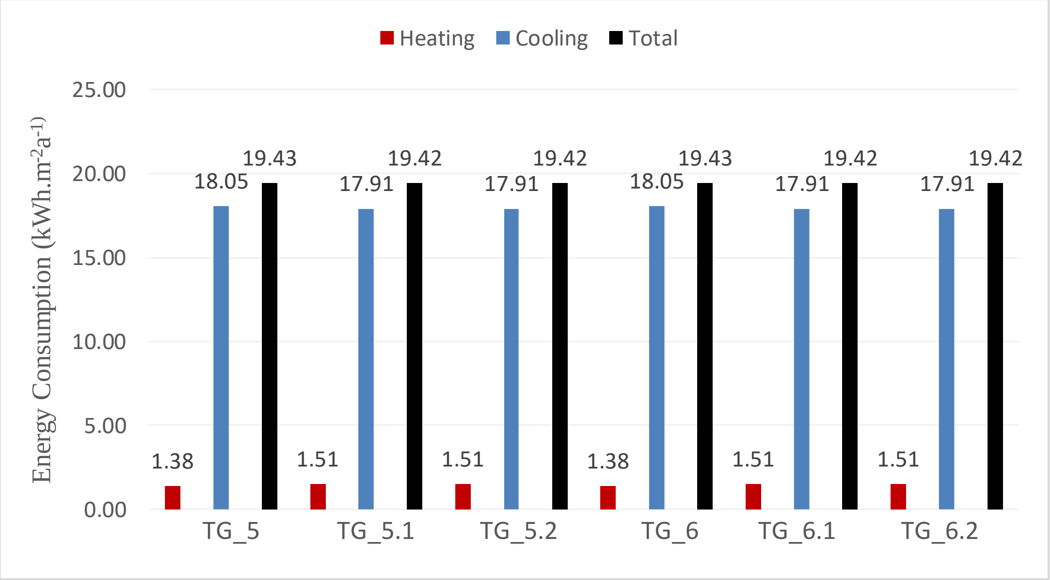


Figure 99. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios south orientated (TG_5, TG_5.1, TG_5.2, TG_6, TG_6.1, TG_6.2).

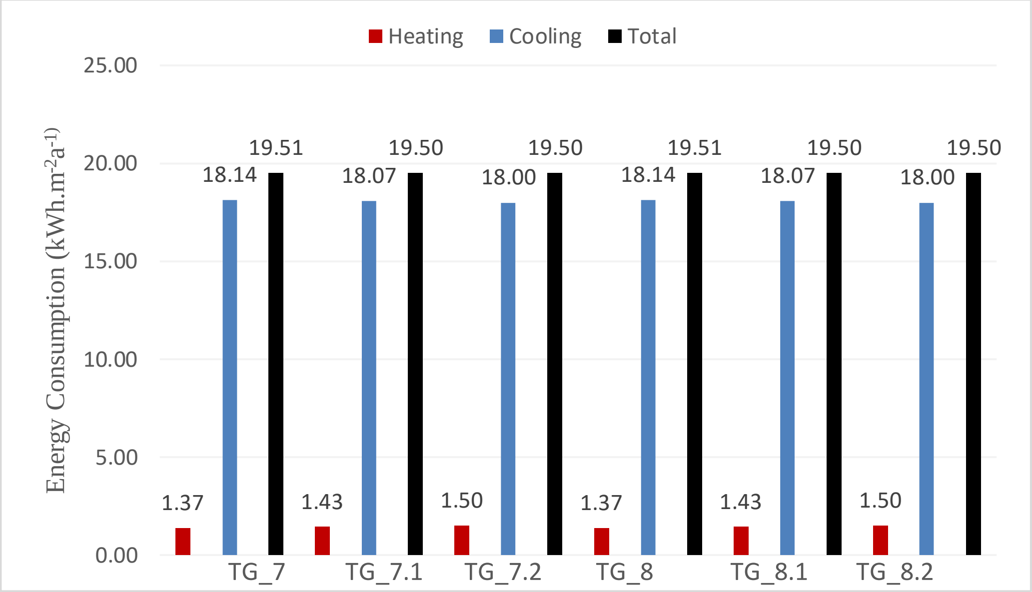


Figure 100. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios south orientated (TG_7, TG_7.1, TG_7.2, TG_8, TG_8.1, TG_8.2).

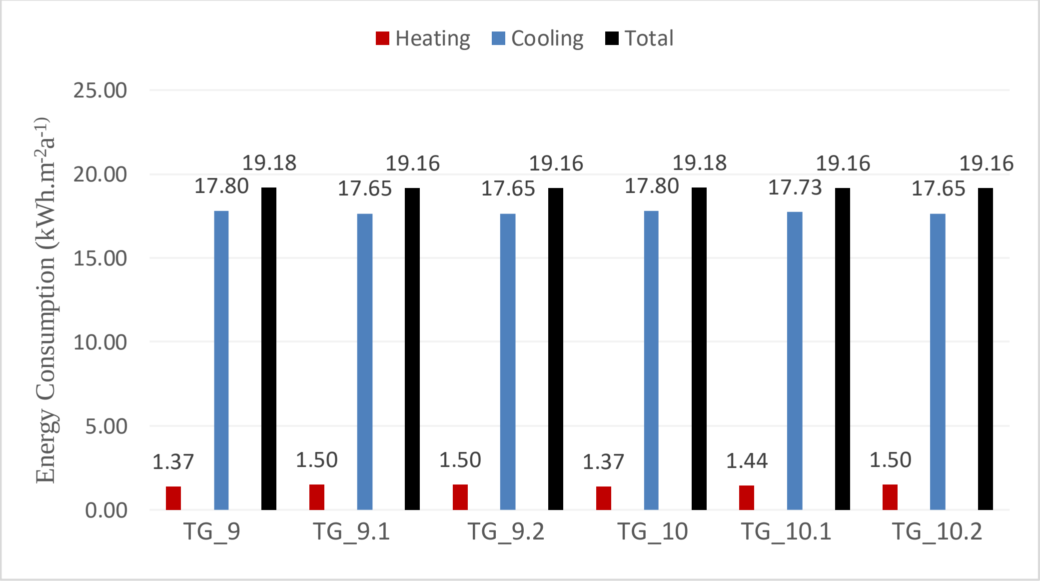


Figure 101. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios south orientated (TG_9, TG_9.1, TG_9.2, TG_10, TG_10.1, TG_10.2).

As figures show, the heating load for triple glazing scenarios south oriented ranges from minimum 1.37 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_7, TG_8, TG_9, TG_10, and maximum 1.57 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_1.1, TG_1.2, thus giving ± 14% difference between minimum and maximum heating energy consumption. For the cooling load, the trend shows a higher energy consumption as for this, the cooling load ranges from minimum 17.57 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_2.1 and TG_2.2, and maximum 18.14 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_7 and TG_8, with ± 3% difference between minimum and maximum cooling energy consumption. The total shows that the minimum energy consumption is 19.08 (kWh.m^{-2}a$^{-1)}$ from scenario TG_2.1 and TG_2.2, and the maximum is 19.51 (kWh.m^{-2}a$^{-1)}$ from scenario TG_7 and TG_8, with ± 2% difference in energy consumption.

4.3.3 TG West Orientation

Figure 102-106 illustrates the yearly energy consumption for heating, cooling and the total for the scenarios of triple glazing typology with west orientation. Specifically, *Figure 102* illustrates the yearly demand for heating, cooling and total for the scenarios: (TG_1, TG_1.1, TG_1.2, TG_2, TG_2.1, TG_2.2). *Figure 103* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_3, TG_3.1, TG_3.2, TG_4, TG_4.1, TG_4.2). *Figure 104* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_5, TG_5.1, TG_5.2, TG_6, TG_6.1, TG_6.2). *Figure 105* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_7, TG_7.1, TG_7.2, TG_8, TG_8.1, TG_8.2). *Figure 106* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_9, TG_9.1, TG_9.2, TG_10, TG_10.1, TG_10.2).

