PASSIVE COOLING:

APPLICATION OF PDEC TOWER SYSTEM IN TIRANA, ALBANIA

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BRISILDA CANI

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IN
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Approval sheet of the Thesis

This is to certify that we have read this thesis entitled **"Passive Cooling: Application of PDEC tower in Tirana, Albania"** 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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Assoc. Prof. Dr. Edmond Manahasa
Head of Department
Date: June, 26, 2023

Examining Committee Members:

Dr. Fabio Naselli (Architecture)

____

Dr. Ina Dervishi (Architecture)

____

Dr. Anna Yunitsyna (Architecture)

____

MSc. Manjola Logli (Architecture)

____

MSc. Nerina Baçi (Architecture)

____

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Name Surname: Brisilda Cani

Signature: ______________

ABSTRACT

PASSIVE COOLING:

APPLICABILITY OF PASSIVE COOLING IN TIRANA, ALBANIA

Cani, Brisilda

M.Sc., Department of Architecture

Supervisor: Dr. Anna Yunitsyna

In the last few years there is a multiplication of the air conditioning in the use of everyday life all around the world. As awareness on the energy consumption has increased, there are attemptsto use a sustainable adaptation method of passive cooling in buildings located in places withhot and dry climates. Passive cooling is a technique that provides a solution to the air conditioning matter in a sustainable way. The study analyzes the application of PDEC tower, itsadvantages and the way how it works. The aim of the study project is to propose the passive cooling method application in a villa located in Tirana, Albania. This research project, exemplifies that passive downdraught evaporative cooling (PDEC) system could be easily adapted into the modern construction in Albania due to the Mediterranean Climate, the results illustrated in this research shows outstanding improvements in thermal comfort for the inhabitants.

Keywords: *passive cooling, porous ceramic system, energy efficiency, simulation, residential building*

ABSTRAKT

FTOHJE PASIVE:

IMPLIKIMI I FTOHJES PASIVE NË TIRANË, SHQIPËRI

Cani, Brisilda

Master Shkencor, Departamenti i Arkitekturës

Udhëheqësi: Dr. Anna Yunitsyna

Në vitet e fundit, është vënë re një rritje e shpeshtë në përdorimin e ajrit të kondicionuar dhe në jetesën e përditshme në të gjithë botën. Si rezultat i rritjes së ndërgjegjësimit në lidhje me konsumin e energjisë, ka pasur përpjekje për të zhvilluar një metodë të qëndrueshme për të aplikuar ftohjen pasive në ndërtesat që ndodhen në vende me klimë të nxehtë dhe të thatë. Ftohja pasive është një teknikë që ofron një zgjidhje të qëndrueshme për reduktimin e përdorimit të ajrit të kondicionuar. Në këtë studim, do të analizojmë ftohjen passive dhe aplikimin e saj në ndërtesa rezidenciale. Do të shqyrtojmë avantazhet e saj, mënyrën e funksionimit dhe nivelin e përshtatshmërisë së për ndërtesa rezidenciale. Objektivi kryesor i këtij studimi është të propozojë aplikimin e metodës së ftohjes pasive në një objekt rezidencial në Tiranë, Shqipëri, e cila ka një klimë mesdhetare. Kjo do të ndihmojë në përmirësimin e efikasitetit të energjisë në Shqipëri gjatë procesit të projektimit të ftohjes passive.

Fjalët kyçe: *ftohje pasive, efiçienca e energjisë, simulim,ndërtesa banimi*

I would like to dedicate this to myself and family for their love and sacrifices in educating and preparing me for my future career. I am very thankful to each one who supported me during my architecture degree.

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I would like to express my appreciation to my supervisor, Professor Anna Yunitsyna, who has guided me to be professional and achieve my master thesisstudy. Without her help, the goal of this project would not have been realized in such a detailed way. It was a great privilege to work under his guidance.

I wish to thank all the people whose assistance in the completion of this study,Epoka University, my friends, and Professors. Finally, I wish to show gratitude also to my family for their support.

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CHAPTER 1

INTRODUCTION

1.1 Problem statement

As in the last 20 years there has been a drastic increase in energy waste, recently humanity has had a rise of awareness of this phenomenon. Concentrating in Albania which in the last years has had an increased number of populations in urban areas, a massive rise of population has been in the capital of Albania, Tirana. Due to this increase of population, there has been the rise of energy use too. However, Albania, being a country with a Mediterranean climate has great opportunities and potentials for developments in energy-efficient buildings. With the analyzing of different factors, the application of passive cooling will be introduced for Tirana city as an energy-efficiency solution, so as to reduce the energy that the air conditioning uses in buildings. The air conditioning in Albania as in the other countries with hot climates has a large use and this brings the concerns on the energy waste. The aim is how to give this problem a solution. Passive cooling is a solution for air conditioning and how it can be applied in Albania. Residential villa is a building that will be designed with the application of the passive cooling technique after studying its potentials and other facilities that are needed. The next step after having an overview on the passive cooling techniques is to create a design process for a residential villa in Tirana. The study consists of an analysis on the passive evaporative cooling system and its methods and the application of the method in the country of Albania. For this system to be applied in a certain building, we need to clarify the conditionsor potentials that the building should have in order to apply the system successfully and to have fully potential energy efficiency. There have been applications of this system around Europe in different kinds of buildings. With the energy problems that we have noticed through the last two decades, particularly the air conditioning, especially in summer, the passive evaporative cooling has been found as a solution toenergy consumption. All the methods discovered until now of passive downdraught evaporative cooling are applied all around the world in different kinds of buildings. Passive evaporative cooling is a technique for air cooling which uses the evaporation of water and various elements. So, if we want to apply this technique in a certaintype of building the development of this system will be based on the accessibility of water resources. This technique of air cooling provides the use of the local climate potential which gives us a low-cost system, also an environmentally friendly solution. Through different studies it will be shown that passive downdraught evaporative cooling (PDEC) is an easily adapted system into the modernconstruction, also it is well integrated with it.

1.2 Objectives

Until the 20th century, the Albania population was concentrated in the village, as in the last 20 years there has been a drastic increase of the population toward the urban areas especially a massive rise of population has been in the capital of Albania,Tirana. Due to this increase of population, there has been the rise of energy use too.

However, Albania, being a country with a Mediterranean climate has great opportunities and potentials for developments in energy-efficient and try to solve the problem of energy consume especially in the building sector

The present project proposal is focused on understanding these problems:

- Identifying sustainable potential on building sector energy efficiency during hot weather taking into consideration the climate.
- How does energy-efficiency effect the house passive cooling
- Application of PDEC tower

But, on the other hand, together with the main energy benefit go numerous co-benefits: the economic saving, and increase of indoor comfort in the building.

The goal of this research is to adapt passive cooling in residential building and develop a Simulation result for this intervention. The objectives of this research are listed as follow:

1. Studying the existing literature to provide a perception into the subject of

passive cooling.

2. Evaluation of the current thermal comfort and cooling energy performance ofthe house project.

3. Generation of models for passive cooling of this building (simulation).

4. Comparison of the simulation and Real Case house.

The Simulation results follow that the buildings passive cooling could improve the buildings' energy performance and thermal comfort during the spring summer months.

1.3 Motivation

Today, energy efficiency is a well-known topic concerning especially the building sector due to the fact that 40% of the energy per year is used by buildings. (EuropeanCommission., 2008). The 20th century helped in increasing the importance of energy efficiency through media, standardization, and national regulations (Ionescu, Baracu, Vlad, Horia, & Badea, 2015). According to (Petroleum British, 2013) with the development of technology and the increase in population energy consumption increased drastically from 1992 to 2012 by 52%. All these brought the need for increasing energy saving worldwide and investing different alternatives for saving energy and promote energy efficiency (Sahin, Arsan, Tuncoku, Broström, & Akkurt, 2015). However, Albania, being a country with a Mediterranean climate has great opportunities and potentials for developments in energy-efficient buildings. With the analyzing of different factors, the application of passive cooling will be introduced for Tirana city as an energy-efficiency solution, so as to reduce the energythat the air conditioning uses in buildings. The air conditioning in Albania as in the other countries with hot climates has a large use and this brings the concerns on the energy waste. Passive cooling is a solution for air conditioning and how it can be applied in Albania. Residential villa is a building that will be designed with the application of the passive cooling technique after studying its potentials and other facilities that are needed.

1.4 Aim and originality of the study

The literature review persuade in the previous paragraph highlights the importance of energy efficiency in the building sector using passive cooling methods. This research can provide an original endowment to the passive cooling efficiency.

Therefore, the aim of this project is to develop a method based on a systematic approach which would remarkably contribute to the energy efficiency field in Albania and the Mediterranean climate. The project is based on energy performance and indoor comfort analysis, taking into consideration summer months of the year. The main significance of this project is improving the inhabitance indoor comfort and reduces the yearly energy.

The aims of the study are as follows:

1. Having a general overview in passive cooling technique.
2. Study of the selected site in Tirana for its conditions and potentials.
3. Application of the passive cooling system in a residentialvilla.
4. Evolution of the building performance.

1.5 Design Approach

The site selection is made taking in consideration all the climate conditions of Tirana city. The selected building is residential, this decision was made because according to different statistics on the Albanian country the residential sector is the main user of electricity considering also the number of residential buildings the consume of the energy for heating and cooling in the residential sector is 46.5% of the total used energy. Almost all residents use air conditioning as a solution to the summer heat, but of course there are also people that, according to their economic conditions are not able to have such a solution, they just keep going with the heat. One of the passive cooling methods will be applied in a two-floor high building. The passive cooling application the approach is to have led to energy waste and more energy efficiency. How can the PDEC tower be applied in a residential villa through thedifferent analysis of the passive cooling and the selected site.

1.6 Organization of the thesis

This thesis is divided into 6 chapters. The organization is done as follows: In Chapter 1, the Introduction, thesis objective, motivation, design approach and Aim ofthe study are presented. Chapter 2, consists of Literature Review: theoretical background, case study and case study comparison. Chapter 3, consists of explaining the project area study, focusing on the position of the site, climate and terrain. Chapter 4 is the results followed in this study, concept of the project, implementationof passive cooling method, simulation and comparison of the Real Case and Proposed Passive cooling method and Limitation. In Chapter 5, the discussions are explored while Chapter 6, conclusions and recommendations for further research are stated.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of the passive cooling application

Creating energy-efficient buildings has attracted and increased recognition in the literature the past decade in an effort to pursue sustainable development. As in the last 20 years there has been a drastic increase in energy waste, recently humanity has had a rise of awareness of this phenomenon. Concentrating in Albania which in the last years has had an increased number of populations in urban areas, a massive rise of population has been in the capital of Albania, Tirana. Due to this increase of population, there has been the rise of energy use too. However, Albania, being a country with a Mediterranean climate has great opportunities and potentials for developments in energy-efficient buildings. With the analyzing of different factors, the application of passive cooling will be introduced for Tirana city as an energy-efficiency solution, so as to reduce the energy that the air conditioning uses in buildings. The air conditioning in Albania as in the other countries with hot climates has a large use and this brings the concerns on the energy waste.

Passive cooling is a solution for air conditioning and how it can be applied in Albania. Residential villa is a building that will be designed with the application of the passive cooling technique after studying its potentials and other facilities that are needed. The next step after having an overview on the passive cooling techniques is to create a design process for a residential villa in Tirana. The study consists of an analysis on the passive evaporative cooling system and its methods and the application of the method in the country of Albania. For this system to be applied ina certain building, what are the conditions or potentials that the building should have in order to apply the system successfully and to have fully potential energy efficiency. There have been applications of this system around Europe in different kinds of buildings. With the energy problems that we have noticed through the last two decades, particularly the air conditioning, especially in summer, the passive evaporative cooling has been found as a solution to energy consumption. All the methods discovered until now of passive downdraught evaporative cooling are applied all around the world in different kinds of buildings. Passive evaporative cooling is a technique for air cooling which uses the evaporation of water and various elements. So, if we want to apply this technique in a certain type of building the development of this system will be based on the accessibility of water resources. This technique of air cooling provides the use of the local climate potential which gives us a low-cost system, also an environmentally friendly solution. Through different studies it will be shown that passive downdraught evaporative cooling (PDEC) is an easily adapted system into the modern construction, also it is well integrated with it.

