ASSESSMENTS OF ENERGETIC EFFICIENCY OF VARIOUS ALBANIAN HOUSE TYPOLOGIES

A THESIS SUBMITTED TO
THE FACULTY OF ARCHITECTURE AND ENGINEERING
OF
EPOKA UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
ARCHITECTURE

July, 2021

Approval sheet of the Thesis

This is to certify that we have read this thesis entitled **"Assessments of energetic efficiency of various Albanian house typologies"** 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

ASSESSMENTS OF ENERGETIC EFFICIENCY OF VARIOUS ALBANIAN HOUSE TYPOLOGIES

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Recently the concept of energy efficiency in buildings is a topic of great interest due to several factors, including the expensive costs of energy and environmental issues related to pollutants emissions. Nowadays, energy efficiency and passive system are appraised for improving the environment. In this work will be conducted a comparative study on the energetic efficiency of various building typologies involving assessments on important factors like active building envelope technologies and the models of heat transfers via the thermal bridges. Throughout this research, a comparative analysis will be conducted not only on direct measurements using several forms of sensors in the selected buildings, but also several mathematical models for evaluating the heat transfer within a building, among which we inspect multidimensional analysis.

These evaluations will stress the importance of understanding the impact of passive systems applied in these house typologies that we are going to study. In this study, there are three post-communism residential buildings, built in recent decades using different construction technologies. These residential buildings will be a villa massively affected by the 2019 earthquake and reconstructed later, an old villa with an extension added in the recent years and a brand-new villa which is still under construction. The study will comprise these building typologies' energy efficiency in various seasons, thus estimating both heating and cooling energy efficiency.

Keywords: *energy efficiency, building typologies, efficiency assessments, heat transfer models, residential buildings, passive systems, HVAC application*

ABSTRAKT

VLERËSIME TË EFIÇIENCËS ENERGJITIKE TË DISA TIPOLOGJIVE TË NDRYSHME TË SHTËPIVE SHQIPTARE

Shiku, Jola

Master Shkencor, Departamenti i Arkitekturës

Udhëheqësi: Prof. Asoc. Dr. Sokol Dervishi

Kohët e fundit koncepti i efiçiencës energjitike në ndërtesa është një temë që nxit interes. Për shkak të disa faktorëve, përfshirë kostot e shtrenjta të energjisë dhe çështjet mjedisore në lidhje me emetimet e ndotësve është bërë e domosdoshme auditimi energjitik në projektimet e godinave të reja. Në ditët e sotme, efikasiteti i energjisë dhe sistemet pasive ndihmojnë bindëshëm në vlerësimin dhe përmirësimin e mjedisit. Në këtë studim do të analizohet efikasiteti energjetik në tipologji të ndryshme të ndërtesave që përfshijnë vlerësime të faktorëve të rëndësishëm si teknologjitë aktive të mbështjellësve të ndërtesave dhe modelet e transferimit të nxehtësisë përmes urave termike. Gjatë gjithë këtij hulumtimi, një analizë krahasuese do të kryhet jo vetëm në matjet e drejtpërdrejta duke përdorur disa forma të sensorëve në ndërtesat e zgjedhura, por edhe disa modele matematikore për vlerësimin e transferimit të nxehtësisë brenda një ndërtese, ndër të cilat inspektohet analiza shumëdimensionale.

Këto vlerësime do të theksojnë rëndësinë e të kuptuarit të ndikimit të sistemeve pasive të aplikuara në këto tipologji shtëpish që do të studiojmë. Në këtë studim, ka tre ndërtesa banimi post-komunizëm, të ndërtuara në dekadat e fundit duke përdorur teknologji të ndryshme ndërtimi. Këto ndërtesa banimi do të jenë një vilë e prekur masivisht nga tërmeti i vitit 2019 dhe e rindërtuar më vonë, një vilë e vjetër me një shtrirje të shtuar vitet e fundit dhe një vilë e re e cila është ende në ndërtim e sipër. Studimi do të përmbajë efikasitetin e energjisë së këtyre tipologjive të ndërtesave në sezone të ndryshme, duke vlerësuar kështu si efikasitetin e energjisë së ngrohjes ashtu edhe atë të ftohjes.

Fjalët kyçe: *Efikasiteti i energjisë, tipologjitë e ndërtesave, vlerësimet e efiçencës, modelet e transferimit të nxehtësisë, ndërtesat e banimit, sistemet pasive, aplikimi HVAC*

To my beloved family…

ACKNOWLEDGEMENTS

For constantly inspiring, motivating and supporting me, along with his continuous guidance, I would like to express my deep gratitude to my supervisor, Assoc. Prof. Dr. Sokol Dervishi, for supporting my whole experience in Architecture and especially my initial ideas on behalf of this research study. I consider myself greatly fortunate that I had the chance to work with professor Sokol, giving me the chance to benefit a lot from his experience, advice and intellectual freedom he afforded to me during the research period.

Acknowledgement and gratefulness also to all the Epoka University lecturers for their efforts throughout this intensive five-year journey. I want to extend my sincere thanks to my friends and project collaborators for being part of this memorable experience, especially my architect and special friend of me, Irena Lazi, for truly inspiring me and motivating in all the given projects, providing her contribution to the learning process and dedicated work throughout my journey in Architecture and not only.

In conclusion, I must thank my family. Their belief in my success was my primary motivation to continue with the hard work and complete my studies. I would like to endless thank my family for the opportunity they gave me to study architecture and helping me the entire years. If it wasn't for the hard work and sacrifices of my family they have always expressed, I wouldn't have had the possibility to continue my studies.

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CHAPTER 1

INTRODUCTION

This thesis was conceived as volition to contribute to a buzz concept in our modern world: energy efficiency. The road towards improvement goes through a careful analysis of the existing technologies trying to spot their shortcomings and providing insights in the search for new frontiers. Also, several simulation scenarios are conducted based on modern simulation software which assess the energy efficiency regarding to the construction, location and climatic parameters. Definitions and considerations regarding passive systems' techniques are thoroughly covered in this study too, indicating the importance of the energy efficiency in the environment. In order to preserve well-representation, the selected typologies involve a variety of residential buildings types, including a villa massively affected by the 2019 earthquake and reconstructed later, an old villa with an extension added in the recent years and a new villa which is still under construction. In this chapter, the background and motivation behind this research are described, its goals and objectives are highlighted, and finally, the general organization of this thesis is also outlined.

1.1 Motivation

In the current world, there is a growing concern about energy consumption in buildings and its consequent adverse effects on the environment (Perez-Lombard L, Ortiz J, Pout C. A review on buildings energy consumption information. Energy Build; 40:394–8 (2008)). Buildings are the dominant energy consumers in modern urban areas, but their consumption can be diminished mainly via efficiency improvements, which is an effective means to lower greenhouse gas emissions and slow down the depletion of nonrenewable energy resources.

However, the potential energy cost saving alone is hardly a sufficient incentive to invest in improvement measures unless thing energy soars. To reduce the extent of global warming to approximately two °C, world leaders have endorsed proposals in various agreements for developed economies to reduce their emissions drastically. For instance, the European Union has presented its goal to reduce greenhouse gas emissions by 80-95% by 2050 (EERE U.S. Department of Energy, 2010. Office of Energy Efficiency and Renewable Energy. Building America e Resources for Energy Efficient Homes,Washington, DC.). The European Commission believes that the critical approach to achieving these limitations will be increased energy efficiency, estimating that by 2050 built environment emissions could be 90% lower (Alshuwaikhat, H.M., Abubakar, I., 2008. An integrated approach to achieving campus sustainability: assessment of the current campus environmental management practices. J. Clean. Prod. 16 (16), 1777e1785.).

It is essential to understand how energy is distributed throughout a building and how building parameters contribute to energy consumption and demand to slow the energy demand growth and reduce the amount of energy used associated with buildings (Addis, B., Talbot, R., 2001. Sustainable construction procurement: a guide to delivering environmentally responsible projects. In: Paper Presented at the CIRIA C571. CIRIA, London.)

Energy consumption analysis of buildings is a difficult task because it requires considering detailed interactions among the building, HVAC system (a system standing for air conditioning, responsible for heating and cooling our houses, by including a variety of products), and surroundings (weather) and obtaining mathematical/physical models that are effective in characterizing each of those items. These are issues that the building professions worldwide have to address. The design of buildings that optimize energy consumption is a topic of great interest due to several factors, including the expensive costs of energy, environmental concerns and considerations on the inhabitants' health (Maroni, M., Siefert, B., and Lindvall, T., Indoor Air Quality. A Comprehensive Reference Book, Elsevier, Amsterdam, 1995, chaps. 32, 34, 37.)

According to recent statistics, the building sector is responsible for approximately 40% of worldwide energy consumption and 33% of the worldwide carbon emissions (which is a significant risk factor in global warming and climate changes). In recent decades the improvement of the thermal environment performance has been in focus not only in designing new buildings however also in the renovation projects. Furthermore, recent studies indicate that this trend is expected to persist in the forthcoming years related to the building regions' extensions and the energy demands.

1.1.1 The need for a better indoor environmental quality

All the conditions inside a building are known as indoor environmental quality, including conditions such as air quality, lighting, thermal conditions, ergonomics—and their effects on occupants or residents. Strategies used for a better indoor environmental quality can help protect resident's health, improve quality of life and air inside a building, and last but not least, can help reduce stress and potential injuries. Indoor air quality may relate to different building typologies from residential structures, institutional buildings, offices, commercial structures, as well it may be present even in vehicles of transport.

Aforesaid, the building sector is being raised day by day by affecting both outdoor and indoor environmental quality. Recent statistics made by The National Human Activity Pattern Survey (NHAPS) show that 87% of human time is spent indoors, both in residential and non-residential structures, causing different mental and physical difficulties. There is a distinction in non-residential structures because occupants have little or no control over the environments. In sequence, to avoid these obstacles as much as possible, project teams must balance the selection of strategies used to promote efficiency and conservation with that strategy that addresses the occupants' needs and promote well-being. Somehow it is inconceivable how determinants such as people smoking tobacco inside the building, building materials (paints, coatings, adhesives), cleaning materials, mold caused by moisture and even the occupants' respiration can cause indoor air contaminants. Considering the number of activities administered and how these structures are constructed and maintained, residential and non-residential frequently vary in indoor environmental quality. Two different modelling techniques estimate indoor environmental quality and energy consumption, known as physical modelling and data-driven black-box modelling. Physical modelling is based on the use of energy and mass balance integral–differential equations. Accurate models are obtained; with this approach, it is necessary to know the building's physical properties.

A constant increase is seen in energy use since adopting the Policy of Reforming and Opening, and energy conservation are of vital importance both economically and environmentally. There have been many studies and initiatives to improve the energy efficiency of residential buildings and non-domestic premises by introducing new building regulations with tighter requirements in the building envelope's thermal and energy performance and better operational efficiency of the building services installation. Computer building energy simulation is a good technique for assessing the dynamic interactions between the external climates, the building envelopes and the HVAC systems and has played an essential role in the designs and analyses of energy-efficient buildings and the development of performance-based building energy codes.

Furthermore, a significant concern is being raised around the world according to energy efficiency and energy consumption. During current times a great interest in building more efficiently is seen massively in the world of construction and architecture, and this is shown in many types of research that different scientists have done according to this fact. Energy efficiency means building wisely and economically. Different studies can quickly approve the incredible impact of energy-efficient buildings in saving our world by reducing c02 emissions. The GEA-Efficiency (global energy assessment) proclaims that using energy efficiency technologies in the building sector, a remarkable percentage decrease of global final heating and cooling energy use can be achieved in several years. At the global level, it is studied that efficient technology buildings can deliver a 30% cost-effective greenhouse gas emission reduction by 2020.

Heating and cooling technologies, passive systems, and energy efficiency in buildings play a crucial role in achieving energy efficiency potentials. Energy efficiency improvements in the building envelope can reduce indoor heating, including the optimization of the heating system. However, different barriers and factors affect the implementation of energy efficiency technologies in building, for example, imperfect information and lack of knowledge. Some other barriers are related to the development of these energy efficiency implementations, and some others are defined as market failure, i.e., flaws of market operation not allowing optimal allocation of goods and services, and often hindering cost-effective actions (Levine et al., 2007; Sutherland, 1991).

A meaningful percentage of energy use is mainly seen in the building, compared with residential and commercial sectors, including different usages of energy starting from the energy used for the buildings' climate and the energy used for appliances. The impact of several factors, such as geographical location, economic development, and cultural orientation, can change the actual amount of energy used in residential or non-residential buildings.

Finally, to achieve a more energy-efficient environment and build energy-efficient structures, it is widely proposed to use different passive systems. Various circumstances, such as countries and socio-economic factors, play a fundamental role in designing passive system structures. Passive systems are compositions designed to optimize the usage of natural sources such as heat, light, and cooling breezes. In order to achieve an excellent passive design structure, different techniques and principles are taken into consideration. The fundamental elements of passive design are building location and orientation on the site; building layout; window design; insulation (including window insulation); thermal mass; shading; and ventilation. Each of these elements should be integrated to achieve comfortable temperatures and good indoor air quality.

The concept of passive systems dates back to ancient history, and it has been practiced for years, and it has always remained a part of vernacular architecture in many countries. According to passive system application in different building structures, a massive improvement is seen during recent decades, raising interest in the building sector worldwide. Designers tend to build structures considering the thermal characteristics to moderate external environmental conditions and maintain internal conditions using minimal resources. A general technical revision of passive wall systems will be part of this thesis. Different types of energy-efficient walls will be theoretically explained in this thesis. Moreover, other new wall techniques and their potential to reduce the energy used are proposed. Experiments in different countries show how much energy consumption is used and recommendations to make every building reduce energy usage. Moreover, a comprehensive study will be presented following different wall typologies and techniques while discussing their respective potentials towards optimizing energy efficiency.

1.2 Thesis Objectives

Even though these types of energy efficiency methods are being used every day by architects and building engineers in different building typologies, there will be a specific chapter regarding their effects on a building´s thermal performance. Consequently, the primary research aims to analyze energy efficiency and sustainability on energy savings and how to make existing buildings, mainly residential typologies, more energy-efficient, combined with passive systems.

In this paper is presented the work and its findings and discusses the implications for building energy efficiency. In order to design an energy-efficient building carefully, special programs are known as building energy simulation programs may be utilized. These programs model and predict the behavior and energy consumption of buildings. Most of the current simulation programs are based on solving the equations governing heat transfer by considering only one-dimensional flow, while a higher dimensional analysis significantly increases equations' complexity.

Among the objectives of this thesis, a vital one is to test and compare several well-known heat transfer models on a few building samples and compare the energy efficiencies in these buildings' designs. Firstly, according to the structure factors method, several significant parameters which govern the building's thermal behavior, are carefully inspected. Some of the most significant parameters, include the overall capacity, resistance and the fractions of heat stored in-wall volume in transitions. These parameters depend on the wall's thermal structure (resistances, capacities and their arrangement). The outcome are more prominent when the thermal mass is positioned near the interior surface, are more significant when the thermal mass is positioned near the exterior surface and are more prominent when the thermal mass is positioned near the center of the wall.

1.3 Organization of thesis

After providing the general background, motivation and main objectives during the first introductory chapter, then this thesis will continue with the second chapter, where the literature review and the theoretical background are covered. In this chapter, various existing technologies and research activities conducted within the scope of energy efficiency optimizations are carefully inspected. Here a broad spectrum of approaches is explored, including regulatory and voluntary ones, accurate physical measurement and computer software simulations, even state-of-the-art data science models. Special attention will be paid to research works that have more influenced the current work.

In the third chapter, the theoretical models upon which our study is relying, will be formally described. Here both mathematical models and computer simulation models will be involved. To simplify the model's computational workload, as mentioned above, this study is relying on a programming library that will simultaneously facilitate the evaluation procedures and operate on the third phase carrying out the "trial and error" testing for the parameters.

The fourth chapter is provided with a detailed description of the involved external and internal parameters involved in our system. Furthermore, a complete summary of the applied measurements, their usage in the system's mathematical model, and the final efficiency evaluation are provided.

The fifth chapter will carefully cover an analysis of the obtained results, including comparing the results on various typologies and optimization guidelines for each of these typologies. The last chapter will resume the obtained results and conclude this work, including essential guidelines about the possible energy optimizations applied according to the various house typologies. Furthermore, possible extensions of this work for future researches will be explained too.

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL BACKGROUND

2.1 Energy efficient houses

For years housing industry, the construction and the development of residential houses have been accused of causing environmental issues regarding excessive energy consumption. Definition of housing typology may be described as the different physical characteristics of a structure, such as a shape, material used, location, cultural and social aspect. The majority of these house typologies around the world consist primarily of old non-energy efficient structures. Different experiments are made in foreign countries according to energy efficiency, demonstrating that in some places, the apartment building has a higher energy consumption than other typologies. It is worth mentioning that scientists and designers have worked hard these last three decades for new proposals according to energy efficiency in housing. However, the lack of knowledge for applying suitable materials and methods for reducing energy consumption has led to a problem by rising fossil fuel use.

As a result, building unconsciously may risk the environment seriously affecting the natural resources. In the before-mentioned cases, sustainable architecture is proposed, initially focusing on concerns such as limited sources, especially in energy, and how to reduce the impact on the natural environment. Achieving the most significant impression in socio-economical and the environment lies in a substantial design. For each building planned and designed in various locations, designers should consider the energy efficiency parameters. Living, and especially creating new structures in the third world, means that much more attention is paid to different factors from location, climate and most importantly, the economic sector.

2.1.1 Sustainable Architecture

Building wisely with materials that have a positive impact on the environment means sustainable architecture. Sustainable housing improvement integrates environmental policies and development strategies. The development of sustainable housing notes a society with a proper balance regarding economic factors, social and environmental ones. Environmental sustainability influences the housing industry to build more delicately by considering renewable energy, energy efficiency, water efficiency, ecology, conservation, material efficiency, air pollution, pollution control, indoor environmental quality, sustainable site and land utilization and management—social sustainability forces social dilemmas for safer, comforter and sustainable behaviors of each life.

The percentage of crime, social issues, poor health and lately the social distancing brings the necessity for a good education. Recently people are expressing the will for safety, comfort, satisfaction. To conclude, quality of life is what describes social sustainability. Observed from the economic point of view, the building industry must consider housing affordability, renovating and developing structures by adding sustainable systems.

2.1.2 Energy efficiency parameters

For saving energy in housing typologies, energy efficiency parameters are selected. These parameters are defined as helpful techniques that assisting in achieving sustainable housing construction. Contemporary architecture has been designed for energy efficiency by combining various sustainable elements (passive systems.) Incorporating these suitable elements in traditional architecture will improve the energy efficiency of a building. It is crucial to mention that the building sector should implement the selected methods in the exact form. Different authors have mentioned energy efficiency in the housing industry: Oktay (2002) only discussed insulation and housing orientation, Seyfang (2010) mentioned solar gain and the use of daylighting. Various green parameters have been introduced to achieve energy efficiency in sustainable housing developments and identified in previous studies (Cukovic and Ignjatovic, 2006; Maliene and Malys, 2009; Oktay, 2002; Seyfang 2010; Zhang et al., 2011; Zimmermann et al., 2005).

Overall, previous studies focused primarily on passive systems, solar homes, ventilation and insulation of lighting, cooling, and heating. These parameters, as listed above, are taken into consideration for a more energy-efficient structure. As (Tsai and Chang, 2012) stated in their research, it is agreeable that the design phase of a structure is the critical stage when implementing sustainable and passive systems into construction projects.

Achieving sustainable construction requires effort from all the designers and engineers involved in constructing and maintaining the structure. (Consultants, 2001) With proper planning and design approaches and considering all the above parameters, residential energy consumption can be reduced. As future architects and engineers, we are responsible for thinking eco-friendly while designing or planning a building.

Table 1 - Energy Efficiency Parameters

Design Base	Energy Efficiency Parameters	Key References
Architectural	Usage of energy efficiency sources Use of wooden logs is suggested by architects Attention is paid to building orientation Application of different passive systems	Zimmerman et al. 2005 Seyfang 2010 Ding 2008 Maliene and Malys, 2009

Mechanical	Application of different heating and cooling systems HVAC systems Pipes and tubes Efficient water heating systems	Oktay, 2002; Seyfang,
Electrical	Different lightning applications to save energy Efficient lightning Integrative use of natural lighting (day lighting) with electric lighting system	Monahan and Powell, 2010 Tenorio, 2007

2.1.3 General Characterizations of Residential Architectures

Residential architecture, known as domestic architecture, is about designing and building safe and functional structures. Residential houses must provide safety issues and functionality matters. Architects must work with their customers to develop homes that meet necessities and expectations, and each customer usually has a slightly different list of needs and requirements for a home. The concept of residential buildings can usually be described based on the context of use, the population they serve, ownership status, building types, construction characteristics, heating and cooling systems, site characteristics, occupants and occupant behavior, and exposure concerns.

Residential houses must provide shelter for everyone ranging in age from infants to the elderly—the rate of people consuming more time indoors ranges in various countries. Worth mentioning is also the homeownership status that each resident should pay attention to. The homeowner's responsibility is reflected in better building maintenance, reducing the potential for water damage and mold infestation problems.

According to residential building typologies, there are two main types classified as single-family and multi-family dwellings. Single-family structures are usually detached from other residential buildings, whilst multi-family structures are one single large building that provides many individual apartments. Single-family structures are site-built buildings; often, with lower-cost materials, these structures are usually more vulnerable to wind, weather-related damages and site-related damages. As a result, more attention is paid to planning and designing a multi-family dwelling. Compared with single-family structures, the multi-family structures are always site-built, and the building material used often reflects cost and engineering considerations.

As seen from the construction characteristics, it is worth mentioning that residential buildings styles vary from the size of the structure, design, building materials used, and the site condition. However, most of the residential structures share the exact construction requirements. They involve a substructure, sidewalls, flooring, windows, roofing, attic and crawlspace ventilation, plumbing, electrical wiring, attic and wall insulation (depending on the climate), roof and site drainage. Interior furnishings are also construction components of a building. These requirements reflect building practices that depend on the local environment, site components, design preferences, and availability of construction supplies. The most critical factor in residential building construction is the cost of all these materials and conditions.

Buildings rely on a substructure that supports the weight and anchors them to the ground. The common types of substructure are listed as slab-on-grade, crawlspace, and basement. Following the substructures is roofing, one of the main elements of a building. Roof construction protects the interior part of a building from climate changes. The importance of material used is also seen in roofing construction. In different countries, roof construction reflects resource availability and cultural preferences.

The roof must take away water without any shrinkage if significant internal structural damage and mold infestation occurs. In cold, wintry environments, the roof must be durable enough to carry the weight of heavy snow. In countries with severe snowstorms, roofs must be securely attached in order to avoid severe damage.

Exterior walls and walls are structural elements used to form the periphery of a building. Both exterior and interior walls are constructed based on the client's preferences. Typically, the material used in exterior walls is constructional elements providing further low-cost insulation, oriented-strand board sheeting in corners and around windows to provide more durability. Brick, stone and timber are also used in the construction of external walls.

Nowadays, modern buildings are being constructed to be more energy efficient. In many parts of the world and Europe, climate changes in the outdoor environment need that some heating and cooling appliances or systems have to be used to provide more acceptable thermal conditions than occur outside.

2.1.4 Historical Overview on Albanian Residential Architecture

Albanian's architecture was influenced by its position within the Mediterranean basin as a country classified by the rich cultural heritage. Different civilizations from Illyrians as well as Italians have lived in Albania, inheriting valuable architecture. During the 18th and 19th century, medieval Albanian municipalities experienced urban transformations by various Austro-Hungarian and Italian architects, providing them with the appearance of western European cities; this is mainly seen in Tirana and Korçë. Architects suggested some architectural techniques used in historicism, art nouveau, neo-renaissance and neoclassicism.

Through the Epoque of communism in Albania, the country's architecture evolution was thoroughly developed by the socialist ideology, and numerous ancient and sacred structures across Albania were destroyed. Large socialist-styled structures, spacious streets, roads and factories were constructed, while most of the main squares in important towns were redesigned.