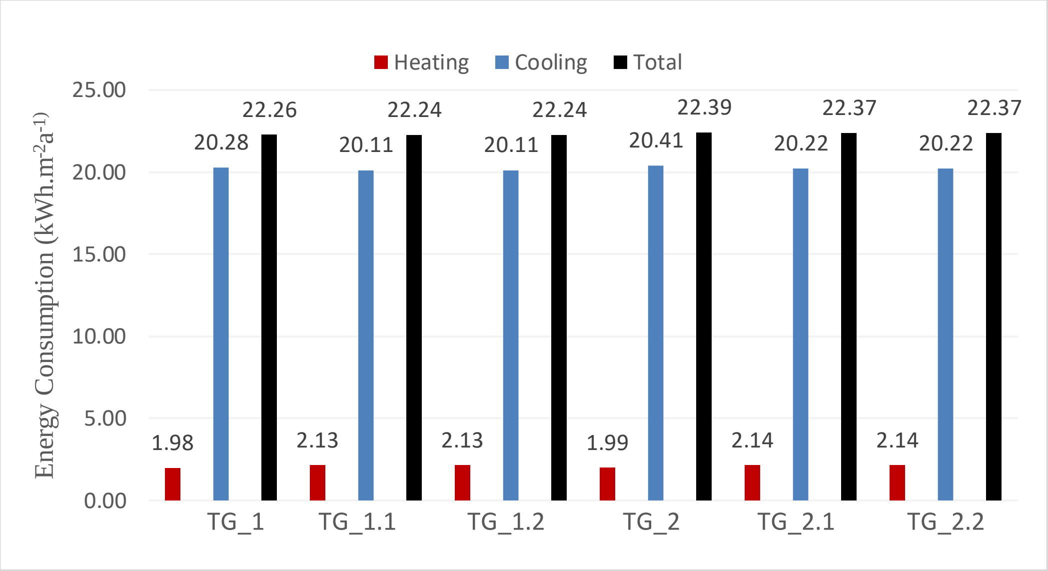


Figure 102. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios west orientated (TG_1, TG_1.1, TG_1.2, TG_2, TG_2.1, TG_2.2).

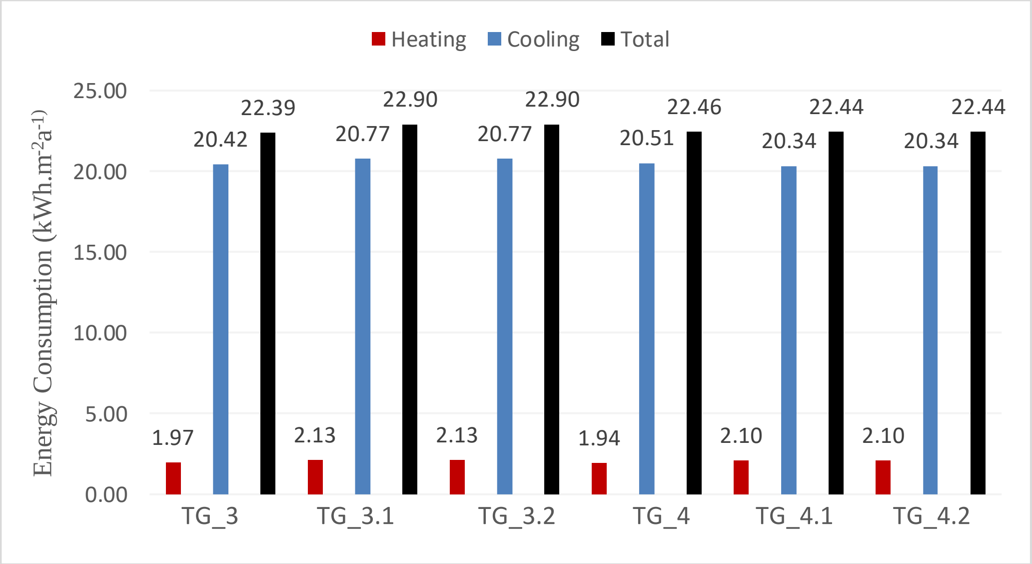


Figure 103. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios west orientated (TG_3, TG_3.1, TG_3.2, TG_4, TG_4.1, TG_4.2).

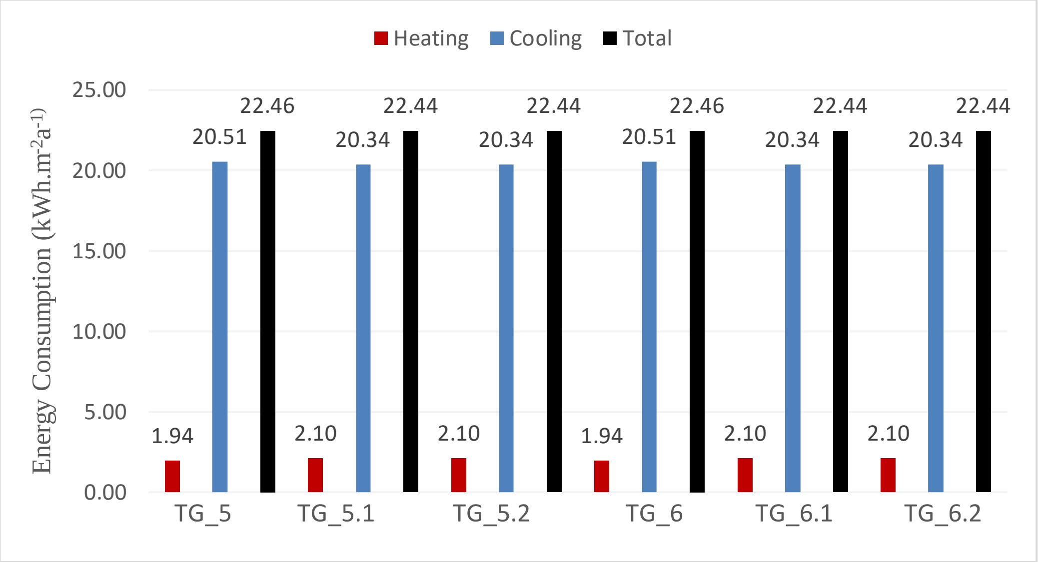


Figure 104. Comparison of simulated energy consumption (kWh.$m^{-2}a^{-1}$) for heating, cooling and total for the scenarios west orientated (TG_5, TG_5.1, TG_5.2, TG_6, TG_6.1, TG_6.2).

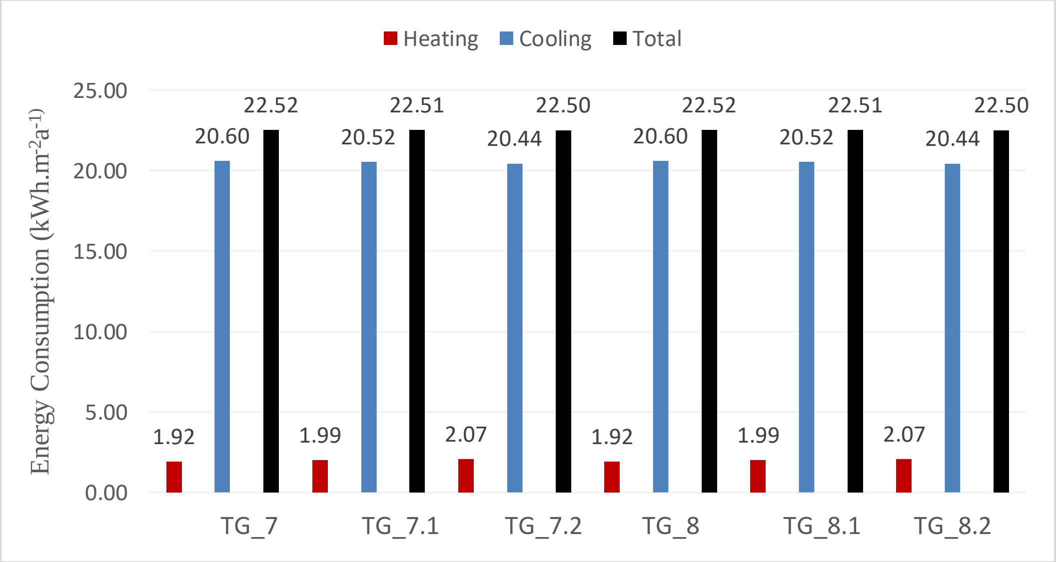


Figure 105. Comparison of simulated energy consumption (kWh.$m^{-2}a^{-1}$) for heating, cooling and total for the scenarios west orientated (TG_7, TG_7.1, TG_7.2, TG_8, TG_8.1, TG_8.2).