Water consumption as the evaporative cooling system is not so applied and spread as a process because of the water consumption that is thought to have shown that it consumes more water than the electric powered ac system. But different studies that are made prove that with the right calculations and measurement of different elements we can achieve a successful sustainable system of evaporative cooling

2.2 PDEC-passive downdraught evaporative cooling

PDEC is a technique originated from ancient Egypt applied in most of the countries with hot and dry climates (Kamal, 2011). In the ancient period for cooling, they used traditional techniques such as "wind catchers" or "malqafs", they were called wind catchers because of the way they functioned, and they were like towers placed in a certain place of the building or just attached to the building. Their main function was the cooling, so they function as wind catchers, they capture the wind and as the wind enters the tower it reacts with the porous water in the pots. This process also with evaporation which cools the air before it enters the space brings a drop of temperature after the air enters the interior space (Kamal, 2011). PDEC towers are used as a method of air cooling in a natural way; they consist of towers that are constructed among the buildings. The main function of passive cooling consists of removing unwanted heat gains in a certain space and the main characteristics or potentials that affect the PDEC functioning are the wet dry bulb temperature and dry bulb temperature (Y. Song , K. S. Darani , A. I. Khdair , G.Abu-Rumman, R. Kalbasi, 2021). These two important elements are important because if the difference between the indoor dry bulb temperature and wet bulb temperature is higher than 22°C it causes problems with thermal comfort for the inhabitants. It is suggested that this difference mentioned above to be low enough to have maintenance of the thermal comfort temperature. As long as the air-dry bulb temperature similar or close to the ambient air wet bulb temperature it is achieved a higher evaporative efficiency for the building. The elements of the PDEC tower havea variation and also a limitation depending on the conditions and the potentials of theintervention space or building. The main element is the water supply which is usuallyplaced on the top of the tower, the other elements are: fiber pads, corrugated cellulose and spray. PDEC is a term that is defined as a passive and low energy technique for cooling and ventilating spaces in hot, dry climates and improve the inhabitants' comfort (J B Paanchal, N Mehta, 2017).

The PDEC system is divided into two main methods which consist of a PDEC tower with pad and a PDEC tower with spray shown in *(Figure 1).* The towers include a top side opening and an inner division. They function in a way that theparts of it capture the wind from different directions and in such a way it creates a different air system cooling through the evaporation of water than goes straight to theattached building. Large volumes of fresh air from PDEC towers considerably improve the thermal comfort and the quality of the air in a space (D. Robinson,K. J. Lomas, M. Cook, H. Eppel, 2004). They are also relevant in regions without wind, creating airflow by transferring from water drops to the air and density difference (M. J Wu , K. Zhao , F. Fils-Aime, 2022).A modelling in Energy Plus was developed by Givoni (Givoni, Indoor temperature reduction by passive cooling systems, 2011) which by this far is the only and most reliable made model for predicting the impact that PDEC towers with spray have on the air cooling. This model works as atechnique of PDEC for measuring two main parameters which are able to be determined when the water flow rate is known: the temperature and the volume flow rate of the exit air. The advantage of sprayers rather than wet pads is that aerodynamic resistance is lower, and airflow through the tower was expected to be inflated, and also the pads in desert regions are difficult to be implemented (E.V. Gómez,F. J. Rey-Martínez, F. Varela, 2005).

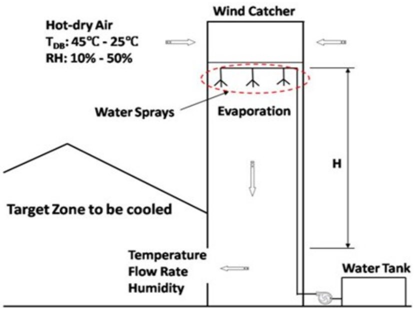

Figure 1. Schematic of PDEC tower with spray (pp. Kang, Stand;2009)

2.3 PCS-porous ceramic system

Porous ceramic system is another technique of air cooling which consists of a column unified into a perimeter cavity wall and can also is in contact with the roof where ceramic evaporators are treated as a wind-catcher (John Kaiser S. Calautit, Ben Hughes, 2016). The fact that this system needs to be in the perimeter wall makesit possible to be applied only in the perimeter spaces. If we have a certain building with a deep plan the other spaces that are located in the middle need to apply another alternative method. The advantages of the porous ceramic system except the air cooling are also the effects on the noise and pollution problems in the meantime the security problems too; because of the way this wall system is applied it reduces the impact of the noise entering a certain space. The disadvantage is that it only affects the perimeter spaces; the other spaces in the deeper plan cannot be affected. It is a system which can be easily applied and well-integrated into modern structures and it can be integrated with various functions except cooling, to improve the building performance. Unlike the PDEC system PCS does not apply with water and there is no need for a pressure system (G. Chiesa, M. Grosso, A. Bogni,, G. Garavagliaa, 2017). PCS can be applied in different buildings and with different ceramic materials, always depending on the potentials of the building such as the climate and the important factor is the dry bulb temperature and wet bulb temperature the sameas the PDEC system. The PCS can be applied in various elements of the building but the most appropriate and effective element is the wall integrated system where it consists of the integration into the perimeter wall of the building. As the air enters through the controllable opening of the PCS it becomes heavier and cooler as a resultof the contact with the wet surface of the PCS which then goes into the indoor space through another controllable opening in the low part *(Figure 2).* Another application can be in the roof system where PCS can be integrated with a wind-catcher always depending on the conditions on a certain space. One of the limitations of the PCS is the operation of it which works only at a room level. The application of the PCS depends on the type of the constitution of the building. PCS contains ceramic modules which are easy to be integrated into the concrete wall construction, but itcan also be an addition to the wall when there is no possibility for the integration in the wall. A diaphragm wall can be added into the existing wall, it can be added also on the outside part when there is a balcony or terrace located in the perimeter wall. According to various analyses, the PCS comprise approximately 10% of the deadload of a concrete structure per linear (Schiano-Phan, 2004).

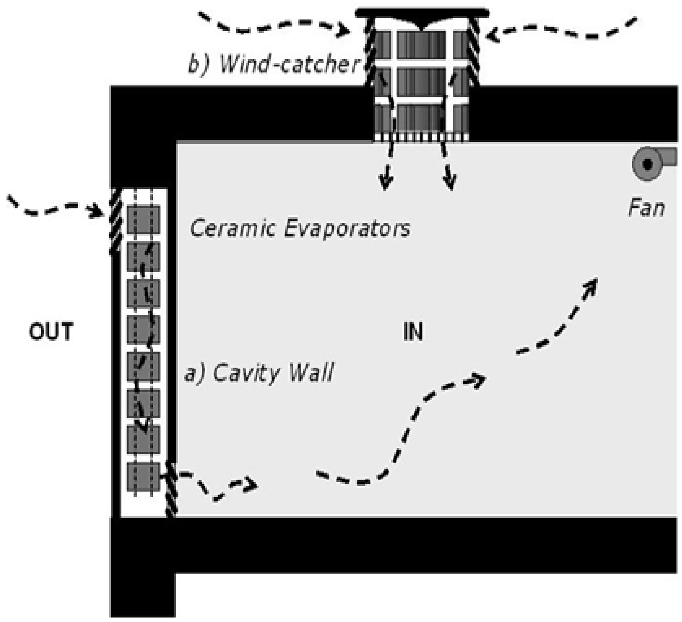

Figure 2. Principles of integration of the porous ceramic system (pp. Schiano-Phan,2004)

2.3 Case Studies

2.3.1 EXPO’92 in Seville

EXPO’92 in Seville designed by Nicolas Normia and Jean Marie Hennin is considered to be the first modern approach of the PDEC towers with a spraying system (S. Álvarez, E. Rodríguez, J. Molina, 1991). These towers serve mostly for the cooling of the outside space around the location. PDEC towers are about 30 m high and they consist of three main elements: wind catcher, water pond and an evaporative column. The geometry of the design achieves an acceptable and satisfactory in the air temperature distribution Night ventilation is another cooling method which in this design is combined with PDEC to have a successfulapproach in Seville’s climate. Also, another important element was the control of solar heat gain, in order to have a successful approach of the passive cooling it was necessary to have as low as possible solar heat gains. Solar heat gains were managed by the combination of two elements in this design: the sun-shade andthe south-facing glazing which were used as an element to maximize the reflection light into the offices. According to the studies by De Montfort University, UK the performance of the PDEC tors in the EXPO’92 Seville consist to be a smart choice as economically and technically applicable. Some calculations of the study through simulation shows that the energy consumption was 75% below the air-conditioning reference building and the costs were 3-5% below the air-conditioning reference building. Also, a disadvantage was the wet bulb temperature which sometimes was too high (S. Álvarez, E. Rodríguez, J. Molina, 1991).

Figure 3. EXPO'92 Seville towers (Expo 92: A look back at Seville's City of the Future by Barry Neild, CNN)

2.3.2 Home+

Home+ designed by the Hochschule für Technik team in Stuttgart, Germany was part of the Decathlon competition where it won several prizes and one of the prizes was about the passive features including: thermal mass, sun-shading elements and evaporative cooling system. This house was equipped with a PDEC tower with a pad system. Several studies have been conducted for the performance of the PDEC tower and it resulted with different problems. Firstly, the force of the wind was not asexpected, since the wind is an important feature for the tower to be functional but nature is unpredictable. In this case study, temperature between 20 °C and 27 °C and humidity between 4 and 15 g/kg have been considered as the set up for the internal comfort for the analyze of the location where the project is located (F. Babich, M. Cook, J. Cremers, G.Papachristou, 2017). Another problem for the good performanceof the tower was its height which was needed to be at least 6m above the roof but dueto the criteria of the competition was not able to arrive 6m height, it was allowedonly until 5.5m as shown *(Figure 4,5,6)*. Also, the wet pad which is a recommended system for the low wind conditions did not function as expected. The main methods of the site location were the wet bulb temperature, dry bulb temperature, and wind speed and wind direction for the weather prediction (F. Babich, M. Cook, J. Cremers,G.Papachristou, 2017).

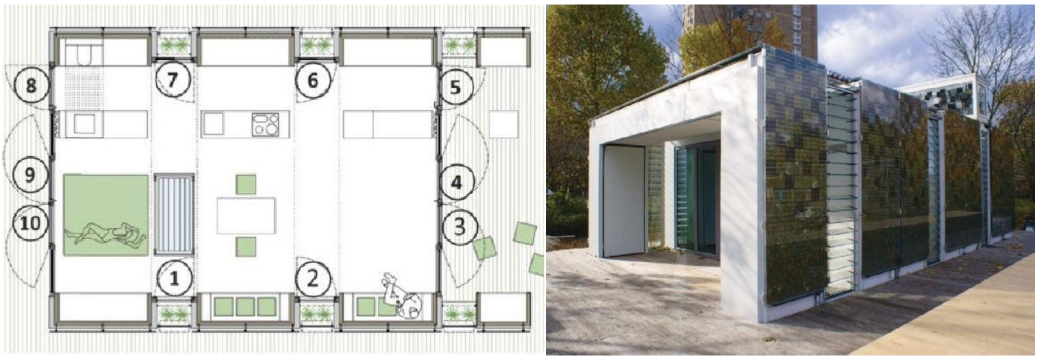

Figure 4. 'Home + ' floor plan, Outdoor photo (F. Babich, M. Cook, J. Cremers, G.Papachristou, 2017)

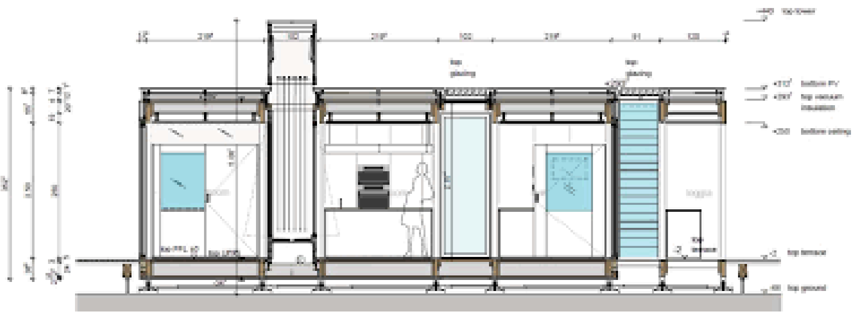

Figure 5. *'Home + ' section (Team HFT Stuttgart, 2010)*

Figure 6.'Experimental setup-top of the tower (left) and textiles used as moist surfaces (right) (F. Babich, M. Cook, J. Cremers, G.Papachristou, 2017)

2.4 The Ten Commandments

The Ten Commandments housing complex located in Seville *(Figure 7)*, Spain consists of ten social housing blocks and 300 housing units *(Figure 8)*. The porous ceramic system that is applied in the above-mentioned complex provides temperaturebelow 28 °C lower than the outdoor temperature that is 32 °C. A risk of applying thissystem was thought to be the humidity level but it was avoided as a result of the inlet opening which is controlled automatically. In the first studies at the apartment buildings in Seville it was conducted according to the geometrical applicability 70% of the building can be fully applicable but on the other hand the 30% could not remove the air conditioning loads entirely. As a result of the study, it is achieved 31 kWh/m2 energy saved with the application porous ceramic system. Apart from the energy saving also the cost is estimated to be lower than the air conditioning system cost. So as a conclusion of the study on the apartment complex in Seville the porous ceramic system is an achievement economically and in energy saving.

