ADAPTIVE SUSTAINABLE REUSE FOR AGRICULTURAL PURPOSES OF ABANDONED BUILDINGS IN MALESIA E MADHE DISTRICT, ALBANIA

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Approval sheet of the Thesis

This is to certify that we have read this thesis entitled **"Adaptive sustainable reuse for agricultural purposes of abandoned buildings in Malesia e Madhe district, 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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ABSTRACT

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Since ancient times, agriculture in Albania has been one of the most pivotal industrial sectors that drives the economy of the country consisting of various advantages regarding trade and commerce. However, this sector has been facing several problematics in terms of its organization and financial situation. “Malesia e Madhe” district in Albania is selected in this study in order to create a bottom-up approach to improve district the agricultural sector of the entire country. Based on the feedback gathered from questionnaires and statistical data from INSTAT, one of the main factors that influence the downgrade of the agricultural sector is indicated to be the absence of a well-organized trade. Several proposals are conducted on this study for the implementation of Agro-Logistics centers activity in old abandoned traditional dwellings of the district. As a result of the building materials and techniques on this building typology, the selected structures are very beneficial in terms of energy performance. The proposed structures are derived from simulations computed in this study by means of Design Builder software. Variables such as the air temperature, relative humidity, building orientation, agricultural context, building materials and techniques are used utilized in order to perceive the most efficient simulation results. The outcome of the study indicates that this building typology associated with the proper retrofit measurements, can consume up to 65.8% less energy than a typical warehouse.

Keywords: *Agro-logisitc center, Energy efficiency, Agriculture, Sustainable development, Temperature, Relative Humidity.*

ABSTRAKT

RIPERDORIMI ADAPTIV PER ARSYE AGRIKULTURORE I BANESAVE TE BRAKTISURA NE ZONEN E MALESISE SE MADHE, SHQIPËRI

Dushaj, Venera

Master Shkencor, Departamenti i Arkitektures

Udhëheqësi: Prof. Dr. Sokol Dervishi

Agrikultura në Shqipëri ka qënë dhe vazhdoin të jetë një ndër sektorët bazë industrial që ndikon në ekonominë e shtetit duke mundësuar disa avantazhe në lidhje me tregtinë dhe industrinë. Megjithëatë, ky sektor, po përballet me disa vështirësi në lidhje me organizimin e tij dhe situaten financiare. Zona e Malësisë së Madhe është zgjedhur në këtë studim për krijimin e një plani organizimi “bottom-up”, në mënyrë që ky sektor, gradualisht të permirësohet në të gjithë shtetin. Bazuar në të dhënat e mbledhura nga pyetsorët që u janë bërë banorëve të zones, dhe të dhënat e INSTAT, një nga faktorët kryesorë që influencon degradimin e sektorit agrikulturor është mungesa e një tregu të mire organizuar. Disa propozime janë përcjellur në këtë studim për implementimin e qendrave logjistike agrikulturore ne banesat tradicionale të braktisura të zones. Strukturat e zgjedhura përbëjnë disa avantazhe përsa i përket konsumit energjitik si rezultat i materialeve dhe teknikave të ndërtimit që ato kanë. Strukturat e propozuara janë perftuar nga simulimet e bëra me software-in “Design Builder”. Variablat si temperature e ajrit, lageshtia relative, orientimi i ndërteses, konteksti bujqësor, materialet dhe teknikat e ndërtimit janë përdorur në mënyrë që të përfitohen të dhëna sa më efiçente. Rezultatet tregojnë që kjo tipologji ndërtimi së bashku me masat e termoizolimit te propozuara mund të konsumojë deri në 65.8% kWh/m2 më pak energji sesa një magazine e zakonsheme.

Fjalët kyçe: *Qender logjistike bujqësore, Efiçenca energjitike, Agrikultura, Zhvillimi i qëndrueshëm, Temperature, Lagështia Relative.*

I dedicate this thesis to my family for the support and motivation that they showed to me during my studying years and for always inspiring me to fulfill my ambitions. I also dedicate this thesis to my future self who will hopefully be very proud of every step I'm taking from now on in the architecture field.

ACKNOWLEDGEMENTS

This thesis is a result of a very hard work that however would not be completed without the guidance of my supervising professor Prof. Dr. Sokol Dervishi, who has helped me greatly during the development process of this research. I am very grateful for all the hard work and dedication that he put in this thesis.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Albania had been a village concentrated country in the last centuries, giving us a legacy of traditional vernacular buildings located all over the rural areas. Eventually, because of migration and not only, these buildings went out of use and became completely abandoned. Malesia e Madhe, an agricultural district located in Northern Albania, is one of these rural areas which is full of traditional vernacular buildings. The main reason for depopulation of this area is the lack of its economic development. As an area which relies on agriculture, the infrastructure improvements should focus on this sector. The above-mentioned district lacks a trading center for its agricultural products, which results in significant losses both in terms of goods produced and earnings. Simultaneously, Malesia e Madhe district has many old abandoned buildings dating from the 18th-20th century, which are advantageous for preserving both temperature and humidity. Considering the fact that traditional buildings were built of stone and timber, they possess qualitative characteristics regarding energy efficiency of the structures. Having a wall thickness of 50-60 cm, these buildings provide the most optimal conditions for maintaining HAMT values constant and as preferred. In conjunction with the data collected from the various stimulators, these commercial buildings can be used in such a way as to facilitate the most efficient storage and commerce among many different agricultural activities. As an alternative to demolition, this paper proposes to rehabilitate old buildings by leveraging their natural energy efficiency, and by utilizing the most current technologies to adapt them to their new purpose. improve the export of agricultural products to other countries and consequently increase the employment ratios, giving people one less reason to migrate. Additionally, the preservation of the historical and cultural value of these recycled buildings, that include a significant number of commercial activities, boosts the local tourism industry. creation of energy efficient buildings that fulfill their new purpose by eliminating energy waste, grouped in clusters that could be easily integrated and repetitive along many sites in Albania.

1.2 Objectives

Being a country that depends greatly on the agricultural sector, Albania has to improve the infrastructure which affects this sector in order to make use of the resources available to its full potential. This would lead to a great economic growth that would solve many other problems that this country is facing nowadays such as migration, unemployment, etc.

The agricultural sector is partially functioning in rural areas nowadays in Albania. Meaning that the goods are produced in the rural environment but the commerce of these goods is made in the urban environment, leading to a massive destabilization of the agricultural sector's performance. The purpose of this research is to analyze and understand the following problems:

- Identification of the optimal HAMT values for agricultural storage units
- Comparing and contrasting the environmental conditions of the existing old buildings that could be potentially used as storage units
- How does the energy efficiency of the buildings differ from one climate to another?

In conjunction with making use of the energy efficiency performance of the abandoned buildings, other aspects of the economic development would be affected, such as: agro tourism, import-export business, boost in employment, etc.

The main purpose of this research is to combine the data of the existing energy efficiency values of the abandoned buildings with the values obtained from different stimulators collected after proposing new solutions regarding the efficiency of energy used in these structures. The objectives of this paper are listed below:

1. Assembling feedback from the existing literature in order to make use of the resources available to their full potential.

2. Ongoing monitoring of the data collected from different data loggers inserted in the buildings in different climatic conditions.

3. Analysis of the data collected from the devices

4. Proposing solutions regarding the obtainment of the optimal environmental conditions based on simulation programs.

5. Comparing existing data regarding the energy efficiency of the buildings to the data obtained from the simulators in the proposed models.

1.3 Motivation

Energy efficiency is one of the most important topics of the 21st century. Considering the fact that buildings consume up to 40% of the energy worldwide, solutions need to be found in order to balance this consumption to the minimum possible. New technologies are being presented each day that can be useful about this task. Most of the contemporary buildings are being built with the energy efficiency criteria as their main aim, but on the other side there are the old buildings that did not have access to the technologies needed to fulfill the task.

However, even in the past centuries' buildings were built with some comfort criteria as their aim. Architects would try to make use of all the possible resources available to come up with sustainable buildings even before the term sustainability first appeared. Different solutions lead to the historical buildings that we have today, both in terms of strategic position and structure.

Nowadays, making use of the technologies that were used previously in the last decades and centuries would be considered a waste of resources, leading to the contemporary structures that are being built nowadays all over the world. Implementation of the new technologies on the old buildings, however, wouldn't be a waste of resources, on the contrary, it would make use of them to their full potential.

The implementation of modern technologies in the old traditional buildings which are in a good condition are very beneficial for several purposes that also spark interest in global causes of environmentalism and humanity. Sustainable development goals is a set of goals that were assembled by international authorities in order to achieve the best living conditions of different communities. The adaptive sustainable reuse of the abandoned buildings in Albania for agricultural purposes influences directly and indirectly 5 of the 17 goals that this initiative has.

- **Goal 8 - Decent work and economic growth**

"Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all."

The majority of the people who live in suburban areas of Albania have agriculture as their primary source of income. According to the questionnaire held to the country-dwellers, investments in local trading of agricultural crops in Albania would be very beneficial in terms of economy and employment rate. The output of the questionnaire resulted in 92% of the farmers going through several obstacles related to the lack of needed infrastructure while vending their goods. The most frequent barrier according to the questions asked is the cost of transportation of the goods from the village to the nearest city and the rented area cost for trading purposes.

Thus, assembling clusters of trading centers in three main spots of the suburban area of Malesia e Madhe, not only facilitates the trading procedures of the farmers but also develops socio-economic aspects such as new employment positions, generates vitality of the area, influence on agro-tourism, etc.

- **Goal 9 - Industry, innovation and Infrastructure**

"Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation."

Old traditional buildings, not only in Albania but worldwide, have the potential to maintain a resilient state in the future because of the eco-friendly and durable building materials used. Taking advantage of this aspect and implementing new technologies, the potential of being resilient structures increases, leading to new innovations and solutions without using many resources.

The solution proposed by the adaptive reuse of the old buildings for agricultural purposes, is considered to foster innovation which consists of ideas that have not been proposed or implemented previously. The central theme is the improvement of the industry of agriculture by using different innovations to improve the infrastructure that the sector uses.

- **Goal 11- sustainable cities and communities**

"Make cities and human settlements inclusive, safe, resilient and sustainable."

One of the main drawbacks not only in Malësia e Madhe, but also in the general state of Albanian population rate is migration. The vast majority of country-dwellers of Albanian suburban areas consider migration and emigration as the most suitable solution for their economic and social problems.

As mentioned above, this study focuses on the improvement of the three sectors of the community; economy, society and environment. By implementing the idea proposed in this study, sectors such as tourism, marketing and economy are to be developed, leading to a healthier and more livable lifestyle for the suburban community. By improving these sectors, country-dwellers will be able to make use of a greater variety of job opportunities, thus subsequently migration rate will decrease.

- **Goal 12 - Responsible production and consumption**

"Ensure sustainable consumption and production patterns."

Circular agriculture is a mission which involves all farmers to calculate the production of the right amount of goods needed. Currently, Malësia e Madhe district does not comply with the circular agriculture's principles. This setback relates to the verity that farmers in this district are not able to properly calculate the right amount of goods that will be produced to be consumed. The number of products produced must be as close as possible to the amount of the products that will be consumed to ensure circular agriculture. However, notwithstanding the willingness of the farmers, this mission cannot be accomplished without a regular plan of trading beforehand planting and harvesting. In most cases farmers plant and harvest as much as they can in order to sell as much as they can. This leads to a collapse of agriculture trading in most villages where goods are wasted because of overproduction.

In other words, overproduction of the crops is a result of the unplanned trading that occurs because of the lack of necessary infrastructure distributed equally in the farmlands.

- **Goal 15 - Life on Land**

"Protect, restore and promote sustainable use of terrestrial ecosystems, sustainability manages forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss."

One of the particularities of Malesia e Madhe district is the variety of crops that are distributed across the area. The wild crops such as tea and salvia naturally grow in the mountainous areas of the district, while grape and olives grow in the lake coastal areas. However, over the years this natural distribution was lost leading to the current state of a homogeneous area consisting of crops planted anywhere with no consideration of the qualities needed for each specific plant. Salvia plants for instance, can now be found even in lake coastal areas and grape can be found in mountainous areas as well. This is the result of the problem mentioned above which relates to unplanned trading.

Generating this homogeneous farmland can be very harmous to biodiversity and wildlife. The production of crops in farmlands that do not fulfill all the necessary terrestrial parameters can lead to a distortion of the ecosystem and production of unhealthy crops.

1.4 Aim and Originality of the study

Nowadays, energy efficiency is a widely discussed topic. Many different industrial sectors engage in the inter-corporation of efficient usage of energy in product making processes. Thus, a variety of studies, especially architecture related studies, have been made regarding this topic. However, it has to be noted that

- No previous studies were made regarding the advantages of the revitalization of old traditional buildings that were previously used as dwellings into structures performing new agricultural purposes taking into account different contexts of climate and agricultural activities in each area mentioned.

- No previous simulations generated by input collected (site analysis, materials analysis, weather data results, questionnaires,) were conducted in order to adjust the building materials of old traditional dwellings in order to conceive energy efficiency for agricultural purposes.

- No previous studies were made in Albania that suggest a way of improving one of the main sectors of the country which is agriculture in terms of energy efficiency and modern technology by taking into consideration questionnaires results and migration rates over the past decade.

Therefore, the aim of this study is to introduce an innovation which is a result of computing input from analytical and quantitative data into the solution of several drawbacks regarding the economy and the environment of rural areas. Different microclimates were taken into consideration in order to ensure implementation of this study into other rural areas in Albania and other countries with similar climates as Albania. This paper focuses on sustainability and energy efficiency of the buildings. Climate contexts, agriculture context, building typologies, window to wall ratio (WWR), and materials used are taken into consideration when collecting the input data that is used in the simulation process. Developing a strategy that can be implemented in other farmlands, which require minimum investments, is the main objective of this study. Sectors such as economy, tourism, marketing, are part of the target group that this paper intends to ameliorate in undeveloped countries. The study conduction on this paper is strongly intertwined with worldwide solution strategies such as the SDGs (sustainable development goals) making it the earliest tentative to implement worldwide strategies in rural areas of Albania by energy retrofitting of old abandoned traditional dwellings.

1.5 Organization of the thesis

This paper is composed of 7 chapters which are divided into their respective subchapters explained below. Chapter 1 starts with the introduction of the thesis followed by its objective and motivation on the research. This chapter is concluded with a brief scope of work. Chapter 2 is composed by the literature review of the optimal HAMT values for agricultural products storage and the optimization of efficient energy of the old buildings. Chapter 3 includes the analysis of the selected areas regarding the climate agriculture contexts. Chapter 4 consists of the methodology applied in this research in order to obtain the most efficient results for the intervention of the adaptive reuse of the old abandoned buildings for agricultural purposes. Chapter 5. Chapter 6. Chapter 7.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Rural areas in Albania are filled with traditional old dwellings (Dipasquale, L., et.al). Because of economic situations and migration these dwellings slowly started to become abandoned (Petreski, M., et.al). These areas depend greatly on the agricultural sector, thus more attention should be given to it. The northern part of Albania, more specifically Malesia e Madhe district, will be the focus of this research. Consisting of different climate zones, varying from mountainous to lake coastal ones, this district is rich in agricultural production. However, Malesia e Madhe district lacks a trading center, causing a lot of waste and damage in terms of goods produced and economy respectively. Therefore, the proposed solution to the above-mentioned problems in this research would be the adaptive sustainable reuse of these abandoned old buildings for agricultural purposes such as storage and trading. Rehabilitation of these dwellings would improve many sectors, such as: agriculture, tourism, economy, etc. by the lowest means of expenses. Implementation of natural and conventional materials are considered to be successful in order to fulfill the thermal requirements (da Silva, A. V., et.al,2018). Adaptive reuse is considered to be a keyword when talking about restoration of old buildings of historical values. Furthermore, what is more important in rehabilitation of buildings nowadays is the sustainability elements that are to be considered. With nowadays technology this aspect can be easily implemented in the most efficient way possible. Innovation in technology plays an important role in the designing process, resulting in more successful and creative designs when it comes to rehabilitation of old buildings (Shao, D., et.al,2018). The rehabilitation process of old buildings leads to a more sustainable product compared to establishing new structures. (Shao, D., Nagai, Y., et.al, 2019). Buildings made of stone masonry may attain positive energy efficiency values. This can be possible by obeying some stipulations which resulted as effective according to simulations programs such as Enerphit in a research project done by (Rodrigues, F., Parada, et.al, 2015). This would lead to minimization of the energy consumption and also it would reduce the greenhouse gas emissions. Therefore, considering the fact the new function of the buildings, which will mainly be storing agricultural goods, the hygrothermal conditions are very important. By implementing the proposed solutions on the building's fabric, a boost on the performance of energy is obtained. Statistics result in 46.3% improvement on the energy performance and a thermal comfort of 7.2'C. (Dervishi, S., Pashako, F., Dushaj, X., & Dervishi, I. O. 2022).

2.2 Agriculture sector in Albania

Agriculture is one of the pivotal sectors in Albania where the national product of the country is influenced by it sector by 19 %.(Risilia D., Pagria I., Tabaku I., et al.). This sector consists of 40% of the labor force in the country. However, over the past decades, agriculture has been significantly deserted resulting in defective maintenance and development. (Llazo.E). Agricultural lending has been facing various challenges when it comes to finances and its policies. Several issues regarding this statement would be the low number of farms and their fragmentation and also the low number of technological investments implemented in farming and post-harvesting processes. (Risilia D., Pagria I., Tabaku I., et al.). Albanian rural communities reflect dissatisfaction regarding the agricultural industry, evidently, by investing their non-agricultural assets into moving out of crop-production. The farmers don't consider agricultural investments in technology and innovation as a profitable convenience. (Kilic T., Carletto C., Miluka J., et al).

Efficient data regarding agriculture storing conditions is required in order to improve the crop production (David, 2006). This would lead to a better management of the most beneficial sector that Albania has. Agricultural goods are produced in rural areas, thus, in order to minimize the potential damage that the product undergoes during its transportation process, a more efficient way would be to provide a stationary environment which is close to the harvest zone. This would lead to a reduced number of products lost and a reduction on energy waste. Energy efficiency formulas are a veracious way of analysing and comparing the energy needed in different scenarios in order to preserve goods in the healthiest conditions (James C. Atuonwu, Craig Leadley, Andrew Bosman, Savvas A.Tassou, Estefania Lopez-Quiroga, Peter J. Fryer, 2018).

2.3 Bottom-up approach of Agricultural Logistics Centers

Logistics industry has been developing considerably recently. As a result of the economic boost, trading and economics are considered catalysts of this industry which currently generates assets and working capital for the national financial management. Nevertheless, along with the logistics industry growth, consequently, the ecological environment must be taken into consideration. (Wei Zhang 1, et.al). Agro-logistics centers serve as microfinance institutions for the zone that they perform at. These centers may perform as a regulatory of financial institution. (Risilia, D., Pagria,).

For the purpose of obtaining a sustainable development of the logistics industry, renewable resources, such as sunlight, are reckoned with by making use of the emergy and its outputs. (Cui Wang, et.al)

2.4 Optimization of traditional buildings into agricultural logistics centers

Structures built as heavy mass reduce the heating and cooling loads which lead to a very beneficial state regarding energy consumption performance. Kim, S. H. (2018)

The rehabilitation of existing structures for agricultural purposes by achieving a functional renovation with minimal interventions consists of various advantages. Retrofitting leads to a beneficial outcome in terms of protection and valorization. An upgrade of the environmental sustainability is achieved by taking these measures. (Santi ., Laiola G). A sustainable method of minimizing energy consumption of a building is by upgrading its energy performance. This process, called buildings' retrofit, also plays an important role in reduction of GHG. By fulfilling these criteria, buildings can be considered as zero energy buildings. (Rodrigues, F., et.al). Old stone masonry buildings, dating from XIX -XX century, are one of the best scenarios of building retrofits. Not only are they made of durable and strong materials, but they also benefit from some of the most natural ways to naturally produce energy. Being in Rural areas, these buildings are potentially a reservoir of natural resources energy.

Framework of policies is focused on renovating the energy performance of the old existing buildings by addressing all categories of design. Access to building technology is considered to be a major advantage in terms of reduction of building energy use. (IPCC. Working Group III, Mitigation of Climate Change, Chapter 9, Buildings. 2014).

2.5 Optimal HAMT value for agricultural products clustering

Agricultural products are breathing tissues whose post-harvest lifespan is influenced by varius environmental conditions such as the ai temperature, relative humidity, storage period, etc. Specific crops require specific environmental conditions in order be stored as long as possible without injuries or shrinkage. These consequences are a result of higher or lower temperatures.

When storing several types of crops together some variables need to be considered. These variables consist of the air temperature and the relative humidity. (Thompson et al., 1996; Tamimi et al., 2010). As a result of the food requirement enhancement, strategies regarding agricultural sector need to be made (Bhaskare and Shinde, 2017). Several of the aspects that need to be considered when thinking about agriculture sector development are the market’s infrastructure. Cold-chains, as one of the most essential post-harvest points, requires great attention in its development scope. This aspect has been implementing some clustering strategies for the agricultural crops in order to make a connection from the farm to the trade (Perdana and Kusnandar, 2012; Negi, 2014). Another important key point that needs to be considered in the post – harvest situation is the controlling and monitoring of the parameters needed for suitable storage of the crops (Chaudhuri et al., 2018). One of these parameters is the temperature which may lead to injuries if not monitored and controlled. Also, humidity is another parameter that requires attention during the storage period so that the crops don't rot.

The Organization of the crops in a precalculated way leads to a healthy environment for the crops. Furthermore, this well-organized strategy influences minimal costs regarding expenditures on energy consumption and machinery used. (John et al., 2011).

CHAPTER 3

STUDY AREA

3.1 Geographical and climatic context of the selected sites

The agricultural sector dates back in Albanian history to the Illyrian period (8^{th} century BC), being one of the first affirmations of trade and commerce. This sector was mostly popular alongside important routes and landmarks. Trading, historically, has been more developed in border towns, where accessibility is the most beneficial tribute.

The selected sites of this research are located in "Malësia e Madhe" district. This zone has been considered to be a very crucial section of the trading network in Albania since the Labeatae Illyrian tribes. Located in Northern Albania, Malesia e Madhe connects Albania to its neighbooring country Montenegro. This district consists of a veriety of geographical attribues such as "Shkodra Lake", "Albanian Alps", valleys, streams, etc.

During communism period in Albania, the agricultural lands were converted into cooperative lands owned by the country. *Figure 1* displays the agricultural cooperative during communism in Albania. In "Malesia e Madhe" district 5 cooperatives were established according to the crops produced by each zone. The selected sites of this study are based on the previous division of the cooperative lands, in order to perceive data and feedback regarding all the crops produced in the district. Koplik cooperative, Gruemire cooperative and Kelmend cooperative are considered to be relatively distinct from each other in terms of crop production typology, where the selected sites, S1 - Dobër, S2 - Gruemirë and S3 - Marshej are located respectively.

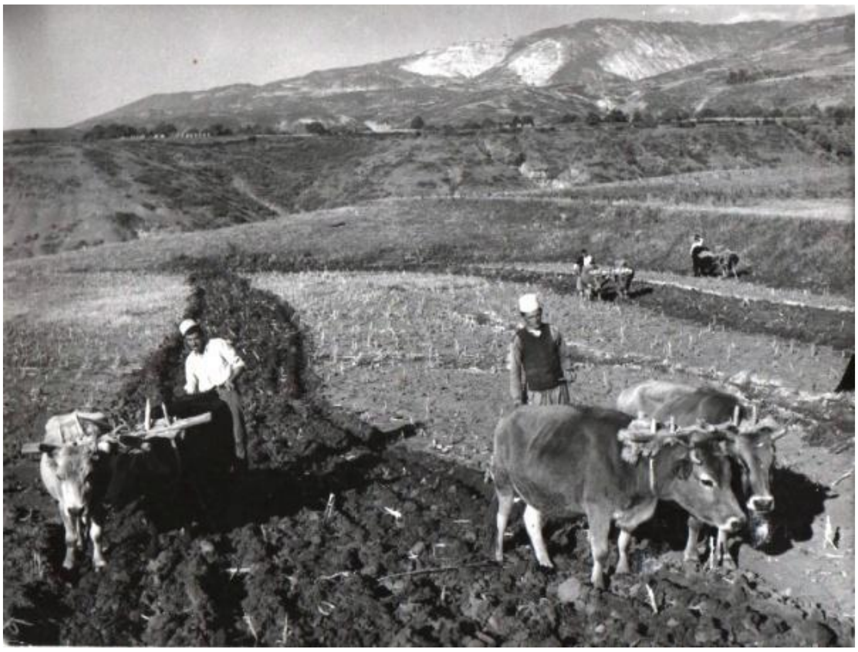


Figure 1 Hysa, Y. (2016) Agricultural Cooperative during communism in Albania.

3.1.1 Dobër, Malësi e Madhe

Site 1 (S1), Dobër, is a lake coastal village in Malesia e Madhe district in Albania. With a population of 417 this village is situated in northern Albania, in the former Qendër municipality, Shkodër County. This village dates early in history with ruins of settlements from the Ottomans incursion in the 14th and 15th centuries found in its sites. However, the first mention of "Dobër" in a map corresponds to the 16th century. The latest proof of history are the bunkers which are spread around the village which belong to the communism period during the 1960s. These bunkers were built by the leader of the country Enver Hoxha as a defense mechanism in case of a military attack from Yugoslavia. In the 2015 local government reform, the municipality Dobër (also known as Dobre) integrated into Malësi e Madhe. It sits at an altitude of 42.190 meters above the sea level.

The village is located in a strategic position at the beginning of the small city called Koplik, serving as a connection between the highway and the city. Being lake coastal, this village has another point worth mentioning is the active railway that passes through the village. Dobër as mentioned above is located on the coast of Lake of Shkodër. This village is characterized by a Mediterranean climate consisting of mild rainy winters and hot dry summers. The average temperature of the air is 16.2°C. The absolute maximum temperature corresponds to 40.6°C and the absolute minimum temperature -10°C. Dewpoint temperatures vary from 2.3°C in January to 18.3°C in August. The average wind speed during one year is 1.7 with a direction of 90°, while the average air pressure results to be 1008 hpa.

The mean irradiance on global radiation horizontally is 177 and the mean irradiance of the beam is 191. The mean irradiance of diffuse radiation horizontally is 70. The average cloud cover fraction during a year is 3 while the average global illuminance during one year is 19345. As for the air humidity, a variation from a minimum of 60 during July and August and a maximum of 76 during February, and December is noted. *Figure 2* , *Figure 3* and *Figure 4* display the annual temperature, radiation and relative humidity chart of Dobër, Malësi e Madhe respectively.

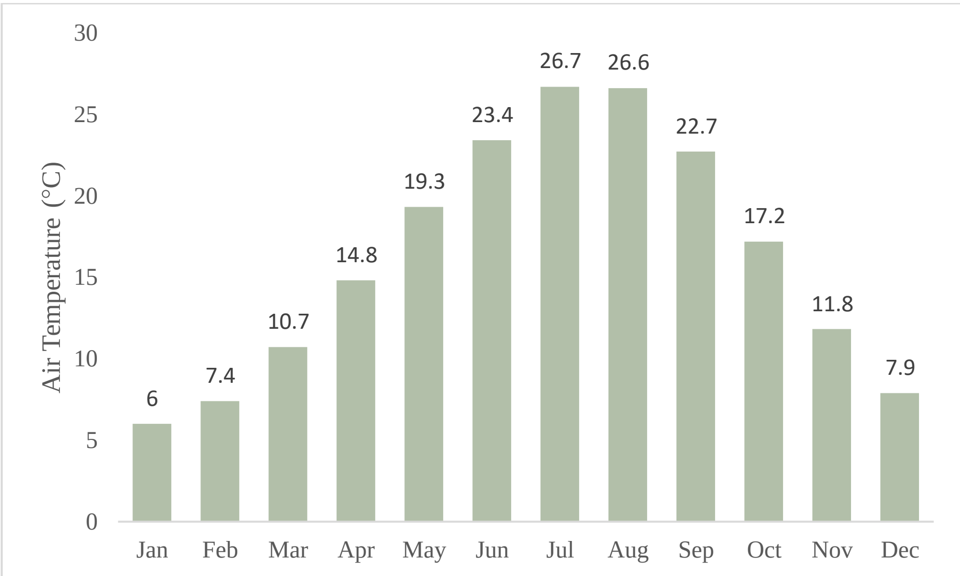


Figure 2 Annual Temperature chart, Dobër ,Malësi e Madhe (Meteonorm 2020).

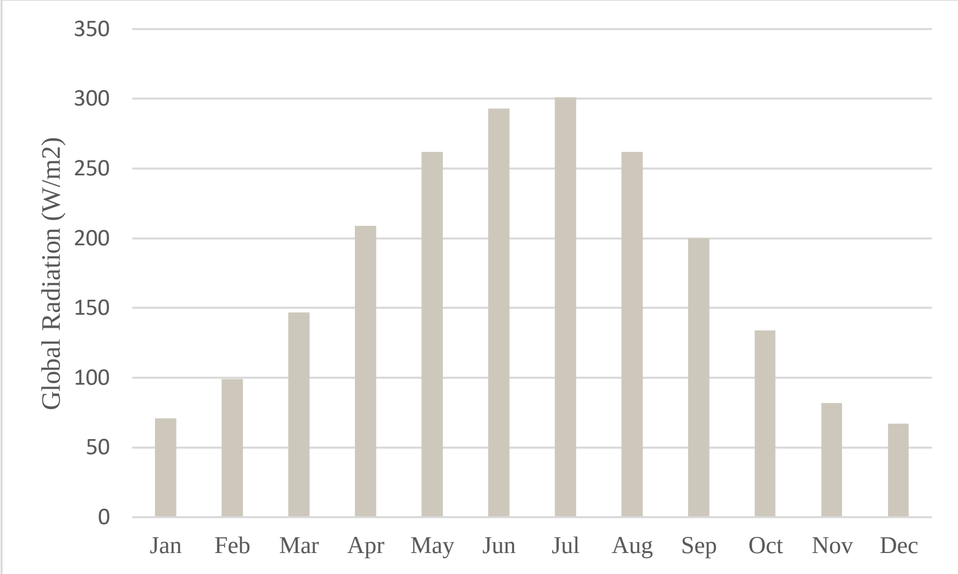


Figure 3. Annual Radiation chart Dobër (Metenorm 2020).

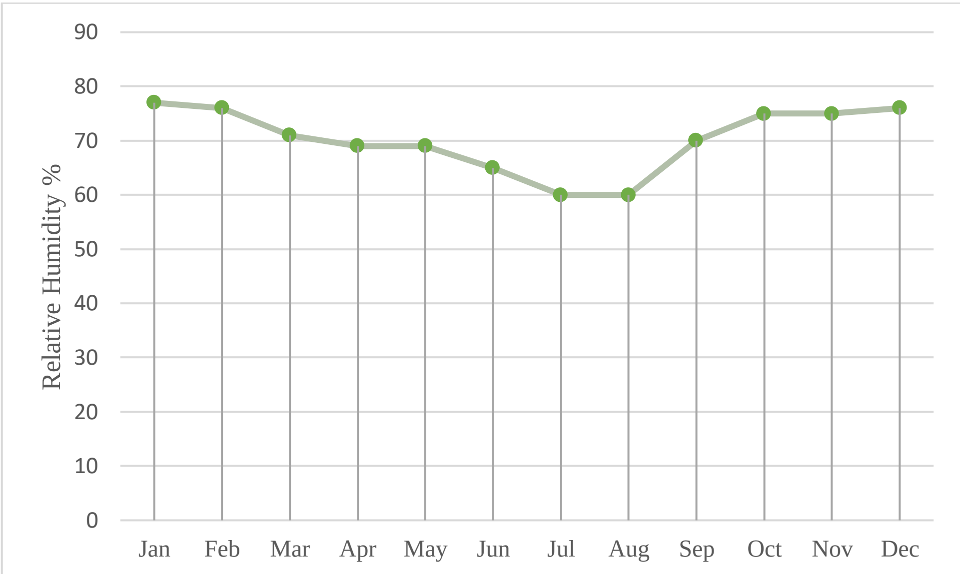


Figure 4. Annually Relative Humidity Dobër (Meteonorm 2020).