The main factors for housing typologies transformations are socio-political and socio-economic changes, especially regarding Tirana city, where political influences are seen in most buildings. (Vokshi A.: Trace of Italian Architecture in Albania 1925-1943, (Tracce dell'Architettura Italiana in Albania 1925-1943), DNA Editrice, Firenze (2014).

This thesis will state the evolution of housing typology in Tirana during the Years 1929-1943. The main factors for housing typologies transformations are socio-political and socio-economic changes, especially regarding Tirana city, where political influences are seen in most buildings. A significant impact of foreign architects started when Tirana was the capital city of Albania. Austrian architects present in Tirana during 1927-1932 until when Italians arrived in Albania in 1939.

From 1939-1943 essential undertakings regarding architectural projects are made. This case study presents the data of dwelling typologies from Austrian architects in the period from 1929 to 1932 and then the housing typologies for Italian Official's from 1939 up to 1943. The study of housing evolution is accompanied by graphically explaining the types to detect each example's evolutionary characteristics between two periods. In this case study, the analysis is focused mainly on the ground floor of the housing structure. The houses shown in the study are completed with plans and facades to create a better idea of their existing situation. The procedure of methodology is based on observation and interpretation for each case. Nowadays, architects should pay attention to this period. For years and years, socialist architecture has produced a rigid, pure and primitive architectural typology. All the samples shown in this case study are planned to be developed in Tirana, which some of them are standard cases, so somehow, they could be used in different places and urban situation. Firstly, houses for officials were designed, placed all around the city of Tirana, followed by other private buildings. Housing typologies for the first period (1929-1932) are listed below. Designed by Austrian architect, Kholer, this house is a one-floor structure with two apartments in which each apartment has two rooms.

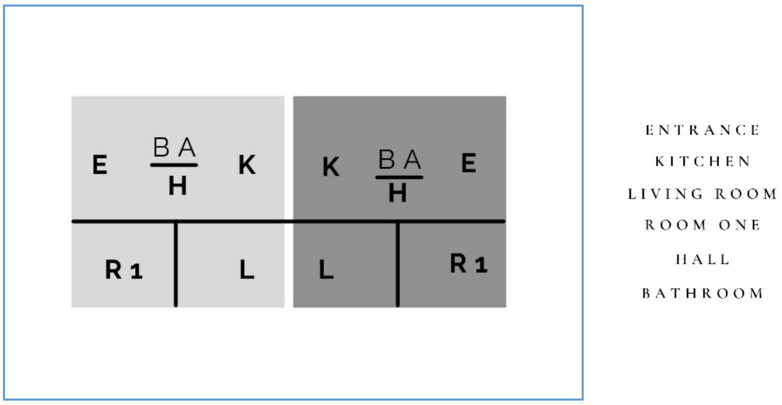


Figure 1. Apartment Layout

The example listed below shows a dwelling with three rooms conceived with a basement, two apartments for each floor, and it goes up to two floors. Both apartments are constructed with stairs connecting the basement vertically with the ground floor and the first floor.

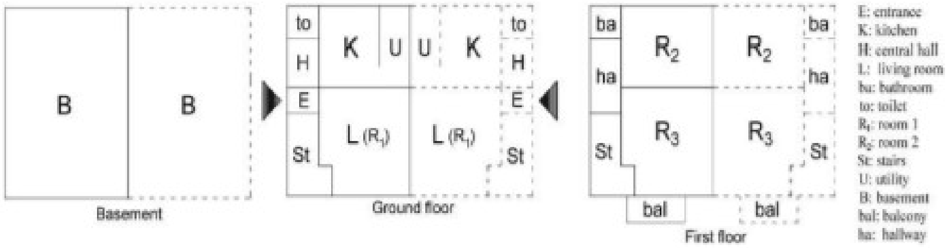


Figure 2. Apartment Layout

The other case shows the typical house with four rooms planned for a family, composed of two floors above and underground.

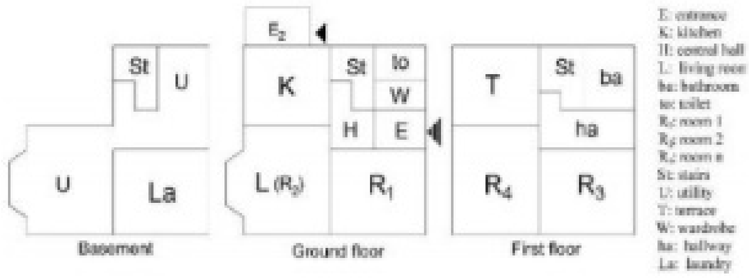


Figure 3. Apartment Layout

Worth mentioning is the importance that Italian architects gave to structures built in the period 1939-1943. Italian architects tried to develop the social and physical conditions of residents. The growth in the number of officials and inhabitants made architects plan many housing partitions inside an entire building.

To conclude, the evolution of housing typology between these periods is widely reflected in existing buildings. The illustrations show that the division of functionality inside a house is made based on the necessities of a habitant. With the increase of population, more enormous structures were made by combining shops and other facilities inside a building. The transformation process of plans described in the present research showed that the arrangement of rooms inside each apartment changes and the interaction between the apartments and shared spaces inside a building. The analysis of examples shown, explains that during 1929-1932, the structures were designed up to two floors and arrived at four floors in 1943. This evolution of a house is briefly exhibited in plans, facades and volumes.

Aforesaid, some appliances and methodologies can be applied in different building structures to better energy efficiency performance. As different surveys can prove, it is evident that noticeable progress is made in energy-efficient buildings in recent years, including sophisticated mathematical modelling of heat transfer processes and modern design of buildings optimizing energy consumption. Many designers and engineers have worked on diverse designs, proving the techniques used for heat transfer methodologies.

2.1.5 Elbasan Architecture

In this thesis, four housing typologies located in Elbasan, Albania, will be analyzed. Elbasan is a city whose location is in Albania and is classified as the fourth largest city. Different ethnicities have continuously occupied this city, and after the Ottoman occupation has remained as the center of Islam in Albania, reflecting it also in the city architecture. One of the famous neighborhoods representing this city is the " Kala" neighborhood, with a traditional architecture harmonized with ethnic features, symbolizing the way of life of this city. The architecture of Elbasan has always been characterized by low-rise buildings, one and two stores, with extensive gardens and greenery. Two are the main types of buildings developed mainly in this city. A typical element used in the housing typology is the dwellings built of stone walls and covered with roofs and kumie tiles. The other typology symbolizing the traditional architecture of Elbasan is the civic dwelling with a loggia. It is a two-story construction composed of the porch and veranda, located in the center of the composition. All the housing typologies positioned inside the castle and other parts of the city are composed of the ground floor made of stone walls, the second floor designed with a brick wall, accompanied by a roof. The second floor is treated with unique architectural components, such as vertical windows with wooden frames and a broad canopy.

2.2 Passive systems

2.2.1 Historical overview

The notion of passive system design dates back to the beginning of the settlement building. *Passive design* is a design concept that considers the environment's climate to maintain a comfortable temperature range inside the building. It is achieved by adequately planning the structure on its site and accurately designing the building envelope, including roof, walls, windows and floors of a home. Because we as architects may not obtain the ultimate passive design concept on every designed structure, applying the passive design approach to the fullest extent will reduce building energy use. As mentioned above, structure shape, orientation, and composition can enhance occupant comfort by providing acceptable site-specific energy forms and offering protection from undesirable forms of energy. We can significantly reduce building energy requirements by properly implementing passive design principles before concerning mechanical systems. Architecture and its application methods vary from one country to another, primarily by climate changes and location. Taken as an example, the architecture in southern America differs from other regions. The sun's motion in this country made it possible for the inhabitants to build their dwellings recessed within the opening of caves and under cliffs that would prevent the sunlight during the summer months but allow the winter sunlight to shine in. The building materials used also helped as a passive strategy to absorb the sun's heat through the day and slowly releasing that heat at night. In comparison to the other side of the world, Persian architectural techniques differ since the climate in these regions has a vast day-night temperature difference, varying from cold to very hot, making the air very dry all day long. For more durable indoor temperatures, an architectural tower known as a windcatcher is often used—a tall structure designed to reach cooler breezes that remain at higher levels above the main building. The method used in these structures efficiently cools down the residents by maintaining a constant circulation similar to our modern-day HVAC systems. However, this example of the historic passive design was accomplished well before energy-intensive active cooling, and venting systems became the status quo.

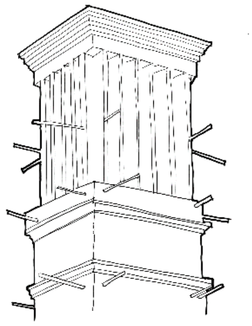


Figure 4. Windcatcher

Another example is the architectural techniques used in New England, in which early colonists had no other choice but to plan a residential structure that could maximize the winter sun and minimize the summer heat. In the early stages before electric baseboard heat and oil consumption, people used wood cords for heat and, more importantly, the careful placement of windows and overhangs to their homes. Known as the Saltbox, the windows were mainly oriented to the south to absorb the most sunlight during the cold New England winters. According to the north side of the building, the roof plane was extended to allow more insulation and fewer windows. Usually, the dwelling seemed as if it was only one story with a long steep roof to snow a natural slide down from the north side. There is the strategic placement of an overhang on the south elevation to prohibit summer sun, which is situated higher in the sky, and at a lower angle during winter.

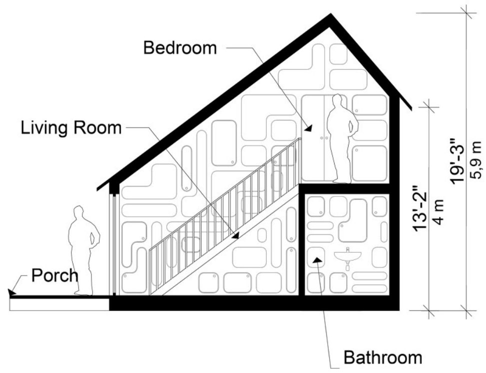


Figure 5. Saltbox House

Architecture worldwide varies from different factors, as factors as mentioned above such as climate, local materials, culture. For years and years, people designed buildings that confronted climate problems with passive design solutions. However, changes are seen mainly in the middle of the 20th century when man invented technology like air-conditioning and cheap energy; with the commercialization of these technologies, a fundamental transformation from climate responsive design to a lack of direct contact with variations in climate and weather is majorly seen. Architects and developers stopped looking at the cycles of the sun and other local climatic concerns. New modern heating and cooling systems became the norm for design standards. Architects and developers stopped looking at the cycles of the sun and other local climatic concerns. Designers can no longer afford to continue building due to all the global climate and energy cost changes without considering the local weather conditions. The passive design systems have worked in numerous past situations to reduce energy consumption in a building responding wisely with natural non-active systems.

When planning, designing or remodeling a new structure, it is necessary to know the country's climate. There is enough data available to understand how the local climate operates in any given region in recent times. Architects have consistently shown the urge to visit the site to acclimate to the unique climate concerns of their area. To better understand the climate at the site, some pieces of information are needed. ("Passive Solar Design - Location and Climatic Conditions." Passive Solar Design. N.p., n.d. Web. 20 Sept. 2015.)

1.The overall climate of the site (hot-dry, warm-humid, cold-windy).

2.The average high temperatures in the summer and average lows in the winter.

3.All the months of the year that the house must be air-conditioned/heated.

4. The latitude of the site.

5.The direction of wind blow.

2.2.2 Solar Geometry

Moreover, it is crucial to note other data for the design process like rainfall records, native plants, fruit, vegetables, trees and local insects like termites. There are plenty of good references for most of this information online; however, it should be noted to study local building codes properly. One of the strategies used in passive systems is solar geometry. The orientation of a building is eighty per cent of the passive solar design. The designer and the building itself must be meticulous regarding the sun. According to the slope of Earth's orbit, the sun's position in the sky moves during the year depending on the season. During the summer period, the sun remains in the sky the longest and thereby arises at the highest point of the sky. However, in the winter, the sun is present to a lesser extent, and it appears closer to the horizon.

Note: This applies to the Northern hemisphere of the Earth, and it is switched when referring to the Southern hemisphere.

Architects and planners have been using this technique to their advantage by planning structures that utilize southern fenestration and more extended overhangs. The south as orientation is essential in a building since the sun can be used to its absolute extent during winter when it is mainly required to heat the structure passively. The overhang is equally crucial because, during the summer, when heating is rarely needed, the overhang prevents the summer sun from accessing the building. Using these techniques in the south elevation of the building will make it possible for a maximum heat gain in the winter while providing shading through the summer months.

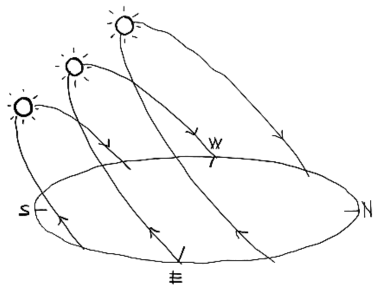


Figure 6. Solar Path

2.2.3 Passive Solar Systems

The methodology that collects, stores, and redistributes solar energy without using ventilators, pumps, or complex controllers of active systems, describe the passive solar system. This method is achieved by approximating structure design to understand the local climate, building geometry, and orientation regarding solar geometry. Orientation alone can change drastically the ability to produce an adequate amount of passively achieved energy in a building. (Lechner, Norbert. Heating, Cooling, Lighting. Sustainable Design Methods for Architects. 3rd ed. N.p.: John Wiley & Sons, n.d. Print.). Among the orientation, there are a few other additional components of passive solar design that should be integrated within the building when considering passive design approaches.

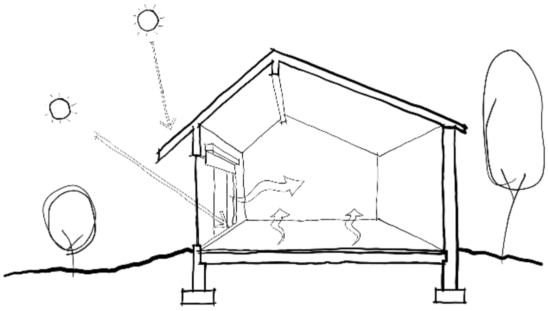


Figure 7. Passive solar system elements

Aperture: As known, fenestration and glazing play an essential role in passive solar design because it is how the heat will primarily access the building. The position of windows should be focused primarily on the south elevation of the given structure to allow the maximum exposure to the sun that is needed to passive heat the building.

An Absorber: The action when the heat entering within the aperture of a structure is stored and collected for future use. An absorber, also identified as a Trombe wall, operates better when located in the direct path of sunlight. Materials with high thermal mass like concrete, masonry, adobe, or, most effectively, water are used during this process. Materials with a high heat capacity work best as an absorber of heat. The usage of darker color paints on walls is another technique used for absorbing properties, while on the other hand, the usage of light colors is used for reflective properties. An absorber may include a concrete slab floor, an adobe brick common wall, or even a water storage tank. The structure must note the volume of thermal mass. If the volume of thermal mass is too big for the building, it can turn from an asset to liability by requiring more heat. Plenty of information, tables and formulas are available online to establish how much thermal mass needs to be exposed to utilize the passive solar effect best.

Heat Distribution: A time interval exists between the high thermal mass materials and losing their stored heat. This time interval is used by designers and architects to combine the indirect heat gain to be distributed during the night when it is differently needed. The process of releasing heat after the primary source of heat is known as the indirect gain, whilst direct gain is the act of consuming heat directly from the sun, like standing in front of a window. Indirect heat gain brings the need to continue heating a building at night, allowing for more balanced heat distribution. This passive process reduces the need to condition a building with active systems as aforementioned, and it saves energy by using the sun's free energy. ("Passive Solar: Indirect Systems."Usc.edu. N.p., n.d. Web. 20 Sept. 2015.)

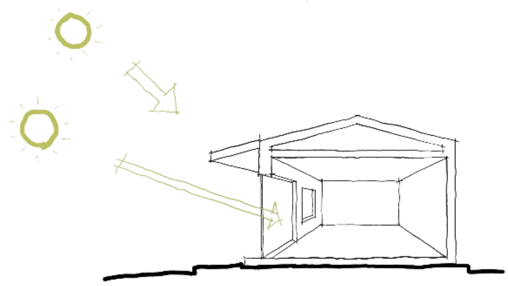


Figure 8. Direct Gain solar system

Control: Listed as one of the most important elements in passive systems in which also controlling is involved. It means applying all the above features only when necessitated and managing them when they are less desired.

2.2.4 Passive Control Methods

Fenestration: For better performance of the structure, glazing should be handled to be both good at gaining heat and daylight and efficient at insulating when sunlight is not needed. This can be achieved using thermal liners, awnings or overhangs, low-emissivity coatings, or high-performance double, triple pane windows. (Lechner, Norbert. Heating, Cooling, Lighting. Sustainable Design Methods for Architects. 3rd ed. N.p.: John Wiley & Sons, n.d. Print.)

Roof overhangs can be classified as a tremendous passive design strategy at blocking the summer sun's direct rays' overhead while providing the winter sun's direct rays. Balcony, a reflective mirror or a design aspect that shields the summer light from entering the building, can be classified as overhangs of a building.

Thermosyphon: A passively driven thermal control device that practices the motive forces of natural convection and conduction. One of the passive strategies that make possible the recycle and movement of warm air from a collector to storage (or room in a building) and back to the collector as colder air is known as the convective loop system. This process is achieved by using the thermodynamics of a convective loop system to move the warm air anywhere it is required and convert the air to the collector area. (Passive Thermosyphon System."Maartje. N.p., n.d. Web. 20 Sept. 2015.) The collector area is comparable to a Trombe wall, except that it is placed at a lower elevation than the main room being conditioned. This placement can be counted as a disadvantage depending on the site constrictions. This process has been classified as an active design strategy; however, its origins remain a passive system due to the nature of convective loops.

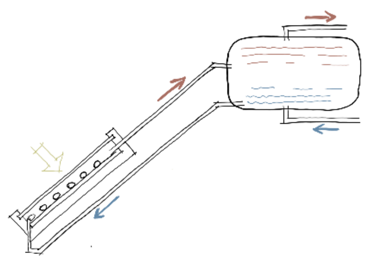


Figure 9. A convective loop system

The *landscaping technique* may also be classified as a passive system design. The usage of trees and plants as a passive design strategy is an excellent way to shade a space from sun or wind during the year. The methods for using trees can be great for shading during the summer. A significant role plays the type of tree that landscapers should take into consideration while choosing them. The better the tree's properties, the better are the results during different seasons of the year. These properties allow winter sun to enter through the tree while allow summer sun to be prevented in the summer is the most effective way to maximize the control on the solar gain in a building.

2.2.5 Natural Ventilation Strategies

Cross Ventilation: Cross ventilation method is achieved by having two openings on different sides of the building to provide for natural airflow. It is essential to consider the designer of the structure, which should pay very detailed attention to how the site's wind patterns are in order to maximize the effectiveness of this strategy.

Solar Chimneys: Another alternative methodology used in passively venting a building is a building science phenomenon known as the stack effect to the building's advantage. This method, known as the stack effect, uses temperature differences to move air. The "stack effect" is the movement of warm air upward in a structure. Warm air increases because it is lighter than cold air, and it is lower in pressure. An opening in the roof will provide the hot air to be released. However, various methods exist, including roof vents, gable vents, thermal chimneys, or thermosiphons. Wind can enter the structure by a lower aperture or by a windcatcher tower.

2.3 Passive heating systems of buildings

As declared, 6.7% of the global energy requirement is utilized for the thermal management of buildings. Using alternative sources, architects can determine that 35% of the whole building's energy demands can be satisfied. For the provided construction to be equipped entirely according to the energy requirements, various physical methods for better thermal comfort include solar radiation, long-wave radiation exchange, radiative cooling, and evaporative cooling. (Agrawal, P. C. 1989. A review of passive systems for natural heating and cooling of buildings. Solar Wind Technol. 6:557–567.) Worth mentions that passive solar design is a cost method used in architecture for achieving a natural harmony between the environment, buildings, and people.

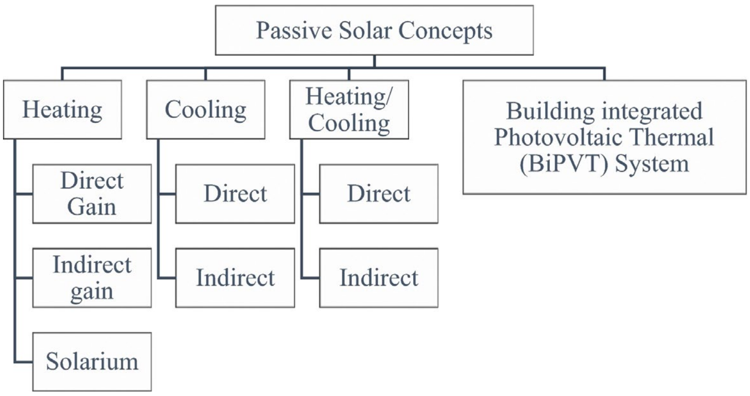


Figure 10. Classification of Passive systems

2.3.1 Passive solar heating concept

In passive solar building design, elements such as windows, walls, and floors are produced to collect, reflect, and share solar energy in the form of heat in the winter and refuse solar heat during the summertime. This whole process of exchanging different heat inside a structure during different seasons is called passive solar design because it does not involve mechanical and electrical appliances, unlike active solar heating systems. The answer to building a passive solar structure is to consider the local climate best and taking advantage of it by making a detailed analysis. An important role plays all the elements that have to be considered for a better passive design performance which include window placement size, glazing type, thermal insulation, thermal mass, and shading. A fundamental change is seen in new buildings with extensive usage of passive solar design techniques, whilst in the existing buildings is seen an adaption of these techniques. The essential fundamental concept in passively heating a home is the South-facing windows. Considering this way in which the sun shines more, it makes it possible for the sun rays to enter into all the windows and directly warming the air inside.

Factors such as shape, size, orientation, form, and layout of a building are highly related to the passive design strategies, and mostly, the impact of these factors is majorly perceived in the performance of the building's energy use. Elements such as massing, and design of the structures can create self-shading effects by improving ventilation and lighting.

In the article: Design of buildings shape and energetic consumption-Build—Environ., **Decker et al**. analyzed the ratio within shape coefficient and heating loads. In this study, it is proven that the heating load, which is the measured amount of heat energy needed to be added to a space to maintain the temperature in an acceptable range in cold climatic conditions, was in direct proportion to the shape coefficient considering that the solar gain within the glazing was low. (Depecker, P., C. Menezo, J. Virgone, and S. Lepers. 2001. Design of buildings shape and energetic consumption. Build. Environ. 36:627–635.) In this case, it is not suggested to apply opaque walls since these walls do not connect with either heating load or shape coefficient.

Another example is the study made by **Stevanović** which, investigated the heat flow over a structure envelope and coming to a conclusion that an optimized building form could lessen the heating load up to 12% per total volume of the structure. (Stevanović, S. 2013. Optimization of passive solar design strategies: a review. Renew. Sustain. Energy Rev. 25:177–196.)

In **Aldawoud's** case, there are observed different geometries of the atrium for energy-saving performance and concluding, Aldawoud states that the square-shaped atrium has the best performance. More to be added are the suggestions that more energy savings can be achieved in a low-rise structure with an atrium with more large glazing to roof ratio for temperate and cold climatic conditions. A high structure with low glazing to roof ratio is chosen for hot and dry climatic conditions. Different methodologies are being applied for reducing cooling and lighting loads combined with various façade types, glazing, orientations, shapes, and life cycle costs have been developed, especially an algorithm based on self-shading building envelopes being applied often nowadays. The square shape was found to give better results for all climate types. (Aldawoud, A. 2013. The influence of the atrium geometry on the building energy performance. Energy Build. 57:1–5.)

A high structure with low glazing to roof ratio is chosen for hot and dry climatic conditions. Different methodologies are being applied for reducing cooling and lighting loads combined with a variety of façade types, glazing, orientations, shapes, and life cycle costs have been developed, especially an algorithm based on self-shading building envelopes being often applied nowadays. The square shape is invented to give better results for all climate types. The whole research concludes that there is a corresponding reduction in the total annual amount in cold climatic stipulations and the same increases in warm climatic conditions with an expansion in the south-facing window.