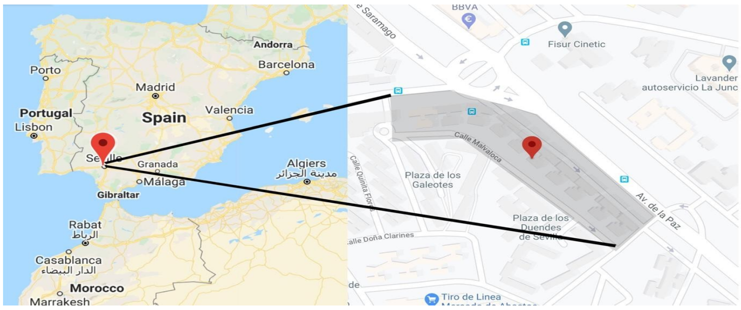

Figure 7. Location of the building Ten Commandments (GoogleMaps, 2023)

Figure 8. Location of the building Ten Commandments (pp. Schiano-Phan,2004)

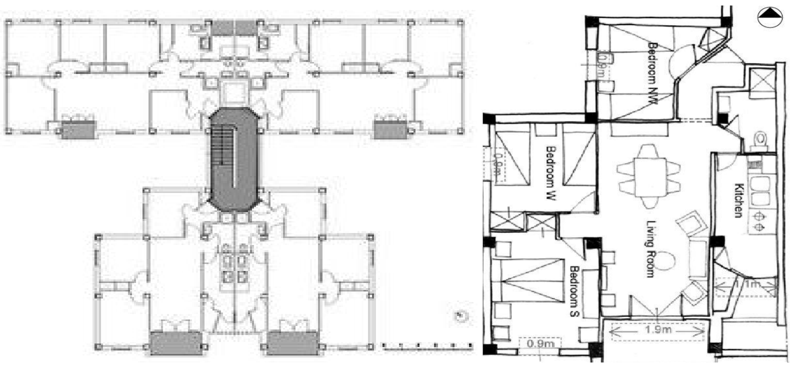

Figure 9. Apartment plan and Living Unit (pp. Schiano-Phan,2004)

2.5 Complex of the inspector general of police (IGP)

Complex of the inspector general of police (IGP) located in Gulbarga, Karnataka is a two-story building constructed with modern materials *(Figure 10)*, (J.Prajapati, J.K Nayak, 2007). The location of the IGP building consists of hot and dry climate. In the buildings are considered various methods for energy saving, one of them is the use of PDEC tower system "tower shower" *(Figure 11)*. The study of the performance of PDEC towers which are applied in the entire building shows that the temperature is 12°C -13°C lower than the ambient air temperature. The PDEC tower system in this building has achieved the predicted results *(Figure 12,13)* (J. Prajapati,

J.K Nayak, 2007).

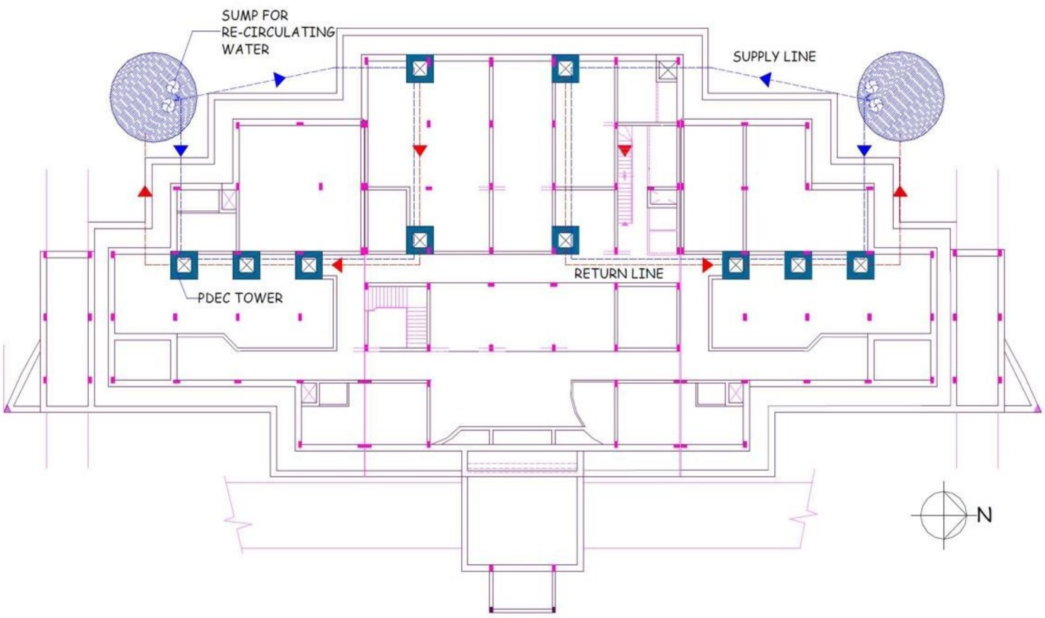

Figure 10. The layout plan of I.G.P. Complex, Gulbarga (J. Prajapati, J.K Nayak, 2007)

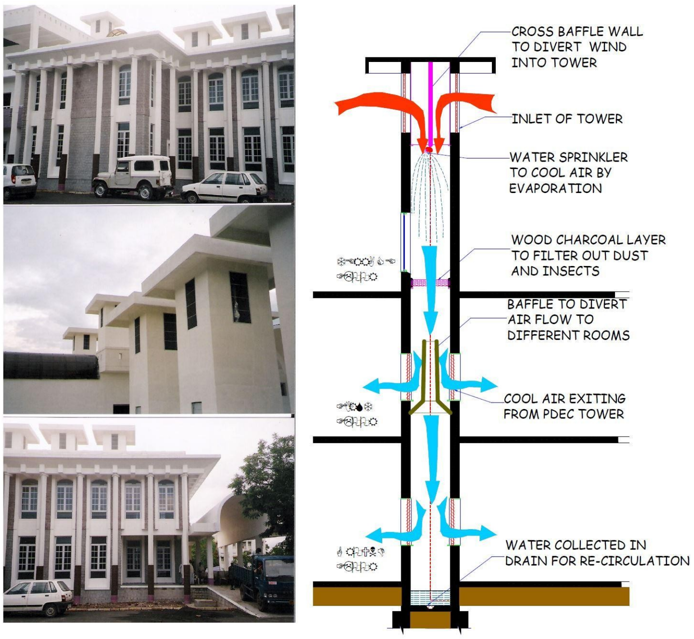

Figure 11. Image and Detail Section of I.G.P. Complex, Gulbarga (J.Prajapati, J.K Nayak, 2007)

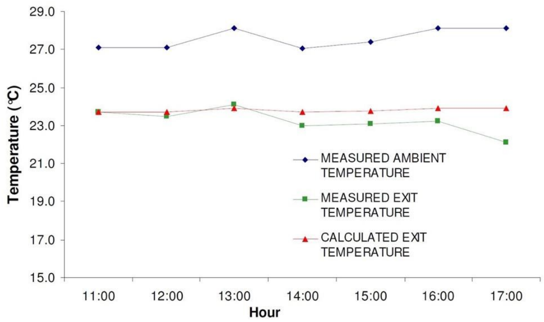

Figure 12. Comparison of measured and predicted temperature of air exiting PDEC tower (J. Prajapati, J.K Nayak, 2007)

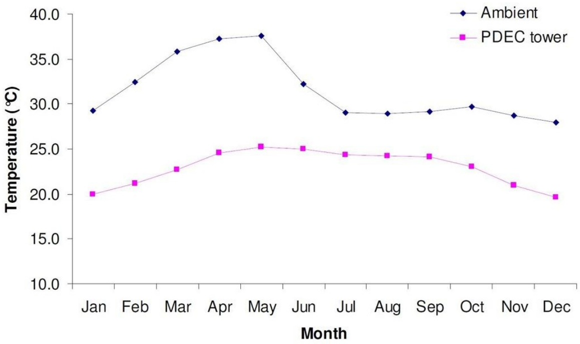

Figure 13. Monthly prediction of the temperature of air exiting the PDECtower (J. Prajapati, J.K Nayak, 2007).

2.6 Prototype house

Prototype house located in Riyadh; Saudi Arabia it is a one floor house designed for 8-11 inhabitants. The PDEC towers are applied in different spaces ofthe house including: lounge, dining area and bedrooms *(Figure 14)*. The PDEC towers applications bring a satisfactory drop in temperature (Givoni, Performance of the “shower” cooling tower in different climates, 1997). The system applied in the prototype house is the “misting towers” which consists of misting nozzles that are used to spray tiny droplets of water bringing the evaporative process. The void of the tower during the proposal was a problem because of the measurements it achieved a 2.2% void/floor ratio *(Figure 15,16)*. But during the construction there were some interventions in the voids of the towers and their location in order to have anappropriate distribution of cool air through the spaces. The results of this application were satisfactory as for the energy saving and also for the economical part (Givoni, Indoor temperature reduction by passive cooling systems, 2011).

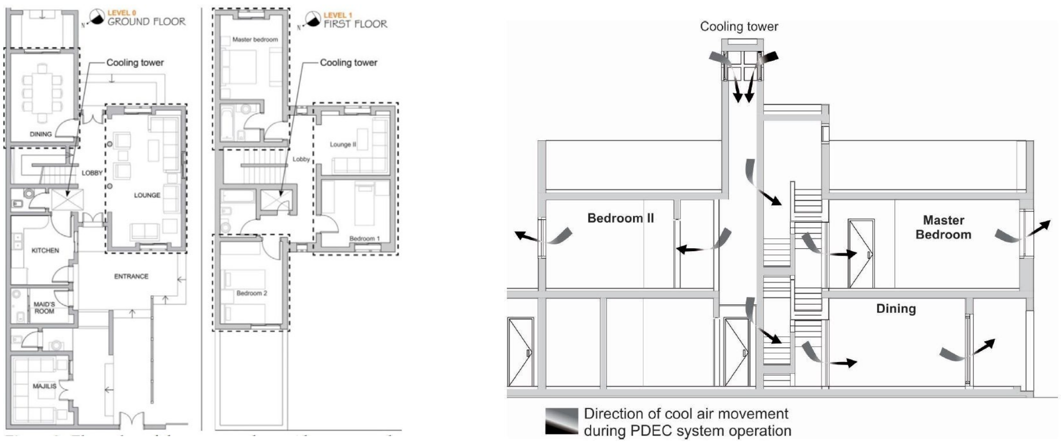

Figure 14. Floor plan and section of the prototype house (Givoni, Indoor temperature reduction by passive cooling systems, 2011)

	(% hours in comfort zone)			
	Case 1: Base case with natural ventilation	**Case 2:** Solar control and building envelope enhancement	**Case 3:** PDEC in operation (present)	**Case 4:** PDEC in operation (future)
G.F lounge	41	52	81	77
Dining	38	50	80	76
F.F lounge	39	49	88	85
Bedroom 1	36	48	89	84
Bedroom 2	39	47	86	81
Bedroom 3	36	46	83	79
Average**	38	49	84	80

Figure 15. Floor plan and section of the prototype house (Givoni, Indoor temperature reduction by passive cooling systems, 2011)

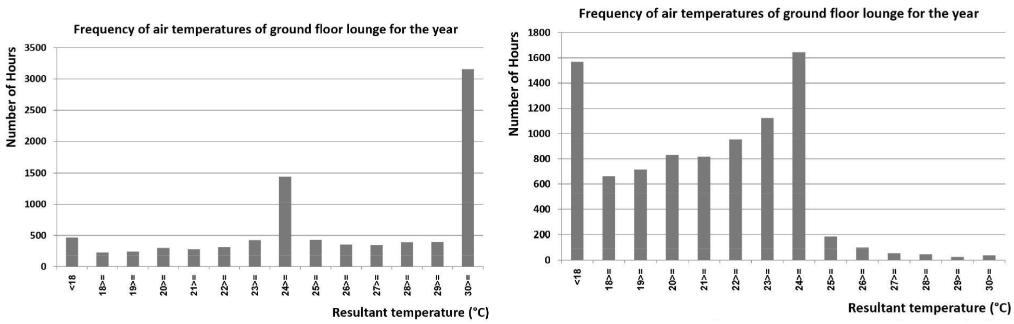

Figure 16. Frequency of air temperatures of ground floor lounge space forthe year (Case 2 & 3) (Givoni, Indoor temperature reduction by passive cooling systems, 2011)

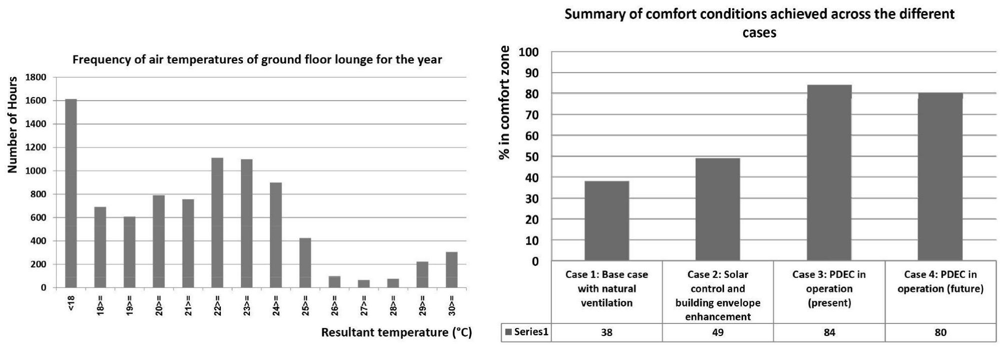

Figure 17. Frequency of air temperatures of ground floor lounge space forthe year (Case 4) & Summary of comfort conditions achieved across the different cases (Givoni, Indoor temperature reduction by passive cooling systems, 2011)

2.7 Summary Table of Case Studies

Table 1. Summary table of case studies (Cani 2023)

Case Study	Location	Climate	Keyword
EXPO'92	Seville, Spain	Mediterraneanclimate	PDEC tower, Evaporative column, Ventilation, Wet bulb
Home+	Stuttgart, Germany	Slightly Continental	Pad System, wind, tower, water
The Ten Commandments	Seville, Spain	Mediterraneanclimate	Ceramic system, apartment, towers, porous system, ceramic
Complex of the inspector general of police	Gulbarga, India	SubtropicalClimate	Tower Shower, PDEC Tower, Wind, Water, Air Flow
PrototypeHouse	Riyadh, Saudi Arabia	DessertClimate	Water drops, cool air, misting tower, PDEC Tower

As the summary table shows, the five selected study project analyzed and compares all the examples with each other. The first project expo 92' is taken into analyzed since is the first approach to cooling tower implemented even though it didn't work on an actual building. The second example Home+ is analyzed due to thefact that it is a residential building but is not the best example of the cooling tower due to some technical fails. The third and last example are cooling tower implemented on residential building which are similar to the project proposal since they are residential and the cooling towers are placed in the common areas of the building. The ten-command project located in Spain is also similar to the climate of Albania which is Mediterranean with hot summers. While last but not least the IGP complex is a good example of the cooling method tower which in analyzed in details but, the purpose of the building is not the same as the project.

