# Bioclimatic Analysis of the Traditional Cypriot House

Computergestütztes Entwerfen
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M2.1

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Ill.1 Sketch of a Traditional House

"Architecture has recorded the great ideas of the human race. Not only every religious symbol, but every human thought has its page in that vast book."

-Victor Hugo

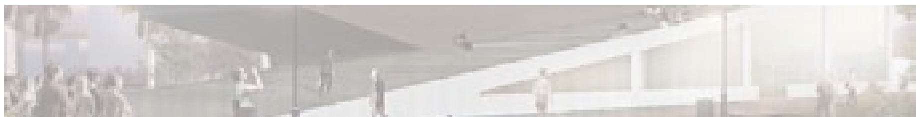
# Background

According to Bjarke Ingels, “Architecture is the art and science of making sure that our cities and buildings actually fit with the way we want to live our lives, the process of manifesting our society into our physical world.” From the start of mankind architects helped to create and shape the society to the form that we all know today. This project aims to study the traditional architecture of Cyprus and exploit the traditional bioclimatic elements that Cypriot ancestors utilised to create buildings that were not only sustainable to reside within as they had the necessary means to mitigate the weather conditions, they were also harvesting the environmental conditions to have optimal acoustic, luminosity and air circuity. It will then propose who some of the traditional architectural elements that were utilised in the past can be shaped and adapted to modern society.

Throughout time the primary objective of architecture was the creation of comfortable and appropriate living conditions that protected the population from adverse climatic conditions. The Mediterranean Traditional Architecture of Cyprus is heavily dependent on the topography, the altitude of the region and the historical background. Specifically, as Cyprus throughout the years was under different conquerors, that left their architectural stigma, cultural and architectural standards, these merged together affected the formation of Cyprus’ architecture. Cyprus is located in the centre of 3 continents; Europe, Asia and Africa, the cultural, economic diversities and influences on architecture of that time were vast. Traditional architecture was shaped in such a way not only to provide the basic needs; food and rest but also the epoche’s everyday functions such as entertainment and looking after the farm animals. Due to these specific needs, there was a tendency to separate the residential structures, in units; creating closed-off spaces, semi-open and open spaces to meet the needs requested.

Traditional forms were developed according to the way of life, the local available materials and the climatic conditions of the area. From researching traditional houses, a wide range of factors emerged which contributed to the creation of folk homes. Some of these were; the availability of resources in an area and therefore the materials that could be used, the topography of the area i.e. whether the dwelling was in contact with a plain, hill, mountain or coast region.

The Traditional House was divided into four main rooms: Makrinari, Dichori, Iliakos and Sospito, with all of the homes having interior courtyard. More specifically, Iliakos and the yard were essential elements for the creation of microclimates and hence allowing the residents to better control the temperature that resided inside and outside their homes. In Mediterranean countries sun is desirable in the winter, while in the summer months, residents aim to find the best ventilated locations to protect themselves from the high temperatures. The buildings were mostly south-oriented, while the transition areas lied between east and west. Partially closed rooms were mainly used for guest hospitality, rest, sleep, food preparement, laundry facilities and for growing agricultural products.



Ill.2 Nicosia Buffer Zone Concept Perspective



## Issues

To understand and better explain the necessity and niche of this project, it important is to consider the current situation that the country, Cyprus is phasing. Following the national chaos caused by the 2013 banking crisis and subsequently the European bailout a number of organisations opted for financial austerity measures to ensure their viability within the local market and up to this day some organisations still settle to such measures. This in combination with the National Minimum Wage of the country being at €870 per month, the introduction of NHS in March 2019 increasing employees social insurance contributions to 1.70% and the interest rates of house mortgages ranging between 2.35 – 2.75% (Bank of Cyprus, 2019), makes the Cypriot citizen to carefully consider what means they are to employ to have their independence and their own place without depriving themselves from other basic wants and needs. The socioeconomic situation of the country, indirectly affects the overall architecture and the real estate market of the country. As for a normal 1-bedroom apartment the rent is about €600-700, excluding electricity, water etc. This in connection with the millennial generation earning less than €900 per month, results with the majority of Generation Y consciously selecting to reside in their familial homes with their parents until their late 30s as it is simply impossible to survive in dignity with such socioeconomic conditions on their own.

## Aim & Objectives

The project aims to mend the gap in the above national issue by implementing the Bioclimatic features from the past in a modern context. Thus, creating modern, affordable and low-cost residential settlements that people from all generations could live in dignity and comfort. Aiming to optimise the current socioeconomic conditions of the country with the utilisation of historical Cyprus’ architecture in a modern formation.

Ill.3 Nicosia Buffer Zone Concept

# Bioclimatic Architecture Principles

Bioclimatic architecture is a specific form of building a design that exploits the physical characteristics of the landscape, which vary according to the natural relief, morphology and topography of an area. Along with considering the environmental climate so that the construction has energy benefits from the sun and the wind. Further, energy gains are strengthened according to the orientation of the building either via the area or the materials used.

## Natural Lighting

Natural lighting in Cyprus was created through the small openings, the outdoor areas and semi-outdoor areas such as the courtyard and the interspace (Ηλιακός). The orientation for the openings was located in the south because the solar radiation was greater on that side in the winter. This manifests because the movement of the sun is deeper in the horizon and the radiation shines almost perpendicular to the southern view. In contrast in the summer months, the sun is higher which means that the radiation is almost parallel to the southern side. This resulted that in the summer the southern side had more shade and in the winter the sun rays occupied the whole house.

## Natural Ventilation

The wind in Cyprus usually has a north-westerly direction in the mountain areas and a south-westerly direction in the coastal areas. The openings in the south provide cool ventilation in summer, as the cool winds blow to the southwest or southeast. If the wind direction has a deviation of 45 degrees in the direction of the openings, then the wind circulates in the air and distributes it evenly. Natural ventilation is most effective when the airflow changes direction in the room. The change in wind direction can be achieved by using vegetation and small shrubs in front of the openings to control the intense air and the size and position of the opening in relation to the orientation.

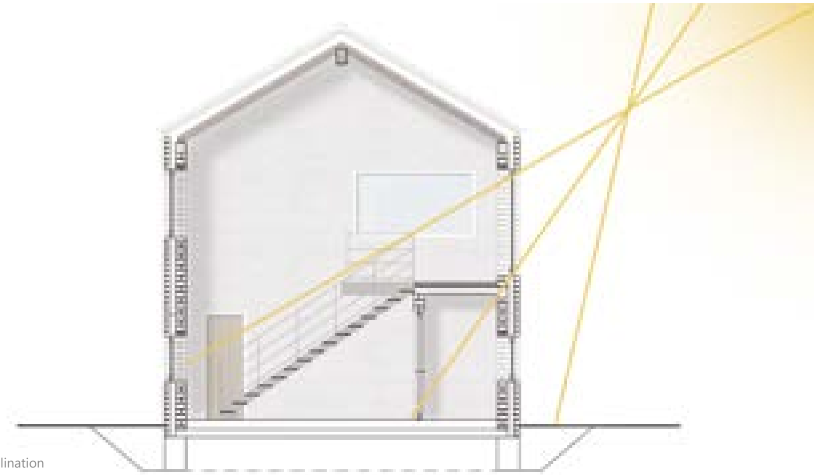
Depending on the direction and size of the openings, different conditions are met, such as a large opening from the south and a small opening from the east, so that we can achieve a low air velocity. This is the Venturi phenomenon, when the air intake is small and at the exit large, a high velocity is achieved. The correct use of ventilation through the exterior and semi-exterior areas indicates comfort inside the building.

## Passive Solar Heating

The heat accumulator for the winter takes place according to the location of the houses in the ecosystem and comes in particular from the solar energy of the shell. The shell collects heat from the roof, masonry, flooring and openings. Each material and structural element of the structure stores heat in different amounts, depending on the mass. The heat is stored during the day and released inside during the evening hours when the temperature is lower.

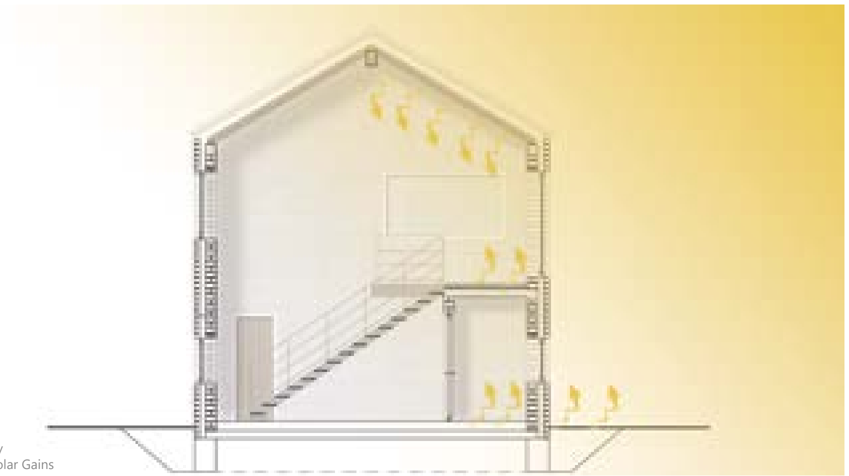
The thermal inertia of the structure is achieved with materials that have a high thermal capacity, such as stone, and thus slows down the heat transfer to the inside through solid materials that are used to create the masonry and the roof. In traditional buildings, the most widespread heating strategy was south orientation. Thermal energy was stored indirectly in the air.





Sun Rays
Ill.4 Sun Rays Inclination

Air Flow
Ill.5 Ventilation



Solar Ray
Ill.6 Shell Solar Gains

As the air was heated by the sun, the movement and the direction of the air transferred the heat to the solid materials. There was also the solar radiation that warmed the building materials and was stored by the structures molecules. The solar radiation was transported through the openings into the interior, where it was captured thus creating the greenhouse effect by the incident of solar radiation.

Another heating strategy was to protect the northern façades of the house by planting trees - bushes, shafts, neighbouring buildings, etc. - in order to prevent greenhouse effect being absorbed and minimised by the sun.

## Natural Cooling

The Mediterranean climate in Cyprus during the summer has generally high temperatures. When buildings are directly exposed to sunlight in the summer, they could overheat and transfer the heat inside, so there is no thermal comfort. Overheating can be prevented with appropriate sun protection and proper settlement alignment for cool ventilation.

Some of the most important natural cooling strategies during the summer season are ensuring adequate ventilation, shading of the building and sun protection in the openings. In addition to, thermal inertia of the construction, and the colour of the exterior surfaces. Sufficient ventilation should be provided, especially at night, in order for the over-accumulated heat load to be removed from the interior.
Natural ventilation is influenced by climatic conditions, from the arrangement of the openings to the orientation, the size of the openings, the operation of the building, the texture of the material and the colour of the exterior surface.

The shading of the building and the sun protection of the openings protect the inside of the building as well as its external surface. This is achieved with vegetation or deciduous trees in the right orientation. Another way of ensuring adequate shading is to use a full-coverage cover and external dark roller shutters with movable blinds. The typology of Ηλιακός (Iliakos) and the courtyard, offer the best natural cooling in the house. The πόρτιο (portio), which is the internal Ηλιακός (Iliakos), in combination with the external Ηλιακός (Iliakos) (Loggia), are placed across the main part of the building, improving the natural cooling and avoiding overheating of the masonry. The inner courtyard provides natural cooling in the house through a liquid element; such as vegetation or a water element.

Wind
Ill.7 North Wind Protection

Wind
Ill.8 Venturi

Shutters
Sun Rays
Ill.9 Solar Protection

Wind
Ill.10 Iliakos

# History

From a retrospective exploration of Traditional Architecture it is evident that our predecessors took advantage of the natural elements of the region and dealt with the temperature problems by configuring their buildings. According to the article "The Wisdom of the Mediterranean Traditional Architecture versus Contemporary Architecture - The Energy Challenge", a study of folk architecture showed a particular form of buildings that emerged from customs, culture, needs and dreams, all of which accompanied the climatic conditions of a region. The needs of a house develop over time and it is shaped according to the prevailing conditions. These conditions are culture, conquerors, religion and customs of the place.

The below section will depict some of the residential settlements in the past and the ways that these were created.

## Neolothic-khoirokitia 7000-3000 B.C.

Neolithic settlements were discovered in various places in Cyprus, the first being khoirokitia. It was situated on a south-facing hill near the river Paroni and six kilometres from the sea. The settlement was divided into groups of circular buildings and each group belonged to a family.

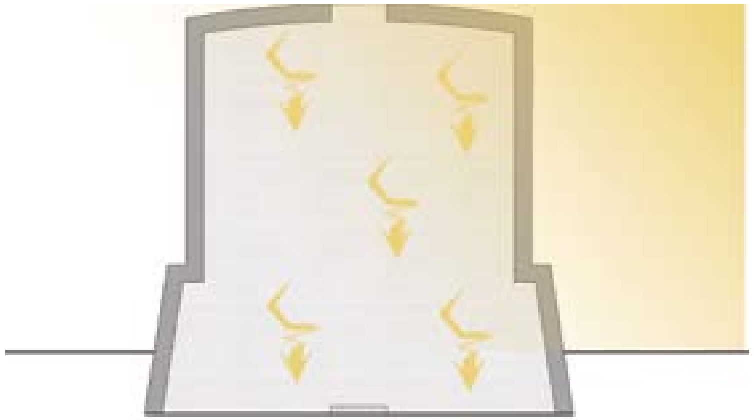
Each group of buildings were placed around an outside area that was the inner courtyard. All the houses were facing the courtyard and had direct access to the buildings. The installation of the entrance to the terrace helped to keep the ventilation in good condition.

