“Basic Principles, Methods and Techniques of Bioclimatic Design. Adjustments in the vernacular architecture.”

Brenta Maria
SID: 3302110006

SCHOOL OF SCIENCE & TECHNOLOGY
A thesis submitted for the degree of
Master of Science (MSc) in Information and Communication Systems

OCTOBER 2012
THESSALONIKI – GREECE
“Basic Principles, Methods and Techniques of Bioclimatic Design. Adjustments in the vernacular architecture.”

Brenta Maria

SID: 3302110006

Supervisor: Prof. Isaac A. Meir
Supervising Committee Members: Assoc. Prof. Name Surname
                         Assist. Prof. Name Surname

SCHOOL OF SCIENCE & TECHNOLOGY
A thesis submitted for the degree of
Master of Science (MSc) in Information and Communication Systems

OCTOBER 2012
THESSALONIKI – GREECE
Abstract

This dissertation was written as a part of the MSc in Energy Systems at the International Hellenic University. Here goes a summary of the dissertation.

The present thesis has as major objective the investigation of the methods and techniques of bioclimatic architecture. The mean of bioclimatic design as well as the need of its integration in buildings will be analyzed compared with all the bioclimatic components and principles adopted for the optimization of buildings thermal behavior. More specifically, the bioclimatic characteristics of the vernacular architecture will be identified. Mount Pelion, which is characterized by local legislation as “traditional region requiring absolute protection” is selected as a case study. The basic question that has to be answered through the thesis is if the traditional and vernacular architecture of Pelion have bioclimatic attributes. If yes, what are these and how can one extrapolate from them for a more environmentally friendly, energy conserving contemporary architecture?

The interesting building forms and types of the traditional and vernacular architecture are based mainly on locally available materials and cultural characteristics. Therefore, in order to answer the above question, these buildings should be studied and investigated in a critical way based on their spatial and environmental performance and their interaction with the climate. The relation among environment, building and user will be identified, analyzing all the factors including shape, morphology, orientation, topography, materials, plan and section, microclimate and the occupants’ interventions that could affect the thermal behavior of such buildings.

The energy profile and the passive systems of this Pelion mansion and houses of 18th and middle of 19th century combined with the requirements of thermal comfort of the residents will be recorded. The energy and environmental performance of the vernacular buildings will be investigated, whereas a variety of methods and techniques like in-situ surveys, monitoring, questionnaires and ventilation patterns detection will be conducted to draw meaningful conclusions.

At the end of the investigation, there would be an evaluation of vernacular dwellings’ characteristics, as well as a description of the current way of structuring that is followed. The understanding of the way in which the traditional buildings work in
relation to the climates, environments and cultures will provide us basic information for more appropriate new buildings.

Acknowledgements

This thesis would not have been possible without the help and the guidance of several individuals who contributed to the preparation and completion of this dissertation.

First of all, I would like to thank and express my sincere gratitude to my supervisor Professor Isaac A. Meir for his continuous help and support for my MSc dissertation.

Besides my advisor, I am very grateful to the staff of the Laboratory of Heat Tranfer and Environmental Engineering of Aristotle University of Thessaloniki for the devices that I lent. Especially, I would like to thank Professor Agis Papadopoulos and Natalia Boemi for their help and their suggestions about the on-site monitoring part of this dissertation.

Moreover, I am extremely grateful to Giorgos and Stauroula Kapourniwi for their help and their hospitality.

I would also like to thank all the academic assistants and the staff members of the International Hellenic University for their encouragement and help.

Finally, I take this opportunity to express my thanks and my deep appreciation to my family for their support throughout my life.

Brenta Maria

29/10/2012
# Contents

Abstract .................................................................................................................................................. iii

Acknowledgements ................................................................................................................................. iv

Contents .................................................................................................................................................. v

Introduction ............................................................................................................................................... 1

Chapter 1. Literature Review .................................................................................................................. 4

Chapter 2. The Bioclimatic Architecture ................................................................................................. 8

2.1 What is bioclimatic architecture? ..................................................................................................... 8

2.2 The need for bioclimatic design integration in buildings ................................................................... 9

2.3 Bioclimatic design components ....................................................................................................... 11

2.3.1 Climate - Microclimate .................................................................................................................. 11

2.3.2 Thermal comfort ............................................................................................................................. 12

2.3.3 The importance of thermal mass .................................................................................................... 15

2.4 The systems of bioclimatic design ................................................................................................... 17

2.4.1 Categories of bioclimatic design systems ....................................................................................... 18

2.5 Benefits of bioclimatic design ........................................................................................................ 20

Chapter 3. Bioclimatic Architecture in Greece ....................................................................................... 22

3.1 General ............................................................................................................................................... 22

3.2 Application of bioclimatic design in Greece ..................................................................................... 24

3.3 Use and energy efficiency of passive systems in Greece ................................................................. 26

3.4 The parameters for optimum performance of bioclimatic systems .................................................. 29

3.4.1 Proper planning and rational choice techniques ............................................................................. 29

3.4.2 Proper implementation of systems during construction ................................................................. 30
3.4.3 Proper use and operation of the building and its systems .................. 30
3.4.4 Adequate maintenance ........................................................................... 31

Chapter 4. Vernacular architecture ................................................................. 32

4.1 General ........................................................................................................... 32
4.2 The Greek Vernacular Architecture ............................................................ 33
  4.2.1. Morphology ......................................................................................... 36
  4.2.2. Functional organization and typology ....................................................... 37
4.3 The bioclimatic design factor in the vernacular architecture ................. 39
4.4 Integration of the natural environment’s elements in vernacular architecture 40
  4.4.1 Landscape - orientation ........................................................................ 41
  4.4.2 Floor plan .............................................................................................. 42
  4.4.3 The Envelope ......................................................................................... 43
  4.4.4 Building materials ................................................................................ 45
  4.4.5 Ventilation – Insolation .......................................................................... 46
  4.4.6. Constructing Elements ....................................................................... 47
  4.4.7. Vegetation .......................................................................................... 48

Chapter 5. Case study: Mount Pelion, Zagora village ....................................... 49

5.1 Mount Pelion .................................................................................................. 49
  5.1.1 Location and Landscape of Pelion ............................................................ 50
  5.1.2 Zagora Village ....................................................................................... 51
  5.1.3 Climate .................................................................................................... 52
5.2 Pelion architecture ........................................................................................ 54
5.3 The Mount Pelion houses ............................................................................. 54
  5.3.1 Pelion houses during the period 1700-1750 ........................................ 54
  5.3.2 Pelion houses after the year of 1750 ...................................................... 56
  5.3.3 Pelion houses in the middle of 19th century ......................................... 61
5.4 The bioclimatic elements of the Pelion vernacular architecture ............. 62
5.5 Contemporary architecture of Zagora village ........................................... 67
Chapter 6. On-site survey and analysis of Kapourniwtis’ vernacular building at Zagora ......................................................................................................................... 68

6.1 Building elements and materials before renovation .................................... 68
6.2 Building elements and materials after renovation ....................................... 70
6.3 On-site investigation and analysis of the results ........................................... 72
6.4 Thermal comfort evaluation ........................................................................ 80

Conclusions ........................................................................................................ 84

References .......................................................................................................... 87

Appendix ............................................................................................................ 92
Introduction

The story of the viable, bioclimatic, energy, environmental or ‘green’ design has its roots in antiquity and the traditional architecture of the entire world. It virtually started at the beginning of the 70’s, with the break out of the energy crisis that unsettled all industrially developed nations, but also forced them to take action.

Nowadays, the architecture samples of bioclimatic approach are numerous, their aesthetics is constantly improving and a great number of new materials and systems have been widely accepted (new types of glass, transparent heat insulation, high performance solar panels, improved shading systems, manageable control and measurement systems etc.). Many and more people think that bioclimatic design will become the architecture of the future and its wide use will soon be necessary, because of the degradation of the environment.

As time goes by, it becomes clear that buildings have a heavy impact on the planet’s environmental problem (Table 1) and more and more people think that environmental factors and energy saving should, among others, be fundamental elements in an architecture design. The incorporation of these new parameters in architectural creation can be done with the bioclimatic design of buildings. We should note that the principles of bioclimatic design do not hinder, but offer numerous possibilities in architectural design and can be part of a quality design.

Table 1: Building section in Europe and environmental problems

<table>
<thead>
<tr>
<th>FACTORS AND ENVIRONMENTAL IMPLICATIONS</th>
<th>CONSEQUENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption (42% of the whole)</td>
<td>Heat island effect</td>
</tr>
<tr>
<td>Carbon dioxide emissions</td>
<td>Climatic changes (greenhouse phenomenon, extreme weather conditions and catastrophes)</td>
</tr>
<tr>
<td>Gas emissions on the atmosphere</td>
<td>Oil crisis and financial implications</td>
</tr>
</tbody>
</table>
Therefore, the bioclimatic architecture will help us express the problem of the system: architecture - climate - environment. The architectural object is a factor that enriches the environment, considering that it can be easily integrated in it and, at the same time, it makes the best of all environmental sources: sun, wind, water, soil.

The bioclimatic design chooses the best solutions for saving energy, without aggravating the environment and also provides the best indoor climate conditions (thermal and visual comfort, air quality). It is based on the eclectic function of the building’s envelope, and applies settings, called passive solar systems, in order to take advantage of the most ‘mild’ forms of energy.

More specifically, the benefits of the bioclimatic and energy design of buildings in general, are multiple, such as: energy (energy saving and thermal – visual comfort), financial (reduction of fuel costs and costs of electro – engineer installations of heating – cooling – ventilation – lighting), environmental (reduction of gas emissions, limitation of the greenhouse effect) and social (improved quality of life).

On the other side, by observing the traditional building techniques around the world, from the mud houses, the traditional Islamic houses which take advantage of natural ventilation to cool the rooms, the igloos with their conic shape and the lack of windows having the least possible amount of heat losses, to the underground homes in Santorini which keep the temperature almost stable and unaffected by the outside temperature changes, we can conclude that the indigenous wisdom imbued in these buildings and the applied knowledge of the handymen, whose experience was based on observing and interpreting nature, is what we are nowadays trying to recreate, with the term ‘energy design’, with a touch of technological evolution. Furthermore, vernacular architecture is based on local materials and can be adjusted to the occasional social and economic situation.

Traditional architecture has another aspect that is worth noting, such as the element of cultural heritage and the identity of a certain place. The structured environment incorporates the values of a social reality and the human ingenuity, it represents the knowledge and the priorities and needs, but also the way of life of all locals. That is the reason why the value of traditional architecture, as an important part of our Hellenic cultural heritage, is appreciated and protected by the national body of laws.

Therefore, the present paper, which was realized from June to October 2012 in the framework of the post – graduate studies program in the International Hellenic Uni-
University entitled ‘Energy Systems’ will deal with the triptych environment – civilization – building. Due to the fact that the building and construction sector is the cause of many environmental impacts but, at the same time, it is also a cultural element with a lively local character, we need to find a way to make the best of this technology, according to the place we are in. This local ‘know how’ affects all social – political changes and developments (architecture is not stable, but it constantly adapts to the lifestyle of residents by using new technologies) and aims to provide comfortable spaces (thermal and visual comfort) and a healthy environment to work and live in, by using environmentally friendly construction methods. Eventually, what can be achieved through spreading the knowledge and experience and through a design, which will understand and incorporate the expectations and the needs of its local user, the social, economic, cultural and environmental values and its lifestyle, is an improved standard of living and the preservation of the certain character in every different place.

Ergo, the object of the present paper is to investigate the bioclimatic principles and their integration to the vernacular architecture by studying the traditional settlement of Mount Pelion and more specifically Zagora village. This settlement is particularly interesting for the following reasons:

- It is a preserved settlement and restrictive building terms are applied.
- It is located in a mountainous region, with an amazing natural environment,
- with hard winters and relatively warm summers
- It shows an increasing touristic and financial development.
- It has greatly preserved its traditional aspect, nevertheless there are signs of deformations and the local residents look for new and practical building methods, in order to have a certain level of comfort at a low operational cost.

The present thesis is structured in six chapters that are presented below.
Chapter 1. Literature Review

The aim of this thesis is to investigate the methods, techniques and principles of bioclimatic architecture and more specifically to identify the bioclimatic characteristics of the vernacular architecture, monitoring a real case study. On-site monitoring is carried out at a typical house of Mount Pelion, an area that is characterized by hot and dry summers. In this section of the literature review, there will be a brief presentation of studies that are carried out at an international scale in order to investigate the bioclimatic characteristics of the vernacular architecture.

For the purposes of the thesis, we conducted a literature review using electronic databases (Science Direct, Google Scholar) and terms such as “energy performance”, “vernacular architecture” and “building characteristics”. Additionally, many conference proceedings were reviewed such as Passive and Low Energy Architecture (PLEA) conferences (PLEA 2006, 2008, 2011) and Passive and Passive and Low Energy Cooling for the Built Environment (2005). Finally, numerous papers were selected from all the sources, they were analyzed and categorized according to the subject of the thesis' chapters, aims and targets.

In order to investigate the bioclimatic techniques and more specifically in vernacular architecture, among different studies, the “Architectural structure and environmental performance of the traditional buildings in Florina, NW Greece” (2011) was used. In this research, Oikonomou and Bougiatioti (2011) presented the aspects that characterize the traditional architecture of Florina which is the similar to that of Mount Pelion. They based their analysis on forty remaining houses of the 19th century, with materials of the building envelope, construction techniques, building form and typology. The results concluded that the principles, used in these buildings, concern the proper orientation of the houses independent of the plot position, the proper orientation of openings promoting daylighting and natural ventilation, the use of natural materials and finally the distribution of thermal mass improving thermal comfort conditions and reducing energy use.

Moreover, Oikonomou (2004) described the thermal behavior of vernacular architecture of the city of Florina. She investigated the thermal behavior of three buildings through simulation using Ecotect software and she resulted in the following ascertainments:
- Ground floor: heavyweight construction, winter accommodation.
- First floor: lightweight construction with large openings, summer accommodation.
- The building with only south openings has less hours of excess over the comfort limits during the winter period.
- The building with most openings in the first floor presents the best behavior during the summer period.