2.8 Terms

PDEC-Passive downdraught evaporative cooling

PCS- Porous ceramic system

AC- Air conditioning

RC- Real Case

CHAPTER 3

CASE STUDY SELECTION

3.1 Position of the selected site

The physical and geographic position of Albania sets in the Adriatic-Ionian Sea, western part of the Balkan Peninsula, southeastern Europe.

Figure 18. Europe Map with location of Albania (https://www.mapchart.net/europe.html)

The 19th century marks growth of the Albanian urban areas. During this century, cities located on flat terrain like Tirana, Shkodra, Elbasan, Kruja, etc., experienced an expansion of architecture moving away from the villages toward the cities (K. Lulo, K. Tummers, 1970).

After the research and study of the two methods of the passive cooling such as

PDEC and porous ceramic system and the analysis of the selected case study project in literature revie, PDEC tower will be applied in the case study selection as the mosteffective intervention based on the Albanian climate.

3.2 Climate context of the selected site

The climate of Albania is Mediterranean and it is distinguished by mild winters with generous precipitation and hot, dry summers (Lionello, et al., 2006). Taking in consideration the complexities of all the geographical and physical factors, the country isdivided into four main climate areas: Field Mediterranean Area, Hilly Mediterranean Area, Pre-mountainous Area, and Mountainous Mediterranean Area (Kuriqi & Ibrahimllari, 2014).

Albania is characterized with Mediterranean climate with soft and humid winters andhot and dry summer (Kuriqi & Ibrahimllari, 2014). During the summer season in the inner spaces the amount of the heat that enters is caused by various factors such asthe sun heat, the electrical and mechanical equipment and from people. The most important factor is the sun heat which brings the need for air-conditioning and with the use of AC there is energy consumption. The sun heat is transferred in a space through different building elements such as the transparent glass windows, the wall surfaces and others. Tirana is the capital of Albania and is characterised by the warm and temperate climate. According to climate data researchers the average temperature of Tirana is 23.8 C/ 74.8 F and July is considered the warmest month (Meteonorm, 2020).

The lowest average relative humidity is in July-62%. Also, it is illustrated in the table of the average humidity in Tirana (Meteonorm, 2020).

The average daylight goes to 15.1 h in June which is considered to be the month with the longest days as it is shown in the table of average daylight and sunlight in Tirana, the average sunshine is 11.4h in the month of July which is considered to be the month with most sunshine.

The average hourly wind speed and direction in Tirana varies through the course ofthe year. For the statistics as illustrated in graphics the windier part of the year lasts for 5.6 months with the average speed more than 7.0 miles per hour from October19- April 8, and the calmer time lasts for 6.4 months with the average speed of 5.6 miles per hour from April8-October 19 (Meteonorm, 2020).

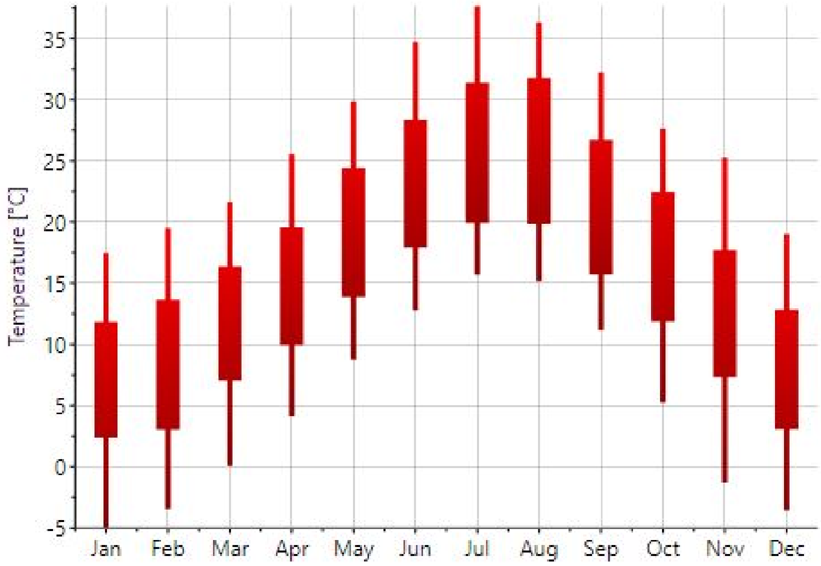

Figure 19. Average high and low temperature (Meteonorm, 2022)

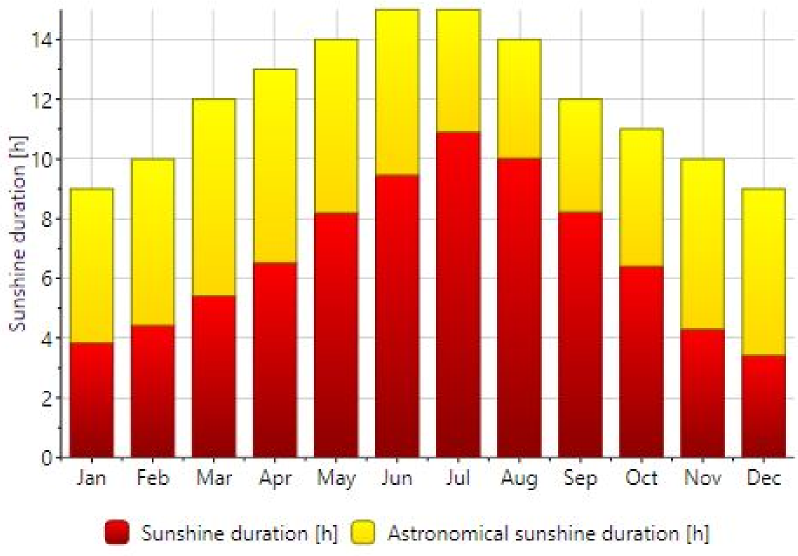

Figure 20. Average sunshine duration (Meteonorm, 2022)

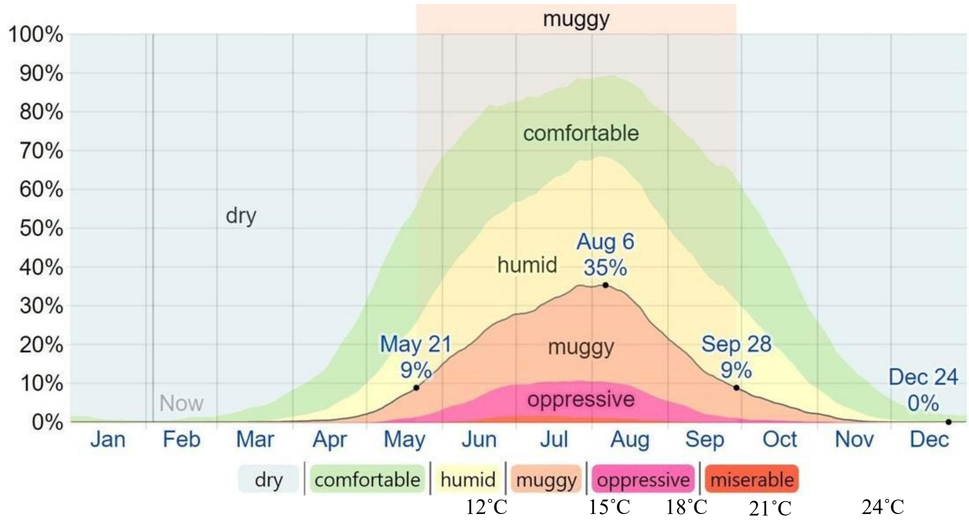

Figure 21. Humidity control levels (the percentage of time spent at various humidity comfort levels categorized by dew point) (Spark, 2022)

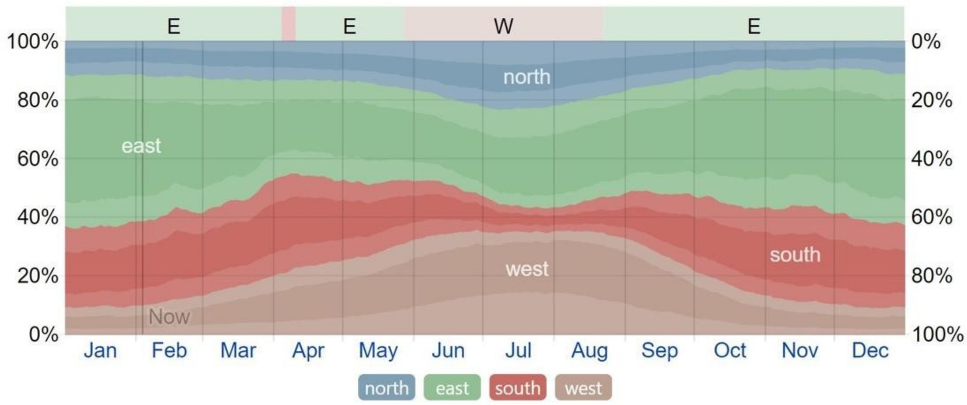

Figure 22. Wind direction (Spark, 2022)

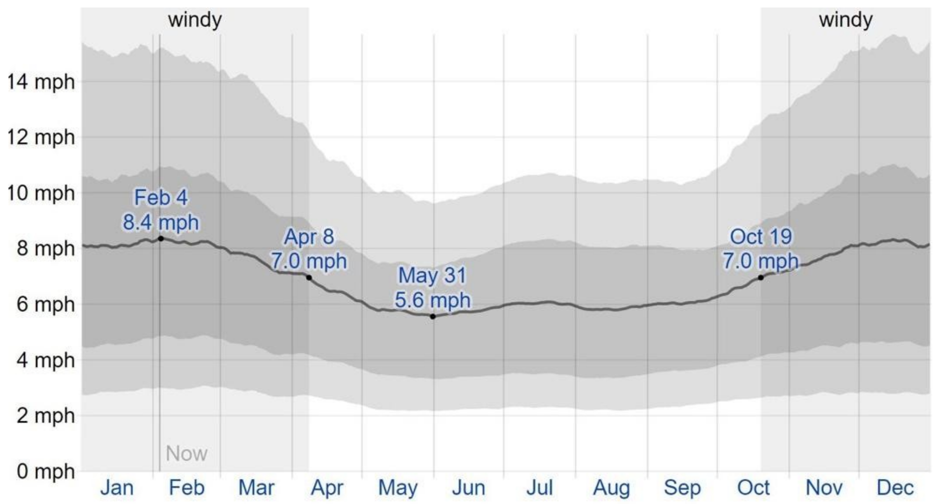

Figure 23. Average wind speed (the average of mean hourly wind speed (Spark, 2022)

Figure 24. Hours of daylight and twilight (Spark, 2022)

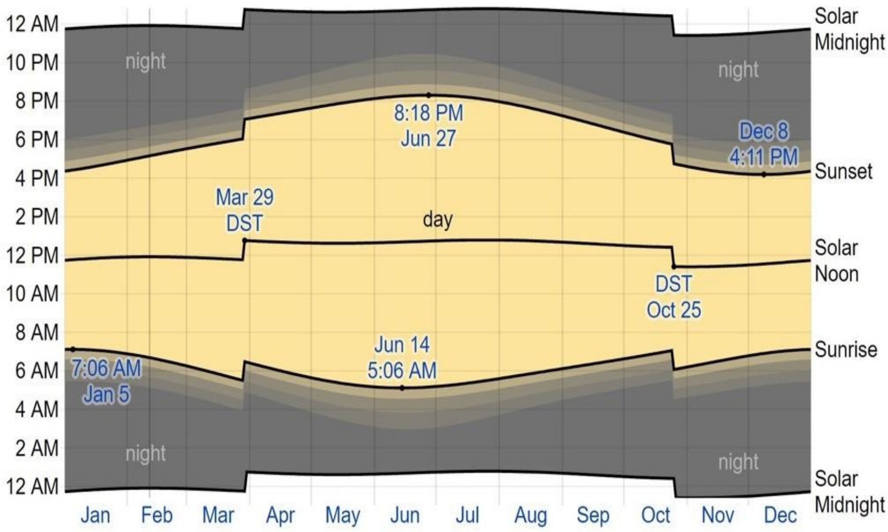

Figure 25. Sunrise & Sunset with twilight and daylight-saving time, (Spark, 2022)

3.3 Terrain of the site

The physical and geographic position of Albania sets in the Adriatic-Ionian Sea, western part of the Balkan Peninsula, southeastern Europe. The terrain is mountainous, where hills and mountains present 77% of the country’s territory. Such a terrain positionhas given complex landscapes, strong tectonic movements, particularly in its southern portion.