2.3.2 Passive Heating Concepts

One of the primary critical aspects of passive heating design is the exact amount of sunlight that enters through the windows of the structure and manages that free heat released from the sun rays to keep the building at a comfortable temperature. This methodology is proper for any typology of a structure, in any place provided that has reasonable approach to sunlight. A superb passive heat design is defined by using a combination of various insulations and features that prevent overheating. Passive heat design is classified as one of the most environmentally friendly techniques for heating a structure by reducing the heating costs, including heating techniques such as gas and electricity and other harmful emissions. Sometimes for a better performance of passive heating in a building may cost. Often better insulation is usually more expensive than a standard passive heating design; however, the appliance of window frames with double glazing will pay for themselves over time since less energy will be needed to heat the structure, ending in cheaper power bills. Usually, when planning or designing a structure, architects should consider every detail before applying the passive heating systems since it may affect the fundamental aspect of the design of a structure.

When implementing a passive heating system in an existing structure, architects must find a way without making significant changes to the building. One way is by attaching extra insulation in the roofs, especially in the ceilings and under floors. Another way is using double glazing the windows, instead of those cheap and performing windows, which are mainly used in residential housing typologies. However, further utilization for passive heating techniques is required to satisfy all the local needs of the structure and the environment.

The concept of **insulation** is one of the fundamental principles of passive heating design. During different seasons of the year, it helps prevent the heat on hot days and maintain it during cold periods during the year. It is classified as one of the main techniques since it reduces condensation and dampness, and it can change the quality of a building fundamentally. A variety of legal requirements are needed to be filled before designing a passive heat structure. The same importance as insulation also plays the **glazing** concept in a new or existing structure. If the building is well insulated, using elements such as close-fitting, floor-length heavy drapes with pelmets will reduce the heat loss made through poorly performing glazed areas. The usage of elements such as timber, polyvinyl chloride (PVC) or thermally broken aluminum window frames will help with the reduction of heating problems. The design of more oversized windows on the northern side and smaller windows on the southern sides of the structure are widely suggested.

A good design for better performance is when there are no **draughts** in the entire structure. What causes droughts in the building is air passing from inside to outside and vice versa due to pressure variations produced by wind or warmer indoor temperatures. In contrast to the ventilation process, which architects can command, draughts usually create heat loss and uncomfortable breezes when architects do not want them. Gaps within frames and walls and between windows and doors can also make draughts during construction.

Another element that helps for an excellent passive system design is the **room layout** inside a building and its location. In order to prevent heat loss, it is widely suggested for the rooms such as garages, bathrooms or laundries to be oriented to the south, so in this case, it prevents heat loss in living areas. In external entrances of a structure, airlock usage is proposed to keep cold draughts out. The rooms as mentioned above can be applied as airlocks.

Architects typically suggest a simple **footprint** of a building. The fewer are in number the weak thermal points, the better for the roof. It is much easier for a multi-story structure to keep the inside space warm since it has less roof surface. The top story will also be warmer because heat rises through the house.

It is essential for the building to carefully combine all the elements so the environment can get a passive heating structure. For the architect, it is essential to study all the factors; by considering only one, the structure may risk avoiding all the suns warmth, and it may become uncomfortable for the residents. The installation of large windows on the north wall of the structure without thinking about how to store or conserve heat may be unsuitable for the structure to avoid hot temperatures during the day, and it may be freezing inside as soon as the temperatures drop. There exist a variety of passive heating concepts, which are divided and presented below.

2.3.3 Passive Heating- Direct Gain

In a direct gain situation, the sun rays are transmitted directly through the glazed window into the living room for thermal heating. The concept of direct gain makes it possible for the structure to absorb and collect heat all day through windows and releases the eat during the night for a more comfortable environment.

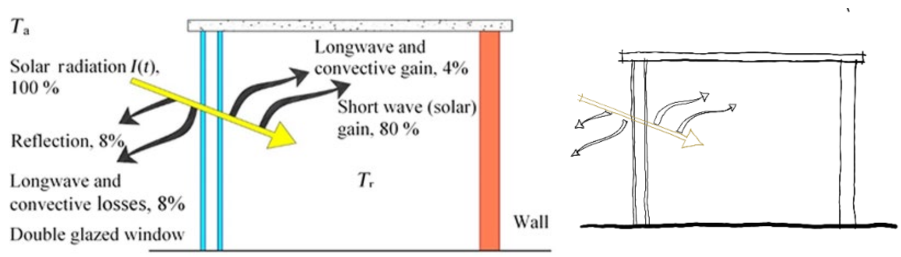


Figure 11. Direct Gain of Heat Transfer during sun hour

The rate of direct gain of heat transfer inside a room can be measured as follows,

$$\dot{Q} = \left(\frac{1}{U_t} + \frac{L}{K} + \frac{1}{h_i}\right)^{-1} (T_{sa} - T_r) = U_L(T_{sa} - T_r)$$

were,

$$T_{sa} = \frac{\tau I(t)}{U_t} + T_a \text{and} U_t = \left(\frac{1}{h_0} + \frac{1}{h_i}\right)^{-1}$$

(Agrawal, P. C. 1989. A review of passive systems for natural heating and cooling of buildings. Solar Wind Technol. 6:557–567.)

An example is given by the author Balcomb et al. (Balcomb, J. D., J. C. Hedstrom, and R. D. McFarland. 1977. Simulation analysis of passive solar -heated buildings- Preliminary results. Sol. Energy 19:277–282.) in who proposed a comparison between the single-glazed south-oriented system and a double-glazed system. A single glazed system without storage mass is relatively inefficient, whereas a double-glazed system along with night insulation and soundly storage mass heat capacity determines to be efficient in satisfying the heating necessities.

Based on different calculations, the percentage of annual solar heating for elements such as single-glazed system, double-glazed system, the single-glazed system with night insulations and double-glazed system with night insulation proves the fact that double-glazed systems with night insulation are as good as an active system tilted near the optimum angle. It is often suggested by architects and designers that double glazing should be applied in structures in order to avoid heat loss from room to outside air, and for windows, it is proposed to be covered by insulation at night to solve the corresponding problem.

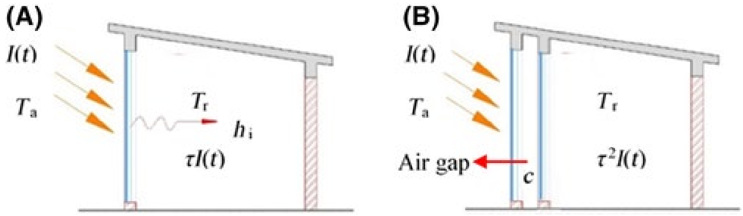


Figure 12. Figure A shows the single glazed window, Figure B shows the double-glazed window.

Even for the single glazing and double-glazing windows there exist equations that show the rate of useful energy for each case as following,

The ratio for single-glazed system,

$$\dot{q}_u = \tau I\,(t) - U_t(T_r - T_a),$$

where,

$$U_t = \left[\frac{1}{h_0} + \frac{L_g}{K_g} + \frac{1}{h_i}\right]^{-1} = \left[\frac{1}{5.8} + \frac{1}{2.8}\right]^{-1} = 1.88\,\text{W/m}^2, \left(\text{neglecting}\,\frac{L_g}{K_g}\right)$$

The ratio for double-glazing system,

$$\dot{q}_u = \tau^2 I\,(t) - U\,(T_r - T_a),$$

where,

$$U = \left[\frac{1}{h_0} + \frac{1}{c} + \frac{1}{h_i}\right]^{-1} = \left[\frac{1}{5.8} + \frac{1}{4.8} + \frac{1}{2.8}\right]^{-1} = 1.35\,\text{W/m}^2$$

Reduction of losses can be calculated as $\left[\frac{1.88 - 1.35}{1.88}\right] = 28\%$

2.3.4 Passive heating- Indirect gain

In reverse with direct gain, the concept of indirect gain allows the heat to enter the building through the glazing and is deposited in the thermal mass. As stated, before in this thesis, the concept of conduction and convection will also be presented, which in this case make possible the transfer of heat to the room. There exist three main elements that are responsible for the heat flow inside the room, and these elements can be classified as thickness, surface area, material, and thermal properties. (Liu, Y. W., and W. Feng. 2011. Integrating passive cooling and solar techniques into the existing building in South China. Adv. Mater. Res. 368–373:3717–3720.) One main property of thermal mass is its dark-colored texture that makes possible the absorption of solar radiation. Indirect gain is defined by concepts such as Trombe wall, water wall and trans-wall.

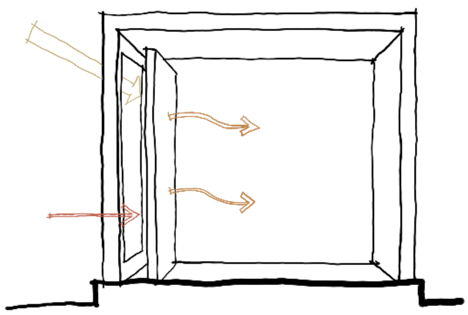


Figure 13. Indirect Gain of Heat Transfer

2.3.5 Trombe Wall

Trombe wall idea dates back to the 19th century, first developed by the engineer E. S. Morse, and recently it is presented as the Trombe wall, the name is taken by the engineer Felix Trombe. These walls are classified as huge concrete block, usually with a thickness of 40 cm. It is preferred by the architects to be exposed to daylight through large windows facing the south. All the sunlight and sunrays needed and absorbed on the surface of the thermal mass for heat during the day are transmitted inside the building through conduction and convection. When there is no sunlight, the wall may be insulated to prevent heat loss through the glass.

2.3.6 Solarium

Passive heat conduction is followed by the solarium concept, which is a combination of direct gain and thermal storage methods. The notion of solarium consists of three divisions: sunspace with a thick mass wall on the south side (for the

Northern hemisphere), linking space, and living space. The distance of the thermal wall connecting the living space and sunspace helps to maintain and distribute the heat by improving efficiency. The energy needed and collected by the sunspace windows is absorbed in the air for the living space. The direct gain principle may be defined by the sunspace systems works on the direct gain principle, in which the heat gained through glazing is utilized to keep the temperature needed suitable for the living space.

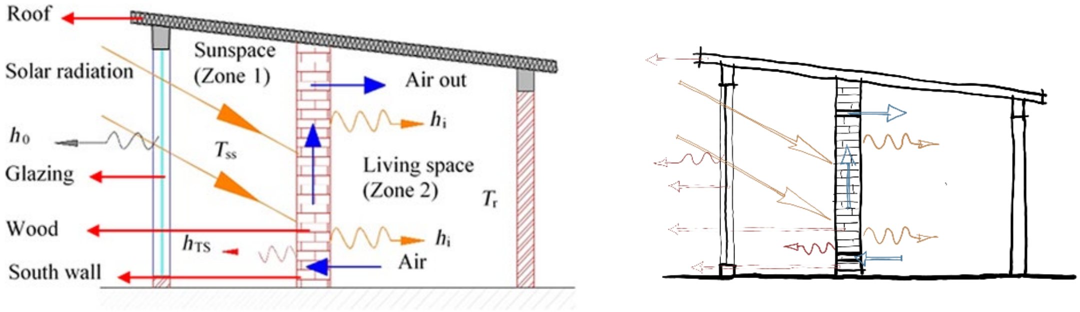


Figure 14. Cross Section view of solarium passive design

The figure above shows a thermal analysis of a solarium-cum-passive house presented by authors Tiwari and Kumar in which their study is based on the energy balance between different components, including link walls (like air collector, trans wall, water wall, metallic sheet), and on the best thermal load levelling. (Tiwari, G. N., and S. Kumar. 1991. Thermal evaluation of solarium-cum-passive solar house. Energy Convers. Manage. 32:303–310.)

The thermal load levelling can be measured by the followed equation.

$$\mathrm{TLL} = \frac{(T_{r,\max} - T_{r,\min})}{(T_{r,\max} + T_{r,\min})}$$

Figure 15. TLL Equation

2.3.7 Water wall

Due to various reasons, such as a fast rise in energy prices, it has inspired the designers, planners, and homeowners to build new energy-efficient structures to increase energy efficiency for heating and cooling systems in buildings. As said above, one of the most desirable and economical solutions for all the buildings and the environment is passive solar design, using all the needed building elements to accumulate and collect solar energy for heating.

Like the Trombe wall technique, the concept of Water wall systems can be classified as the technique seen more in a passive solar structure. As known, the type of thermal mass used and applied plays a crucial role in passive design systems. The same is with the water walls, here instead of thermal mass, water is used by providing the same mass at a lower cost than concrete. Several reasons show the importance of water walls applications.

Water walls provide a rapid and economical installation in a new building, being more efficient than masonry or bricks for heating and cooling, especially in places with cool climate during the night. The system of water walls works both for heating and cooling since these walls do not have a specific working temperature, making the walls more flexible in usage. By being smaller in size, water walls avoid the feeling of living in an entire masonry structure.

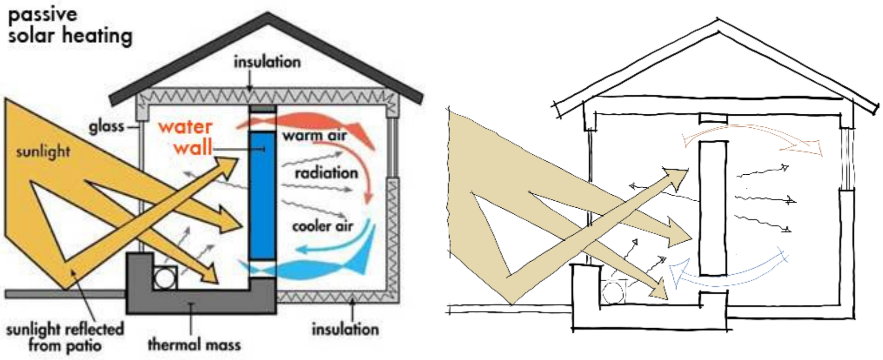


Figure 16. Water Wall Insulation

2.3.8 Trans-Wall

A thermal storage wall near the windows, which partly consumes and partly transfers solar energy, may be defined as the trans wall system. This type of wall provides an optical transmission through the windows comparable to that of tinted glazing. Regarding thermal performance, worth mentioning is that between trans wall and conventional thermal storage wall, more solar energy is received at the center of the wall, not at the front surface facing the windows. A small transmitted fraction can heat the room directly, but this fraction must be small enough to prevent the overheating and photodegradation of interior space and uncomfortable situations for the resident.

2.4 Passive Cooling Systems

In many countries worldwide, overheating has become a common summer problem for many structures, so the passive cooling system can improve the air inside the structure during summer, offering a comfortable environment for everyone without using any electronic devices. Passive cooling systems assist if architects and designers use shade or insulation technologies to prevent heat inside the structure, followed by various materials such as heat-storing or concrete, which assist in absorbing heat. Passive cooling should be considered while building new structures since it is free, easy and effective, especially when combining passive heating and passive cooling principles. For architects and designers, to achieve a better passive cooling system in an existing structure, extra insulation is suggested. Like in the passive heating system, even in passive cooling, windows play an essential role in providing protection, either through shading or by tinting. Elements such as tinting and low-emissivity coating need to be considered while designing a new structure. Before window application, the designer will present an overview of different colors and shading levels of window tinting. Every homeowner should count that tinting will still warm up the glass itself even though it keeps the sunlight out. Tinting may be a solution for passive cooling, but it will still allow the warmth to enter the building, and during cold winter days, it may be uncomfortable for the homeowner since it will reduce the sunlight. A good combination of tinting and external shading may be effective for the building to provide a suitable environment inside it.

The same as the tinting method works with low-emissivity coating, which usually is used to reduce heat loss within a window by being installed in a specific way to prevent the entrance of solar gains.

2.4.1 Wind Tower

In the passive cooling techniques, it is also seen the usage of the wind tower concept. As earlier mentioned in this thesis, a wind catcher or wind tower concept provides hot air to enter the wind tower during the day in which heat is transferred to the walls by producing an excellent downward draft. The heat needed is stored in the walls warming the cold night air. A wind tower is classified as a crucial element in the ancient world of architecture, used primarily in hot and dry climates. With an appearance similar to a chimney, wind towers are structures with vertical beams and apertures on the top, providing thermal comfort. Due to its details, a wind tower is an architectural element that proves the harmony of architectural design and the environment; this structure is ideally used in passive systems since they provide natural ventilation in different buildings. The structure of a wind tower is composed of several apertures on its top, allowing only one aperture facing away from the wind and drawing the air upwards. This opening allows the structure the cooling ventilation. As a structure composed of several elements, sometimes it is not enough to bring cooler temperatures within the interior spaces, so adopting the air gap provided by the qanat (a water system to supply water) allows the architects and designers to generate the cooling technique for suitable temperatures within the building. Since the qanat has enough water wholly and inside and shaded from the sun, it allows the structure to collect the cold inside. In a suitable climate, a wind tower performs as a solar or thermal chimney.

In different case studies and researchers, authors such as Saffari and Hosseinnia (Saffari, H., and S. Hosseinnia. 2009. Two-phase Euler-Lagrange CFD simulation of evaporative cooling in a Wind Tower. Energy Build. 41:991–1000.) suggested that the drop of indoor temperature and the increment of humidity will be achieved by using specific wet columns. Hughes et al. listed several cooling methods that are combined with wind towers. However, crucial parameters should be considered, including here the ventilation rate and the temperature. These elements define the utility of implementing the devices for their application. By adding cooling devices, it helps to defeat the airflow rates and the efficiency of the wind tower. (Hughes, B. R., J. K. Calautit, and S. A. Ghani. 2012. The development of commercial wind towers for natural ventilation: a review. Appl. Energy 92:606–627.) Two other authors, such as and Montazeri et al. and Chaudhry et al., studied a two-sided wind tower. This study, based on various calculations, stated that there is an increase in the exit temperature that uses traditional cooling without having an impact on the height in the proposed design. (Montazeri, H., F. Montazeri, R. Azizian, and S. Mostafavi. 2010. Two-sided wind catcher performance evaluation using experimental, numerical and analytical modeling. Renewable Energy 35:1424–1435.) (Chaudhry, H. N., J. K. Calautit, and B. R. Hughes. 2015. Computational analysis of a wind tower assisted passive cooling technology for the built environment. J. Build. Eng. 1:63–71.)

2.4.2 Evaporative Cooling

Represented by different definitions such as an evaporative air conditioner, swamp cooler, swamp box, desert cooler and wet air cooler, evaporative cooling signifies a device used for cooling the air cools the air within the evaporation of water. The methodology used for evaporative cooling varies from the air conditioning methods, which use the term absorption as the refrigeration cycle. The evaporative cooling technique utilizes the fact that water will consume a comparatively massive amount of heat to diffuse, which causes the temperature of dry air to be released significantly within the phase transition of liquid water to water vapor. This technique cools the air and uses a minimal amount of energy, especially in dry climates, where the evaporative cooling technique provides a conditioned air with more moisture to afford comfort for the inhabitants of the building. The Evaporative cooling technique is directly related to elements such as wet-bulb depression (the overall temperature measured by a thermometer wrapped in water-soaked cloth, on different levels of humidity, the wet-bulb temperature changes), the dry-bulb temperature (the overall temperature of air measured by a thermometer that is intentionally exposed to the air), and the difference between each-other. The results of evaporative cooling are seen in hot and dry climates where reduces energy consumption but also in cold climates offering an environment without increasing humidity.

A method used in the middle east is the combination of both techniques, evaporative cooling and the wind towers, in order to and directly the cool wind over water cisterns so that the entire building will have cooling and refreshing air. (Miyazaki, T., A. Akisawa, and T. Kashiwagi. 2006. The effects of solar chimneys on thermal load mitigation of office buildings under the Japanese climate. Renewable

Energy 31:987–1010.) It is suggested that evaporative cooling temperature should vary from 37 to 42°C, without considering the increased indoor air humidity. In this case, author Kamal proposed a passive downward evaporative cooling system composed of a two-elements, a tower with wetted cellulose pads installed at the top of the tower with a beverage inside temperature ranging between 29 and 30°C. (Kamal, M. A. 2012. An overview of passive cooling techniques in buildings: design concepts and architectural interventions. Acta Tech. Napocen. Civil Eng. Architect. 55:84–97.) Another part of the structure, the roof surface, has to be considered where the water is sprayed. Different calculations made in this type of roof, the wetted roof, showed that the temperature within the building is lower than outside. (Qingyuan, Z., and L. Yu. 2014. Potentials of passive cooling for passive design of residential buildings in China. Energy Procedia 57:1726–1732.)

2.4.3 Solar Shading

When architects think about passive cooling devices, shading is one element that should be considered while planning a structure. The shading must be designed following the sun's path of every location during all the year's seasons. As records show, the sun is placed higher in the sky during summer days, so the designer should provide a shading element that keeps the summer sun out of the building and allows it during winter. Observations and various applications allow the architect and the homeowner to track the sun's path for existing or new structures. If designed properly, the solar shading devices reduce the heat, providing a reduction in cooling costs and an aesthetical function for the exterior of the building. As in other cases stated before, author Kumar et al. noted a drop in the temperature of the inside environment during different periods and stated that solar shading is one of the passive cooling elements responsible for this temperature change. (Kumar, R., S. N. Garg, and S. C. Kaushik. 2005. Performance evaluation of multi-passive solar applications of a non-air-conditioned building. Int. J. Environ. Technol. Manage. 5:60–75.)

The diverse needs of the inhabitant bring the need for architects to design various shading techniques based on the site and the climate where the structure will be built. Based on these needs, there exist three types of shading techniques that are used mainly. These types are the shading that is used to protect the structure from the high-angle summer sun from the north part, the one when the building is protected from the low angle of the summer sun in the direction of east and west. and the last one, allowing the winter sun to enter from all directions. Overall the north side of the building needs another shading above glazing based on the circumstances. Based on their functions, shadings can be in the form of eaves, pergolas, fixed louvres covered balconies and plants. For better performance of eaves elements around a structure, they should be composed in that way to let as much light and sun as possible. The amount of glazing that will be used in the structure defines the quantity of the eaves that should be applied. The same importance also plays the planting element, which offers flexible shading options. Trees and other plants allow sunlight during all the seasons, whilst other plants provide low temperatures on the surface and ground. All the shading devices are classified as vertical, horizontal, egg-crate, and screening devices, divided into their own classifications. A horizontal shading device is suggested for south-oriented openings within a building, whilst vertical shadings are suggested for east- and west-facing facades.

Over the past few years, authors have been studying different cases regarding shading devices and their impact; for example, author Kima et al. (Kima, G., H. S. Lim, T. S. Lim, L. Schaefer, and J. T. Kim. 2012. Comparative advantage of an exterior shading device in thermal performance for residential buildings. Energy Build. 46:105–111.) has studied the impact of four shading types suitable for every structure. The results show that there is a high percentage of saved energy due to shading and its devices. Grynning et al., (Grynning, S., B. Time, and B. Matusiak. 2014. Solar shading control strategies in cold climates- Heating, cooling demand and daylight availability in office spaces. Sol. Energy 107:182–194.) based on a study data made in an office building, stated that these shading devices play an important role in reducing artificial cooling. Simulations concerning north- and south-oriented structures with various floor areas, openings, and shading schemes are made, and these simulations prove that the examples mentioned above of shading devices help reduce the transmittance value of the window. Due to the orientation, north-facing structures, in this case, offices, more energy is required. Immense importance also plays into the usage of these devices; if somehow the shading devices are inappropriately used, there is a high chance for the resident to increase the energy needs; so, these devices should not be applied to north-oriented spaces. With the application of the shading device correctly, energy demands can be reduced quickly. The comparison between four-pane glazing and two or three-pane glazing is that four-pane glazing is more beneficial than the other pane glazing’s. The methodology as mentioned above has existed since early times in history, where shading devices have always been a solution. Its usage is seen in Mughal architecture (India), where the shading devices are used in prone areas, followed by deep carvings on building surfaces. These carvings assist in creating common shading, and the extended surface helps increase the convective heat transfer. (Ali, A. 2013. Passive cooling and vernacularism in Mughal buildings in North India: a source of inspiration for sustainable development. Int. Trans. J. Eng. Manag. Appl. Sci. Technol. 4:15–27.)