The buildings were separated from each other and consisted of different sizes, probably depending on the use and number of people living there. The residential buildings had only the 0.5 meter high entrance and a small window placed in a higher position for light and ventilation. Also in many representations of the houses there was a central hole in the room for fire and lighting. The brickwork was made of stones and as it was proven to be more resistant to water and moisture.

In the summer, the entrance was assumingly open to ventilate and cool the area with water from the river. The materials used to shape the outside of the houses were; soil which was made from earth and clay. The utilisation of the above mentioned materials ensured thermal insulation both in the summer and winter months, as the temperatures inside the house were normal. Particularly, in the summer months the floors were cooler due to the shadows created by the buildings and in winter time the heat from the fireplace maintained within the house due to those materials insulating properties. An important feature of the circular shell is also its behaviour to the wind, which circulated in a parametric way to the masonry.



Ill.11,12 Khoirokitia

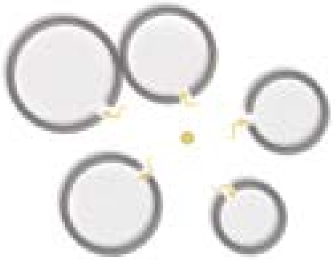


Ill.13 Khoirokitia Heating

Ill.14 Khoirokitia Ventilation

## Neolithic-Kalavasos-Tenta
## 5000-1450 B.C.

Another Neolithic settlement, similar to Khoirokitia, is located in the Kalavasos-Tenta. The difference is that the settlement was surrounded by a defensive wall. The defensive wall as a secondary means acted as a wind resistant division. The settlement' roofs were flat with a minimal inclination in order for the rainwater to fall down the sides of the roof. The fireplace was not inside as it was in khoirokitia settlement, but outside in the courtyard to warm the air that moved through the courtyard. important feature of the circular shell is also its behaviour to the wind, which circulated in a parametric way to the masonry.



Ill.15,16 Kalavasos-Tenta Site & Heating Concept

## Archaic, Classical and Hellenistic Period
## 725-30 B.C.

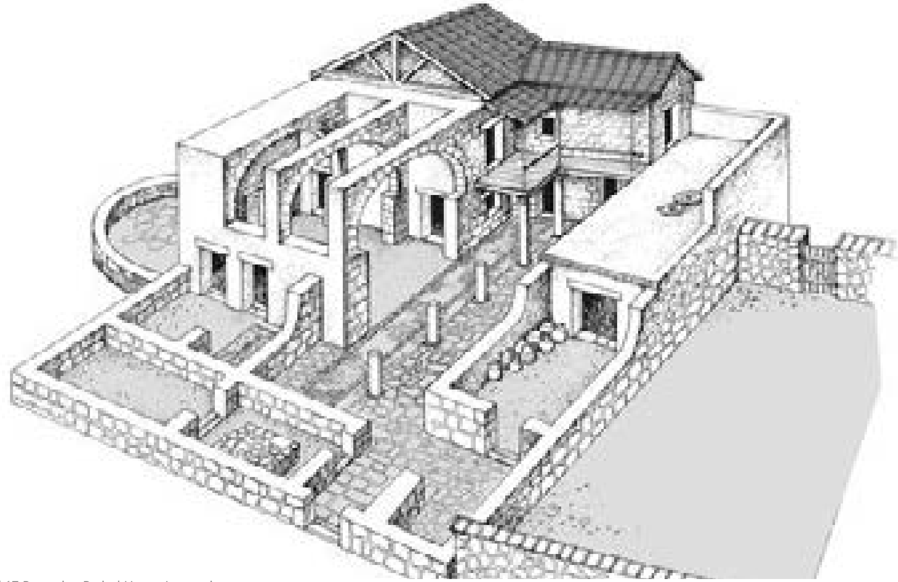
Since the Classical period, there was an evident introverted character in the houses and public buildings. The courtyards were designed with peristyle, and the other rooms were developed surrounding the courtyards. An example of this settlement was in ancient Athens and it was referred to as the market, which consisted of a semi-free space that provided shade and shelter from unwelcome weather conditions and as a secondary cause served as a meeting place.

## Byzantine Period
## 330-1191 A.D.

Christianity came to the island during the Byzantine Period. A new type of building was introduced which spreaded throughout the urban fabric of Nicosia, the capital of Cyprus, which positioned the buildings on the street border and to narrow streets. The roadside building provided shade for both the narrow street and the buildings themselves. In this way, the buildings were not overheating in the summer and pedestrian traffic was introduced. An important feature of this period was the so-called Portio; the arch. It was a central area that connected the southern outer Iliakos with the inner courtyard. This typology offered better thermal comfort in all areas. It provided ventilation and lighting from the outside of Iliakos to the entrance of the building.

During the Byzantine period, with the introduction of a new religion, Christianity, the architectural residence formation changed. The courtyard became in an iliakos form. There were large openings in the south and smaller ones in the north. The use of wood in the south to obtain more heat gains and stone was used in the north to serve as thermal insulation in the winter. In the northern side of the structure a balcony (sachnisi) was introduced for the summer months breeze.





Ill.17 Byzantine Period House Isometrie

Ill.18,19 Iliakos

## Frankish/Venetian Time
## 1191-1570 A.D

An important bioclimatic feature of this period was the Iliakos on the ground floor, which protected the masonry during the summer months from the sun's rays. In winter the sun was lower therefore the Iliakos allowed the solar radiation in the building to enter. There were also other openings on the ground floor for ventilation and cooling during the summer season.

Further influences on the architectural design of the house at that time were the creation of small openings in the ground floor positioned in the north for a better ventilation of the building. There was also another opening on the parallel side at a lower point, which created the venturi effect.

Ill.20 Frankish City Wall

## Ottoman Occupation
## 1570-1878 A.D

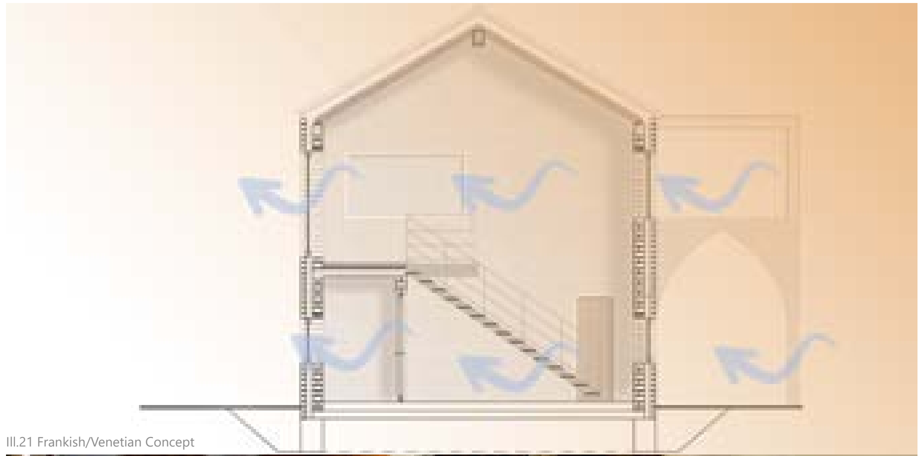
The Ottoman period, lasted 308 years, and left a number of influences on the architectural culture of Cyprus. The houses were divided into smaller parts and the interventions in the existing houses were inexpensive constructions of clay bricks and wood. One of the most famous houses in the area was the villa of Hadjigeorgaki Kornesios, seen at Ill. 22. An important Bioclimatic feature that appeared at the time was the two-story house with the Sachnisi, which was used as a balcony. The passers-by could not see the people inside of the house, but the residents of the house could view the street.

Sachnisi provided optimal ventilation in the summer. It was mainly used as a day-summer area and as a southern Iliakos for the winter. Sachnisi was a room that rised up the second floor to the street like an enclosed balcony (Ill. 23).

In the south there was the Iliakos system with a number of large openings that helped ventilate the building. The most important element in the openings was the movable wooden blinds, which regulated the entrance of the sunlight. When the wooden blinds were closed in the summer, they protected the openings and the interior from the sun. In contrast, during the winter months, when they were open, they delivered direct solar gains to the house. In the middle of the courtyard there was a washbasin and the water gathered provided cooling during the summer months.

## British Rule
## 1878-1960 A.D

During the British domination the roofs were tiled, especially in the mountain regions. On the sloping roof there was a fan to ventilate the room. Within this period the roofed balconies and terraces in the south were formed.



Ill.21 Frankish/Venetian Concept

Ill.22 Hadjigeorgaki Kornesios Villa

Ill.23 Sachnisi

# Settlement Types And Principles

There are three types of settlements in Cyprus, the mountain, the lowlands and the city. Each settlement differs according to the characteristics of the location. The characteristics that determine the shape are topography, weather, orientation, and the natural materials that the place offers. The below section will depict some of the residential settlements in the past and the ways that these were created.

The organisation of a settlement reflected the social impact of the customs and the topography of the place. The location of buildings in a village or town varies depending on the weather. The location of mountain settlements depended on the need to protect themselves from the wind and sun, while in the lowlands and urban settlements the existence of a liquid element such as river, sea and the need for the sun. The building construction in the cold areas was dense and in the mildest climates the settlements had more freedom in design.

## Mountain Settlements

Mountain settlements were usually located on mountain slopes and the buildings were positioned in accordance to the slope. The arrangement of the buildings reduced the heat loss, as the part of the structure was located inside the mountain and therefore only a few surfaces were exposed to the extreme cold weather conditions.

The house orientation was usually to the south or southeast. This direction contributed to the warming of the settlement and provided natural light due to the sun's rays. Mountain villages usually had dense structures to reduce surface area and heat loss. As the settlements were dense, people did not have the space to create an inner courtyard. In addition, the buildings did not have Iliakos; semi-open spaces, as the sun was desirable all year round. The dense, high structure of the settlement and the narrow streets minimised the sun exposure, and provided shading and cooling down during the summer months. Contrastingly, in the winter, the irregular shape of the streets and cut off the wind's power and reduced the cold.

Ill.24 Mountain Settlement Heating concept

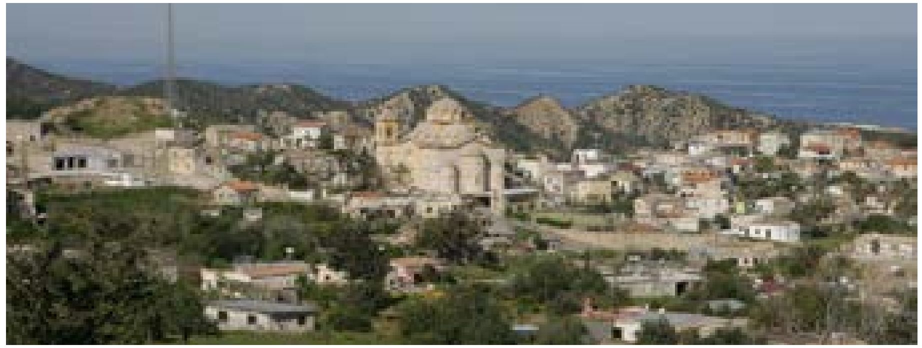
Ill.25 Mountain Settlement

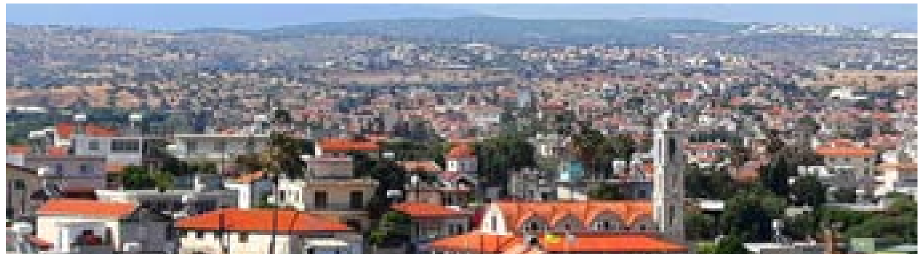
## Lowland Settlements

These settlements were located near a river overlooking the sea. The majority of the settlements were amphitheatrically positioned, as they started from a mountain perspective and ended at the end of the sea.

Buildings were usually built in a sparse arrangement, to allow the cool sea air circulation between buildings and provide cooling.

The typology in lowland houses was usually L-shaped with an inner courtyard to maintain maximum Bioclimatic function. They created the Microclimate through the courtyard and plant usage to cool the house in the summer months and amplify heating in the winter. The existence of a second floor was mainly intended for sleeping purposes in the summer months as it was cooler. The reason that the upper floor was cooler was an outcome of the Iliakos and the Arch that such settlements had.





Ill.26,27 Lowland Settlements

Ill.28 Sparse Arrangement

## Urban Settlements
Urban settlements were the result of the development of rural settlements that came in effect following the influence of the Franks, Venetians and Ottomans. The most important urban settlement model was Nicosia, the capital of Cyprus.