3.1.2 Gruemirë, Malësi e Madhe

Site 2 (S2) is a hillside village in Malesia e Madhe district, called Gruemirë Çezme. With a population of 351 this village lies in the hills of the district with a view from the lake on the west and the mountains on the east. Grumirë Çezme sits at an altitude of approximately 27 meters above sea level. Gruemirë was a municipality in Shkodër County, however in 2015 at a local government reform it became part of the municipality of Malësia e Madhe. This village was mentioned for the first time in the Venetian cadaster Shkodra in 1416.

Gruemirë - Çezme is also located in a very strategic location when it comes to trading and economy. Lying next to the main highway of the district, Shkodër - Hani i Hotit, this village is easily accessible from passengers. Located at the base of the hills of Malësia e Madhe, this village has a view of the Shkodra Lake on the east and the Mountains on the North.

Gruemirë - Çezme corresponds to a mediterranean climate with humid subtropical characteristics. The average temperature of the air is 16.2°C. The absolute maximum temperature corresponds to 40.6°C and the absolute minimum temperature -10°C. Dewpoint temperatures vary from 2.3°C in January to 18.3°C in August. The average wind speed during one year is 1.7 with a direction of 90°, while the average air pressure results to be 1008 hpa.

The mean irradiance on global radiation horizontally is 177 and the mean irradiance of the beam is 192. The mean irradiance of diffuse radiation horizontally is 70. The average cloud cover fraction during a year is 3 while the average global illuminance during one year is 19350. As for the air humidity, a variation from a minimum of 60 during July and August and a maximum of 76 during February is noted. *Figure 5* , *Figure 6* and *Figure 7* display the annual temperature, radiation and relative humidity chart of Gruemirë, Malësi e Madhe respectively.

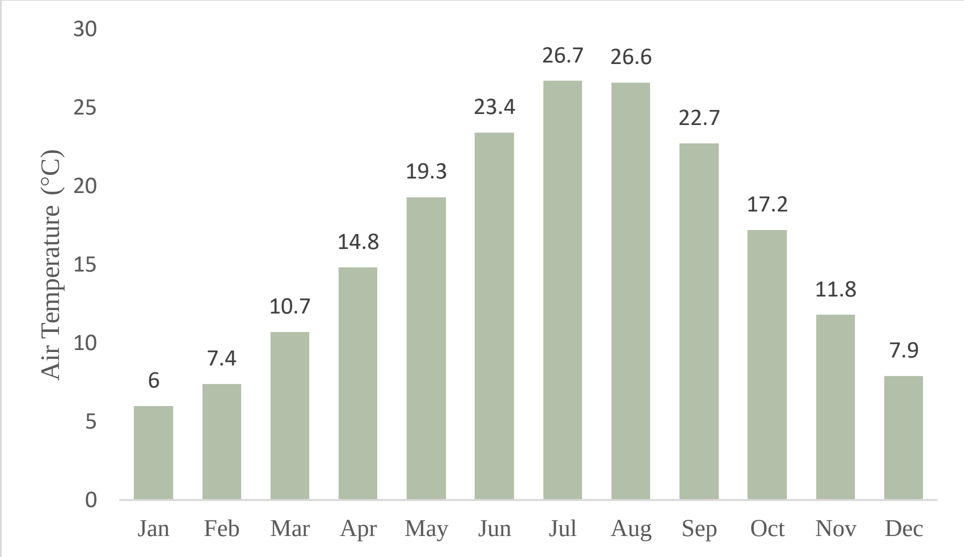


Figure 5. Annually Temperature chart Gruemirë (Meteonorm 2020)

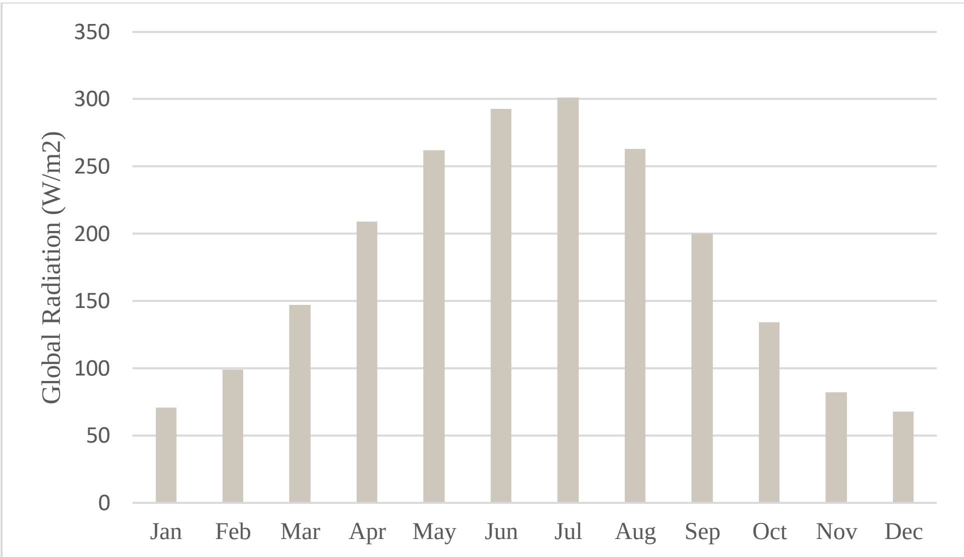


Figure 6. Annually Radiation chart Gruemirë (Meteonorm 2020).

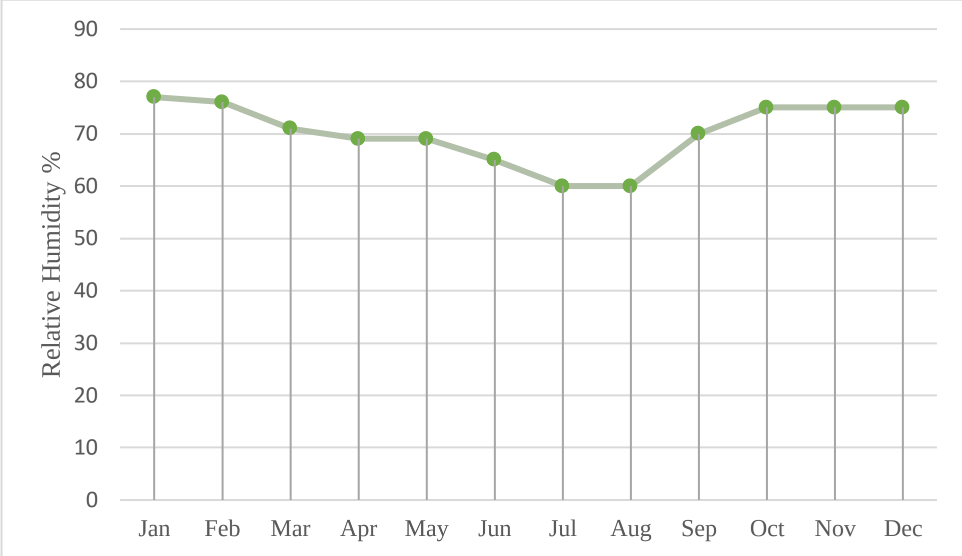


Figure 7. Annually Relative Humidity chart Gruemirë (Meteonorm 2020).

3.1.3 Marshej, Malësi e Madhe

Site 3 (S3) is a mountainous village in Malesia e Madhe district, called Marshej. This village dates back in history with stories and monuments that are considered to be in the UNESCO cultural heritage list. Several archaeological discoveries were conducted in the area of Perroi i Thatë which is a water stream located in this village. According to archeologists this stream was a settlement of the Illyrians called Marshej. Marshej's Fortification was a prehistoric Illyrian settlement built in the copper age. This village is partly located in the base of the mountain and also in the slope. Lying near the Main highway of the district Shkoder - Hani i Hotit and next to the main street that connects every other city to the Albanian Alps, this village is located in a very strategic location in terms of tourism and economy.

Marshej corresponds to a Mediterranean climate with oceanic characteristics. The average temperature of the air is 16.2°C. The absolute maximum temperature corresponds to 40.6°C and the absolute minimum temperature -10°C. Dewpoint temperatures vary from 1.3°C in January to 17.3°C in August. The average wind speed during one year is 1.7 with a direction of 90°, while the average air pressure results to be 988 hpa.

The mean irradiance on global radiation horizontally is 172 and the mean irradiance of the beam is 177. The mean irradiance of diffuse radiation horizontally is

73. The average cloud cover fraction during a year is 4 while the average global illuminance during one year is 18804. As for the air humidity, a variation from a minimum of 56 during July and August and a maximum of 72 during January is noted. *Figure 8, Figure 9 and Figure 10* display the annual temperature, radiation and relative humidity chart of Dobër, Malësi e Madhe respectively.

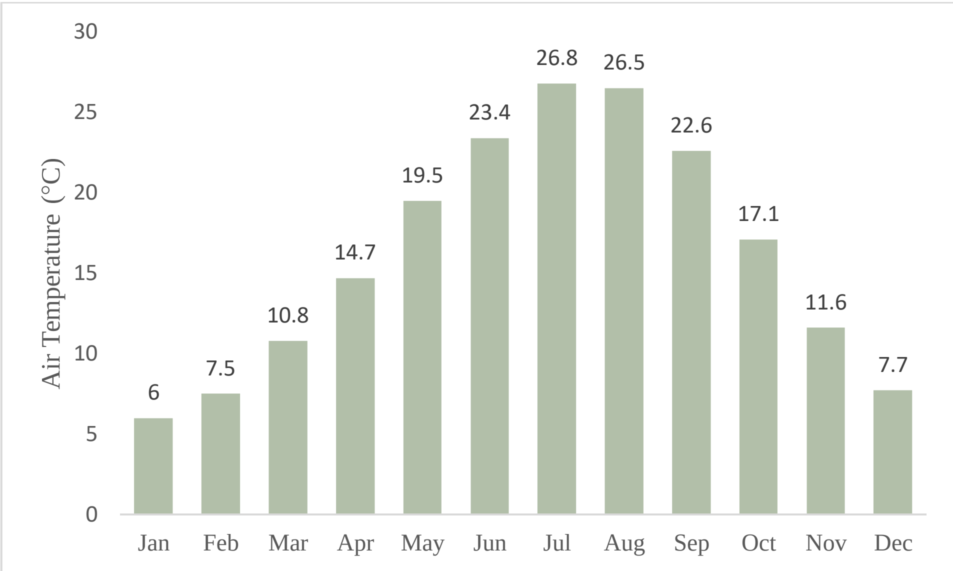


Figure 8. Annually Temperature Marshej (Meteonorm 2020).

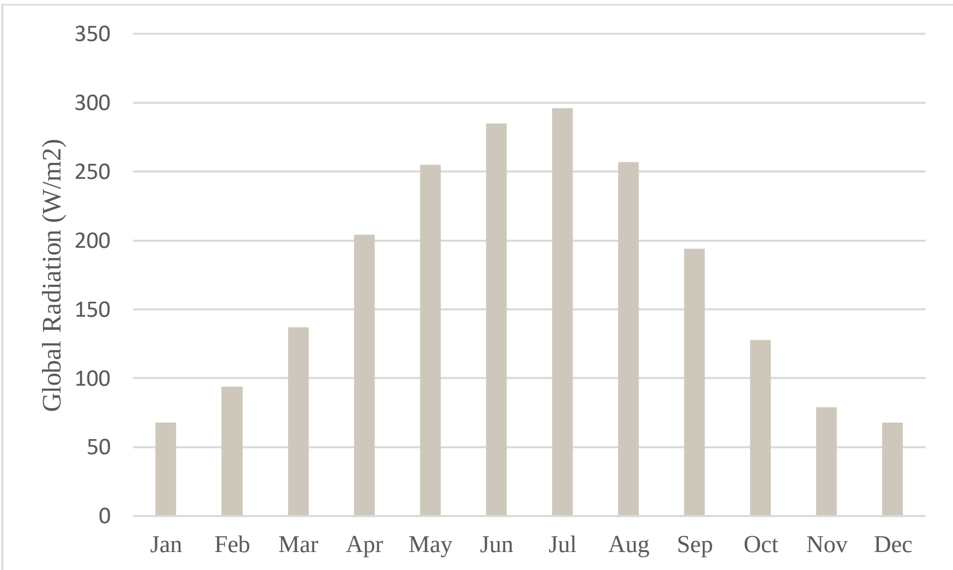


Figure 9. Annually Radiation Marshej (Meteonorm 2020).

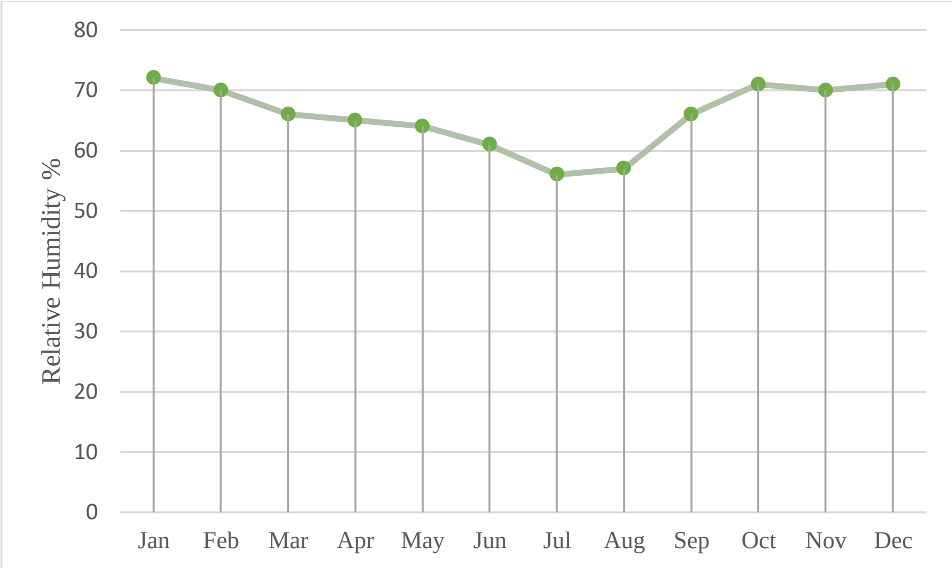


Figure 10. Annually Relative Humidity (Meteonorm 2020).

3.2 Agricultural Context of the selected sites

In Malësia e Madhe district, the agricultural sector is developed in groups of crops that consist of field plants such as: bread cereals (corn and wheat), vegetables, potatoes, legumes (beans), fodder , among which medicinal plants. Orchards are also produced which include: fruit trees, table and oil olives, chestnuts, vineyards for table grapes and wine. The area of agricultural land is 15,9555 ha. The number of farms is 8,222, mainly of family nature and small average size, about 1.85 ha. Most of them are located in the areas of Gruemirë, Qender e Shkrel, but also in Kelmend, in which the population is mostly employed in the agricultural sector. The three selected sites are also located in these three zones. *Table 1* shows the average temperature, moisture and the storage time required for each crop and the harvest period of each crop. Whereas, *Table 2* demonstrates the harvest period and storage period of each crop. *Figure 11* demonstrates the chart of the storage temperature range of each crop produced in the district, whereas *Figure 12* demonstrates the chart of the humidity range.

Table 1. Agricultural Products of "Malësia e Madhe" district and their storage HAMT values.

Agricultural Products of "Malesia e Madhe" district							
No.	**Crops**	**Temperature (°C)**	**Avg. Temp. (°C)**	**Moisture (%)**	**Avg. Moisture (%)**	**Storage time**	**Harvest Period**
1	Brinjal	8 to 12	10.0	90 to 95	92.5	1-2 weeks	June
2	Cabbage	0 to 1	0.5	95 to 100	97.5	3 - 7 months	September - October
3	Tomatoes	18 to 22	20.0	92.5	92.5	1 - 3 weeks	August - September
4	Onion	0	0.0	67.5	67.5	1 - 8 months	July - August
5	Olive	7.2 to 10	8.6	85 to 90	87.5	4 - 6 weeks	October - November
6	Garlic	0	0.0	65 to 70	67.5	6- 7 months	August - September
7	Potatoes	4 to 5	4.5	90 to 95	92.5	1 - 2 weeks	July
8	Pepper	7 to 13	10.0	92.5	92.5	1 - 2 weeks	June
9	Cucumber	10 to 13	11.5	95	95	10 - 14 days	July - September
10	Beans	4 to 7	5.5	95	95	7 - 10 days	August
11	Peas	0	0.0	96.5	96.5	1 - 2 weeks	September
12	Pear	-1.5 to -0.5	-1.0	92.5	92.5	2 - 7 months	November
13	Plums	-0.5 to 0	-0.3	92.5	92.5	2 - 5 weeks	June
14	Pomegranate	0	0.0	90	90	2 - 4 weeks	October
15	Watermelon	10 to 15	12.5	90	90	2 - 3 weeks	July
16	Apples	-1 to 4	1.5	92.5	92.5	1 - 8 months	October
17	Grapes	-1 to 1	0.0	90 to 95	92.5	3 - 6 weeks	September
18	Mandarin	4	2.0	92.5	92.5	24 weeks	November
19	Cherries	0	0.0	92.5	92.5	3 - 7 days	May
20	Kiwi	-0.5 to 0	-0.3	90 to 95	92.5	3 - 5 months	November
21	Melon	7 to 10	8.5	92.5	92.5	2 weeks	July
22	Strawberries	0	0.0	90 to 95	92.5	5 - 7 days	July
23	Nut	0 to 10	5.0	55 to 77	66	6 months	October
24	Chestnut	-1 to 0	-0.5	90 to 95	92.5	4 months	October
25	Common sage (early)	8 to 25	16.5	65	65	2 - 3 years	June
26	Common sage (late)	8 to 25	16.5	65	65	2 - 3 years	December
27	Lavender	8 to 25	16.5	70	70	3 - 4 years	July
28	Tea - Plant	20 to 25	22.5	60 to 70	65	12 months	July
	Total Average		**6.1**		**86.2**		

Table 2 Overall Crops Harvest and storage Period.

Overall Crops Harvest and storage Period													
S.No	Crops	January	February	March	April	May	June	July	August	September	October	November	December
1	Binjal						H						
2	Cabbage	S	S	S						H	S	S	S
3	Tomatoes								H	S			
4	Onion	S	S					H	S	S	S	S	S
5	Olive										S	S	
6	Garlic	S							H	S	S	S	S
7	Patatoes	S	S	S	S	S	S	H	S	S	S	S	S
8	Pepper						H						
9	Cucumber							H	S	S			
10	Beans								H				
11	Peas									H			
12	Pear	S	S	S	S							H	S
13	Plums						H						
14	Pomegranate										H		
15	Watermelon							H					
16	Apples	S	S	S	S	S	S				H	S	S
17	Grapes									H	S		
18	Mandarin	S	S	S	S	S	S	S	S	S	S	H	S
19	Cherries					H							
20	Kiwi	S	S	S								H	S
21	Melon							H					
22	Strawberries							H					
23	Nut	S	S	S							H	S	S
24	Chestnut	S									H	S	S
25	Common sage (early)	S	S	S	S	S	S	S	S	S	S	S	S
26	Common sage (late)	S	S	S	S	S	S	S	S	S	S	S	H
27	Lavander	S	S	S	S	S	S	H	S	S	S	S	S
28	Tea - Plant	S	S	S	S	S	S	H	S	S	S	S	S

H = Harvest Period; S = Storage Period

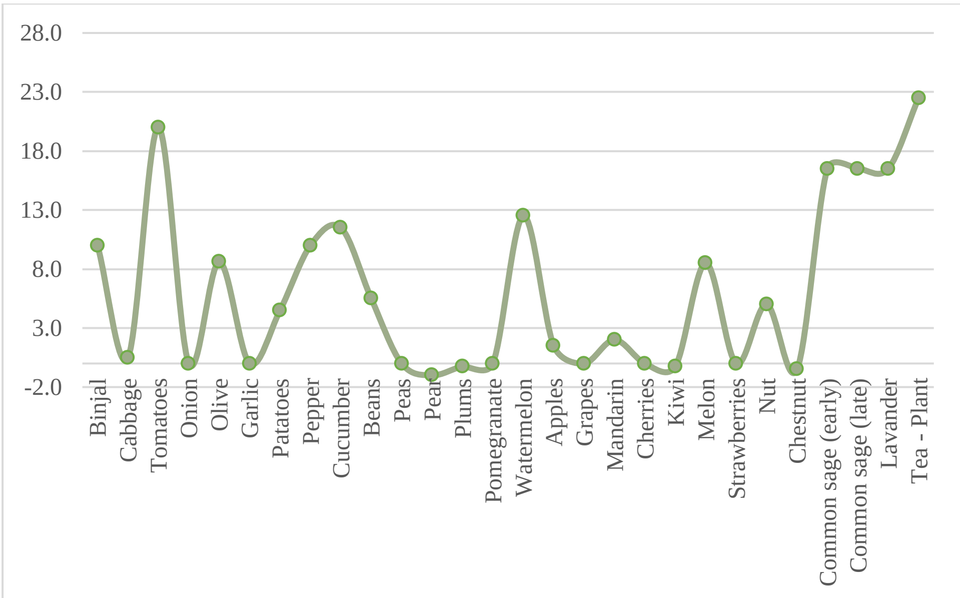


Figure 11 Overall Average Temperature value required for each crop.

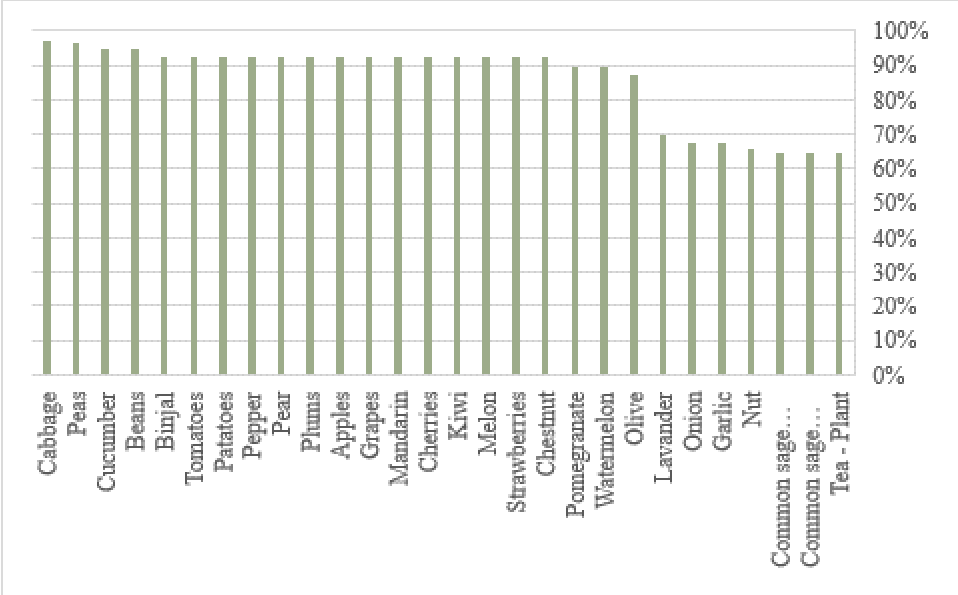


Figure 12 Overall Average Moisture required for each crop.

3.2.1 Agricultural context of Dobër, Malësi e Madhe

The agriculture sector of Dobër consists of small farms owned by landholders. Almost each family owns at least one piece of land that they use for agricultural purposes. The crops produced in this area are mostly vegetables such as pepper, potatoes, cucumber, etc. Medicinal plants are also produced in this area. The common sage is the most produced medicinal plant in this area. A great production of olive and watermelon is also noticed in the area.

As demonstrated in *Table 3*, regarding the temperatures values required for storage in this area, the values vary from 0 °C, which is suitable only for peas, to higher temperatures that go up to 20 °C. As for the humidity percentage values vary from 65%, which is required for storage of the common sage, to 95% for the beans.

Storage and harvest periods in this area also vary according to the crops produced. As demonstrated in *Table 4*, Most of the fruits and vegetables can only be stored for 2-4 weeks, whereas the medicinal plants can be stored up to 2 years in the optimal environmental conditions.

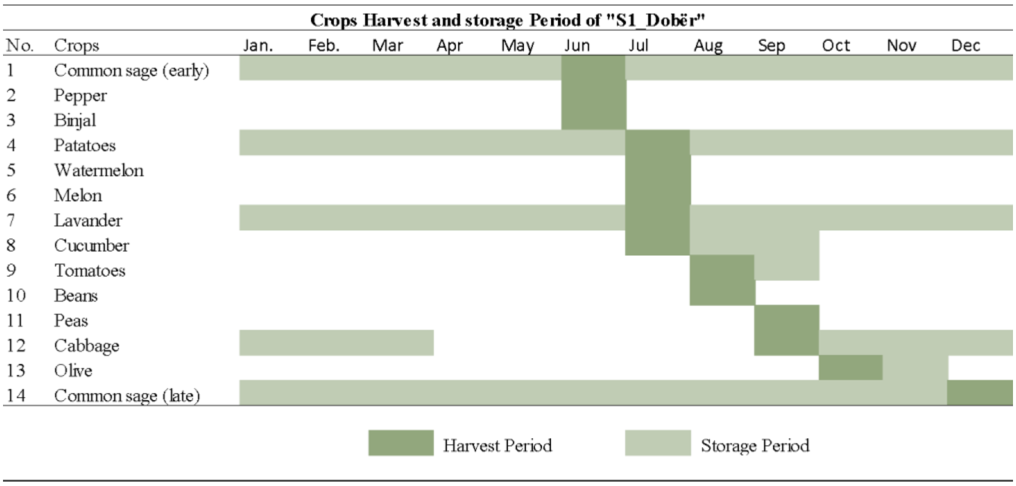
The majority of the crops which constitute of fruits and vegetables are harvested during the summer period, whereas olive and the late common sage are harvested during autumn and winter respectively. *Figure 13* demonstrates the chart of the storage temperature range of each crop produced in the zone, whereas *Figure 14* demonstrates the chart of the humidity range.

The total average temperature required for storage of the crops in this area is 10.1 °C, while the average moisture value required for storage in this area is 87.4%.

Table 3 Agricultural Products of S1 and their HAMT values.

Agricultural Products of "S1_Dobër"							
No.	**Crops**	**Temperature (°C)**	**Avg. Temp. (°C)**	**Moisture (%)**	**Avg. Moisture (%)**	**Storage time**	**Harvest Period**
1	Common sage (early)	8 to 25	16.5	65	65.0	2 - 3 years	June
2	Pepper	7 to 13	10.0	92.5	92.5	1 - 2 weeks	June
3	Brinjal	8 to 12	10.0	90 to 95	92.5	1-2 weeks	June
4	Potatoes	4 to 5	4.5	90 to 95	92.5	1 - 2 weeks	July
5	Watermelon	10 to 15	12.5	90	90.0	2 - 3 weeks	July
6	Melon	7 to 10	8.5	92.5	92.5	2 weeks	July
7	Lavender	8 to 25	16.5	70	70.0	3 - 4 years	July
8	Cucumber	10 to 13	11.5	95	95.0	10 - 14 days	July - September
9	Tomatoes	18 to 22	20.0	92.5	92.5	1 - 3 weeks	August - September
10	Beans	4 to 7	5.5	95	95.0	7 - 10 days	August
11	Peas	0	0.0	96.5	96.5	1 - 2 weeks	September
12	Cabbage	0 to 1	0.5	95 to 100	97.5	3 - 7 months	September - October
13	Olive	7.2 to 10	8.6	85 to 90	87.5	4 - 6 weeks	October - November
14	Common sage (late)	8 to 25	16.5	65	65.0	2 - 3 years	December
	Total Average		**10.1**		**87.4**		

Table 4 Crops harvest and storage period of S1.



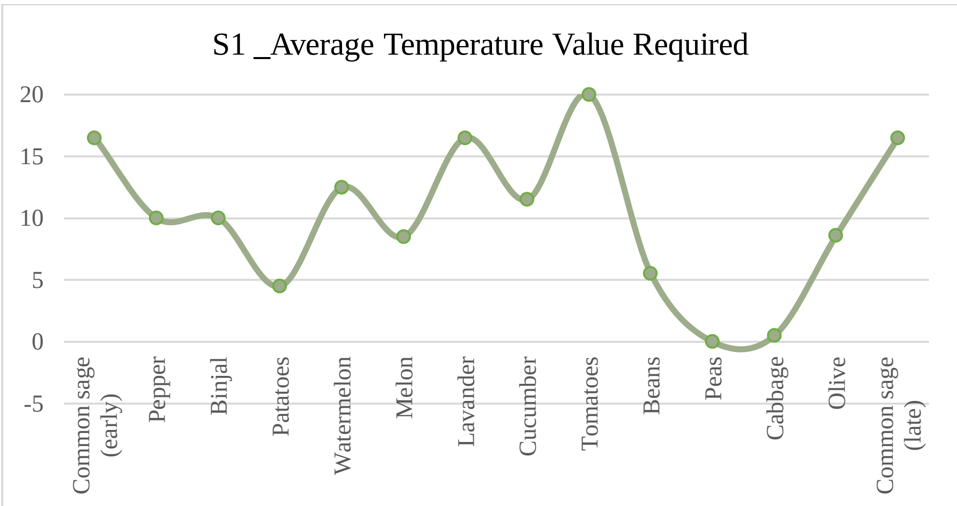


Figure 13 Average Temperature value required for each crop in S1.

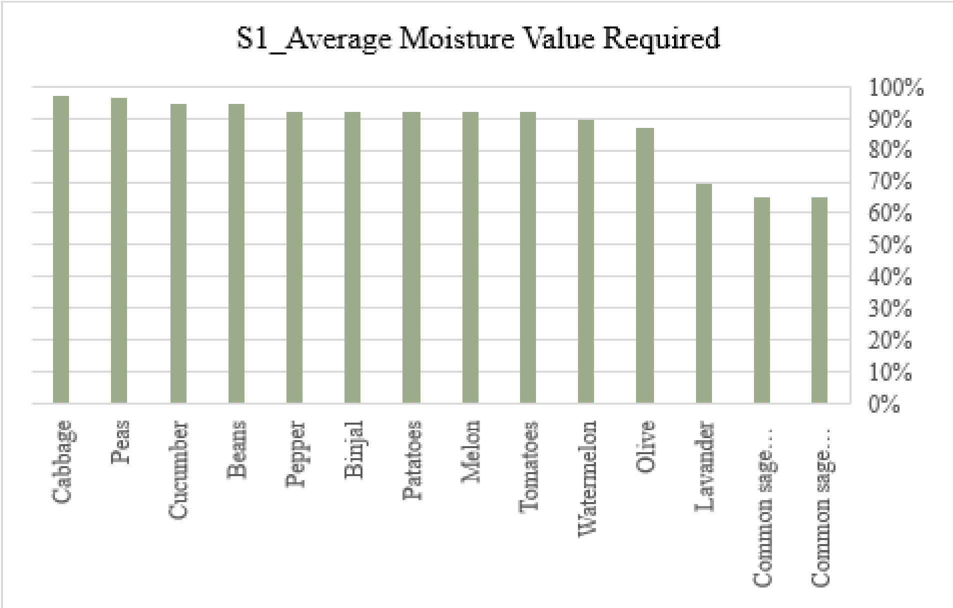


Figure 14 Average Moisture value required for each crop of S2.

3.2.2 Agricultural context of Gruemirë, Malësi e Madhe

The agriculture sector of Gruemirë also consists of small farms owned by landholders. Almost each family owns at least one piece of land that they use for agricultural purposes. The crops produced in this area are mostly fruits such as apple, strawberries, plums, etc. Medicinal plants are also produced in this area. The common sage and lavender are both produced in Gruemirë . A great production of onion and garlic is also noticed in the area.