2.4.4 Ventilation

Air movement helps to increase the rate of moisture evaporating by keeping the environment cool. Every inhabitant can control the air movement by adapting the building to prevailing winds. Usage of passive ventilation helps the air to circulate within the structure.

Elements that accomplish passive ventilation needs are doors, windows, opening skylights and clerestory windows, vents, louvres and other openings that let the air enter the structure. With the usage of these elements, it is easier for the structure to remove moisture, and it prevents cooling as well. Structure designs are based on the architect's proposals and as well the site and its climate. In sloppy terrains, with different floor levels, opening the windows for their respective floors helps to avoid the stack effect of warm air rising.

In every structure, there exist two typologies of airflows caused by the pressure difference pointing to natural airflow. The concept of infiltration happens due to the openings existing in every building, classified as interfaces, cracks, gaps. The minimization of infiltration can be achieved using airlocks, airtight and quality construction of doors and windows. In the study that Wang et al. have proposed, airtightness alone can seriously change the heating and cooling performance within a building. (Wang, Z., Y. Ding, G. Geng, and N. Zhu. 2014. Analysis of energy efficiency retrofit schemes for heating, ventilating and air-conditioning systems in existing office buildings based on the modified bin method. Energy Convers. Manage.

577:233–242.) As stated in the study, the infiltration of both hot and humid air headed to an increase of a high percentage in overall cooling load and latent load.

2.4.5 Hybrid ventilation

One of the terms used primarily on ventilation is hybrid ventilation—a scheme where the ventilation of a building is not entirely natural nor entirely mechanical. There exist different schemes designed by the architect to be useful for natural ventilation considering the most occupied hours, which can be served or expanded by mechanical systems under heating or cooling conditions. A wide variety of systems based on natural ventilation are covered by Hybrid ventilation. A strong relationship is seen in hybrid ventilation between the control strategy applied and the actual performance of the ventilation system regarding indoor climate, energy consumption and expenses.

An example showing the hybrid ventilation application is a two-story building located in Belgium, known as the Probe building is an office building composed of cellular offices for one or two persons. Its location is perfect regarding external air pollution and noises. Designed and constructed in 1977 by architects, a mechanical ventilation system supplies air to the offices in this building. This mechanical ventilation system maintains a satisfactory indoor air quality even if the windows are closed for some time. Large louvres are placed in the window frames to provide summer cooling, where these louvres can be left open. For summer cooling, there are large louvres in inactive hours. In addition, on the west and east orientation of the building, vertical external solar screens are applied, thus avoiding the solar gains through the window. A presence sensor is located in each office, controlling the mechanical supply of air inside any office, where these sensors are also integrated with a control damper. Applying two different controllers makes it possible for various situations to be used properly, so these units replace the traditional supply grille. Individual occupants in the offices control both elements, the louvre and the solar shading. Occupants are not necessarily requested any further action for the mechanical ventilation. Night ventilation used for cooling has some disadvantages. If the temperature is still warmer outside than inside and one of the louvres is opened, the building is heated during the first part of the night. If the temperatures during the night are cold, the interior space of the offices can be too cold following the following day. The functionality of the system may have problems if the instructions are not followed properly. Based on this case study, it is noticeable the importance of automatic control of the night; overheating is stated to be much lower in those cell offices where automatically controlled windows are applied.

Comparing different case studies states that hybrid ventilation control works perfectly in office buildings where the occupants of these offices have complete responsibility for controlling their climate during working hours. This type of controller can be manual or motorized and accessible by a panel or the users' PC. Through non-occupied hours, automatic control is necessitated to benefit from cooling the structure by using night ventilation. Automatic control also serves as a system needed to reset the ventilation system at the end of the working day by closing the windows and stop the fans automatically to save energy. However, it is more challenging to apply automatic control in open offices since it is challenging to find an acceptable strategy for controlling the windows. If the windows are operated automatically during occupied hours, and the external temperature is more a few degrees lower than the room temperature due to the sensation of draught. If the inlet air (A low specific cost methods in which the gas turbine power is increased during hot days is known as an Inlet air) is overheated, it is most beneficial to have separate control of the inlet temperature since that inlet temperature is necessary even when there is excess heat in the room. It is mostly suggested by the architects and designers to have two individual heaters. One used for room heating and the other heater for preheating the inlet airflow.

2.4.6 Passive Daylighting Systems

One of the most potent tools in architecture is natural light; with the same importance as sustainable design, the passive technique of natural light is perceived as one of the elements transforming the built environment's impact. With a huge variety of tools, from innovative materials to advanced computer modelling, the concept of natural daylight is easily applied in new structures. How passive daylight technique is applied in structures increases the quantity of natural light entering the building by reflecting it in darker areas. More than a technique, passive lightning is classified as a strategy since it does not want any specific energy source or mechanical equipment. As soon as the sun rises, the passive daylighting strategies accumulate and distribute the light through the entire building. Architects and designers use windows, transparent doors, skylights, light tubes, mirrors, light shelves and other reflective surfaces to store the light to crucial places of the entire room. For instance, if a lobby or a waiting area of commercial buildings is located in a corner with insufficient light, architects can afford light by using passive reflective elements. Using this type of system is beneficial for both sides, for the buildings and their owner. This type of system is beneficial both for building owners and for visitors.

Structures differ in every architectural aspect, so each designer tries to adapt passive lightning strategies based on the location and building characteristics. The primary purpose of daylighting is to collect enough light during summertime to avoid electrical machines and helps the building during winter to maintain the heat. However, there are a few design elements listed below that should be considered for more natural daylight.

Building orientation and light direction play an essential role in every structure. The light entering the south orientation is usually most desirable for daylighting as sunlight is constant during the day and year and is ideally used for solar heat gain. Following the south orientation, the next best orientation for sunlight is the north one. Architects highly suggest avoiding the light from east and west since the sunlight entering from these orientations is harsh and is available only for half of the day. Following these instructions, architects must arrange rooms that require lighter so that these rooms can face south and north orientation, while the other rooms that require less daylight must be faced to east and west orientation.

The *window* is another element that is essential while discussing passive daylight. Architects tend to use tall head high windows in order for the light to enter the structure as much as possible. In addition, horizontal ribbon windows and bilateral placement–windows are also helpful for passive daylight technique.

Skylights are openings from above the structure, allowing the light to enter quickly inside the structure. These openings are helpful when located at the center of the building, so the light that cannot enter from the windows can enter in this way.

Clerestories are another type of window which are always placed high above the eye level can light the entire room. The light entering through the clerestories and reflects off the roof help spreading very scattered light throughout the flat below.

External Shading Systems: Through certain intervals of the day, the light entering the structure varies due to the orientation, making the light too bright and producing an excessive brightness inside the building. In this case, the usage of external shading systems is brought into the interest of the architects. These devices help protect the windows and other building openings, and usually, a combination of horizontal and vertical elements is included in these systems, always depending on the building's orientation, geographic location, climate.

Solar tubes, light wall colors and parametric modelling are also used for passive daylight technique. Solar tubes make it possible for the light to flow from the roof through narrow openings. During the day, these solar tubes resemble ceiling lamps. For a more reflective space and a brighter room, the application of light wall colors helps a lot. However, in recent times, architects highly propose parametric software to produce optimized daylighting strategies. These software types analyze the building geometry and calculate the daylight entering the building for the entire year.

A combination of these strategies allows architects to maximize the natural light inside a structure. An example is the CSU Monterey Bay Joel and Dena Gambord Business and Information Technology Building, designed by HMC architects. In this structure, three different passive daylight strategies. First, the building highlights a central atrium connecting the interior and exterior spaces. Second, the atrium is encrusted with large skylights and clerestories to bring daylight inside the building—and installation of floor-to-ceiling windows on interior walls is made. Third, skylights allow the light to enter and reflect through the interior windows, providing light for the entire room. Finally, exterior windows are maximized for the north and south orientation, followed by an external shading system for the east and west orientation. Combining these three strategies allows the building to be bright and well ventilated, providing students with a lovely space by protecting the environment.

The usage of natural daylighting is good not only for the environment but also for the health and wellness of the residents. However, not only for other passive design systems but also for the daylight technique may be challenging for architects since some factors may complicate the design. For example, it is difficult for a multi-story apartment to maximize daylighting, and this happens since these structures are profound but not wide. It is easier for a well-experienced architect to adapt reflective surfaces inside the building, so more light is provided.

These techniques of passive daylight can also be applied to existing structures. For example, installing light shelves into an existing building is one way of passive daylight application; the addition of windows and storefront systems is another technique used by designers.

2.4.7 HVAC Systems

A system including the heating, ventilation and air conditioning known as (HVAC) system is one of the systems designed by architects to deliver the wanted environmental demands of the comfort of occupants. The usage of HVAC systems is widely seen in buildings such as industrial, commercial, residential and institutional buildings. A main purpose of the HVAC system is to provide the thermal comfort need of inhabitants by setting and changing the outdoor air conditions to the desired conditions each occupant needs. The process of HVAC systems is highly dependent on outdoor conditions. The air brought into the building is heated or cooled before it is divided into the occupied spaces, then it is drained to the ambient air or reused in the system. The selection criteria of these systems are based on the climate, location, the building's age, and the preferences that the building owner wants. Before applying these systems, the architect and the engineer should provide an outstanding performance regarding the budget and its architectural design. The most known HVAC systems being applied are the heating, cooling, and ventilation processes. As aforementioned, there are a variety of heating systems and ventilating systems. This process can be achieved using suitable HVAC equipment such as heating systems, air-conditioning systems, ventilation fans, and dehumidifiers.

Different elements and criteria make the engineer responsible for the application of HVAC systems in every building. These elements may be are arranged as climate change, building's characteristics including its spatial demands and other factors, spatial requirements, cost such as reliability and flexibility. For these systems, the selection criteria have some limitations that need to be settled. Some standards according to the building configuration, the space available and the heating and cooling building loads.

While applying the HVAC systems, there should be taken into consideration four main requirements. The HVAC systems need primary equipment, space requirement, air distribution, and piping.

The primary equipment involves heating equipment such as steam boilers and hot water boilers, allowing buildings to be heated enough, air delivery equipment working as packaged equipment to produce conditioned ventilation air for the structure's interior spaces, and cooling coils serving chillers or refrigerants. Space requirement is crucial for shaping an HVAC system. Different from primary equipment, the space requirement is followed by five facilities as listed.

Equipment rooms serve as spaces available for mechanical and electrical appliances, with a range of space between 4 and 9% of the entire building area. Architects prefer to locate these devices in the center of the building, reducing unnecessary elements such as long and large tubes, pipe, and cable runs. HVAC facilities for heating and refrigeration equipment require many elements to perform the fundamental duties of heating and cooling techniques. Boiler units, pumps, heat exchangers are some of the elements needed for the heating equipment, followed by the refrigeration equipment where elements such as water chillers, water pumps, control air compressor and other elements are necessitated. For these types of equipment to share the same space, the size, weight of each piece of equipment are needed, and all the other policies according to the installation and maintenance should be considered. Fan rooms, despite the HVAC fan equipment, also contain other necessary devices, bringing the need for enough space for placement. According to the needed airflow rate, location, and costs, fan size depends on the owner needs and requirements.

For each distribution, specific components are available. HVAC supply air, exhaust air and return air ductwork are used for air distribution, while different types of water are used for pipe distribution. For each of these types of equipment, an equipment room must be designed to provide enough area and other pieces of equipment during the installation, replacement, and maintenance.

2.4.8 Types of HVAC systems

Single or Multi-Stage

For colder winter climates, followed by hot and humid areas, single-stage heating and cooling are mainly suggested since they provide great comfort for the coldest or warmest days of the year. However, this also means that the amount of time and energy these systems operate brings the need for a multi-stage system by saving more money and energy at the same time. Mainly the single-stage system is proposed to be combined with variable fan speeds to create a variable airflow.

Zoned Systems

When applying Zoned HVAC systems, the occupant of the structure can heat or cool individual areas of the structure by managing zone valves or zone dampers inside the vents or ductwork, which selectively block airflow. Architects always suggest the zoned systems since a significant amount of energy and money is saved only by heating or cooling certain areas when needed.

Humidity Control

Humidifiers and dehumidifiers can be added as options for heating and cooling systems for arid and humid climates. By adding these systems to the structure, the inhabitant can automatically control the humidity levels in a home. The occupant cannot control the humidity levels when the system is not on. Sometimes is better if the humidity/dehumidification systems are separated.

Heating Systems

Based on different studies according to energy, modern conventional heating systems can obtain efficiencies as high as possible, converting nearly all the fuel to proper heat for the structure. These heating units applied in the structure can be classified into furnaces that provide heated air through ductwork. These furnaces usually function by using natural gas or fuel, compared with boilers in which they use gas or oil. Accompanied by the furnaces is the technique of radiant floors or hydronic heating systems, in which piping under a floor is regularly used. The flexible tubes used are supplied with water or a glycol solution to heat a concrete or other floor. These systems are usable even on a wooden floor, though these systems are much more effective if applied to a concrete floor.

Cooling Systems

Nowadays, there exist several different sizes and types of Air conditioning systems based on client needs. Location of the structure plays an essential role while choosing these systems. For specific orientations, different systems are suggested. For example, recent statistics show that the best air conditioners use less energy for producing the same amount the old air conditioners used. Seasonal Energy Efficiency Rating (SEER) is one of the most known energy efficiency ratings in which SEER 13 is the minimum efficiency every habitant should consider. In some cases, the air systems have SEERs of 16. Energy efficiency rating is another indicator that denotes and suggest what type of cooling system and how well the system will work in hot and dry climates. The main essential parts in the Air conditioners are three pieces in which a compressor, a condenser, and an evaporator are included. Elements such as compressor and the condenser are located outside the air conditioner, while the evaporator is located inside. Consequently, most central air conditioning systems in residences are split systems. In some areas where the climate is hot but non-humid, the usage of evaporative coolers is seen, also named as swamp coolers that provide cool outdoor air by passing it over water-saturated pads, causing the water to evaporate. In addition, room air conditioners implemented into windows or installed in walls are good options for cooling selected spaces. Finding or installing the proper sizing is essential for efficient air conditioning. A bigger unit does not necessarily mean that it is better because a unit that is too large will not cool an area uniformly. Elements to be considered while selecting an air conditioner are room height, local climate, shading, window size.

Deep Energy Retrofit: HVAC Overhaul

Following the techniques mentioned above are also the modulating aqua stats used for hot water boilers. These boilers help reduce the hot water temperature related to the outside temperature by saving 10 per cent in fuel costs. Replacing an old, inefficient burner on an oil boiler helps to reduce unwanted costs and to save the environment. It is always suggested to consult with a local heating contractor in order to avoid undesired problems.

2.4.9 Heat Pump Options and Uses

The heat pump is another method utilized for a more efficient structure. Heat pumps do not work for heating but are moreover utilized for warming and air conditioning. These types of pumps operate as a piece of hardware by utilizing a refrigerant to move warm from one put to another; furthermore, it achieves warmth from the interior of a structure among the summer days exchanging it to the exterior, whereas in winter, the warm is picked up from open-air discuss, compressed, and discharged in the interior of the structure. Due to its work, heat pumps perform up to four times the vitality devoured in power. Indeed for the heat pumps, the region climate plays a crucial part, and since the heat pumps utilize no combustion, there are no indoor poisons like carbon monoxide. The foremost well-known sorts of heat pumps are the air-to-air heat pump and the air-source warm pump. These heat pumps are generally introduced on the interior of a wall and are primarily utilized in average climates. In any case, within the final few a long time, these air-source warm pumps have more progressed by making the coils bigger. There are mini-split frameworks in which a portion of the heat pump is put exterior and a portion interior, accommodating for retrofit establishments. Planners and originators prompt considering the length of the tubing, how distant the runs are and where the lines need to be protected. Solar-powered mini-splits are proposed in man southern climates, where the discuss conditioning is required the foremost amid sunny days. Each tenant can include a warm pump to an existing heater for periods with an average climate. During this period, it is more prudent to run a heat pump instead of utilizing gas. Another sort of heat pump, as a rule, utilized in vast regions of a structure is a heat retention pump that employments ammonia-based water assimilation or lithium bromide. These sorts of heat pumps are pumps driven not by power but by a warm source.

On the off chance that these pumps are well introduced, they can work concerning other HVAC systems. Using two-speed compressors permits heat pumps to work near to the warming or cooling capacity required at any specific minute, sparing a considerable sum of vitality. The engines utilized, the variable-speed and dual-speed engines, give the discussion to move into a comfortable speed by maximizing the electrical reserve funds. Another strategy utilized is the application of desuperheaters, in which it is recouped the squandered warm and change over to warm water. These frameworks are exceedingly prescribed by planners these past few long times. Scroll compressors utilized in Warm pumps offer assistance to decrease the refrigerant by constraining it into progressively littler zones. As a result, scroll compressors are calmer and have a longer working life than regular cylinder compressors.

2.5 Remarks on Passive Heating and Cooling Concepts

In the following chapter, it will be discussed for the passive techniques that are used both in heating and cooling systems. Some of these concepts have been explained below. As explained before, the concept of the Trombe wall represents a large mass, with specific thickness composed of different materials, exposed to daylight through south-facing exterior glazing of the structure. The thickness in walls makes it possible for the absorbed solar energy to be transferred to the interiors by conduction and convection. Trombe wall reduces the heat flux from the exposed outer surface wall to the interiors of the building. In the passive heating technique, the thermal resistance of glazing used proves to be more beneficial because glazing decreases the heat loss within itself. One example that use this technique is one solar house n constructed in Jordan during 1983–1984, divided into two sections: the heated and non-heated areas. In this case study, the author Ta'ani et al. (Ta'ani, R., H. El-Mulki, and S. Batarseh. 1986. Jordan solar house-second testing year. Solar Wind Technol., 3:315–318.) proclaimed a high percentage of the building's heating demands of solar energy with collector array efficiency with proper retrofitting. Some units, known as phase change materials, require less space and are lighter in weight, proposed by authors Tyagi and Buddhi (Tyagi, V. V., and D. Buddhi. 2007. PCM thermal storage in buildings: a state of art. Renew. Sustain. Energy Rev. 11:1146–1166.) to improve passive heat storage in the masonry wall. By improving the coating exteriors of a thermal mass with superior absorption strength of a Trombe wall, the heat transfer and heat storage will provide a better performance, stated author Nwachukwu et al (Nwachukwu, N. P., and

W. I. Okonkwo. 2008. Effect of an absorptive coating on solar energy storage in a Trombe wall system. Energy Build. 40:371–374.)

Balcomb and McFarland et al (Balcomb, J., and R. McFarland. 1978. Simple empirical method for estimating the performance of a passive solar heated building of the thermal storage wall type. 2nd National Solar Conference, ISES, USA.) stated that more efficiency resulted in the Trombe walls combined with vented openings, mainly when these walls are used in a location with extreme climatic conditions whilst Saadian et al. (Saadatian, O., K. Sopian, C. H. Lim, N. Asim, and M. Y. Sulaiman. 2012. Trombe walls: a review of oppurtunities and challenges in research and development. Renew. Sustain. Energy Rev. 16:6340–6351.) examined various Trombe walls, including classical and modified, zigzag, composite, fluidized, solar water wall, solar trans wall, solar hybrid wall, and Trombe wall with PCM and PV-Trombe wall.

The usage of a fan will improve the efficiency of the Trombe wall with a low percentage. The insulation applied to a Trombe wall will increase the efficiency and decrease the size of the thermal wall. The study made by author Bojić et al. (Bojić, M., K. Johannes, and F. Kuznik. 2014. Optimizing energy and environmental performance of passive Trombe wall. Energy Build. 70:279–286.) discusses both the terms of energy and environmental performance, and both of these concepts have been compared with and without the Trombe wall. In the first case is studied, the structure without Trombe walls, whilst in the other case, has discussed the structure of the Mozart house located in Lyon, France, in which two of these walls are applied at the south side of this house. A 450mm clay bricklayer has been applied as the Trombe core material in the first case study. In the second case, solar energy usage is seen in which a high percentage of annual energy is saved compared to the first case. Studies prove that these savings can be further increased with a specific period if the Trombe walls and their thickness are used appropriately. It is highly suggested a thickness around 25 cm and 35 cm.

In the passive cooling technique, the concept of the Trombe wall is treated as a thick thermal mass applied in the exterior facade in which the decrement factor is reduced. Due to its function as heat storage, the thermal mass is mainly preferred to be applied in a heavy structure. Various materials are used for the construction of unglazed Trombe walls, and it is classified as an antique method and is visible in historical buildings like Humayun's Tomb, Qutub complex, Fatehpur Sikri.

One of the systems acceptable for heating and cooling technique, as author Shen et al. , suggests is installing adaptable dampers at the glazing and adjustable vents at the wall. About its functionality, architects explain briefly how this system functions during winter times. In the winter season, it is highly recommended that the closure of the upper damper should be utilized when the lower damper and both vents are open. Whilst in the summertime, the lower damper is closed. The usage of composite walls improves the energetic performance compared to the classic wall in places with climate changes.

For the application of these walls, a case study is analyzed by author Krüger et al., in which the performance of Trombe walls is highly improved by installing two test cells with a specific floor area and internal volume. In one of these spaces, both of the methodologies are applied, the natural ventilated Trombe wall and the other one where the specific test cells are not implemented. More crucial performance was seen in the case where these test cells are applied under cold conditions. According to the passive heating technique, these Trombe walls operate with different air vents closed with dampers installed in the storage wall openings. These air vents are classified into three categories, air vents 1 and 3 closed (case 1), air vent 3 closed (case 2), and air vents 1 and 3 closed with dampers installed in the storage wall openings (case 3). In different cases where these air vents are applied based on different climate changes and site location prove their importance that should be considered when designing a structure, for example, case number two is more applicable during winter, whilst case number three is more efficient during summertime.

As stated in previous studies, in single-story structures, more than 50 per cent of heat during summertime is obtained via the roof. As one of the main elements of a building, the roof provides a covering for the entire structure. A variety of solutions are used to reduce the heat flux collected by the roof, and these elements are false ceilings, insulations, and increasing the roof thickness, roof shading, or roof coatings. (Nahar, N. M., P. Sharma, and M. M. Purohit. 1999. Studies on solar passive cooling techniques for arid areas. Energy Convers. Manage. 40:89–95.) The technique of roof pond dates back to the 1920s in Texas, and later on, was developed further in its application. Sutton stated that the roof surface temperature might be very high if the roof is designed without any treatment, and if the same structure is designed carefully, installing an open roof pond a drop of temperatures is seen. (Sutton, G. E. 1950.

American social heating ventilation engineers guide. p. 131.) A survey is done by authors Kharrufa and Adil 76 in which, in a certain room with certain dimensions is tested the effectiveness of the roof pond. (Kharrufa, S. N., and Y. Adil. 2008. Roof pond cooling in buildings in hot arid climates. Build. Environ. 43:82–89.)

Nowadays, it is easier for architects to apply different passive heating and cooling strategies since many methodologies are available for reducing energy by combining these strategies altogether or using them individually. However, predominantly in new structures being built daily is highly suggested using passive techniques for better performance.

To achieve a high level of energy performance, a combination of different passive solar techniques is necessary. However, based on the before mentioned concepts, it is easily recognizable that using an unglazed Trombe wall can be used in both techniques, and the combination of this Trombe wall with other thermal insulations demonstrates to be very efficient.

To conclude, different concepts of passive systems are used in specific conditions; for example, direct gain in passive heating technique is suitable for commercial buildings, rather than the other concepts used chiefly in residential buildings. For passive cooling applications, the usage of wind towers and the concept of evaporative cooling is proposed, in which the technique of evaporative cooling is the most efficient. In both of the passive heating and cooling concepts, a combination of various elements can obtain a high percentage of savings during winter and summer.