The location of Nicosia was chosen on the foundation that the water river flowing through the city, cooled down the settlements during the summer months. Also the surrounding mountains ensured that the settlement was protected by the strong wind from the north.  The buildings were on the roadside, with courtyards, and the adjacent rooms were L-shaped or Π-shaped due to the high summer conditions in the area. The dense structure of the settlement created cooling conditions through the utilisation of narrow streets. Cold air was trapped within the narrow sections and the outside temperature of the house was subsequently lowered. The undivided structure of the settlements and the narrow streets served to protect the masonry of each building; as one protects the other by shading, thereby reducing heat loss to the outside.

## Orientation
This section will discuss the orientation that the residential settlements had at the time utilising a descriptive approach. For the correct placement of the settlement the sun orbit played an important role. The most energetic orientation of the settlement was the south and southeast, as it provided cool ventilation in the summer from the southwest or southeast side. At the same time, it helped to capture the sun's rays in the winter and provided sun protection in the summer by directing the sun's rays to the south.

The orientation of the settlement can determine its shading by various factors depending on its location. Specifically, the shadows were formed by trees, hills, high walls and buildings that casted shadows on the streets. Buildings usually had a north-south direction, in the north there was the entrance area and in the south the inner courtyard. The rooms of the building were arranged according to their function and their need for thermal comfort. The most suitable settlement orientation was the south, which provided sunshine all year round. In winter time the sun is lower and the length of the overhang semi-open roofed room (Iliakos) helped to retain and store heat in the masonry. In contrast, during the summer the Iliakos protected the masonry from vertical solar radiation up to 77 degrees. The solar function provided natural lighting in all areas, and cooling through the courtyard as the liquid element was evident there.

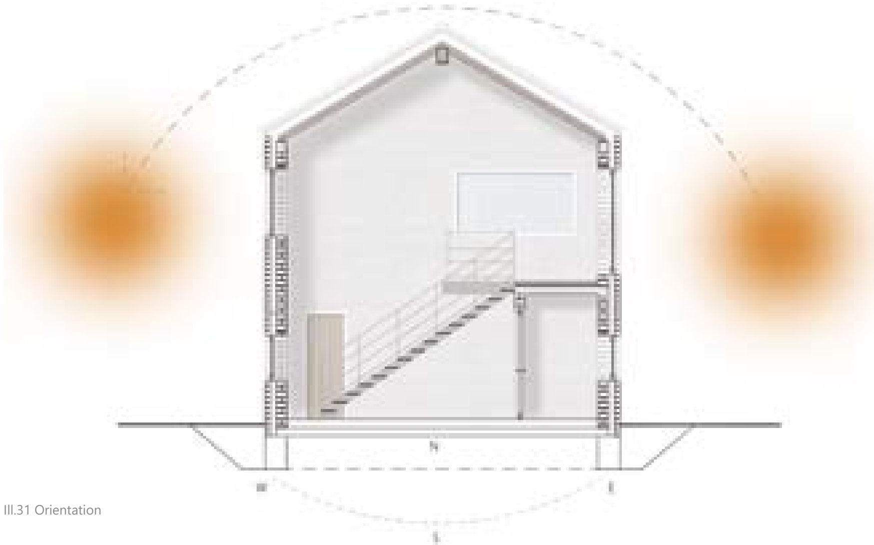
## Building Layout & Typology
The house was proportionate to the size of the plot, usually being elongated and arranged with the long side facing south for heating purposes and the parallel side facing north for cooling purposes.

Urban settlements in which the buildings stand side by side minimized the surface exposure to the east and west in order to avoid overheating. The compact shape of the building and the type of development (very close to each other) of mountain settlements reduced the surface area of the building to avoid heat loss in the winter and reduce overheating in the summer. There were two construction options: firstly, the two closely spaced houses not having the same partition wall, hence creating narrow alleys of fifty centimetres without openings, which was common in dense settlements, and secondly, the buildings were in a continuous formation connected with a wall.




Ill.29 Nicosia:Urban Settlement


Ill.30 Urban Settlement: Dense Structure


Ill.31 Orientation

Due to the diversity of the terrain in Cyprus, the buildings did not have the same type. The typology was simple as the main requirements were; a closed room that offered protection against weather conditions and a semi-closed room that made it possible to ventilate the area. The remaining rooms were incorporated into an I-, L- and Π-shaped layouts to provide shade and minimize the wind.

Lowland settlements were also formed according to the topography. The buildings were usually south or southeast oriented at the property boundary, while the transition areas between east and west were mostly parallel to neighbouring buildings. The most widespread typology was L, for the room to be illuminated in the winter and ensure the heating factor was elevated.

## Iliakos

Iliakos played an important role in the organization of the house. It reduced the room's temperature during the summertime, as the microclimatic conditions of the Iliakos ensured the correct thermal behaviour of the building. There were two types of Iliakos indoors and outdoors.

The interior of Iliakos was in the entrance area and usually had a north-south direction. It had a direct connection to the outside Iliakos. The inner iliakos allowed air to flow through the parallel spaces of the inner iliakos and with a direct connection to the outer space. Through the openings that were either skylights or small openings above the entrance. In the summer, when the main entrance (north) was open, it transported the cold air inside. The inner Iliakos could also be placed in the second floor (if there was a second floor) and was connected to an internal staircase so that the hot air can escape on the ground floor. The height of the ground floor was usually up to 4 meters.

The outdoor Iliakos was usually located in the south or east of the house to create a pleasant microclimate. It was a protected semi-open space that was used for family work during the summer months.

It protected the walls from overheating and controlled how much solar radiation enters the interior. In the winter, when the sun is lower, it allowed the sun rays to penetrate the interior. The walls stored the heat and directed it inwards during the evening hours Normally the side was closed with walls or other rooms to protect against wind. The Iliakos was a room with outdoor functions. At the one end of its small side there was a faucet and on the other side there was the stove as the open space allowed the smoke to escape.


Ill.32 Iliakos




Ill.33 Limassol: Denste Structure


Ill.34 Iliakos


Ill.35 Vine as Iliakos

## Inneryard
The house was surrounded by walls with the main entrance opposite the house. In the courtyard there was a small paved area to avoid puddles of water. Normally there were a few animals and the necessary harvest for the housewife. Around the courtyard, the rooms were designed to provide good ventilation and cooling as an outcome of the low temperatures of the courtyard.

## Vegetation
The vegetation in the inner courtyard shaped the inner climate of the house and protected it from the sun and wind. Sun protection was achieved through the absorption and consumption of solar radiation from photosynthesis. Even in the summer, the trees did not allow the sun's rays to get through and into the building. Because of the shade, they kept the air cooled, depending on the distance the trees had to the building. The vegetation was also used as a windscreen to protect the building from the wind.

In traditional Cypriot architecture there was a stern, a fountain or a fountain in the courtyard. With the correct orientation of the liquid element in the wind, water vapour could be reached, cooling the air through the openings and transporting it inwards.

## Openings
The openings were larger in the south and smaller in the east, so that a low air velocity could be achieved. This was the so called ,'Venturi phenomenon'(page 2 Natural Ventilation), in which the air intake in the building is small and large at the exit, hence achieving a high velocity.

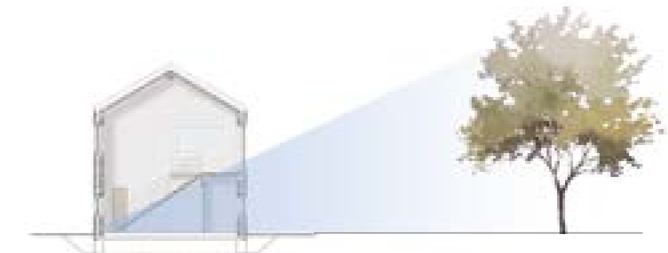
In the past the windows were smaller because of the amount of conquerors that the island had, and as a secondary factor to allow ventilation through the small openings. These were at the top of the building façades where the heat rose and dissipated in the summer.

A balcony was evident in traditional Cypriot houses which was usually located above an entrance area and offered shade and weather protection. It protruded from the street and hence protected the masonry and subsequently offered sun protection for the passers-by.

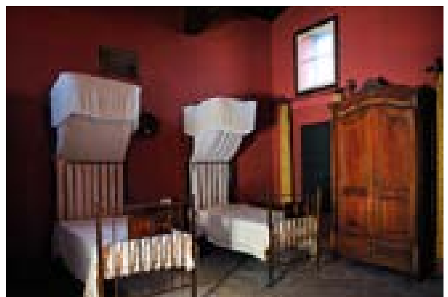
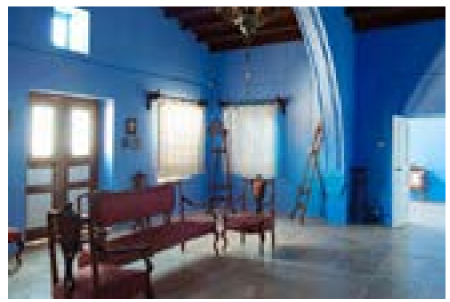
## Colour
Colour on the outside and inside of the buildings was used by wealthier families to protect the stone walls or brickwork; clay, gypsum or plaster were used and covered with a thin layer of lime, partly painted in ochre powder or indigo. The warm colours such as ochre were mainly found in the northern rooms, which were mainly used in the winter. The warm colours have higher heating absorption properties; hence in the winter they have the capability to absorb and retain solar power and manifest it in the room as heat.

While the cold colours such as blue were found in the southern rooms, which were mainly used in the summer months. As in direct contrast of the warm colours, they offered the exact opposite effect and acted as cooling systems to the rooms. This justifies the utilisation of different colours in accordance to the functionality of the room.


Ill.36 Vegetation in Inneryard


Ill.37 Vegetation as Sun Protection

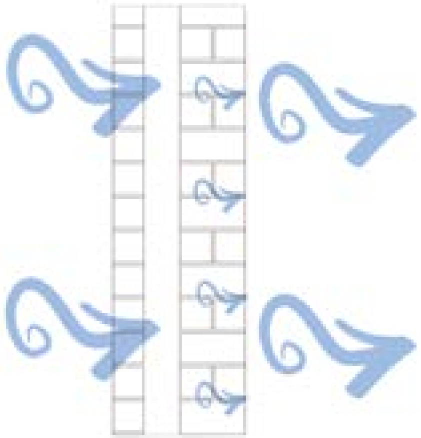

Ill.38 Water Element



Ill.39,40 Colour in the Traditional House

# Walls

The main materials used in the construction of the masonry in Cyprus were stone and oak bricks with a small proportion of wood. One strategy was the thickness of the wall, which provided thermal inertia to the shell. Due to the materials used in the building shell, they had a higher thermal capacity. In the summer, outdoor enclosures and balconies protected the masonry and provided shade. This led to a natural cooling in the building.

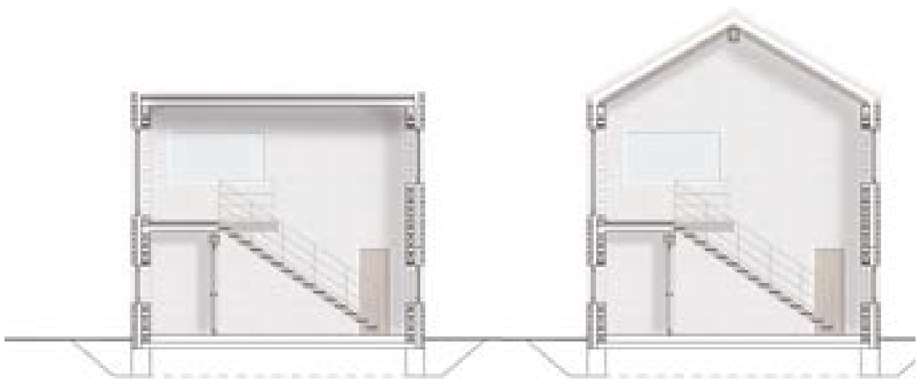
The stone was one of the most utilised building materials at the time. There were three types of stone: calcareous (lime), pyrogenic and sedimentary. The lime was easy to work with and it had a better bearing capacity. The pyrogenic stone was more difficult to process, so it was provided with a gravel bed to fill the gap. The sedimentary rocks are the limestones we still use today. The combination of these materials and the thickness of 50-70 cm slowed down the heat loss inside the building to the outside and vice versa.



Ill.41 Wall

# Roof

Two types of roofs were mainly utilised in Cyprus traditional architecture. The first was the flat roof which consisted of beams with thick layers of reed, wood panels or thick branches. Then they laid leaves, added layers of soil and formed a minimal slope that pushed the water down without draining the soil.



Ill.42 Roof Variations



# Today

With the uprising of the industrial revolution in the 19th century, reinforced concrete and iron was introduced in the architectural structures, which very quickly influenced the architecture of the island of Cyprus as well.

The trend that emerged, having a universal building model created a particular problem in preserving and exploiting the unique bioclimatic features that in the earlier years were integral elements of Cyprus' architecture. The traditional building began to be abandoned, and replaced with this new trend of building. This new type of architecture may have had good functionality in the country of its origins, however adapting it to the island of Cyprus, were specific climatic conditions are prevalent resulted in the development of a number of issues. For instance, middle-European countries such as Germany or England have different climatic conditions than Cyprus, in which it is architectural built must adhere to. Hence, if the building is transposed to a warmer climatic country such as Cyprus in which the temperatures all year around are warmer, the building will be extremely hot to reside in.