Additionally, Oikonomou (2005) advanced her researches and she dealt with the summer thermal comfort of traditional buildings of 19th century in Florina. In this research, she used Ecotect software in order to describe the construction methods and the materials used. It was calculated that there were not thermal comfort conditions only for the 5-15% of the whole summer period.

Trying to investigate, also, the summer visual and thermal comfort conditions, Oikonomou (2006) compared the simulation results of Ecotect and Radiance software with real measurements. The in-situ measurements, as well as the software results proved the behavior of the heavyweight and lightweight construction at ground and first floor respectively and the influence of windows location on ventilation. Regarding the measurements about natural lighting, the results of the real measurements and of the simulation proceed are converging.

In the same framework about vernacular architecture, Visilia (2008) evaluated a Greek sustainable vernacular settlement and its environment. She chose Sernikaki settlement in Fokida, in order to find the bioclimatic characteristics of its buildings. It is demonstrated that bioclimatic architecture is integrated in the vernacular buildings. In short, the bioclimatic characteristics of Sernikaki buildings according to Visilia (2008) are the following:

- Building materials: stone and wood
- Proper orientation of windows
- Wooden shutters (shading systems for summers and movable insolation system for winters)
- Walls with thickness about 0.6-0.7 meter.
- Sloped roofs
Apart from Greek regions that they have several examples of vernacular settlements, there are a lot of studies about the relationship between bioclimatic design and traditional architecture. Nicolae Petrasincu and Laurentiou Fara (2006) studied on the bioclimatic elements of the Romanian traditional dwellings in order to be adjusted in the present social and economical conditions using new technologies and materials. The result of this research was that the vernacular dwellings are able to be used as prototypes for the development of Romanian modern architecture.

Entirely, different outcomes were arisen by Rossanco Albatici (2006) who investigated 62 buildings in Italian Alps that were based on the principles of bioclimatic architecture using systems for the best energy efficiency of the building. Nevertheless, they were not able to be characterized as sustainable due to the fact that they were not related, in harmony, to their surrounded environment and to the styles of the region bioclimatic architecture. The result was that the design of buildings should not only use modern technological systems, but also it should use the architectural elements of each region and culture.

In 2006, Rosalia Manriquez, Victor Fuentes and Luis Guerrero described the traditional architecture and the bioclimatic design of Tecozautla in Mexico. It was concluded that the morphology of the buildings corresponded to the conditions of the climate, whereas the bioclimatic methods that were integrated in the dwellings were: thermal mass, evaporative cooling, natural ventilation, shading systems, vegetation.

As far as the vernacular architecture in Mount Pelion that is used as a case study, and the buildings type of 19th century, Kizis (1994) wrote that the traditional architecture of Pelion is a great example not only for its historical context, but also due to the fact that it is an architectural-environmental response to the climatic conditions. In the case of Pelion mansions as well as in Balkan region in general, the cultural and the architectural standards are affected by the Ottoman Empire. Furthermore, Kizis (1994) focused on the building form of Pelion and described how people chose the site of their houses according to the South orientation of the main spaces. The ground floor is divided into two zones: the entrance hall and the storage spaces. Each floor is divided into the public and the private zone, and floors are connected vertically by wooden staircases.

Sakarellou-Tousi and Lau (2009) analyzed the living patterns of the vernacular dwellings of Mount Pelion as these relate to the climate of the region that is character-
rized as moderate during summer and cold during winter. For the temperatures, the relative humidity and the wind directions in the Mount Pelion during our survey, Hellenic National Meteorological Service and the Meteorological Station at Pelion were used.

Additionally, via a review of the proceedings of the conference on Passive and Low Energy Architecture (2006) it is concluded that good architecture should realize and understand the past and the present values, while simultaneously it should combine them with contemporary methods in order to result in an energy efficient up-to-date architecture. Also, a part of the World Architecture module that is taught to first year students at the Welsh School of Architecture is described during which students chose some vernacular buildings in order to learn from the vernacular models and employ them in their own designs.

These tools can be used either by themselves or combined with quantitative measurements. On the one hand, some researchers think that such tools are no less accurate than physical measurements and monitoring, whereas some others consider the type of tools drawn from psychological/social sciences to be supplementary.

In this thesis, on-site observations of the selected building, monitoring of the indoor-outdoor temperatures and relative humidity, as well as measurements of the surfaces’ temperatures were undertaken. Moreover, occupants answered a questionnaire that was given to them –in hard copy- about their satisfaction for their house and the results will be presented in the chapter 6.

The main purposes of the above tools are to understand the relationships between the building, its users and the systems operated in the building. Occupants that had to answer the questionnaire were asked to rank their overall satisfaction.
Chapter 2. The Bioclimatic Architecture

The term “bioclimatic design” was first used in the 60s by the brothers Olgyay during their investigations on the ways of a building adaptation to its climatic environment [1], while the energy crisis in the 70s increased interest in the systematic consideration of the relationship between buildings and climate, targeting the minimization of energy consumption.

By using the term “bioclimatic design”, we mean the appropriate design that aims to protect the environment and its natural resources. On the other hand, “bioclimatic building” is a building that corresponds to the climate conditions of its environment resulting in an indoor climate that provides thermal and visual comfort to the occupants consuming the least possible energy [2].

2.1 What is bioclimatic architecture?

Bioclimatic Architecture is the design of buildings and spaces (internal and external) that depend on the local climate and target the assurance of thermal and visual comfort conditions, exploiting the solar energy and other environmental sources. The basic elements of bioclimatic design are the passive systems integrated into the building which aim at utilizing natural resources for heating, cooling, and lighting.

During the last decades, bioclimatic architecture is, worldwide, a significant approach to the construction of buildings, whereas in the most states it is the main design criterion that is taken into account by architects and engineers. The advantages that arise from bioclimatic design are the least energy requirements for heating, cooling, and lighting, while by its use, there are several benefits like: energy (energy savings and comfort conditions), economic (cost reduction of electromechanical installations), environmental (pollution reduction) and social.

Moreover, it should be noted that the utilization of solar energy and environmental resources is achieved under the overall thermal performance of the building and the relationship between building – environment. The building thermal operation is a dy-

Dynamic situation that not only depends on the local climatic and environmental parameters (sunshine, ambient air temperature, relative humidity, wind, vegetation, shading), but also depends on the use of buildings (residential, office, hospital etc.) based on the corresponding energy behavior of construction materials and of integrated passive systems [3,4].

Finally, the bioclimatic design efficiency depends on several parameters which make it sensitive to external factors. For this reason, basic criteria for bioclimatic design implementation are the following:

- The simplicity of applications use and the avoidance of complex passive systems and techniques
- The small users’ contribution to the systems’ operation
- The use of extended applied systems
- The use of efficient energy technology.

2.2 The need for bioclimatic design integration in buildings

The building sector is one of the strongest markets in the world, since the jobs in the construction sector represents 10% of the world economy, 50% of global investments and 7% of the labor market.

Moreover, the building sector is responsible in a large percentage for the emission of air pollutants and the consumption of natural resources. More specifically, about 50% of natural resources is used for the constructions, 50% of energy produced is consumed for lighting, ventilation and air conditioning, while a percentage about 3% of energy is spent during the building construction. Also, the 50% of water is consumed in buildings and 60% of the total timbering is used in the building constructions.

Consequently, the means of viability, sustainability and protection of natural environment should be utilized through a construction strategy that is able to combine the reduction of negative impacts on environment with the provision of comfort conditions to the occupants with lower cost. In order to achieve this combination, bioclimatic design with passive systems should be used.

Regarding the European Union, the building sector is responsible for 40% of the total energy consumption, while the residential buildings are consumed about 57% of
energy for heating. Therefore, the E.U. in order to improve the energy security issues, established the European Directive 2002/91/EC on the Energy Performance of Buildings, while in May 2010, EPBD recast was established, obligating all the buildings to be nearly zero energy balance buildings after 2018. Moreover, Greece has recently drafted the Energy Regulation Performance of Buildings (KENAK), while there had been a study of the Rules of Rational Use and Conservation of Energy.

The targets that are being set are the following:

- Reduction of thermal needs and energy loads (domestic hot water, heating, cooling and ventilation)
- Use of cleaner fuels and reduction of conventional fuels use (improvement the COP of installations, use of renewable energy)
- Obligation of energy study
- Energy audit
- Obligation for the audit of boilers and central air conditioning systems.

(Papadopoulos, 2012).

In Greece, the energy consumption in building is about 33% of the total energy consumption with average annual growth rate of 4.5%. The percentage of 75% refers to residential buildings in which about 60% of energy is consumed for heating.

The increased consumptions in our country are partly excused by the fact that the 80% of all the Greek buildings were built before 1980 (before the adopt regulations for insulation) and they have not insulated building elements.

Apart from the fact that the production and use of energy lead to environmental pollution and to climate conditions change, the energy costs consist one of the highest household expenditures, mostly for the low-income families.

Therefore, bioclimatic design is a significant strategy in order to achieve the following aims:

- Improvement of buildings’ energy efficiency
- More rational use of energy
- Utilization of renewable resources
- Reduction of environmental impacts
- Use of materials that are friendly to the environment
Furthermore, the bioclimatic principles and systems can be combined with active systems and modern technologies leading to energy savings like:

- Photovoltaic systems
- Geothermal energy
- Small wind turbines
- Use of biomass for heating
- Solar heating
- Hybrid solar systems for space heating and domestic hot water production (Kalogirou, 2009).

2.3 Bioclimatic design components

The components which affect significantly the bioclimatic design of a building are the following: the climate and the microclimate, the thermal comfort, as well as the utilization of thermal mass.

2.3.1 Climate - Microclimate

It is widely accepted that not only the buildings have a great influence upon microclimate, but also the climate and weather affect significantly the buildings. The use of the quantitative climatic data is important for the rational design of passive buildings, since the need for heating or/and for natural cooling is influenced by the ambient air temperature. The architects have firstly to investigate the region climate in which they will build, and then assess its modification within the site [7].

The essential climatic requirements, apart from the outdoor air temperature data are presented below:

- Solar radiation data. The short wave radiation is one of the most important sources of energy, so the seasonal analysis is required. The overheating during the summer period is a major problem in many areas impacting on cooling energy demands of buildings.
- Wind speed and direction data. Wind is, also, a major factor for the building design, since it can keep the buildings cool through natural ventilation. It influ-
ences both heat losses at the external surfaces of buildings and the rates of indoor ventilation. Moreover, wind direction affects the site microclimate influencing the energy demands of building for cooling and heating.

- Long wave radiation. Long wave radiation cause losses at the external buildings’ surfaces by exchanges and by convection. There is a net energy loss from buildings due to the fact that the downward flux of this radiation is less than the outward loss of radiation back to the atmosphere. The losses due to the convection depend both on the difference between air and outside surface temperature and on the wind [8].

### 2.3.2 Thermal comfort

It is possible to define the thermal comfort as the condition in which the human body temperature is 36.5-37.5°C, the average skin temperature is 33-35°C, the skin surface is free of sweat and the muscles are not contracting. Deviation from this temperature zone, excess sweating or shaking, all of those together or each one separately, will cause a feeling of discomfort which will increase proportionately to the deviation.

It is widely accepted that one of the major goals of building design is to provide the proper conditions for the occupants in order to have a healthy life. According to ASHRAE comfort means “the condition of mind which expresses satisfaction with the thermal environment” and depends on several factors some of which are not quantifiable like the psychological well-being. On the other side, thermal comfort is strongly related to quantifiable factors like air temperature, air movement and relative humidity that in turn depend on variables like personal activities and clothing.

In order to achieve comfortable internal conditions, there are certain values depending on given clothing and activity ranges under which people feel comfortable. These values are taken into account during the design of buildings in order to achieve thermal comfort by using mechanical means or passive systems [9,10].

In order to estimate how warm or cool can feel a person in an environment, we have to calculate the Predicted Mean Vote (PMV). The PMV index predicts the mean response of a large group of people according to the ASHRAE thermal sensation scale (Table 2.1) that is presented below [8]:
Table 2.1: Thermal sensation scale

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+3</td>
<td>hot</td>
</tr>
<tr>
<td>+2</td>
<td>warm</td>
</tr>
<tr>
<td>+1</td>
<td>slightly warm</td>
</tr>
<tr>
<td>0</td>
<td>neutral</td>
</tr>
<tr>
<td>-1</td>
<td>slightly cool</td>
</tr>
<tr>
<td>-2</td>
<td>cool</td>
</tr>
<tr>
<td>-3</td>
<td>cold</td>
</tr>
</tbody>
</table>


As it is mentioned, the PMV predicts the mean value of the thermal votes of people who are exposed to the same environment. Nevertheless, there are important differences between people so the individual votes are scattered around the mean value. For this reason, the Predicted Percentage of Dissatisfied (PPD) index can be used in order to find the percentage of people who felt more than slightly warm or slightly cool [8].

The relationship between the PPD and PMV is shown in the below diagram (Fig. 2.1).

![Figure 2.1: PPD as Function of PMV](http://www.sciencedirect.com)
Additionally, the comfort diagrams are the most direct and understandable way in order to present the relationship between the thermal index and the rest of thermal comfort parameters. One of the first attempts was the Olgyays bioclimatic chart which was developed in the 1950s. This building bioclimatic chart is used in order to indicate the different zones of thermal comfort in relation to air temperature and humidity, mean radiant temperature, solar radiation, wind speed and evaporative cooling. As it is shown in Figure 2.2, the comfort zone is in the centre of diagram, while for temperatures above the comfort zone the wind speed that is required in order to restore comfort in presented related to humidity [9].