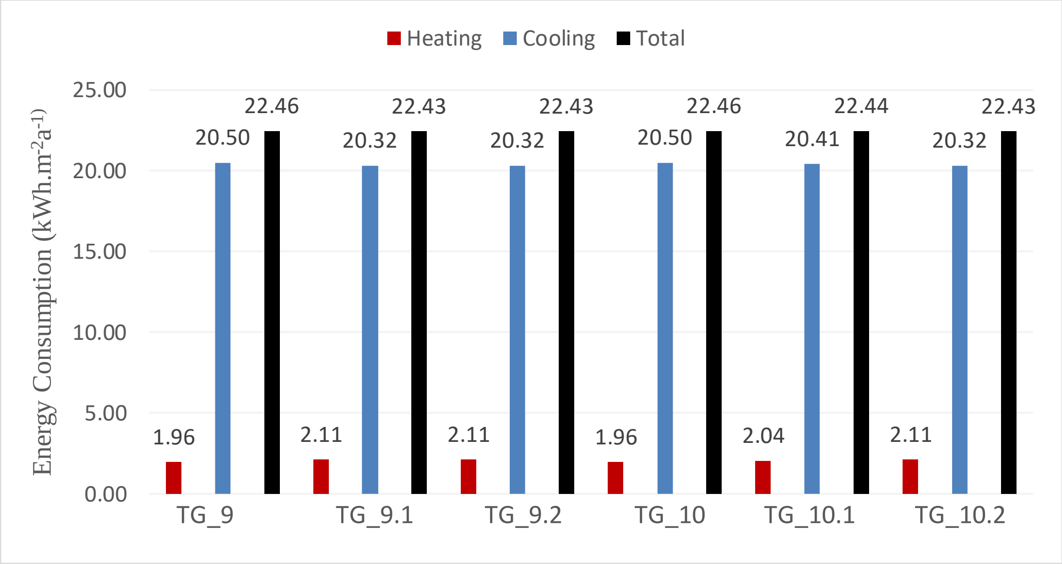


Figure 106. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios west orientated (TG_9, TG_9.1, TG_9.2, TG_10, TG_10.1, TG_10.2).

As figures show, the heating load for triple glazing scenarios west oriented ranges from minimum 1.92 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_7, TG_8, and maximum 2.14 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_2.1, TG_2.2, thus giving ± 11% difference between minimum and maximum heating energy consumption. For the cooling load, the trend shows a higher energy consumption as for this, the cooling load ranges from minimum 20.11 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_1.1 and TG_1.2, and maximum 20.77 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_3.1 and TG_3.2, with ± 3% difference between minimum and maximum cooling energy consumption. The total shows that the minimum energy consumption is 22.24 (kWh.m^{-2}a$^{-1)}$ from scenario TG_1.1 and TG_1.2, and the maximum is 22.90 (kWh.m^{-2}a$^{-1)}$ from scenario TG_3.1 and TG_3.2, with ± 3% difference in energy consumption.

4.3.4 TG North Orientation

Figure *107-111* illustrates the yearly energy consumption for heating, cooling and the total for the scenarios of triple glazing typology with north orientation. Specifically, *Figure 107* illustrates the yearly demand for heating, cooling and total for the scenarios: (TG_1, TG_1.1, TG_1.2, TG_2, TG_2.1, TG_2.2). *Figure 108* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_3, TG_3.1, TG_3.2, TG_4, TG_4.1, TG_4.2). *Figure 109* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_5, TG_5.1, TG_5.2, TG_6, TG_6.1, TG_6.2). *Figure 110* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_7, TG_7.1, TG_7.2, TG_8, TG_8.1, TG_8.2). *Figure 111* illustrates the yearly demand for heating, cooling and total for the scenarios (TG_9, TG_9.1, TG_9.2, TG_10, TG_10.1, TG_10.2).

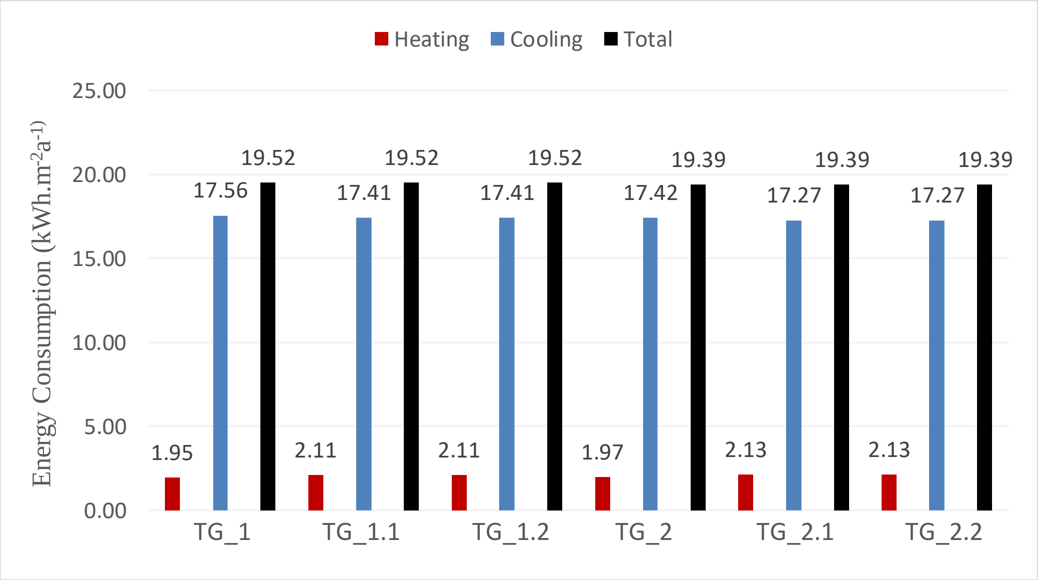


Figure 107. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios north orientated (TG_1, TG_1.1, TG_1.2, TG_2, TG_2.1, TG_2.2).