2.5.1 Further case studies related to passive design

One of the further case studies represented in this work is **The Giordano – Smeltz Residence**, a 1,500 square feet home in Greenfield, MA. This house is classified as a net-zero structure, representing the building style originating in the Northeast parts of the United States as a passive design strategy adjustable to the local cold climate. This house combines and produces all the energy requirements by guaranteeing heat retention, high-efficiency HVAC, solar PV panels, and implementing vernacular architecture by designing it as a passive solar saltbox building. The structure is mainly composed of glass, especially in the southern orientation. Due to the passive elements applied, the house remains 100% solar-heated during sunny winter days. The passive design allows the home to be 100% solar-heated on sunny winter days; regarding the west orientation, a large tree is placed, reducing the cooling load required during summer days. A specified foam board is used; usually, in passive houses, the concrete slab is left only with the finish layer, sometimes stained or polished. This happens if there is any other layer added above the floor. As mentioned above, the slab is covered with a thin layer of salvaged granite counter-top scraps. Architects widely suggest the usage of granite due to its high thermal mass, which allows maximum solar heat gain. Some rooms, including the mudroom, root cellar, mechanical closet, stairs, closet, and laundry, are placed on the structure's north side. The north elevation is designed with a light-colored roof for reducing cooling loads, and one triple glazed window is included for daylighting in the stairs, while the air source heat pump is proposed by the architect to be located in the southwest corner of the building. All the passive design strategies used in this building ensure and prove to be a net-zero structure in which no heating is required during all winter. ("Giordano Smeltz Case Study." NESEA.org. N.p., n.d. Web.) ("Home Statistics Case Study." Design Construction of Spartan Hannahs Home. N.p., 05 Apr. 2013. Web. 20Sept. 2015.)

Case study number two is the ***factor 10 House located in Chicago***. This two-story house brought interest for architects due to the implementation of a variety of sustainable elements. Unfortunately, though, regarding the site location and its size limitations, the architects cannot maximize the southern exposure of the house for heating in the winter. So, other passive design strategies needed for reducing energy are used in this structure. Natural ventilation is applied for cooling during summer. A solar chimney is placed, pulling warm air up and out of the house during summer, while during winter, the chimney pushes air down. A south-facing clerestory window is placed at the top of the shaft, which can be opened when needed for ventilation. The window is located on the roof of the structure, which reaches above the neighboring structures. The south-facing clerestory window is on the roof of the building, which allows it to reach above the neighboring structures, providing daylight into the house. As stated in different studies daylighting has continuously increased the happiness and the health of the inhabitants, increasing their productivity, especially in office spaces. The window placement is designed based on the architect's needs to maximize the mirrored light into the house. Considered as an intelligent passive design technique daylighting helps to raise healthier environments by reducing excessive energy. As mentioned above, in the given building, a solar chimney is installed for collecting heat. Another technique that acts like a heat sink or a Trombe wall is added to the structure. These techniques help the environment and especially the building itself for maintaining proper indoor temperatures.

("Factor 10 House Case Study." Building Green Umass Database. N.p., n.d. Web. 20 Sept. 2015)

Table 2 - Various passive heating concepts (for thermal heating)

Concepts	**Results**	**References**	**Climatic Conditions**	**Applications**	**Remarks**
Direct Gain	For double Glazed window 80 % solar gain The usage of Double gazed Windows heads To a high % of heat reduction compared to single glazed system	Tiwari, G. N., and S. Kumar. 1991. Thermal evaluation of solarium-cum-passive solar house.	Cold Climates	Office-Commercial buildings	Daylighting
Indirect Gain	Reduction in heating load	Liu, Y. W., and W. Feng. 2011.	Continental -Tropical Climate	Residential housing	No daylighting
Solarium	A combination of direct gain and thermal	Tiwari, G. N., and S. Kumar. 1991.	If well designed it can be used even in cold climates	Residential Typology	Daylight

	storage methods				
Water Wall	Instead of thermal mass water is used	Tiwari, G. N., and S. Kumar. 1991.	Hot climate	Glass construction for sun space and wood construction for interior space	During daytime
Trans-wall	A thermal storage wall near the windows, which partly consumes and partly transfers solar energy, may be defined as the trans wall system	Tiwari, G. N., and S. Kumar. 1991.	Hot climate	Offices Glass construction	During daytime
Solarium combined with motorized shading devices	**A high percentag e reduction in heating demands**	**Bastien, D., and A. K. Athienitis. 2012.**	**Humid continental climate**	**Solar houses**	**Combinatio n of exterior and interior motorized shading**

2.5 Heat Transfer

Generally, heat transfer represents a thermal exchange between different systems, mostly from hotter to cooler systems. Heat transfer in buildings plays an essential role according to the building fabric or the design of passive systems applied in the existing or new structures for a more efficient building. The energy consumed inside a building is based on numerous circumstances, geographic location, house size, construction type, and equipment and fuels.

This part of the chapter will be shown a brief explanation of heat transfer methodology and its function by analyzing different existing experiments. Shortly the mechanisms of heat transfer can be described as conduction, convection and radiation.

The *conduction* mechanism is essential in buildings since it is the diffusion of heat energy within a solid structure from molecule to molecule. Different building materials conduct different energy. Materials conducting less energy can serve as insulators when they are placed between more conductive materials. What makes good insulation in conduction are the air pockets left intentionally by designers; in this way, air pockets disrupt the conductive heat flow through a material.

Convection is another method applied in heat transfer. An essential mechanism in the design of structures, convection makes possible the movement of fluids; in this case, this fluid is air. Air movement in the convection mechanism is classified as 'forced' or 'natural' occurring from pressure differences from one segment of a building to another.

Radiation is the flow of heat via space as electromagnetic waves. Radiant heat flow depends on several elements, such as the distance between two surfaces, the properties of these surfaces (for example, the weather during summer heat absorbed through roofs and windows are two primary sources of heat gain in homes, in this way is proposed the application of different materials on roofs and windows.)

G. Huelsz et al. have worked on diverse models to reproduce time-dependent heat transfer through constructive systems of building walls or roofs with internal air cavities, which are being implemented in whole-building energy simulation programs. The results tasted on these models are evaluated by analyzing the initial predictions with the practical measurements, so in the author's work, different heat transfer models through wall/roof constructive systems composed with air-cavities inside, implemented in whole-building energy simulation programs are compared.

Yang Wang et al. have conducted an extensive study whose objective mainly focuses on the heat transfer and energy flow characteristics of transpired solar collectors for recent years' applications. There are four different investigation methodologies applied for transpired solar collectors' thermal performance: a mathematical modelling study, physical experimental study (including particle image velocimetry, infrared spectroscopy, and prototype experiments and monitoring), numerical simulations (including computational fluid dynamics) and parametric sensitivity studies.

Xinyan Li et al. analyze the effects of critical parameters concerning effective thermal efficiency considering fan power via an investigation of the heat transfer and flow resistance characteristics of a vacuum glazed transpired solar collector with slit-like perforations. In this work, minimizing transient energy growth of heat-driven acoustic oscillations in an open-ended thermoacoustic system is considered. A state-space thermo-acoustic model with an acoustically compact heat source and distributed monopole-like actuators have been developed in this study. Coupling the unsteady heat release model with a Galerkin series expansion of the acoustic waves present enables the time evolution of flow disturbances and acoustical energy to be calculated, thus providing a program on which to gain insight into the system's temporary stability behaviors and the non-normal response of the system to the dynamic actuators.

Julien Quinten and **Véronique Feldheim** have presented a study involving four approaches to model heat transfer correctly through a thermal bridge and introduce it into building energy simulation programs. Their approaches are based on the equivalent wall method: defining a one-dimensional three-layer wall, replacing the thermal bridge with the same steady and dynamic thermal behaviors as the thermal bridge. The methods mentioned above are tested on one simple dimensional case. However, an even superior approach is a hybrid method that relies on combining the structure factors method and a harmonic method: it heads to very accurate results and a unique explication. The mixed methods mentioned above tested on a 2-D thermal bridge make possible a joint within the floor and exterior wall, and the results are again accurate and much better than a classic consideration of the thermal bridge.

M. Mirsadeghi et al. have provided an extensive review of models to calculate exterior convective heat transfer coefficients implemented in commonly used building energy simulation programs and their impact on heating and cooling energy demand. They have shown that the model by McAdams is the most common in building energy simulation programs to predict the hc parameter. Most programs rely on a single model to predict hc, and many assumptions are adopted in the implementation of models based on definitions of the reference wind speed, which are not consistent with that in BES weather files, such Vf, VR and Vloc, increasing the uncertainty in the results obtained with these models. From the models analyzed in this paper, the Ashrae task group models and by Loveday & Taki are recommended for buildings with 6 to 8 stores. The models analyzed in this paper, the models by Liu & Harris and MoWitt, are recommended for buildings with one story; other models analyzed in this paper have limited applicability due to particularities in their experimental setups or lack of information about their scope.

Yin Zhang et al. have conducted a study on covering external building walls with high solar reflectivity materials is another effective way to reduce heat gains from solar radiation and save cooling energy consumption accordingly. In this work, the transient heat transfer model of building external envelopes is established and validated through experiment to investigate building walls' thermal performance coated with retro-reflective materials. An office building in Chengdu is taken as an illustrative example to explain the evaluation during summer the cooling energy-saving potential of these retro-reflective material coated building. Economic analysis is also conducted to compare the payback periods of such coating materials in different climate zones.

The methodology used in evaluating heat transfer objectives is to test and compare several well-known heat transfer models on a few building samples and compare the energy efficiencies in the designs of these buildings. Firstly, according to the structure factors method, five significant parameters govern the building's thermal behavior: the overall capacity and resistance and the fractions of heat stored in-wall volume in transitions denoted. These parameters depend on the wall's thermal structure (resistances, capacities, and their arrangement): is larger when the thermal mass is positioned near the interior surface, is larger when the thermal mass is positioned near the exterior surface and is larger when the thermal mass is positioned near the center of the wall. These parameters satisfy some fundamental criteria like:

- $\varphi_{ii}, \varphi_{ee} \in [0,1]$ and $\varphi_{ie} \in [0, \frac{1}{4}]$
- In the case of a homogeneous wall $\varphi_{ii} = \varphi_{ee} = 2\ \varphi_{ie} = \frac{1}{3}$
- In all circumstances the equality $\varphi_{ii} + \varphi_{ee} + 2\ \varphi_{ie} = 1$ holds.

- For example, the parameter φ_{ii} is expected to comparatively large when most of the thermal mass is positioned near the interior surface and most of the resistance belonging to the outer part is positioned near the exterior surface.

In the basic case of a one-dimensional wall with n layers the evaluation of these parameters may be carried out as:

$$\varphi_{ii} = \frac{1}{R^2 C} \sum_{m=1}^{n} C_m \times \left(\frac{R_m^2}{3} + R_m \times R_{m-e} + R_{m-e}^2 \right) \tag{1}$$

$$\varphi_{ee} = \frac{1}{R^2 C} \sum_{m=1}^{n} C_m \times \left(\frac{R_m^2}{3} + R_m \times R_{i-m} + R_{i-m}^2 \right) \tag{2}$$

$$\varphi_{ie} = \frac{1}{R^2 C} \sum_{m=1}^{n} C_m \times \left(-\frac{R_m^2}{3} + \frac{R_m \times R}{2} + R_{i-m} \times R_{m-e} \right) \tag{3}$$

The methodology of application may be described algorithmically as follows:

1. Run a steady-state simulation to determine the structure factors of the thermal bridge.
2. Determine the three-layer equivalent wall, with the same structure factors, thermal resistance and thermal capacity as the thermal bridge:
    a. Assign the values of R_1 and R_2;
    b. Solving equations (2) and (3) and ensuring the same thermal resistance and capacity, determine the value of R_3, C_1, C_2 and C_3.
3. Different solutions are available where R_m and C_m for m = 1, 2, 3 must be positive. Each consistent pair of R_1 and R_2 must be tested in the style of "trial and error" iterative procedure

To simplify the computational workload in the model mentioned above, designers rely on a programming library that will simultaneously facilitate the evaluation procedures and operate on the third phase carrying out the "trial and error" testing for the pairs of the parameters.

Another approach in modeling the heat transfer would be relying on the matrix of transfer functions. This operates employing the knowledge on the transfer functions $H_{Ai}(s)$, $H_T(s)$ and $H_{Ae}(s)$ of the real structure in the Laplace domain which may be represented as:

$$\begin{bmatrix} q_{si}(s) \\ q_{se}(s) \end{bmatrix} = \begin{bmatrix} -H_{Ai}(s) & H_T(s) \\ H_T(s) & -H_{Ae}(s) \end{bmatrix} \times \begin{bmatrix} T_{si}(s) \\ T_{se}(s) \end{bmatrix} \quad (4)$$

A numerical simulation assists in the evaluation of the transfer functions. So, this methodology consists of two fundamental steps: Firstly, the transfer functions (dynamic simulations) or the structure factors (steady-state simulation) are determined. Secondly, the three-layer equivalent wall is determined and the parameters R_1, R_2, C_1, C_2 and C_3 are evaluated.

2.6 Aim and Originality

The suggested literature review demonstrates the importance of every energy efficiency application in every building, new and existing ones. However, the study shows that applying different passive and HVAC systems is a complex task involving many possible design variables. Therefore, the research can provide original benefits to the body of information by approaching the following knowledge gaps and identifying potential areas for further development in the simulation outlined in the previous literature review.

No previous study performed a comprehensive analysis on three types of housing typologies that addressed complex data variables (building geometry, HVAC operation, occupancy, internal gains, material properties, glazing type). Even though some past studies combined several passive systems in their design, architects did not examine other significant factors, including well-defined building standards operational requirements. For example, no detailed examination is shown in every statement in the literature review made by other authors. Different authors discuss only the results calculated by the given structures, or a variety of these applications is discussed only in its theoretical background. In this regard, the proposed approach of this study is an enhancement and combination of the methodologies proposed by several authors. The study presents three particular simulation models and estimates the significance of specific input parameters mentioned or applied in previous research studies (climate conditions, building typology and activity, details on the construction materials, occupancy schedules, internal gains, HVAC systems and schedules,).

Several situations are presented and identified in the papers reviewed, showing the importance of the climate and location for calculating heat transfer in various buildings. Calculating results for both summer and winter conditions describes an original contribution of the study, helping the reader understand the importance of these systems and the environment.

Studies made by different authors regarding heat transfer analyze the impact of heat transfer and energy efficiency on the thermal performance of the building.

For two housing typologies in the study, a simple simulation analysis is made regarding energy performance, estimating all the output variables within the simulation, such as energy loads, indoor air temperatures, radiant temperatures, indoor and outdoor surface temperatures.

Consequently, for a further detailed study, a new comprehensive framework is proposed to open an analytical and quantitative method towards assessing passive systems' thermal and energy performance on building envelopes, considering the Mediterranean climate context, with the case study of Elbasan, Albania. The main innovation and scientific significance are introducing and assessing different design strategies of passive systems and HVAC applications, already executed on building envelopes, even though no previous study has quantified their efficiency.

CHAPTER 3

METHODOLOGY

3.1 Climate characterization

Determined by the Köppen climate classification like Cfa, the climate of Elbasan, Albania is characterized as Mediterranean weather, comprised of hot, dry, sunny summers and followed by mild and rainy winters. Elbasan is positioned at 41.06 o latitude north and 20.04 o longitude east and 132 m above sea level. With an average temperature of 16°C, winter in Elbasan offers an average temperature of 2.8 °C in January and an average temperature of 23.6 °C in August. The annual temperature is 13.1 °C. January is classified as the coldest month of the winter, followed by August as the warmest month. During January, the temperatures vary from 8 °C to the lowest temperature of -1 °C. August has an average high temperature of 29 ° C and an average low temperature of 17 ° C. Figure below represents the annual temperature of Elbasan. Elbasan assumes average solar radiation of 611 KWh/m2 yearly. The maximum global radiation value is marked in July, reaching about 234 KWh/m^2. Around 3348 hours of sun are received in the whole year, classifying Elbasan as one of the sunniest cities on the European Continent. Climate conditions such as rain and snow are stated to occur all winter.

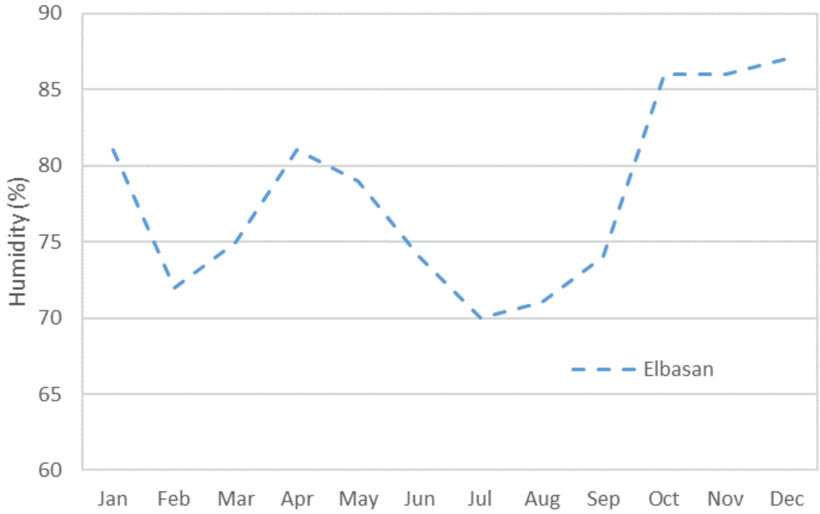


Figure 17. Humidity in Elbasan

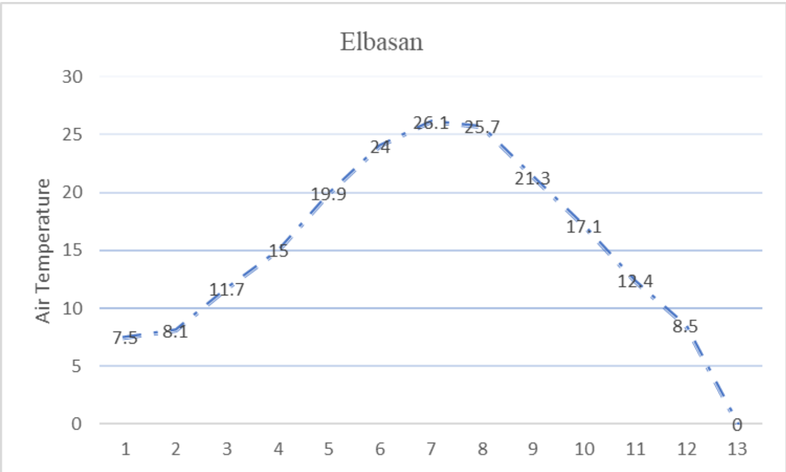


Figure 18. Air Temperature in Elbasan

3.2 Simulation Design

For developing the given simulation models The DesignBuilder interface version 6 (Tindale, 2005) for EnergyPlus (Doe, 2013) was chosen, combined with Meteonorm 7.3 (Meteonorm, 2016) software in order to generate the local weather file.

3.3 Representation of the given building (Base Case)

This is the case of a villa located in Elbasan, which was massively affected by the 2019 earthquake and reconstructed later. It is an existing villa located in the "Skanderbeg" neighborhood, which, as it is ascertained, is an area characterized by individual residential buildings with one- or two-story floors. The given object has a regular geometric configuration between objects. The form of the structure is in harmony with the other existing buildings following the organic construction. However, due to the developer needs, the structure's layout is adapted to the existing condition. The building is currently being developed on the 2nd floor above ground, and the developers are looking to completely reconstruct the existing building and add a 1st-floor sub-roof service.

The construction site has a trapezoidal shape with an average size of 15 x 22 m and is oriented in the northwest-southeast direction. To the north, east and west, the construction site is bordered by private properties to which the regulatory distances of the existing 2-storey building are respected, while the two additional floors will be to the north and east. In the south, the property is bordered by the status less property surrounded and owned by the developer. The existing building has lighting on all four sides of the building. The terrain of the square is almost flat, with a quota level of 20cm.

The project aims to adapt to the urban structure of the unit where it is located. This area has already created a character of its own presented as a residential neighborhood consisting of buildings (mainly villas) 1 -3 floors. In general, the area continues to be composed of old and traditional residential buildings. The architecture of the neighborhood is in harmony with the architecture used in this villa. The elements used in the facade are contemporary. Materials such as graffiti or decorative tiles (stone and wood imitation) bring a perfect combination of all its kinds. What is placed on the front and as a whole is a structure combined with decorative clothing and glass space to bring a contemporary object but with little traditional taste of a genuine residence. The building is intended to be treated with double-wall graffiti combined with decorative tiles, imitation wood, and cladding with decorative stones.

The windows will be treated with transparent double glazing with black aluminum windows RAL 9004, the southern and western facades will be covered with imitation wood tiles and decorative stones. The floors will be laid with wood laminate on the first floor, while the floors of the ground floor premises will be laid with porcelain tiles. The rest of the perimeter walls will be treated with a double wall system with white and grey graffiti. The windows are made of black double-glazed aluminum. The cover will be with a tiled roof—a wooden railing. The ground floor will be completely reconstructed. On this floor will be held the day activities for the residential function. As can be seen from the planimetry on this floor, the entrance to the building, living room + dining + cooking, toilet + laundry, bedroom with internal toilet and the stairs to the first floor. The first floor will be used for night rooms. There are three bedrooms, three bathrooms, and a wardrobe on this floor; the floor has one balcony oriented to the south. The second floor will be used for service facilities. As mentioned above, the investor will create a working environment in the function of his commercial activity. On this floor, there is a waiting room and an office environment with two working rooms. Since the second floor is not built complete, the remaining surface will serve as a veranda. This floor will have no soles and is covered directly by the roof.

Thermal insulation of the house will be made of polystyrene EPS granite material. It is a dark grey thermal insulation material made of polystyrene with graphite content and used in thermal insulation of facades, roofs, between walls, thermal joints. It has the lowest conductivity of all types of polystyrene, thanks to graphite content, which reflects infrared rays. This product enables perfect thermal insulation using more minor scales than other products. It is resistant to moisture absorption, has homogeneous density throughout the mass, good acoustic properties, dimensional stability in time, and temperature changes.

Windows are an important architectural and functional part of the building. They provide lighting for parts of their interior surface. Their size varies, depending on the architectural composition, the size of the interior surface and other requirements of the designer. Windows should be at the height of 80-90 cm above floor level; this also depends on the requirements of the designer. The windows can be made of wood, aluminum or PVC. The main parts of the windows are: the window frame fixed to the wall with iron elements before plastering. The window frame will be screwed to its frame after plastering and painting. Based on the window drawing shown in the technical drawing, the frame will be equipped with hinges and locks of various types installed in it. Shutters composed of open glass, equipped with hinges, fixed gloves and transparent silicone adhesive, and fixed shutters, will be part of the structure. Duralumin windows, treated with protective coverings, will consist of:

A wooden frame that is fixed to the wall utilizing steel pins before plastering (the width of the frame is 4 cm and the size according to the window frame). An aluminum frame (section 7x4cm) to be screwed to the wooden case given above after plastering and painting the walls. For the windows given in the technical drawings, the frame will be with hinges and locks anchored in it for folding windows, framed windows, attic windows, lighting windows.

Double glazed, open flaps equipped with hinges, fixed handles, glass panels (4 mm thick when transparent, 6 mm when reinforced with wire mesh), fixed with full wooden slats and transparent adhesive silicone, window blockers with chain or compass. Full wooden strips around the inner perimeter of the window, when realized with a beam from inside and outside in the absence of beam. Painted with oil paint or varnish.

Doors are an essential part of buildings. They must provide access to their internal parts. Depending on the function they have, the doors can be internal or external. Their sizes are different depending on the architectural composition, the requirements of the project and the Investor. Doors can be made of wood, MDF, metal, duralumin, plastic. The main parts of the doors are: Duralumin interior doors will consist of:

- Fixed frames in the form of tubular duralumin profiles with a depth of 61-90 mm, which are provided with unique elements for fixing fastening to wall structures. The fixed profiles of the case will be with a cover not less than 25 mm away from the wall.
- Duralumin movable profile flap with a depth of 32 mm and a height of 75 mm flat or with a decorative solution. The profile should have a central space required for the insertion of the corner joints (with a space of 18 mm for the placement of the glass) and the rollers for their sliding.
- Glass panels that can be transparent (4 mm minimum thickness) and reinforced mesh (6 mm minimum thickness). MTP laminated wood veneers with a minimum thickness of 1 cm can also be used.
- A metal lock and three copies of secret keys, door handles, and door push handles must be installed as an integral part of the door. Also, armored doors can be equipped with a glass lens to view both sides of the door (magic eye). Exterior doors made of solid pine wood, treated with a wooden protective cover, will consist of: - a wooden frame fixed to the wall employing steel knife-shaped hooks before plastering. (The width of the frame is 3 cm, and the width is according to the size of the wall).