As demonstrated in *Table 3*, regarding the temperatures values required for storage in this area, the values vary from -1.5 °C, which is suitable only for pears, to higher temperatures that go up to 16.5 °C. As for the humidity percentage values vary from 65%, which is required for storage of the common sage, to 92.5% for fruits such as kiwi, pear and grapes.

Storage and harvest periods in this area also vary according to the crops produced. As demonstrated in *Table 6*, Most of the vegetables can only be stored for 2-4 weeks, whereas fruits can be stored up to 8 months. As for the medicinal plants, they can be stored up to 2 years in the optimal environmental conditions.

The majority of the crops which constitute of fruits and vegetables are harvested during the summer period, whereas fruits such as: grapes, pomegranate, kiwi and pear are harvested during autumn. The late common sage is harvested during autumn and winter respectively.

The total average temperature required for storage of the crops in this area is 2.8 °C, while the average moisture value required for storage in this area is 83.1 %. *Figure 13* demonstrates the chart of the storage temperature range of each crop produced in the zone, whereas *Figure 14* demonstrates the chart of the humidity range.

Table 5 Agricultural Products of S2 and their HAMT values.

Agricultural Products of "S2_Gruemirë"							
No.	**Crops**	**Temperature (°C)**	**Avg. Temp. (°C)**	**Moisture (%)**	**Avg. Moisture (%)**	**Storage time**	**Harvest Period**
1	Common sage (early)	8 to 25	16.5	65	65	2 - 3 years	June
2	Plums	-0.5 to 0	-0.25	92.5	92.5	2 - 5 weeks	June
3	Strawberries	0	0.0	90 to 95	92.5	5 - 7 days	July
4	Lavender	8 to 25	16.5	70	70	3 - 4 years	July
5	Potatoes	4 to 5	4.5	90 to 95	92.5	1 - 2 weeks	July
6	Onion	0	0.0	67.5	67.5	1 - 8 months	July - August
7	Garlic	0	0.0	65 to 70	67.5	6- 7 months	August - September
8	Grapes	-1 to 1	0.0	90 to 95	92.5	3 - 6 weeks	September
9	Olive	7.2 to 10	8.6	85 to 90	87.5	4 - 6 weeks	October - November
10	Apples	-1 to 4	1.5	92.5	92.5	1 - 8 months	October
11	Pomegranate	0	0.0	90	90	2 - 4 weeks	October
12	Kiwi	-0.5 to 0	-0.25	90 to 95	92.5	3 - 5 months	November
13	Pear	-1.5 to -0.5	-1.0	92.5	92.5	2 - 7 months	November
14	Common sage (late)	8 to 25	16.5	65	65	2 - 3 years	December
	Total Average		**2.8**		**83.1**		

Table 6 Crops harvest and storage period of S2.

Crops Harvest and storage Period of "S2_Gruemire"													
S.No	Crops	January	February	March	April	May	June	July	August	September	October	November	December
1	Onion												
2	Olive												
3	Garlic												
4	Patatoes												
5	Pear												
6	Plums												
7	Pomegranate												
8	Apples												
9	Grapes												
10	Kiwi												
11	Strawberries												
12	Common sage (early)												
13	Common sage (late)												
14	Lavander												

Harvest Period   Storage Period

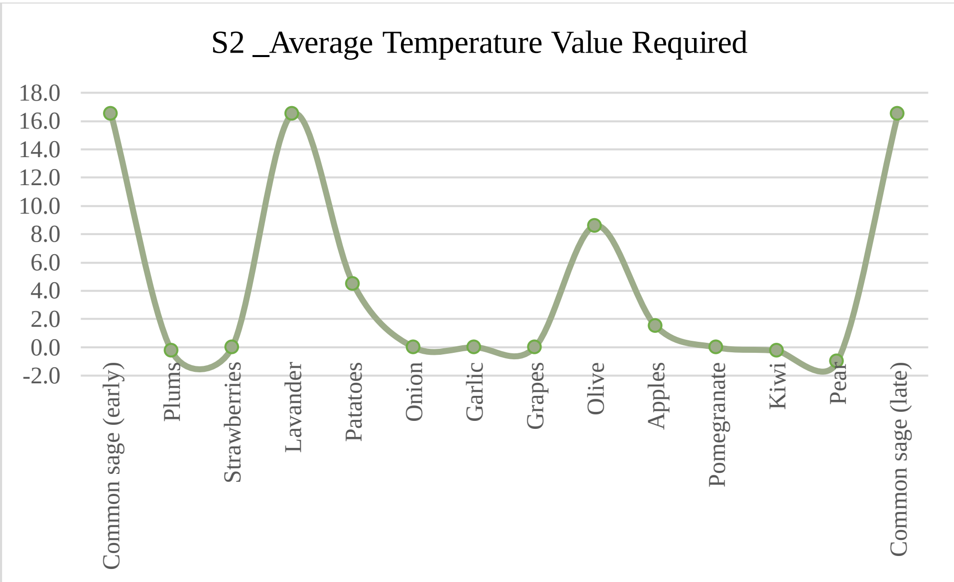


Figure 15 Average temperature value required for each crop in S2.

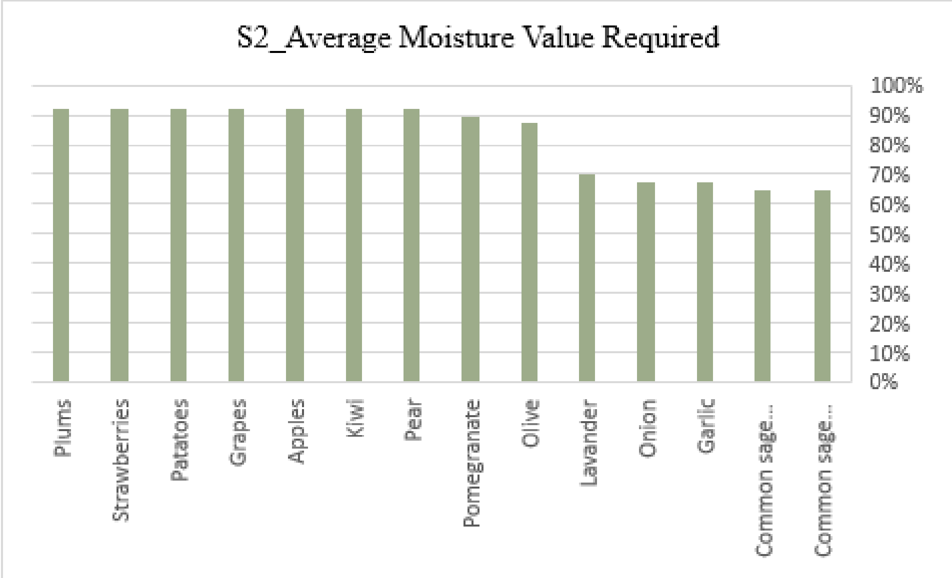


Figure 16 Average Moisture value required for each crop in S2.

3.2.3 Agricultural context of Marshej, Malësi e Madhe

The agriculture sector of Marshej also consists of small farms owned by landholders. Almost each family owns at least one piece of land that they use for agricultural purposes. The crops produced in this area are mostly medicinal plants and beech family plants such as nuts and chestnuts. The common sage and lavender are both greatly produced in Marshej.

As demonstrated in *Table 7*, Regarding the temperatures values required for storage in this area, the values vary from -0.5 °C, which is suitable only for chestnuts, to higher temperatures that go up to 22.5 °C. As for the humidity percentage values vary from 65%, which is required for storage of the common sage, to 92.5% for grapes and potatoes.

Storage and harvest periods in this area also vary according to the crops produced. As demonstrated in *Table 8*, Most of the vegetables can only be stored for 2-7 weeks, whereas nuts and chestnuts can be stored up to 8 months. As for the medicinal plants, they can be stored up to 2 years in the optimal environmental conditions.

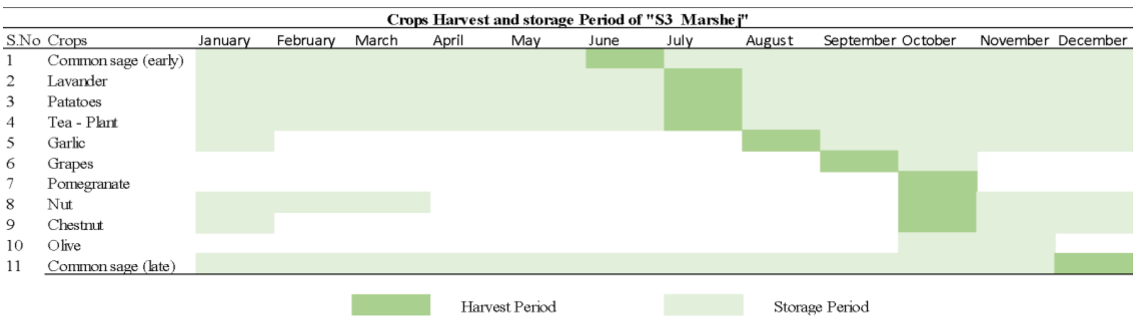
Several of the crops which constitute of fruits and vegetables are harvested during the summer period, whereas most of them are harvested during autumn and winter such as: grapes, pomegranate, nut, chestnut, olive and the late common sage.

The total average temperature required for storage of the crops in this area is 4.2 °C, while the average moisture value required for storage in this area is 80.1 %. *Figure 13* demonstrates the chart of the storage temperature range of each crop produced in the zone, whereas *Figure 14* demonstrates the chart of the humidity range.

Table 7 Agricultural Products of S3 and their HAMT values.

Agricultural Products of "S3_Marshej"							
No.	**Crops**	**Temperature (°C)**	**Avg. Temp. (°C)**	**Moisture (%)**	**Avg. Moisture (%)**	**Storage time**	**Harvest Period**
1	Common sage (early)	8 to 25	16.5	65	65	2 - 3 years	June
2	Lavender	8 to 25	16.5	70	70	3 - 4 years	July
3	Potatoes	4 to 5	4.5	90 to 95	92.5	1 - 2 weeks	July
4	Tea - Plant	20 to 25	22.5	60 to 70	65	12 months	July
5	Garlic	0	0.0	65 to 70	67.5	6- 7 months	August - September
6	Grapes	-1 to 1	0.0	90 to 95	92.5	3 - 6 weeks	September
7	Pomegranate	0	0.0	90	90	2 - 4 weeks	October
8	Nut	0 to 10	5.0	55 to 77	66	6 months	October
9	Chestnut	-1 to 0	-0.5	90 to 95	92.5	4 months	October
10	Olive	7.2 to 10	8.6	85 to 90	87.5	4 - 6 weeks	October - November
11	Common sage (late)	8 to 25	16.5	65	65	2 - 3 years	December
	Total Average		**4.2**		**80.1**		

Table 8 Crops harvest and storage period of S3.



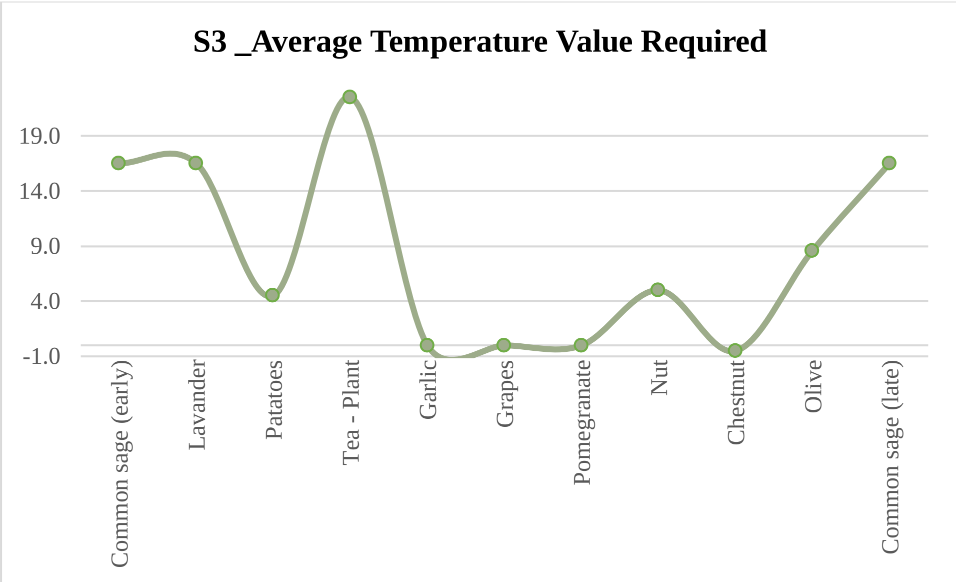


Figure 17 Average Temperature value required for each crop in S3.

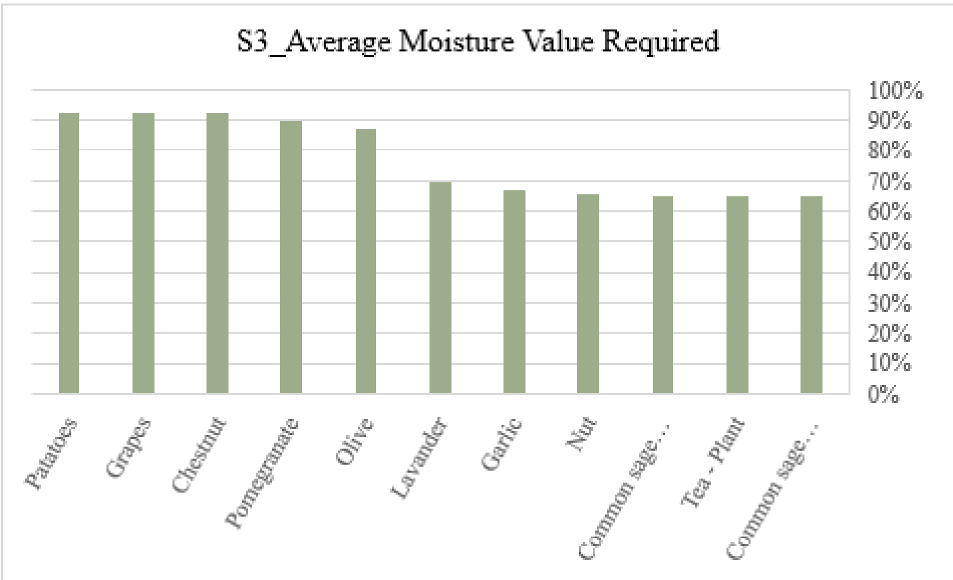


Figure 18 Average Moisture value required for each crop in S3.

CHAPTER 4

METHODOLOGY

4.1 Selection Criteria

The main focus of this research is the vernacular architecture of Albanian rural areas, especially that of Malesia e Madhe district which is located in the northern part of the country, that will be used as agricultural trading centers. This building typology belongs to the 17-19th centuries, reflecting the lack of modern construction technologies. These dwellings can be seen from an architectural point of view as an attempt to make use of the natural resources to their full potential. Analysis of the existing hygrothermal conditions and simulation in the proposed models, is the objective of this research. Three sites are selected for this study.

Following their geographical position, these three sites will each consist of a target building sample. The houses are of the same typology and will serve the same purpose, that of agricultural marketing. However, because of their different climatic conditions that they are in, different agricultural products will be traded. They are characterized by thick outer walls 50-60 cm, small openings, stone masonry, timber roof, etc. The three selected sites S1, S2 and S3 are located in three different villages:

Dobër: Building 1 (B1)

Gruemirë: Building 2 (B2)

Marshej: Building 3 (B3)

These three buildings are selected according to the criteria categorized below:

1. **Climatic conditions and agricultural production,** Dober is a lake coastal village, Gruemire is a hillside landscape and Marshej is a mountainous landscape.

2. **Strategic Location,** the sites are located to be easily accessible. Connection to main highway and other villages.
3. **Tourism influence,** being part of different landscape typologies, can lead to seasonal tourism boost on each site.

4.2 Selected buildings architectural analysis

The selected buildings in this study are old traditional dwellings located in Malësia e Madhe according to their geographical position and agricultural context. These building all belong to the same typology in order to compare the outcome results of each selected site.

Structurally the buildings consist of 60 cm thick heavy mass outer walls of hard stone. The outer walls are made of stone and screed. The pitched roofs are made of timber and clay tiles with and 50 cm overhang. The area between the ceiling of the first floor and the roof is unoccupied and not accessible. The structure of the roof is made of wooden beams. The slab that divides the ground floor from the first floor is mostly made of wood, consisting of the wooden beams and plywood for the ceiling of the ground floor and the floor of the first floor. The partition walls are made of wood and sand aggregate cement. The ground floor slab is composed of plywood, radial oak wood and limestone cement. *Figure 19* and Figure 20 demonstrate some section details and views of the structures.

The u-values of the external and internal walls are 2.28 and 1.50 respectively. Whereas the u-value of the ceiling and floor are 0.67 and 0.59 respectively. The roof consists of a u-value of 0.77.

All of the buildings have gone through a small change in the floor plans by removing some partition walls in order to create the zones for the different types of crops clusters according to their required temperature and humidity values.

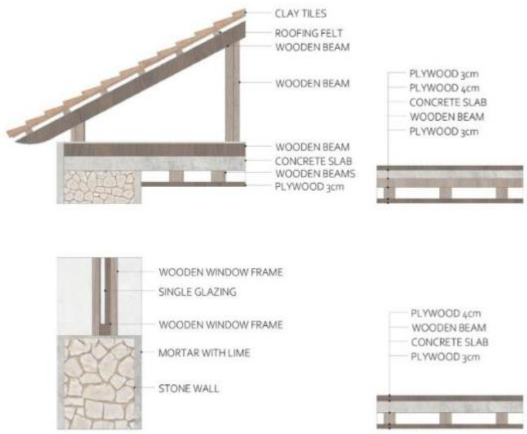
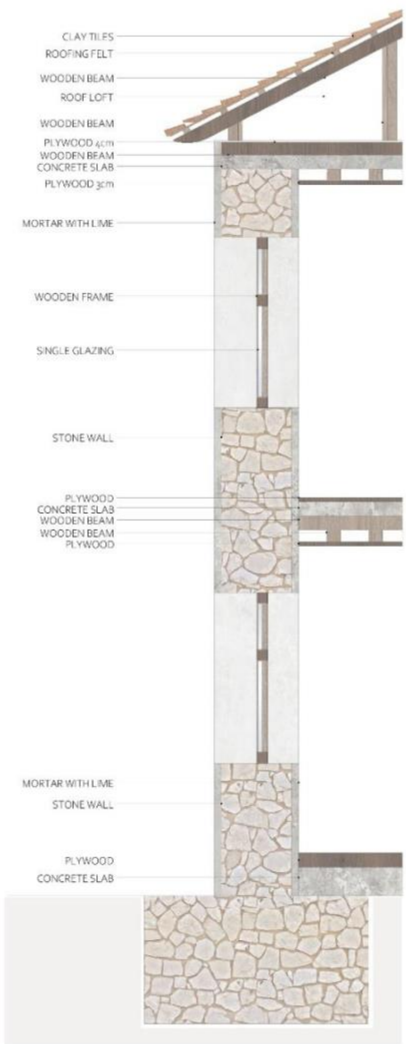


Figure 19 Dushaj, V. (2022) Detail drawings of the building typology.



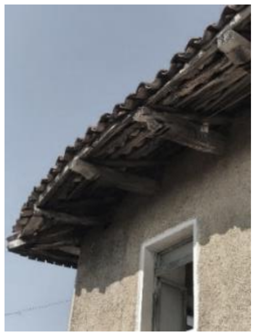


Figure 20 Dushaj, V. (2022) Section detail of the building typology and pictures of B1.

4.2.1 B1 – Building 1 in Dobër

Building 1 (B1) is a two-storey house This building used to be the house of an extended family during the 20th century. The construction of the house dates to 1910. It was mainly constructed of masonry stone walls for outside walls and cement and wood for the partition walls. There is seen a great usage of wood for staircases, doors, casting of windows and the roof. The ground floor was used as a living room and kitchen, meanwhile the upper floors are sleeping areas. The house's main facade faces South-West. It consists of a longitudinal plan divided into 4 different houses. The small openings on the facade are equally distributed. There is the presence of balconies in almost all the houses. *Figure 21* demonstrates a collage of pictures of the building.

Figure 21 Dushaj, V. (2022) Pictures of B1.

The back facade faces North-East. The openings on the facade are even smaller. Only two small doors function as a connection with the outside. Side facades are of a relatively short span. The North-West facade also functions as a main facade for one of the houses. It consists of a balcony and outer staircases, which are elements of the traditional houses in Albania. *Figure 22* demonstrates the facades of the building.

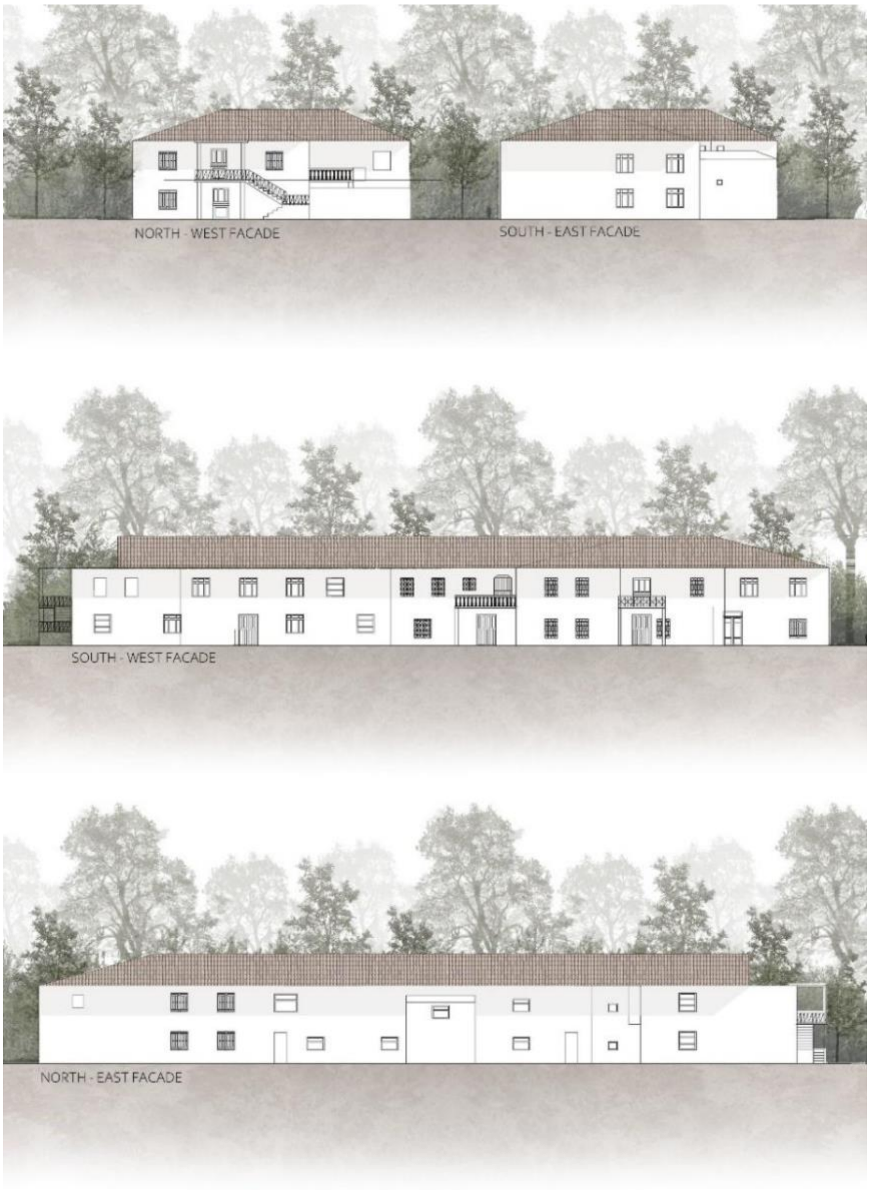


Figure 22 Dushaj, V. (2022) Facades of B1.

Plans of the house reflect the hierarchy of the spaces of the house and also the connectivity of the big rooms through small corridors and stairs. The floors are divided and connected with wooden slabs and doors respectively. *Figure 23* demonstrates the floor plans of the building.

Figure 23 Dushaj, V. (2022) Floor plans of B1

The materials of the building mostly consist of stone and wood. Other materials are: ceramics, plaster, glass, concrete and brick. There is also a small usage of iron in the balcony railing. Except for the first house, all the other houses have been maintained through the decades. Plaster has been added, the roof trusses have been reconstructed and safety elements have been added in the openings of the facade. *Figure 24* demonstrates pictures of the building.

Figure 24 Dushaj, V. (2022) Pictures of B1.

4.2.2 B2 – Building 2 in Gruemirë

Building 2 (B2) is a two-storey house This building also used to be the house of an extended family during the 20th century. The construction of the house dates to 1950-1955. It was mainly constructed of masonry stone walls for outside walls and cement and wood walls for the partition walls. There is seen a great usage of wood for staircases, doors, casting of windows and the roof. The ground floor was used as a living room and kitchen, meanwhile the upper floors are sleeping areas. The house's main facade faces North - East. It consists of a longitudinal plan divided into 3 different houses. The small openings on the facade are equally distributed. There is the presence of balconies in one of the houses. *Figure 25* demonstrates a collage of pictures of the building.

Figure 25 Dushaj, V. (2022) Pictures of B2.

The back facade faces South - West. The openings on this façade are of the same size as the ones. Only two small doors function as a connection with the outside. Side facades are of a relatively short span. *Figure 26* demonstrates the facades of the building.

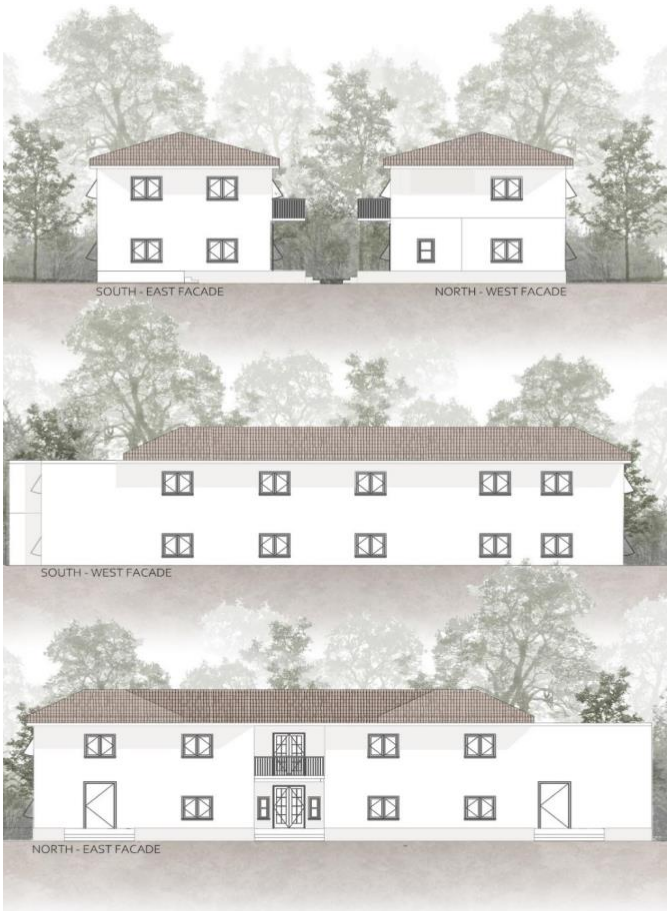


Figure 26 Dushaj, V. (2022) Facades of B2.

Plans of the house reflect the hierarchy of the spaces of the house and also the connectivity of the big rooms through small corridors and stairs. The floors are divided and connected with wooden slabs and doors respectively. *Figure 27* demonstrates the floor plans of the building.

Figure 27 Dushaj, V. (2022) Floor plans of B2.

The materials of this building also consist of stone and wood. Other materials are: ceramics, plaster, glass, concrete and brick. There is also a small usage of iron in the balcony railing. All the other houses have been maintained through the decades. Plaster has been added, the roof trusses have been reconstructed and safety elements have been added in the openings of the facade.

4.2.3 B3 – Building 3 in Marshej

Building 3 (B3) is a two-storey house This building also used to be the house of an extended family during the 20th century. The construction of the house dates to 1950-1955. It was mainly constructed of masonry stone walls for outside walls and cement and wood walls for the partition walls. There is seen a great usage of wood for staircases, doors, casting of windows and the roof. The ground floor was used as a living room and kitchen, meanwhile the upper floors are sleeping areas. The house's main facade faces South- West. It consists of a longitudinal plan divided into 3 different houses. The small openings on the facade are equally distributed. There is no presence of balconies in any of the houses. *Figure 28* demonstrates pictures of the building.

Figure 28 Dushaj, V. (2022) Pictures of B2.

The back facade faces Nort - East. The openings on this façade are smaller and fewer in number. Side facades are of a relatively short span. *Figure 29* demonstrates the facades of the building.

Figure 29 Dushaj, V. (2022) Facades of B3.

Plans of the house reflect the hierarchy of the spaces of the house and also the connectivity of the big rooms through small corridors and stairs. The floors are divided and connected with wooden slabs and doors respectively. *Figure 30* demonstrates the floor plans of the building.

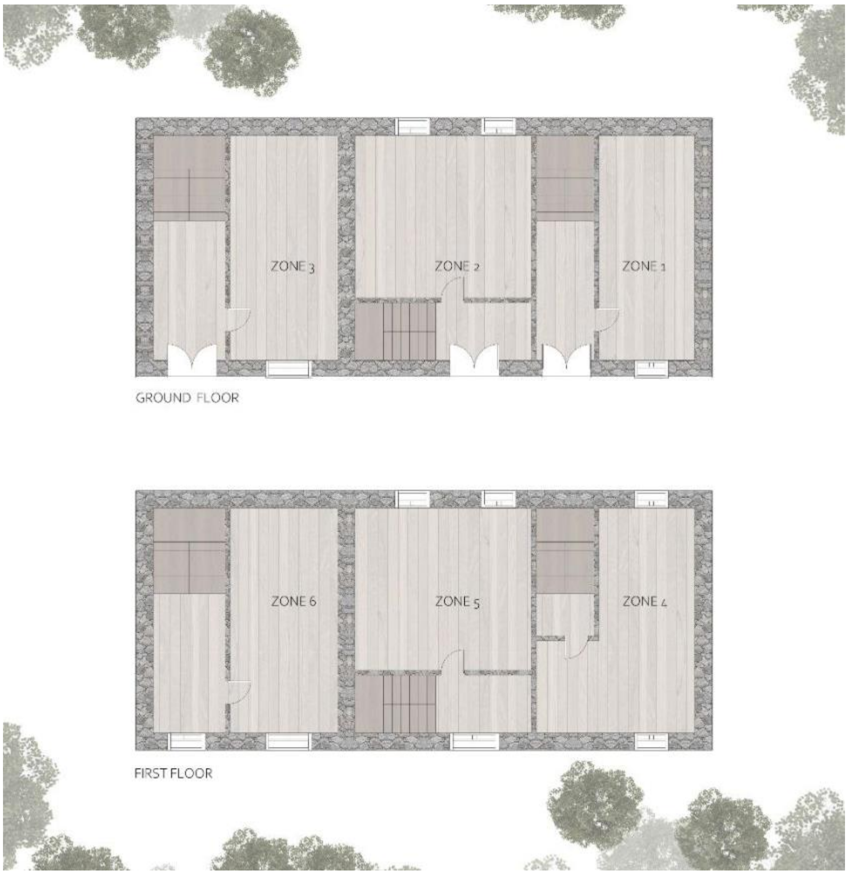


Figure 30 Dushaj, V. (2022) Floor plans of B3.

The materials of the building mostly consist of stone and wood. Other materials are: ceramics, plaster, glass, concrete and brick. There is also a small usage of iron in the balcony railing. Except for the first house, all the other houses have been maintained through the decades. Plaster has been added, the roof trusses have been reconstructed and safety elements have been added in the openings of the facade.