Figure 26. Albania Map with location of Tirana (Google, 2023)

Tirana is located in the central part of Albania; enclosed by mountains and hillswith Dajti rising to the east. Tirana city lies 110 m above sea level.

3.4 Concept Design

3.4.1 Site analysis

The site is located in Tirana, in a village called Mullet which lies 167 m above the sea level. The village is located 10.8 km from Tirana Center. The area is a suburban area, with a mainly residential character. It is mainly characterized by low buildings of the residential villa type with a height of 1-4 floors.

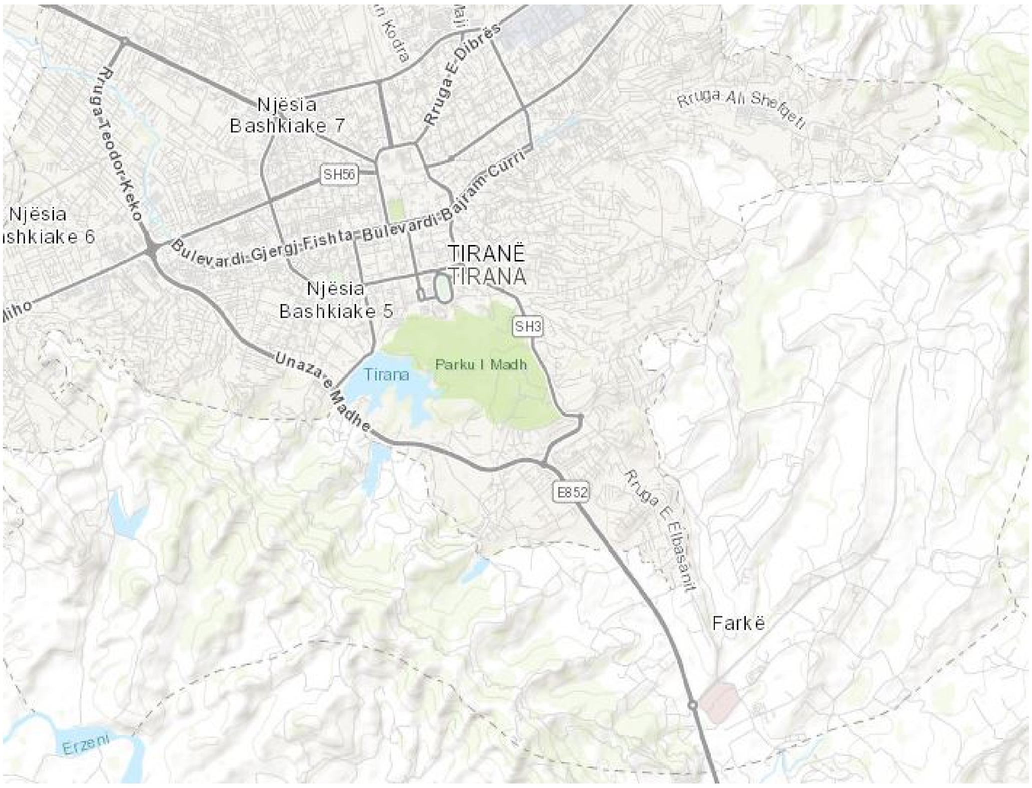

Figure 27. Tirana Map (Google,2023)

Figure 28. Site project proposal (ASIG,2023)

Figure 29. Site project photos (Cani,2023)

The object is developed on a land with an area of 1000 m2 and is surrounded mainly by empty greenery or by residential buildings with a height of 1-4 floors. The proposed project is bordered in the northern part by a building with a height of 1 floor, in the southern part it is bordered by an existing road e, with a distance of 3.3mfrom the border of the plot and 7m from the nearest line of the proposed building. As for the eastern part, it is limited by a 4-storey building with a distance of 2.4m from the border of the site and 12.2m from the nearest line of the proposed building, while on the western side it is limited by empty green areas. Access to the property is through the existing road.

3.4.2 Spatial Distribution

The building entrance is on the southern facade and rises with 3-foot ladder off the ground. The object has two levels. One of the stairs connects floor 0 with the underground floor and is positioned inside the building, in the northern part. The other staircase connects floor 0 to floor 1, positioned inside the building and will be lit by the southern facade and the fifth facade.

On the ground floor, shown in (*Figure 30.b)* the functional distribution includes two living spaces, dining, cooking, sleeping and three toilets. On the technical first floor, shown in (*Figure 30.c)* the functional distribution belongs to a study space, three sleeping spaces and three toilets. While on the underground floor shown in (*Figure 30.a)*, the functional distribution belongs to a recreational space, a studio¸ a technical room, a storage room for wood and a toilet.

On the 0th and 1st floor, lighting and ventilation is realized through the four sides of the facade. The floors are developed high with a floor-to-floor height of 3.44 meters, based on Albania regulation standard for buildings. The surfaces of the floors of the building are as follows: Floor -1: 167.2 m2, Floor 0: 157m2, Floor 1: 143m2.

a

b

c

Figure 30. a. Underground floor spatial distribution, b. Ground floor spatial distribution, c. Second floor spatial distribution (Cani, 2023)

a b

c ***d***

Figure 31. a. Underground floor plan, b. First- floor plan, c. Second floorplan, d. Terrace floor plan (Cani, 2023)

Below you will find attach the sections of the proposed building project.

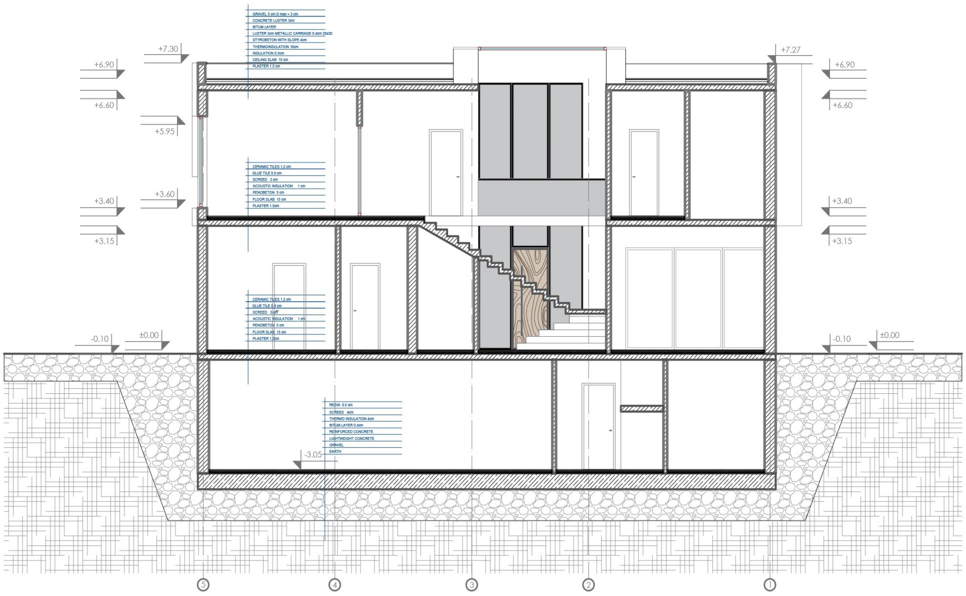

Figure 32. Building Section B-B (Cani, 2023)

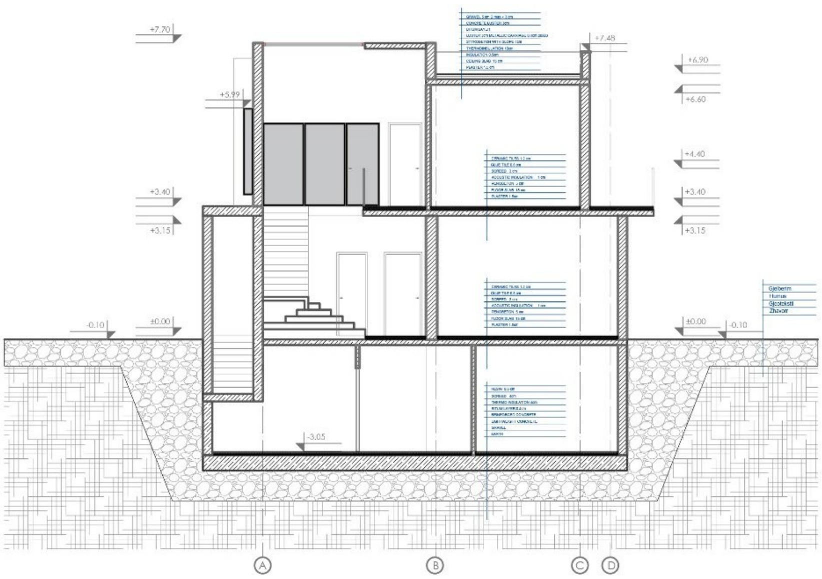

Figure 33. Building Section, A-A. (Cani, 2023)

The facade is the key element that personifies a building; it determines the first impression of a building on individuals contributes to its overall image and positions it within its environment. At the same time, the facade has important functions that provide a comfortable, protected environment for the occupants or users of the building. Together, aesthetically and functionally they create the desired appearance of the building as contemporary.

Figure 34. West, South, East and North Facade Design (up-down). (Cani, 2023)

The northern, southern, eastern, and western facades are proposed to be treated with white and gray plaster, as well as the intervention with HPL coating, for functional and decorative effect. The entrance is treated as a special moment, through a green exterior atrium as shown in (*Figure35)*.

Figure 35. Renders (Cani, 2023**)**

3.5 Passive Cooling Approach

The study approach consists on the application of PDEC tower in Tirana, starting with an overview of the PDEC tower, how it functions, how efficient it is and analyzing its application through different researches and studies that the others have made. The data of the climatic conditions and others are procured by weather simulation programs, also energy software programs for different calculations. The site is analyzed for its climatic conditions, humidity, heat and wind. Then analyzing the residential villa selected in Tirana city through simulation programs such as “Meteonorm”and “Design builder”.

3.6 PDEC Tower Proposal

The Project Design is implemented with a PDEC Tower as a passive cooling technique in order to increase energy efficiency during hot summer days. The concept of the residential house will be the same and the spatial distribution also, the only difference with be by implementing a PDEC tower in the central part of the building, as shown in *(Figure 36, a, b, c, d)* specifically near the main staircase that connects the ground a first floor. The PDEC tower will be 100x150 cm and will start from the underground until theroof top as shown in *(Figure 36, 37, 38)*.

Structure of the tower is usually made of durable materials and features a specific design to enhance the cooling process. Wetted Media is another element which is placed in the tower's surface and is covered with a specially designed media or material that allows water to spread evenly and promotes effective evaporation. This media enhances the contact between air and water, facilitating the cooling process. Another element the air Inlet which is shown in the drawing *(Figure 37, 38)* indicates an air inlet at the bottom or side of the tower. This inlet allows hot air from the surroundings to enter the tower system. As the hot air enters the tower, it comes into contact with the wetted media. The water on the media evaporates, absorbing heat from the air and reducing its temperature. This process is known as evaporative cooling. An outlet at the top or side of the tower through which cooled air exits. This cooled air, which is now at a lower temperature, can be directed into the intended space, providing comfort and cooling.