This particular mentality has led to the necessity to improve indoor temperature resulting in the uncontrolled use of air conditioners. The replacement of traditional buildings with modern constructions led only to the aesthetic upgrading of the landscape while for the internal environment the only solution is the unlimited use of air conditioning mechanisms, which consequently resulted in enormous waste of energy. Modern residences are usually inadequately designed because the natural features of the landscape that offer natural, coolness or warmth, are not exploited.

In modern times, to achieve a comfortable microclimate inside a building in Cyprus, high costs are required for the installation of air conditioning, maintenance and, above all, the cost of running the monthly electricity expenses. In earlier times, thermal insulation in building construction was standard. Prior the design of the building, proper orientation and environmental functionality were decisive factors for not only regulated the heat flow to and from the building but also maintained the internal temperature. Potentially in the past the construction materials varied due to difference in availability of resources from area to area, but mainly there was a proper and separate configuration of spaces and fittings that allowed natural sunlight and natural cooling factors.

Ill.43 Renovated Traditional Home

# Current Study

This study shall prepare the grounds to utilise modern Bioclimatic Architecture as an alternative solution of new affordable buildings in Cyprus. It aims to be a technique that allows the buildings to save energy gains when necessary, from sun and wind, and aim to suggest prevention effects to adverse weather conditions. A bioclimatic plan is appropriate when it meets the specific strategies that the area requires with the conditions prevailing in winter and summer. An optimal design can lead to zero energy use in the building. In order to understand some bioclimatic elements that modern architects can exploit, firstly analyses of traditional home must occur, then identify which elements were evident in the past and optimise them.

## Analysis
## Bioclimatic Traditional Residence in Lofou

The village of Lofou lies between Limassol and Paphos, and is built in a circular pattern on hills, surrounded by mountains with narrow and steep slopes. The landscape is divided by two rivers. The village is situated on a hill between the mountains.

The building that is to be analysed in this section is a monument, from the Frankish period. This project arrived to the company I am employed in an uninhabited and damaged condition.

## Position

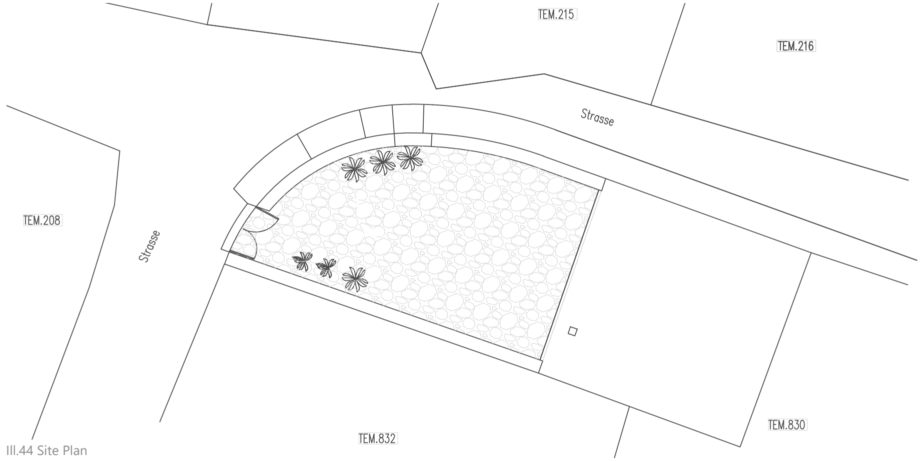
The building was located in the Lofou's centre and on both sides there were other neighbouring buildings that shared the same exterior walls. The orientation of the building was south-eastern and in I-shape formation. There was no courtyard, which is usual formation for a mountain settlement.

## Lighting

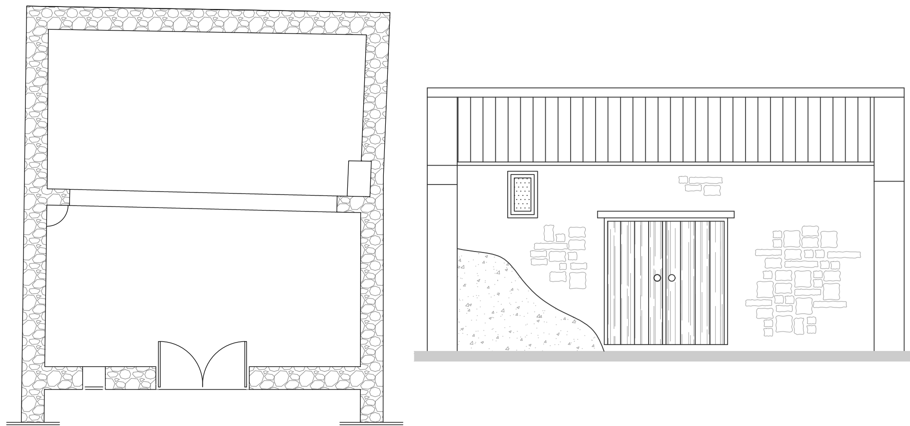
The building was dim with two openings; the door and a small window next to the door, positioned in a high section. The interior of the building was a very large room with an arch, which served as a room divider. The arch also had an additional functionality; in the summer it provided additional shade and cooling inside the building (where the bedroom was located). Despite the two openings, as the house was orientated in the southeast, the building had the greatest potential for lighting. The openings were only two as a precaution to the invaders/conquerors of the time.

## Heating

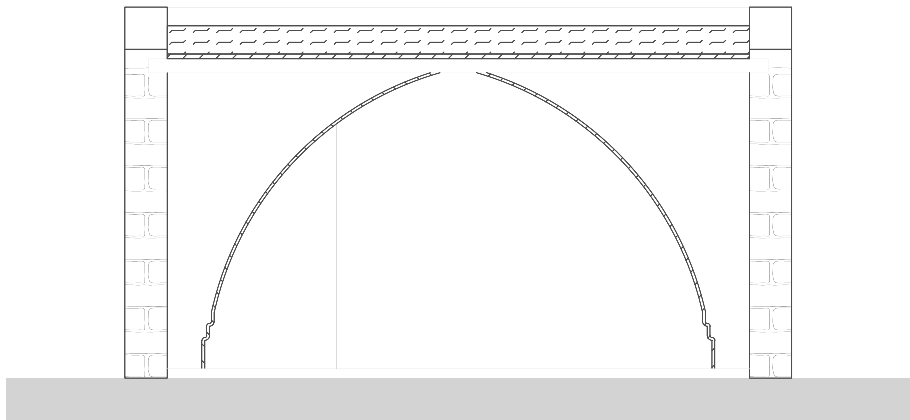
The building had a very good heating solution, like the majority of the buildings in mountain settlements. The arrangement of the buildings, connected to one another, acted as thermal storage units. Additional, heating and heating storage was also obtained as the building was partly underground. This meant that only a few surfaces were not protected from the cold. Due to the building's south-eastern orientation, maximum heat molecules were obtained. Further, the dense structure of the building reduced surface area and subsequently heat loss. The walls were 70 cm thick of limestone, which stored heat. The roof was made of wood, which also helped maintain the heat in the building. Another energetic concept was that the thermal energy was distributed to the body of the building through the orientation of the air and was indirectly stored there.




Ill.44 Site Plan



Ill.45,46 Ground Floor Plan & Front View

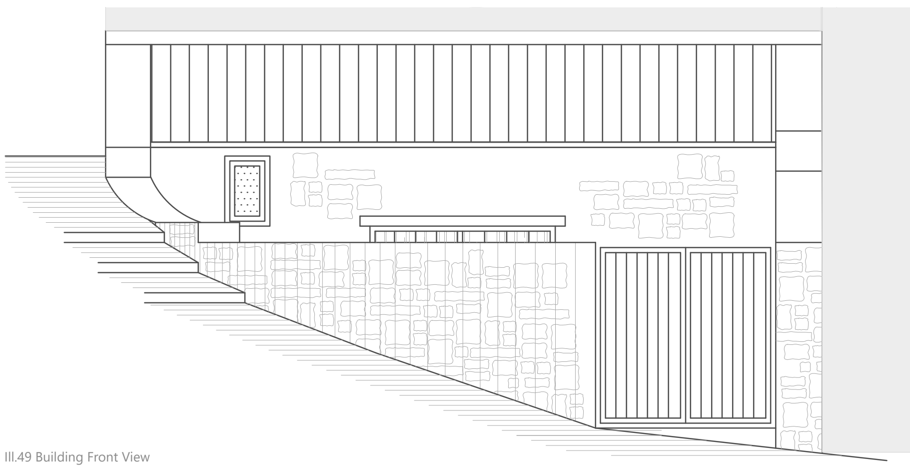


Ill.47 Section

# Ventilation & Cooling

The wind in mountainous Cyprus settlements is mostly north-western and the orientation of the building of interest was south-eastern, this meant that the facade with the openings was in direct contact with the wind. Despite the small openings of the building, the air was evident during the summer months. In addition, an assumption was made that probably several plantings and stern in the garden, were found in the ruins. This vegetation did not only act as sun protection (against overheating), but also cooled down the building. This combined with the liquid and air elements of the house ensured that the house was effectively ventilated. The inner part of the house had an additional protection from the arch for shading and cooling. The openings were protected from the sun by the utilisation of folding shutters.

Ill.48 Building Illustration



Ill.49 Building Front View

Ill.50,51,52,53,54 Building Illustrations

# Analysis
# Bioclimatic Traditional Residence in Limassol

Limassol is the second largest city in Cyprus and the southernmost city in Europe. It is located in the southern part of Cyprus, amphitheatrically built on the bay of Akrotiri between two ancient cities: Amathunta in the east and Kourion in the west. The development of the city is intercepted by the British military base in the west, so the city spreads to the east, with sandy beaches on the coastal front.

The building that is to be explored in this section dates back to the British occupation in Cyprus. This is evident as classical elements of the building, position it historically at that time-period. The building was in uninhabited and abandoned condition.

## Position

The building was located in the city centre of Limassol in an urban settlement. Only the front view had no other buildings attached to it and was relatively close to the sea. This house had an L-shaped courtyard.

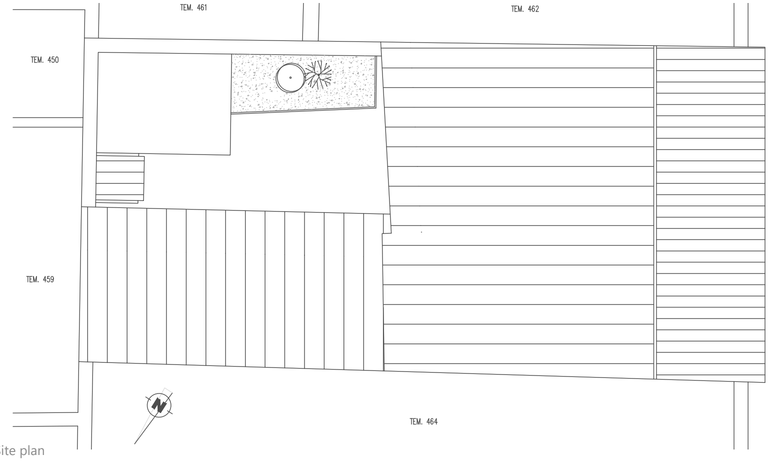
## Lighting

The front view of the building was in the southeast, which meant that this side had the most sunshine and therefore the most windows. As an outcome of the neighbouring buildings, which shared the same wall, there were no windows on the right and left side. Thus, the rest of the light came from the courtyard. As the house had an L-shaped formation meant that almost every room was in contact with the courtyard, in addition to the openings that had a view of the courtyard enable extra light to enter the interior. There was also a semi-interior space between the courtyard and the rooms, which had a similar functionality of Iliakos.

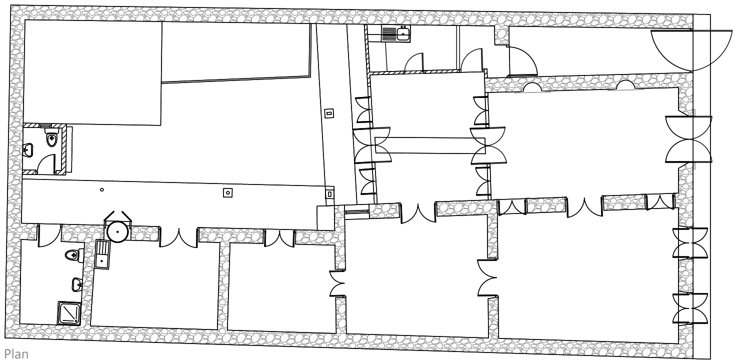
## Heating

The walls were made of 70 cm limestone and the roof tiles of clay. Both materials have absorbing functionalities and stored the sun's rays in the house. They were covered with coloured plaster to protect the walls. As we have prior discussed, the colour of the walls play an important role in the heating concept. The front view of the house had an ochre, yellowish colour to better absorb the sun's rays. The other ochre room was in the central main room, which was mainly used in winter. The colours selected in the above two sections enabled maximum heating molecules to be stored. The northern facade of the house was the coldest area, it was protected from the wind by the neighbouring buildings, and the semi-interior space which acted like Iliakos helped the building absorb as much heat as possible.