![Olgyay Bioclimatic Chart](http://www.buildinggreen.com)

Figure 2.2: Olgyay Bioclimatic Chart

[Source: http://www.buildinggreen.com]

A very important diagram that will be presented below is the psychometric diagram that determines the relationship between temperature and humidity in the atmosphere. According to the psychometric diagrams, bioclimatic diagrams are constructed to record the climatic elements of a region and to investigate the proper construction and bioclimatic choices. The diagrams of Markus and Morris as well as Givoni and Milne diagram are considered to be the most significant charts.
On the one hand the Markus and Morris diagrams are drafted for a variety of 55 different combinations of clothing, activities and wind speed. On the other hand, the building bioclimatic chart of Givoni and Milne (BBCC) defines two thermal comfort zones: the zone for developed countries and the zone for hot-developing countries. This separation is based on the possibilities of the inhabitants of one country to be familiarized to its climate. For instance, the inhabitants of a warm country consider acceptable higher temperatures in comparison to the inhabitants of a cold country. Also, the developed countries cool their buildings at lower temperatures during the summer period and heat them at higher temperatures at the winter. On the other hand, the inhabitants of developing countries can tolerate higher temperatures [2].

![Psychometric Chart](Source: en.wikipedia.org)

**2.3.3 The importance of thermal mass**

The utilization of thermal mass in bioclimatic design targets to meet two significant needs. Firstly, it absorbs the solar heat in order to be used in the diurnal cycle, while at the same time, it helps to avoid overheating.
The effective utilization of solar radiation presupposes the existence of thermal mass in the building in order to store the acquired heat. The most appropriate means for heat storage are the materials of high heat capacity like stone, concrete and marble or new technology materials like PCM (phase change materials) [8].

In order to store heat in the building elements, the insulation of the envelope should be placed external or intermediate to the building components. On the other hand, the internal insulation eliminates the possibility of the building element to store heat.

A building element store the heat derived from the solar radiation through three ways:

- The building element is directly exposed to the solar radiation and it constitutes the main thermal storage. The direct incidence of the solar radiation on the element is the most efficient method for its thermal loading.
The building element accepts radiant heat emitted by the building space which has direct solar gains, like the ceiling of a room whose floor accepts direct solar radiation.

The building element is heated by heat transfer through the movement of the hot air. On the one hand, this way is the less efficient, but on the other hand in this way, heat can be transferred to remote building places.

The stored heat is attributed to the internal spaces with a time lag, i.e. in the evening when the internal temperature starts decreasing. Generally, the thermal storage behavior depends on the material’s:

- thermal storage capacity (specific heat storage capacity)
- thermal conductivity
- density and
- thermal diffusivity,

whereas the thermal storage capacity as well as the thermal conductivity tend to increase with increasing density.

Moreover, the thermal mass is affected by two major factors: the local climate and the use of the building. These factors can influence the heat transfer like for instance the delayed release of heat may occur a few hours later than the peak ambient air temperatures or even slowly over some days (Papadopoulos 2012).

### 2.4 The systems of bioclimatic design

All buildings have as their main target to provide a comfortable environment improving the performance and the health of the occupants. It is widely accepted that a proper indoor environment not only make the occupants feel comfortable, but also it can result in reduction of energy consumption influencing its sustainability.

Nowadays, due to the energy-economic crises, passive systems integrated in buildings play a great role in decreasing the need for high-energy solutions. The quality of indoor environment can be significantly improved by the use of natural and passive cooling and heating methods for the buildings, providing at the same time thermal comfort and reducing the energy demand [11].
2.4.1 Categories of bioclimatic design systems

The passive systems of heating and cooling are systems that utilize the natural resources like the sun and the wind in order to heat or cool the building without the use of mechanical equipment. Their operation is based on the exchange of energy with the environment and includes the energy storage and distribution in different places in a building. The passive systems are components of the buildings and are integrated in the bioclimatic design. The targets of the passive system choice are the improvement of thermal comfort as well as the highest energy savings.

All the passive systems require South orientation, whereas they have to be combined with the proper insulation and the thermal mass of the building. Additionally, they should be combined with shading systems and often with ventilation possibilities.

The solar passive systems are separated into the following five categories:

- Direct solar gain systems
  a. South openings
  b. Roof openings
  c. Roof fins
- Indirect solar gain systems
  a. Thermal walls (Trombe wall, water wall)
  b. Thermosiphonic panel
- Isolated solar gain systems
  a. Sunspaces, greenhouses
  b. Isolated storage wall
  c. Thermosiphonic air panels
  d. Transmission loop

Furthermore, cooling systems and ventilation (natural or forced) play a great role for the bioclimatic design of a building. Not only the air temperature and humidity, but also the winds are such significant factors that affect the human comfort. The design of the building should be realized in relation to the prevailing wind directions contributing to the natural cooling of the houses [12].

The systems that are used in order to cool naturally the buildings are the following:
- Sun protection systems including landscaping, trees on the south side and window shading devices
- Natural cooling systems: wind towers, thermal chimneys, solar chimneys, natural ventilation (diurnal or nocturnal)
- Roof ponds for radiant cooling
- Downdraft evaporative cooling tower for evaporative cooling

Figure 2.5: Generic Passive Solar Types [8]
2.5 Benefits of bioclimatic design

In general, bioclimatic and energy conscious building design has several benefits such as: thermal and visual comfort, energy savings, economic benefits (reduction of fuel consumption and cost of equipment for heating/cooling/ventilation/lighting), environmental benefits like less pollution and reduced greenhouse effect, as well as social benefits such as improvement of the life quality.

It is a fact that, the biggest amount of energy savings in buildings results from the rational and appropriate design. This appropriate architecture includes the proper orientation and buildings’ layout, the size, orientation and location of openings, the protection of the building envelope and finally the rational operation of the buildings’ systems. Particularly during the summer periods, shading and natural ventilation systems are the so important for the reduction of buildings’ energy demand.

Nevertheless, the resulting energy conservation by bioclimatic design, always, depends on the building type, the local climate and the used technologies. More specifically in Greece, energy savings of around 15-40% have been recorded in houses for heating and cooling requirements compared to well-constructed conventional houses of the same age, while comparing to the older buildings, the savings are even greater.

Moreover, regarding the economic aspect, bioclimatic strategies are easily applicable with minimum additional investments. Also, they are able not only to provide a reduction of environmental impacts but also they lead to an operational costs decrease that makes their realization more variable [13].

In conclusion, the energy benefits arising through the bioclimatic design of buildings are due to:

- The energy savings because of the reduction of heat losses (or gains during hot periods) by envelope protection techniques
- The thermal energy production through direct or indirect passive solar systems
- The creation of thermal comfort conditions inside the buildings
- The maintenance of indoor air temperature at high levels during winter periods and at low levels at hot periods, reducing at the same time the load demands (during the startup of the building)
- The creation of favorable microclimate conditions around the building contributing to lower energy requirements.
Furthermore, the bioclimatic architecture contributes to the rational use of natural resources, the improvement of the natural and built environment and to the living in spaces that are characterized by optimal conditions of visual comfort and indoor air quality [14].
Chapter 3. Bioclimatic Architecture in Greece

3.1 General

Several factors lead to the need of solutions for the most proper energy consumption in the building sector and the use of renewable energy. The technological and economical growth results in the rapid increase of energy needs. Particularly with the continuous improvement of the standard of living, the energy consumption for the buildings operation always raises. This increase is not only quantitative, but also qualitative due to the fact that we use consume more for electricity and cooling reasons in our buildings [15].

![Figure 3.1: Percent ratio of electric to total consumption in the domestic and tertiary sector [15]](image)

More specifically, the final energy consumption in Greece was almost state during the period 1990-1994 and the quantity of consumption was about 15Mtoe removing the non-energy uses. During 1994-1995 the consumption raised about 6,5%, while since the average annual growth rate is 2,5%. In total, the final energy consumption increased 50% from 1990 since 2006, mostly as a result of the economical growth.

The building sector requires a significant amount of energy for its operation (heating, cooling, lighting, hot water). It is calculated that in the European countries, the percentage of 41% of the total produced energy is spent in order to cover the buildings’ needs for heating and cooling. The corresponding figure for the Eastern countries and the Central Europe is about 49%, as it is presented in Figure 3.2 (Aksarli, 2009).
According to the Center for Renewable Energy Sources and Saving, in Greece, in 1994, the use of energy in the residential and tertiary sector reached about 4.4 toe for heating and cooling. Although the Greek climate is moderate, it is recorded that the heating of the buildings in the residential and tertiary sector has a significant share of total energy consumption about 69%, followed by the hot water production (13%), the electrical equipment, the cooling and the lighting (18%). Therefore, the need for energy savings in the building sector is particularly evident as it covers about 36% of total energy consumption in Greece.

Sustainable development is proposed as an alternative solution to the current model of development. The concept of bioclimatic design is included in the context of this ecological strategy, since the heating of building is based on the use of oil, whereas the cooling in based on electricity.

At the beginning of the 21st century, the goal is the reduction of heating and cooling loads of buildings and the minimization of fossil fuel use (at least in terms of heating and cooling), using the inexhaustible energy sources like sun and air. Moreover, the building design, construction and operation should be based on the principles of sustainable use and natural resources management. At the same time, they contribute to a healthy and safe way of living without causing environmental impacts without operating at the expense of thermal and visual comfort of the occupants [17].
3.2 Application of bioclimatic design in Greece

The particular climate of Greece which is characterized by increased sunshine levels and cool summer winds is the most significant factor that enables the application and the effective operation of bioclimatic principles in buildings. The higher energy savings can result from the correct and rational design in relation to the building location and orientation, the size and orientation of openings, the building envelope protection with thermal insulation, the solar and wind protection.

In Greece, the implementation of passive systems in the buildings envelope in order to have increased gains from the exploitation of solar energy, concerns mainly the residential sector, while the use of passive systems for heating and cooling has not be applied greatly in the other buildings sector. The bioclimatic design of industrial buildings has started to be implemented only during the last decade. So, from all the recorded bioclimatic buildings, the percentage of 74% is residential buildings, while in the tertiary sector the highest percentages are concentrated by office and education buildings.

The passive systems that are integrated in the bioclimatic buildings of Greece are used during the winter period mainly for the following reasons: the energy savings and the improvement of comfort conditions. On the other side, during the summer period they are used in order to ensure thermal comfort through simple methods and techniques of natural cooling.

According to the Center for Renewable Energy Sources and Saving the most applied systems and techniques recorded in the bioclimatic buildings are the following:

- South openings. They are direct solar gains systems that are used for heating and they are appeared to the 81% of buildings.
- Sunspaces. They are included in the isolated solar gain systems and they are appeared to the 42% of buildings.
- Solar walls (Trombe wall, thermal mass and thermosiphonic panels). They have percentage about 27%. From all the categories, Trombe wall has the highest percentage about 68%, followed by thermosiphonic panels with 17%, mass wall with 11% and water wall with 4%.
- Exterior insulation, green roofs and the minimization of the North openings lead to additional protection during the winter.

Respectively about the summer period, the shading systems, the minimization of the west openings and the cross ventilation consist the main techniques of natural cooling.
that are recorded in the most bioclimatic buildings in Greece. The solar protection is achieved by internal or external shading systems reaching about 29% of all the cases, while the planting of the surrounding environment is about 9%. Additional passive systems that are integrated in Greek buildings are the solar atriums, the skylights on the roof and the solar chimneys, while it is worth being noted that the natural ventilation is applied in all bioclimatic buildings [17].

Below a bioclimatic house in Pelion is chosen to be presented, as the region of Pelion is our main object of this thesis (Fig. 3.3).

The house was built in 1997 in Pelion. The architectural study, done by the architect E. Georgiadi, had morphological constraints due to the traditional character of the area. The building is consisted of two floors and an attic, while its total area is 157.5 m². It is built on the principles of bioclimatic architecture and includes southern windows and skylights for direct solar gains and sunspace.

![Figure 3.3: Bioclimatic house in Pelion [17]](image)

The techniques of natural cooling include the natural cross and vertical ventilation and ventilation of sunspace. The construction of the house comprises masonry of total thickness 45cm, consisting of two Thermoblock (each of them has thickness 15cm) with air gap about 10cm and a wooden roof with insulation of 7.5cm thickness.

The house in Pelion presents very low energy consumption during the heating period not only due to the bioclimatic design and the passive systems, but also due to the users’ behavior. A significant element is the fact that the only auxiliary heating system is two stoves (one in the living room and one in the sunspace).
Residents say that in the building they feel comfortable at 19°C. Also they mention that in the bedroom of attic high winter temperatures (26-27°C) are observed which are attributed to the accumulation of hot air, because stratification.

The total annual energy demand of the building is estimated about 54.5 kWh/m². The building's energy study shows that although the sunspace has a limited number of openings in order to protect the building from summer overheating, it contributes to the thermal load reduction at a percentage of 14%.

The sunspace is used as the main venue in the winter and is heated only during some hours. The auxiliary heating system (wood stove) performs adequately throughout the building. Although the climate is very cold in winter, the wood consumption per year for heating is very low (4 tons per year) compared with other buildings in the area. In summer, there is no overheating in any area, as the sunlit and stack ventilation discharge of excess heat and increased air flow are generated by the vertical and cross ventilation, as shown by the energy study and the testimony of the occupants [17].

3.3 Use and energy efficiency of passive systems in Greece

According to the results and the simulation that are done by the Center for Renewable Energy Sources and Saving depending on the recorded real uses of buildings, the energy consumptions that are arising for the heating of the bioclimatic houses (houses that operate continuously) are the following:

- In A climate zone, the consumption ranges from 25 to 42 kWh/m² per year
- In B climate zone, it ranges from 28 to 55 kWh/m² per year
- In C climate zone, it ranges from 44 to 90 kWh/m² per year.

Also, it is estimated that the bioclimatic buildings have energy savings about 30% compared with the conventional buildings constructed after 1979 (year of implementation of insulation regulations), while if they are compared with the older buildings without insulation, their energy savings reach at 80%.
By the investigation done by the Center for Renewable Energy Sources and Saving, it is emerged that the utilization of the solar energy for heating is too important regardless of the use of the buildings. But it consists always a significant design parameter that should be combined correctly with the shading systems in order to reduce the solar gains during the summer period (and consequently the need for cooling loads).