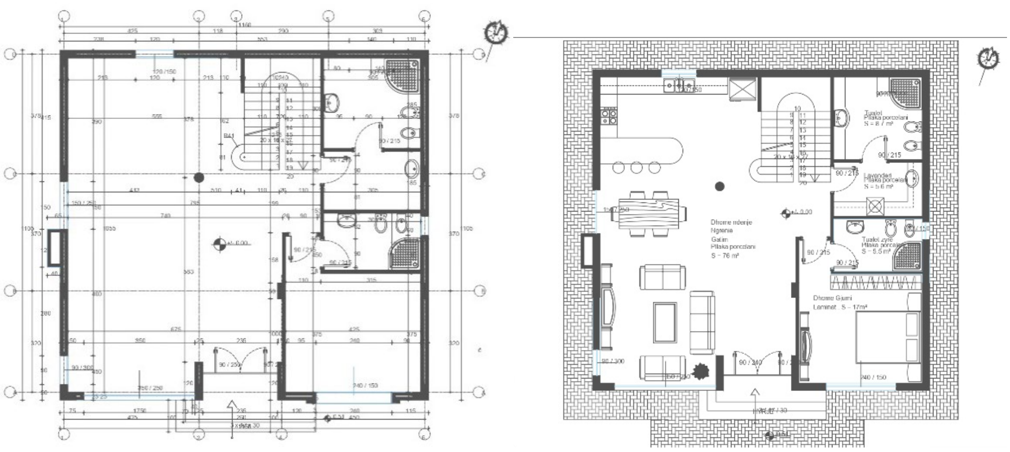


Figure 19. Ground floor

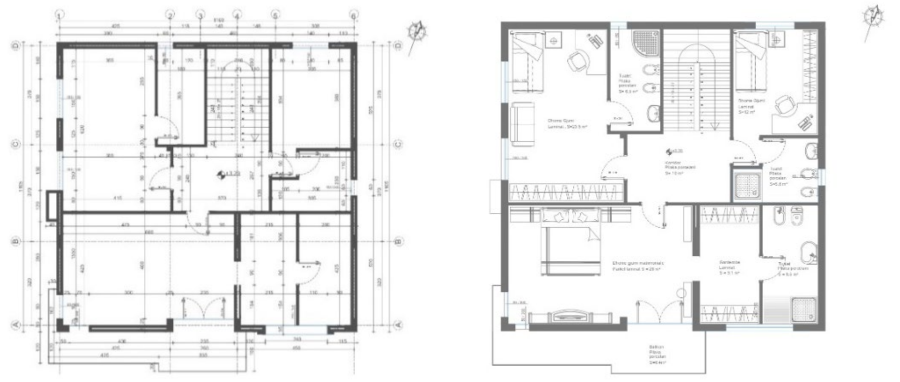


Figure 20. First Floor

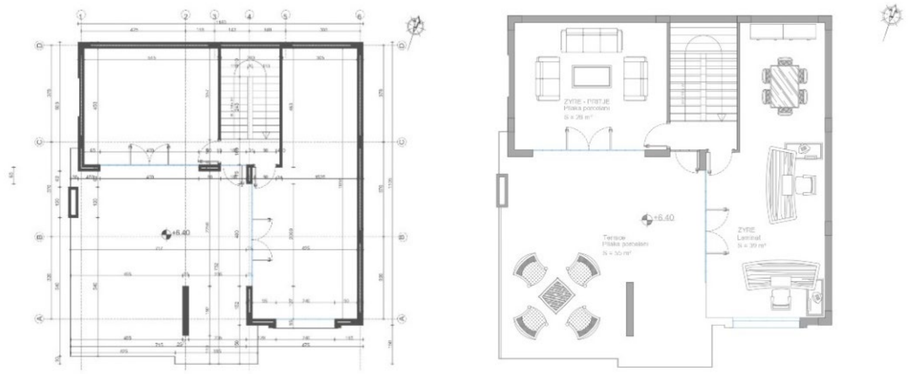


Figure 21. Second Floor

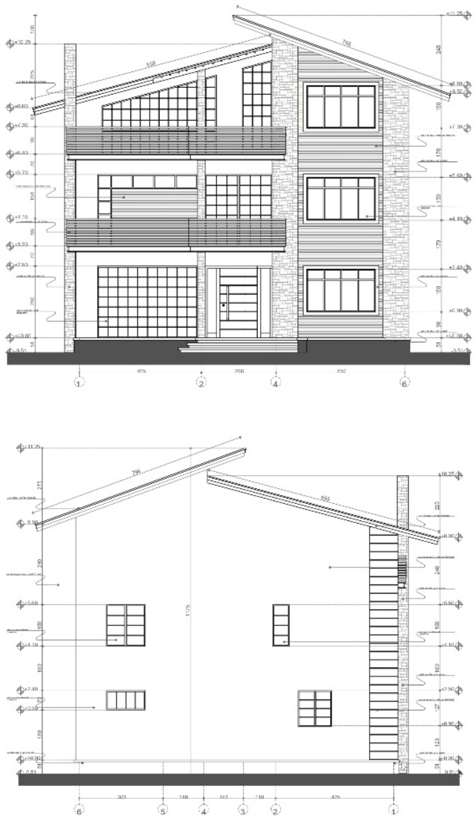


Figure 22. Facades

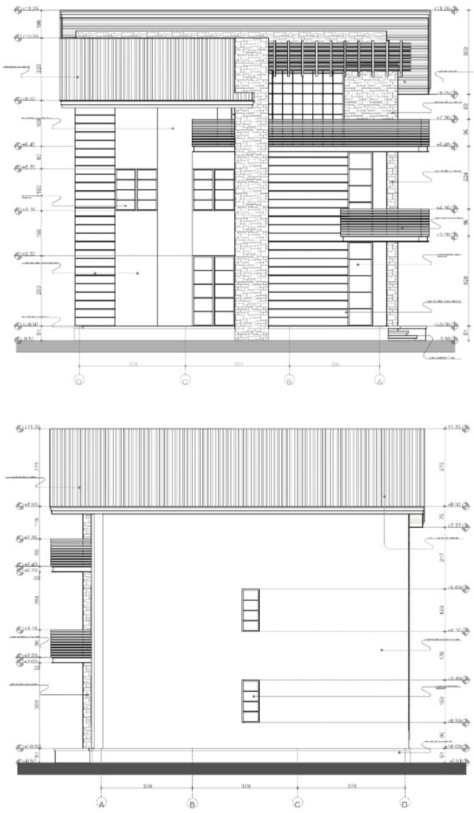


Figure 23. Façades

3.3 Representation of the given building (Base Case)

The second case is related to an existing villa reconstructed based on client needs. The villa has an area of 70.0 m2, of which only 50 m2 are usable for living purposes. This existing building, located in the city Centre, is reconstructed based on the requirements needed. The building is located in an area where reconstruction of existing buildings is quite favorable since the flat terrain. This type of terrain is promising for further reconstructions of new and existing buildings, offering a significant impact on urban development. Based on client needs, the existing object will be reconstructed with an additional floor above the existing building. The additional floor will be designed respecting the urban distances and the organic connection with the existing architectural landscape, adapting to the purpose of its use mainly for Housing. A simple architecture mixed with contemporary elements based on ecological parameters will be used in this additional floor of the existing structure.

Given that only one floor will be added, suggestions for a harmonic architecture regarding other buildings around are given. The additional floor will be designed with glass windows, combined with a parapet, decorative railings, external stairs and greenery. The facades will be partly glazed and plastered. The functional division of the structure is based on the client's needs, where the main spaces will be the living room, kitchen, bedroom, hygienic-sanitary joints, and others. There are cracks in all four directions in the existing building, except for some spaces in the northern part and the ground floor. The structure of the model mentioned above is reinforced concrete, in which horizontal bricks will replace the masonry bricks. The building exterior is designed in such a way as to meet the minimum criteria of energy performance in the building, realizing the exterior walls, floor slab and roof with a thermal insulation layer and selecting doors and windows with low U-value.

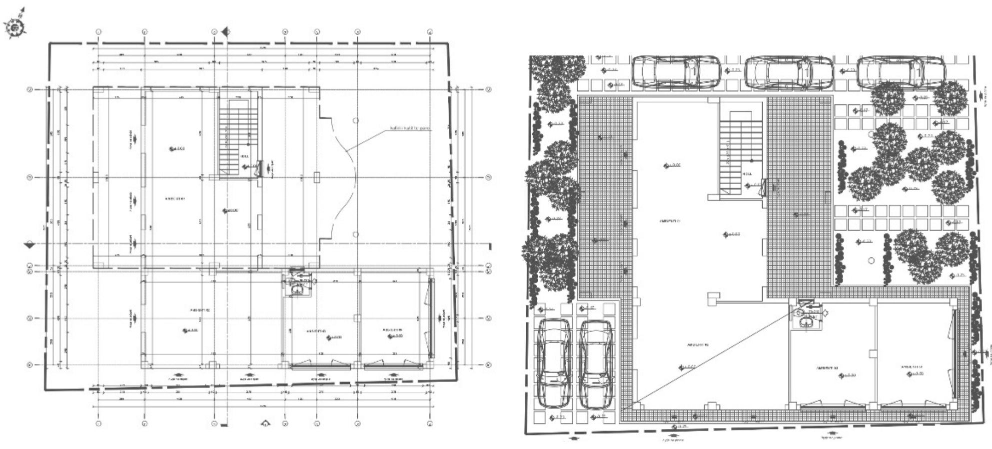


Figure 24. Site plan and Ground Floor

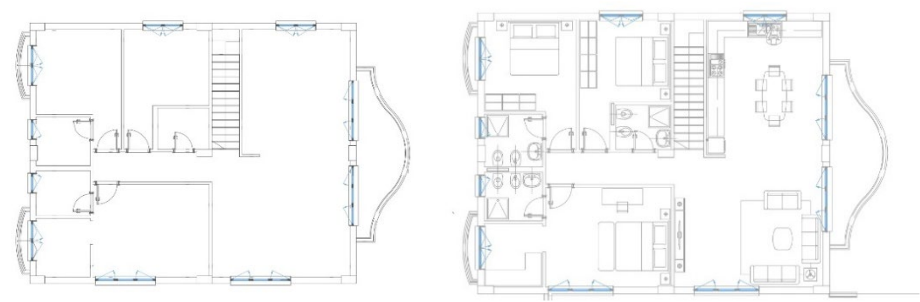


Figure 25. First Floor

Figure 26. Facades

3.3 Representation of the given building (Base Case)

The last case study to be analyzed is a new villa with 348 square meters. The total construction area is about 278.9m², and the underground construction area is about 120m². The ground floor of the planned villa is composed of the main hall, stairs, living room, kitchen and dining room, bedroom, toilet and garage. Regarding the first floor of the villa is comprised of a bedroom with a wardrobe and a toilet, two extra bedrooms, a toilet, and a staircase. Serving rooms, such as the storage room, laundry and the room for water tanks, are placed on the underground floor. Based on energy efficiency parameters, Ventilation of the building is performed naturally due to windows placed on the north, east and south facades. The construction site of the villa is located in the 5 Maji neighborhood, with a total area of 200 m². The surrounding buildings are primarily low residential constructions. The main façade, also the main entrance of this villa, is planned to be the north façade. On the western border, the planned building is adjacent to the building opposite by mutual agreement between the two parties. The eastern façade considering the characteristic of the narrow plot is planned to be Kalkan to respect the distance according to the urban conditions. In this way, the distance to the eastern boundary of the plot is maintained at 1.50 m. The building is interrupted by an atrium in the eastern part intended to give the interior light and Natural Ventilation. The nearest object is near the western border, which is adjacent to the new object. The concrete / reinforced skeleton of the villa is designed with a reinforced concrete foundation with a continuous T-shaped foundation beam and a superstructure of columnar elements + concrete / reinforced beams. The columns are composed of reinforced concrete with dimensions 30 * 30cm to 30 * 60cm. The part of the beams is made of reinforced concrete, and the floor is with travertine and light brick filling. The model of the structures is made by adapting a three-dimensional static scheme of the metal frame type with a reinforced concrete foundation which is best described in the fundamental spatial behavior of the building following the performance of external forces.

The building is accessed by the road that corresponds with the north side of the structure, following the main entrance, the living room and the exit to the garage—continuing with the toilet, accompanied by the staircase and a bedroom next to the stair wall. The living room and dining area are interrupted by a garden inserted inside the structure, which is designed with glass windows and at the same time enables the visual connection how it is intended to give natural light and Ventilation to both rooms. The building on the ground floor has one bedroom and three bedrooms on the first floor. A shared toilet is designed on the ground floor and two toilets on the first floor, one of which belongs to the matrimonial room. Also, each room has its exit to the balcony. At the entrance of the building, a balcony is planned. A passage is positioned to the staircase from the living room on the west side of the building, leading to the house's basement. Regarding the roof construction, a usable terrace has been thought of with a difference in level, which coincides with the living room plan, which is double-height.

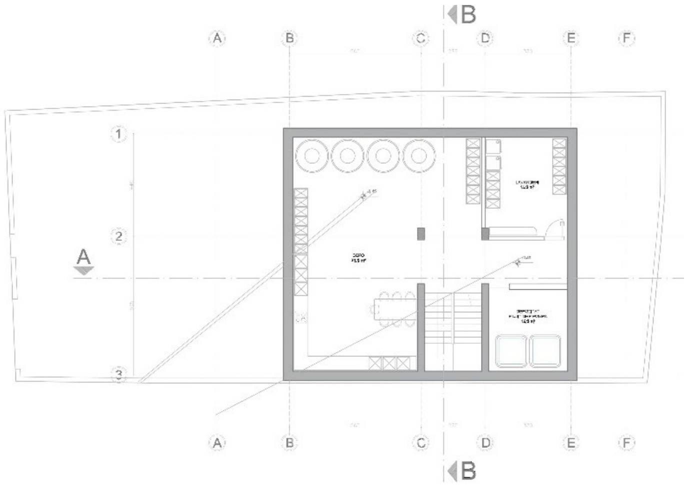


Figure 27. Underground floor

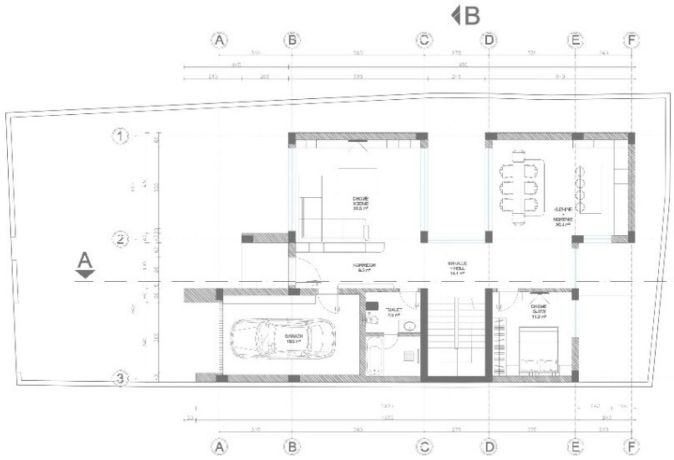


Figure 28. Ground Floor

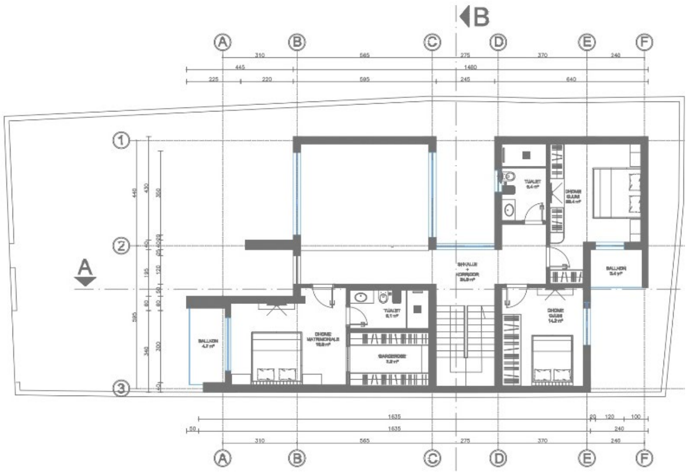


Figure 29. First Floor

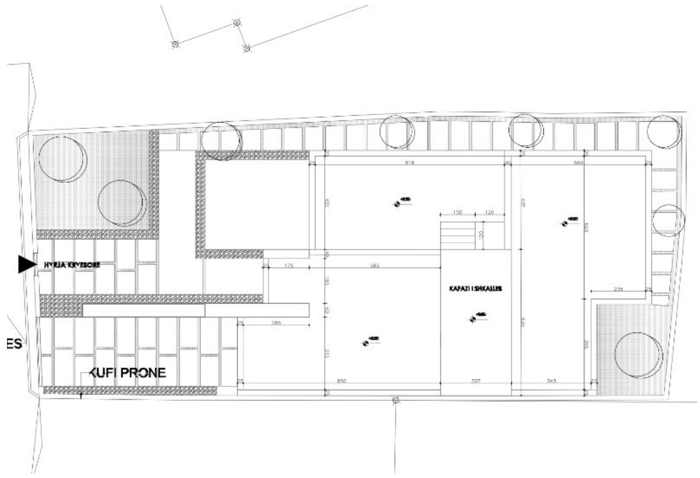


Figure 30. Roof plan

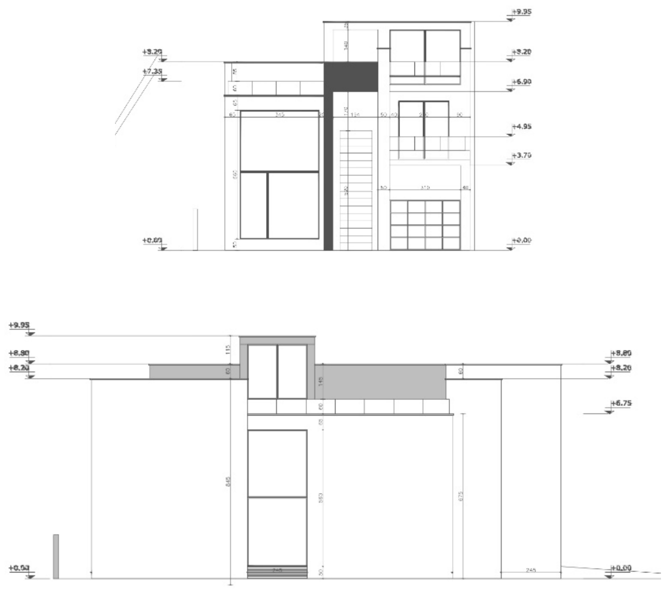


Figure 31. Facades

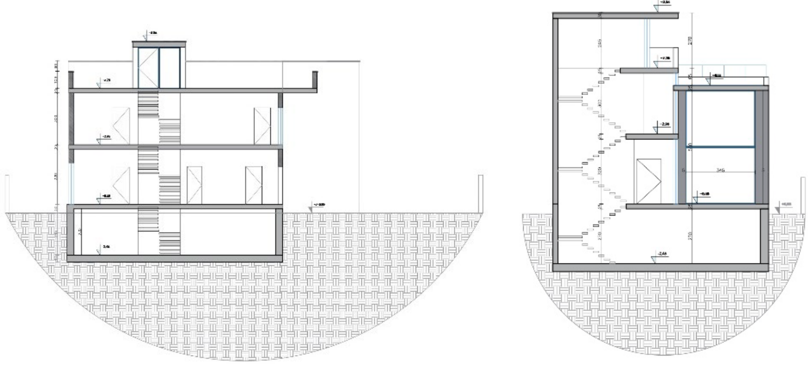


Figure 32. Sections

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Villa NO3

Although energy efficiency techniques and systems have already been integrated into this structure, further improvements must be added to the structure to reduce the total energy consumption and its impact on the environment.

Implementation of insulation elements according to the interventions provided in the project is a necessity for ensuring energy efficiency of the structure and providing the needed requirements for obtaining the Certificate of Use for which the final efficiency audit report must be submitted. Therefore, the building is considered to comply with the minimum energy performance requirements if the calculated value of the primary energy efficiency rating in the CPE is less than or equal to 502.

Attention should be paid to the excellent implementation of insulation of the cladding elements of the building and the installation of glazed components to avoid thermal bridges, which bring not only heat loss but also cause mold in critical areas with different characteristics. Furthermore, exterior doors, including the door connecting the lobby to the garage, must maintain the level of heat transmission provided in the project. Also, during the installation of the technical systems of the building, the efficiency provided in the project must be maintained.

Another measure is advised for windows exposed on the south facade. Although glass surfaces are not significant in this orientation, considering solar radiation in the geographical location of the building, the integration of shutters.

Also, considering the high intensity of solar radiation for this area, it is recommended to consider using alternative systems with high energy efficiency that use renewable energy sources such as solar panels for sanitary heating water, which would significantly reduce energy consumption. Finally, control systems and management of technical systems (heating/cooling system, appliances, lighting) in the building are recommended to ensure safety, comfort and energy savings. These systems enable the automatic or remote management of systems and equipment within the dwelling.

4.1.1 Results

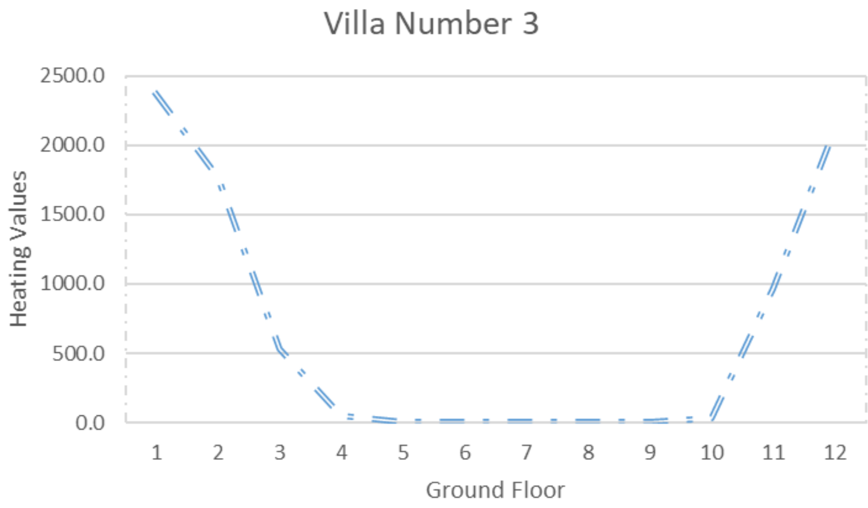


Figure 33. Heating values from the simulation program

Figure 33 illustrates the energy consumption for heating in the third villa. Ground floor window to wall ratio is 23%. The reason why it is so low is because both sides of the facade are covered (next to the other property and there are no windows). Total area of side walls = 211.2 m2. Total area of windows = 48.5 m2.

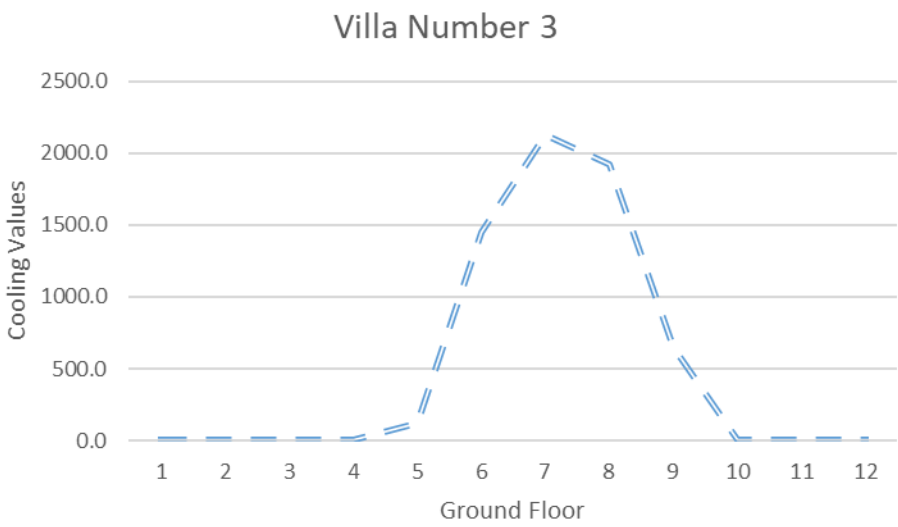


Figure 34. The cooling values during all year

Figure 34 illustrates the energy consumption for cooling in the third villa. The building is oriented as it is in reality. The facade, for example, which is oriented from the south, spends more on cooling demand (for cooling with electricity / air conditioner) because the facade from the south has more sun during the year (spends less on heating).The north-facing façade, for example, spends more on heating because the north façade gets less sun during the year and requires more heating.