Figure 36. a. Underground floor plan, b. First- floor plan, c. Second floor plan, d. Terracefloor plan (Cani, 2023)

x

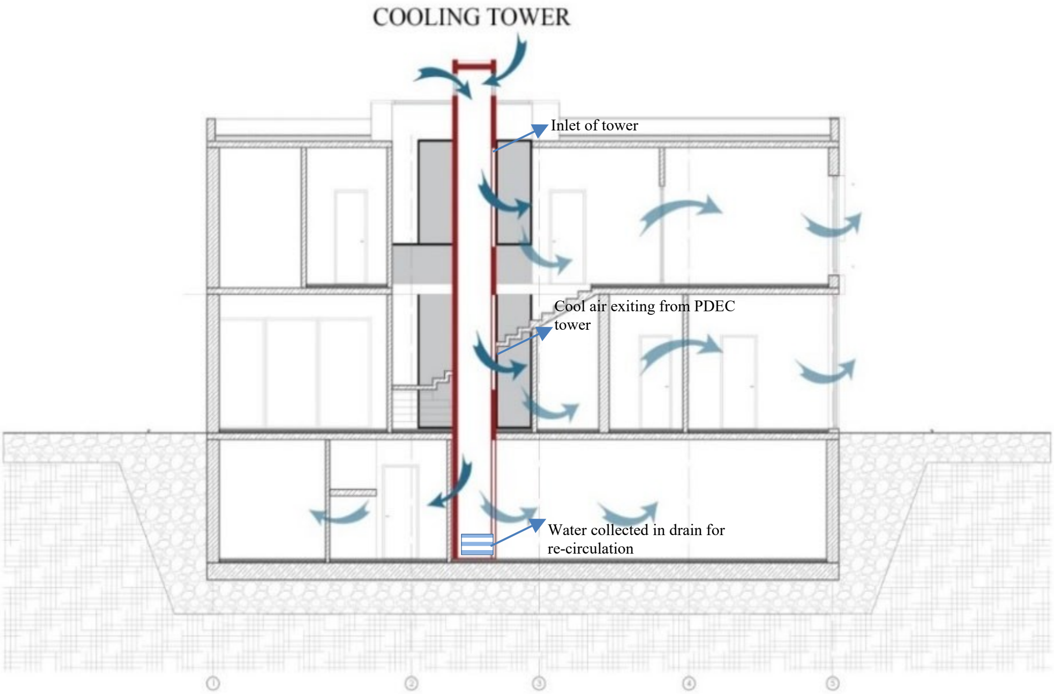

Figure 37. Cooling tower Section B-B (Cani, 2023)

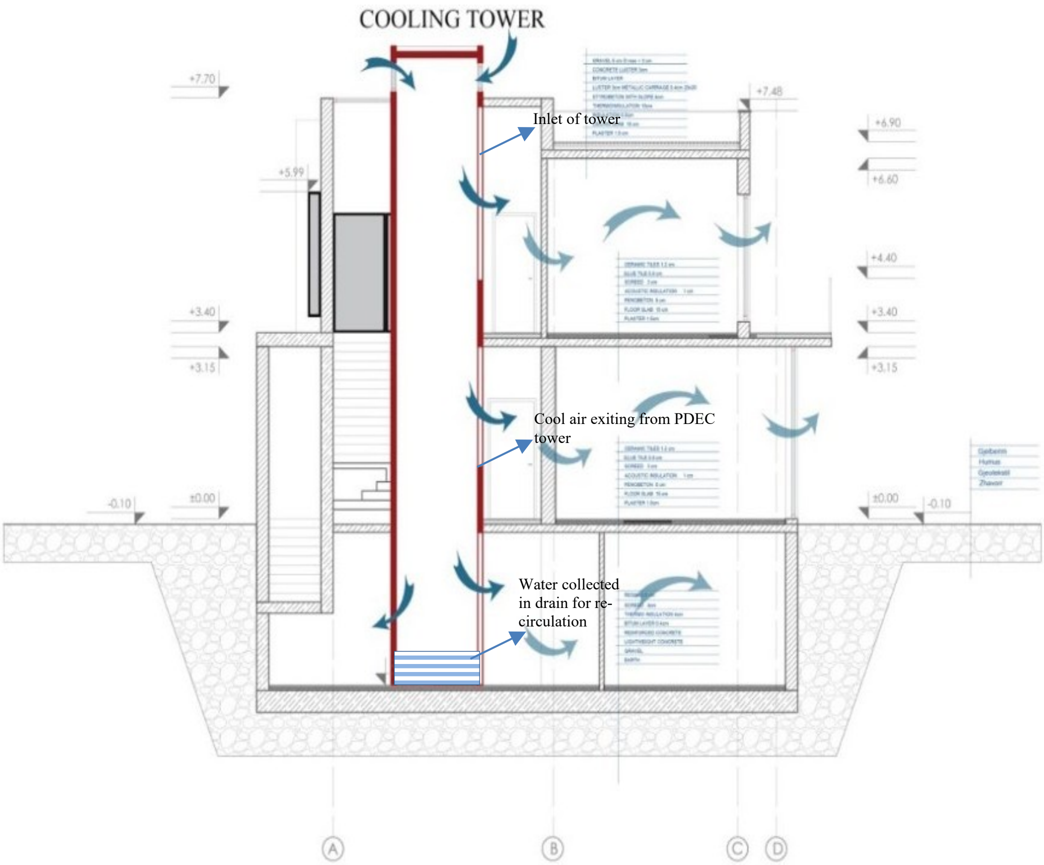

Figure 38. Cooling tower Section, A-A (Cani, 2023)

3.7 Passive Cooling Simulation

The Simulations are achieved with Design Builder, a software used to perform energy consumption, lighting, and comfort performance.

Initial models regarding the real case were generated based on project design, construction material and space distribution which are detailed int the previous chapter. Later the same model simulated as BC is adapted with the cooling system tower (PDEC) and a Simulations Design is conducted with Design (Design Builder, 2019). The results later are compared with each other in order to compare the performance of the building.

The main objective is to estimate the performance of the system in realclimate conditions in order to obtain values of air temperature and airflow rate that using PDEC system during summer months.

CHAPTER 4

RESULTS

The result section presents and discusses simulation results of the cooling tower regarding the indoor thermal performance (passive case) and the annual energy consumption (active case) of project proposal for the summer period. Firstly, indoor thermal performance (passive case) and secondly energy consumption for cooling (active case) of the residential building is analyzed and discussed for each case study.

4.1 Indoor thermal performance *(passive case)*

For calculating the indoor thermal performance (passive case) of the house project and *(Table 2)* comparing the monthly indoor air temperature (°C) vs measured outdoor air temperature.

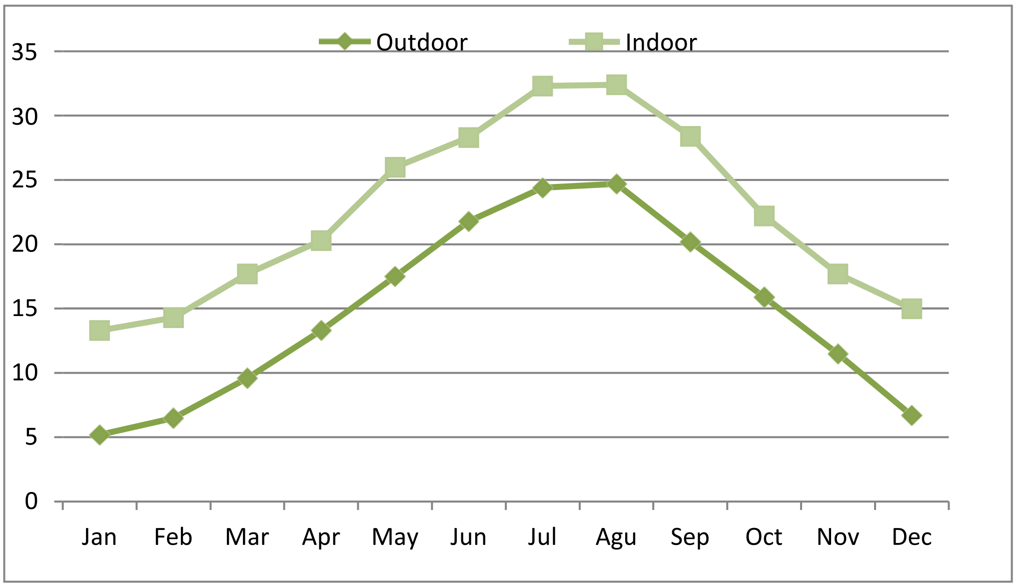

Figure 39. Comparison of computed monthly indoor air temperature (°C) BC vs measured outdoor air temperature. (Cani, 2023)

Table 2. Computed monthly indoor air temperature of BC scenario and measured outdoor air temperature (°C). (Cani, 2023)

Month °C	Outdoor	Indoor
Jan	5.2	13.3
Feb	6.5	14.3
Mar	9.6	17.7
Apr	13.3	20.3
May	17.5	26
Jun	21.8	28.3
Jul	24.4	32.3
Augu	24.7	32.4
Sep	20.2	28.4
Oct	15.9	22.2
Nov	11.5	17.7
Dec	6.7	15

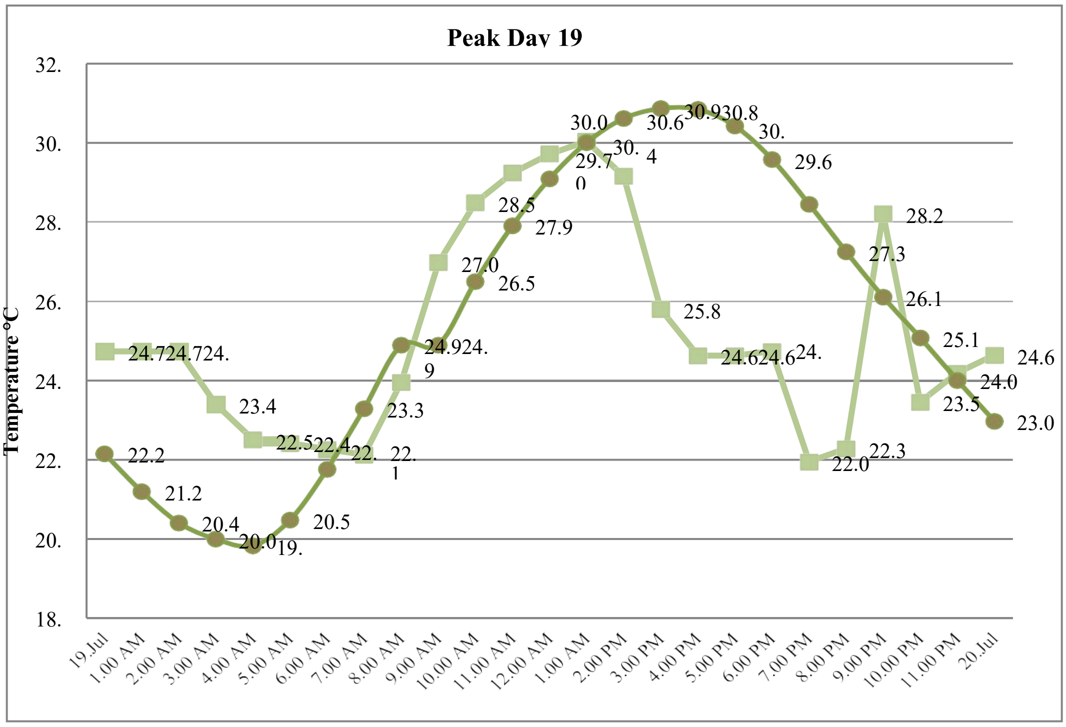

Figure 40. Comparison of computed monthly indoor air temperature (°C) BC vs measured outdoor air temperature. (Cani, 2023)

As illustrated, the table shows the lowest average monthly indoor air temperature in winter (13.3 °C in January) and the highest average monthly indoor air temperature in the summer (32. 4 °C in August). To evaluate thermal comfort conditions during summer period, a reference peak is selected (19 July). *(Figure 39)* and *(Figure 40)* illustration of the hourly indoor air temperature for the peak day selected.

Table 3. Comparison of computed day (19 July) indoor air temperature (°C) vs measured outdoor air temperature. (Cani, 2023)

Date/Time	Exiting temperature	Outside Temperature
19.Jul	22.2	24.7
1.00 AM	21.2	24.7
2.00 AM	20.4	24.7
3.00 AM	20.0	23.4
4.00 AM	19.8	22.5
5.00 AM	20.5	22.4
6.00 AM	21.8	22.3
7.00 AM	23.3	22.1
8.00 AM	24.9	24.0
9.00 AM	24.9	27.0
10.00 AM	26.5	28.5
11.00 AM	27.9	29.2
12.00 AM	29.1	29.7
1.00 AM	30.0	30.0
2.00 PM	30.6	29.2
3.00 PM	30.9	25.8
4.00 PM	30.8	24.6
5.00 PM	30.4	24.6
6.00 PM	29.6	24.7
7.00 PM	28.5	22.0
8.00 PM	27.3	22.3
9.00 PM	26.1	28.2
10.00 PM	25.1	23.5
11.00 PM	24.0	24.2
20.Jul	23.0	24.6

4.2 Energy Consumption

The villa selected for this project is modeled used design builder *(Figure 41)* to analyze its effects on the total energy performance during summer period (April-September). The energy consumption analysis (EC) and indoor thermal performance results are analyzed as a baseline. To illustrate the effect on the passive thermal performance, an optimal/base case (here referred to as BC) is simulated for a parametric study of the house in order to obtain the optimal indoor comfort based on European Union Standards. At first, the base case (BC) scenario shows the existing conditions of the house *(Figure 41)*. This scenario (BC) is conducted in order to define the required energy to use to further evaluate the intervention on energy reduction.