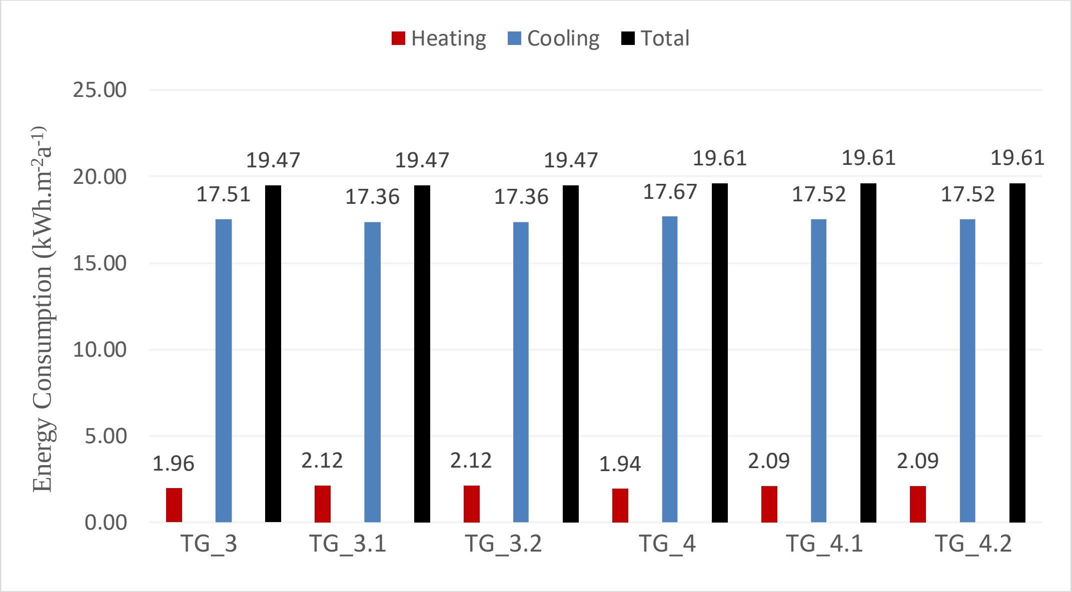


Figure 108. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios north orientated (TG_3, TG_3.1, TG_3.2, TG_4, TG_4.1, TG_4.2).

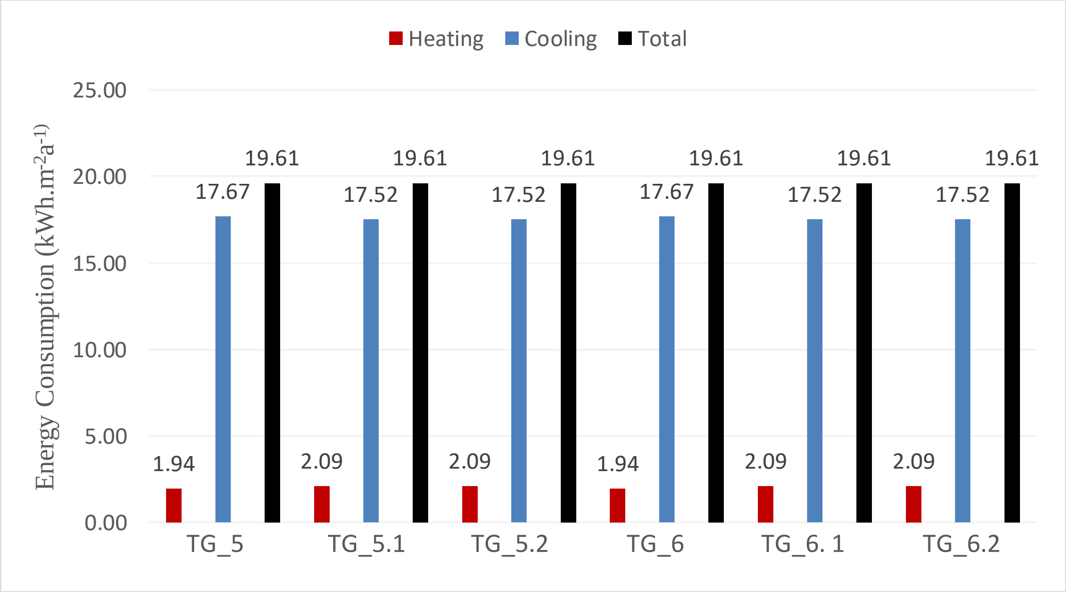


Figure 109. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios north orientated (TG_5, TG_5.1, TG_5.2, TG_6, TG_6.1, TG_6.2).

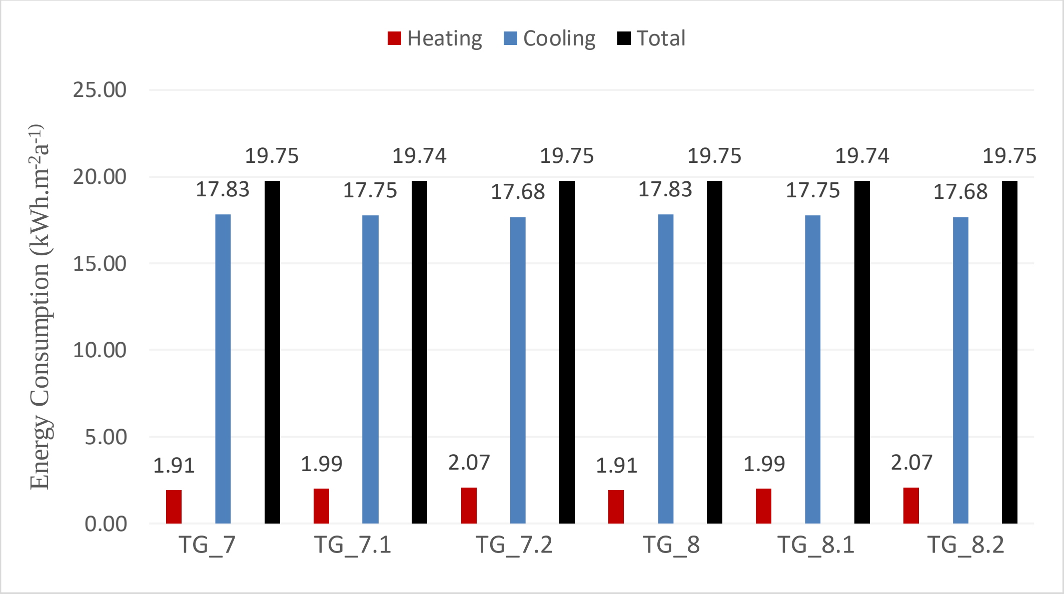


Figure 110. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios north orientated (TG_7, TG_7.1, TG_7.2, TG_8, TG_8.1, TG_8.2).

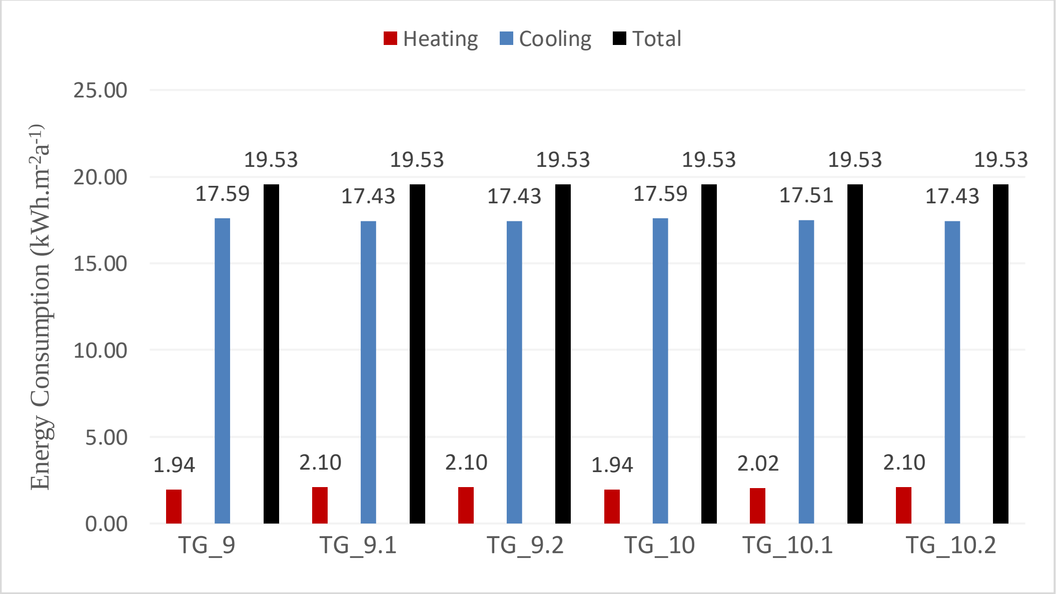


Figure 111. Comparison of simulated energy consumption (kWh.m^{-2}a$^{-1)}$ for heating, cooling and total for the scenarios north orientated (TG_9, TG_9.1, TG_9.2, TG_10, TG_10.1, TG_10.2).