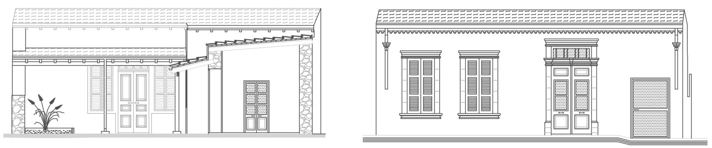

Ill.55 Building Illustration



Ill.56 Site plan


Ill.57 Ground Floor Plan


Ill.58 Section


Ill.59,60 Section & Front View

## Ventilation & Cooling

The city is close to the sea, which meant that the cold air which came from the sea helped cool down the city in the summer. The buildings were close to each other and on the roadside, thus they had maximum shading potential. The narrow streets helped to cool the buildings, as the area was narrow and the outside temperature of the building dropped. The semi-interior space which acted like Iliakos helped the cold air to enter the house, and since all the doors and windows were in one axis, the air flowed through the whole building. All the rooms were in direct contact with the outside courtyard, thus enabling the air to flow through the windows in the whole house. Iliakos and the folding shutters also helped to protect the building from the sun, not overheat in the summer months and remain cool. Another characteristic took into account was the vegetation of the outside courtyard. As an outcome of the greenhouse effect it absorbed the sun's rays in the summer and helped to cool the building. All the rooms were in contact with the outside courtyard ensuring that the air was transported into each room.

Ill.61,62,63,64 Building Illustrations

# Optimization

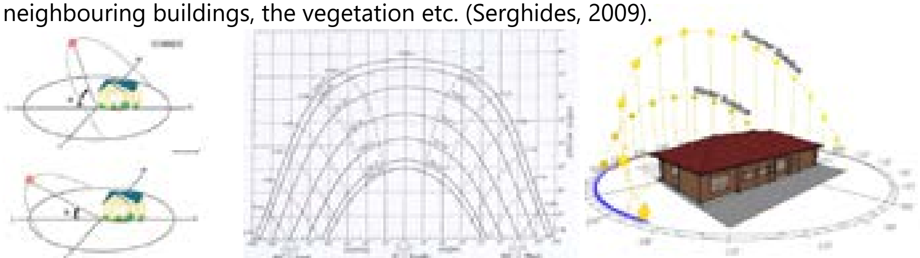
The climate of Cyprus is mainly hot and humid in the summer, while in winter it is rainy and the predominant wind is usually northwest. Cyprus is affected by the climatic conditions prevailing in Europe and Africa, with the result that the climate does not belong to a specific category, in contrast it is considered to be complex and difficult to define in one climatic type. Coastal cities are characterized by humidity especially during the summer season, however, due to their proximity to the sea, they tend to maintain their temperature better during the whole day.

The primary objectives of architecture are to create the right conditions for a comfortable microclimate, and to protect against unfavourable conditions. The Mediterranean traditional architecture is well-diversified in each region, which depends on its topography, morphology, altitude and the layout of the area with mechanisms suitable for dealing with external conditions, but with a significant difference in the quality of the interior by the today's data, so the building shell is an important regulator of the indoor thermal comfort of the building, protecting it from outside climatic conditions. The building design strategies and, in general, the quality characteristics of the shell are formulated with the main goal of consuming less energy and thus ensuring thermal comfort. In order to be able to exploit the natural parameters that are generously offered by nature they should be studied in detail.

## Solar-Solar Power & Solar Map

Cyprus is a Mediterranean island with the main energy renewable energy; the solar energy. Solar energy contributes around 4.5% of the total energy of the country and is mainly used in the domestic sector (93.5%) for the production of hot water. While at the same time it covers 50% of the hotel facilities. The latitude of the island is 34 ° - 36 °, during winter the sun rises southeast, and it sets northwest, marking a 120 ° course (azimuth angle), while in the summer this course from sunrise to sunset is 240 °. The solar radiation on the island is the main renewable energy source and given the above information, the Cypriot architectural model should exploit solar energy to a so that natural lighting and heating is provided.

In order to achieve unimpeded sunshine in the buildings, especially for the winter season, the basic requirement is the study of the solar map. The solar map determines the location of the sun at any time of the day, usually every month on the 21st of the month, according to the angles of azimuth and height (angular distance from the equator) (Kalogirou, 2009). On the basis of the solar map a shadowing profile is created so that it is known for what hours the building will be shaded depending on the obstacles surrounding the building such as the morphology of the plot, the height and size of neighbouring buildings, the vegetation etc. (Serghides, 2009).



Ill.65,66,67 Sun Path & Solar Map



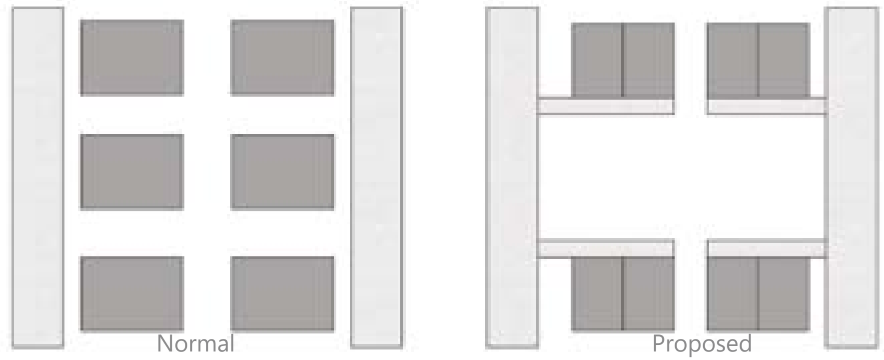
## Solar-The Orientation of the Road Network

In an urban context the sun plays a crucial role as it influences all the bioclimatic features of the settlement such as road network. The design of the road network is a key element of city planning strategy. Thus, the system of primary and secondary road axes in a settlement is one of the main elements of urban planning and constitutes the framework for the development of building blocks and hence of building form and the open spaces. Thus, in addition to the better organization of traffic, each architect should also take into account the access of the settlement to the solar resource.

One of the ways to ensure the correct orientation for the optimal sunshine of the buildings is to arrange the main road axes along the East-West axis in order to achieve the orientation of most buildings towards the south. However, in many cases this is not possible, for example in cases where the topography is influenced by the contoured curves.

If the various local constraints impose the orientation of the main road network on the North - South axis, it is necessary to re-locate the buildings in order to get the required solar access. One way to apply the correct orientation of the buildings is a suitable combination and landscaping of the sites.

For example, two adjacent north - south sites can be redeveloped, resulting in the two neighbouring buildings being oriented to the south enjoying the maximum solar gain without creating any shadows. Also, one settlement can have buildings of different height and size, which means that if they are placed correctly could help even more to get the maximum solar gain.



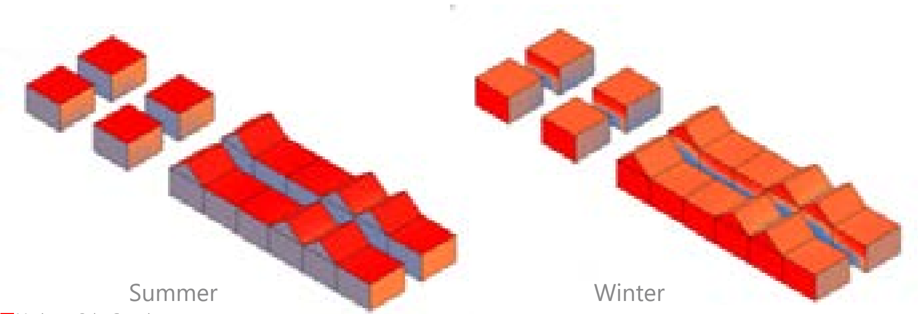

Ill.68 Buildings Orientation in the Road Network

Ill.69 Road Collage

# Solar-Solar & Heat Analysis

This section will aim to find the best orientation of a town and the distance of the streets and the building array of the houses, to have the optimal solar gain throughout the year.

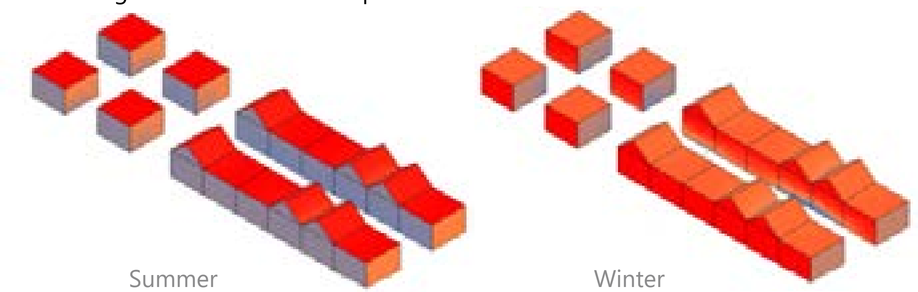
In Cyprus and other Mediterranean countries, there is one particular reason for building houses in urban settlements which shares at least one wall. The reason is that if two buildings share a wall then the wall or surface does not lose heat and enables the structure to retain the heat. As we can see in the illustration below (Ill. 70), the individual houses lose heat to the two sides, due to having more surfaces exposed to the environment. In contrast, the attached houses have the ability to retain the heat as an outcome of their connectivity, (Ill. 70). Also, the solar radiation is different in the summer and winter which subsequently influences the thermal comfort.



Maximum Solar Capacity
Minimum Solar Capacity
Ill.70 Solar Analysis

This analysis will compare the difference between the street distance in association with heat and light. The road between the below buildings is ten meters in comparison to the above illustration which was five meters long, both buildings in the illustrations are 10 meters high. Outcomes of the below analysis demonstrated that during the winter season where the sun is low, the façade of the building is colder and has greater shadow capacities. In direct contrast, when the road distance is 10 meters long, the shadows are shadows are reaching just the lowest point of the façade (Ill.71) .

In comparison, during the summer period as the sun is higher, the sun rays reach the rooftops rather than the façades; hence this as a result the shadow is less evident as it is closer to the building which produces it. Therefore, making no specific difference if the building is five or ten meters apart from the road.



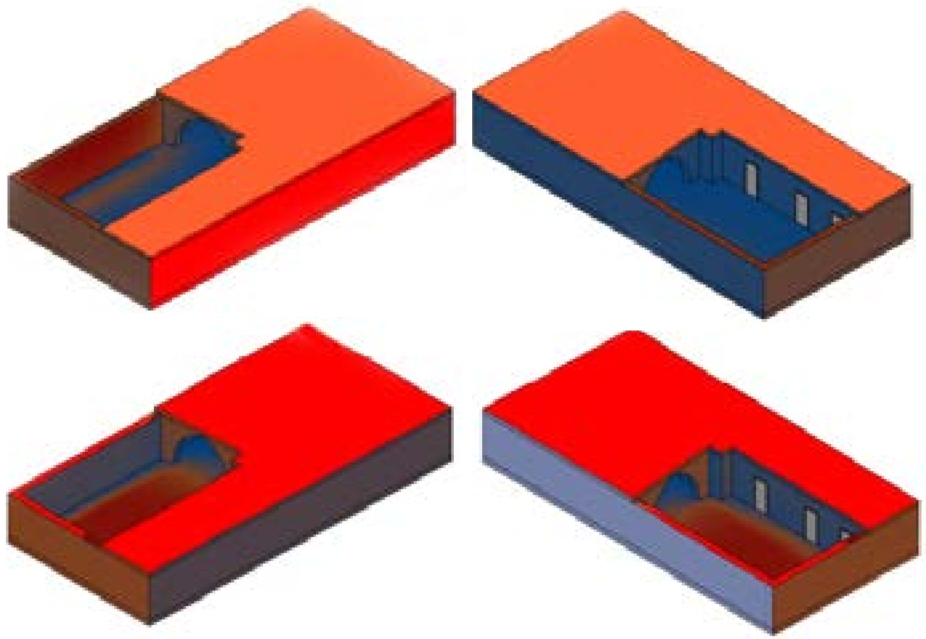
Maximum Solar Capacity
Minimum Solar Capacity
Ill.71 Solar Analysis



# Solar-Orientation of the Building within the Site

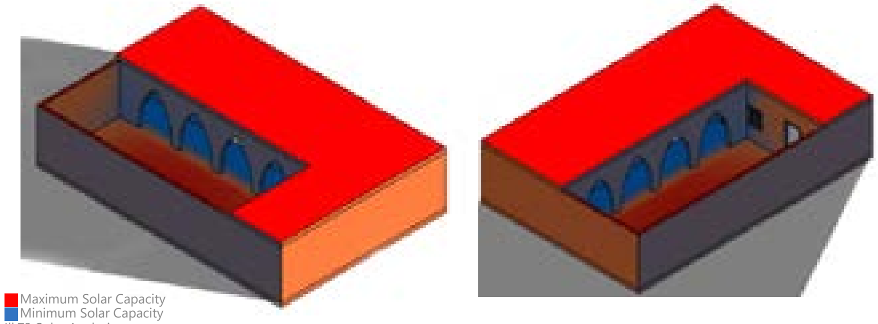
In order to have a complete view of the solar analysis an examination of some principles that are in the context of a house need to be made. The first is the orientation of the building. The term "orientation of a building" means the orientation of the main face of the building, and to its extent the main openings such as windows and glazing, in the external environment.