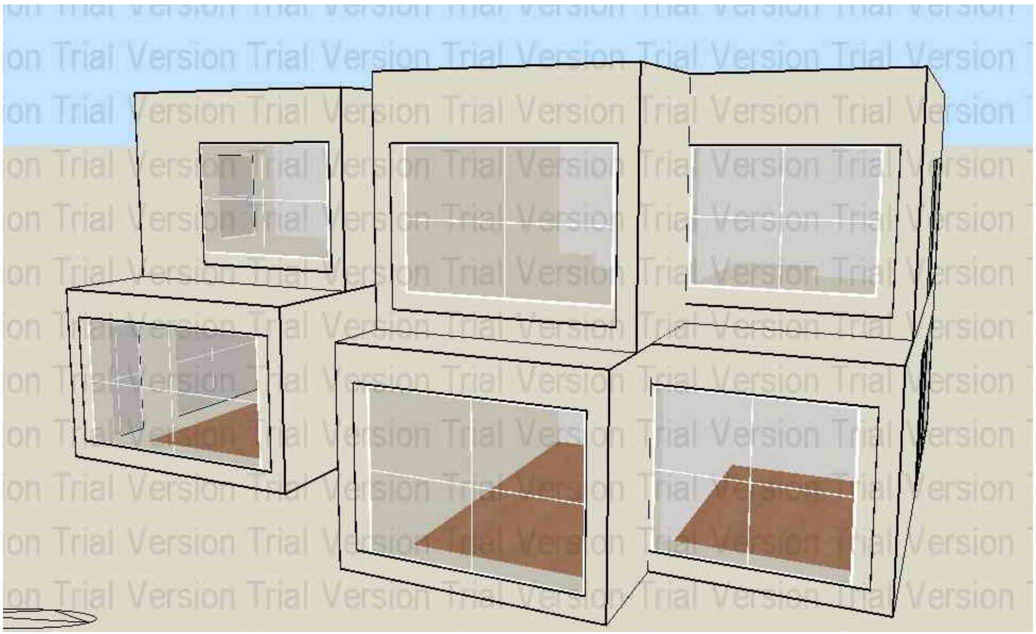

Figure 41. Design Builder Model (B. Cani,2023)

As shown, the *(Table 4)* and *(Figure 42)* shows the comparison between Outside Tem, Indoor Temperature and Indoor Temperature using HVAC for the summer months. As illustrated the results optimize the comfort of the living space based on the EU Standards Comfort zone 24-28 °C for the summer period.

Table 4. **C**omparison between Outside Tem, Indoor Temperature and Indoor Temperature using HVAC (Cani, 2023)

Summer Months Compared Temperatures

Outside Tem	Indoor Tem	HVAC Indoor Tem	
April	21	21.2	20
May	25.6	26.1	24
June	28.1	28.6	26.5
July	32.1	32.6	27.8
August	32.6	33.2	27.9
September	28.2	28.7	25.6

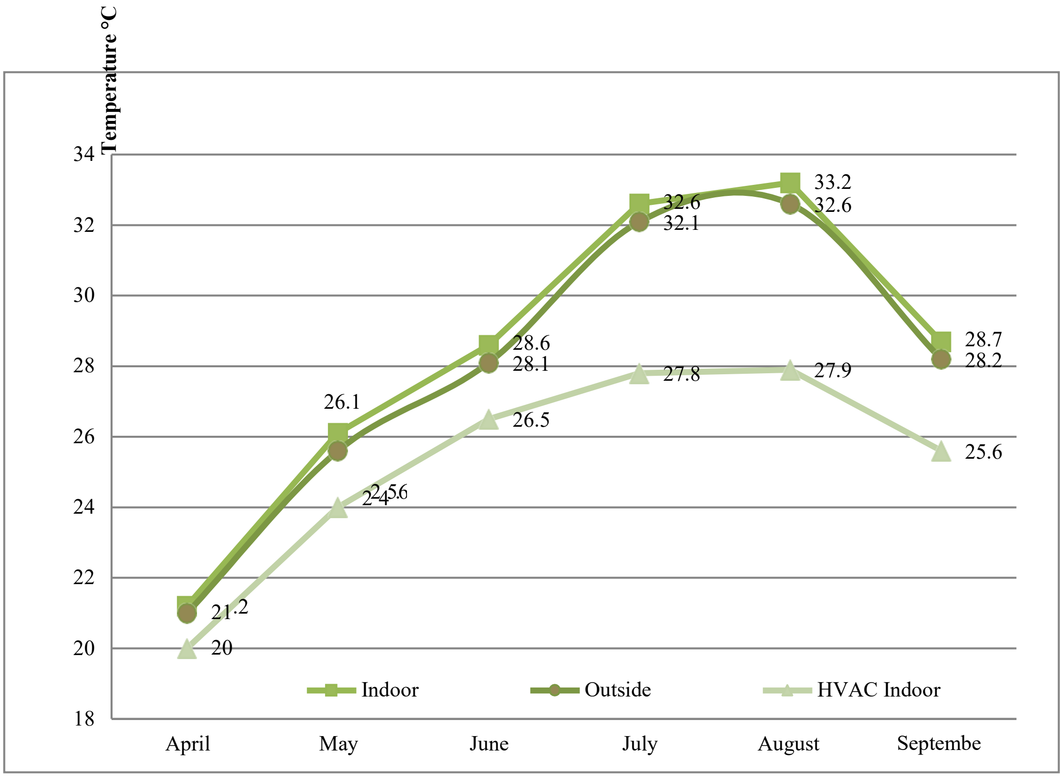

Figure 42. Comparison between Outside Tem, Indoor Temperature andIndoor Temperature using HVAC (Cani, 2023)

As illustrated, *(Figure 43)* shows the KW/h used in order to obtain an optimal indoor comfort for the project. After these results are simulated using Design Builder, a simple calculation in done in order to perceive the amount of LEK usedfor cooling the house during summer periods.

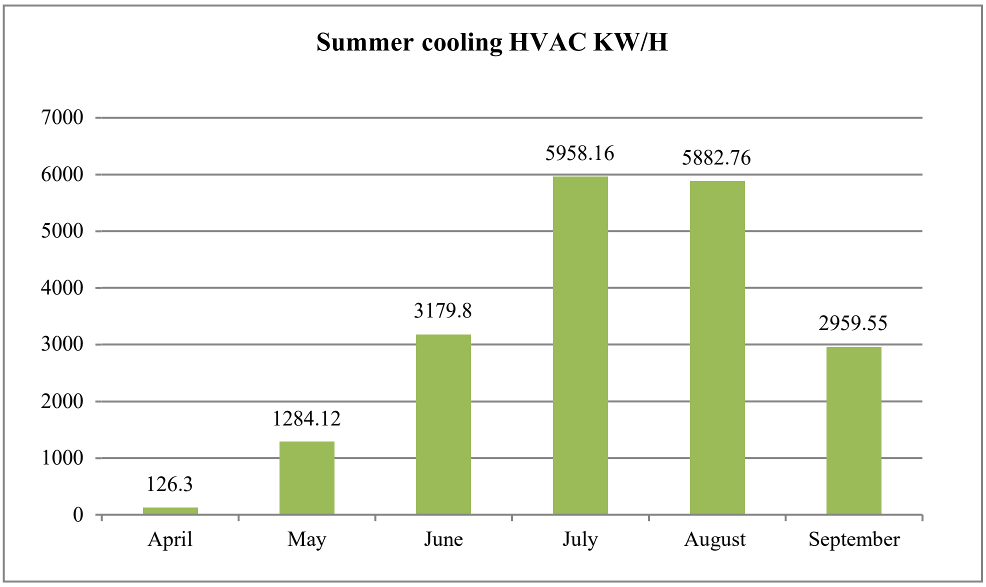

Figure 43. BC (measured) cooling energy loads (KWh) *(Cani, 2023)*

Table 5. BC (measured) cooling energy loads (KWh) converted to Payment Bills (Cani, 2023)

KW/H CONVERTED IN AL LEK (BC)			
	KW/H	**LEK KW/H**	**TOTAL**
April	126.3	9.5	1199.9
May	1284.12	9.5	12199.1
June	3179.8	9.5	30208.1
July	5958.16	9.5	56602.5
August	5882.76	9.5	55886.2
September	2959.55	9.5	28115.7
TOTAL LEK			**184211.6**

.

4.2 Air Changes/ Hour ACH

Air changes per hour, shown as ACH, is calculating how many times perhour the entire volume of air in a space is replaced with supply and/or recirculated air, for residential building ACH should be 3-5 during summer month and up to 1,35 during winter months. ACH is usually obtained by window opening but in the projectproposal case the implementation of PDEC tower improves the ACH. As *(Table 6)* and *(Figure 44)* shows ACH is calculated for BC and BC+HVAC

Table 6. ACH results for BC AND BC+HVAC during summer months (Cani, 2023)

Air Changes/ hour

	BC	BC+HVAC
April	0.88	2.45
May	1.35	2.35
June	1.24	1.97
July	0.97	1.3
August	0.98	1.33
September	1.32	2.02

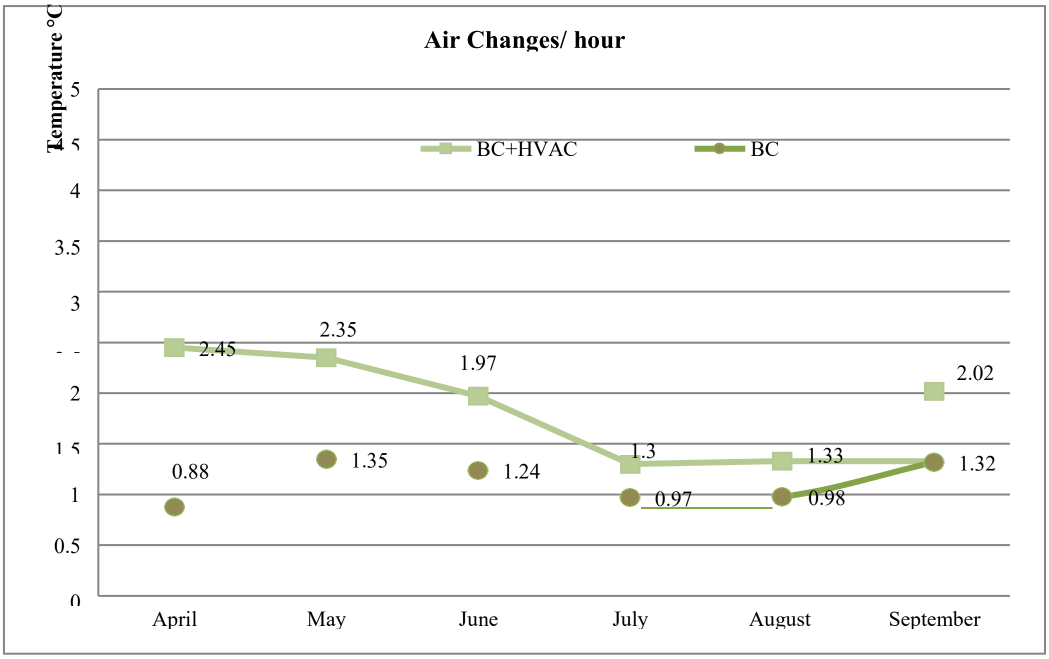

Figure 44. ACH graph for BC AND BC+HVAC during summer months (Cani, 2023)

CHAPTER 5

DISCUSSION

This chapter focuses on analyzing and comparing the Base Case with the implementation of the PDEC tower the results obtained from the calibrated simulation models regarding the comfort, energy usage and Air changes/ hour for case (based on their climate) lead to the following conclusions.

5.1 Comparison of thermal improvement BC and PDEC tower

The present data illustrate the need for improving the thermal comfort of the project while reducing the energy consumption for cooling during summer.*(Figure 45)*. An overview of the thermal conditions of the BC, BC+HVAC and the optimization scenarios using PDEC tower for the monthly summer indoor temperature (°C) *(Table 7)*.