As figures show, the heating load for triple glazing scenarios north oriented ranges from minimum 1.91 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_7, TG_8, and maximum 2.13 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_2.1, TG_2.2, thus giving ± 11% difference between minimum and maximum heating energy consumption. For the cooling load, the trend shows a higher energy consumption as for this, the cooling load ranges from minimum 17.27 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_2.1 and TG_2.2, and maximum 17.83 (kWh.m^{-2}a$^{-1)}$ for scenarios TG_7 and TG_8, with ± 3% difference between minimum and maximum cooling energy consumption. The total shows that the minimum energy consumption is 19.39 (kWh.m^{-2}a$^{-1)}$ from scenario TG_2, TG_2.1, TG_2.2, and the maximum is 19.75 (kWh.m^{-2}a$^{-1)}$ from scenario TG_7, TG_7.2, TG_8, TG_8.2, with ± 2 % difference in energy consumption.

4.4 Comparison

As illustrated on *Figure 112-117,* when a building is rotated between 0° and 180°, or east and west, the annual simulated energy demand, when expressed in terms of rotation angle, exhibits an increasing trend. *Figures 112-117* illustrate the total yearly energy demand for double and triple glazing scenarios for each orientation, east 0°, south 90°, west 180° and north 270°, showing the maximum total and the minimum total of all scenarios, thus giving a comparison result on which glazing has the lowest energy consumption and the highest one. Also, showing which orientation has the maximum and minimum energy consumption. Specifically, *Figure 112* shows the maximum total energy consumption for double glazing scenarios east, south, west and north orientation. *Figure 113* shows the minimum total energy consumption for double glazing scenarios east, south, west and north orientation. *Figure 114* shows the maximum total energy consumption for triple glazing scenarios east, south, west and north orientation. *Figure 115* shows the minimum total energy consumption for triple glazing scenarios east, south, west and north orientation.

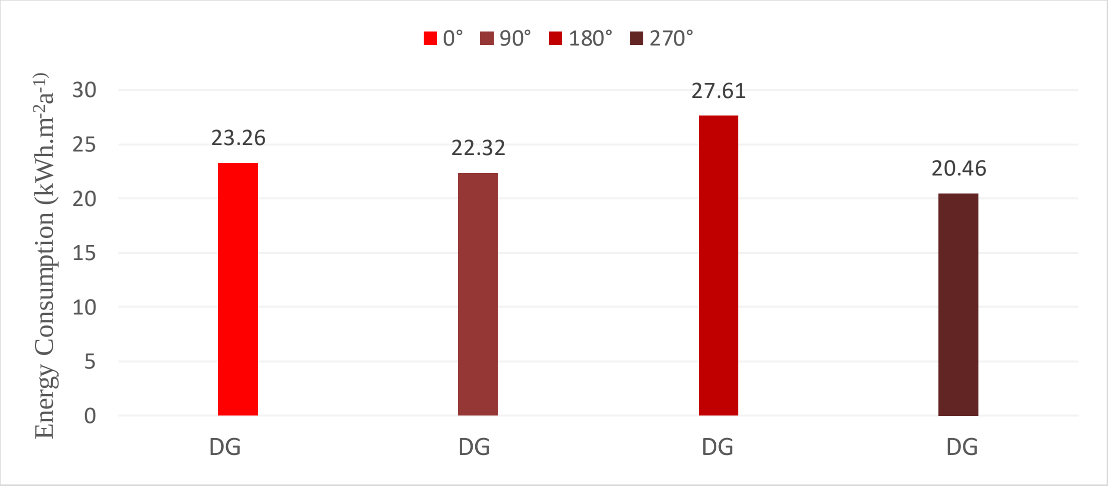


Figure 112. Comparison of simulated maximum total energy consumption (kWh.m^{-2}a$^{-1)}$ for the double glazing scenarios east oriented (0°), south oriented (90°), west oriented (180°) and north oriented (270°).

As illustrated on *Figure 112*, the comparison of simulated maximum total energy consumption (kWh.m^{-2}a$^{-1)}$ for the double glazing scenarios east oriented (0°) are DG_9 and DG_9.1, south oriented (90°) DG_9, DG_9.1, DG_9.2, west oriented (180°) DG_9, DG_9.1, DG_9.2, and north oriented (270°) DG_9, DG_9.1, DG_9.2.

Table 16. Simulation results obtained for the maximum double glazing scenarios.

	Annual heating demand			**Annual cooling demand**			**Annual energy demand**		
Scenarios	Total heating [kWh]	Heating/ conditioned area [kWh/m^2]	**Morphology effectiveness [%]**	Total cooling [kWh]	Cooling/ conditioned area [kWh/m^2]	**Morphology effectiveness [%]**	Total energy [kWh]	Total energy/ conditioned area [kWh/m^2]	**Total Morphology effectiveness [%]**
EAST DG 9 & DG 9.1	4465.08	2.20	_	45751	21.1	_	50216.61	23.26	_
SOUTH DG 9 & DG 9.1 & DG 9.2	1690.36	0.99	**75.8**	36544.60	21.3	**-1**	38234.95	22.32	**4.1**
WEST_ DG 9 & DG 9.1 & DG 9.2	4667	2.72	**-21.1**	42628.66	24.9	**-16.5**	47295.73	27.61	**-17.1**
NORTH DG 9 &DG 9.1 & DG 9.2	6452.02	3.77	**-52.6**	28591.05	16.7	**23.3**	35043.07	20.46	**12.8**

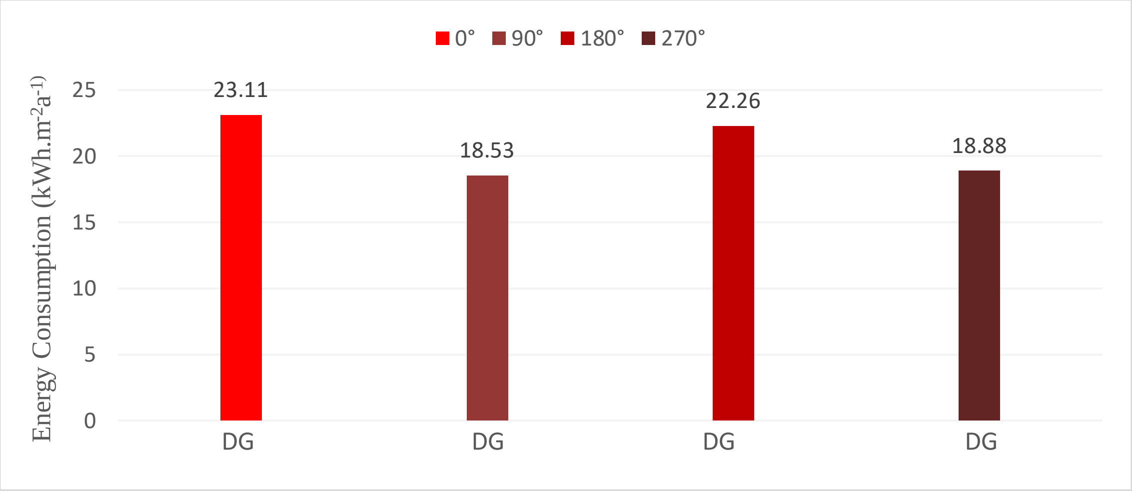


Figure 113. Comparison of simulated minimum total energy consumption (kWh.m^{-2}a^{-1}) for the double glazing scenarios east oriented (0°), south oriented (90°), west oriented (180°) and north oriented (270°).