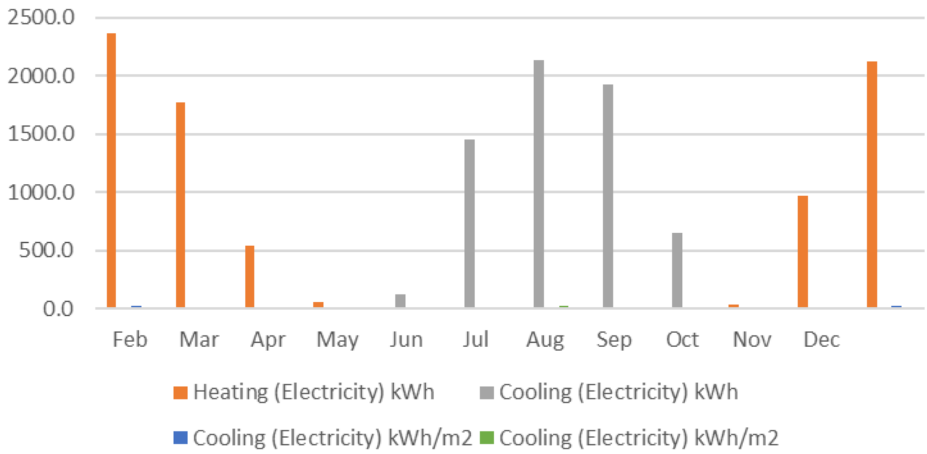


Figure 35. The total value for both heating and cooling for the ground floor

Figure 35 illustrates both the energy consumption for cooling and heating in the third villa. It shows the energy consumption throughout the year, by defining which insulation affects the house better.

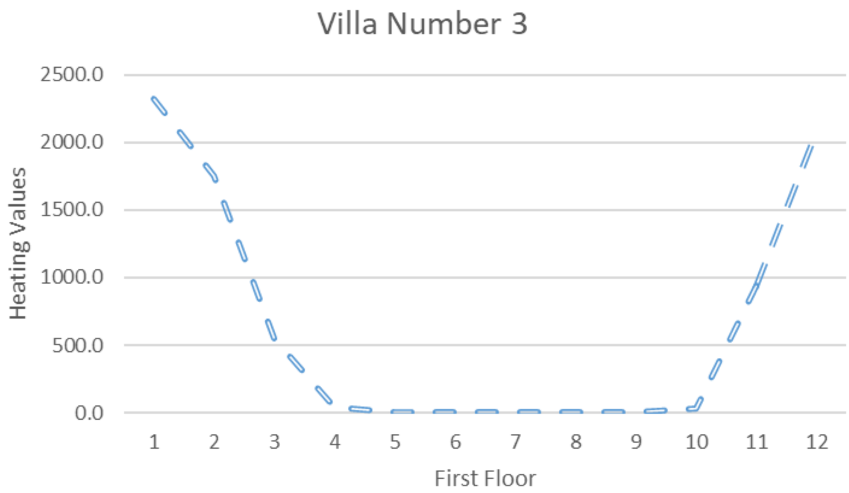


Figure 36. Heating values for the first floor

Figure 36 illustrates the energy consumption for heating in the first floor in the third villa. The second floor consumes more energy than the ground floor because the terrace (probably not very well insulated). And the ratio between the wall and window greatly affects the energy consumption. The more windows to have a house the more it spends on heating and cooling. Window to Wall Ratio = 15.5%, Total area of side walls= 211.2 m2.

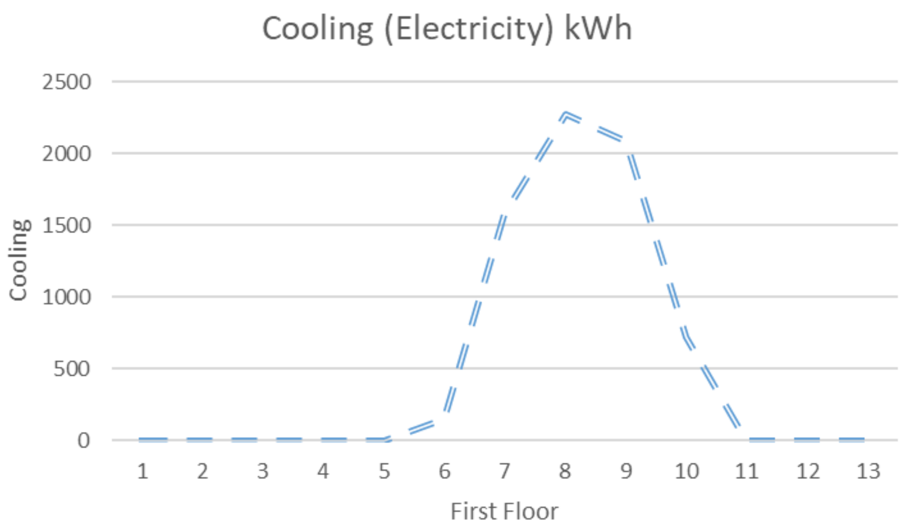


Figure 37. Cooling energy consumption

Figure 37 shows the energy usage for cooling in the first floor in the third villa. The ratio between the window and wall of the whole house is 19.2%. The surfaces of the side walls of the whole house and the surfaces of the windows of the whole house (the first and second floors have been collected finding the ration.) For the whole year heating demand is 48.8 kwh / m2 and for the cooling demand is 40.4 kwh / m2. In total the energy consumption is 89.148.8 kwh/m2 for both heating and cooling.

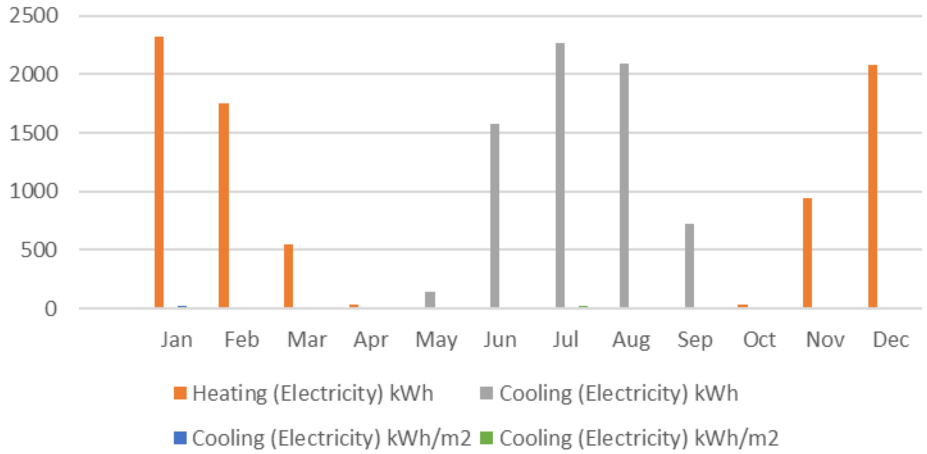


Figure 38. Energy consumption for the entire floor

According to the bedroom located in the ground-floor spends more on cooling. The reason that the room spends more on cooling than heating demand is because it is oriented to the south and has a considerable glass surface. For heating demand this bedroom spends 54.7 kwh / m2 and 95.7 kwh / m2 for cooling demand.

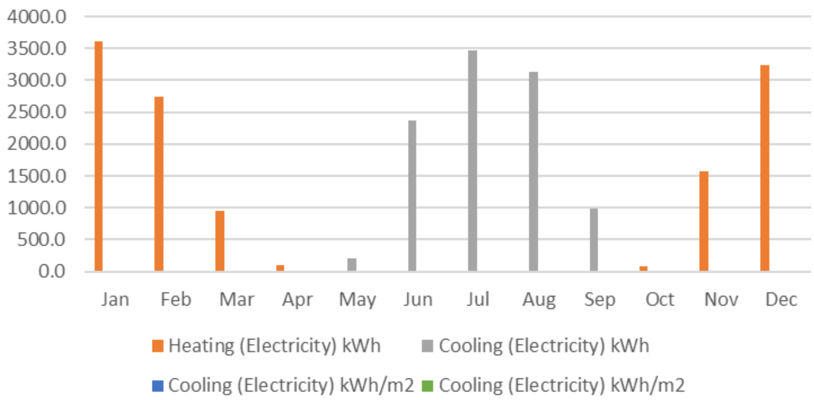


Figure 39. The energy consumption of the entire villa

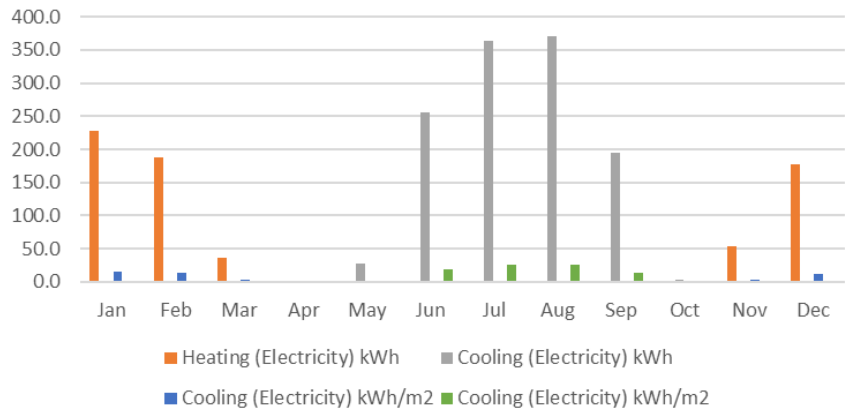
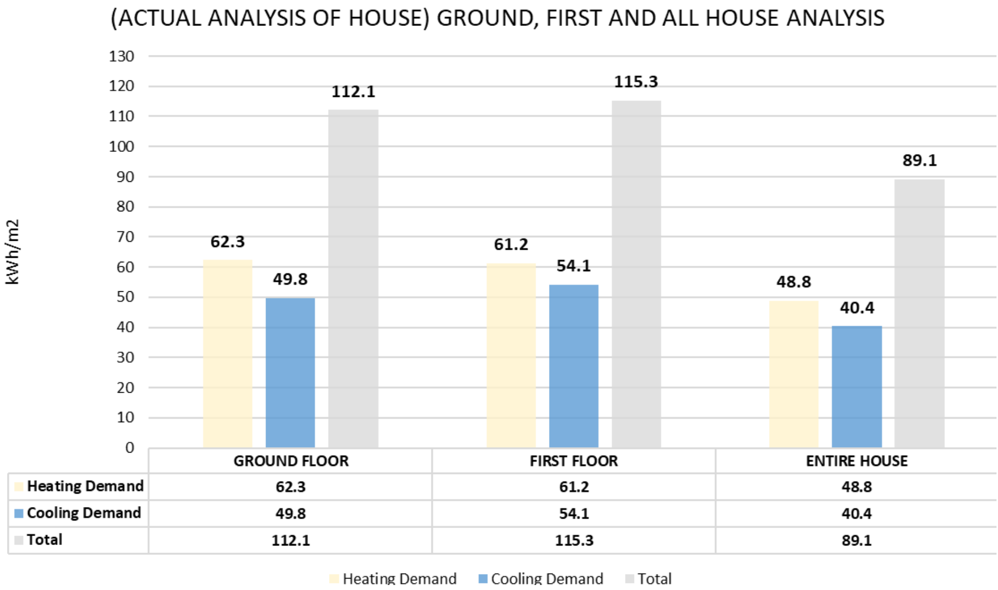


Figure 40. Energy consumption regarding the bedroom located in the ground floor

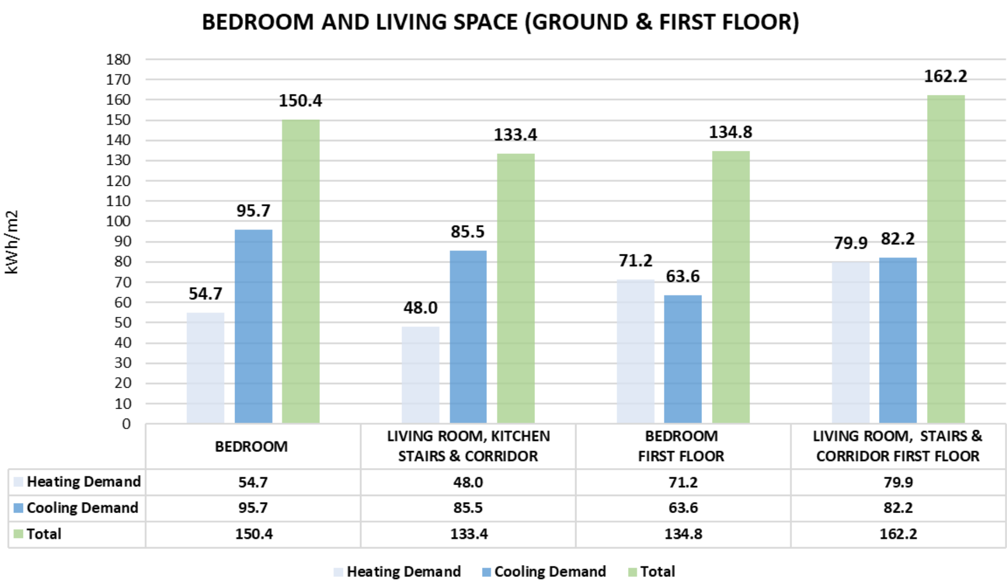
Based on the calculations made in the Designbuilder, it is easier for the architect to understand the values of heating and cooling for every space of the structure. Comparing the given calculations with the new proposals and calculations, allow the structure to use heating and cooling devices as much as needed. As illustrated in the above graphics, a higher value of heating demand is registered in the first floor, regarding with the ground floor. A higher cooling demand is seen mostly in areas of bedrooms oriented to the north of the structure. To be mentioned is the master bedroom located in the first floor of the building where it is seen a highly usage of heating, due to its orientation to the south. The same as the master bedroom is the kitchen placed on the ground floor, due to its design of a high usage of glass, the need for cooling is very high during summer and high usage of heating during winter.

Following the new calculations there are some results stating all the needed changes that should be made in the structure for it to be more energy efficient.



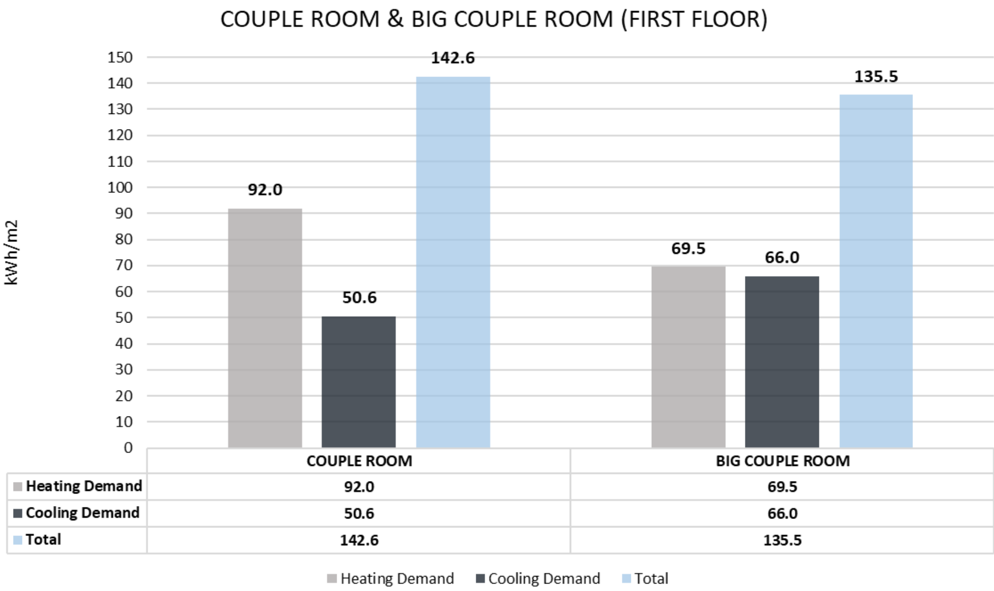
	GROUND FLOOR	FIRST FLOOR	ENTIRE HOUSE
Heating Demand	62.3	61.2	48.8
Cooling Demand	49.8	54.1	40.4
Total	112.1	115.3	89.1

Figure 41. Actual Analysis of House



	BEDROOM	LIVING ROOM, KITCHEN STAIRS & CORRIDOR	BEDROOM FIRST FLOOR	LIVING ROOM, STAIRS & CORRIDOR FIRST FLOOR
Heating Demand	54.7	48.0	71.2	79.9
Cooling Demand	95.7	85.5	63.6	82.2
Total	150.4	133.4	134.8	162.2

Figure 42. Bedroom and Living Space



	COUPLE ROOM	BIG COUPLE ROOM
Heating Demand	92.0	69.5
Cooling Demand	50.6	66.0
Total	142.6	135.5

Figure 43. Master Bedroom

4.1.2 Villa NO2

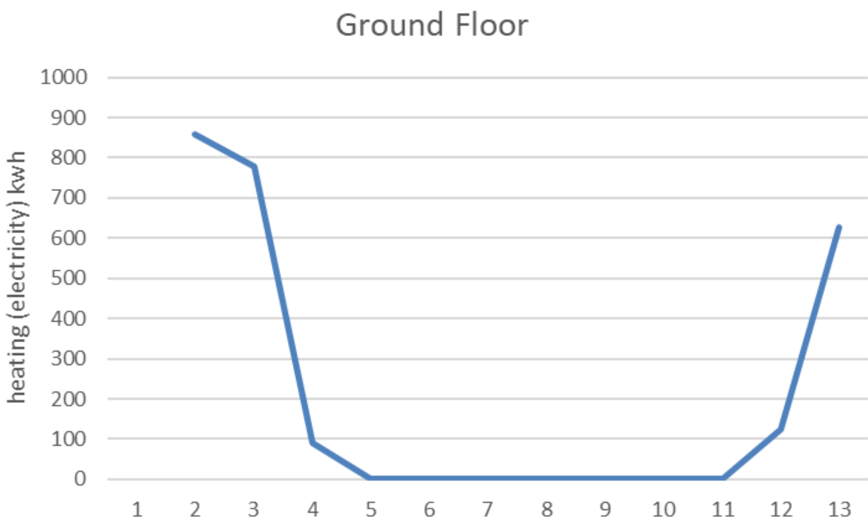


Figure 44. Heating demand on ground floor

Figure 44 shows the heating demand consumed on this housing typology for the ground floor. Due to its design and the high percentage of windows used in the ground floor, make it hard for the surface to be heated enough during winter days. Also, worth mentioning is the climate of Elbasan, Albania in which most of the time the weather is hot and dry. So as stated in the graph no usage of heating devices is seen from May to November.

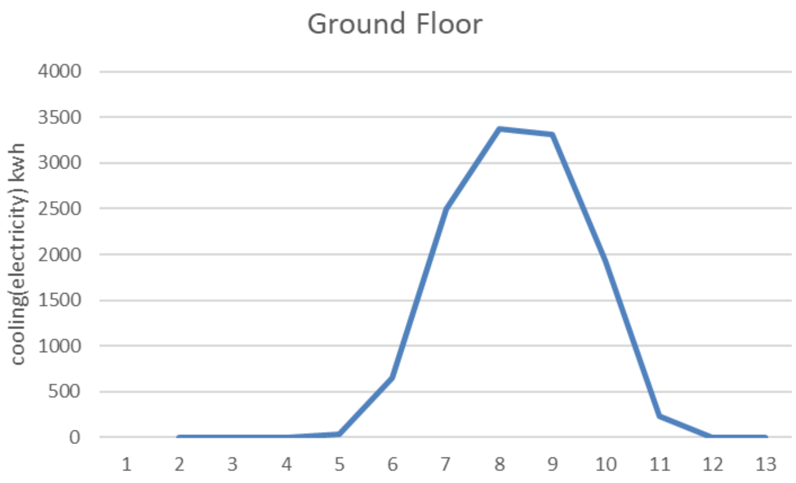


Figure 45. Cooling demand for the ground floor

The above graph shows the electricity used for cooling demands during summer days. Even in the case of cooling devices, there is a high usage of them due to the design of the structure. Due to its surface, the usage of glass is used mostly, making it harder for the area to be cooled rapidly. As seen in the graph, there is a noticeable change of ratio between the heating and cooling demands.

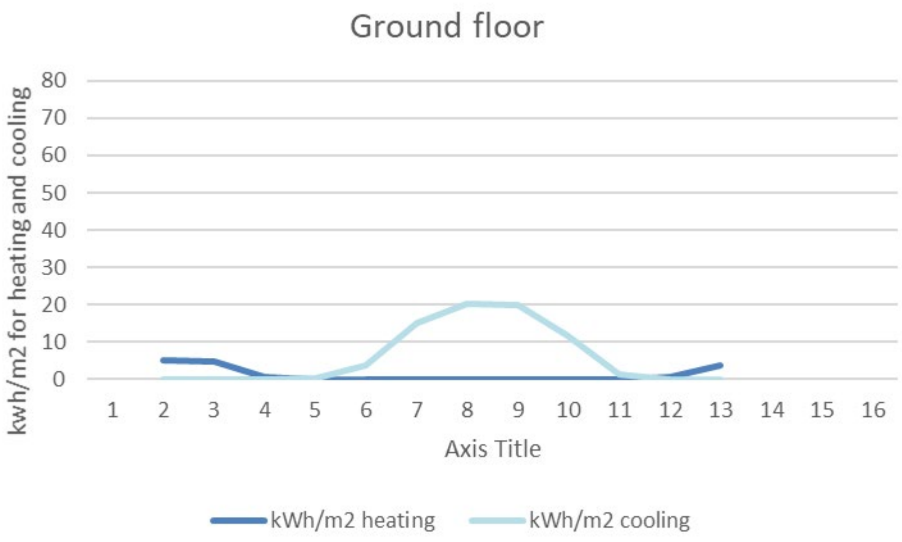


Figure 46. kWh/m2 calculated for both heating and cooling demands

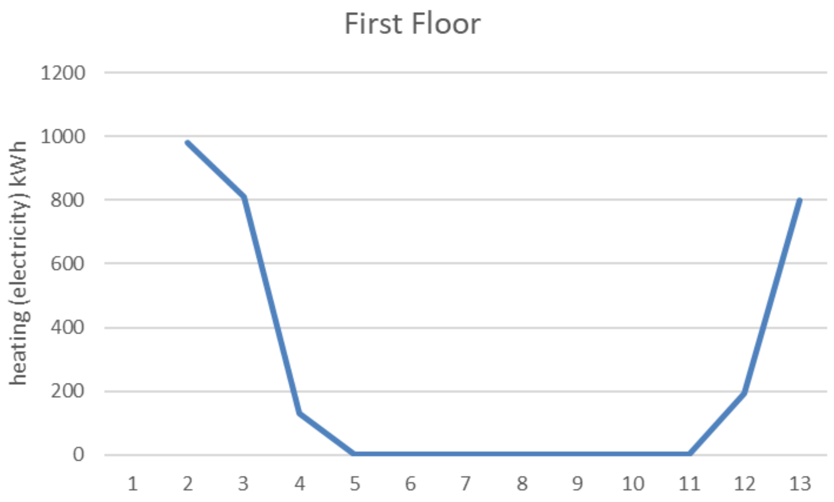


Figure 47. Heating demand electricity calculation for first floor

Figure 47 shows the electricity used for heating demand in the first floor, compared with the ground floor there is a slight change in values, since in the first floor there is not a high usage of windows.