4.3 Questionnaire

A questionnaire was distributed to the inhabitants of the areas. They had to fill the questionnaire anonymously and give their honest opinion regarding the questions asked. These questions were asked to the inhabitants in order to perceive feedback in terms of agricultural problematics and whether they preferred having a agro-logistics center in their area. *Figure 31* demonstrates some scanned papers of the questionnaire.

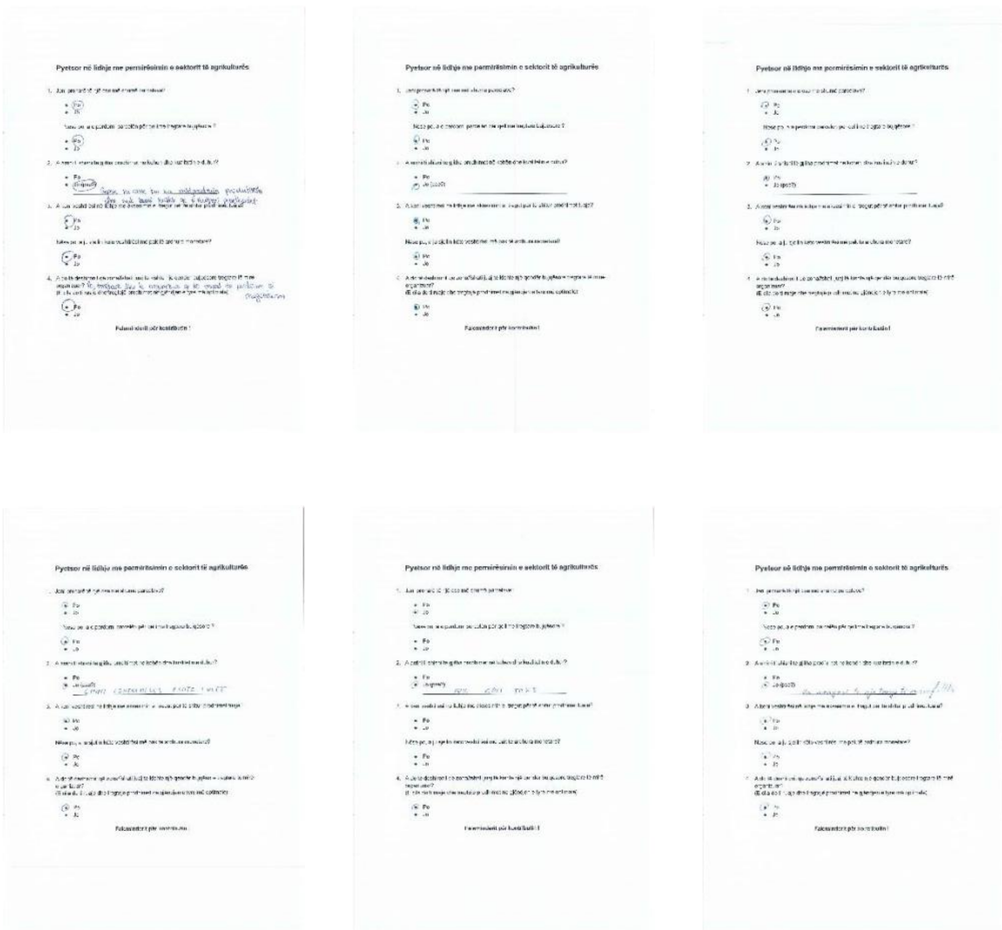


Figure 31 Dushaj, V. (2022) Questionnaire documents

4.4 Computation Simulation Modeling

4.4.1 Software Description

The "Design – Builder" software is a software used by architects and engineers in order to perceive simulations regarding temperature, humidity, energy efficiency, etc. The simulations are computed after 3d modelling the structure and then presuming with the input variables such as building materials, orientation, weather data, etc. Occupancy schedules are also a part of the inputs which are required in order to perceive the closest to reality outcome. The weather data used in the software are retrieved from Meteonorm (2020) software.

4.4.2 Simulation existing state results

Data gathered from the simulations that were computed in order to perceive the passive case of the buildings in the existing state is shown in the figures below. Six simulations were computed to perceive the outcome of the hottest and coldest days of the three sites where the three buildings are located. The coldest day is 10th of January while the hottest day is 10th of July. The building parameters of the buildings are demonstrated in *Table 9.*

According to the results B1 performs better during the coldest day than the other two buildings by keeping a constant temperature around 10 °C, whereas B2 and B3 keep less constant values less than 8 °C. *Figure 32, Figure 33 and Figure 34* demonstrate the comparison between the indoor air temperature of the existing state with the measured air temperature during the coldest day of B1, B2 and B3 respectively. Whereas, *Figure 35, Figure 36* and *Figure 37* demonstrate the comparison between the indoor air temperature of the existing state with the measured air temperature during the hottest day of B1, B2 and B3 respectively.

Table 9 Construction elements and their associated U-values

Construction element	**U-value (W.m2K-1)**	**Description**
External wall	2.28	cement/lime plaster (0.05 m) hard / dry stone (0.5 m) cement/lime plaster (0.05 m)
Roof	0.77	clay tile (0.025) air gap (0.02) roofing felt (0.005)
Window	2.6	single glazing, clear (4mm)
Partition wall	1.5	cement/lime plaster (0.05) sand aggregate cement (0.5) radial oak wood (0.10 m) sand aggregate cement (0.5) cement/lime plaster (0.05)
Floor	0.59	plywood (0.03 m) radial oak wood (0.1 m) radial oak wood (0.1 m) limestone cement (0.08 m) plywood (0.03 m)
Ceiling	0.67	plywood (0.03m) radial oak wood (0.1 m) radial oak wood (0.1 m) limestone cement (0.08m)

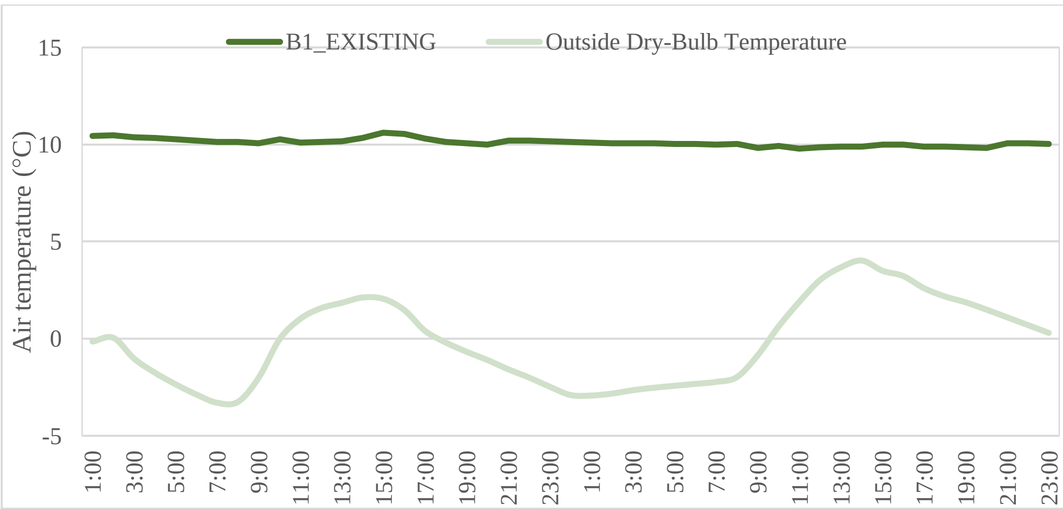


Figure 32 Comparison between the indoor air temperature of the existing state with the measured air temperature during the coldest day of B1.

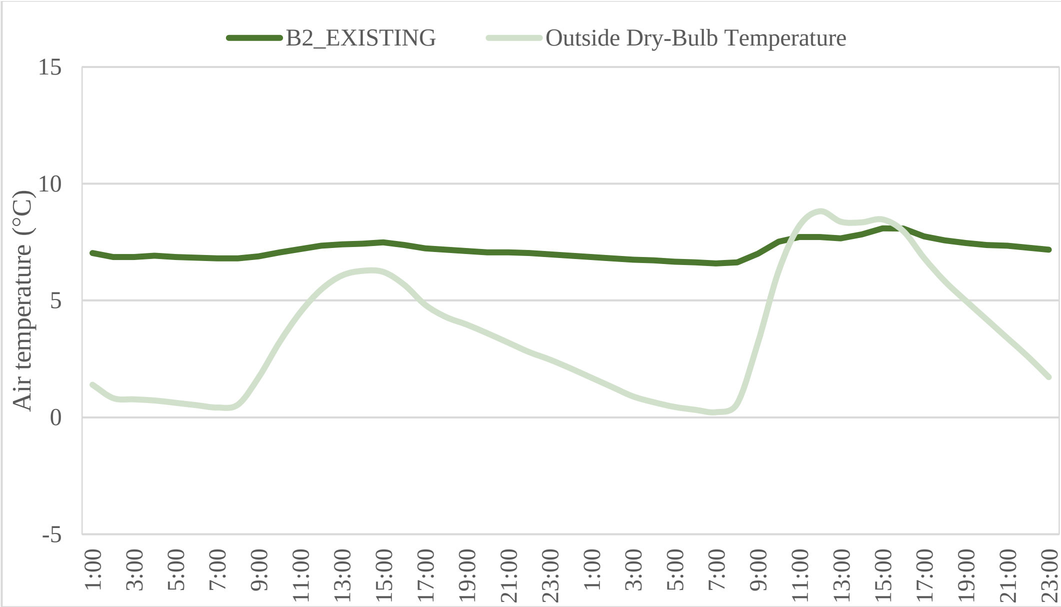


Figure 33 Comparison between the indoor air temperature of the existing state with the measured air temperature during the coldest day of B2.

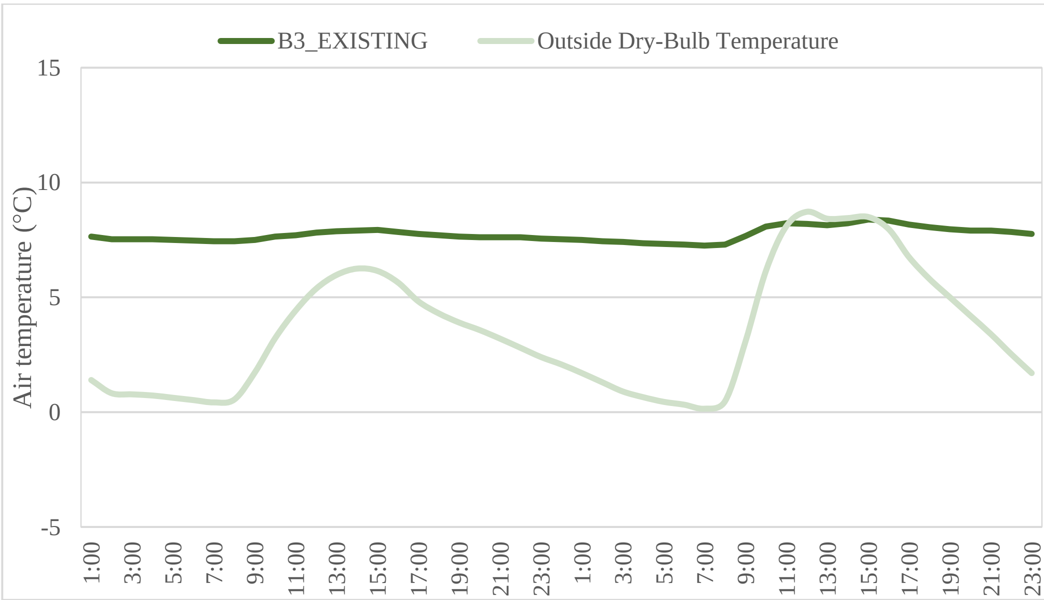


Figure 34 Comparison between the indoor air temperature of the existing state with the measured air temperature during the coldest day of B3.

According to the results B3 performs better during the Hottest day than the other two buildings by keeping a constant temperature around 29 °C, whereas B1 and B2 keep less constant values higher than 30°C.

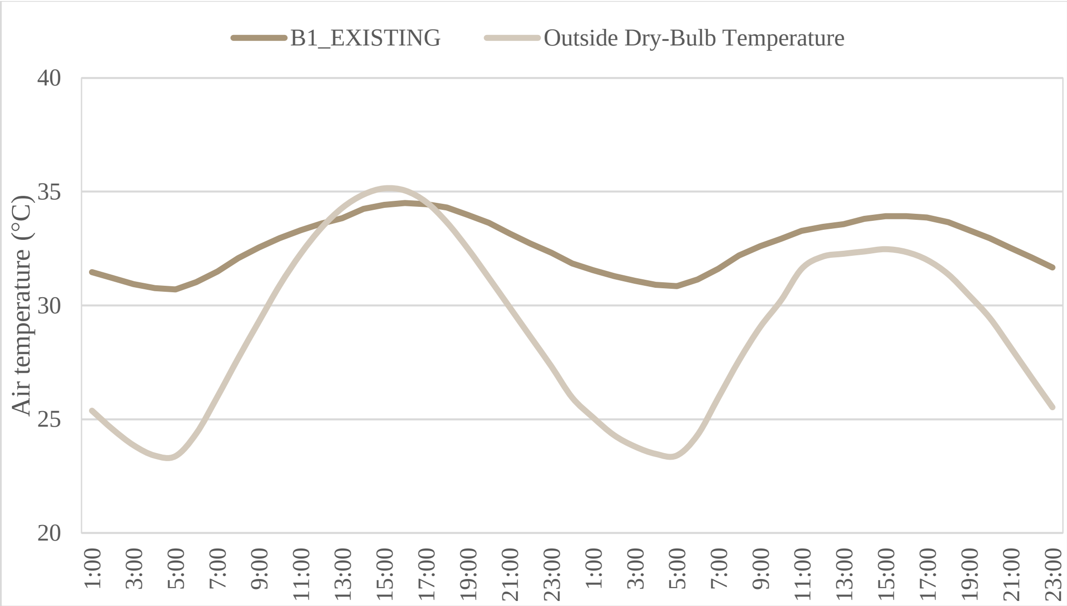


Figure 35 Comparison between the indoor air temperature of the existing state with the measured air temperature during the hottest day of B1.

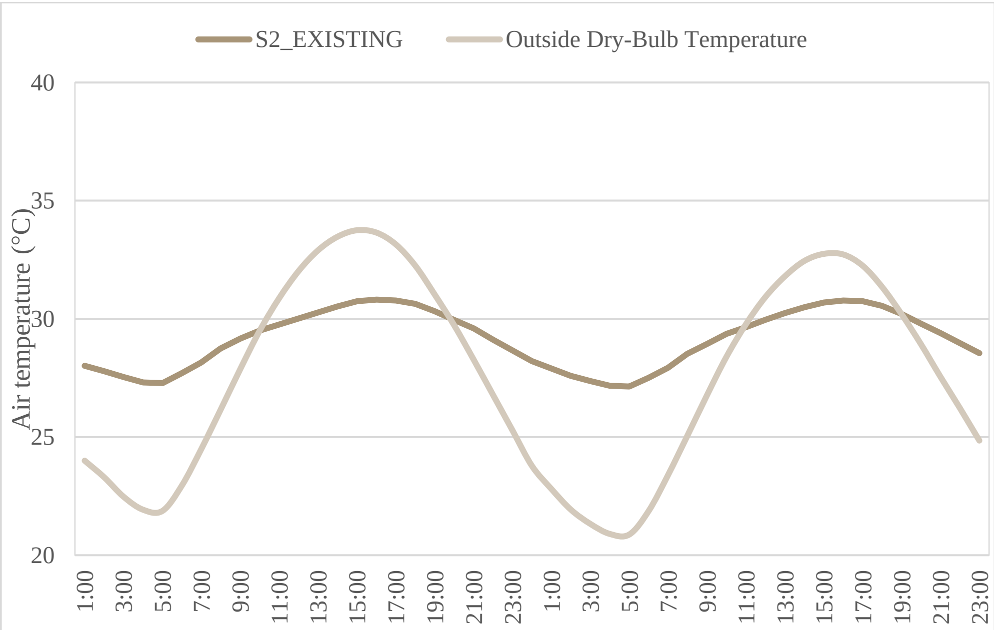


Figure 36 Comparison between the indoor air temperature of the existing state with the measured air temperature during the hottest day of B2.

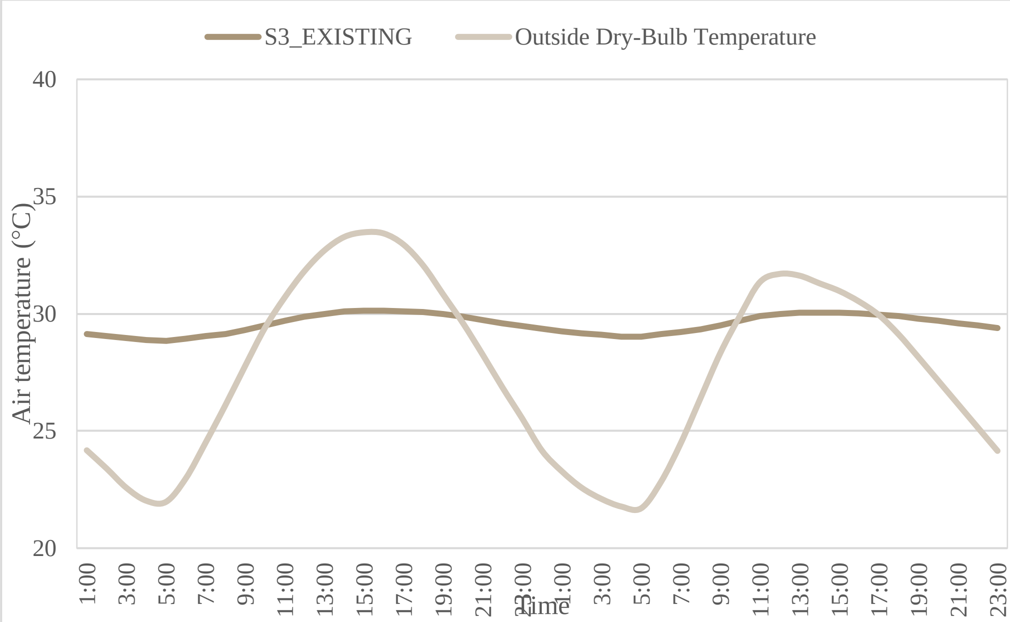


Figure 37 Comparison between the indoor air temperature of the existing state with the measured air temperature during the hottest day of B3.

4.5 Zones distribution according to temperatures and humidity values

The existing buildings floor plans consist of many subdivisions. On this study the number of zones is considerably reduced as a result of the required HAMT values of the crops produced. The zones of the building are divided according to their area and temperature input.

4.5.1 Building 1 (B1) – Dobër

B1 consists of two floors. Each of the floors consists of 5 zones. Each zone is accessed by its own door connecting the zone with the transit area that separates the outdoor from the indoor. Adjacent to each zone there is a wooden stair that leads to the upper floor. One of the zones is planned to maintain a constant comfortable temperature throughout the year which might be used for administration or agro-tourism purposes. Whereas the other rooms are used for storage and consist of temperatures and humidity according to the crop's requirements

The ground floor consists of 5 zones that consist of temperatures ranging from 0°C - 22°C and humidity values from 30% - 95%. The areas of the zones are selected according to the crops produced. Zone 2 has the largest area of 103 m2, as a result of 6 different crop products being stored there. Figure 38 and Figure 39 demonstrate 3D illustrations for the zone's distribution of the ground floor and first floor of the building respectively.

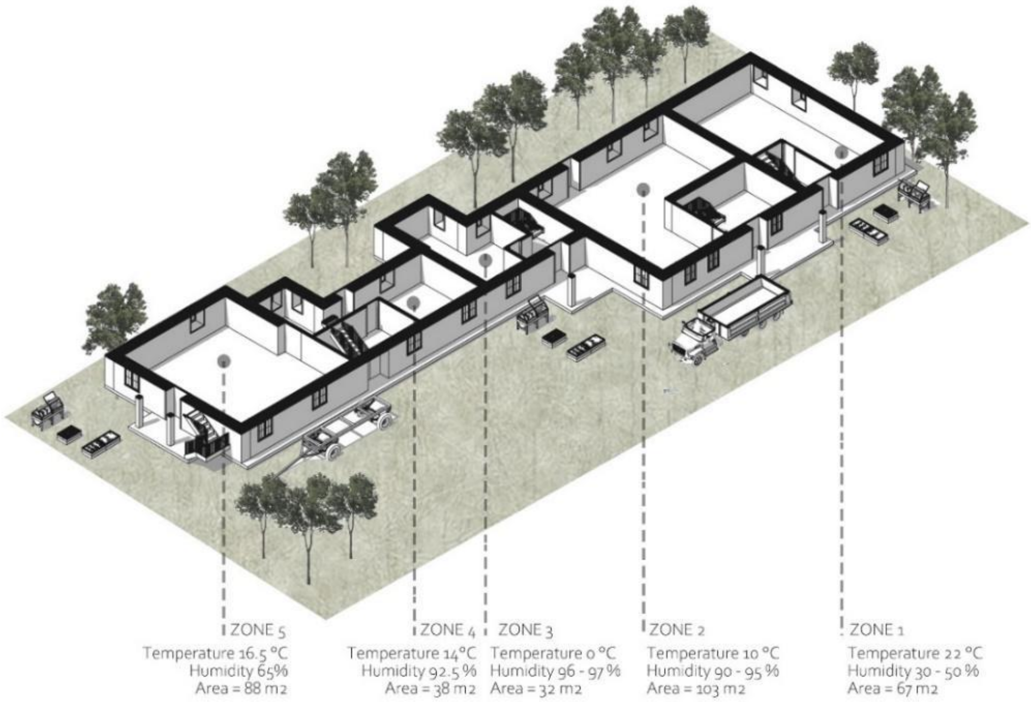


Figure 38 Dushaj, V. (2022) Illustration of the zone distribution of B1, ground floor.

The first floor also consists of 5 zones which have temperatures ranging from 0°C - 22°C and humidity values from 30% - 95%. Zone 9 has the largest area of 103 m2, as a result of 6 different crop products being stored there.

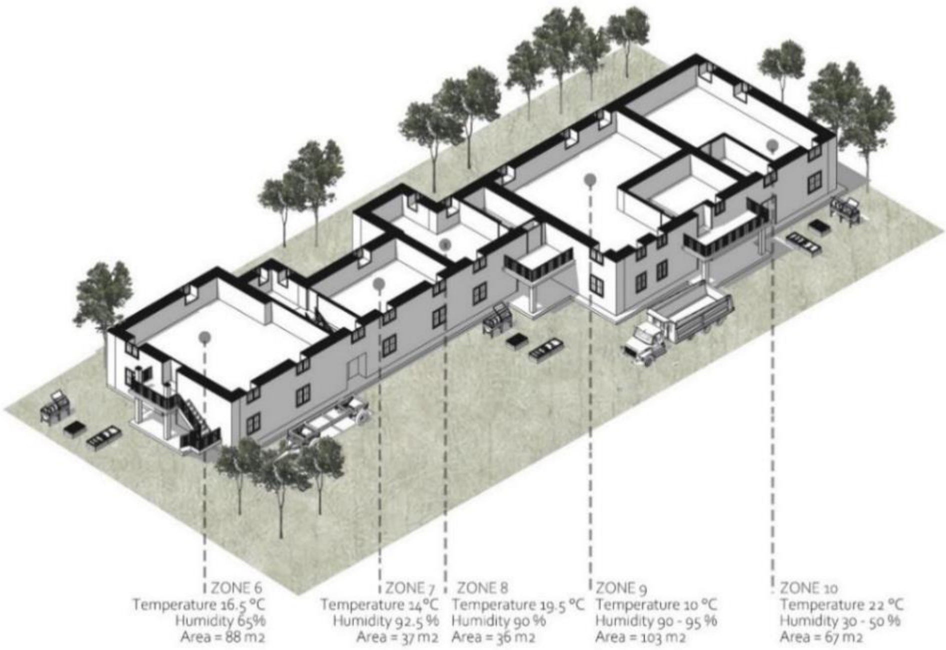


Figure 39 Dushaj, V. (2022) Illustration of the zone distribution of B1, First floor.

4.5.2 Building 2 (B2) – Gruemirë

B2 consists of two floors. Each of the floors consists of 3 zones. Each zone is accessed by its own door connecting the zone with the transit area that separates the outdoor from the indoor. Adjacent to each zone there is a wooden stair that leads to the upper floor.

The ground floor consists of 3 zones that consist of temperatures ranging from 0°C – 16.5°C and humidity values from 65% - 90%. The areas of the zones are selected according to the crops produced. Zone 1 has the largest area of 32 m2, as a result of the mass production of potatoes and olive that this zone has. *Figure 40* and *Figure 41* demonstrate 3D illustrations for the zone's distribution of the ground floor and first floor of the building respectively.

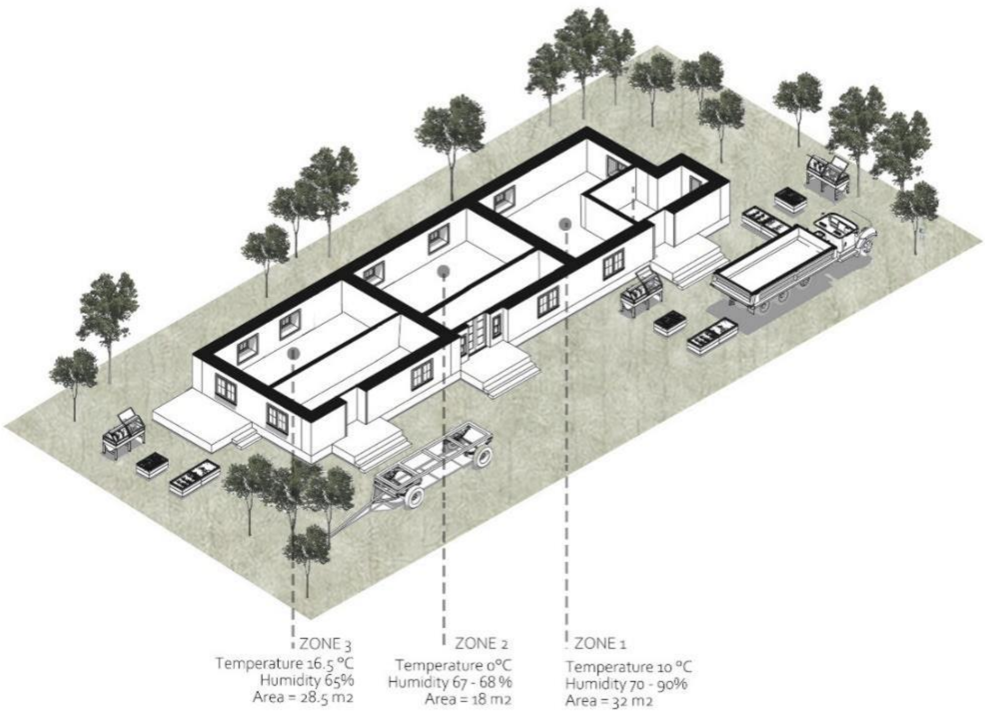


Figure 40 Dushaj, V. (2022) Illustration of the zone distribution of B2, ground floor.

The first floor also consists of 3 zones which have temperatures ranging from 1°C – 16.5 °C and humidity values from 30% - 95%. Zone 5 has the largest area of 36 m2, as a result of the mass production of medicinal plants. One of the zones is planned to maintain a constant comfortable temperature throughout the year which might be used for administration or agro-tourism purposes. Whereas the other rooms are used for storage and consist of temperatures and humidity according to the crop's requirements

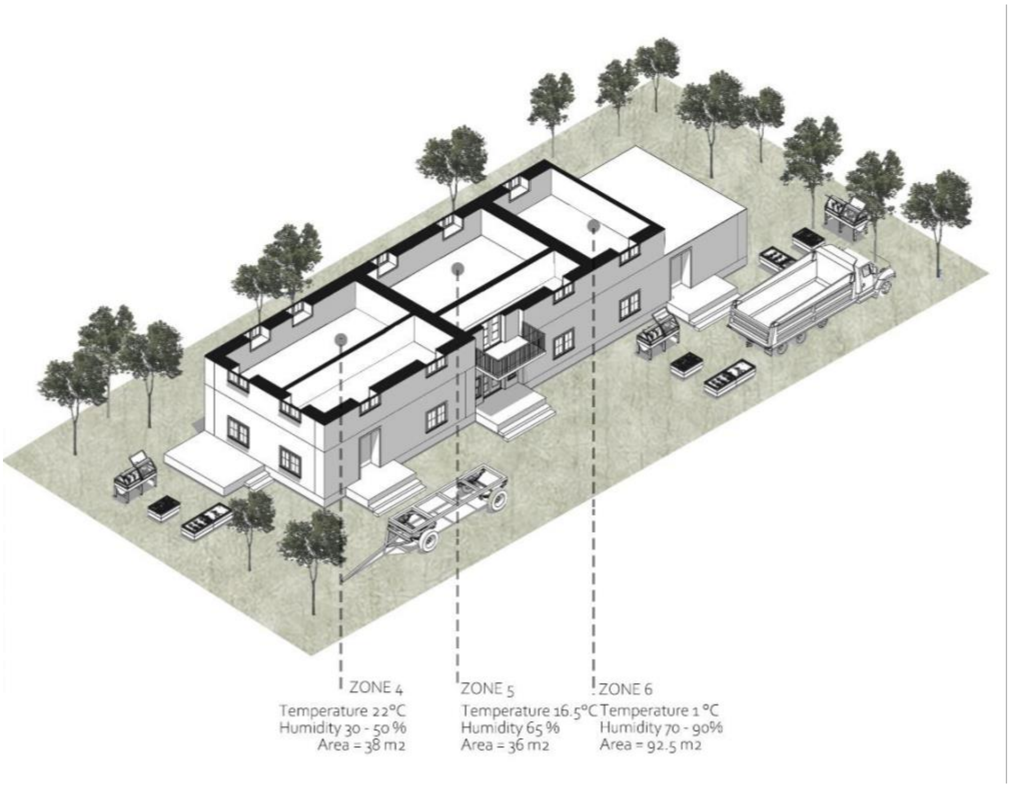


Figure 41 Dushaj, V. (2022) Illustration of the zone distribution of B2, First floor.

4.5.3 Building 3 (B3) – Marshej

B3 also consists of two floors. Each of the floors consists of 3 zones. Each zone is accessed by its own door connecting the zone with the transit area that separates the outdoor from the indoor. Adjacent to each zone there is a wooden stair that leads to the upper floor. One of the zones is planned to maintain a constant comfortable temperature throughout the year which might be used for administration or agro-tourism purposes. Whereas the other rooms are used for storage and consist of temperatures and humidity according to the crop's requirements

The ground floor consists of 3 zones that consist of temperatures ranging from 10°C – 22°C and humidity values from 30% - 92%. The areas of the zones are selected according to the crops produced. Zone 2 has the largest area of 34 m2, as a result of the mass production of medicinal plants that this zone has. *Figure 42* and *Figure 43* demonstrate 3D illustrations for the zone's distribution of the ground floor and first floor of the building respectively.