As illustrated on *Figure 113*, the comparison of simulated minimum total energy consumption (kWh.m^{-2}a^{-1}) for the double glazing scenarios east oriented (0°) are DG_1 and DG_2, south oriented (90°) DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2, west oriented (180°) DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2, and north oriented (270°) DG_1 and DG_2.

Table 17. Simulation results obtained for the maximum triple glazing scenarios.

	Annual heating demand			**Annual cooling demand**			**Annual energy demand**		
Scenarios	Total heating [kWh]	Heating/ conditioned area [kWh/m^2]	**Morphology effectiveness [%]**	Total cooling [kWh]	Cooling/ conditioned area [kWh/m^2]	**Morphology effectiveness [%]**	Total energy [kWh]	Total energy/ conditioned area [kWh/m^2]	**Total Morphology effectiveness [%]**
EAST TG 7 & TG 8	3359.32	1.96	_	36660.43	21.4	_	40019.45	23.36	_
SOUTH TG 7 & TG 8	2346.93	1.37	**35.4**	35576.83	18.1	**16.7**	39222.13	19.51	**17.9**
WEST_ TG 3.1 & TG 3.2	3645.30	2.13	**-8.3**	42628.66	20.8	**2.8**	47295.73	22.9	**2**
NORTH TG 7 &TG 7.2 & TG 8 &TG 8.2	3537.68	2.07	**-5.5**	30287.25	17.7	**18.9**	33824.93	19.75	**16.7**

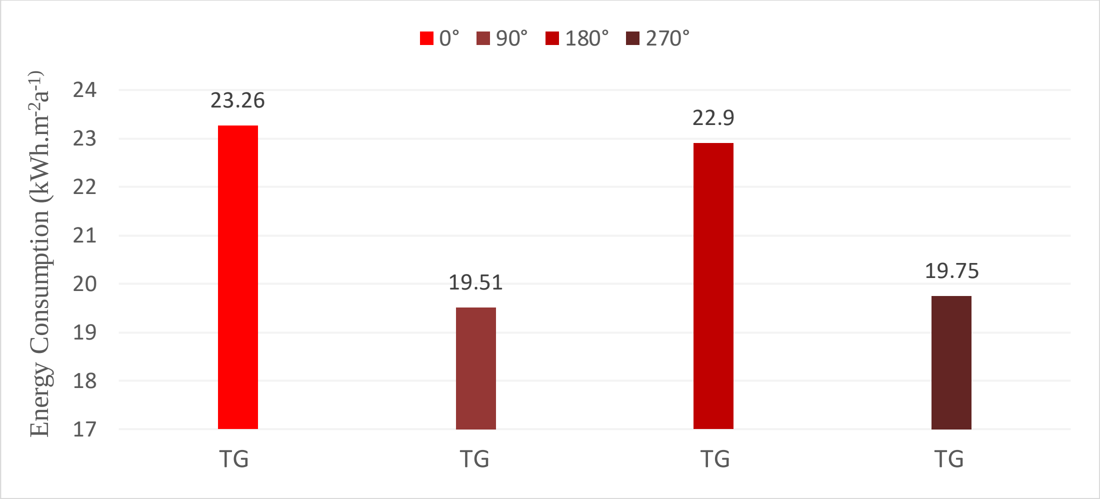


Figure 114. Comparison of simulated maximum total energy consumption (kWh.m^{-2}a$^{-1)}$ for the triple glazing scenarios east oriented (0°), south oriented (90°), west oriented (180°) and north oriented (270°).

As illustrated on *Figure 114*, the comparison of simulated maximum total energy consumption (kWh.m^{-2}a$^{-1)}$ for the triple glazing scenarios east oriented (0°) are TG_7 and TG_8, south oriented (90°) TG_7 and TG_8, west oriented (180°) TG_3.1 and TG_3.2, and north oriented (270°) TG_7, TG_7.2, TG_8, TG_8.2.

Table 18. Simulation results obtained for the minimum double glazing scenarios**.**

	Annual heating demand			**Annual cooling demand**			**Annual energy demand**		
Scenarios	Total heating [kWh]	Heating/ conditioned area [kWh/m^2]	**Morphology effectiveness [%]**	Total cooling [kWh]	Cooling/ conditioned area [kWh/m^2]	**Morphology effectiveness [%]**	Total energy [kWh]	Total energy/ conditioned area [kWh/m^2]	**Total Morphology effectiveness [%]**
EAST DG 1 & DG 2	3903.79	2.28	_	35680.9	20.8	_	39584.69	23.11	_
SOUTH DG 1 & DG 2 ALL	2591.53	1.51	**40.6**	29151.1	17.0	**20.1**	31742.64	18.53	**21.9**
WEST_ DG 1 & DG 2 ALL	3845.07	2.24	**1.7**	34284.53	20.0	**3.9**	38129.60	22.26	**3.7**
NORTH DG 1 &DG 2	3811.07	2.22	**2.6**	28536.32	16.6	**22.4**	32347.39	18.88	**20.1**

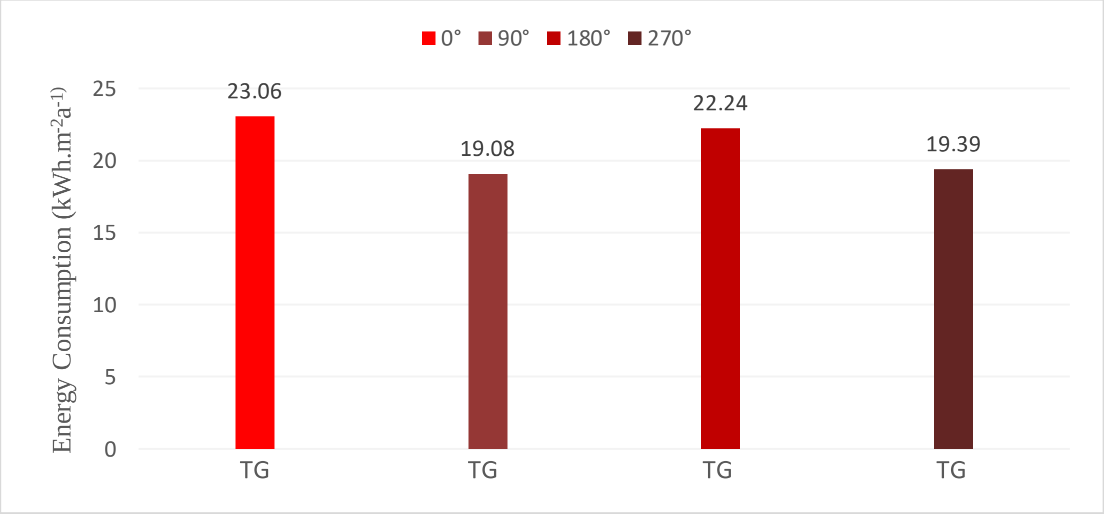


Figure 115. Comparison of simulated minimum total energy consumption (kWh.m^{-2}a$^{-1)}$ for the triple glazing scenarios east oriented (0°), south oriented (90°), west oriented (180°) and north oriented (270°).

As illustrated on *Figure 115*, the comparison of simulated minimum total energy consumption (kWh.m^{-2}a$^{-1)}$ for the triple glazing scenarios east oriented (0°) are TG_1.1 and TG_1.2, south oriented (90°) TG_2.1 and TG_2.2, west oriented (180°) TG_1.1 and TG_1.2, and north oriented (270°) TG_2, TG_2.1, TG_2.2.

Table 19. Simulation results obtained for the minimum triple glazing scenarios.