The Cypriot citizens built their houses with a south/north orientation in order to maximise the use of sun. A solar analysis with an example house is created in order to check how the sun responds to the orientation of the house. The first pictures are oriented in East/West and the yard receives minimum amount of sun which means that the sun point of the yard is lost. On the other hand in the next figures that are oriented South/North the sun rays are working better on the yard and in general in the whole house.


Maximum Solar Capacity
Minimum Solar Capacity
Ill.72 Solar Analysis

In the northern face of the building the sunshine is missing so it can be used for functions such as stairwells and auxiliary spaces or, more generally, for areas where solar radiation should be avoided. In addition, if the taller buildings are on the north side of a road and the smaller to the south then this eliminates the shadows to the smaller buildings as there are not enough surface interferences and thus ensuring more sunshine.

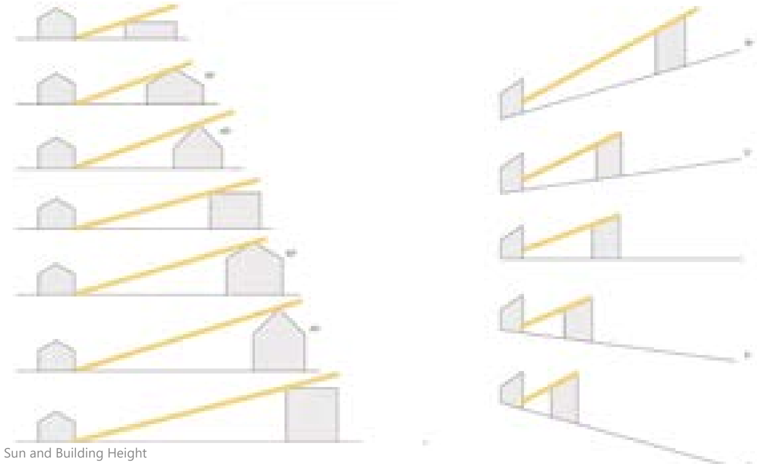
The formation of the house in association with solar energy was also analysed. The below Illustration (Ill.73) examined whether elongated and narrow houses have greater solar potential than wider and smaller houses. Outcomes of this analysis demonstrated that the difference is not significant. Thus, theoretically one could argue that both house forms could be utilized in an urban context with a similar sun potential.



Maximum Solar Capacity
Minimum Solar Capacity
Ill.73 Solar Analysis

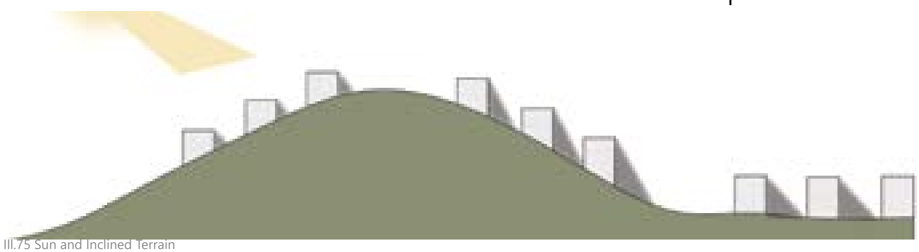
## Solar-Town Network,Geometry and Topography

The width of a road, its orientation, the distance of it and the heights of buildings can play a particular role in increasing the area's solar gains. In the illustration (Ill. 74) below it is evident that the higher the opposite building is, the bigger is the width distance that the road must have, in order to ensure sunshine, during the winter.



Ill.74 Sun and Building Height

On the other hand, in an inclined terrain, the opposite occurs. If a settlement is located on the slopes of a hill or mountain, a solar gain problem can be observed on the northern side of the settlement, since the shading caused by some buildings has a larger extent and thus creates a barrier to the unhurried solar gain of other buildings. On the south slope of the hill there is limited shade. Solutions for this issue, aiming at optimal sunshine, are the placement of building blocks in the shape of a checker-board on the northern side and more dense construction in series in the southern part.



Ill.75 Sun and Inclined Terrain



In conclusion, the planning parameters that affect the sunshine of an open space are the orientation, the inclination and the intersection of the surrounding surfaces. The orientation of a surface and its slope to the horizontal plane affect the intensity of the incident radiation, but also the possibility of shading from adjacent surfaces. Regardless of orientation and gradient, the shading of a surface depends on its geometrical relationship with adjacent surfaces, the latitude of the site, the time of the year and the time at hand. Given the latitude and atmospheric conditions, the orientation of the city's streets and their cross-section are the main regulatory factors of sunshine.

## Solar-Passive Solar Heating

Achieving the desired temperature inside the building is primarily based on the shell, so that the thermal comfort is maintained according to human activities. Solar energy is crucially important but when it is most needed it is often incomplete. The bioclimatic shell is what will provide the desired temperature, thermal needs when the incident solar radiation is minimal and the cooling needs are maximized when the sun's rays peak. Therefore, a system is needed to store heat when it is in surplus to expel slowly when the internal temperature begins to fall and solar energy does not exist without the use of mechanical equipment such as fans, air conditioners and heating. For space cooling it is necessary to store cold amount at night for use on the day (Kalogirou, 2009).

Thermal comfort is directly related to the thermal inertia of the shell, this means, its ability to store and maintain heat during the winter while at the same time resisting its storage in the summer. The materials used in such buildings are heavy and solid because they have the capacity to store more heat than the lighter ones. It is no coincidence that in the traditional Cypriot architecture the use of the stone building offered the appropriate thermal insulation. Today thermal insulation is preferable to the outside of the wall due to the strengthening of the housing resistance to the climate change inside.

The heating and cooling strategies of a building mainly concern passive solar heating systems, i.e. sunlight systems, Iliakoi or greenhouses. To cool the building, the most effective systems are sun protection and natural ventilation.

Ill.76 Heating Strategy

## Solar-Unhindered Sunshine

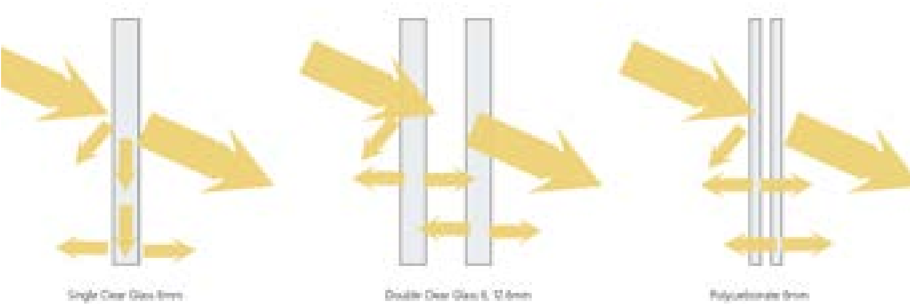
The bioclimatic building has unhindered sunshine all year round, as well as a proper shading of its transparent elements and openings in the summer. For modern bioclimatic buildings, it is important that they are built in the Northern part of the available plot so as to ensure unimpeded sunshine in the winter and to limit the possible shading from the construction of other future buildings. The topography, the height of the adjoining buildings if any, and the perimeter vegetation must be taken into account.

The shading of a building is achieved by the perimeter buildings, the distance between them, the latitude of the area and the vegetation, but all the above are influenced by the seasons and the different course of the sun. The obstruction of the solar incidence and the areas where the building is not shaded are presented with the help of analyses and simulations, thus facilitating the architect in the design of the building and the placement of the necessary elements that make up a home in the most suitable place.

## Solar-Sun & Glass Protection

Passive heating systems use extensive glass protection to the south to collect solar energy. Appropriate glass panes are used which permit the influx of visible radiation while being impervious to thermal radiation, i.e. infrared. Passive systems are differentiated according to the way of storage and distribution of heat over a long period of time and its ability to perform with time lag when the temperature of the outside environment is reduced.

The total solar benefits depend on the element’s material (thermal capacity), the surface, the angle of incidence of the solar radiation and the given radiation available depending on the topography, the morphology of the area and the shading.

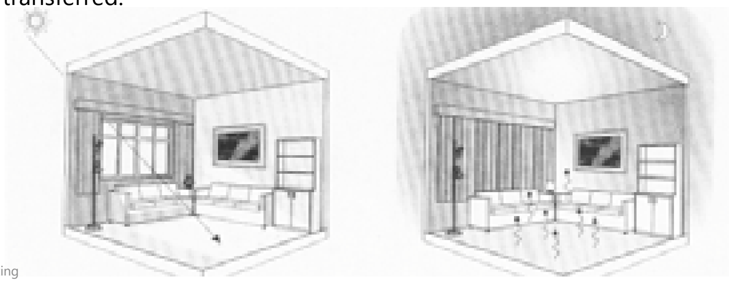


Ill.77 Glass Types

## Thermal - Solar Gain & Thermal Comfort Natural Distribution

The ideal thermal comfort is provided to the building with the passive solar energy being stored in the building and re-emitted inside during the night when there is not solar gain. This does not happen easily when the building is oriented to the north but can be achieved by physical means.

In general, walls with a thermal mass need to be placed in the building so that the heat that is retained during exposure to the solar radiation to the rest of the building is slowly transferred.



Ill.78 Solar Heating



## Thermal - Thermal Circulation inside the Building

The heat cycle takes place when the air is warming up which reduces its density and rises upwards. In this way, the heat generated by direct solar radiation is distributed into colder zones of the house. Motion is created between direct irradiating surfaces and surfaces that do not receive solar radiation and is controlled by openings windows, doors etc.

## Thermal - Reduce Transport Losses

The heat loss from the building is due to the difference of temperature inside and outside the shell and the thermal resistance of the material from which it is made. The most common method to reduce thermal conductivity is by adding thermal insulation to the building shell. Another way is to create a more compact building is to minimize the exposed area. It is desirable to place obstacles such as aluminium foil behind the radiating surface and then glass, so as to limit the heat transfer.

Proper thermal insulation of the building minimizes heat loss in winter, limits the thermal bridges, improves thermal comfort, eliminates the risk of condensation and mold appearance, and reduces the operating costs of a building. At the same time during the summer season the building shell overheating is reduced, and the refrigerant loads are significantly reduced.

## Thermal - Thermal Insulating Materials

Thermal Insulating Materials Are Classified Into Four Categories:

- **Inorganic**: Synthetic fibreglass, mineral wool, foam glass, etc.
- **Organic:** Synthetic expanded polystyrene (EPS), extruded polystyrene (XPS), polyurethane (PUR)etc.
- **Natural materials:** Wood wool, cork, cellulose flax plates, cotton, sheep wool, pressed straw etc.
- **Heavy thermal insulation materials:** Concrete, perlite coatings, heat-insulating bricks, lightweight concrete blocks, lightweight concrete etc.

## Thermal- Ventilation Issue

Over the last 15 years, however, many cases of asthma and skin diseases have been reported in humans due to the current way of building. The cause is the poor ventilation of the building resulting from the installation of heat-insulating materials such as extruded or expanded polystyrene within the gap between the masonry with lack of perspiration and insufficient ventilation of the interior. This can be reduced if ecological or biological materials are used, increasing the level of bioclimatic design a building can have. The natural materials mentioned above together with the recyclable bottled material are resilient and breathable materials which are water repellent materials while absorbing moisture.

## Thermal- Thermal Insulation

The thermal insulation that needs to be done, especially on an island like Cyprus, is not always based on a fixed method. Over-heat insulation for a Mediterranean climate is unnecessary and uneconomical. External thermal insulation is the predominant method for housing, as the moisture content of the wall is reduced, and less glacier damage is achieved.

Another element that is important to be heat-insulated in the outer shell of the building is the roof. In the winter, the hot air rises and if it encounters a cold ceiling. It will cool down and fall again, this time cold, and thus creates a heat loss cycle. In the summer, it overheats and affects the temperature of the entire building. In the case of the roof, it is important to choose the appropriate thermal insulation to avoid water vapor. In Cyprus, the best thermal insulation is made externally. In the case of an inclined roof, thermal insulation is done with a gap for ventilating the heat gains from the roof and the walls.

## Thermal - Using Temperature Differences

When the temperature difference between the interior and exterior increases the heat transfer and heat loss from the building grows.. In order to achieve energy-efficient design, the architect is required to design the building with the largest surface in the south and as small as possible in the north. In accordance to the solar map that was discussed in a prior section, in Cyprus the solar power is at maximum levels in the south in comparison to the north.

In general, the design of the building requires the proper organization of the rooms. The rooms that need more sun should be located on the south side of the building while the rooms which are not used directly such as garages, storage areas, stairs etc. to be placed on the north side of the building in order to act as heat regulator spaces. The spaces that will be thermally insulated are the ones inside and the insulation is made on the side that receives the building the heat. The rooms on the north side can also isolate the heat inside the building by creating a greenhouse effect (Goulding et al., 1992)

## Thermal - Color, Building Shading & Cooling Conditions

Light colored painted buildings have the ability to reflect large amounts of solar radiation. On the contrary, dark-colored outer walls, resulting in the storage of heat added to the interior of the building.