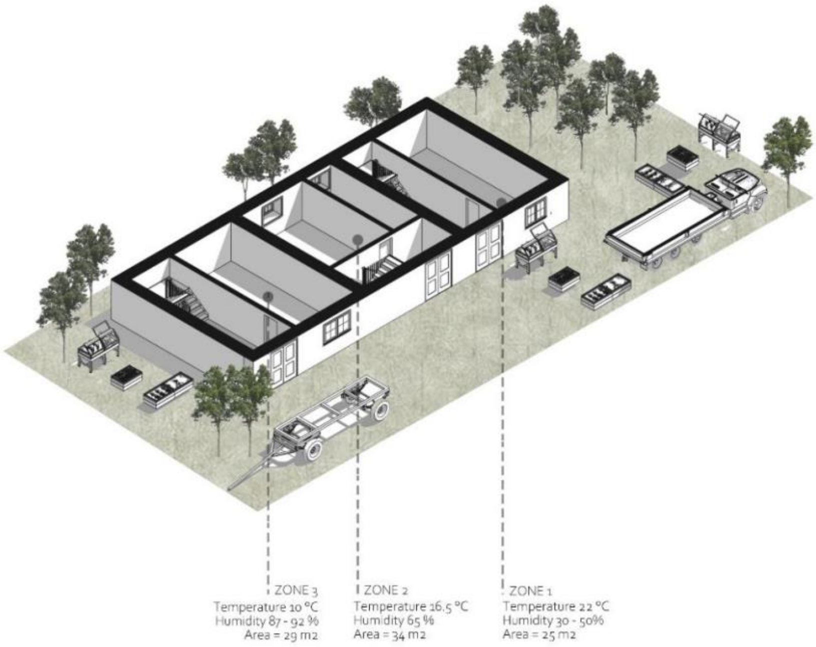


Figure 42 Dushaj, V. (2022) Illustration of the zone distribution of B3, ground floor.

The first floor also consists of 3 zones which have temperatures ranging from 0°C - 5°C and humidity values from 66% - 92%. Zone 5 has the largest area of 34 m2, as a result of 4 different crop products being stored there.

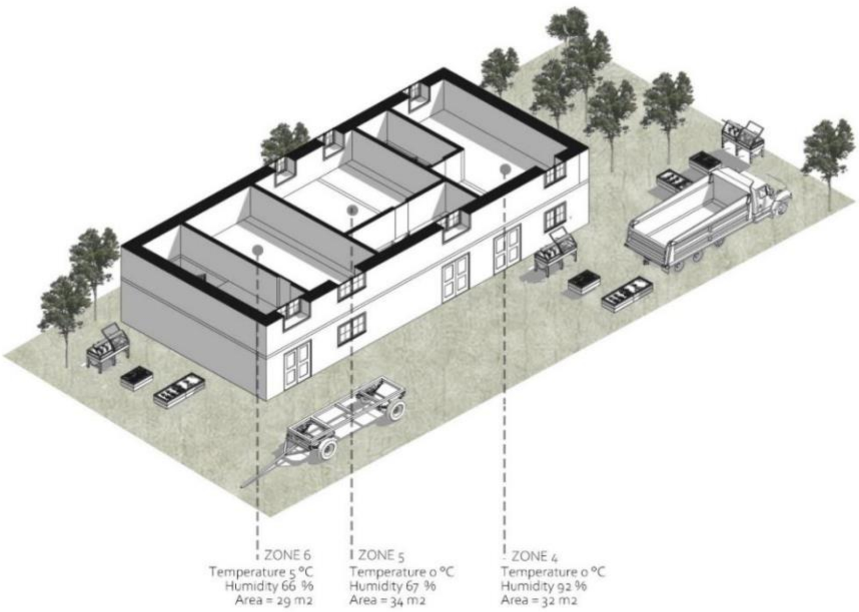


Figure 43 Dushaj, V. (2022) Illustration of the zone distribution of B1, ground floor.

4.6 Optimization Scenarios

In order to achieve the most optimal temperatures by consuming less energy various scenarios were computed in the software in order to compare the outcome. The scenarios consist of affordable thermal insulating techniques. (SC 1) Is the first scenario which consists of the outer wall insulation. The second scenario is (SC 2), which consists of converting the single glazing windows to double glazing. (SC 3) is related to the roof insulation and (SC 4) is a combination of all 3 scenarios. Firstly, the scenarios were computed one by one in each of the buildings in order to perceive the impact that each scenario has on the building. After the implementation of all the scenarios in each building another phase of the simulation process is computed. The final simulation consists of a combination of all three scenarios. *Table 10* demonstrates the descriptions and u-values of each scenario.

Table 10 Description of retrofit scenarios.

Scenario Code	**Description**	**U-value (W.m2.K)**
SC 1	Wall insulation (Fiberglass = 10 cm)	0.361
SC 2	Replacement of single glazing to double glazing	1.499
SC 3	Roof insulation (MW stone wool 10 cm)	0.2
SC 4	SC 1 + SC 2 + SC 3	

4.6.1 Suitable HVAC systems integrated

The HVAC system selected for the scenarios proposed is a 1o Celsius Fan coil unit (4 pipe) wit district heating + cooling. The pressure of the fans is 150 (Pa) with a total efficiency of 70 %. The heating system seasonal, heating coil cooling system seasonal and unitary cooling CoP are 3.00. The humidification and dehumidification control types are both Humidistat.

CHAPTER 5

RESULTS

This section portrays the simulation results in charts and graphs in order to explain the energy consumption of each building. Firstly, the energy performance (active case) of the buildings is analyzed followed by the analysis of the energy consumption simulations (active case) of the retrofit measures implemented in the software.

5.1 Thermal Performance (Passive Case)

Considering the fact that the buildings are separated into zones according to the temperature required for storage of each crop, the thermal performance analysis is zone-based computed. The three common temperatures of all the buildings are selected, 0 °C, 10 °C, 16.5 °C, in order to compare the thermal performance of the sites.

5.1.1 B1 – Dobër, Malësi e Madhe

In the first building which is located in S1 Dober, three zones are selected to be analyzed. These zones are of temperatures 0 °C, 10 °C and 16.5 °C which are classified as zone 7, zone 2 and zone 5 respectively according to their areas and storage conditions.

5.1.1.1 Zone 2 – 10 °C (Passive Case)

Zone 2, which is proposed to maintain a temperature of 10 °C, is 103m^2 and is located on the ground floor of the building. *Figure 44* and *Figure 45* demonstrate the thermal performance of the zone during the coldest and hottest days of the year respectively, which are, 10th of January and 10th of July. During the coldest day the temperature inside the zone seems to provide a very suitable environment, with temperatures ranging from 10 °C to 12 °C. While, as noticed in the curve which represents the air temperature inside the zone, during the hottest day, the temperature inside does not approach the required temperature. However, the building influences on maintaining a more constant temperature inside the zone in comparison to the outside dry temperature.

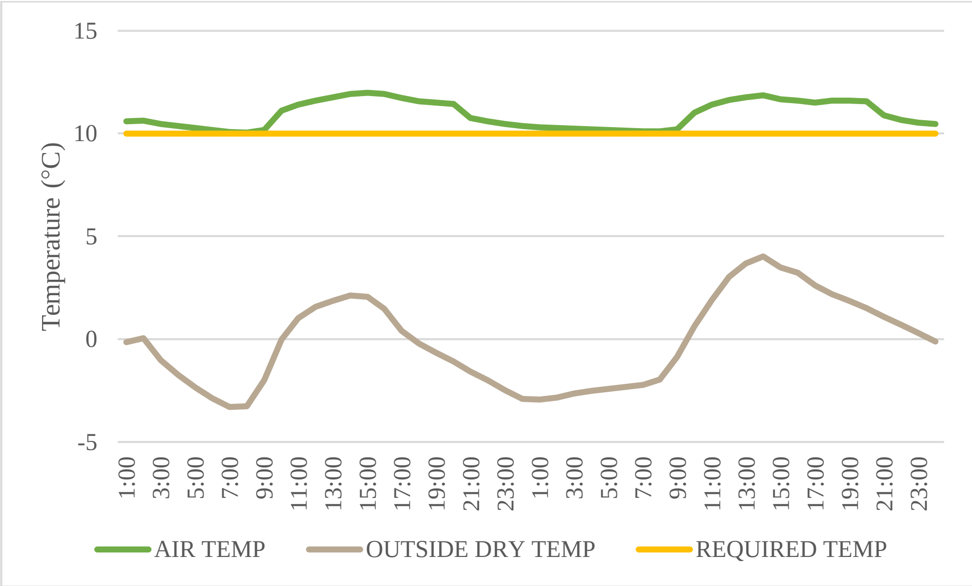


Figure 44 Thermal Performance of Zone 2 in B1 (10 January).

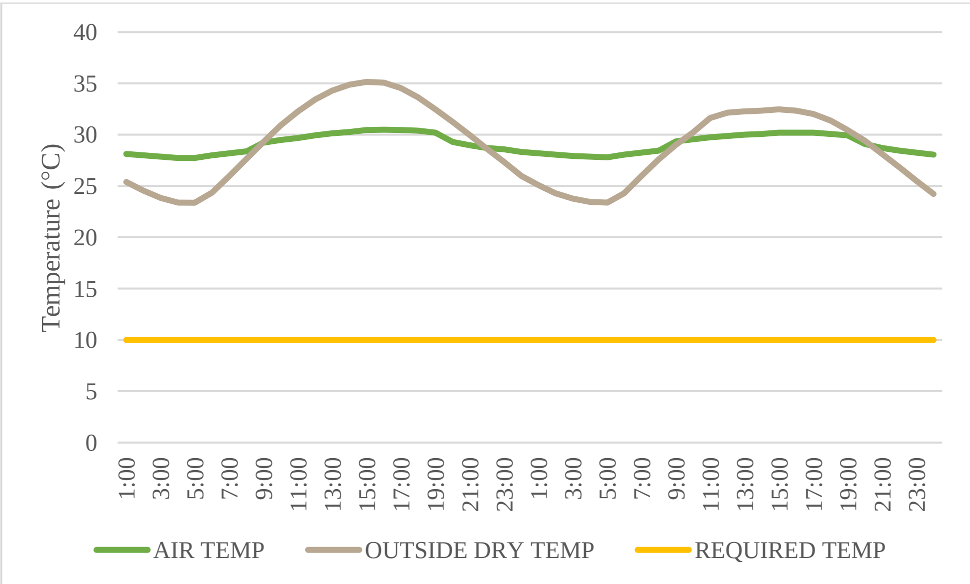


Figure 45 Thermal Performance of Zone 2 in B1 (10 July).

5.1.1.2 Zone 5 – 16.5 °C (Passive Case)

Zone 5, which is proposed to maintain a temperature of 16.5 °C, is 88m^2 and is located on the ground floor of the building. *Figure 46* and *Figure 47* demonstrate the thermal performance of the zone during the coldest and hottest days of the year respectively, which are, 10th of January and 10th of July. During the coldest day the temperature inside the zone seems to provide a more suitable environment than the outside dry temperature, with temperatures ranging from 9 °C to 12 °C. While, as noticed in the curve which represents the air temperature inside the zone, during the hottest day, the temperature inside does not approach the required temperature. However, the building influences on maintaining a more constant temperature inside the zone in comparison to the outside dry temperature.

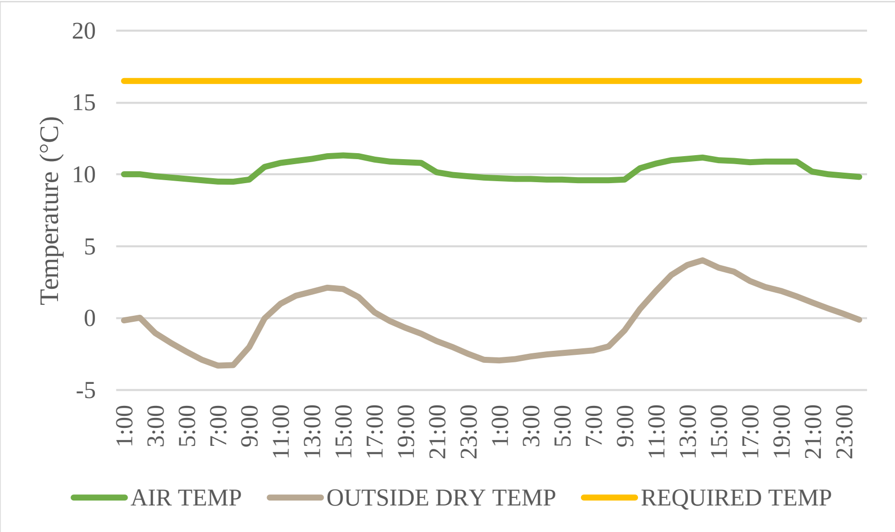


Figure 46 Thermal Performance of Zone 5 in B1 (10 January).

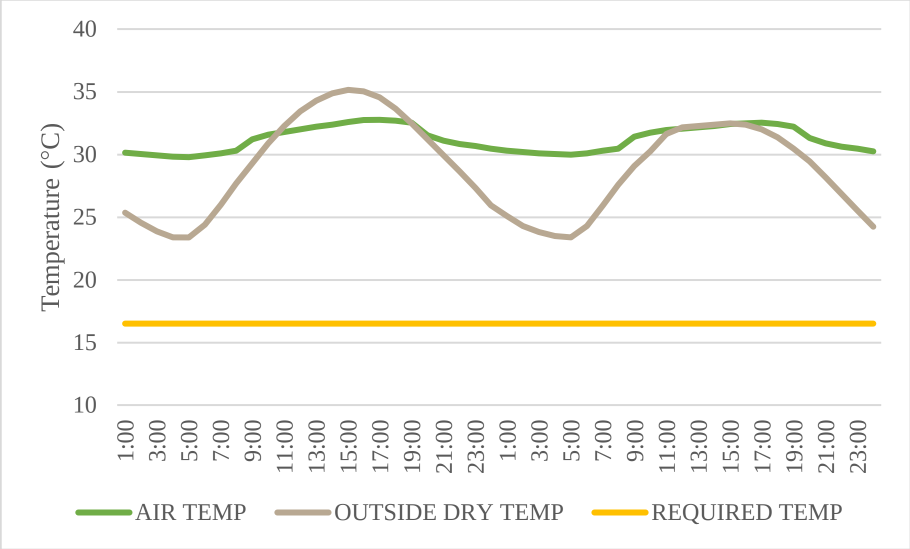


Figure 47 Thermal Performance of Zone 5 in B1 (10 July).

5.1.1.3 Zone 7 – 0 °C (Passive Case)

Zone 7, which is proposed to maintain a temperature of 0 °C, is 37m^2 and is located on the first floor of the building. *Figure 48* and *Figure 49* demonstrate the thermal performance of the zone during the coldest and hottest days of the year respectively, which are, 10th of January and 10th of July. During the coldest day the temperature inside the zone seems to provide a less suitable environment than the outside dry temperature, with temperatures ranging from 4 °C to 6 °C. While, as noticed in the curve which represents the air temperature inside the zone, during the hottest day, the temperature inside does not approach the required temperature. However, the building influences on maintaining a more constant temperature inside the zone in comparison to the outside dry temperature.

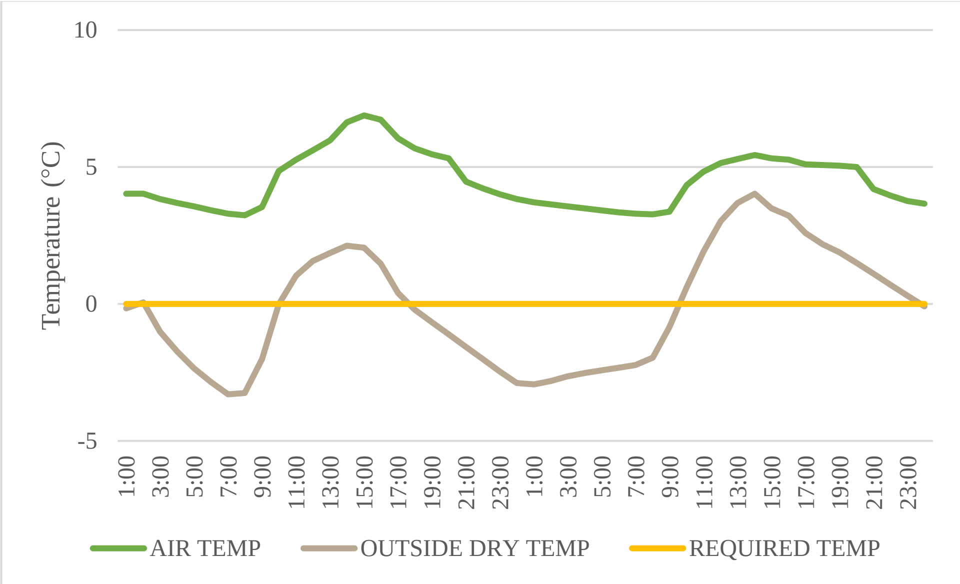


Figure 48 Thermal Performance of Zone 7 in B1 (10 January).

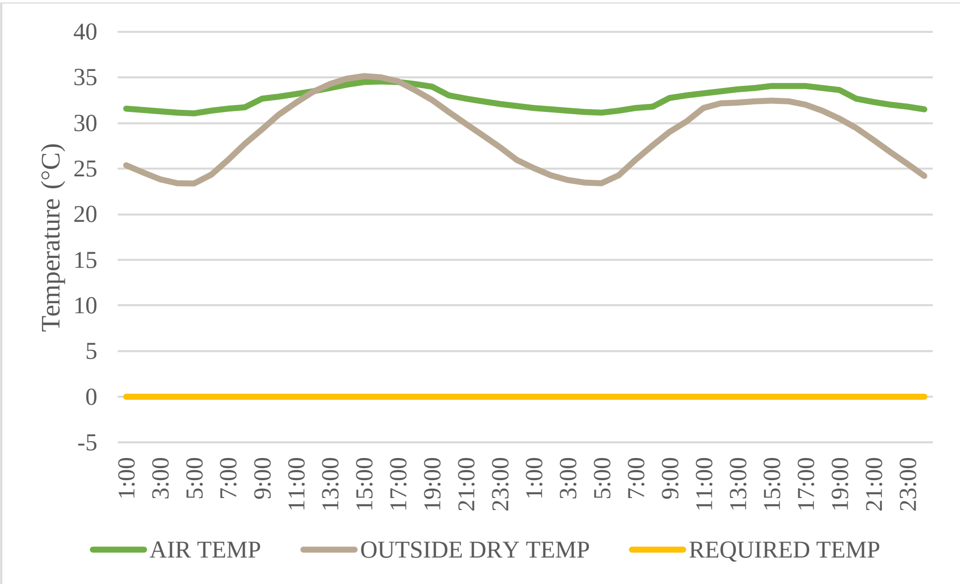


Figure 49 Thermal Performance of Zone 7 in B1 (10 July).

5.1.2 B2 – Gruemirë, Malësi e Madhe

In the second building which is located in S2 Gruemirë, three zones are selected to be analyzed. These zones are of temperatures 0 °C, 10 °C and 16.5 °C which are classified as zone 5, zone 3 and zone 1 respectively according to their areas and storage conditions.

5.1.2.1 Zone 3 – 10 °C (Passive Case)

Zone 3, which is proposed to maintain a temperature of 10 °C, is 32m^2 and is located on the ground floor of the building. *Figure 50* and *Figure 51* demonstrate the thermal performance of the zone during the coldest and hottest days of the year respectively, which are, 10th of January and 10th of July. During the coldest day the temperature inside the zone seems to provide a more suitable environment, with temperatures ranging from 13 °C to 15 °C. While, as noticed in the curve which represents the air temperature inside the zone, during the hottest day, the temperature inside does not approach the required temperature. However, the building influences on maintaining a more constant temperature inside the zone in comparison to the outside dry temperature.

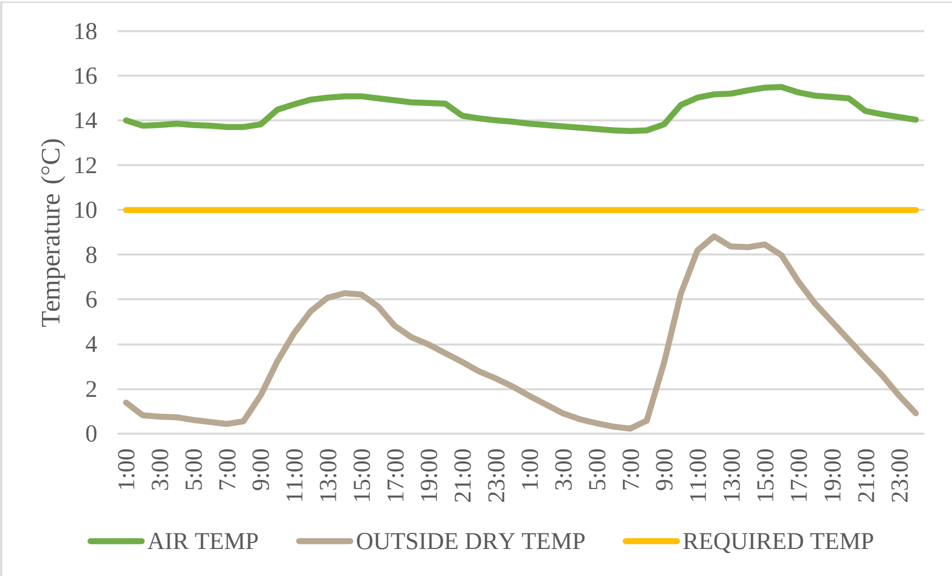


Figure 50 Thermal Performance of Zone 3 in B2 (10 January).

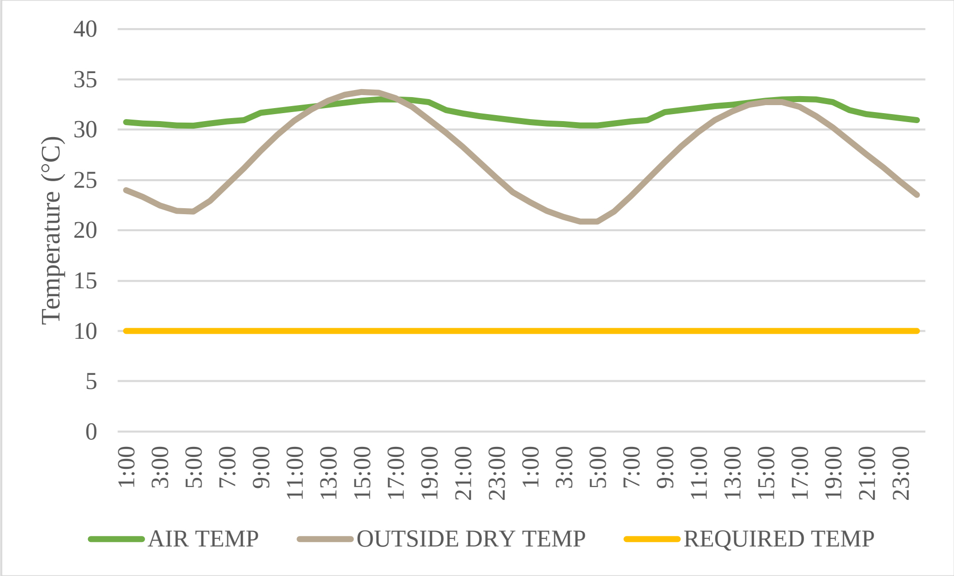


Figure 51 Thermal Performance of Zone 3 in B2 (10 July).

5.1.2.2 Zone 1 – 16.5 °C (Passive Case)

Zone 1, which is proposed to maintain a temperature of 16.5 °C, is 28.5m^2 and is located on the ground floor of the building. *Figure 52* and *Figure 53* demonstrate the thermal performance of the zone during the coldest and hottest days of the year respectively, which are, 10th of January and 10th of July. During the coldest day the temperature inside the zone seems to provide a suitable environment, with temperatures ranging from 15 °C to 16 °C. While, as noticed in the curve which represents the air temperature inside the zone, during the hottest day, the temperature inside does not approach the required temperature. However, the building influences on maintaining a more constant temperature inside the zone in comparison to the outside dry temperature.

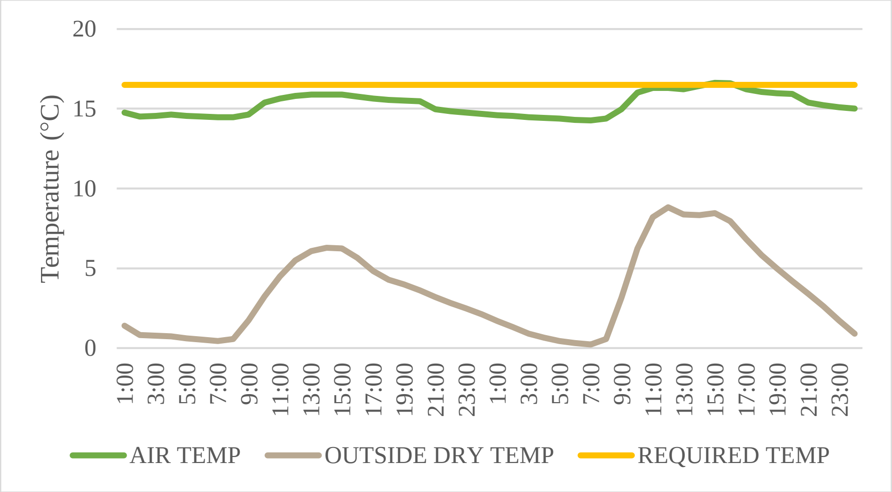


Figure 52 Thermal Performance of Zone 1 in B2 (10 January).

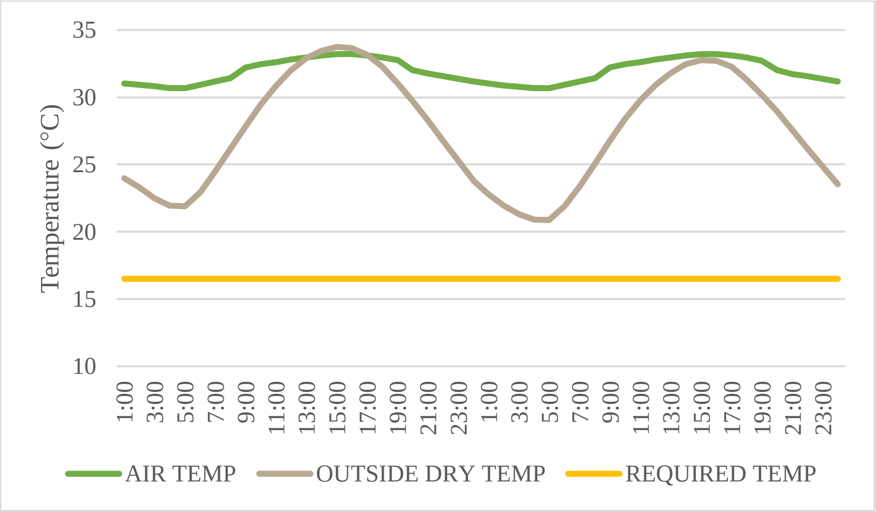


Figure 53 Thermal Performance of Zone 1 in B2 (10 July).

5.1.2.3 Zone 5 – 0 °C (Passive Case)

Zone 5, which is proposed to maintain a temperature of 0 °C, is 36m^2 and is located on the first floor of the building. *Figure 54* and *Figure 55* demonstrate the thermal performance of the zone during the coldest and hottest days of the year respectively, which are, 10th of January and 10th of July. During the coldest day the temperature inside the zone seems to provide a less suitable environment, with temperatures ranging from 14 °C to 17 °C. While, as noticed in the curve which represents the air temperature inside the zone, during the hottest day, the temperature inside does not approach the required temperature. However, the building influences on maintaining a more constant temperature inside the zone in comparison to the outside dry temperature.

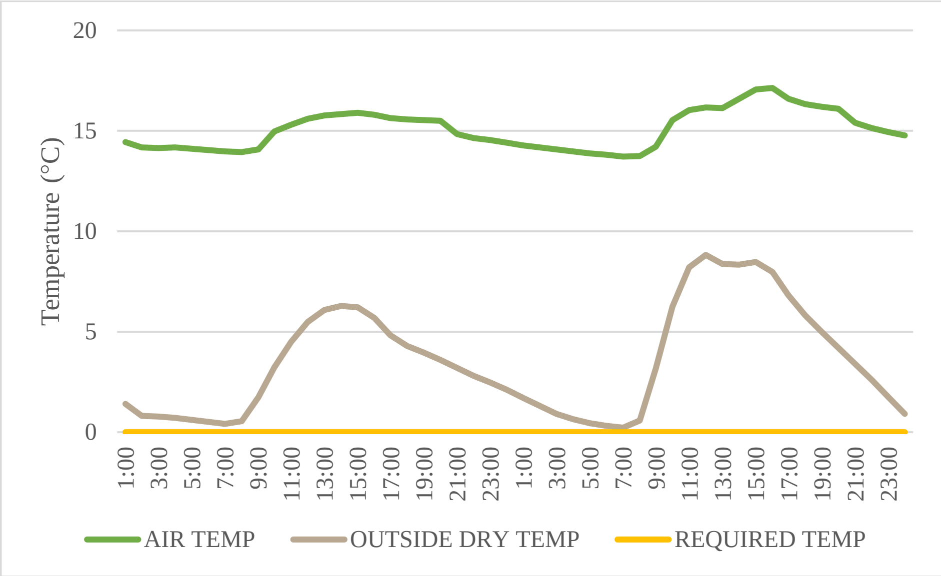


Figure 54 Thermal Performance of Zone 5 in B2 (10 January).

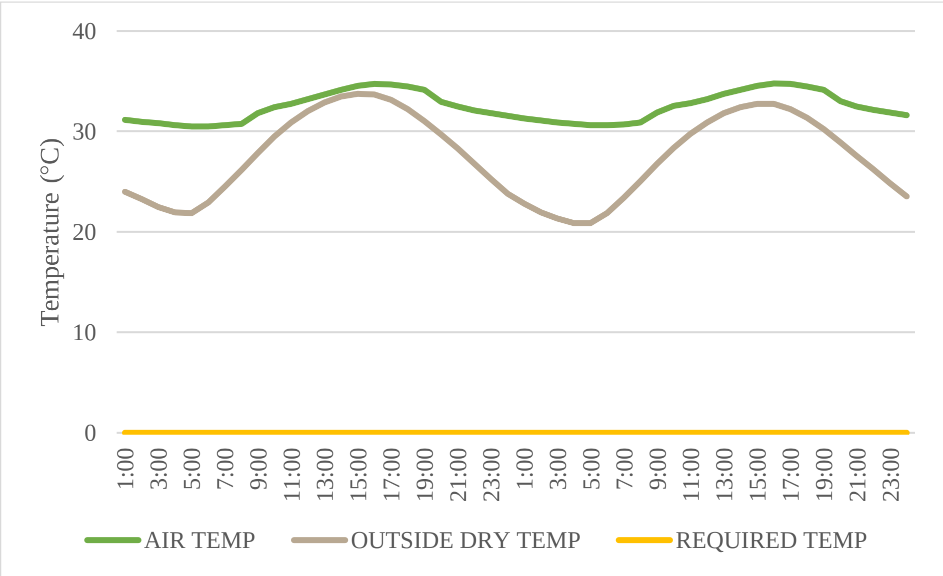


Figure 55 Thermal Performance of Zone 5 in B2 (10 July).

5.1.3 B3 – Marshej, Malësi e Madhe

In the third building which is located in S3 Marshej, three zones are selected to be analyzed. These zones are of temperatures 0 °C, 10 °C and 16.5 °C which are classified as zone 5, zone 3 and zone 2 respectively according to their areas and storage conditions.

5.1.3.1 Zone 3 – 10 °C (Passive Case)

Zone 3, which is proposed to maintain a temperature of 10 °C, is 34m^2 and is located in the ground floor of the building. *Figure 56* and *Figure 57* demonstrate the thermal performance of the zone during the coldest and hottest days of the year respectively, which are, 10th of January and 10th of July. During the coldest day the temperature inside the zone seems to provide more constant temperatures ranging from 16 °C to 17 °C. While, as noticed in the curve which represents the air temperature inside the zone, during the hottest day, the temperature inside does not approach the required temperature. However, the building influences on maintaining a more constant temperature inside the zone in comparison to the outside dry temperature.