	Annual heating demand			**Annual cooling demand**			**Annual energy demand**		
Scenarios	Total heating [kWh]	Heating/ conditioned area [kWh/m^2]	**Morphology effectiveness [%]**	Total cooling [kWh]	Cooling/ conditioned area [kWh/m^2]	**Morphology effectiveness [%]**	Total energy [kWh]	Total energy/ conditioned area [kWh/m^2]	**Total Morphology effectiveness [%]**
EAST TG 1.1 & TG 1.2	3727.51	2.18	_	35782.60	20.9	_	39510.11	23.06	_
SOUTH TG 2.1 & TG_2.2	2591.48	1.51	**36.3**	30091.92	17.6	**17.1**	32683.41	19.08	**18.9**
WEST_ TG 1.1 & TG 1.2	3654.97	2.13	**2.3**	34448.87	20.1	**-3.9**	38103.84	22.24	**3.6**
NORTH TG 2 &TG 2.1 &TG 2.2	3376.60	1.97	**10.1**	29843.94	17.4	**18.2**	33220.54	19.39	**17.3**

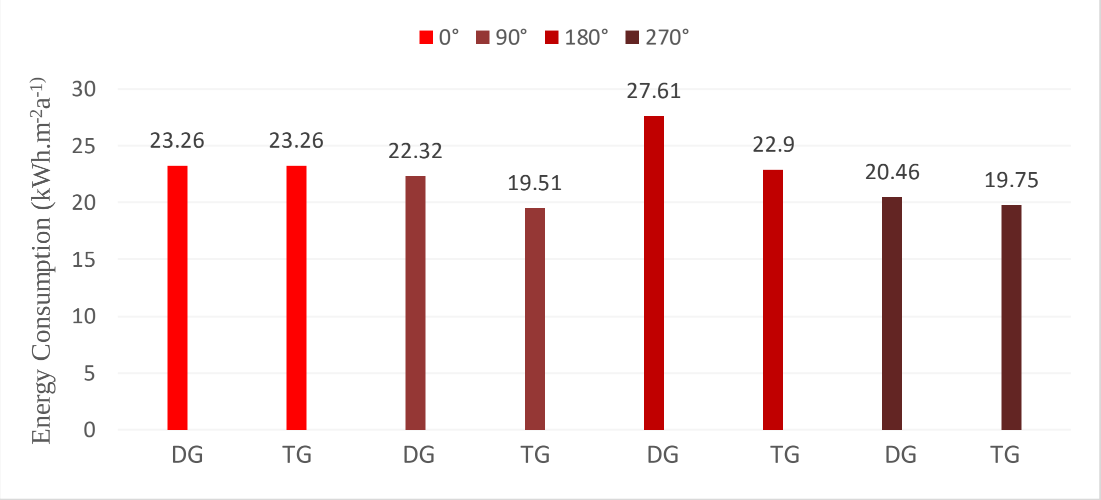


Figure 116. Comparison of simulated maximum total energy consumption (kWh.m^{-2}a$^{-1)}$ for the double and triple glazing scenarios east oriented (0°), south oriented (90°), west oriented (180°) and north oriented (270°).

As illustrated on *Figure 116*, the comparison of simulated maximum total energy consumption (kWh.m^{-2}a$^{-1)}$ for the double and triple glazing scenarios east oriented (0°) are DG_9, DG_9.1, TG_7, TG_8, south oriented (90°) DG_9, DG_9.1, DG_9.2, TG_7, TG_8, west oriented (180°) DG_9, DG_9.1, DG_9.2, TG_3.1, TG_3.2 , and north oriented (270°) DG_9, DG_9.1, DG_9.2, TG_7, TG_7.2, TG_8, TG_8.2.

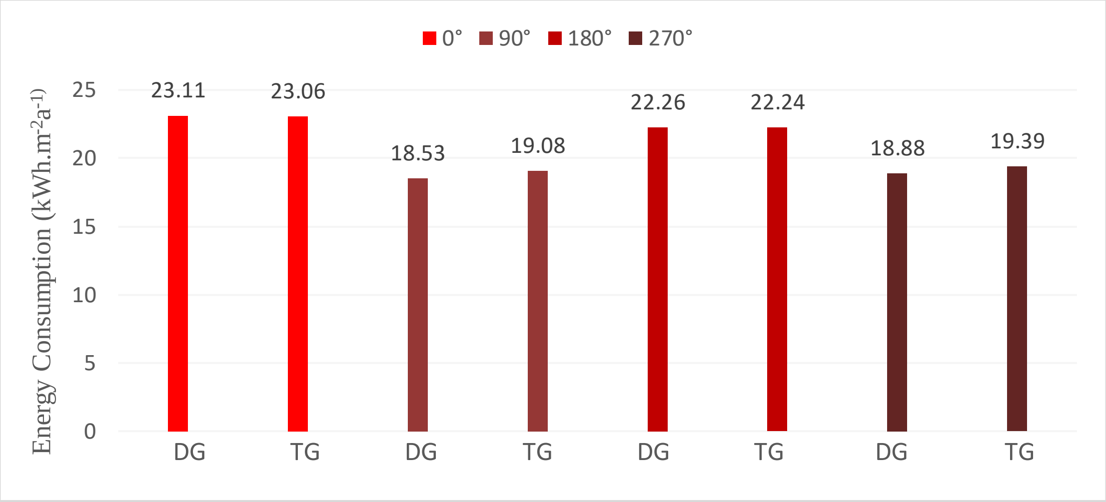


Figure 117. Comparison of simulated minimum total energy consumption (kWh.m^{-2}a$^{-1)}$ for the double and triple glazing scenarios east oriented (0°), south oriented (90°), west oriented (180°) and north oriented (270°).

As illustrated on *Figure 117*, the comparison of simulated minimum total energy consumption (kWh.m^{-2}a$^{-1)}$ for the double and triple glazing scenarios east oriented (0°) are DG_1, DG_2, TG_1.1, TG_1.2, south oriented (90°) DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2, TG_2.1, TG_2.2, west oriented (180°) DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2, TG_1.1, TG_1.2, and north oriented (270°) DG_1, DG_2, TG_2, TG_2.1, TG_2.2.

As figures show, the minimum total energy load for double and triple glazing scenarios with all the four orientations included ranges 18.53 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_1, DG_1.1, DG_1.2, DG_2, DG_2.1, DG_2.2 south oriented, thus making all three scenarios of DG_1 and DG_2 the best options.

Meanwhile, the maximum total energy load for double and triple glazing scenarios with all the four orientations included ranges 27.61 (kWh.m^{-2}a$^{-1)}$ for scenarios DG_9, DG_9.1, DG_9.2, thus making all three types of scenario DG_9 the biggest impact scenario in energy consumption. It is important to mention that this is a real case scenario which has been implemented in Air Albania Stadium in Tirana, Albania. For more detailed description check *Figure 118 and Figure 119* of the stadium and the glazing scenario on the next page.

The morphology effectiveness (difference between total min. & max. energy consumption) ranges ± 40 %. On the triple glazing scenario, the minimal total energy demand is 19.08 (kWh.m^{-2}a$^{-1)}$ from scenario TG_2.1 and TG_2.2, making it the best option for triple glazing scenarios.

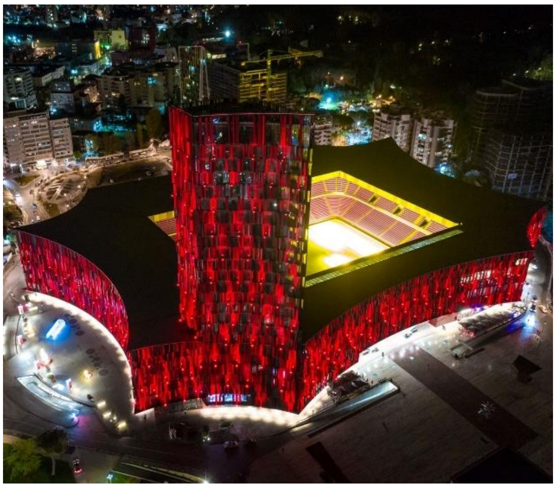


Figure 118. Air Albania Stadium in Tirana, Albania.