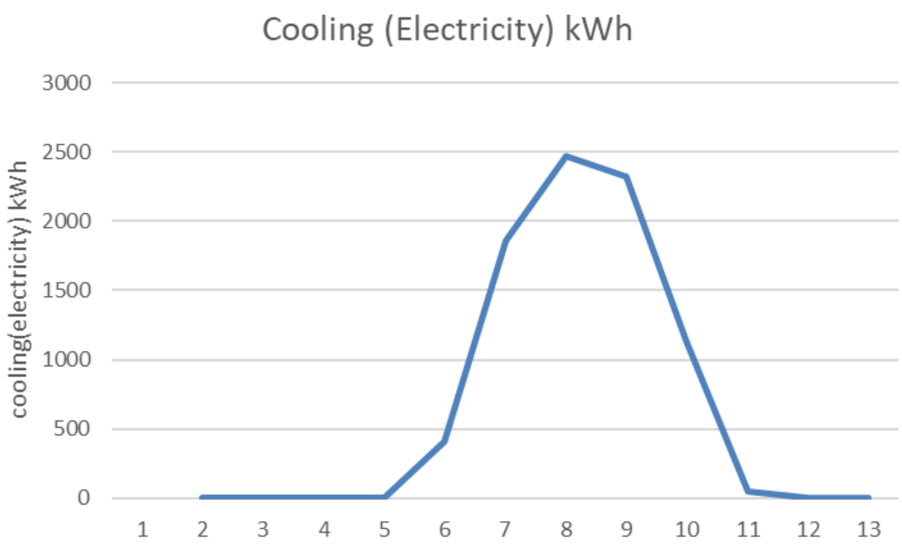


Figure 48. Calculated electricity spent for cooling demands

Figure 48 states the usage of cooling demand on the first floor during the year. Mostly used during the end of the spring until the beginning of the winter.

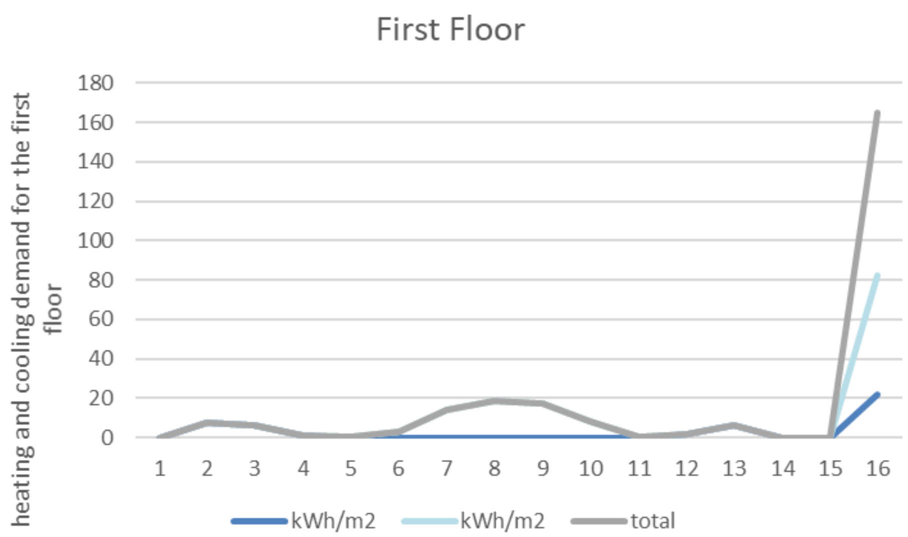


Figure 49. Heating and cooling demand for the first floor

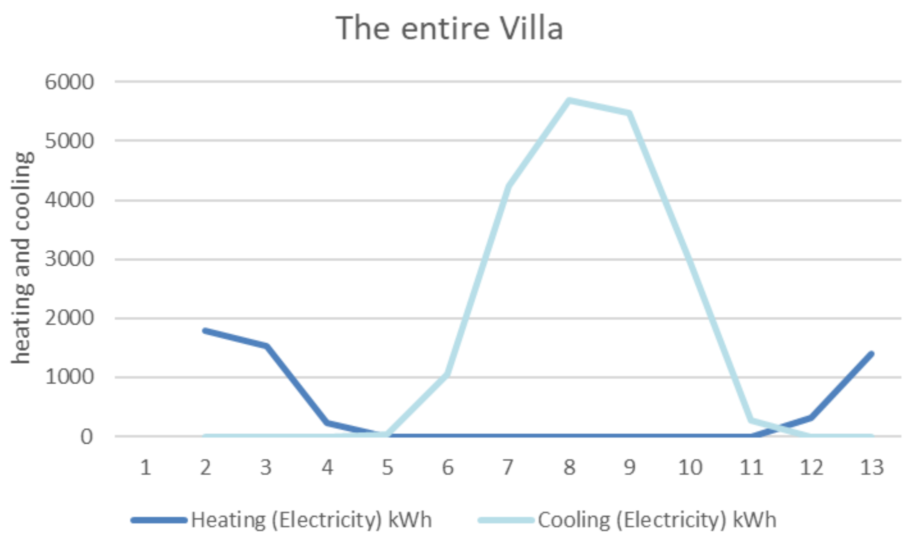


Figure 50. The entire villa cooling and heating calculated values

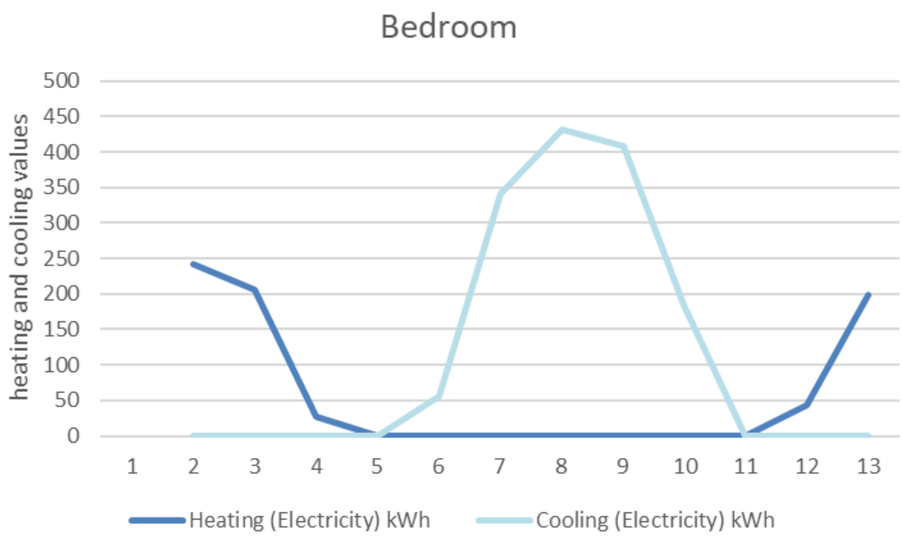


Figure 51. Bedroom, cooling and heating demand calculations

Figure 51 shows the values for both of heating and cooling demands during different time of periods. The surface of this area is too big for spending enough on cooling demands. The bedroom is faces in the south orientation.

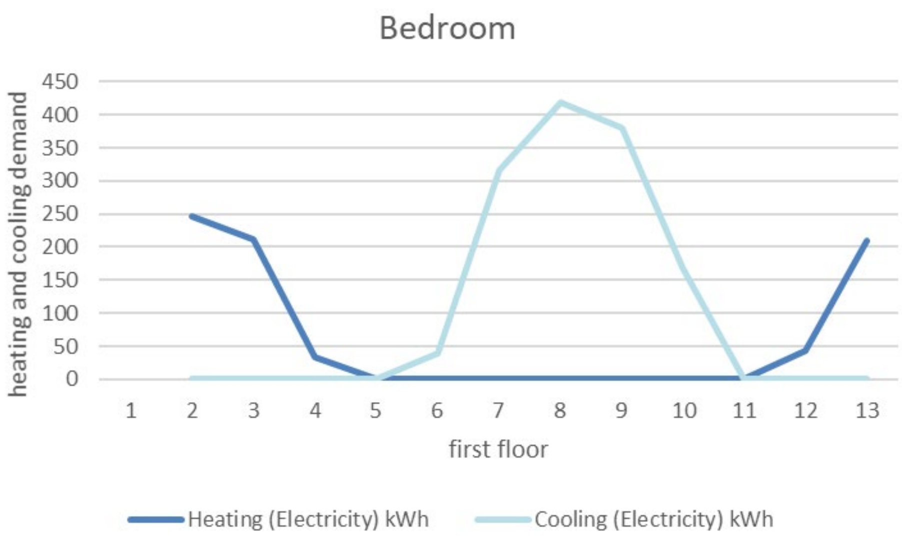


Figure 52. The second bedroom with heating and cooling energy demands

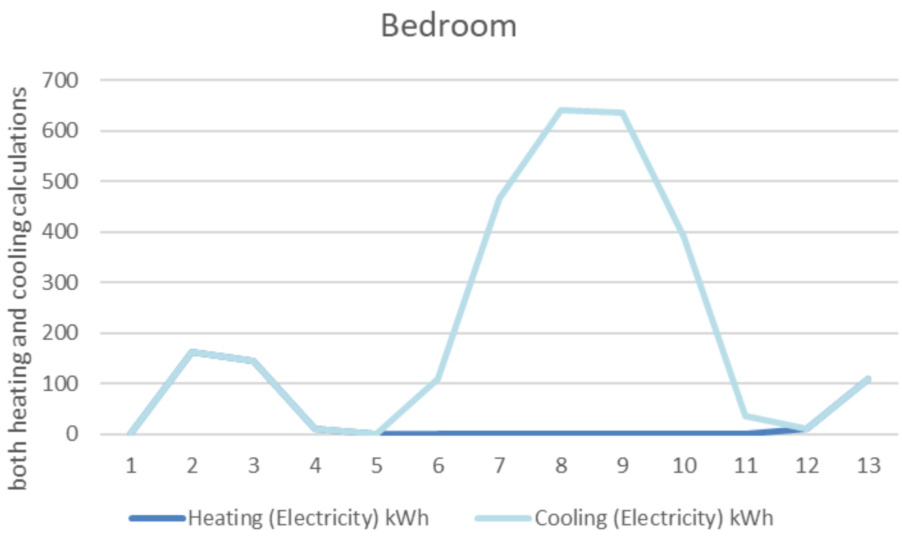


Figure 53. Both heating and cooling calculations

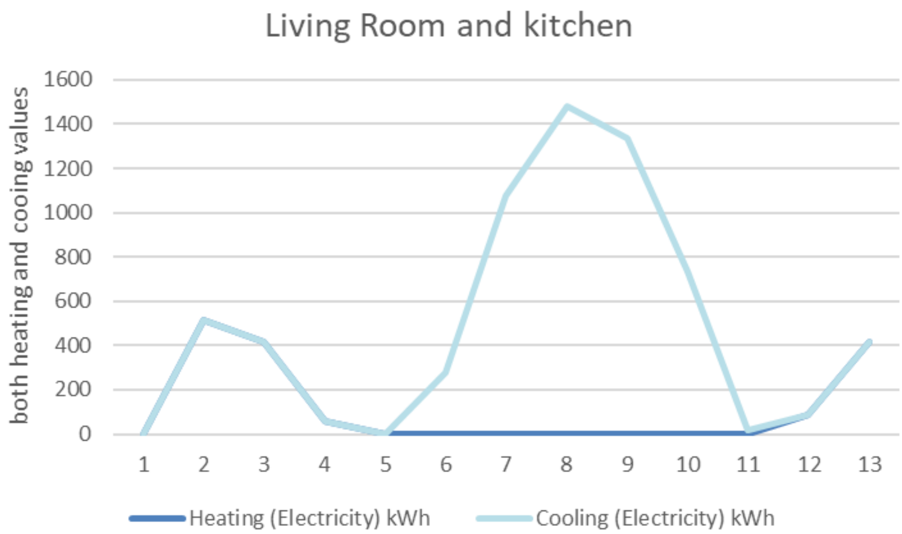


Figure 54. Heating and cooling calculations for living room and kitchen

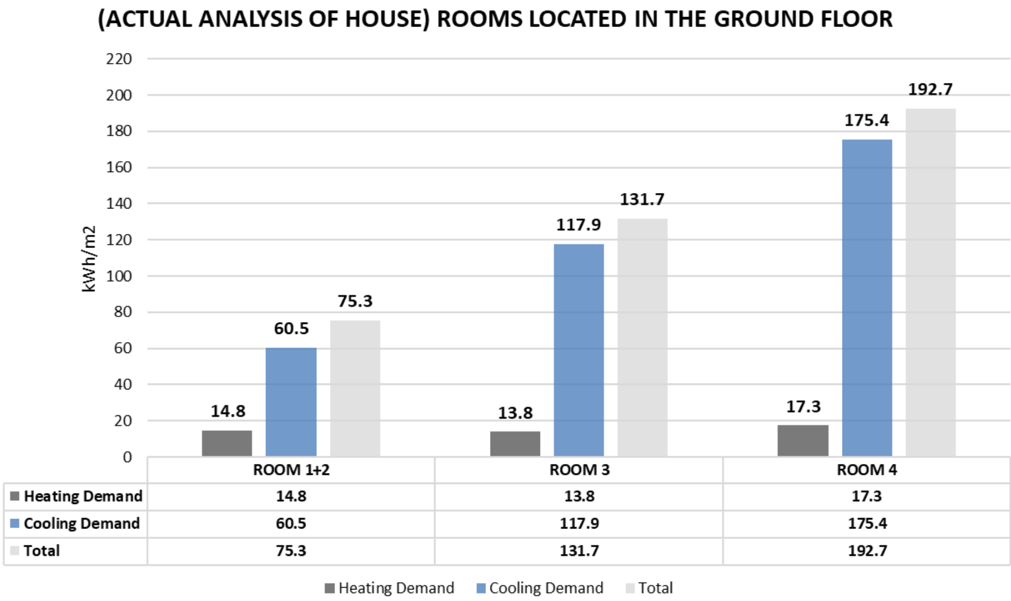


Figure 55. Actual analysis of the house

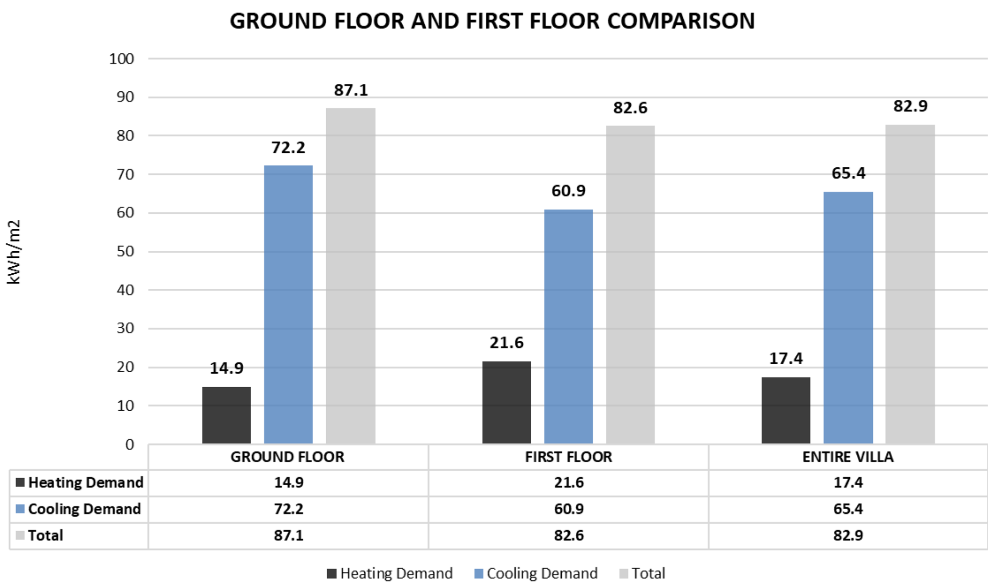
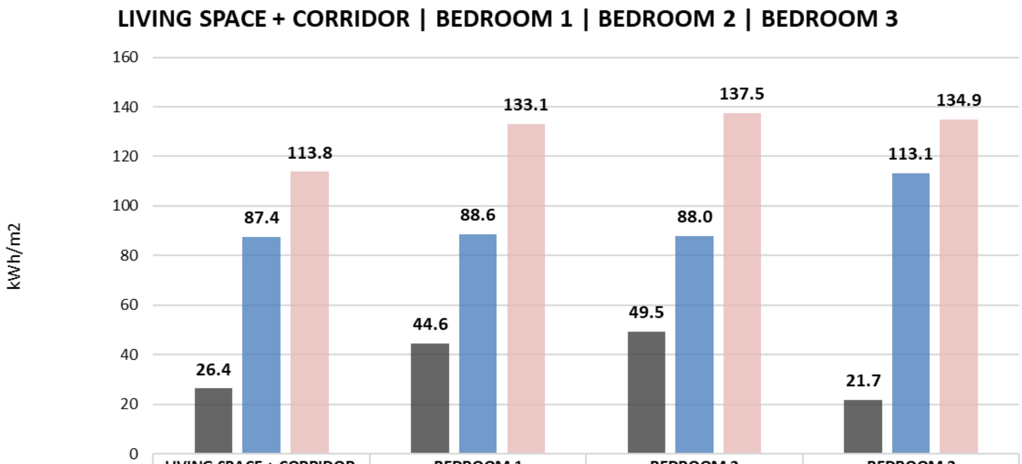


Figure 56. Heating and cooling for ground floor



	LIVING SPACE + CORRIDOR	BEDROOM 1	BEDROOM 2	BEDROOM 3
Heating Demand	26.4	44.6	49.5	21.7
Cooling Demand	87.4	88.6	88.0	113.1
Total	113.8	133.1	137.5	134.9

Figure 57. Heating and cooling demand for living room, bedrooms

CHAPTER 5

CONCLUSIONS

The whole research paper states the importance and the impact of energy efficiency worldwide regarding the environment, concluding that every new structure and existing ones should be based on the parameters given for building more efficiently. Based on the literature review in which all the methods of these systems are explained in detail, further investigations are made in the existing case studies taken for analysis. Based on the simulation program calculations, for the new villa which is in construction, new insulation techniques are proposed. As shown above, each graph shows the existing and new values for each part of the villa. Due to the orientation of the villa, and having both sides surrounded by other structures the ground floor window to wall ratio is 23%. A significant decrease of heating is seen during certain months of the year. Based also in other calculations made by other programs is stated that the energy efficiency materials used are not sufficient to be classified as a zero-net house. With all the given thermal insulations significant changes are also seen in the cooling values.

The window facing the south elevation spends more on cooling demands, since the sun faces the sun mostly. During the year, as stated from the calculations is seen more energy usage on cooling demands rather than heating devices. As illustrated in the above graphics, a higher value of heating demand is registered in the first floor, regarding with the ground floor. A higher cooling demand is seen mostly in areas of bedrooms oriented to the north of the structure. To be mentioned is the master bedroom located in the first floor of the building where it is seen a highly usage of heating, due to its orientation to the south. For this villa attention should be paid to the excellent implementation of insulation of the cladding elements of the building and the installation of glazed components to avoid thermal bridges, which bring not only heat loss but also cause mold in critical areas with different characteristics.

For villa number two, some of the conclusions stated from the calculations are the usage of large surfaces of glass and windows will bring the need for more cooling devices helping the structure during summer time, the same as in winter where temperatures may vary. The fact that this villa is designed with a pitched roof, proves the facilities that structures profit from these types of roofs. The indoor temperatures are stated to be normal due to the good roof design and its insulation, when comparing with the other villa where the roof was totally flat.

CHAPTER 6

APPENDIX - FURTHER CASE STUDIES

Accord, NY Passive House, an architectural project named Accord, NY Passive House, designed in, detail has adopted Passive House design as a challenge and necessity in this project. This project perfectly shows how a passive house can be attractive, flexible, affordable, and, most importantly, comfortable. This project is a much-needed case study designed and built based on passive systems requirements. A major priority in this design is the simplicity and durability of applying structural span design, which allows for future reconstructions and expansions, such as easy interior expansions and renovations. Simplicity is based on the modern expressions of flexibility by combining informality and dramatic expanse of south-facing glass.

The design team implement their concept based on the surrounding farm buildings still familiar and recognizable in New York's Hudson Valley since the Dutch settlers came in the 17th century. In addition, structural spans, utility rough-ins, extensive attic spaces, and modular floor layouts were created to provide for flexible reconfiguration and expansion for future home residents. With PHIUS+ Certification, the project provides an 80 per cent reduction in energy use compared to code-compliant structures. Materials and design choices were selected intentionally for durability, stability, maintenance-free, high-functioning, and simplicity, including plated corrugated steel siding and a trowel-finished concrete slab floor inside. The architects of this project massively propose the usage of large-scale windows on the south façade along with thermal mass floor, building shading devices and adjacent deciduous tree shading. On the other hand, they propose to avoid the design of a hunched slab on grade again on a site that is not close to level.

The New American Foursquare, this structure is located in a transitional suburban neighborhood and is classified as the first Passive House built in this region. For the given structure, the design team aimed to create unique design challenges. For this team, building this structure proved that a spec-built Passive House could compete strongly in the real estate market regarding other houses of standard construction; it illustrated that a Passive House could look and feel like a traditional American house. While designing this structure, the architects considered the sloped site plan, allowing a full walk-out finished basement, effectively creating the house 25% larger than it resembles, avoiding problems related to rainwater striking by implementing an onsite underground rainwater collection and dispersion system, eliminating any drainage from the site.

The cubical shape of the object is excellent regarding the passive house requirements.

These types of designs are large enough for placing all the required programs. In addition, the large overhangs, defining the style of this structure, work intelligently to deal with summer solar overheating. Further elements such as A shallow porch on the south façade, Motorized canvas awnings at all main west windows, capable of 100% shading when required, are placed on the given structure. Both high and low solar gain glasses are placed at different orientations.

This project becomes more special with the integrated designs that are added. Different teams regarding its design and its construction helped this structure to be a passive house design, resulting in a project that proceeded as smoothly and as quickly as any other construction project. Furthermore, for indoor air quality, temperature and humidity, monitoring systems are added.

The *First Passivhaus U.S. School Building*, this structure intends to illustrate the integration of energy-efficient and environmentally sustainable design principles. Firstly, an earth-sheltered program was proposed to be later developed appropriately. The first concepts regarding this school were to serve as an environmental space serving as classrooms and places for practical demonstration. The given object is located in a rural environment with a mixed humid climate.

Mostly this building is occupied by teachers and students, also serving as a building with a capacity of up to 100 people for other purposes. Based on the US climate and its function, various scenarios were calculated to realize the appropriate building requirements in this structure. One situation considered is with a worst-case scenario of 100-person occupancy in mid-summer with high humidity to determine mechanical system loads. Based on these calculations is proved that the building requires only minimal additional heat or cooling. Therefore, there are used a two-stage heating and cooling strategy. Stage one is pre-heating, pre-cooling and dehumidification provided by water to air heat exchanger in the intake of the ERV. Another proposal was made, according to the mechanical systems applied, the application of a high-efficiency mini-split heat pump unit for the second stage, but due to the US-unit, the building is adapted regarding the US-made GSHP.

Glasswood Commercial PH Retrofit, Glass wood is another case study presented in this thesis, serving as a case study in which is treated the Passive House's role in transforming the energy efficiency, inhabitant experience, and marketability of existing commercial spaces, all at affordable cost. Located in a transit-rich neighborhood, the given project transforms the classic 1916 building into an energy-efficient structure, the first Passive House commercial unit. However, the old building construction techniques used have a massive impact on climate change, so the need for readapting these structures is urgent. Therefore, one of the first challenges in this structure was to find the appropriate technology to transform the energy performance while maintaining the same architecture.

Due to several challenges that are given to this structure, architects propose the isolation of the office with the other spaces, especially with the restaurant in which the space between these two functionalities is treated as a partition wall. The adiabatic layer helped this structure to be classified as Passive House. For construction purposes, added layers are placed inside and out of the building, and a new structural exterior element is added. Continuous insulation is added. After testing and verifying proper air-tightness with a blower door fan test, a framed service cavity layer is installed and insulated with cellulose, finished with a layer of interior gypsum. The MEP System used in this structure is classified as a simple one. Heat pump water provides domestic hot water used in the kitchen and for the lavatory room. For cold winter days, the heating system unit can be changed over to electric resistance heat to avoid cooling the space.

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