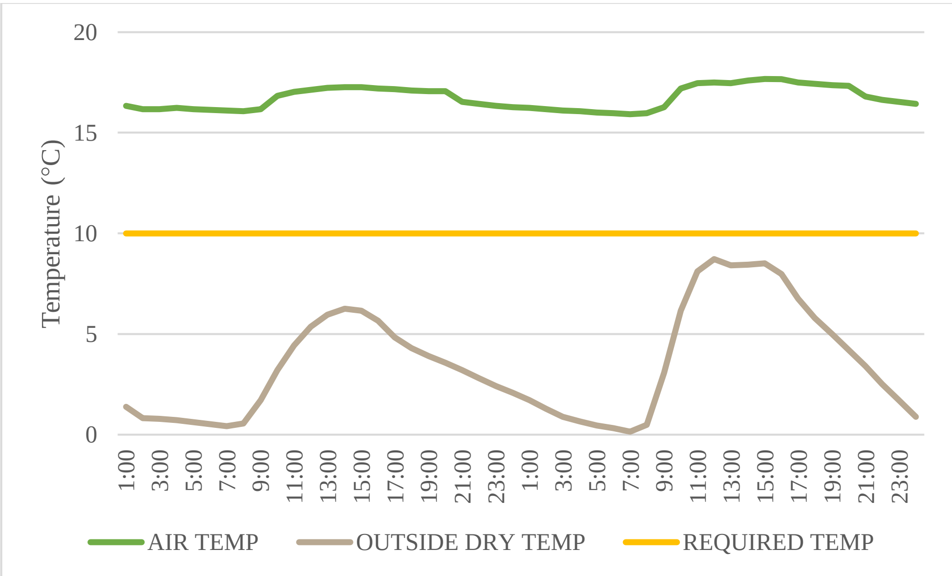


Figure 56 Thermal Performance of Zone 3 in B3 (10 January).

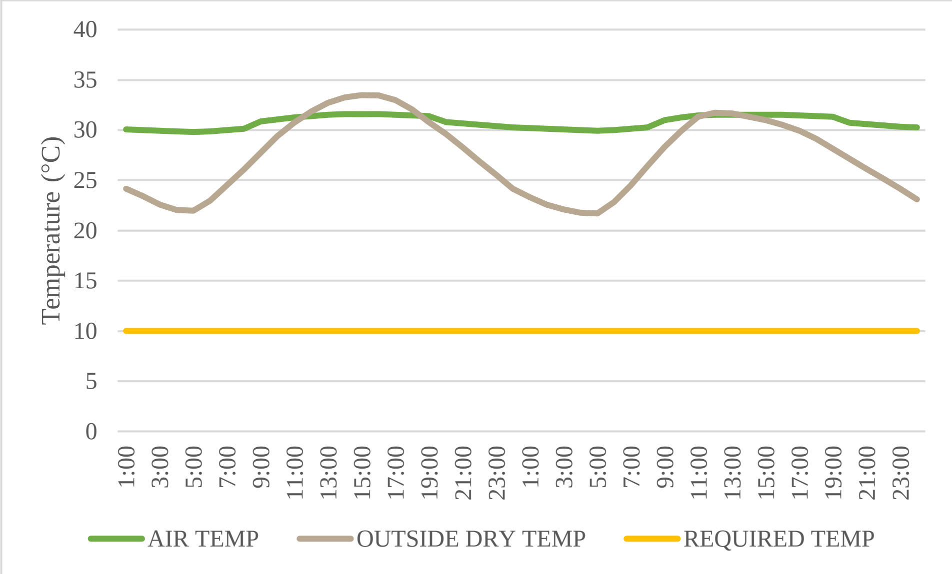


Figure 57 Thermal Performance of Zone 3 in B3 (10 July).

5.1.3.2 Zone 2 – 16.5 °C (Passive Case)

Zone 2, which is proposed to maintain a temperature of 16.5 °C, is 34m^2 and is located on the ground floor of the building. *Figure 58* and *Figure 59* demonstrate the thermal performance of the zone during the coldest and hottest days of the year respectively, which are, 10th of January and 10th of July. During the coldest day the temperature inside the zone seems to provide a very suitable environment with temperatures ranging from 16 °C to 17 °C. While, as noticed in the curve which represents the air temperature inside the zone, during the hottest day, the temperature inside does not approach the required temperature. However, the building influences on maintaining a more constant temperature inside the zone in comparison to the outside dry temperature.

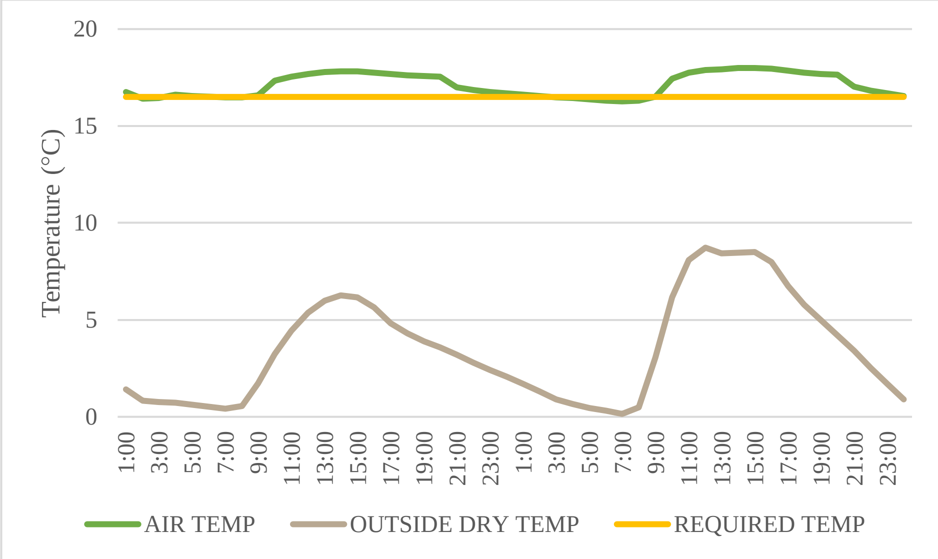


Figure 58 Thermal Performance of Zone 2 in B3 (10 January).

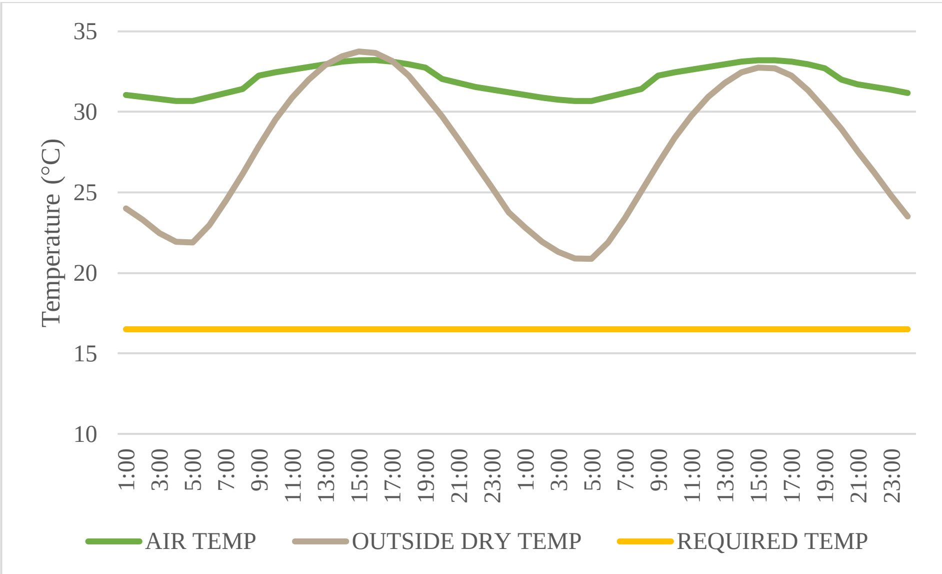


Figure 59 Thermal Performance of Zone 2 in B3 (10 July).

5.1.3.3 Zone 5 – 0 °C (Passive Case)

Zone 5, which is proposed to maintain a temperature of 0 °C, is 34 m^2 and is located on the first floor of the building. *Figure 60* and *Figure 61* demonstrate the thermal performance of the zone during the coldest and hottest days of the year respectively, which are, 10^{th} of January and 10^{th} of July. During the coldest day the temperature inside the zone, although higher in value, seems to provide more constant temperatures, ranging from 16 °C to 17 °C than the outside dry temperature range. While, as noticed in the curve which represents the air temperature inside the zone, during the hottest day, the temperature inside does not approach the required temperature. However, the building influences on maintaining a more constant temperature inside the zone in comparison to the outside dry temperature.

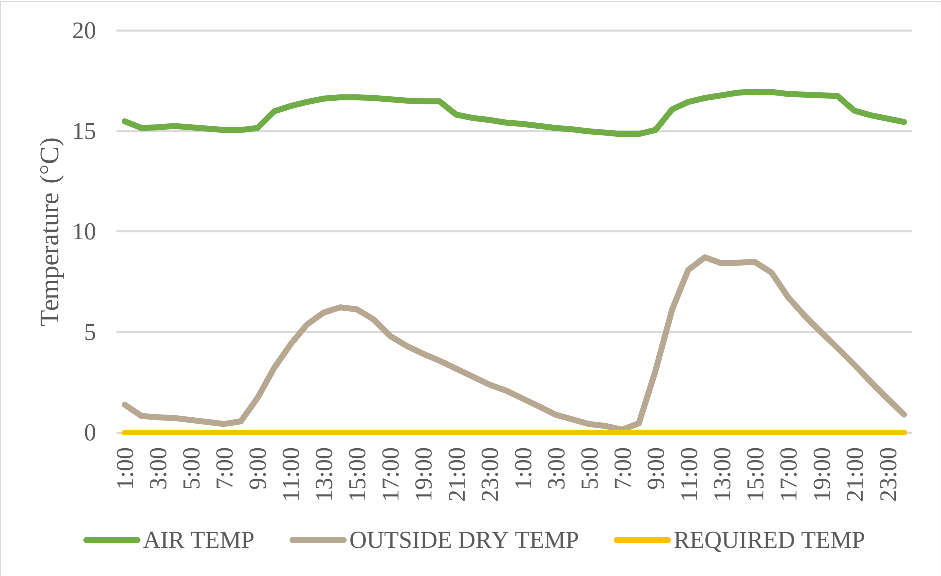


Figure 60 Thermal Performance of Zone 5 in B3 (10 January).

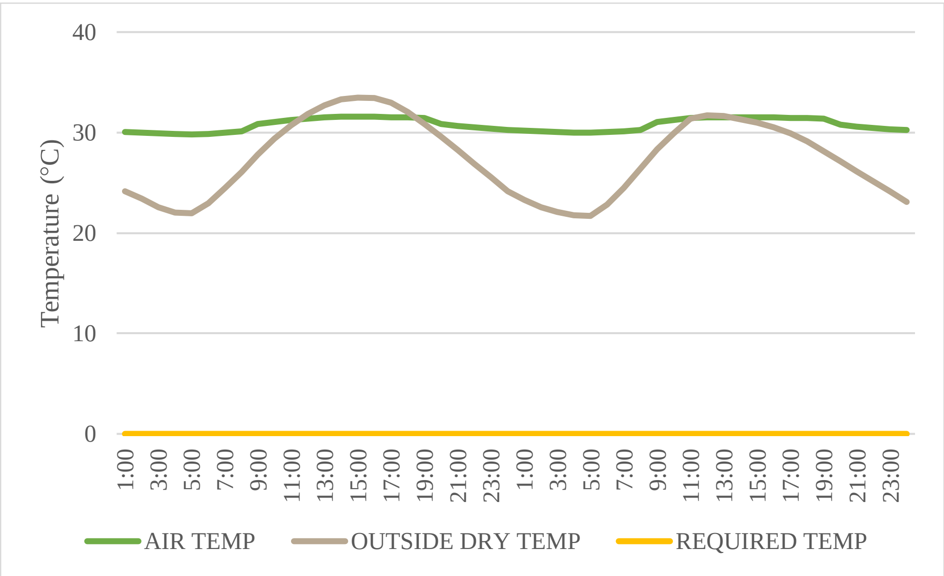


Figure 61 Thermal Performance of Zone 5 in B3 (10 July).

5.1.4 Thermal Performance comparison of the scenarios

The existing state of the buildings is very beneficial in terms of maintaining a constant temperature throughout the day inside the building. However, assisted by a variety of retrofit scenarios, its positive effect on the building is enhanced even more. Retrofit scenarios SC1 - SC4 are implemented in the simulation software in order to analyze and compare which scenario is the most suitable according to the three common temperatures of the buildings, 0 °C, 10 °C and 16.5 °C. The scenarios are compared with each-other during the hottest and coldest days of the year for each temperature zone.

5.1.4.1 Zone – 10 °C (Passive Case)

The first analyzed zone is the zone that requires a temperature of 10 °C. *Figure 62* and *Figure 63* demonstrate the thermal performance of the zone during the coldest and hottest days of the year respectively, which are, 10th of January and 10th of July. During the coldest day all the scenarios influence on providing a suitable temperature inside the zone, excluding SC 1, by maintaining a constant temperature of 10 °C - 12 °C. SC 4 which is the conjunction of the three scenarios, performs best by providing the closest values to the required temperature. Additionally, during the hottest day, the only scenario that has the tendency to provide the closest values to the required temperature is SC 4, whereas the other scenarios are slightly less advantageous.

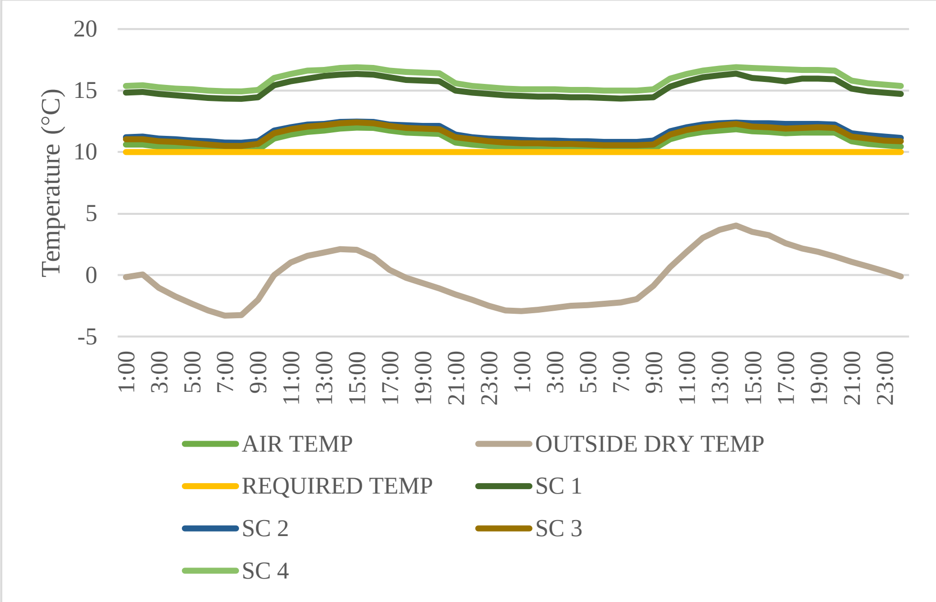


Figure 62 Comparison of thermal performance of ES and scenarios SC1 - SC4 for Zone - 10°C (10 January).

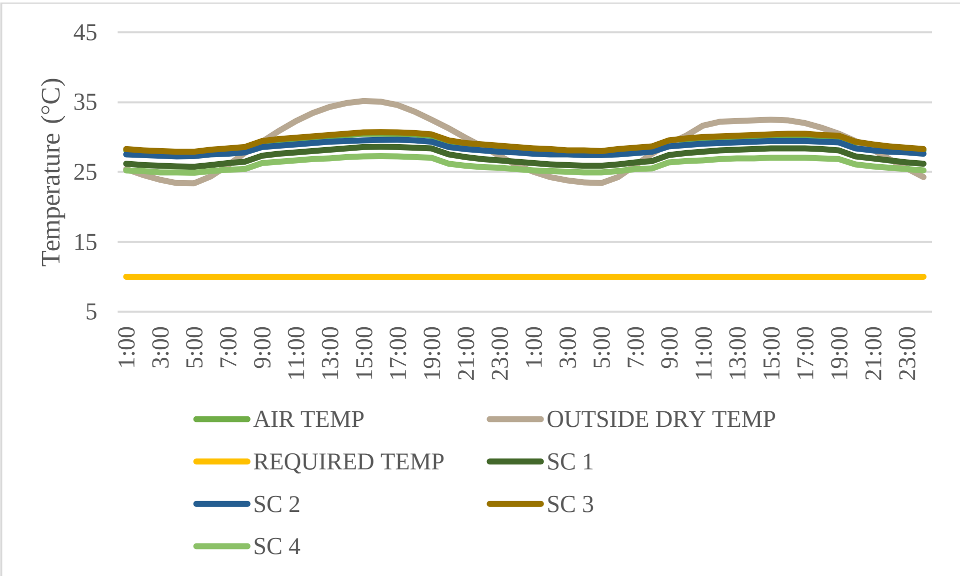


Figure 63 Comparison of thermal performance of ES and scenarios SC1 - SC4 for Zone - 10°C (10 July).

5.1.4.2 Zone – 16.5 °C (Passive Case)

The first analyzed zone is the zone that requires a temperature of 10 °C. *Figure 64* and *Figure 65* demonstrate the thermal performance of the zone during the coldest and hottest days of the year respectively, which are, 10th of January and 10th of July. During the coldest day SC 4 performs best by providing temperature values of 16 °C - 17 °C throughout the day. Furthermore, SC 1 also maintains very close values to the temperature that SC 4 provides. Correspondingly, during the hottest day SC 4 performs best with temperature values ranging from 25 °C - 26°C. SC 1 succeeds with a relatively slight difference in temperature values.

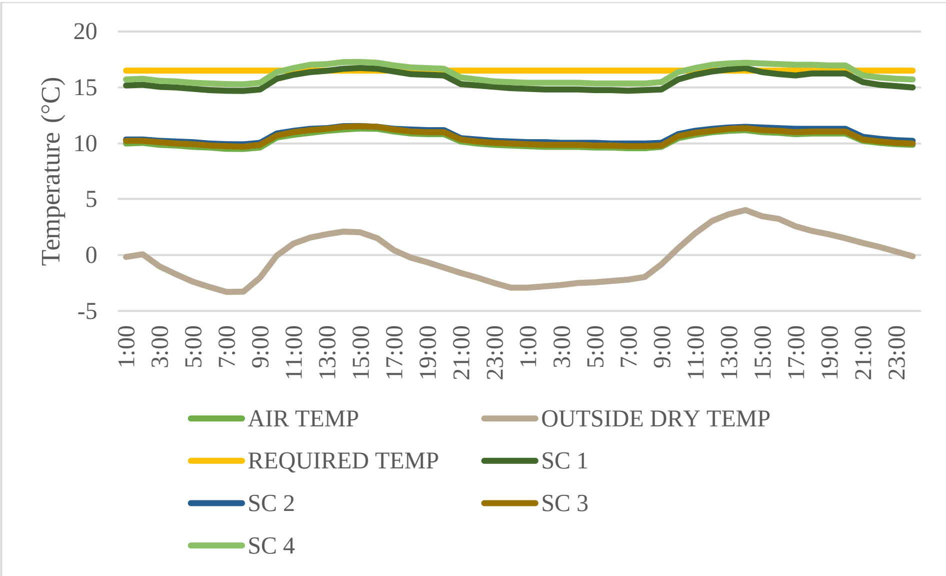


Figure 64 Comparison of thermal performance of ES and scenarios, SC1 - SC4 for Zone – 16.5°C (10 January).

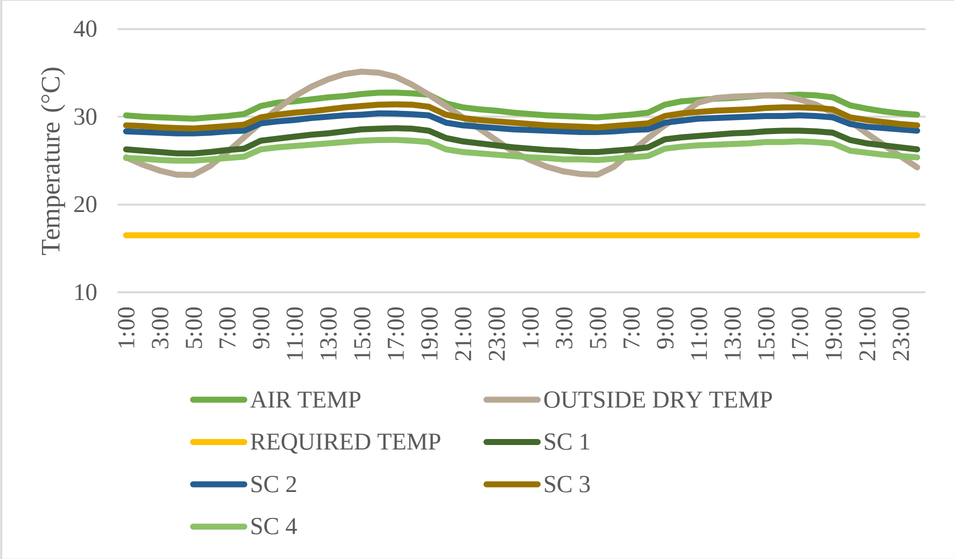


Figure 65 Comparison of thermal performance of ES and scenarios, SC1 - SC4 for Zone – 16.5°C (10 July).

5.1.4.3 Zone – 0 °C (Passive Case)

The first analyzed zone is the zone that requires a temperature of 0 °C. *Figure 66* and *Figure 67* demonstrate the thermal performance of the zone during the coldest and hottest days of the year respectively, which are, 10th of January and 10th of July. During the coldest day the existing state, SC 2, and SC 3 perform best by providing temperature values of 5 °C - 7 °C throughout the day. Correspondingly, during the hottest day the existing state performs best with temperature values ranging from 28 °C - 29°C, being succeeded by all the other scenarios with slight differences in the provided temperature values.

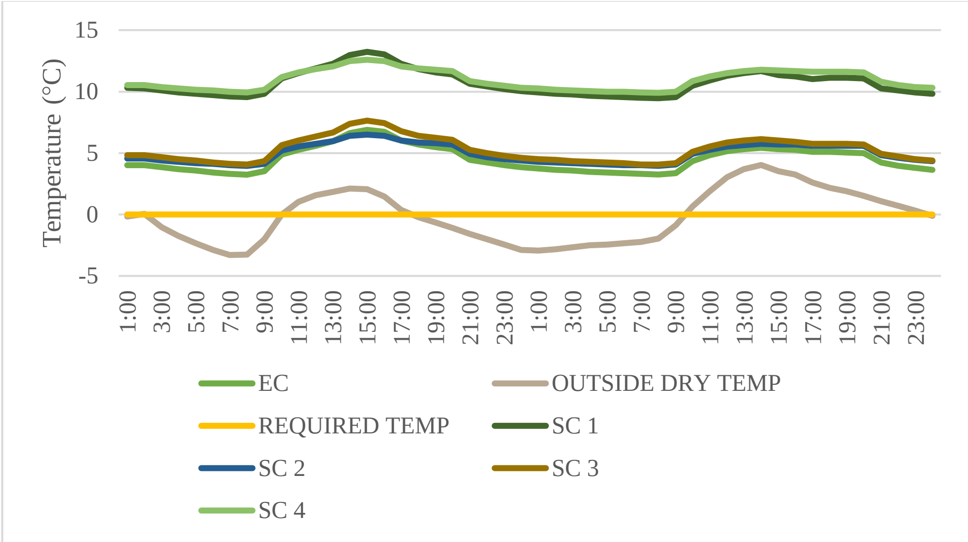


Figure 66 Comparison of thermal performance of ES and scenarios, SC1 - SC4 for Zone - 0°C (10 January).

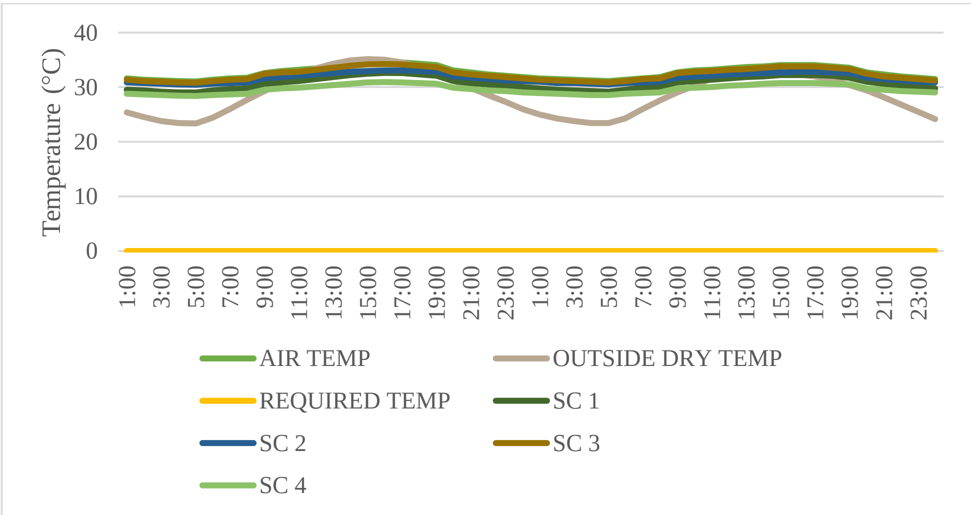


Figure 67 Comparison of thermal performance of ES and scenarios, SC1 - SC4 for Zone - 0°C (10 July).

5.2 Energy Consumption of the Existing State (Active Case)

The heating and cooling energy loads of the existing state of the three buildings are measured in the simulation software. The simulations are computed yearly in order to perceive which building performs best regarding the total energy consumption. By comparing and analyzing the results simulated by the software, a clear conclusion regarding the best performing building is obtained.

5.2.1 B1 – Dobër, Malësi e Madhe

The first building, B1, and its variables are applied to the simulation software in order to obtain the heating and cooling energy loads. As shown in Figure 68 the majority of energy load of B1 corresponds to the summer months because of the relatively low required temperatures. However, regarding the heating loads, the building does not consume much energy as a result of the considerable suitable temperatures provided by the building itself. The highest energy consumption value corresponds to the month of July, with a value of 12 kWh/m^2, as a result of the highest recorded air-dry temperatures. Whereas, the lowest energy consumption value corresponds to the month of March with only 2.2 kWh/m^2, as a result of the most suitable temperatures provided by the building itself. *Figure 68* demonstrates the yearly heating energy loads of B1.

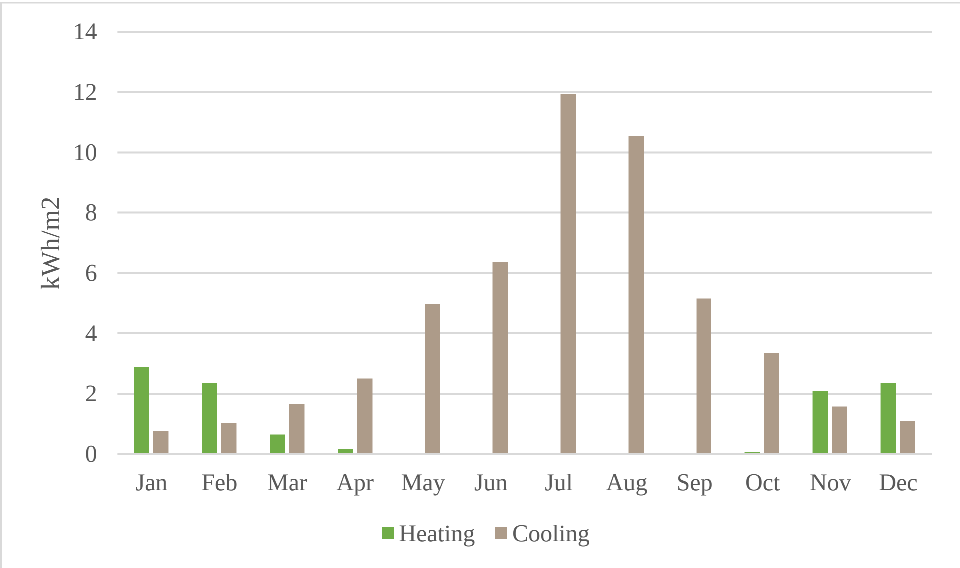


Figure 68 Heating energy loads measured yearly (kWh/m2) of B1.

5.2.2 B2 – Gruemirë, Malësi e Madhe

The second building, B2, and its variables are applied to the simulation software in order to obtain the heating and cooling energy loads. As shown in Figure 69 the majority of energy load of B2 corresponds to the summer months because of the relatively low required temperatures. However, regarding the heating loads, the building does not consume much energy as a result of the considerably suitable temperatures provided by the building itself. The highest energy consumption value corresponds to the month of July, with a value of 21 kWh/m^2, as a result of the highest recorded air-dry temperatures. Whereas, the lowest energy consumption value corresponds to the month of March with only 2.1 kWh/m^2, as a result of the most suitable temperatures provided by the building itself. *Figure 69* demonstrates the yearly heating energy loads of B2.

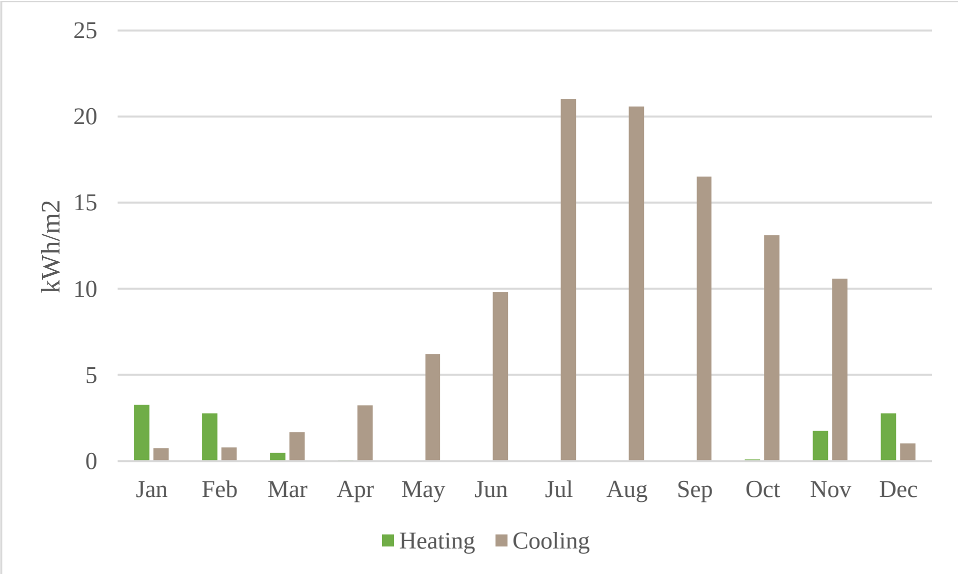


Figure 69 Heating energy loads measured yearly (kWh/m2) of B2.

5.2.3 B3 – Marshej, Malësi e Madhe

The second building, B2, and its variables are applied to the simulation software in order to obtain the heating and cooling energy loads. As shown in Figure 70 the majority of energy load of B2 corresponds to the summer months because of the relatively low required temperatures. However, regarding the heating loads, the building does not consume much energy as a result of the considerably suitable temperatures provided by the building itself. The highest energy consumption value corresponds to the month of August, with a value of 11.6 kWh/m^2, as a result of the highest recorded air-dry temperatures. Whereas, the lowest energy consumption value corresponds to the month of March with only 1.8 kWh/m^2, as a result of the most suitable temperatures provided by the building itself. *Figure 70* demonstrates the yearly heating energy loads of B3.