Glazing type

Glazing 1
PLANICLEAR (12mm) - Tempered

Cavity 1
Argon 90% 16 mm

Glazing 2
PLANICLEAR (12mm) - Tempered

Figure 119. Double Glazing conceptual section drawing (configuration) of glazing scenario DG_9, (Air Albania Stadium case).

CHAPTER 5

CONCLUSION

5.1 Conclusion overview

Performance-based architectural design is increasingly capturing the interest of both practicing architects and academic researches. This growing focus is contributing significantly to the enhancement of climatic awareness among designers and architects, particularly in the crucial decision-making phases of their projects. Recognizing the importance of this trend, a new comprehensive framework has been developed to foster an analytical and quantitative approach assessing the thermal and energy performance of office building morphologies, specifically within the context of Mediterranean climate.

This innovative framework offers a systematic methodology and technique that not only provides novel and valuable contributions to the field of performance-driven design but also aids in the optimization of the architectural practices. By integrating these advanced analytical tools, architects, construction and glazing companies are better equipped to make informed and effective design decisions that balance aesthetic considerations with energy efficiency and thermal comfort.

The approach employs cutting-edge simulation tools and sophisticated performance metrics to rigorously evaluate a range of design alternatives. This helps to identify the most energy-efficient solutions while maintaining the desired architectural quality. The comprehensive nature of the framework ensures that all relevant factors, including building orientation, glazing types and economical aspects are meticulously analyzed and optimized. Through detailed analysis and interpretation of the simulation results, several key conclusions can be drawn.

These conclusions not only highlight the efficacy of the proposed methodology but also underscore its practical applicability in the real-world architectural design projects, residential or commercial. The insights gained from this research are poised to significantly influence architectural practices and glazing manufacturers, driving the adoption of more sustainable and energy-efficient design strategies in the Mediterranean and similar climatic regions.

5.1.1 Double and Triple Glazing

Triple glazing, based on the simulations done showed that it is not recommended much in Mediterranean climate nations because of the greenhouse effect it causes in the summer. Due to the presence of three glass panes and two layers of Argon gas, the thermal insulation of the system is significantly enhanced. As a result, the accumulated heat during a warm day is effectively trapped within the environment. Based on the data shown in the preceding pages, it is evident that the initial scenarios with double and triple glazing exhibited superior energy efficiency, although with a negligible difference. Consequently, there is no need to increase the thickness of the glass in order to improve the energy efficiency of buildings, but taking into account some other conditions such as noise reduction, which is essential for buildings near roads or other circumstances, meaning that the thicker the glass, the better is at reducing noise (soundproof & acoustic glass), and also natural ventilation which is described in the following page, there can be some exceptions, thus said for the climatic conditions of Mediterranean.

5.1.2 Glazing Spacing

The analysis revealed that the 16mm spacer emerged as the optimal thickness across various glazing scenarios. Deviations from this thickness, either by reducing to 14-12mm or expanding to 20-24mm. resulted in unsatisfactory energy performance. Thus, the 16mm spacing emerged as the optimal choice for glazing spacing, representing the ideal compromise between thermal efficiency and overall energy performance. This finding not only enhances the precision of glazing selection processes but also underscores the critical role of spacer thickness in achieving optimal building energy efficiency and sustainability objectives.

5.1.3 Orientation

The role of orientation proved to be pivotal in determining building energy performance, exerting a significant influence on energy consumption rates. As described in previous chapters, it was discerned that orientations towards the east (0 degrees) and west (180 degrees) exhibited the highest energy consumption rates within the context of the Mediterranean climate.

This finding underscores the critical importance of orientation considerations in architectural design, highlighting the need for strategic planning to mitigate energy consumption and optimize thermal comfort. By acknowledging and addressing the impact of orientation on energy performance, architects and designers can implement informed design strategies that promote sustainability and enhance the overall environmental performance of buildings in Mediterranean climates.

5.1.4 Glazing Coatings

An important factor influencing energy performance is the type of coatings applied to glazing scenarios. In this study, the only coating utilized was the Planitherm 4s Low-e (low-emissivity) coating on the outdoor glass pane. This coating significantly enhances thermal insulation; however, energy performance can be further optimized by also applying a Low-e coating on the indoor glass pane, which would enhance insulation and reduce energy consumption even more effectively.

Additionally, tinted coatings serve an important function in blocking direct solar rays, reducing heat buildup during sunny days. Tinted coatings, as seen in the image below, may significantly lower the quantity of solar radiation entering the building, resulting in greater interior thermal comfort and less dependency on cooling systems. The exploration of glazing coatings is an ongoing process, with continuous advancements and innovations being integrated into building designs. The models and coatings examined in this research are grounded in real-world applications, having been implemented in Albania and various other countries across Europe. These practical implementations provide valuable insights and validate the effectiveness of different glazing coatings in enhancing building energy performance.

5.1.5 Ventilation

Taking into account that the office building had no openings, the primary aim of this study was to evaluate the effectiveness and properties of various glazing options. However, it is indicated that by introducing openings throughout the façade, the building's energy performance could be significantly enhanced.

This is due to the benefits of natural ventilation, which allows for improved air circulation and the exchange of indoor and outdoor air. By facilitating natural air circulation, these openings help to regulate the indoor temperature more efficiently, reducing the reliance on mechanical cooling systems. The introduction of openings enables the warm air accumulated inside the building during the day to escape, while cooler air enters, creating a more comfortable and energy-efficient environment.

5.1.6 Economical Perspective

When it comes to the investor side, the economic viewpoint is a very essential component. Based on the results of the simulations done and results on *Table 14 & 15*, it indicates that the best options to invest are in the first glazing scenarios ex. (DG_1-2-3-4, TG_1-2-3-4), which means that the investment is done in the scenarios that have the lowest cost per m2. As the thickness of the glazing pane rises, the price of the product likewise expands. In the same way, the spacers experience the same thing when their thickness is raised. With regard to the difference between double and triple glazing, it is evident from the *Table 15* that triple glazing is more expensive than double glazing. This is because it consists of one more glass pane, which means that there is one more space between the panes and argon gas filling, thus automatically making it much more expensive compared to double glazing scenarios.

5.2 Recommendations for future research

Every day, as urban landscapes evolve, we witness the emergence of diverse architectural structures. Glazing, a ubiquitous feature in modern building design, adorns the facades of these structures, ranging from traditional windows to sleek curtain walls. Despite its prevalence, the significance of glazing is often overlooked in architectural discourse.

In this study, 60 distinct glazing scenarios have been examined, representing the most commonly used models across a spectrum of building typologies, including residential, office, which is part of our research, commercial, and other. These scenarios serve as foundational templates, offering valuable insights into the varied applications of glazing in contemporary architecture. The scenarios simulated and analyzed in this study can be implemented in each building typology, as they were chosen carefully so future researchers can implement these scenarios in other building typologies such as residential, commercial and other.

However, the exploration of glazing possibilities extends far beyond the confines of this study. The field of glazing design is characterized by its boundless potential for innovation and experimentation. With endless permutations and combinations available, researchers have the opportunity to explore a myriad of factors, including variations in pane thickness, spacer design, glazing coatings, types of glazing, window frames, and considerations of diverse climatic conditions. The dynamic nature of glazing technology invites further investigation into its evolving capabilities. As advancements in materials science and engineering continue to push the boundaries of architectural innovation, researchers are poised to explore the integration of smart glazing systems. These systems, capable of adapting to environmental stimuli and optimizing energy performance, hold immense promise for the future of sustainable building design. As the conclusion chapter emphasizes the significance of various factors, it's essential for researchers to delve deeper into these aspects and encourage further exploration in this field, recognizing its boundless potential for advancement and innovation.

In essence, the study of glazing embodies a dynamic and diverse realm ripe for exploration. By embracing a comprehensive approach that integrates both aesthetic and functional considerations, researchers can pave the way for performance enhancement, sustainability, and resilience of architectural structures, ushering in a new era of innovative building design.

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