Not only the solar gains of the direct solar gain systems are significant factors, but also the contribution of other indirect solar gain systems to the total energy behavior of bioclimatic houses is equally important. More specifically, the simulation analysis shows that:

- The sunspaces attribute up to 30%
- The thermal storage walls can result in energy savings more than 40% in buildings that are in A and B climate zone, while in the C climate zone the percentage is about 12%.

The energy savings due to the several south openings depends on the openings’ surface and the total operation of the building (insulation, internal gains, climate of region etc.). In some cases, the large glazing surface because of the huge thermal losses
during the night at regions with cool nights can result in increase of the building heating load. This phenomenon can be restricted by the use of night insulation at the openings.

The sunspaces are the most prevalent passive solar system in the Greek buildings. Their efficiency depends on their size and their usage patterns that are similar in the three climate zones. All sunspaces have either external or internal shading system and they consist of opening parts for their summer ventilation decreasing in this way the thermal loads in the building that result from their existence. In the most cases, sunspaces are covered by opaque roof or their roof is perfectly shaded in summer in order to prevent overheating of the building.

![Bioclimatic house in Malesina, Greece](image)

Figure 3.5: Bioclimatic house in Malesina, Greece

[Source: Hellenic Ministry for the Environment, Physical Planning and Public Works]

Regarding the solar walls, their efficiency depends on their size in relation to the building and its use. Thermal storage walls and small thermosiphonic panel have a small contribution to the energy performance of buildings.

The solar walls can charge the building, if they are not shaded and they are not ventilated during the summer period. On the other hand, if they are shaded, they will be able to have a positive contribution to the building and particularly to its natural ventilation [17].
3.4 The parameters for optimum performance of bioclimatic systems

As resulting from the Center for Renewable Energy Sources and Saving, the basic parameters for the successful performance of bioclimatic design are the following:

- the right design and the rational choice of techniques,
- the proper implementation of systems during the building construction,
- the proper use and operation of the building and systems and
- the adequate maintenance

3.4.1 Proper planning and rational choice techniques

In general, it is proposed to apply the principles of bioclimatic design ensuring the maximum solar gains during the winter period in order to heat the building, while adequate ventilation is needed in summer. Moreover designers should select the most appropriate protection techniques and systems which will be able to utilize the available environmental resources. For instance, if the southern openings have large area and there is not enough insulation, the direct solar gains will have a negative efficiency during the night.

For southern climates the extensive application of passive solar systems is not suitable, despite only if the inverse operation in the summer can be ensured. On the other hand, for the north and cold climates, the passive systems contribute significantly to energy savings achieving at the same time thermal comfort for the occupants.

By using solar walls better results of thermal comfort can be achieved, while by the use of sunspaces and solar atriums the indirect solar gains that meet the requirements of neighboring spaces and help in smooth functioning of other systems preheating the air or recovering the heat.

The natural cooling achieved by cross and vertical ventilation is effective and necessary for the climate of Greece. The use of natural cooling systems is able to lead to energy savings up to 100% for the cooling needs in the northern climatic regions. Shading techniques and nighttime ventilation can contribute to improve the efficiency of the methods that may be used.

Passive systems like evaporative cooling and cooling by radiation have not great results at areas that are characterized by high relative humidity, while they can achieve high performance in hot and dry climates and in small houses. Moreover, the green
roofs and green terrace can result in benefits for both heating and cooling, only if the design state has done carefully and properly.

Another aspect which should be considered is the cost of each system and the technique used that can vary depending on the type, the size and the use of the building, the local climate etc. Therefore, designers should firstly make a techno-economic analysis of costs and benefits of the selected techniques and systems, so that the costs do not exceed the capacity benefits and the payback system become smaller.

### 3.4.2 Proper implementation of systems during construction

The proper implementation of the systems during the building design and construction of the house is the second parameter of a successful implementation of bioclimatic design. The reduced efficiency of passive solar systems in the most passive solar buildings in Greece is due to the discrepancy between the initial design and the final construction. This is caused by construction errors, omissions, changes of users preferences, resulting in creation of adverse conditions such as increased energy consumption and reduced thermal comfort inside the building.

During the building construction, the following factors should be always taken into account:

- Topography (site orientation, slope)
- Movement of the sun and its impact
- Climatic conditions (temperature, air moisture, wind patterns, solar radiation)
- Daylight and shading systems. It should be noted that daylight can decrease the consumption of artificial light from 40% to 80%.
- Size of the building and its mass
- Use of local building materials
- Local architectural standards [18].

### 3.4.3 Proper use and operation of the building and its systems

The contribution of the users of passive solar houses to the appropriate use and operation of the building and its systems play a significant role for the optimum performance of the passive systems. For instance, the direct solar gains systems require the immediate contribution of users (open the windows or close the shutters) in order to be able to
result in expected high efficiency. Moreover, if during the night solar gain systems are not protected, the building will have significant heat losses.

On the other hand, the users’ contribution is not always feasible and mainly in large buildings with a big number of occupants. For this reason, the technological development provides automatic control systems that are able to optimize comfort and energy efficiency at all times. The passive buildings performance can be increased by these control systems that manage passive solar gains, ventilation, cooling, auxiliary heating and ventilation reducing energy consumption and providing thermal and visual comfort to the occupants [19].

3.4.4 Adequate maintenance

Finally, the adequate maintenance ensures the maximum performance of bioclimatic houses in which passive systems and other techniques are integrated. Although passive systems operate without mechanical means, the maintenance is essential as it contributes to their timeless functionality without efficiency reduction. The main reasons that lead to the need for maintenance are firstly the dust that increases the shading coefficient, the age of transparent materials that reduces light transmittance and it changes the thermal properties, the age of frames which increases the air intake and the rate of hot-air infiltration, the rusting that impairs the function of shading louvers and ventilation openings. All these factors are created over time, due to the use and operation of systems (Kalogirou, 2009).
Chapter 4. Vernacular architecture

4.1 General

According to the Encyclopedia of Vernacular Architecture of the World (Oliver, 1997), the term vernacular architecture is used worldwide to depict the construction practice which uses natural resources and takes into account needs and social structures (tradition, customs). Vernacular architecture is not fixed, it is constantly evolving, reflecting thus the natural, historical and cultural reality that surrounds it. Sometimes the background knowledge is emerging from the building practice as an experience of incorrect and correct design choices, and it is imparted to future generations.

The vernacular architecture concerns the houses and, in general, all the buildings, which have a direct relationship with their natural environment and natural resources, they are either private or public and they have been used in traditional construction technologies. All forms of vernacular architecture are constructed in that way to meet specific needs, showing the values, the economy and the lifestyle of the civilization that produces them.

Observing the samples of vernacular architecture throughout the world (Fig. 4.1, 4.2) one can soon realize that the basic parameters that affect the design in vernacular architecture are climate, culture and the available materials. Buildings in cold climates have high thermal mass or significant insulation and small (or nonexistent) openings, in warm climates are light constructions with openings that allow cross or stack ventilation, while in hot dry climates like deserts, they are made of 1 m thick walls of stone or mud. Also, the buildings have different shapes depending on the precipitation in the area, thus flat rooftops are usually not found in areas of high rainfall [20].

Figure 4.1: A southern African rondavel
[Source: en.wikipedia.org]

Figure 4.2: Defensive housing in Georgia
[Source: en.wikipedia.org]
Concerning the cultural factor, the lifestyle of the buildings users and the way they use them affect their form. The size of the households, the arrangement, the customs, the method of food preparation, the occupation with production activities, the religious beliefs and other cultural elements affect the shape and size of the shells.

Finally a distinction in vernacular architecture is that of the nomadic and of the permanent shell (Fig. 4.3), which points out the fact that lifestyle decisively affects the shape of the dwellings.

![Arab Beduin tent from North Africa](https://en.wikipedia.org)

**Figure 4.3: Arab Beduin tent from North Africa**

[Source: en.wikipedia.org]

### 4.2 The Greek Vernacular Architecture

Vernacular architecture is the total of the built area, as it is formed in every area, in the pre-industrial period. It concerns individual buildings (houses, schools, churches, inns, etc.), building complexes (the traditional dwelling includes the main house and other smaller buildings in direct relation to it – storeroom, baking room, kitchen, etc.), organized sets of buildings which compose the settlements as well as sets of settlements.

The village is an organized set of buildings and functions, in which, except for the private and public buildings, a network of public areas - squares, roads, paths and fountains are also included. In traditional societies, the location of the settlements is chosen based on criteria such as security, view, access to water, proximity to other settlements, etc. Many settlements in the same area compose a functional ensemble. Usually one of these is the social, commercial center of the other smaller settlements. Moreover, a number of buildings and structures are included in vernacular architecture.
mills, water mills, water-powered sawmills, etc. - samples of the technological development of their time (Giannakopoulou, 2008).

![Image of village structures](image)

**Figure 4.4: The vernacular settlement of Metsovo**  
[Source: Guide of Metsovo village]

The whole of the vernacular architecture is entirely created by the common (anonymous) workmen (craftsmen) - folk architecture. The craftsmen were organized in guilds and groups and traveled from place to place throughout Greece as well as abroad. Their origin is mainly from the most mountainous, infertile and dry parts of the country. Moreover, animals have an important role in all of this like the mules that were used to transfer the building materials.

The traditional settlements are a feature of the overall Greek area, with aesthetics of great value like urban and historical value. They are residential ensembles, composed by dwellings not too far from each other, connected with roads that often meet in a square or open area in front of churches. They were composed within historically formed conditions and were developed over time, sometimes as shelters, in order to protect the populations from conquerors or from the threat of piracy and sometimes as focal points of local agricultural, livestock or craftwork production and trade.

Vernacular architecture is constructed by the materials of the area, while the transporting material was rare and reserved for religious or administrative and rulers' buildings. Thus it has great morphological and constructive diversification, as well as similarities. The extraordinary diversity of the Greek countryside - mountain, valley or island - is responsible for the respective morphological differentiation of the architecture of each region (Epirote, Macedonian, Cycladic, etc.) (Fig. 4.4-4.6).
However, even in similar geographic locations, architecture varies locally, often dependant on environmental and social conditions (see architecture of different mountainous regions of Epirus, Macedonia and Thrace). The necessity to meet similar needs (housing, work, etc.), the use of similar construction materials, but also the craftsmen and the workers’ syntexnies that travelled around and built similar structures are the reasons for the architecture’s morphological similarities.

In the mountainous regions, the main construction materials are stone (exterior masonry, roof coating and external tiling of the floors) and wood (interior masonry, flooring, doors windows and stairs). The natural resources of each region determine the
final form, look and construction of the local architecture (e.g., in west Zagori-villages the shimmery blue-grey stone found there dominates, while in east Zagori-villages, black granite stone and wood dominate, due to the abundant forests).

It should be noted that the Greek mountainous regions have a rich tradition in architecture, although not inalterable. The reason for this is their long isolation and their slow contact with cultural progress. This contact happens faster on the plains. The fact that the mountains are inaccessible and rough helped preserve the mountain culture (Giannakopoulou, 2008).

4.2.1. Morphology

Although we focus on the Greek vernacular architecture, the concept of vernacular architecture refers to a wide geographical context that includes the united cultural area of the Balkans and Asia Minor during the period of the Ottoman domination.

Initially, the types of dwelling were simple derived from the improvised existential response of the basic needs. Gradually, from the end of the 18th century, dwellings became an element of social image and an indication of success. The official architecture of the capital is a model and is expressed through the local ruling class. The construction materials are stone, wood and mud. As far as the structure, consisted of:

- Vertical structure supporting elements (masonry) (Fig. 4.7): on the base of the building they are constructed by structure supporting stonework made of unmortared walls. In the masonry’s body there are horizontal tension members made of wooden elements which ensure the operation of the cross- masonries as a united structural element.

Figure 4.7: Vertical masonries

[Source: DUTH, 2012]
On the upper floors of the buildings the load-bearing structure is made of wooden elements (timber-frame constructions), without it being excluded from the construction of the walls in the basements, which are nettings constructed by vertical pillars, horizontal beams and diagonal elements which ensure that the construction is undistorted.

In timber-framed constructions the wooden load-bearing structure is filled with mud-bricks or other types of bricks and is either coated on both sides with nailed joints, knitted branches or reeds.

- **Horizontal structure elements:** The floors are made of wooden beams arranged in a parallel way at a distance of 40-50 cm between. Beams are based on the masonry, either directly or through a longitudinal beam which ensures the proper load distribution on the wall.

- **Roof:** is the covering of the building for the protection of its interior parts from external conditions. It consists of inclined planes to facilitate the flow of rainwater and snow removal. The load-bearing structure of the roof is constructed from wood and is made from trusses. The truss is a level netting of triangular cross section made of wooden elements. The arrangement of these elements with the correct links between them creates the support structure of the roof [22].

### 4.2.2. Functional organization and typology

The traditional dwelling is mainly on two or three floors. On the ground floor are located secondary uses areas such as store rooms and stables, while on the first floor the social and private life of the family is accommodated. Of basic structural and functional importance to all types of traditional dwelling is the “chagiati”\(^1\).

The loggia is a standard architectural element that characterizes the whole range of vernacular architecture from the humble anonymous rural architecture to mansions

\(^1\)Chagiati: Loggia. The covered balcony that was an extension of the internal spaces. In its simplest form was an elongated space at the southern part of the floor. Many times it was protruded about one meter of the wall, based on skewed wooden struts. The function of this semi-open space (loggia) was essential for the life of rural residents.
and houses. Defined as a semi open-air area extension of the interior space, it is an important space for the residence’s life.

The common housing in rural areas is as follows:

- One-storey wide front building with loggia,
- Two-storey one room building with open loggia,
- Two-storey wide front building with open or closed loggia (Fig. 4.8).

![Figure 4.8: Two-storey wide front building with open loggia](source: DUTH, 2012)

The urban residence or mansion (Fig. 2.9) has the following characteristics:

- Related to types of broader folk tradition.
- Influences by the architecture of the larger urban centers (Istanbul, Central Europe).
- Functional organization of the residence is based on a front loggia and around it are arranged all the other individual areas.
- Sometimes it has an independent decorated reception area (kalos ontas²).