Summer in Cyprus and the Mediterranean countries in general, the meridian sun is high and any shelter protects the underlying space from the hot sun. The best shelters are those that are complemented by plants, to allow air to circulate between them without entrapping them. The advantage of the plantation is that they let the winter sun penetrate and heat the space while in the summer they cut off the sunlight leaving a cool breeze.

The summer sun in Cyprus mainly affects the roof of the building on the eastern and western sides. The idea of forming an umbrella above the building prevents the solar beam from reaching the building while allowing the air to circulate creating a semi-open space between the building and in the protective element, suitable for the various activities of the tenants.

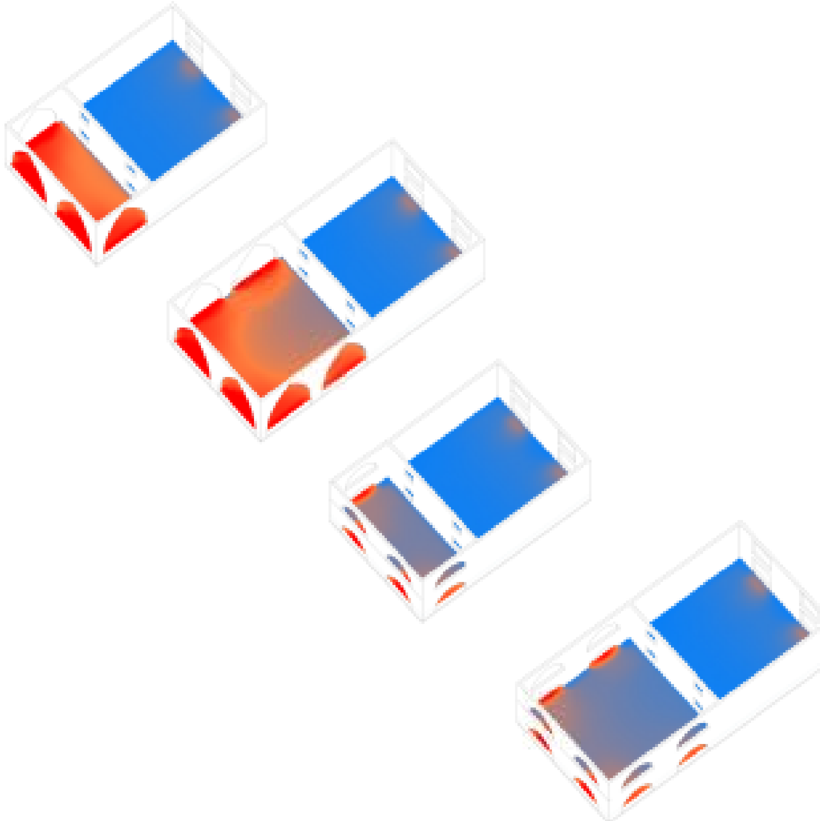
Movable sun protection features have the advantage of daily control, but user occupancy or electronic adjustment according to sunshine. The movable shades can be in the form of awnings and shutters. They can be closed at peak hours and their construction allow ventilation and do not completely depress natural lighting. Another way to receive optimal shade is the Iliakos. There are a lot of variations of Iliakos that one can analyse. In the following section different styles and distances of Iliakos are goring to be examined in order to identify the best morph.

Ill.79 Umbrella Principle

Ill.80 Movable Shades

Ill.81 Colour

The double Iliakos(2 small arches on top of each other) fails to work as it does not provide light in comparison to the  larger iliakos. Comparing the 2 distances (first one being 5m and the other 10m), it was evident that the best iliakos is the 5 meters long since it gives the most possible light.



Maximum Solar Heating
Minimum Solar Heating
Ill.82 Thermal Analysis

## Air - Ventilation & Wind Protection

The air permeability of a city is inextricably linked to urban planning parameters. The various urban microclimates that are created are very complex because of the many factors that affect the movement and the flow of wind. Urban parameters that affect the movement of the wind in the urban fabric of a region are (as in sunlight - sun protection):

-The orientation of the various surfaces (buildings, roads, free spaces, etc.)
-Density and building system of the urban area.
-The geometric form of the urban web
-The building and building parameters.



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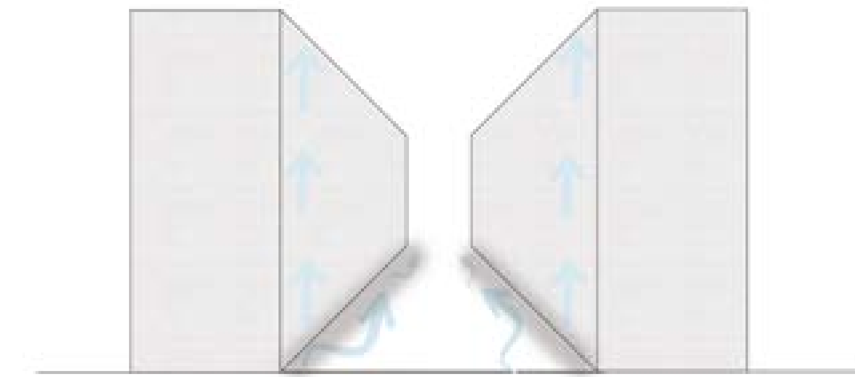
-The geometric form of the urban web
-The building and building parameters.

## Air - Wind Flow Parallel To Street Direction

The direction of the wind is parallel to the road axis with the flow being above the buildings. In this case the flow is parallel to the road axis except for the areas with vertical surfaces, where an upward flow of wind is observed. Thus, adequate ventilation of the road is observed.



Ill.83 Wind Flow Parallel to Street Direction

## Air - Wind Flow Vertically to Street Direction

The direction of the wind above the buildings is perpendicular to the road axis, so the flow depends on the geometric characteristics of the road.

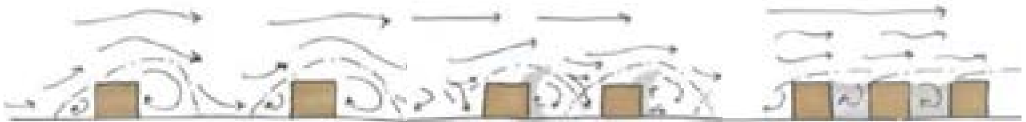
## Air - Wind Flow at an Angle In Relation to the Direction of The Street

The wind direction flowing over the buildings forms an angle to the road axis (this is the most common case in a city), then the wind moves on a helical trajectory both across the street and along the road at the same time. The wind speed at the height of the leeward building is higher than that of the windy building.

## Air - Aeration General Principles

Regarding the ventilation and wind protection, the general principles are the following. Buildings act as obstacles in the wind. The wind speeds in cities are generally smaller than in the open countryside. This reduces the diffusion of the thermal surplus, intensifying the urban thermal isle. It also has an impact on the dispersion of pollutants and hence on air quality and aeration of outdoor spaces and buildings.

Regarding the orientation of the road arteries and the layout of the building blocks, it is understood from above that in order to provide adequate ventilation to the urban fabric of a city, the roads must be parallel (or almost parallel) to the direction of the wind. The main road arteries must, in other words, be geared to the prevailing winds (during the summer period) and the building blocks should be appropriately arranged. A case could be mentioned here: on a road with a continuous building system, the direction of the wind direction roads creates the most efficient ventilation



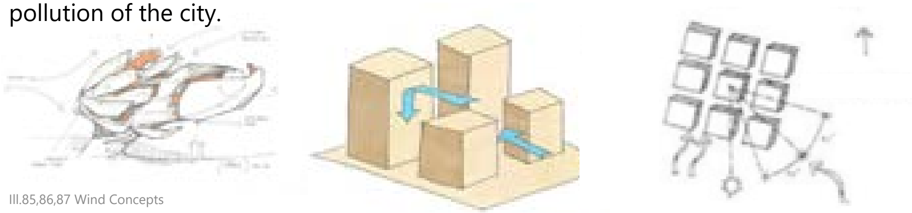
Ill.84 Wind Flow Through Different Distances of Buildings

Along with the measures that can be taken for aeration-damping, measures must also be taken to wind-protect the urban fabric from the winter winds. They may hit the urban area during the winter season or simply adversely affect the environment by swirling and unwanted speed.

In the hot and humid climates such as Cyprus, ventilation must be provided at all times with shelter from the north winds orientated East-West. Thus, together with the appropriate densification of the urban space and the placement of a high and compact building volume in the direction affected by the winter winds, we can achieve effective wind protection during the winter season.

Buildings act as windbreaks and as a point protect the outdoors. Transition spaces (pergolas, stoa, canopies etc.) of buildings can have a great positive effect if designed and used appropriately.

In conclusion, the most effective cooling - aeration of the urban fabric is achieved where the wind is parallel to that of the roads, since the air movement is freer. Also, when the streets have a larger width and the average height of the buildings is low, the urban fabric has good air-permeability and consequently the wind is running smoothly. So the pollutants, caused by the vehicles and the various man-made activities carried out in the city, escape to the upper parts of the atmosphere, helping to unload the pollution of the city.

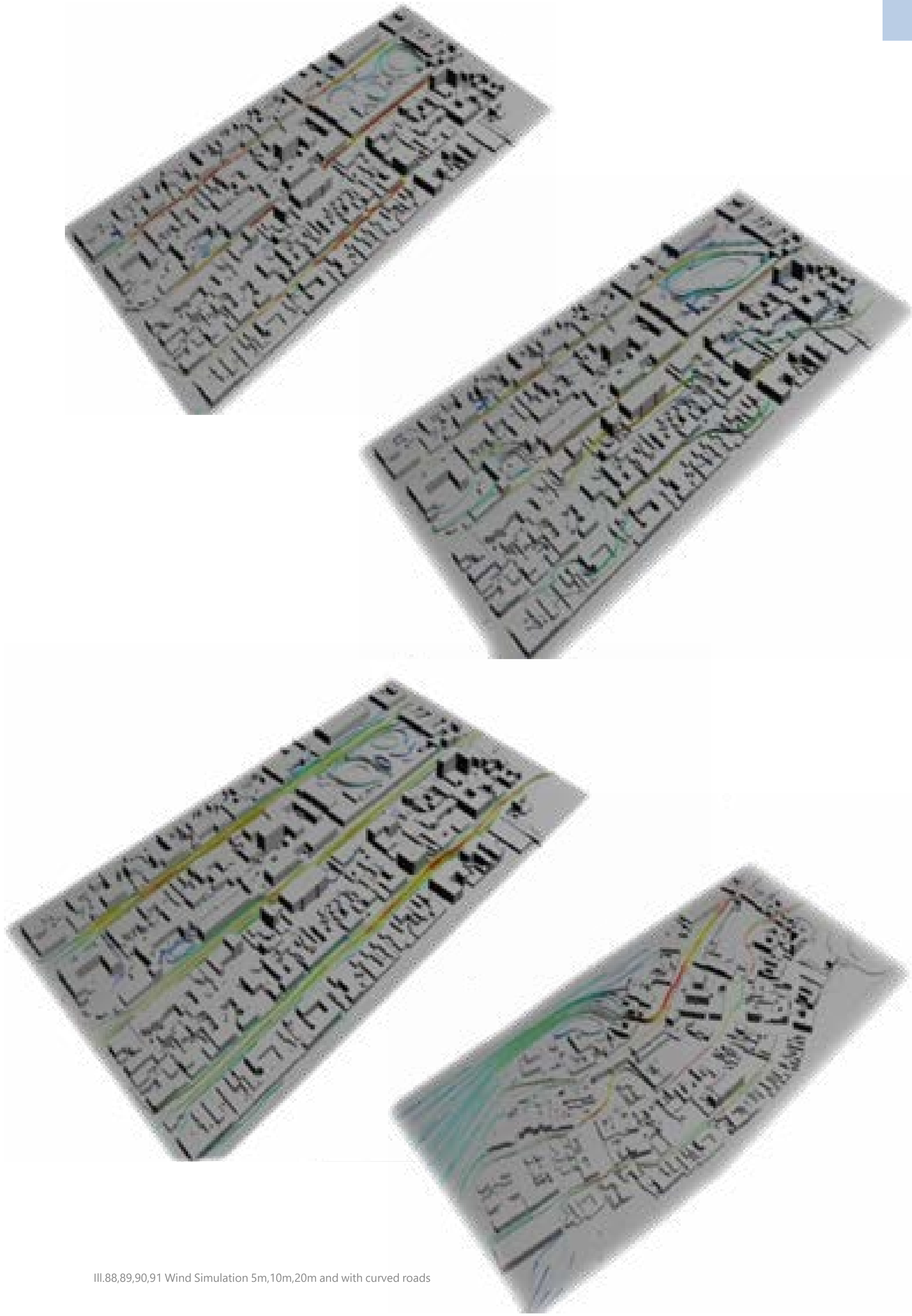


Ill.85,86,87 Wind Concepts

## Air - Urban Simulation

A wind simulation could be used in an urban context, in order to check how large the distance for one building to another or if orthogonal or curved curves should be used. The first analysis consists of a town part with different street width of five, ten and twenty meters. From this simulation it is noticed that the street with the optimal wind speed is between five and eleven meters with this distance the wind speed is between 1 m/s to 5m/s. Then a simulation of the same town part was carried out instead of utilising orthogonal streets, curved streets were used. From the below illustrations it is evident that the wind flows better in curved streets.