Table 7. Monthly indoor air temperature (April-September) (°C) for the BC,BC+HVAC, PDEC tower. (Cani, 2023)

INDOOR TEMPERATURE			
	BC	**BC+HVAC**	**DEC TOWER**
April	21	20	19.54
May	25.6	24	23.9
June	28.1	26.5	26.5
July	32.1	27.8	26.47
August	32.6	27.9	26.08
September	28.2	25.6	25.15

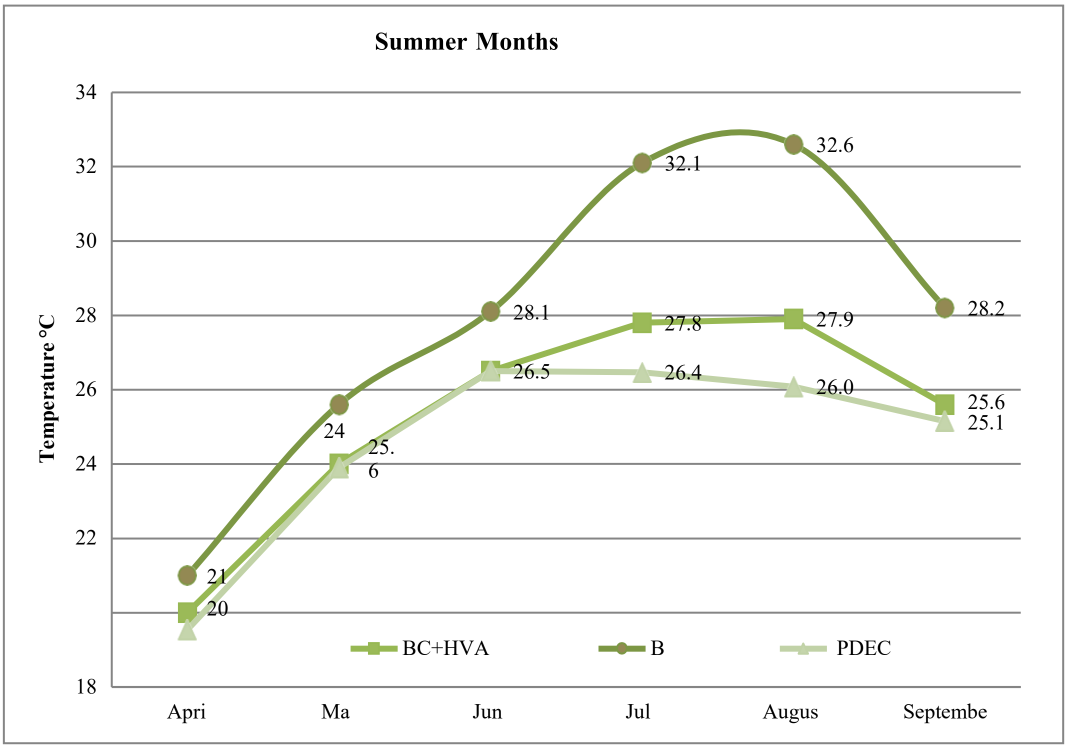

Figure 45. Monthly indoor air temperature (April-September) (°C) for the BC, BC+HVAC, PDEC tower. (Cani, 2023)

As *(Figure 45)* and *(Table 7)* illustrates, PDEC tower performs by decreasing the monthly average temperature especially during the peak months July and August almost with 6°C without using any Energy Consumption, simply just by implementing the tower in the hallway of the building.

5.2 Comparison of energy consumption BC and PDEC tower

The point compares the energy consumption during summer months for the BC and PDEC tower case. *(Figure 46)* and *(Table 8)* is shown an overview for the monthly energy consumption of the BC and PDEC tower.

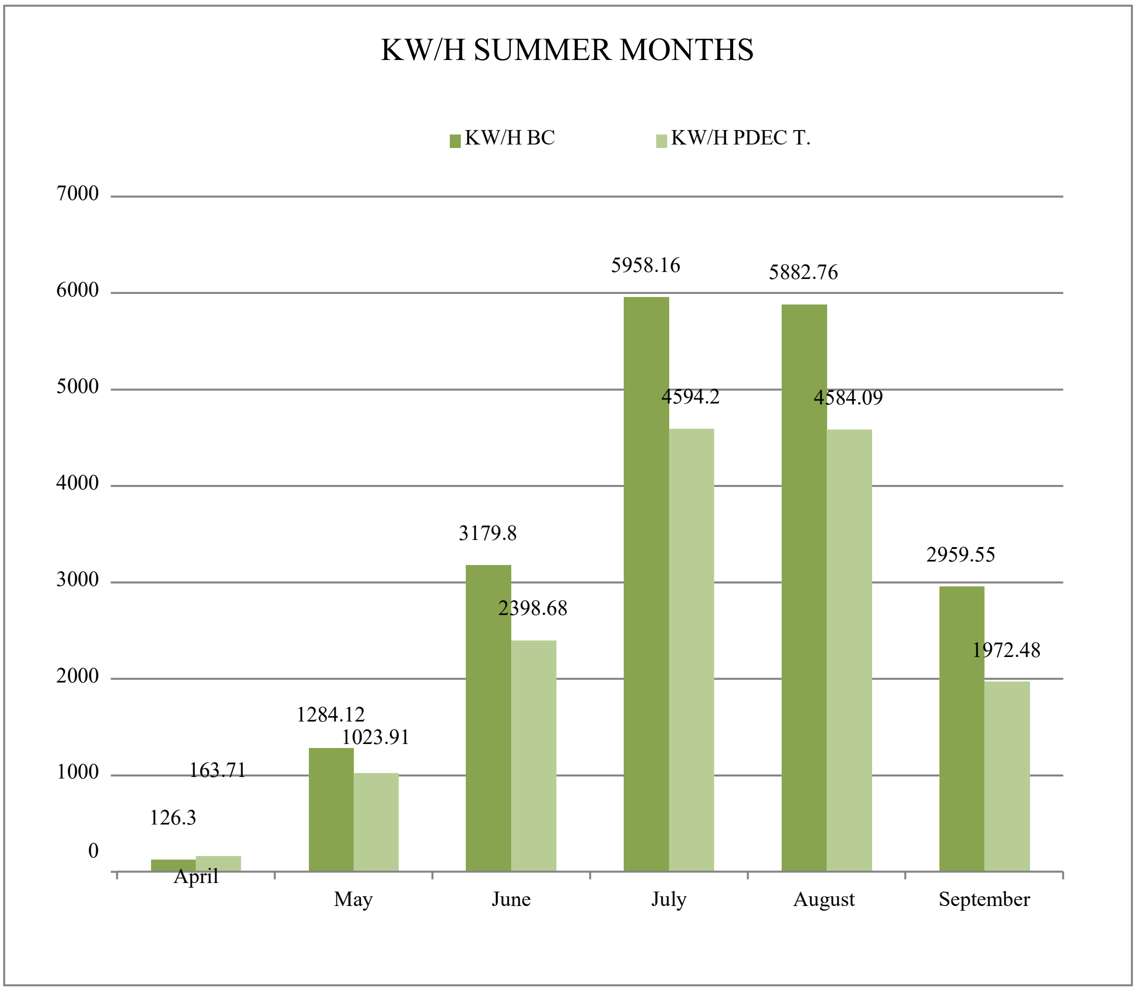

Figure 46. Monthly Energy Consumption (April-September) for the BC and PDECTower. (Cani, 2023)

Table 8. Monthly Energy Consumption (April-September) for the BC and PDECTower Converted into AL LEK (Cani, 2023)

KW/H CONVERTED IN AL LEK

	KW/H BC	KW/H PDEC T.	TOTAL
April	126.3	163.71	-37.4
May	1284.12	1023.91	260.2
June	3179.8	2398.68	781.1
July	5958.16	4594.2	1364.0
August	5882.76	4584.09	1298.7
September	2959.55	1972.48	987.1
	TOTAL KW/H		**4653.6**
TOTAL KW/H*9.5 LEK/KW			**44209.4**

As the results obtained from the calibrated simulation models shows implementation of the PDEC towers improves the Energy Consumption during summer by 4553.6 KW/H which if it is translated in Albanian Lek, it means 44209.4 LEK which meansa saving of 31.6 % yearly compared to the BC+HVAC system.

5.3 Comparison of Air changes/hour BC and PDEC tower

Air changes per hour ACH for residential building should be 3-5 during summer month and up to 1,35 during winter months. ACH is usually obtained by window opening but in the project proposal case the implementation of PDEC tower improves the ACH.

Table 9. Air changes per hour (April-September) for the BC, BC+HVAC and PDEC Tower. (Cani, 2023)

Air Changes/ hour

	BC	**PDEC**	**BC+HVAC**
April	0.88	0.92	2.45
May	1.35	2.06	2.35
June	1.24	2.39	1.97
July	0.97	2.6	1.3
August	0.98	2.61	1.33
September	1.32	2.52	2.02

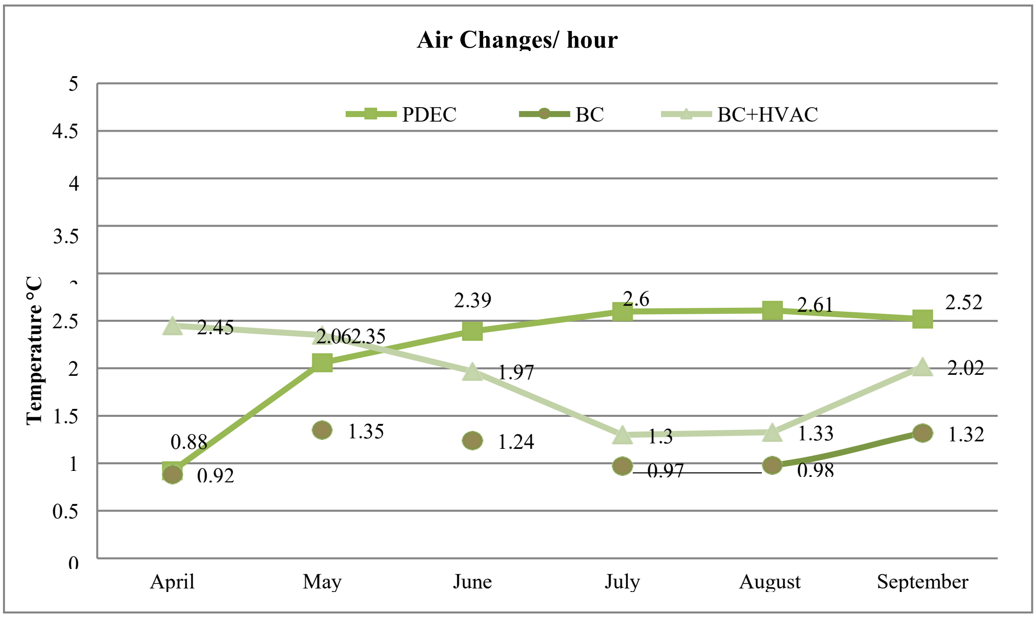

Figure 47. Graph of Air changes per hour (April-September) for the BC, BC+HVACand PDEC Tower (Cani, 2023)

As the results obtained from the calibrated simulation models shows Air change perhour change up to 1,64 during July/august month which is the peak month of summer.

5.4 Limitation

There may be some possible limitations in this study. The first is the fact thatthe results are estimates in Design Builder which is a model based on computer software might be not 100% valid compared to real life, it just a possible prediction.

The second limitation concerns the fact that the study is only calculated for a1-year period, specifically for 2022 which means that further studied can be calculated for more than just one year in order to evaluate the climate change andhow this affects the cooling efficiency.

Another limitation is the fact that the study did not include unrelated costs for building the PDEC towers in the residential building of the study in order to calculatethe saving/cost.

In conclusion, even though the study is highly detailed related to cooling efficiency in Albania still the cooling efficiency term is more general. This studyaims at finding good solutions cooling system in residential buildings in Albanianand develops a methodology that would contribute to the energy saving in theresidential buildings.

CHAPTER 6

CONCLUSION

6.1 Conclusion

As in the last 20 years there has been a drastic increase in energy waste, recently humanity has had a rise of awareness of this phenomenon. Concentrating in Albania which in the last years has had an increased number of populations in urban areas, a massive rise of population has been in the capital of Albania, Tirana. Due to this increase of population, there has been the rise of energy use too. However, Albania, being a country with a Mediterranean climate has great opportunities and potentials for developments in energy-efficient buildings. With the analyzing of different factors, the application of passive cooling will be introduced for Tirana city as an energy-efficiency solution, so as to reduce the energy that the air conditioning uses in buildings.

The study focuses on comfort and energy consumption of residential buildings in Tirana, Albania, using one-year simulation measurements for summer months (April-September). The provided scenarios are simulated focusing on the thermal comfort, energy consumption and ACH.

As the results obtained from the simulation models show, the PDEC tower performs well in the project proposed.

As long as the results associated with the cost-effective of these simulation actions show the improvement of building decreasing the yearly energy consumption (electricity kWh) during summer months by 4553.6 KW/H which if it is translated in Albanian Lek, it means 44209.4 LEK which means a saving of 31.6 % yearlycompared to the BC+HVAC system

The results related to thermal comfort decrease the monthly average temperature especially during the peak with 6°C without using any Energy Consumption, simply just by implementing the tower in the hallway of the building.

To conclude this research project, exemplify that passive downdraught evaporative cooling (PDEC) system could be easily adapted into the modern construction in Albania due to the Mediterranean Climate, the results illustrated in this research shows outstanding improvements in thermal comfort for the inhabitants.

6.2 Future Work

The previous studies related energy efficiency in Albanian field is deficient especially in the cooling energy efficiency. Previous research can be considered asthe first step towards more detailed research on cooling energy efficiency of residential buildings in Albania.

The research which has been undertaken for this thesis study has highlighted a specific topic on which further research would be beneficial. Firstly, for this study only one climate is selected which represent the central Albania to which further studies might be focused on analyzing the effect of thermal performance on other Albanian climates in particular the coast of Albania where most of the inhabitants pass their summer months.

Another additional area might be simulating and different climate in order to see which cooling energy efficiency performs better in which climatic conditions.

This study aims at finding good solutions cooling system in residential buildings in Albanian and develops a methodology which would remarkably contribute to the energy saving in residential buildings. This methodology might be seen as a future reference for researchers.

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