² Kalos ontas: The largest and most monumental space in the building. It is a typical example of a great room with tribelon and wooden painted ceiling.
- Often the purity of geometry is lost as it has to be fitted into the properties of the plot without however having its functional structure altered.
- It has an artistic architectural design aimed to create impressions and social image [22].

Figure 4.9: Gourgiwtis Mansion in Makrinitsa village, Pelion
[Source: DUTH, 2012]

4.3 The bioclimatic design factor in the vernacular architecture

Throughout the Greek vernacular architecture, the exploitation and integration of the natural environmental elements may be noted - terrain morphology, climate, orientation, vegetation, etc - in the construction of settlements and buildings. In this way, the traditional craftsman managed to ensure comfort conditions for inhabitants in the interior of both buildings and settlements - insolation, ventilation, insulation, cooling, lighting. The use of the natural environment’s elements in the traditional design has emerged as a solution to respective needs, given the lack of technology available, while at the same time it reveals the profound knowledge of natural environmental limits and capabilities - a result of long coexistence of the local communities with nature.

The result is the creation of settlements completely integrated in their local natural environment, functionally and aesthetically complete. Even now, vernacular architecture is a valuable source of knowledge and a reference base for the modern bioclimatic building.
4.4 **Integration of the natural environment’s elements in vernacular architecture**

Man’s effort to build that will serve his needs according to the fixed and variable data of the natural environment started in prehistoric times.

The systematic observation of the seasonal changes in nature during the annual cycle, the study of their impact on living beings and the use of perennial experiential observations, led the primitive people (as well as the animal kingdom) in expanded use of possibilities offered by nature in the struggle for survival.

In general, the construction of a building is creating a system that is closely connected to the surrounding environment and is subject to a range of impacts associated with the seasonal and daily changes of the natural conditions, as well as with the various requirements of the occupants. The climate of a region can be considered to have positive and negative aspects. The aim of architecture based on environmental factors is the protection from the negative ones and the benefits from the positive, done in a way to ensure both the comfort requirements and the occupants’ safety.

Observing the various traditional dwellings around Greece, one can see that they were built according to a common wisdom compatible with the environmental conditions (climate, available materials) and social needs. Therefore, in Greece, common experience and knowledge were incorporated into the buildings with simple and perhaps not conscious ways. The traditional builders were forced – due to the luck of technological means and material abundance – to adapt the dwelling and the settlement to the climatic, topographical and general environmental conditions of their region in the best possible way. Their objective was the best possible protection against weather conditions, but also the maximization of efficiency in effort and resources. The Greek vernacular architecture had incorporated many bioclimatic design principles, which today are studied and analyzed, not to become unchanged imitative models, but to be the foundation of modern ideas and suggestions.

The traditional dwelling was a result not only of the master builder’s self-taught knowledge, but also of the craftsman and the architectural tradition that was passed on from generation to generation. First of all, there was deep experiential knowledge of the climate data, the sun’s movement and of the prevailing local conditions. The houses and interior spaces are orientated in such a way that they are cool in the summer and warm in the winter, something that we now call passive solar heating and cooling strategies.
The lighting levels were also studied. We can see in different region the systems for limiting the strong summer light.

Mainly local materials are used of low embodied energy and of high thermal mass resulting low energy requirements of the house through the year. Consequently, the search for materials in the immediate physical environment, necessary due to the a lack of means to transport them from elsewhere, helps to minimize the production costs and reduces the energy consumption (transportation of materials) and it also utterly integrates the buildings with the natural landscape.

At the same time, they are supporting a building method that does not depend on the industrial processing of raw material and the transfer from other regions and thus there is no consumption of energy resources, neither the concomitant environmental pollution. Moreover, these materials are recyclable and they are degradable by nature. (Papapetrou, 2008).

Following are the means and techniques that integrate the bioclimatic design factor with the Greek vernacular architecture, with regards to the typology of the building and its spatial structure.

4.4.1 Landscape - orientation

The starting point of the settlements’ and the dwellings’ construction during this period, is the choice of the location, with geomorphology, climate conditions and existing natural resources as general criteria, especially the site's orientation to the sun and the wind, and its proximity to water.

The layout of the buildings, roads and paths follows the natural inclination of the terrain. In this way both the buildings and layouts are smoothly integrated into the natural landscape. Also, the layout of the buildings is such that it allows unrestricted entry of air and natural light in every building. The whole settlement is built with the best possible balanced distribution in space and water sources for the best service of all the individual neighborhoods, while the public services (square, café, market, school, church, etc.) are all together either in the centre or in more than one central point of the settlement, so as to ensure access and service to all the inhabitants.

Protection from the north winds and the exploitation of the south orientation, where the sun is located in winter, the natural cool wind breezes, the ground, the high vegetation and the natural water sources, were assessed as advantages for a good
location. Thus, settlements on the mainland are developed on the southern slopes of the mountains, so that the mountainous volume behind them works as a protection against the north winds, while the openings of their houses are facing to the south.

On the islands, the choice of the location and the method of settlements’ development were aimed not only at their protection from the winds, but also from the high temperatures during the summer. The latter are, among other things, the cause for the dense and continuous construction or interrelation of the building volumes, so that while the main orientation remains to the south, during the summer the shading of one building by the other is ensured creating a microclimate of coolness.

In addition, the different constructions (semi-outdoor spaces, covered passages, etc.) are interlinked in such a way that creates individual spaces within the structure of the settlement, with comfortable microclimatic conditions for the residents (Papapetrou, 2008).

### 4.4.2 Floor plan

On the dwellings microscale the organization of the house’s floor plan had a defined role in creating a positive microclimate of comfort. The Greek traditional house is usually built facing south east in order to take advantage of the sun. So, due to the solar azimuth and altitude, during the summer it is cool and in the winter, when the sun is lower, it is heated. The layout of the individual volumes of the building is such that it creates shaded corners (protection during the summer months).

In the traditional house, winter and summer living room areas are constructed for better handling of climatic conditions. The summer rooms are usually built on the first floor and their exterior masonry is made of timber frame construction (with several variations from region to region). On this masonry are placed large openings which ensure adequate ventilation (mainly in summer). Moreover, in the north side of the building are placed areas such as kitchen, store rooms and only one room or a courtyard in which they stay during the summer period. In contrast, most daytime rooms are positioned in the south side of the building - in some regions they are positioned in the SE or SW side. Usually in rural houses, in the north side is placed the store room or the stable so that a barrier area is created to protect the residence from the cold (Kizis, 1994).
Although there are local variations concerning the shape of the floor plan, the basic philosophy of the design is distinguished in a Macedonian house. The form of the floor plan in “Π” shape creates a central cavity, “liakoto” facing directly to the south, while the roofing of the house is rectangular ensuring the required shade of “liakoto” during the summer. Often there is an area attached to the volume of the building or a corridor on a floor closed with surfaces of glass. In the winter the glazing surfaces are closed functioning as a greenhouse, while in the summer they open and the area serves as a semi-sheltered space which protects this side of the building from the sun. The heating of the house during the night is achieved by a fireplace in every room that usually is placed on the north side, so that the heat that is produced directly balances the cold that normally effects this side of the room.

In the island settlements, the floor plan is usually rectangular, while the whole shell has a cube like form - often with rounded corners, hemispheric domes and small openings. This architecture is based on the geometric principle that the smaller the total exterior surface of the building the smaller the heat gains and losses. This is, therefore, a deliberate contraction of the exterior surface of the building, which is achieved by using the curves and small surfaces that are exposed to the external environment. The curvature of the edges and angles in many cases is associated as much with the avoidance of air intended to cool, as these regions suffer from many and strong winds throughout the year, as with the shortening of the exterior shell (Papapetrou, 2008).

4.4.3 The Envelope

Masonry: The stone walls have a thickness of 0.60-0.80 m, something which ensures the insulation of the building (mild temperature changes). Nevertheless, the thermal capacity of a building should always be considered in relation to the building plan and type as well as the climatic conditions and the location. Moreover, a significant factor for the proper utilization of thermal mass is the appropriate operation of the building, since the improper operation can make thermal mass not to cool down or heat up in a sufficient way [24]. In some cases the thickness reaches 1.00m (when the height of the building is 4-5 floors or for defensive purposes).

3 Liakoto: 1. The part of the house exposed to sun and it is used as living room, 2. Terrace enclosed with glass surfaces and it is exposed to sunlight.
The stone masonry is usually dry (stones without any mortar to bind them together). However, traditional craftsmen make sure that the construction of the joints is such that the interior of the building is protected from the wind and the rain. The internal partitions of the buildings (also the exterior ones on the floor, when the ground floor is made of stone or in the entire building) are constructed with wooden slats, coated with gypsum-lime plaster (tsatmas\textsuperscript{4}). This construction ensures flexibility in the building and makes it earthquake resistant. In some cases the exterior walls are internally coated with wood, the same with the wooden floors and ceilings, whereas fabrics (Fig. 4.10) were used in cold areas contributing to the rapid heating of the interior.

Roofing: The roofing of the buildings is done either with inclined roofs (plains, mountainous and coastal regions) or with level rooftops (coastal and island regions). The slopes of the roofs are mild while around the perimeter of the building end in a cornice (with significant width of 0.70-1.40 m), which protects from the rain and the sun. Thus, the windows are shaded with the shutters open so that light enters the room, while they can stay open to ventilate the interior of the building. Moreover, the cornice

\textsuperscript{4} It is a type of wall in the traditional architecture whose surface was made of slats or woven reeds that were filled with mud or brick and it was covered with plaster.
protects the building from the rain (avoidance of humidity), especially in the interface areas of different materials (wall-roof) which are usually more vulnerable than continuous surfaces of the same material. Also, when opposite cornices are very close, they protect the road as well from the rain and from the strong sunlight in the summer. Furthermore, the inclined roof ensures the removal of water (rain-snow) from the residence’s area, whereas the air between the roof and the ceiling of the house serves as an excellent insulation as much for the hot as for the colder days of the year.

When the roofing is flat (islands) it is thermally insulated by dense layers of dried seaweed, straw or bulrush, creating a complex of light material and micro spaces of air that eliminates with a natural and effective way the overheating of the residence. It is worth mentioning that the flat rooftops are used to collect the rain water (from the roof the water is led to the gutters and from there to the cisterns, where it is stored).

*Colour:* The colour’s attribute to absorb or reflect, depending on its intensity and its saturation seems to be an old knowledge, which was used very early on the buildings. A typical example is the white colour used in the island settlements. The high degree of reflectance contributes to the reflection of a significant part of solar radiation and reduces as a consequence the overheating of the building’s shell. In the northern parts of mainland Greece one can find warmer, thermal absorbing colors on the facades of the buildings, such as ochre and terracotta (Kalogirou, 2009).

### 4.4.4 Building materials
The building materials in a traditional Greek house are those that already exist in its natural surroundings. Their process is simple and done using natural means. Stone and wood are the basic construction materials that vary in type and method of use, depending on each region’s conditions. In mountainous regions stone is the main material, as much for the exterior masonry as for the covering of the roof (slates). Wood is used in regions where it can be found in abundance (mountains and forests) and it is used for the interior walls, the base of the roof (Fig. 4.11), the architectural projections, the floors, the doors and windows, the stairs etc.

Stone with thickness, which can be up to 80 cm, acts like a natural skin for the building that protects the interior areas temperature-wise contributing at the same time to the indoor air quality.
Soil, mixed with water and straw, and sun dried, gives bricks which also have high insulating power. Soil is also used as basic material for making plaster as lime is often hard to find and expensive.

Wood, which is mainly used for the manufacturing of the doors and windows, has also three times higher insulating value in comparison to modern insulating frames (PVC) [6]. These are natural materials, do not contain any toxic / cancerous pollutants, and they do not attract such pollutants from the time that they are fitted until their destruction, they have a low maintenance cost and they have a long lasting durability. Thus they can be considered man and environment friendly.

Besides the aforementioned materials, lime, tuff, bricks, iron in small quantities (mainly protective bars for the windows), gypsum, glass (openings), sand, reeds, sea weeds (insulating material), clay (island settlements) are used. In certain regions of volcanic terrain (e.g., Santorini) they used volcanic stones (Kalogirou, 2009).

**4.4.5 Ventilation – Insolation**

The ventilation of the dwelling area, is important as much from a health point of view – cleaning of the atmosphere, as for reasons of temperature and it is ensured in a traditional house in numerous ways. Dormer windows basically undertake this role. They are smaller openings on higher levels that facilitate the removal of the worm air that concentrates at ceiling level. The north side has either very small openings or none at all – minimizing thermal losses – which open for cooling and ventilation during the summer months. The cross ventilation that are created when the open dormer windows ensure ventilation and cooling of the interior spaces.
Window technology is remarkable. In mainland Greece windows are made of wood with glass panes divided into two parts that have the ability to slide vertically creating in this manner ventilation and cooling slots when this is necessary. Additionally, the shutters are made of solid wood that can be opened as a canopy for shade above the window, alternatively when they are closed they can function as insulation reducing the thermal loss from the glass. Grills offer desirable shade by filtering the sunlight. On the south side the openings are larger making the rooms act as large sun parlors for the storage of solar radiation. On the islands the openings are generally small to the glare from the excessive sunlight and also to aid in controlling the variations of temperature. The screens are of similar construction as those used in mainland Greece. The balconies, contrary to those in the houses of mountainous regions are projected – when they exist – from the building's body and thus are more exposed to the sea breeze.

The chimneys, as roof openings create vertical drafts that also contribute to the overall cooling of the dwelling. Those houses that are dug into or semi dug into the ground have small openings in their façade limiting the amount of heat able to enter during the summer and the amount able to exit during the winter, but also they have a very poor ventilation potential. The arched roof (dome, vault) provides a high interior height that allows the circular movement of the air (Papapetrou, 2008).

4.4.6. Constructing Elements
On the front of the building are placed independent, external auxiliary structures in such a way as to stop the overheating of the walls. Often, a projection is used in the construction of buildings. It’s role, among other things, is to achieve the optimal insolation of the dwelling. The loggia is another common element and is a cool and extremely pleasant place to rest during the summer months.