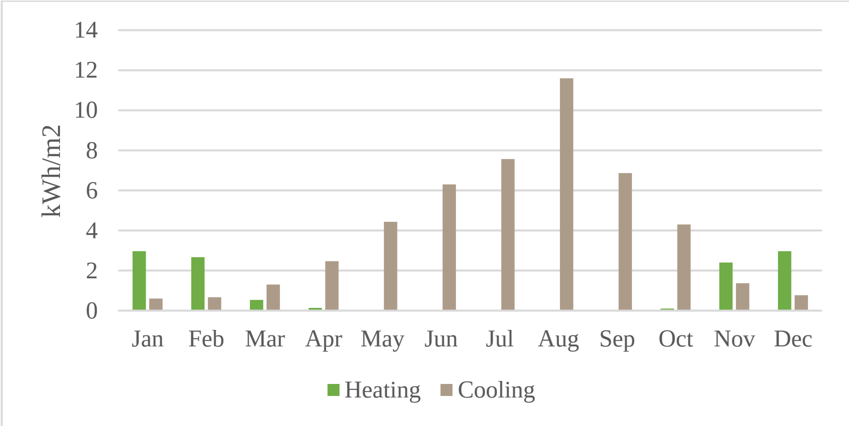


Figure 70 Heating energy loads measured yearly (kWh/m2) of B3.

5.3 Results of Energy Consumption Simulation (Active Case)

Simulations regarding the annual energy consumption of all the scenarios in comparison to each-other and to the existing state of the buildings are computed in order to perceive which scenario is the most advantageous for each site.

5.3.1 B1 – Dobër, Malësi e Madhe

All the results of the 4 scenarios are compared with each other in order to perceive which scenario is the most efficient regarding energy consumption about B1. The fourth scenario, (SC 4), which consists of the implementation of all the 3 scenarios together is the most efficient one according to the simulation results, with a total of 55.6 kWh/m^2 consumed. This result was expected; thus, a second-best result is also necessary to be taken into consideration which is the (SC 1) with a 56.9 kWh/m2 total energy consumption. *Figure 71*, *Figure 72* and *Figure 73* demonstrate the monthly energy demand of the existing state, SC1, SC2, SC3 and SC4 for total loads, cooling loads and heating loads respectively. Whereas, *Figure 74* demonstrates the comparison of the total yearly energy demand of the existing state, SC1, SC2, SC3, and SC4.

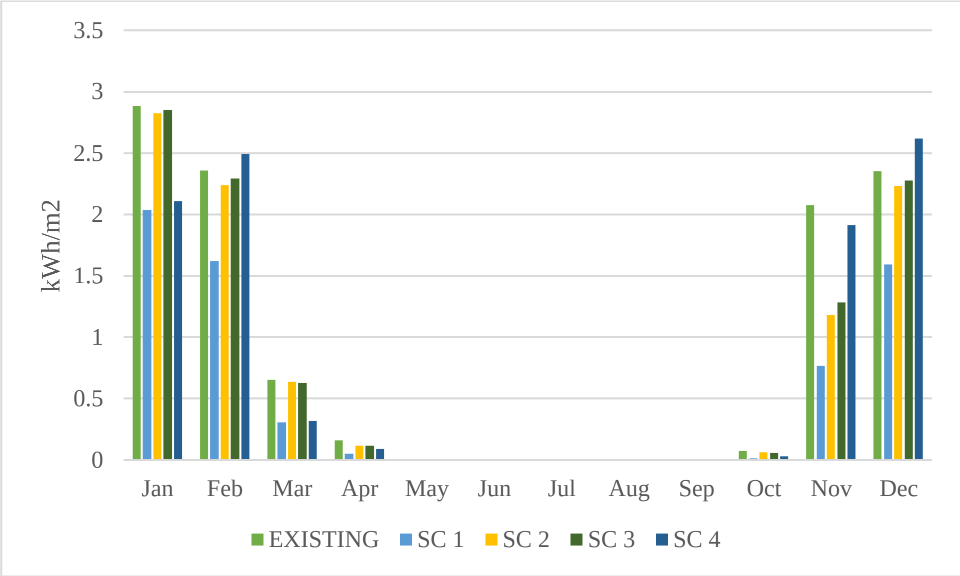


Figure 71 Comparison of total monthly energy demand for Heating of the Existing state and SC1 - SC4 for B1.

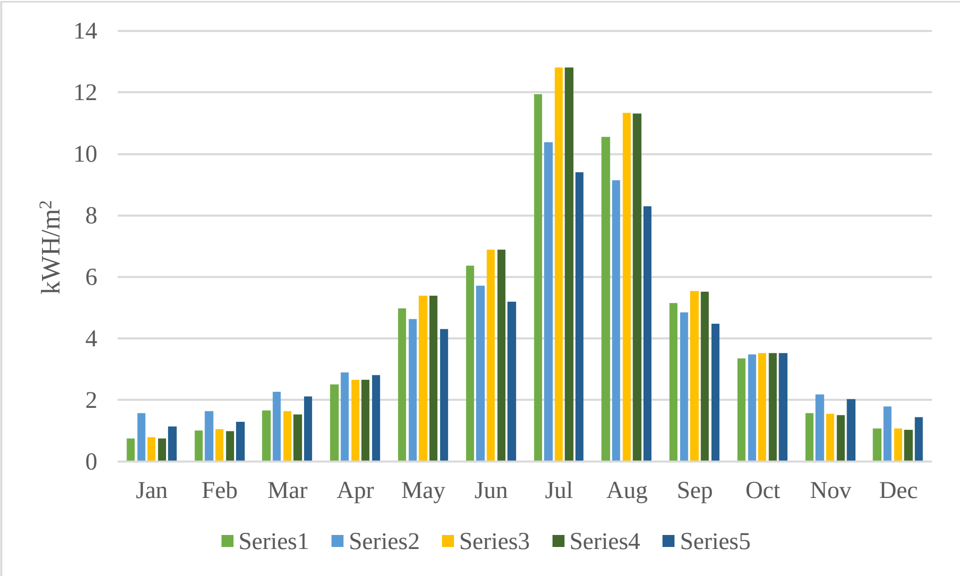


Figure 72 Comparison of total monthly energy demand for Cooling of the Existing state and SC1 - SC4 for B1.

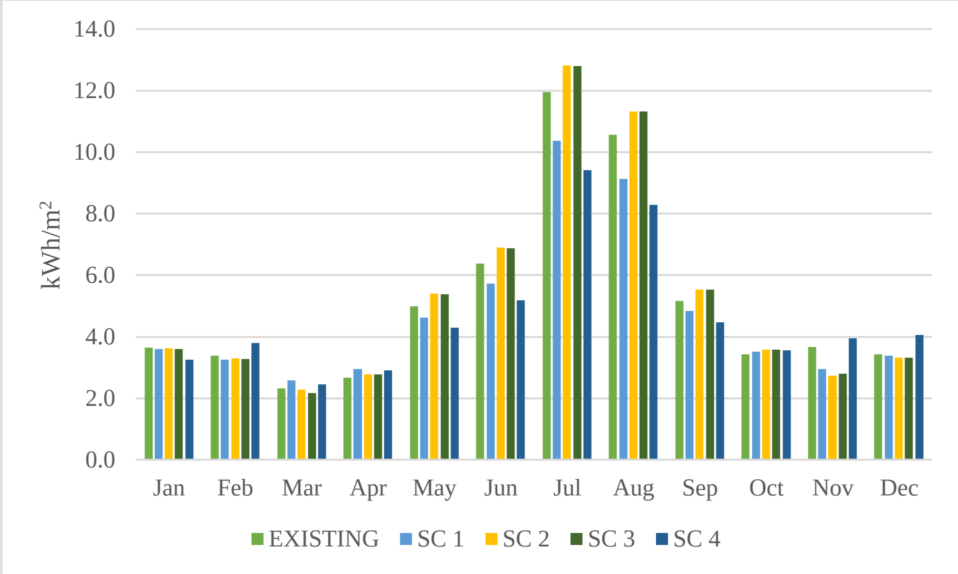


Figure 73 Comparison of total monthly energy demand of the Existing state and SC1 - SC4 for B1.

Figure 74 Comparison of total yearly energy demand of the Existing state and SC1 - SC4 for B1.

5.3.2 S2 – Gruemirë, Malësi e Madhe

In order to perceive which scenario is the most efficient regarding energy consumption about B2, the results of the 4 scenarios are compared with each other. Similar to B1, the fourth scenario, (SC 4), which consists of the implementation of all the 3 scenarios together is the most efficient one according to the simulation results, with a total of 79.9 kWh/m^2 consumed. This result was expected; thus, a second-best result is also necessary to be taken into consideration which is the (SC 3) with a 97.2 kWh/m2 total energy consumption throughout the year. *Figure 75*, *Figure 76* and *Figure 77* demonstrate the monthly energy demand of the existing state, SC1, SC2, SC3 and SC4 for total loads, cooling loads and heating loads respectively. Whereas, *Figure 78* demonstrates the comparison of the total yearly energy demand of the existing state, SC1, SC2, SC3, and SC4.

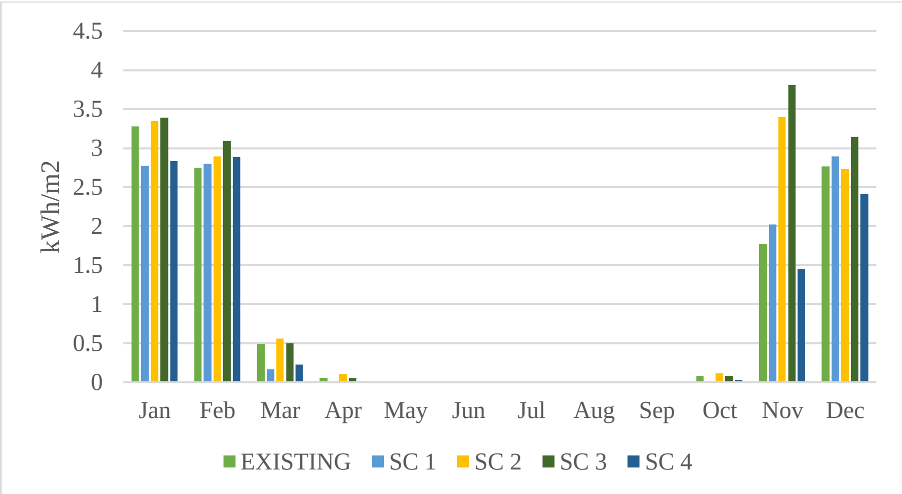


Figure 75 Comparison of total monthly energy demand for Heating of the Existing state and SC1 - SC4 for B2.

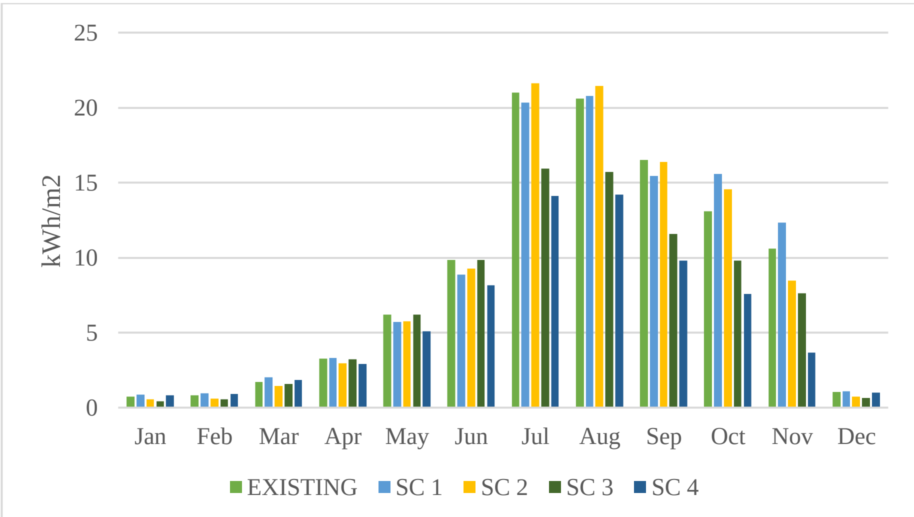


Figure 76 Comparison of total monthly energy demand for Cooling of the Existing state and SC1 - SC4 for B2.

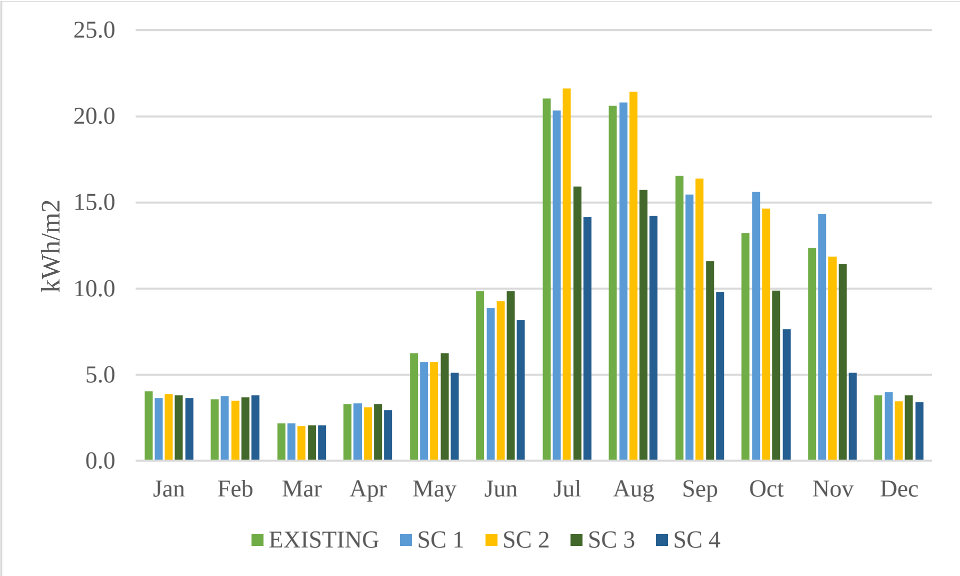


Figure 77 Comparison of total monthly energy demand of the Existing state and SC1 - SC4 for B2.

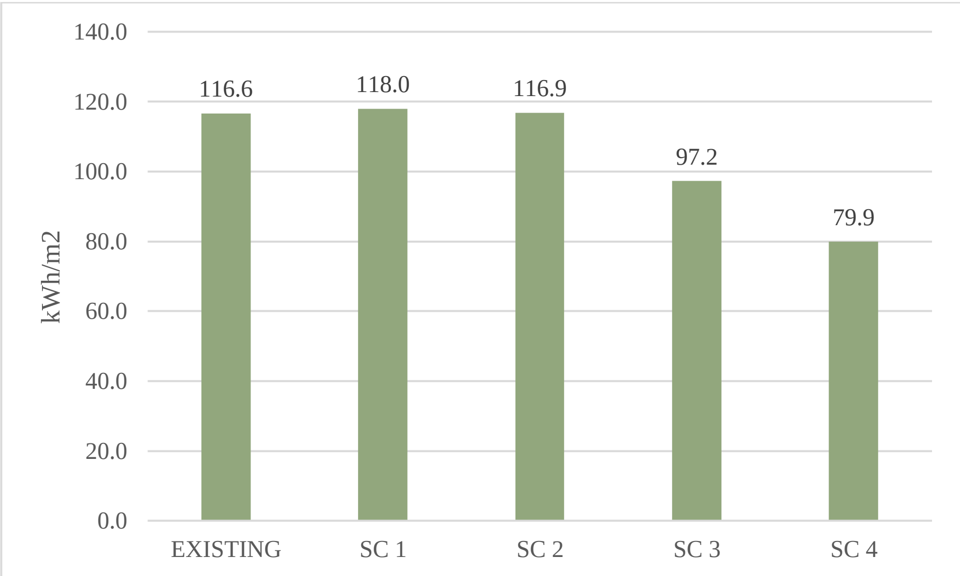


Figure 78 Comparison of total yearly energy demand of the Existing state and SC1 - SC4 for B2.

5.3.3 S3 – Marshej, Malësi e Madhe

Regarding energy consumption about B3, in order to perceive which scenario is the most efficient the results of the 4 scenarios are compared with each other. Similar to B1 and B2, the fourth scenario, (SC 4), which consists of the implementation of all the

3 scenarios together is the most efficient one according to the simulation results, with a total of 55.4 kWh/m^2 consumed. This result was expected; thus, a second-best result is also necessary to be taken into consideration which is the (SC 1) with a 56.0 kWh/m2 total energy consumption throughout the year. *Figure 71*, *Figure 72* and *Figure 73* demonstrate the monthly energy demand of the existing state, SC1, SC2, SC3 and SC4 for total loads, cooling loads and heating loads respectively. Whereas, *Figure 82* demonstrates the comparison of the total yearly energy demand of the existing state, SC1, SC2, SC3, and SC4.

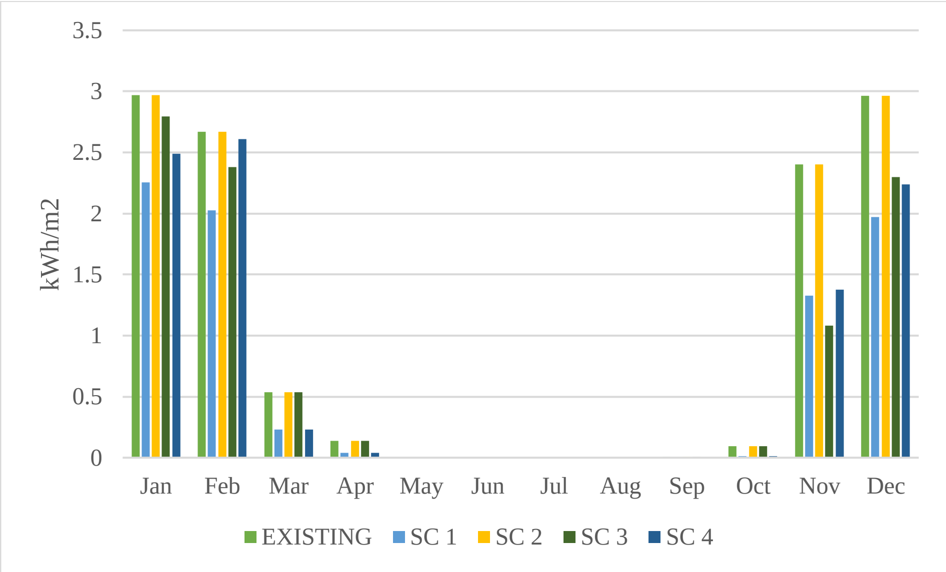


Figure 79 Comparison of total monthly energy demand for Heating of the Existing state and SC1 - SC4 for B3.

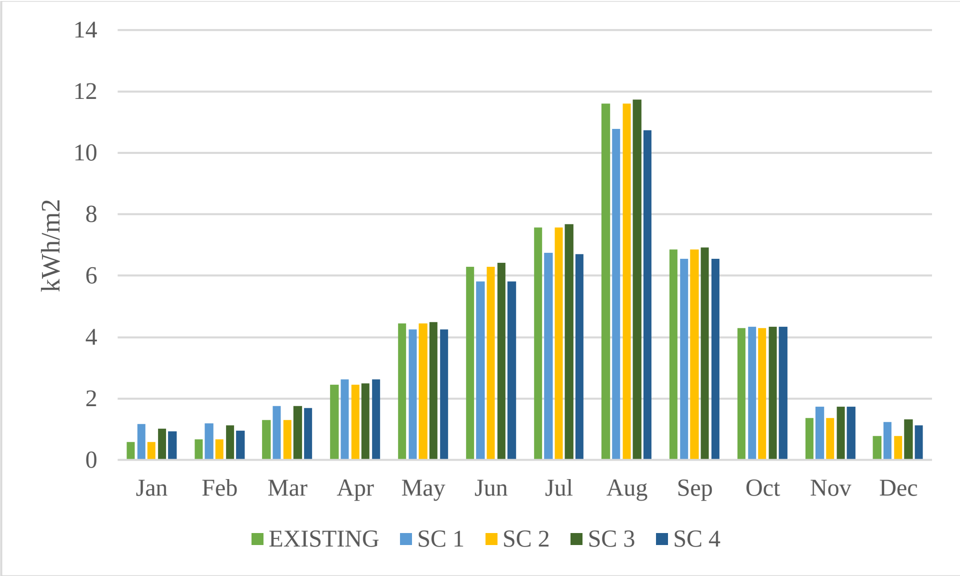


Figure 80 Comparison of total monthly energy demand for Cooling of the Existing state and SC1 - SC4 for B2.

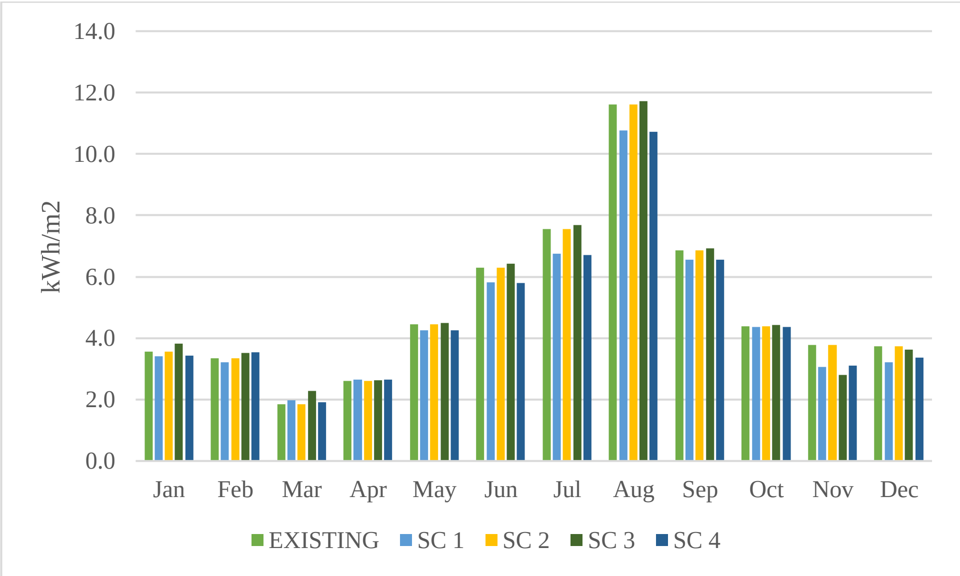


Figure 81 Comparison of total monthly energy demand of the Existing state and SC1 - SC4 for B3.

Figure 82 Comparison of total yearly energy demand of the Existing state and SC1 - SC4 for B3.

5.4 Comparison of Energy Consumption Results (Active Case)

Table 11 reflects the results of the computed simulations regarding the energy performance of all the scenarios of the three selected buildings. The maximum of the total energy consumed can be reduced up to 12.55 % for B1 through the application of the most suitable retrofit scenario, which corresponds to SC4. The worst performing scenario for B1 regarding the energy performance is SC2 with a total energy load of 63.59 kWh/m2. Whereas, for B2, the maximum of the total energy consumed can be reduced up to 32.26 % through the application of the most suitable retrofit scenario, which corresponds to SC4. The worst performing scenario for B2 regarding the energy performance is SC2 with a total energy load of 117.98 kWh/m2. B3 differs from the previous two buildings as a result of the higher temperatures provided for the crops stored. The maximum of the total energy consumed can be reduced up to 6.47 % through the application of the most suitable retrofit scenario, which corresponds to SC4. The worst performing scenario for B2 regarding the energy performance is SC3 with a total energy load of 60.33 kWh/m2.

Table 11 Simulation results obtained for all the scenarios of the three buildings.

	Annual Heating Demand		Annual Cooling Demand		Annual Total Demand	
Scenarios	Heating Loads (kWh/m2)	**Scenario effectiveness (%)**	Cooling Loads (kWh/m2)	**Scenario effectiveness (%)**	Total Loads (kWh/m2)	**Scenario effectiveness (%)**
B1_ES	10.56	**-**	50.99	**6.09**	61.55	**3.20**
B1_SC1	6.39	**39.47**	50.54	**6.91**	56.93	**10.46**
B1_SC2	9.29	**12.01**	54.29	**-**	63.59	**-**
B1_SC3	9.51	**9.97**	53.92	**0.69**	63.43	**0.25**
B1_SC4	9.57	**9.40**	46.04	**15.20**	55.61	**12.55**
B2_ES	11.19	**20.41**	105.42	**1.75**	116.61	**1.16**
B2_SC1	10.68	**24.05**	107.30	**-**	117.98	**-**
B2_SC2	13.14	**6.57**	103.73	**3.33**	116.87	**0.94**
B3_SC3	14.06	**-**	83.18	**22.48**	97.24	**17.57**
B4_SC4	9.84	**30.03**	70.09	**34.68**	79.92	**32.26**
B3_ES	11.77	**-**	48.25	**5.40**	60.02	**0.53**
B3_SC1	7.85	**33.24**	48.17	**5.57**	56.02	**7.15**
B3_SC2	11.77	**-**	48.25	**5.40**	60.02	**0.53**
B3_SC3	9.33	**20.73**	51.01	**-**	60.33	**-**
B3_SC4	8.99	**23.58**	47.44	**6.99**	56.43	**6.47**

CHAPTER 6

DISCUSSION

This section focuses on the comparison of the thermal and energy performances of the selected buildings and the proposed retrofit scenarios. This analysis is obtained by inputting the results data from the simulation software into charts and graphs in order to easily distinguish the best performing scenario for each building.

6.1 Comparison of Thermal performance

The thermal performance of the buildings is analyzed by comparing three common temperatures required in each building during the hottest and coldest days of the year, which are selected based on the temperature mean of the three locations. These temperatures correspond to the 10th of January and 10th of July, as the coldest and hottest days respectively.

6.1.1 Comparison of Zone 0° C in all buildings

The zones of each building that require a temperature of 0 °, which is a temperature value mostly required to preserve fruits, are compared with each other in order to make a distinction regarding the best performing building. This comparison is made according to the coldest and hottest days of the year in order to understand whether the best performing case is advantageous during both summer and winter.

According to the simulation results the best performing building for the zones that require a temperature value of 0 °C is B1 with temperatures ranging from 4 °C – 7 °C during the coldest day and 31 °C – 33 °C during the hottest day. *Figure 83* and *Figure 84* demonstrate the comparison of temperatures in Zone 0° during the coldest and hottest days respectively.

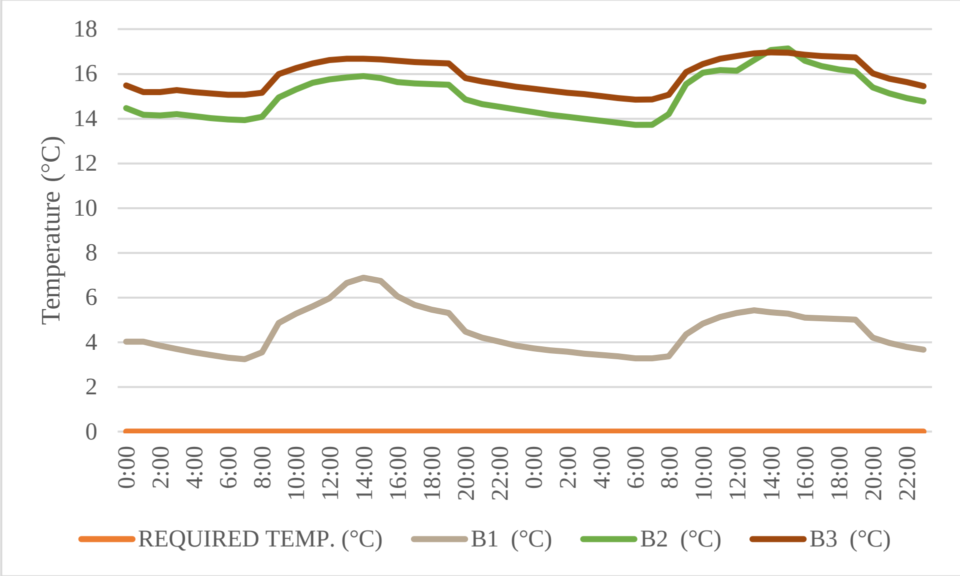


Figure 83 Comparison of zone 0 °C in all buildings during the coldest day.

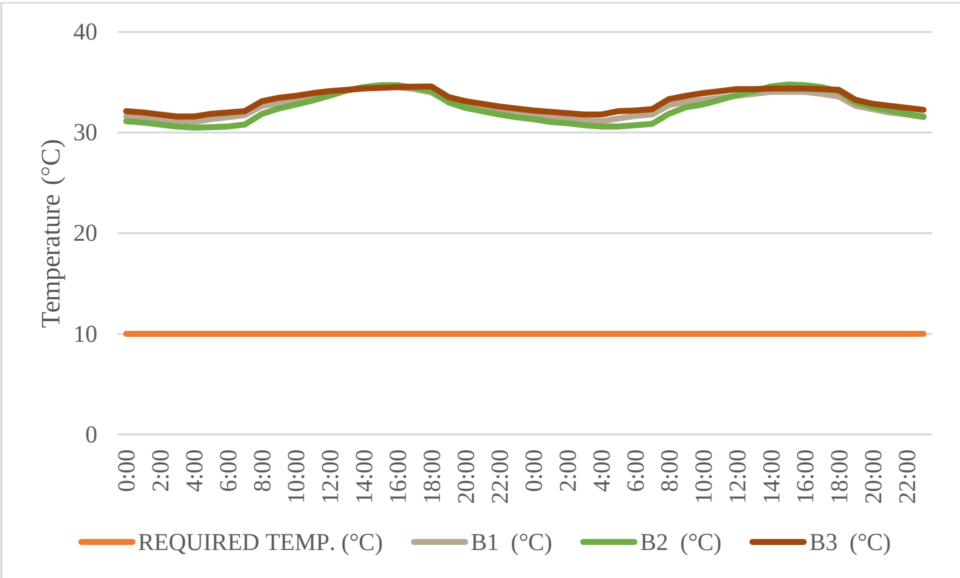


Figure 84 Comparison of zone 0 °C in all buildings during the hottest day.

6.1.2 Comparison of zone 10 °C in all buildings

The zones of each building that require a temperature of 10 °, which is a temperature value mostly required to preserve vegetables, are compared with each other in order to make a distinction regarding the best performing building. This comparison is made according to the coldest and hottest days of the year in order to understand whether the best performing case is advantageous during both summer and winter.

According to the simulation results the best performing building for the zones that require a temperature value of 10 °C is B1 with temperatures ranging from 10 °C - 12 °C during the coldest day and 28 °C - 30 °C during the hottest day. *Figure 85* and *Figure 86* demonstrate the comparison of temperatures in Zone 10° during the coldest and hottest days respectively.

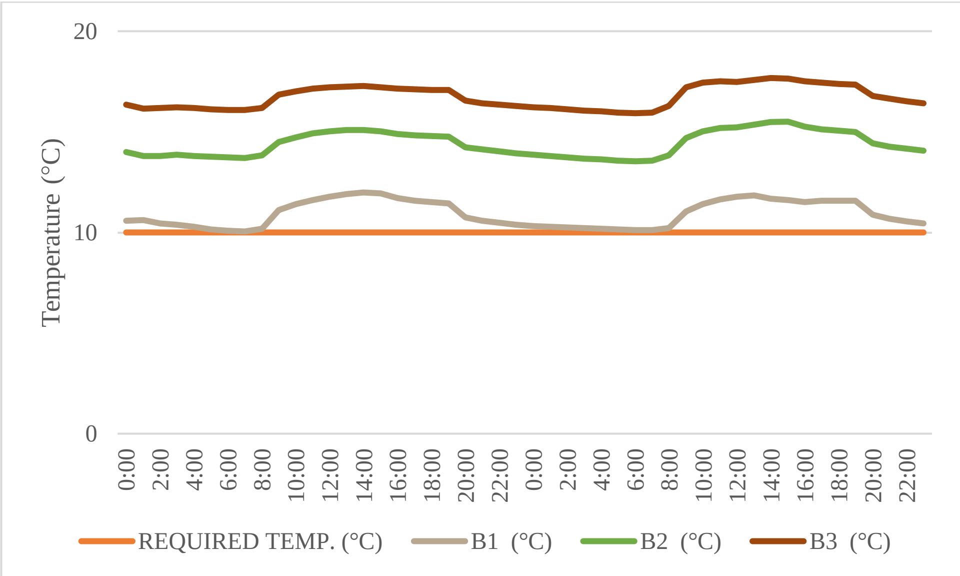


Figure 85 Comparison of zone 10 °C in all buildings during the coldest day.