Another element of the architectural tradition of the whole Mediterranean region are the ‘transition living areas’. They are arcades – supported by the columns that are around the building – covered walkways between the buildings – and also the semi-open spaces, open covered areas integrated in the building. The shade that they offer works as sun protection but also as a means of cooling the air provided that they create natural air flow channels [3,25].
4.4.7. Vegetation

Vegetation in the traditional house is a significant component and holds a regulatory role concerning shading - sun protection as well as insulation – and cooling. It is true that foliage does not overheat – contrary to most shading surfaces – (Fig. 4.12). It prevents the radiation reaching the wall, absorbing much of it for photosynthesis and it does not trap the air, which as it passes it cools through evaporation.

The deciduous trees in the south side of the house provide shade during the summer, whilst not preventing the entry of solar radiation during the winter. The climbing plants usually growing horizontally on a pergola, such as vine, create the desirable shading in the open areas of the house. Also in vertical growth in the west and east walls they help with insulation. On the north side of the dwelling or in the direction of the main winds, the evergreen trees – cypress, coniferous trees - planted densely create a natural windbreak (Kalogirou, 2009).

Figure 4.12: Vegetation at a vernacular building of Mount Pelion

[Photo: M.Brenta]
Chapter 5. Case study: Mount Pelion, Zagora

Mount Pelion is selected as our research field due to the fact that it is an area rich in remarkable examples of traditional architecture and preserved villages, as well as due to the intense modern building activity mainly because of tourism.

5.1 Mount Pelion

Mount Pelion is one of the most significant and popular traditional settlements of Greece. It is located near Volos and consists of twenty four villages that were developed during the Ottoman period. Its fame is mainly due to the natural beauty, its traditional character, its heritage and because of the large number of national benefactors who lived in the villages of Pelion.

The area of Mount Pelion can be divided into three categories:

- North Pelion
- Central Pelion
- South Pelion

North Pelion is less populated but is covered by dense vegetation, whereas South Pelion is characterized by less water and less vegetation. On the other hand, in the Central Pelion that can be divided into East and West, the signs of culture and tradition growth are evident. Zagora where the on-site investigation took place during this thesis, is located in the East Pelion (Environmental Educational Center of Makrinitsa, 2012).

The conditions that contributed to the Mount Pelion villages’ growth in the 18th and 19th century were mainly the fertile land with the clean, running water, the possibility of easy shipping and the creation of major manufacturing facilities by expatriates who lived in Egypt.

But, at the end of 19th century when the liberation of Thessaly and the development of large urban centers took place, the villages of Pelion started declining. Today, what remain of this great economic development are the vernacular buildings of Pelion and the big mansions (Paliouras, 2008).
5.1.1 Location and Landscape of Pelion

Mount Pelion (39.44N 23.04E), with a maximum altitude of 1,624m, belongs to the Eastern Region of Thessaly in Greece and it surrounds the city of Volos creating in this way the peninsula of Magnesia. Pelion extends from NW to SE between the Aegean Sea and the Pagasitikos Gulf (Fig. 5.3), approximately 44km long, 10-25km wide in South and North respectively.

The whole mountain is covered by forests of tall beeches and sycamore, whereas olive trees cover a large area of the coastal zone of the Eastern side of Pelion. Moreover, it is an interesting area characterized by rich biodiversity (both flora and fauna) and is supported by the temperate Mediterranean climate.
The environmental quality and the ecological importance of the area of Pelion are determined by significant ecological, economic, historical and aesthetic qualities. The ecological value lies in the variety of habitats that are characterized by excellent structure and conservation status.

The human presence is evident throughout the area of Pelion, apart from the central mountains located at high altitudes and the steep shores of the Aegean, while it is more intense in the southern part that is easily accessible. Although all villages are connected with each other, as well as with the city of Volos with a good road network, it is a fact that the roads are rudimentary in many parts (EECM, 2012).

5.1.2 Zagora Village

The mountain village of Zagora is situated at an altitude of 220 meters and is 47km from the city of Volos (Fig. 5.4). The village consists of four large neighborhoods. It is one of the most famous villages of Pelion for its natural beauty, the tradition and the arts and literature during the Ottoman period. Noteworthy is the “Zagorian ships” that transport the products of the region from Chorefto that is 7km far from Zagora and is said to be the old center of trade to the European ports. The village flourished during the Middle Ages and in more recent times. It was an important center of trade and crafts as well as the cultural center of Pelion during the 17th and 18th century.

The houses are built according to the traditional style and maintain the Pelion vernacular principles. The protection of the traditional character of Zagora is imposed by law according to the Ordinance Gazette 374 D’-04/07/1980 that characterize the Pelion villages as “traditional settlements requiring absolute protection” (Leonidopoulou-Stilianou, 1992).

According to Kizis (1994), the physical conditions of the local mountain environment impose particular restrictions in both the establishment of the urban planning of Zagora and the buildings’ location.

In general, the specific location of the settlement ensures the following:

- Protection from North winds
- Sun exposure for lighting and heating reasons
- Access to spring water in order to cover the needs of the village
- Access to natural and agricultural areas
- Panoramic view of the surrounding area
- Protection from the enemy under the Ottoman Empire
- Surveillance of all the area.

Figure 5.4: Zagora village  
[Source: Guide of Volos Municipality]

5.1.3 Climate
The climate can be characterized as moderate during the summer period and cold during the winter. The winter months are cold and humid while the summer months are characterized as warm and humid. Also, during the winter period, snowfalls are observed that last until early spring, as well as high precipitation values during the winter and spring period.

The cold prevailing winds in winter and spring come from the west, whereas in summer, the hot prevailing winds come mainly from the east.

In the Eastern side where Zagora is located, there are calm streams and rich vegetation which affect the local microclimate. During the winter the average temperature is 3.7°C and can be lower than -3.0°C.

On the other hand, the mean maximum temperature in June reaches 26.6°C, while the mean minimum temperature is 20.1°C. In July, the hottest month of the year, the mean maximum temperature reaches 29.5°C, whereas the mean minimum is about 22.9°C. In August the mean temperature is about 25.4°C.

Table 5.1 shows the annual climatological summary of Zagora for 2012. All the data are taken by the meteorological station located at an elevation of 505m. The station
Table 5.1: Temperature, precipitation and wind speed of the year 2012 at Zagora

[Source: Meteorological station of Zagora by National Observatory of Athens]
5.2 Pelion architecture
The vernacular architecture of Mount Pelion evolved during the 18\textsuperscript{th} and 19\textsuperscript{th} centuries that can be characterized as the period of acme under the late rule of the Ottoman Empire. Due to the Turkish arrival, the population in Pelion villages started expanding rapidly, as Greek residents immigrated to the Mount Pelion in order to protect themselves from piracy and conflicts. This fact led to the creation of a network of shepherding, farming and family-based economic units, while later the twenty-four villages of Mount Pelion were converted into important economic centers by the wealthy newcomers [30].

5.3 The Mount Pelion houses
The vernacular houses were constructed, over time, in order to meet the occupants’ basic living needs. Therefore, the main concerns about the buildings were functionality, safety, ease of production and low cost. If these needs could be covered, then new elements were involved into the planning and the organization of the houses as means of social status. These included the residences’ size, the floor plans that became bigger and more complex, as well as the improvements of the construction quality and indoor decoration.

The houses followed the economic development and the social changes. The builders and the craftsmen coming from the mainland, brought several characteristics of the Northern Greek architecture that were adopted by the Pelion houses. This expertise was influenced by the local natural environment that played a significant role for the Pelion architecture that respects its landscape [31].

5.3.1 Pelion houses during the period 1700-1750
The older buildings that have been preserved in Pelion are houses like towers with strong fortress character. These buildings were built in the early of 18\textsuperscript{th} century and perhaps many of them were built earlier. Although they are structures whose main concerns were security, defense and protection of the occupants, they managed to operate simultaneously as houses and places suitable for crafts due to the large projections of the closed balconies on the top floor (Fig. 5.5,5.6).

The houses of this period were built by stone and are characterized by the numerous, narrow openings and the battlements. Their plan was rectangular or square, whereas the entrance door was always constructed about 3 meters above the ground.
Occupants could have access by wooden stairs or a small movable bridge. At the top of the whole construction, there were indentations which emphasized the fortress character of the house. Internally, the last two floors were used for the multi-family needs, whereas the courtyards were used only in periods of peace (Kizis, 1994).

Figure 5.5: Kokoslis Tower in Makrinitsa, Pelion

[Source: Kizis, 1994]

Figure 5.6: Skotiniotis tower, in Makrinitsa

[Source: Kizis, 1994]
5.3.2 Pelion houses after the year of 1750

During this season, houses showed the economic and cultural growth of Pelion, which was based on the export of raw materials and local goods to Europe. The conception of the houses reflected the social-cultural forces of the period including the religious ideals, the family structure and their social class and it was formed by the climate, the available materials and the building technology. These houses known as mansions of Pelion were two and three storey houses that follow the northern style, with internal decoration, painted ceilings and colorful skylights (Fig. 5.7-5.11). Nevertheless, the feeling of insecurity that characterized the years of Ottoman rule imposed the conservation of castellated residences (Kizis, 1994).

Figure 5.7: Vatsareas Mansion in Makrinitza, Pelion

[Source: Kizis, 1994]

Figure 5.8: Vatsareas Mansion in Makrinitza, Pelion

[Photo: M. Brenta]
The urban fabric is composed of paths along the altitudinal curves with an East-West orientation, whereas homes are placed parallel to the south. The entrance was always located on the ground floor that was used as storage and a covered transitional space with a steep staircase leading to the first floor. On the first floor, the staircase leads to an open plan room with stone walls, small windows and in many cases, fire-
places that were used by the occupants during the winter period, while behind this space, there were the bedrooms and the kitchen (Fig. 5.12, 5.13).

Figure 5.12: The first floor of Evilion Mansion, used today as guesthouse

[Photo: M.Brenta]

Figure 5.13: The staircase of the Evilion Mansion

[Photo: M.Brenta]
The upper storey is characterized by a wooden frame that projects from the stone base where the open plan hall is used as living room. This is called “summer” accommodation and consists of successive openings and skylights resulting in a pleasant microenvironment (Fig. 5.14). Apart from its seasonal use, this storey is the main area in the house that is used for crafts.

Figure 5.14: The summer accommodation of Evilion Mansion

[Photo: M.Brenta]

Figure 5.15: The bedroom of Evilion Mansion

[Photo: M.Brenta]
Most of the times, all the floors have the same layout, whereas each storey is separated into two zones: the public and the private. The first one consists of the living rooms, the sitting rooms and the kitchen. The private zone contains only bedrooms and bathrooms (Fig. 5.15). The building envelope is exposed to the external environment, while one façade is often shielded by the steep mountain slope [30].

Regarding the envelope elements, the ground and the first floor consist of external walls of about 0.6-1.0m and thinner internal walls (0.3m-0.7m), that play a self-supporting role with a small number of openings. The first floor is called “winter accommodation” and is a heavyweight construction, while the second floor (summer accommodation) is a combination of heavyweight and lightweight construction. The whole building is covered by a slate pitched roof that projects about 0.70m from the external walls in order to protect the vulnerable envelope from rainfalls, snowfalls and overheating during the hot periods (Fig. 5.16).

![Figure 5.16: Naoumidis Mansion, Mount Pelion, Makrinitsa](photo.png)

In the same period, apart from the Pelion mansion, homesteads appeared (Fig. 5.17). They consist of two stories. On the ground floor, there was the required number of bedrooms and the rest of the story was used as storage. The upper floor was characterized as the winter accommodation and contained the bedrooms and the living room with the fireplaces. Moreover, in this type of houses, occupants used an outdoor courtyard where there was a small space used as kitchen, while materials and construction method followed the models of mansions described above (Kizis, 1994).
5.3.3 Pelion houses in the middle of 19th century

In the middle of the 19th century, a new type of houses that rise from the combination of neoclassical and traditional architecture appears and it lasts until the liberation of Thessaly from the Turks, in 1881. These houses belong to rich Greeks who returned from Egypt and settled down on Mount Pelion.

The “Egyptians” as they were called by the local people, combine the local traditional elements like masonry and few windows on the lower floors, and several windows with neoclassical elements on the top floor such as arched windows, painted meanders, entrance with columns and arches and double exterior staircase (Fig. 5.18-5.19).

Figure 5.17: Homestead in Zagora, Mount Pelion
[Photo: M.Brenta]

Figure 5.18: Houses of the 19th century in Zagora
[Photo: M.Brenta]

Figure 5.19: Houses of the 19th century in Zagora
[Photo: M.Brenta]
The most basic and essential feature in the internal organization is the change of the position and the shape of the front hall. It becomes airy and it is placed perpendicular to the house façade, dividing it into two symmetrical rooms, whereas the staircase is placed opposite the entrance door. The auxiliary rooms have their own private entrance from the basement (Paliouras, 2010).

5.4 The bioclimatic elements of the Pelion vernacular architecture

The vernacular settlement of Pelion has been built according to the basic principles of the bioclimatic architecture that characterize many of the Mediterranean settlements, where the climate, the similar habits and the use of local materials lead to common solutions covering a large part of the heating and cooling needs of the occupants by the appropriate design, the right building construction and site choice [31].

Regarding the buildings’ architecture, the bulk of the house is south or south-east oriented since the need for thermal and visual comfort had increased. More specifically, in the type of Pelion mansions the most interesting phenomenon is the occupants’ intramural migration in response to the climatic conditions (Fig. 5.20). The occupants’ migration could happen either horizontally or vertically depending on their activities, the season and the time of the day.

As for the horizontal migration and the different function of the spaces (bedrooms or living room), natural light is required in different quantities and qualities. The rooms that are used for resting and sleep should be characterized by higher thermal protection and relatively low light level and therefore, the external walls of the bedrooms have only one window. On the other side, the living room where occupants spend most of their time, require lower thermal protection and are better illuminated by daylight.

In the past, occupants used to move from one floor to another (vertical intramural migration) depending on the season. They used the “summer accommodation” in summer and the “winter accommodation” during the winter period. This living pattern that responded to the families’ comfort needs enabled them to live without the need for heating and cooling systems.

On the one hand, in the winter accommodation (Fig. 5.21), builders and occupants in the past managed to strike the right balance between the reduction of heat
losses and the maximization of the solar gains providing at the same time a well day-lit environment. During the winter periods, occupants used the ground and the first floor for their activities, while they did not use the second floor with the lightweight construction except for the silk production. The heavyweight construction of the ground and first floor – masonry walls - stabilize the internal temperature leading to high thermal performance. Their façade treatment with less openings and their internal layout show the occupants’ need for protection against the low temperatures, the snowfalls and the prevailing winds. Also, the external stonewalls result in a high thermal performance stabilizing the internal temperature. Moreover, in the past, occupants used fireplaces or cordwood stove in order to reduce their heating needs, while their clothes were thick and woolen having high insulation values.

The summer accommodation not only has to reduce overheating and solar gains, but also should provide an airy indoor environment. For these purposes, during the summer period all the activities were concentrated on the second and ground floor. The summer accommodation is characterized by a lightweight construction with large windows area and an open plan living room. The windows with the wooden shutters are able to protect the public zone by overheating and glare, whereas they offer to the family a surrounding view connecting them with the external environment. Apart from the windows, in the most cases of mansion there are fixed multi-color clerestories that improve the luminous environment. Additionally, the projections of the roof act as overhangs which protect the second floor from the summer sun.

Figure 5.20: Internal migratory living pattern: vertical migration by season (winter-summer) and horizontal migration by activity (communal-resting), [30]
Although the second floor is surrounded by a construction that is inexpensive and user-friendly due to the fact that it is based on local natural materials like clay-rich mud, soil, thin fiber and sheep wool, this structure does not have high thermal the ability to reduce the temperature fluctuations leading to occasional overheating. In order to decrease this risk, occupants used to leave the windows fully open and the shutters half open to achieve cross ventilation and solar control.

Last but not least, the roofs are extremely vulnerable and they have to be protected in order to prevent the building from overheating. Their small inclination of about 30° has as main purpose the protection of the building from the heavy snow loads. The roof construction is covered by traditional Pelion slates that operate like insulation. The drawback of the Pelion slates is the fact that they have a low albedo so they absorb a lot of solar radiation. If there is hot air that enters the building through the roof affecting mostly the upper storey, lightweight ceilings are constructed in the summer accommodation, while a horizontal trapdoor is used to prevent the hot air from the ground and first floor to move into the second floor leading to its overheating [30].

Regarding the spatial and urban planning of the settlement, it is worth noting the following:

- Most of the buildings have rectangular shape, while their long axis is orientated east-west so that the long façades face south and north, in order to increase the di-
rect solar gains and to achieve the insolation of the outdoor spaces. At the same time, the vernacular houses exploit the slope of the mountain to protect their north facades.

- The building layout is not dense so that there are open outdoor spaces between the houses, whereas the vegetation is used to ensuring comfort conditions during the summer period providing shading.
- The topography, the ground morphology and the planting are used in order to protect the buildings from the prevailing winds during the winter period.
- Water running freely in the neighborhoods contributes to the evaporative cooling.
- The roofs’ projections in the narrow roads offer shading in the summer and rain protection during the winter period.
- The roads are narrow and in conjunction with the high garden walls or the building mass are able to provide wind protection (Kalogirou, 2009).

The design principles that are adopted in the vernacular architecture and their bioclimatic elements are presented in the following Table 5.2:

Table 5.2: Bioclimatic function of the vernacular elements

<table>
<thead>
<tr>
<th>Vernacular Architectural Element</th>
<th>Bioclimatic Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>External stonewalls (thickness: 0.5m-0.7m)</td>
<td>Thermal mass</td>
</tr>
<tr>
<td>Internal walls, wooden floors and ceilings</td>
<td>Rapid heating of indoor spaces, reduction of vapor condenses</td>
</tr>
<tr>
<td>South-oriented spaces with large glazing areas</td>
<td>Solar gains</td>
</tr>
<tr>
<td></td>
<td>Natural lighting</td>
</tr>
<tr>
<td></td>
<td>Indirect lighting when the shutters are closed</td>
</tr>
<tr>
<td>Auxiliary underground spaces exploiting the mountain slope</td>
<td>Appropriate conditions for food preservation</td>
</tr>
<tr>
<td>Windows location</td>
<td>Cross ventilation</td>
</tr>
<tr>
<td>Feature</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Windows orientation</td>
<td>Small and few windows on north or in winter rooms, more windows on south or in summer spaces</td>
</tr>
<tr>
<td>Shutters</td>
<td>Movable insulation or/and shading system: Reduction of thermal losses in winter, Reduction of thermal gains in summer</td>
</tr>
<tr>
<td>Roof with high inclination</td>
<td>Reduction of thermal losses</td>
</tr>
<tr>
<td>Pelion plates on the roof</td>
<td>Protection against extreme weather conditions</td>
</tr>
<tr>
<td>Roof projections</td>
<td>Protection of the walls and the windows against rain in winter and sun in summer</td>
</tr>
<tr>
<td>Fireplace</td>
<td>Auxiliary heating system</td>
</tr>
<tr>
<td>Use of local natural material</td>
<td>Inexpensive, user-friendly materials, durability, easy maintenance and replacement</td>
</tr>
<tr>
<td>Vegetation (Fig. 5.22,5.23)</td>
<td>Solar protection, contributes to house cooling</td>
</tr>
</tbody>
</table>

Figure 5.22: Use of vegetation at building façade of a vernacular house at Zagora, Pelion

[Photo: M.Brenta]

Figure 5.23: Use of vegetation at mansion courtyard at Zagora, Pelion

[Photo: M.Brenta]
5.5 **Contemporary architecture of Zagora village**

In regards to the ‘traditional’, recently built houses in Zagora, the current situation can be characterized by the following:

- The board of urban protection aims at visual similarity.
- The new buildings are constructed with armed concrete, the walls are insulated with stone and the thermal insulation is not scrupulous and results in heat loss.
- The new constructions often have wide openings and disregard the natural orientation of the house, as well as the low temperatures during the winter. Therefore, they do not fulfill the heat insulation requirements.
- Often, the wooden windows that are imposed by the legislature are being replaced by aluminum frames, in order to become more effective.
- More and more roofs are covered with tiles and not slates.
- The building grounds are being abused to an end. As a result, the buildings are now higher and, at the same time, cover the entire building ground. Therefore, all open air spaces are being decreased, the settlement gets thicker, the microclimatic conditions are degraded and the sun does not reach the ground.

In a nutshell, Zagora has been declared a preserved settlement and all new structures should follow specific rules, especially concerning the shape of the buildings (maximum height), the construction materials (stone facades), the size and the shape of all openings, the shape of the roof etc. despite the fact that the legislation aimed at the preservation of the traditional character of the settlement, a new identity has been created. This is mainly because of the following reasons:

- Costs and difficulty of construction (i.e. the slate is more costly than the tiles and its transport is demanding).
- Use of contemporary materials and exploitation of technical systems, in order to insure thermal comfort.
- Exploitation of the land
- New needs and new functional, social and financial conditions (the interior design of the buildings has drastically changed; Zagora is now a tourist attraction).
Chapter 6. On-site survey and analysis of Kapourniwtis’ vernacular building at Zagora

This chapter focuses on a well-preserved vernacular house in the village of Zagora at Mount Pelion dated at the late 18th century which is characterized by the typical architectural elements of several houses after 1750.

Kapourniwti’s house is occupied by a family consisted of 4 members. It can be characterized as weekend house in the mountain with occasional operation and with the same constant requirements. Also, it is worth being noted that the building was renovated during the year of 1984 and the new elements concerned about the internal organization of rooms and the building materials used.

Regarding the architectural point of view, the building has an Eastern orientation that is strongly related to the road and the views (it exposes the largest side with the main residence quarters to the road and to the views). The house was built not only to provide protection from the bad weather conditions of the mountainous regions but also from raids and robberies. Because of the incline of the ground, it is a two-storey building integrated in the surrounding landscape. Its shape is simple, normal angle, without any decoration on the outer surfaces and openings. The main factors are the building materials, the natural environment, the social character and the tradition of Mount Pelion.

Like the most vernacular houses in this area, the house has several openings oriented towards the sea in order to receive the sea breeze inside the home. As a natural process, during the night hours the wind moves from the land towards the sea entering the house through the doors and the windows and keeping it well ventilated.

As far as the external walls (before the renovation of the first floor), they had thickness of about 40cm losing the heat through transferring and radiation during the night hours. Due to this fact, their temperature remained low during the day providing comfort for the occupants at hot periods.

6.1 Building elements and materials before renovation
Kapourniwti’s house is a heavy construction while the masses are clean and rigid with only a few projections. Before the house renovation that took place in 1984, the stone masonry walls in both floors had a thickness of 40cm and they were separated by
horizontal timbering- timber-framed. Moreover, all supporting walls were made of stone while the interior partitions were made of wooden frame and then plastered. The use of wood was generally extended: ceilings, floors, doors and windows, interior decoration, timbering. The roof angle was about 30-40%, made with simple wooden trusses and the covering was done with Pelion slates.

The floor plan of the houses had a rectangular shape, while the raised ground floor consisted only of one rectangular space that was used as storage for the food preservation. The staircase was external and led to the first floor that was used as the main building containing the bedrooms and a living room with the fireplace. Additionally a projection was added to the first floor (sachnisi). The kitchen was a very simple construction and it was placed out of the main building, at the courtyard that is covered until today by trees for shading reasons. The courtyard was surrounded by a tall stone wall, it was paved and it had small stone benches due to the inclination of the mountain (Fig. 6.1-6.3).

Figure 6.1: Eastern façade of house
Figure 6.2: Southern façade of house
Figure 6.3: Section of the house
6.2 Building elements and materials after renovation

Today after the renovation, the space buried in the ground is exploited and a kitchen, a bedroom and a bathroom are added to the ground floor that is occupied by a person. The exterior stone walls and the openings of the ground floor remain the same, while the wooden floors are replaced by white tiles.

Moreover, the research recorded all the modern changes and interventions to the original building envelope concerning mainly the first floor. The old wooden windows are replaced with new wooden frame with double-glazing and the stone masonry is replaced with brick walls. Moreover, in the first floor the wooden floors are reserved only in the bedrooms and the living room, while tiles are used for the other internal spaces. Both of the floors are used as main house offering desirable stable conditions (Fig. 6.4, 6.5).

The plans of the house after renovation are presented below in Figures 6.6. and 6.7.

Figure 6.4: Kapourniwtis house at Zagora village, Mount Pelion [Photo: M.Brenta]

Figure 6.5: Kapourniwtis house at Zagora village, Mount Pelion [Photo: M.Brenta]
Figure 6.6: Plan of the ground floor and the surrounded environment

Figure 6.7: Plan of the first floor
6.3 **On-site investigation and analysis of the results**

The investigation of the internal conditions and the access of their influence in the thermal comfort of users carried out by in situ investigation with measurements of temperature and relative humidity, while questionnaires were given to the occupants in order to evaluate the users’ satisfaction.

- **Temperature and Relative Humidity measurements**

The measurements were conducted by the HOBO data loggers (Fig. 6.8) that measure the temperature and the relative humidity every quarter of time, during the period from 12\textsuperscript{th} August, 2012 at 21.00 p.m. until the midnight of 17\textsuperscript{th} August, 2012.

The three loggers used were located in the following way:

- The first data logger was located on the ground floor. A table in the living room was chosen to locate the thermometer far from openings that could create several temperature fluctuations during the day.
- The second data logger was put in the living room of the first floor.
- The third data logger was located outside at the courtyard protected by the weather conditions in order to record the outdoor temperature fluctuations and the relative humidity.

The results are extensively presented below.

![Figure 6.8: HOBO data logger](Photo: M.Brenta)
From the measurements, it was found that the outdoor ambient air temperature has a diurnal variation from 23°C to 33°C, while the relative humidity varies from 30% to 70%, as it is showed at the below charts. Also, it is showed that the outdoor relative humidity is fluctuating more during the day when it is increasing rapidly and it reaches about 60% (close to maximum) when the temperature is minimum about 23°C (Fig. 6.9,6.10).

Figure 6.9: Ambient Air Temperature vs. date and time during 12/07-17/07

Figure 6.10: Relative Humidity vs. date and time during 12/07-17/07
From the observation it was found that the temperature fluctuations in the ground floor ranges from 26,50 °C to 28,50 °C, while the relative humidity starts from a percentage about 36,6% and reaches at 74,4% (Fig. 6.11,6.12).

![Figure 6.11: Temperature vs. date and time at ground floor during 12/07-17/07](image1)

Here, we should remind that the only shading systems that are used for the ground floor are the curtains and the vegetation at the courtyard. Therefore and due to the eastern orientation of the house and courtyard, during the mornings the openings of the ground floor are shaded, while the occupant uses to open the windows early in the morning (06.00-09.00). Windows and curtains are closed at noon and are open again early in the evening (19.00-21.00) for natural ventilation due to the fact that they cannot remain open at night because of the lack of shutters that lead to lack of protection.

![Figure 6.12: Relative Humidity vs. date and time at ground floor during 12/07-17/07](image2)
On the other hand, in the upper storey the temperature swings varies from 25°C to 35°C, while relative humidity starts from 23% and reaches at 50% presenting continuous fluctuations during the whole day (Fig. 6.13,6.14).