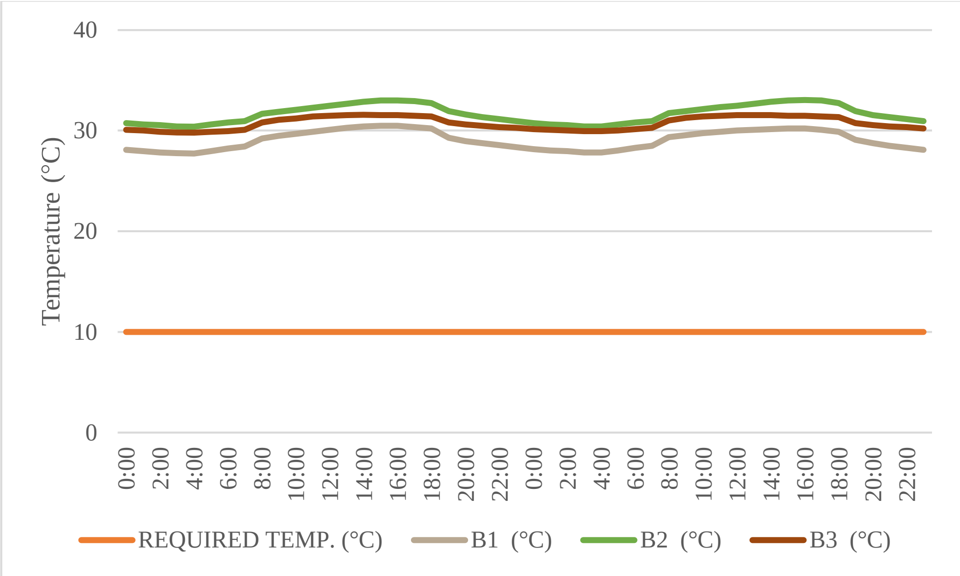


Figure 86 Comparison of zone 10 °C in all buildings during the hottest day.

6.1.3 Comparison of Zone 16.5 °C in all buildings

The zones of each building that require a temperature of 16.5 °, which is a temperature value mostly required to preserve medicinal plants, are compared with each other in order to make a distinction regarding the best performing building. This comparison is made according to the coldest and hottest days of the year in order to understand whether the best performing case is advantageous during both summer and winter.

According to the simulation results the best performing building for the zones that require a temperature value of 16.5 °C is B3 with temperatures ranging from 15 °C - 17 °C during the coldest day and 30 °C - 32 °C during the hottest day. *Figure 87* and *Figure 88* demonstrate the comparison of temperatures in Zone 16.5° during the coldest and hottest days respectively.

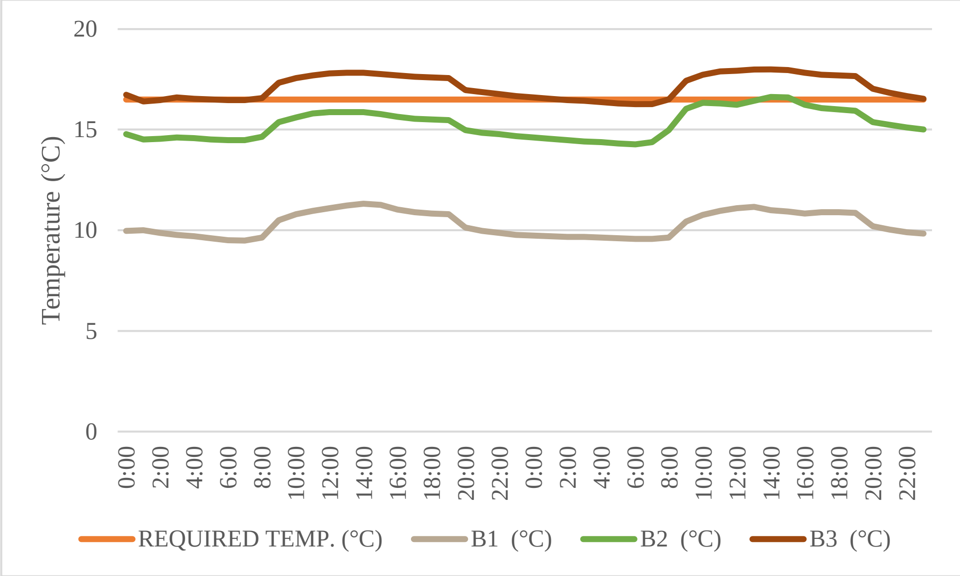


Figure 87 Comparison of zone 16.5 °C in all buildings during the coldest day.

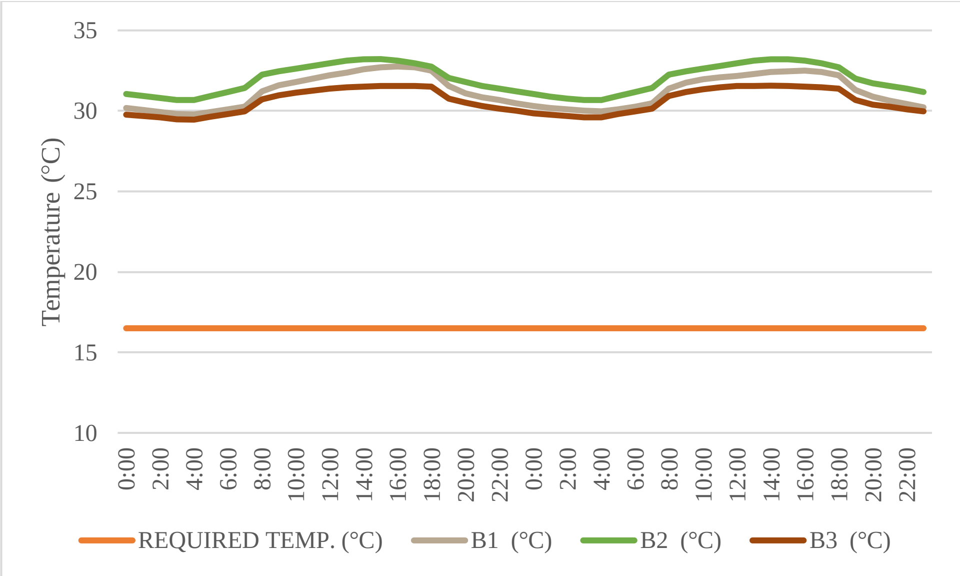


Figure 88 Comparison of zone 16.5 °C in all buildings during the hottest day.

6.1.4 Comparison of thermal performance of the scenarios

Considering the fact that the simulation results of the zones display relatively slight differences in terms of temperature provided in each zone, only one building is selected to analyze each zone according to the parameters of the proposed scenarios. The analysis is carried out by comparing the temperature provided by each scenario in the three selected common temperature zones during the coldest and hottest days of the year.

6.1.4.1 Coldest day (10th of January)

During the coldest day the best performing case is the existing state regarding the 0 °C temperature zone is the existing state (ES), which provides the closest temperature value to 0. Similarly, regarding the 10 °C temperature zone, ES also provides best by providing the closest average temperature value to 10. Whereas, the temperature zone that requires a relatively higher temperature value, which is 16.5 °C, acquires SC4 to obtain the best performance. *Figure 89* demonstrates the comparison of zones 0 °C, 10 °C and 16.5 °C implemented in all scenarios during the coldest day.

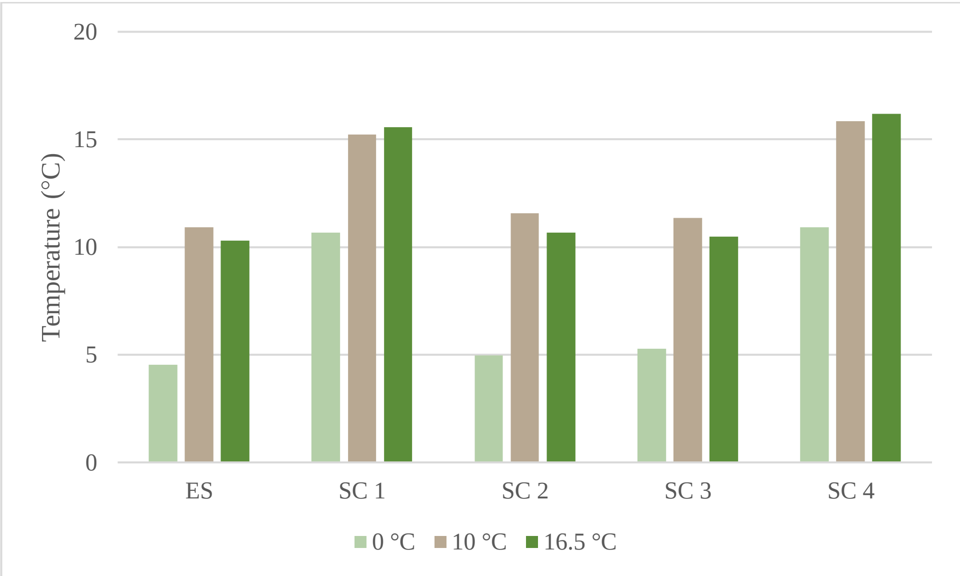


Figure 89 Comparison of zones 0 °C, 10 °C and 16.5 °C implemented in all scenarios during the coldest day.

6.1.4.2 Hottest day (10th of July)

During the hottest day the best performing case is the existing state regarding the 0 °C temperature zone is SC4, which provides the closest temperature value to 0 as a result of the combined thermal insulation techniques. Similarly, regarding the 10 °C and 16.5 °C temperature zones, SC 4 also provides best by providing the closest average temperature value to the ones required. *Figure 90* demonstrates the comparison of zones 0 °C, 10 °C and 16.5 °C implemented in all scenarios during the hottest day.

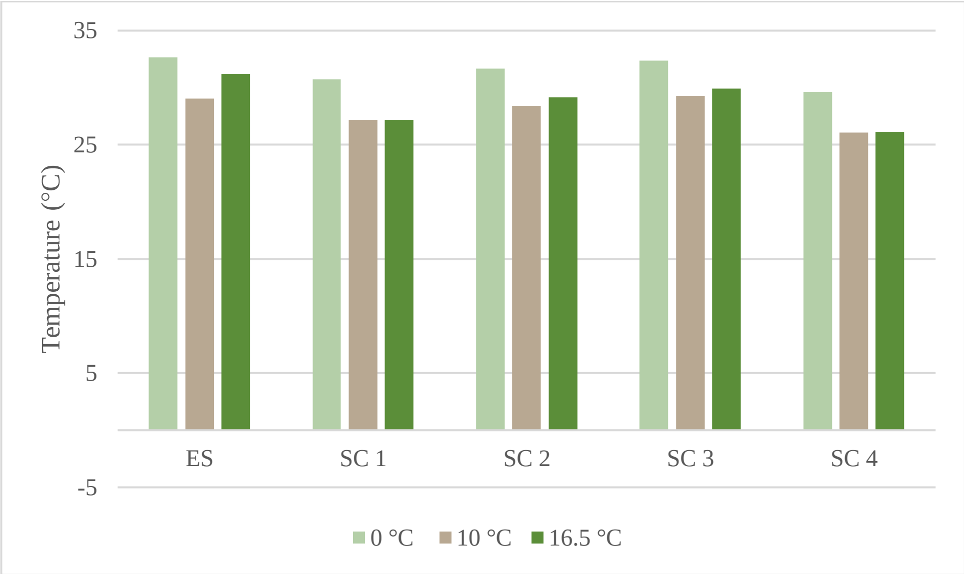


Figure 90 Comparison of zones 0 °C, 10 °C and 16.5 °C implemented in all scenarios during the hottest day.

6.2 Comparison of Energy Performance

As displayed in *Figure 91* the heating loads of the buildings result in low values by implementing SC 1 and SC 4, which correspond to the insulation of walls and a combination of 3 scenarios respectively. Whereas, regarding the cooling loads, as demonstrated in *Figure 92*, SC4 which corresponds to the combination of the three scenarios together performs best and it is followed by SC3 that correspond to the roof thermal insulation.

Figure 93 conveys the energy consumption for both heating and cooling loads of the buildings B1, B2, B3. The results indicate that the buildings that perform the best regarding energy consumption are (B1) and (B3). This performance is a result of the types of crops stored in the buildings that consist of mostly vegetables and medicinal plants which require relatively higher temperatures than the crops stored in (B2).

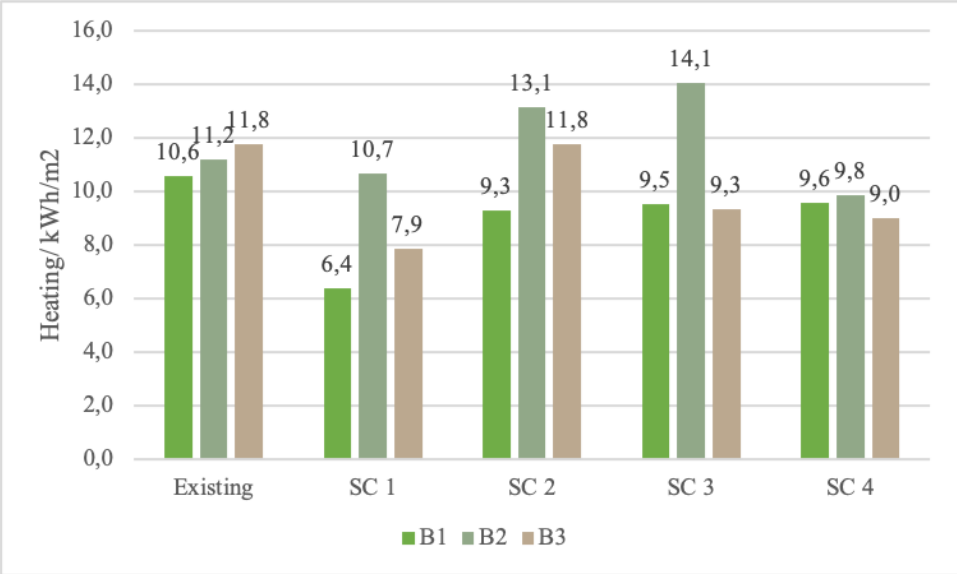


Figure 91 Simulation based heating energy loads for B1, B2, B3.

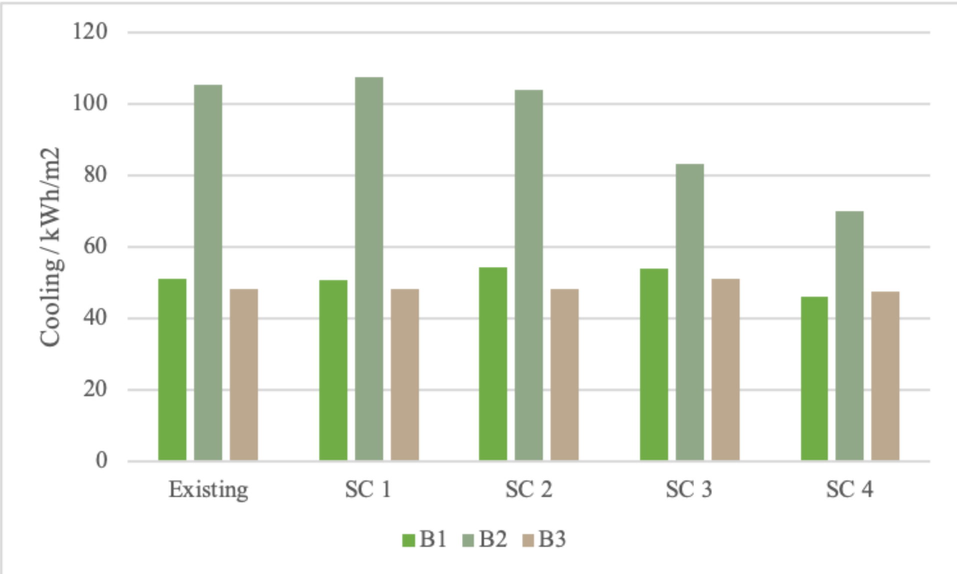


Figure 92 Simulation based cooling energy loads for B1, B2, B3.

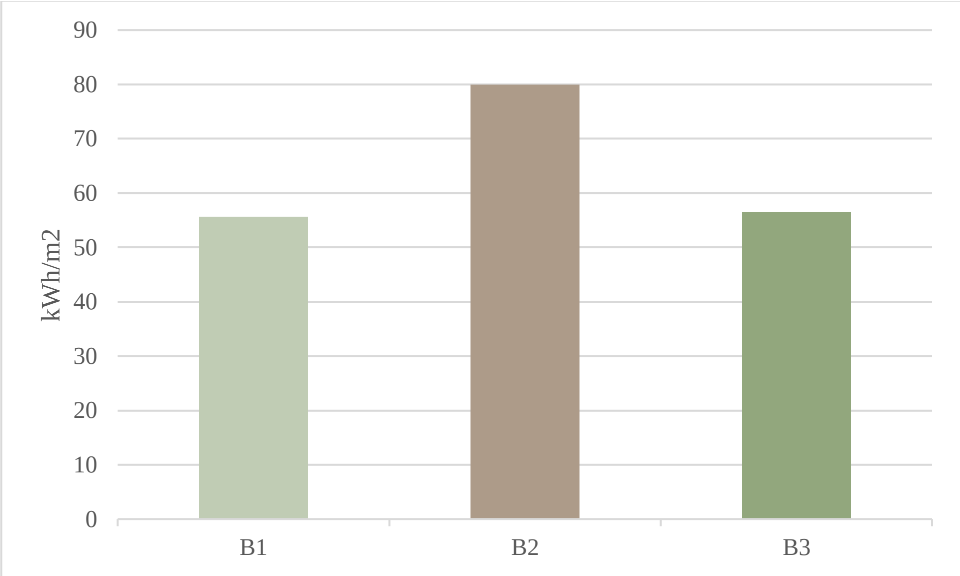


Figure 93 Total energy loads of B1, B2, B3, by implementation of SC1, SC2, SC3.

6.3 Energy performance compared to typical warehouses

In a study conducted by Konrad Lewczuk, Michał Kłodawski and Paweł Gepner, (2021), the energy loads of 6 variants of typical green warehouses are evaluated in order to perceive the yearly total energy consumption of each case. *Figure 94* demonstrates the parameters of the selected variants, among which, the highlighted values display the area of each building. Whereas, in *Figure 95*, the energy consumption of specific tasks is demonstrated, among which, the highlighted values display the energy loads of heating and cooling processes.

Parameters	V1	V2	V3	V4	V5	V6
A_{WH} (m^2)	10,834.11	7820.02	3399.50	3399.50	2100.00	2100.00
P_{WH}^{PV} (kWp)	1147.14	828.18	360	360	222.48	222.48
E_{WH}^{PV} energy generated (kWh/year)	1,147,140	828,180	360,000	360,000	222,480	222,480
Expenditure (million EUR)	1.26	0.91	0.39	0.39	0.24	0.24

Figure 94 Parameters of the selected variants. Retrived from Lewczuk K., et al., (2021). Energy Consumption in a DistributionalWarehouse:A Practical Case Study for DifferentWarehouse Technologies

Category	V1	V2	V3	V4	V5	V6
Energy consumption for heating and cooling (kWh/year)	1,249,281	901,726	390,657	390,657	294,744	294,744
Energy consumption for ventilation (kWh/year)	46,652	33,673	14,638	14,638	9043	46,652
Surface to be illuminated (m^2)	10,834	7820	3400	3400	1050	1050
Energy consumption for lighting (kWh/year)	244,905	176,772	76,846	76,846	23,735	23,735
Energy consumption for IT networks and equipment (kWh/year)	23,326	16,836	7319	7319	4521	4521
Other energy consumption (kWh/year)	209,922	151,521	65,869	65,869	40,690	40,690
Total energy consumption for building maintenance (kWh/year)	1,774,086	1,280,528	555,329	555,329	372,733	372,733

Figure 95 Parameters of the selected variants. Retrived from Lewczuk K., et al., (2021). Energy Consumption in a DistributionalWarehouse:A Practical Case Study for DifferentWarehouse Technologies.

According to the parameters displayed in *Figure 94* and *Figure 95* the area-based energy consumption of the selected buildings is perceived. As demonstrated in *Table 12,* The energy loads calculated correspond to the heating cooling and ventilation in order to compare the total results. V3 and V4 are the best performing variants regarding the HVAC systems which consume 119.61 kWh/m2 yearly, whereas, V6 is the worst variant as a result of a total of 162.56 kWh/m2 yearly energy consumption.

Table 12 Area-based energy consumption of the selceted variants. Retrived from Lewczuk K., et al., (2021). Energy Consumption in a DistributionalWarehouse:A Practical Case Study for DifferentWarehouse Technologies.

Parameters	**V1**	**V2**	**V3**	**V4**	**V5**	**V6**
Area (m2)	10834.11	7820.02	3399.5	3399.5	2100	2100
Energy consumption for heating and cooling (kWh)	1249281	901726	390657	390657	294744	294744
Energy consumption for ventilation(kWh)	46652	33673	14638	14638	9043	46652
Total energy consumption (kWh)	1295933	935399	405295	405295	303787	341396
Total energy consumption (kWh/m2)	**119.616**	**119.6159**	**119.2219**	**119.2219**	**144.6605**	**162.5695**

Figure 96 displays a comparison between the total energy loads of each variant of the typical warehouses and the proposed scenarios of B1. The calculations are area-based in both cases and the measurements are conducted yearly. The green bars on *Figure 96* demonstrate the variants of the typical warehouses, whereas, the beige bars

demonstrate the retrofit scenarios of B1. Considering the fact that the proposed buildings in this study consist of suitable building energy efficient materials and techniques, regarding the HVAC, the energy loads values are considerably lower than that of a typical warehouse. According to the results of the chart, by means of retrofit measures, B1 consumes up to 65.8 % less energy than a typical warehouse for cooling heating and ventilation.

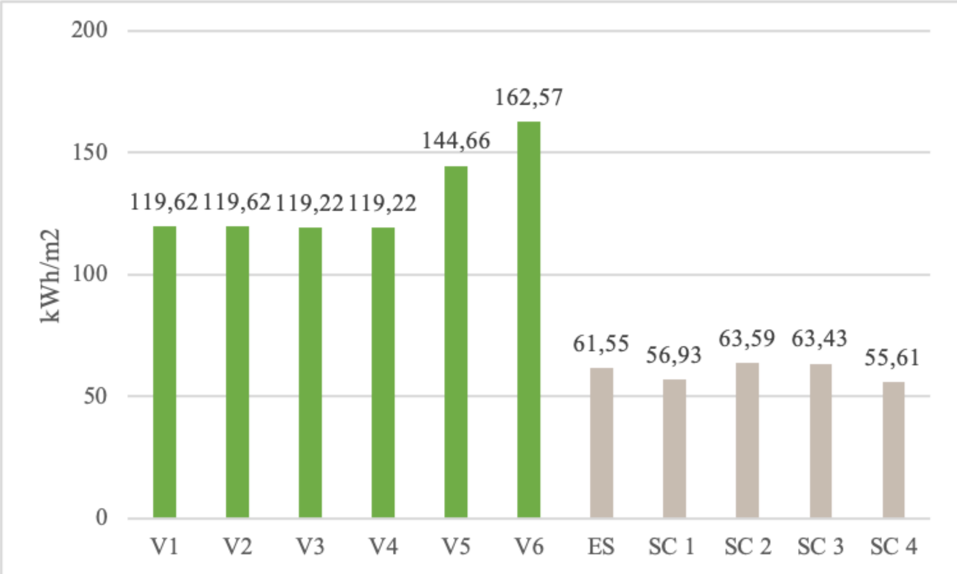


Figure 96. Comparison between the total HVAC energy loads of each variant of the typical warehouses and the proposed scenarios for B1.

Figure 97 displays a comparison between the total energy loads of each variant of the typical warehouses and the proposed scenarios of B1. The calculations are area-based in both cases and the measurements are conducted yearly. The green bars on *Figure 97* demonstrate the variants of the typical warehouses, whereas, the beige bars demonstrate the retrofit scenarios of B2. Considering the fact that in this building crops that require lower storage temperature are stored, the energy loads values of the existing state of B2 and the first two scenarios resemble the values of a typical warehouse. Whereas, the retrofit scenarios SC3 and SC4 perform considerably better. According to the results of the chart, by means of retrofit measures, B2 consumes up to 50.8 % less energy than a typical warehouse for cooling heating and ventilation.

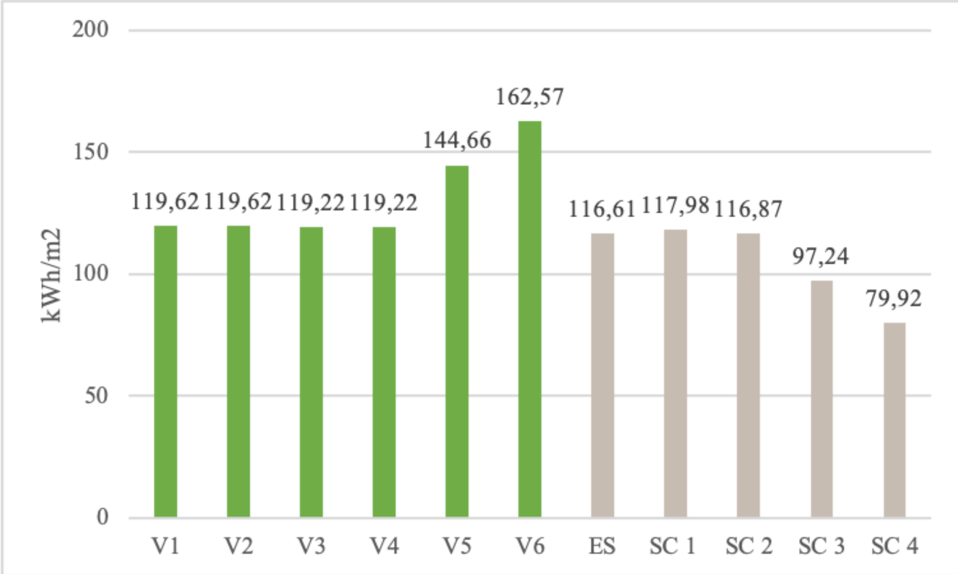


Figure 97 Comparison between the total HVAC energy loads of each variant of the typical warehouses and the proposed scenarios for B2.

Figure 98 displays a comparison between the total energy loads of each variant of the typical warehouses and the proposed scenarios of B1. The calculations are area-based in both cases and the measurements are conducted yearly. The green bars on *Figure 98* demonstrate the variants of the typical warehouses, whereas, the beige bars demonstrate the retrofit scenarios of B3. Considering the fact that the proposed buildings in this study consist of suitable building energy efficient materials and techniques, regarding the HVAC, the energy loads values are considerably lower than that of a typical warehouse. According to the results of the chart, by means of retrofit measures, B3 consumes up to 65.2 % less energy than a typical warehouse for cooling heating and ventilation.

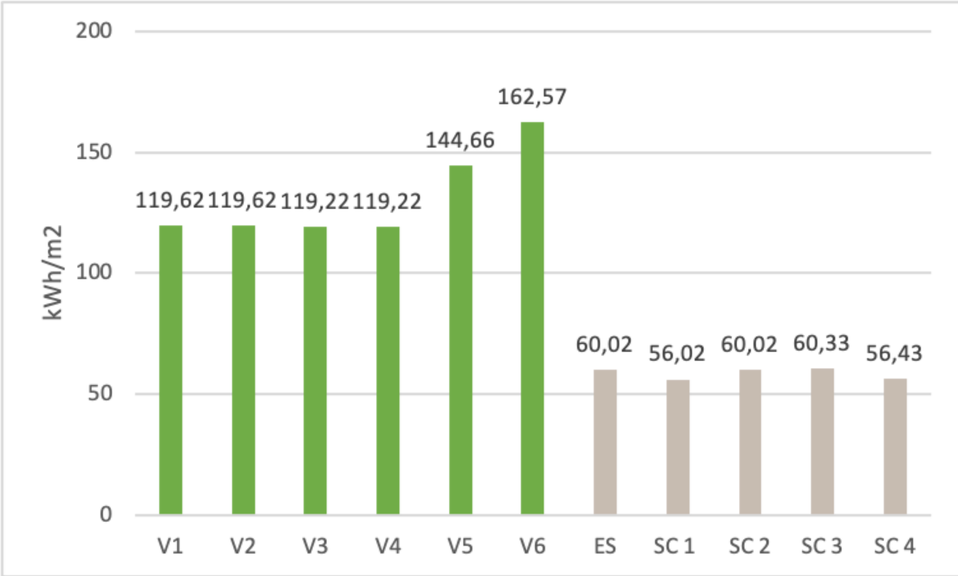


Figure 98 Comparison between the total HVAC energy loads of each variant of the typical warehouses and the proposed scenarios for B3.

CHAPTER 7

CONCLUSIONS

7.1 Conclusions

Agro-Logistics centers are a very crucial aspect of the agricultural sector worldwide. These buildings are the most important part of the sector regarding post-harvest period. Considering the fact that agricultural products require specific temperature and humidity values, typical warehouses usually consume great amounts of energy in order to maintain a suitable environment for the products stored in the building. By revitalizing old abandoned buildings of heavy mass wall of 60cm thickness, these parameters can be reduced significantly. Application of retrofit measures are also an alternative in order to achieve even better results.

This study focuses on the energy performance of three buildings in Malesia e Madhe, district which will be revitalized for agricultural purposes after being abandoned for several years. Taking advantage of the building materials and techniques used in this building typology agricultural trade markets are proposed to be implemented as the new function of the buildings.

The buildings are modelled in a 3d simulation software which calculates the HAMT values of the buildings and their correlating retrofitting scenarios. Results indicate that the buildings that are located near the lake and mountain perform better in terms of energy consumption that the building that is located in a hillside. This outcome is a result of the geographical position and consequently the crop production typology. The buildings that perform better are located in areas where vegetables and medicinal plants are mostly produced. Considering the fact that these plants need relatively high temperatures for suitable storage, they demand less energy to cool the building during summer months. While the building that performs the worst is located in a fruits production area where temperatures of storage mostly vary from -1 to 10, leading to a greater need of cooling loads during the summer.

7.2 Recommendations for future research

The selected sites in this research are chosen purposely in order to include almost all the crop production typologies in order to be implemented as a program elsewhere in Albania, or even worldwide. The variables of this study are common variables that might be encountered in many other zones of the Mediterranean climate.

Considering the fact that this building typology is very widely spread in Albania, this study serves as an open door for further studies and research based on the architecture implemented in agriculture. One of the most advantageous results indicate that the lakeside buildings and mountain side building both perform very well, thus the altitude of the area is not as important as the crop production typology.

Another key point to be mentioned is the boost of agro tourism that this research project would influence. Zones of comfort temperatures are situated in each building in order to provide commercial activities and administration offices. An expansion of this zone can be considered in future research in order to rehabilitate various activities such as restaurants, test farms, crowd-farming, etc. In addition to assisting farmers to gain independence and accessibility, agro-tourism empowers the surrounding community through increased participation. Dasipah, E., et al. (2021).

Rural areas pf Albania can benefit from utilizing traditional buildings for agricultural and commercial purposes. Among the characteristics of local tourism development and marketing management programs are rural and farm tourism development issues, since in rural areas, historical cultural tourism and rural tourism tend to co-exist. Petroman, C. et al. (2019).

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APPENDIX

Appendix A – Questionnaire to the farmers

1. Do you own a piece of land?

   - Yes
   - No

2. Do you use the land for agricultural purposes?

   If not, why? ____

   If yes, what crops? ____

3. Do you manage to sell all the crops in the supposed time and best quality?

   If not, why? ____

4. Do you find difficulties in accessing trade market for your crops?

   - Yes
   - No

   If yes, do these difficulties lead into less monetary profit?

   - Yes
   - No

5. Would you like your zone to have a well- organized market place/ agriculture logistics center which will preserve the crops in the most optimal conditions?

   - Yes
   - No