Figure 6.13: Temperature vs. date and time at first floor during 12/07-17/07

Figure 6.14: Relative Humidity vs. date and time at first floor during 12/07-17/07
Figure 6.15: Openings of the ground floor
[Photo: M.Brenta]

Figure 6.16: Openings of the ground floor
[Photo: M.Brenta]

Figure 6.17: Living pattern in the first floor
[Photo: M.Brenta]

Figure 6.18: Living pattern in the first floor
[Photo: M.Brenta]

Figure 6.19: Living pattern in the first floor
[Photo: M.Brenta]
In the first floor that is occupied by a four-member family, the living pattern is more complicated during a whole day (Fig. 6.15-6.19). The on-site investigation recorded that the eastern windows are the most times of the day open or semi-open, while the shutters are closed or semi-closed (mainly in the mornings). On the other hand, southern windows and shutters are open during the day and are closed at the night time. Also, the window from the western bedroom is open in the morning until noon, while then become semi-open with closed windows. The answers of the occupants to the questionnaires showed that they prefer ventilation early in the morning and in the night when it can remove heated air from inside. On the contrary, the ventilation during the afternoon has not a positive contribution to the indoor temperature, as the ambient air is hotter than the indoor.

The diagrams that are arisen by concentrating the above temperatures and relative humidity diagrams are presented below in Figures 6.20 and 6.21.

Figure 6.20: Cumulative diagram of Temperature vs. Date and time
The first conclusion that can arise is the fact that the diurnal variation of indoor air temperature in the ground and first floor is less compared to outdoor air temperature. Comparing the temperatures of both floors, we can see that the ground floor has no huge temperature fluctuations during the investigation period, while on the other hand the first floor presents extended temperature swings even in the duration of a day.

A characteristic example can be drawn from the hottest day of the on-site investigation period, when the exterior temperature reaches at 33.0°C at 09.00 in the morning. That moment, the temperature in the first floor was 30.29°C, while in the ground floor the temperature at that time reaches at 27.83°C creating a more pleasant indoor environment.

On the other hand, the lowest temperature was about 24.27°C at 11.00 in the morning, when the indoor temperature of first floor reached at 29.46°C, while in the ground floor was about 27.21°C.

Moreover, from the state points of living pattern, it can be seen that natural ventilation lowers the absolute maximum and minimum indoor temperatures up to 2% degrees C. Also, it is observed that the night-time temperatures of first floor are always higher than those of the ground floor.
Regarding the percentages of Relative Humidity, as it is shown by the above diagram, first floor presents the lowest amounts of RH. This may be due to better ventilation patterns followed during the daytime. On the other hand, ground floor, in the biggest part of the investigation period, follows the RH swings of the outdoor environment with small deviations about 5-10%.

- Surfaces’ Temperature measurements

Apart from temperature and relative humidity measurements, the in situ investigation recorded also the surface temperatures of different building elements (walls, roof, tiles etc.). The measurements were held with Non-Contact Infrared Thermometer, 8818H/8819H/8828H Series IR Thermometer by PCE Group (Fig. 6.22). This device can be used to measure the temperatures of objects’ surface that is improper to be measured by traditional, contact thermometers.

![Figure 6.22: Non-Contact Infrared Thermometers](Photo: M.Brenta)

The measurements took place in the two-storey, Kapourniwtis house at 14th of July, in different periods during the day. The results are presented in the following Table 3. As it can be observed from the Table 6.1, the surfaces’ temperatures between ground and first floor have significant differences. The building element that presents the biggest difference in temperature is the internal wall. It is based on the fact that the specific wall for the lower floor is built in the ground leading the temperature at lower levels. Moreover, wooden floors are shown to have higher temperatures than the used tiles,
while the tiles of ground floor have during the day lower temperature than tiles of first floor due to the fact that they are adjacent to the ground.

Moreover, another significant element is the difference between the temperatures of the two sides of the southern external wall. Observing the given numbers for ground floor, we can see that stonewalls with thickness 40cm operate as good insulators. During the daytime, they store heat and radiate it into the room at night when the outdoor temperature is not in the comfort range.

Table 6.1: Results of surfaces’ temperature measurements

<table>
<thead>
<tr>
<th>Building Element</th>
<th>°C</th>
<th>°C</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14/07/2012_11.00a.m.</td>
<td>14/07/2012_16.00p.m.</td>
<td>14/07/2012_21.00p.m.</td>
</tr>
<tr>
<td>Ground Floor</td>
<td>27.4°C RH:54%</td>
<td>29.4°C RH:60%</td>
<td>27.5°C RH:50%</td>
</tr>
<tr>
<td>First Floor</td>
<td>28.9°C RH:50%</td>
<td>30.1°C RH:54%</td>
<td>29.4°C RH:43%</td>
</tr>
<tr>
<td>Southern External wall (side adjacent to external air)</td>
<td>29.1</td>
<td>29.2</td>
<td>39.2</td>
</tr>
<tr>
<td>Southern External wall (side adjacent to internal air)</td>
<td>29.7</td>
<td>28.7</td>
<td>28.5</td>
</tr>
<tr>
<td>Internal wall</td>
<td>29.6</td>
<td>26.0</td>
<td>26.6</td>
</tr>
<tr>
<td>Wooden Floor</td>
<td>-</td>
<td>28.6</td>
<td>-</td>
</tr>
<tr>
<td>Tiles</td>
<td>24.6</td>
<td>27.5</td>
<td>28.8</td>
</tr>
<tr>
<td>Ceilings</td>
<td>27.8</td>
<td>29.6</td>
<td>30.0</td>
</tr>
<tr>
<td>Internal Column</td>
<td>25.7</td>
<td>29.1</td>
<td>26.2</td>
</tr>
<tr>
<td>Internal Beam</td>
<td>26.0</td>
<td>30.2</td>
<td>25.6</td>
</tr>
<tr>
<td>Roof</td>
<td>30.8</td>
<td>52.7</td>
<td></td>
</tr>
</tbody>
</table>

6.4 Thermal comfort evaluation

All the above presented climatic data are now imported to the software PsycPro 1.1.16 in order to evaluate the thermal comfort conditions of the two floors. The psychrometric charts are generated with the PsycPro software, for the summer period from 12th of July until 18th of July, when the climate can be characterized as warm-dry. The questionnaires answered by the occupants will also help to the thermal comfort evaluation.
The summer thermal comfort was calculated using a lower limit of 21°C and an upper limit of 27°C. Based on these assumptions, it is showed that internal conditions for the first floor exceed the upper limit of the thermal comfort zone during the biggest part of the days of investigation. Nevertheless, from the psychrometric chart we can see that thermal comfort conditions are prevailing mainly at early in the mornings or during the night between 21.00 and 23.00 p.m. when the rooms are naturally ventilated (Fig. 6.23).

From the questionnaire result, it is showed that occupants (parents and one child) of the first floor who have different ages (45 and 10 years old) feel relatively hot during the day. Mostly the parents that are occupied with housework at the day time, they feel sweaty and hot until late in the evening when they use natural ventilation, feeling much cooler.

Regarding the ground floor, it can be seen from the Psychrometric chart that during the summer days of investigation, thermal comfort on the ground floor was considerably better than on the first floor (Fig. 6.24). Internal conditions of the ground living spaces
are characterized by lower temperatures when the outdoor temperature is at the highest level.

Nevertheless, ground floor presents much higher percentages of humidity. From the answers to the questionnaire of the occupant of the ground floor who is 80 years old and male gender, we can confirm that he feels much hotter than the actual temperature early in the afternoon when the relative humidity is high. On the other hand, when the relative humidity is low, he can feel much cooler than the actual temperature because his sweat evaporates easily, cooling his off.

![Psychrometric chart for the ground floor](image)

**Figure 6.24: Psychrometric chart for the ground floor**

By the thermal comfort approach and taking into account the different construction methods between the ground and first floor of Kapourniwti’s house, it is estimated that vernacular architecture and its construction methods were influenced by the local climatic conditions.
The design of the living spaces according to the correct orientation and along with the creation of several windows for natural ventilation leads to efficient cross ventilation. Simultaneously, the time lag of the stonewalls is such that highest envelope temperatures are registered during the night. Additionally it should be mentioned that the activities of people can affect the thermal behavior of the house, as well as their clothing should be adjusted and varied according to the weather conditions. More specifically, the occupants of both floors declared that they use to open or/and close the windows and the balcony doors (only for the first floor) and not so often the external doors in order to adjust the thermal comfort of the indoor environment. Using this option, they claimed that they feel difference not only to the thermal comfort, but also to the indoor air quality.

Here, it should be noted that although, there are deviations of monitored temperatures from thermal zones, it should be noted that ASHRAE standards tend to be more limited than the adaptive model, as in Mediterranean countries which tend to have much broader zone acceptance.
Conclusions

The present thesis shows the need for a systematic research of vernacular building types and technologies in order to understand the living conditions both in the past and in the present. This can lead to the improvement of conditions within a sustainable framework. Available materials, construction methods and alterations are taken into account as well as their possibility to create a comfortable indoor environment with minimum auxiliary energy input requirements [32].

First of all, it should be noted that architecture is a living organism that constantly evolves. Morals, ethics and traditions, lifestyle, social rules, work habits, living conditions, climate are all factors that contribute to the evolution and alterations in construction practices. Bioclimatic architecture, in turn, can offer solutions to the issue of a healthy, safe, operational dwelling, with little environmental costs, energy efficiency, in harmony with the natural and the man-made environment.

Through the on-site monitoring and investigation of the Kapourniwti’s house at Zagora, is concluded that vernacular buildings take advantage of the region climate through the proper application of building elements and technologies for both energy preservation and improvement of comfort conditions. Through the thermal comfort evaluation, it seems that indoor conditions in the vernacular house were found to be within and/or near the comfort zone. However, no winter monitoring was possible due to time constraints therefore we cannot comment on indoor conditions in winter. In general, we conclude that the type and the design of the building are based on the bioclimatic principles in order to optimize the relationship between site, building and climate.

Nevertheless, it should be mentioned that the monitored case study is an isolated one. To generalize conclusions from it, a broader survey of the specific village and other such in the region is necessary so that building technology, materials and details, as well as orientation may be catalogued and conclusions may be generalized within a reasonable margin of doubt.

Another important outcome of this dissertation is that the theory of bioclimatic architecture is a part of our traditional architecture. Vernacular architecture is the result of long lasting historical evolutions and interactions realized in a specific time and space reality, and the indigenous wisdom is ‘hidden’ behind every construction choice, while
two of the fundamental reasons for which architecture differentiates between different places and spaces is the climate and the natural resources. Due to the lack of natural or manmade resources and technical means, the traditional techniques (first instinctively, and then through a trial and error process) turned to financially and environmentally optimized solutions.

Mount Pelion and more specifically the village of Zagora that were selected as the case study, are vernacular settlements with interesting building types and forms. Local raw materials were used in the building of the traditional Zagora dwellings. The defensive structures with small and numerous windows and wooden ceilings in order to minimize heat losses, fireplaces, excess thermal mass, internal rooms with appropriate orientation, and vegetation providing cool temperatures during the summer months, are recorded and examined.

Through this research, we conclude that the vernacular architecture of Mount Pelion incorporates and includes the techniques and the principles of bioclimatic architecture. The direct solar gains are stored in the internal spaces in high heat capacity materials, while the heat losses are limited through the use of high thermal mass in the envelope (thick masonry walls), and low conductivity ceilings and shutters (wood). Furthermore, the steady environmental conditions in the stone part of the building can provide cooling in the summer using night ventilation.

In any case, the energy efficiency and the rational use of traditional building are recognized. Relations between man and natural environment, which evolved in past, must be restored since this seems to be one of the most viable options for the future, certainly in the less developed countries, but also under the constraints of energy and other resources depletion. Modern architects and engineers should investigate the traditional architecture styles, in order to use the knowledge in modern construction practices. Moreover, the understanding of the way traditional buildings work and the recognition of the characteristics defining thermal comfort conditions according to the climate of each territory are critical parameters in preserving and reusing old traditional buildings. Finally, the need arises to make a proper combination of traditional experience and modern know how, in order to achieve optimal living conditions and the best thermal behavior.

Nevertheless, nowadays, many villages of Mount Pelion, as well as the Zagora village face the withering of their traditional architecture, while their aesthetics are being
degraded by new structures, bad restorations or non-contextual new houses. These problems are mainly caused by:

- Misinterpretation of the authentic, in regards to construction methods and the choice of materials.
- Badly preserved buildings due to lack of funding.
- Trouble in incorporating new systems (i.e., air conditioning units).
- Lack of proper energy design (i.e., structures, systems and details added at a later date, like aluminum window frames).

In order to curb all these phenomena, the existing legislature about the protected settlements ought to be revised.

In conclusion, it is a vital need to understand the way in which the vernacular buildings work in relation to the local cultures, climates, environments and economies as they are described above. By this way, architects, designers and students of architecture schools will acquire a better understanding of how buildings perform and how they can be modified to optimize their performance in the future.


29. Meteorological station of Zagora operated by the National Observatory of Athens.


31. Iliopoulou E., Investigating the energy values in vernacular architecture. Coursework of the Msc in Environmental Design of Buildings, University of Cardiff.


Appendix

User Satisfaction Questionnaire

Name:                                      Flat No:
Date:                                      Time:
Temperature:                              Relative Humidity:

1. Personal Information:
   ○ Male
   ○ Female

2. Age:
   ○ <20
   ○ 20-30
   ○ 30-40
   ○ 40-50
   ○ 50-60
   ○ 60-70
   ○ 70-80

3. Please highlight your level of satisfaction in relation to the following items:

Ventilation
   ○ Very poor
   ○ Poor
   ○ Good
   ○ Excellent

Temperature
   ○ Very poor
   ○ Poor
   ○ Good
   ○ Excellent
Lighting
  o Very poor
  o Poor
  o Good
  o Excellent

4. How do you feel?
  o Hot
  o Warm
  o Slightly warm
  o Neutral
  o Slightly cool
  o Cool
  o Cold

5. How would you prefer to feel?
  o Much warmer
  o A bit warmer
  o No change
  o A bit cooler
  o Much cooler

6. How would you rate the overall comfort?
  o Very comfortable
  o Moderately comfortable
  o Slightly comfortable
  o Slightly uncomfortable
  o Moderately uncomfortable
  o Very uncomfortable
7. *Which of the following environmental control do you use?*

- External door open/closed
- Balcony door open/closed
- Internal door open/closed
- Window open/closed
- Curtains open/closed