Ill.88,89,90,91 Wind Simulation 5m,10m,20m and with curved roads

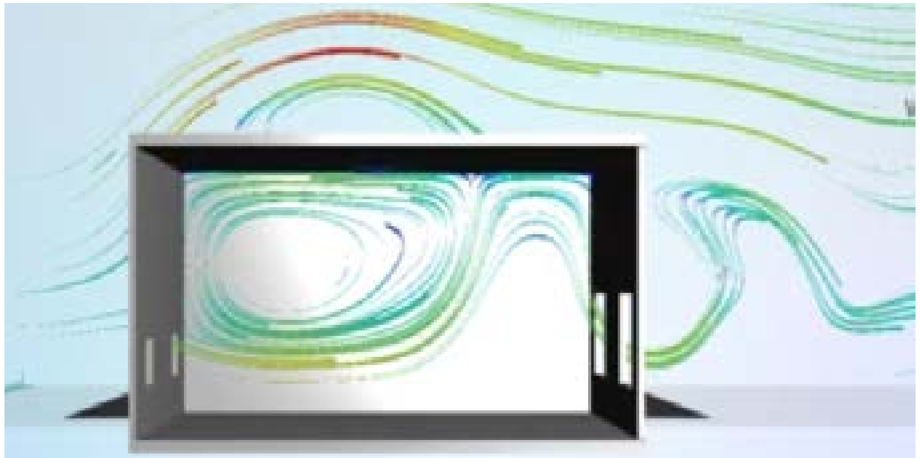
# Air - Exploitation of Wind Power for Ventilation

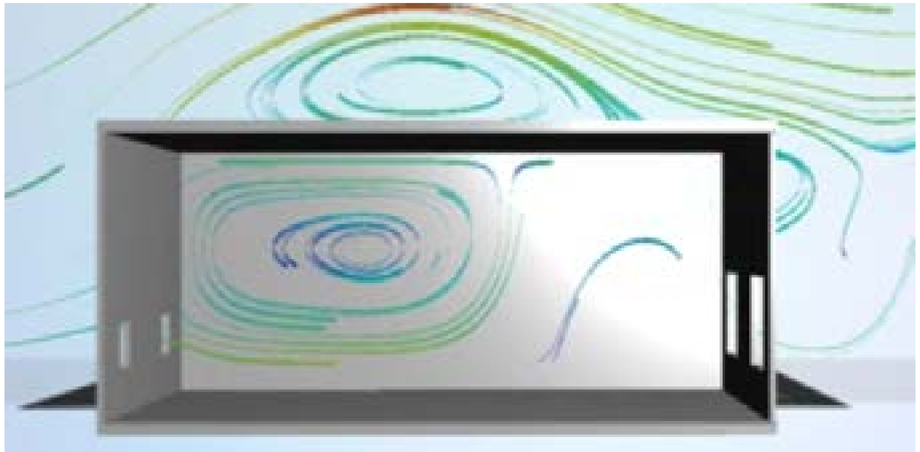
Cooling inside a building takes place as long as there is air in the building, which removes heat off the building. Air movement internally improves heat exchange and increases the moisture evaporation rate. Air moves from high pressure to low pressure areas. The ventilation of the building is proportional to the indoor and outdoor temperature of the building, i.e. if the outside temperature is less than the indoor temperature then the ventilation of the building can expel to the outside the solar thermal gains accumulated during the day leaving building with cool air during the night.

Where the window is placed refers to the general design of the building and the surrounding area. The hourly air renewal depends on the wind speed, temperature difference, orientation to the prevailing wind, dense arrangement of surrounding buildings, obstacles on the site, etc. To be efficient, ventilation requires openings distributed on the side of the building where there is the natural air and there are very few internal obstacles to prevent the air flow that is necessary for cooling.

In order to test some qualities of the air distribution in the building and see how to optimize them simulation will firstly need to take place. The general wind speed in Cyprus is 8.5 m/s, by running the analysis in a building with different measurements, enables us to observe the air circulation inside the building and use the best result. A simulation with five, ten, fifteen and twenty meters was conducted in order to check the air circulation.

The result is that the five meter was too short and twenty meter too long which resulted in the airflow not being optimal. It failed to create enough aeration in the building. Fifteen and twenty meters were too lengthy, as seen in the illustration (Ill. 93,94), because the air circulated only in one place and not in the whole room. Although, ten meters fitted quite well, it was not fully optimal, since even if the air circulated it could not reach the optimal air acceleration to aerate the area. Resulting in the air's speed to decrease whilst exiting the structure. Therefore the optimal length is between seven and thirteen meters, as the five and ten meters were found not to be adequate, and the 20 meters were too lengthy to offer air circulation in the room.





Ill.92,93,94,95 Wind Simulation, Venturi Effect 5m,10m,15m,20m

## Air - Chimney Effect as Air Circulation Technique

Another way to help ventilate the inside of the building is to cause the chimney effect where, of course, openings are needed at the top and bottom of the building. With this phenomenon, the hot air rises and escapes from the top of the building while the cooler air is coming from the lower openings of the building. Of course, the ventilation is achieved when the openings are vertical.

Ill.96,97 Chimney Effect

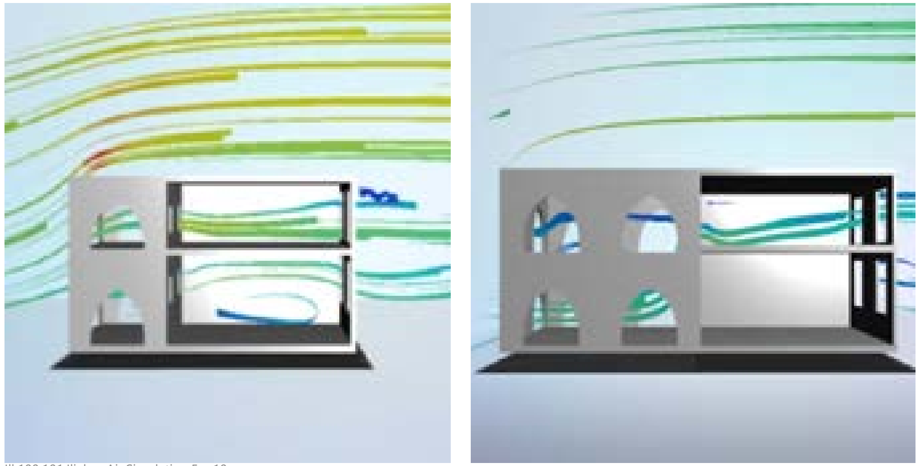
## Air - Iliakos as Air Circulation Technique

Iliakos is a very important element in creating a microclimate. The air analysis, shown below, was carried out to see how much was the distance between the wall and the Iliakos should be to create optimal air circulation. The distances of the below analysis were at five and ten meters long. From the analysis it was revealed that the best result is the five meters variation. In the 10 meters, the air entered the structure from the iliakos, and directly exited the room from the window due to high air acceleration prior being able to circulate within the given space. In comparison at the 5 meters, the air entered the structure from Iliakos, circulated and then exited the given space from the opening as not enough acceleration was created to have the same effect as in the 10 meters case.

Ill.98,99 Iliakos Air Simulation 5m,10m



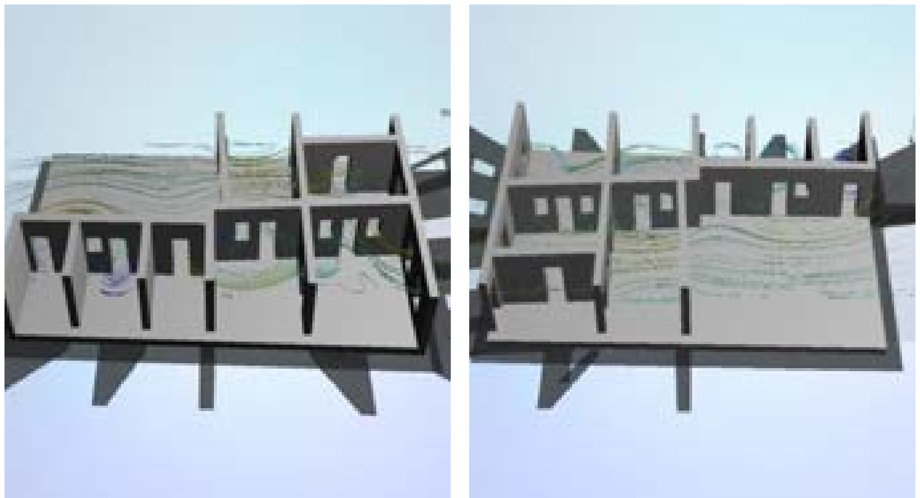
Next analysis was carried out to examine the shape and form of Iliakos and the effects it had on aeration. The building was divided into two floors and two small Arches one on top of the other. Results revealed that at the 10 meters, the air circulated within the Iliakos and exited from the second floor window, hence the ground floor received no/minimal amount of air circulation. In contrast, at the 5 meters, the air had inadequate space to circulate within the Iliakos and hence entered to both the upper floor window and the downstairs window, enabling air circulation in both floors.



Ill.100,101 Iliakos Air Simulation 5m,10m

## Air - Windows & Doors as Air Flow Techniques

The windows and doors in the traditional houses were in the same axis for the wind to flow through the whole building. In order to check this principle, a simulation was run as seen at Ill.102,103. Results proved the above theory, that having openings in both axes, the wind flow carries through the whole building without any obstacle and exits from the end point opening, providing adequate air flow.



Ill.102,103 Air Simulation

# Vegetation
An important part of a town complex is the landscaped areas within urban fabric, i.e. "urban green", as well as the pine-covered areas surrounding the urban fabric, i.e. the "periurban green", which has a significant contribution to the city. The main contribution of vegetation is the improvement of the microclimatic conditions of the city and, by extension, the improvement of the climate.

Trees can play different roles, so planting must be taken very seriously when planning a design of a structure on a bioclimatic formation. Some of these functions are: providing sun protection to buildings and open spaces, reducing the temperature through evapotranspiration, noise absorption, pollutant filtration, and wind protection. In particular, vegetation improves the urban climate as follows:

Table 1 Vegetation in Urban Planning

| | |
|---|---|
| *-With transpiration, plants create increased humidity conditions in the atmosphere, especially in the summer months, reaching 5-8% creating a pleasant cool environment.* | *Protects from the wind and reduces the risk of frost in an area. Plants can be used to prevent, filter and lead the airflow, thus affecting ventilation.* |
| *Due to the diffusion of solar radiation from the foliage of trees, we have improved the light status of the area.* | *It has low heat capacity and thermal conductivity and absorbs much less heat during the summer months.* |
| *Continuously renews oxygen in the atmosphere. It is estimated that a spruce tree produces 1-3 grams of oxygen* | *With the shade increases the thermal comfort in the cities.* |

# Vegetation - Sun Protection
Vegetation is a natural solar control that blocks sunlight as well as reflections from various surfaces. The main factors shaping the shade formed by a tree are: location, density, foliage size and tree shape. Also, the type of vegetation, its durability, its height and its positioning depend on the movement of the sun throughout the year, as well as the number of trees in a region. Thus, using trees, maximum solar access can be obtained during the winter, while in the summer period satisfactory shading can be achieved.

Ill.104 Vegetation as Sun Protection

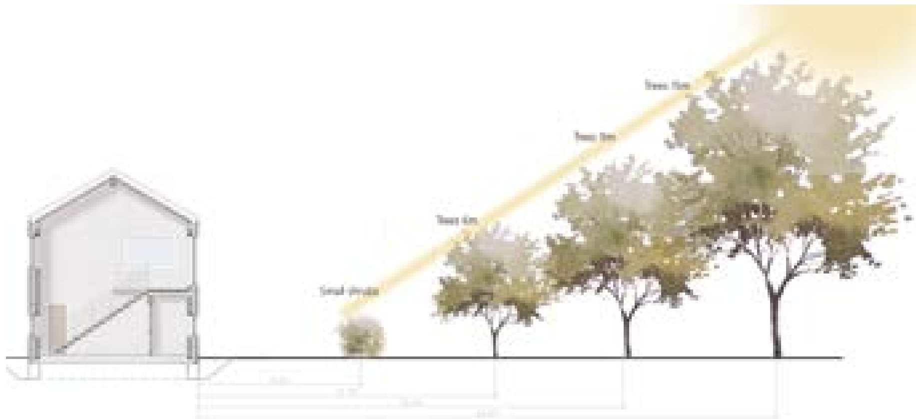


# Vegetation - Temperature and Humidity Equilibrium
Green spaces can make a significant contribution to controlling the temperature of urban areas during both winter and summer months. Trees absorb water, which evaporates through photosynthesis (evapotranspiration), consuming relative energy, and helps to cool an area. Maximum benefits can be achieved when considering the organization and placement of plantings, so that the airflow created by this zone removes the hot air and balances its speed.

# Vegetation - Wind Protection
Vegetation can significantly affect wind speed by reducing it. Thus, by grouping tree clusters, wind protection can be achieved in nearby buildings affected by winter winds, but wind re-direction is made possible when cooling is required.

Areas of low vegetation cause seamless ventilation and air permeability, while shrub areas prevent air flow near the surface of the soil.

# Vegetation - Bioclimatic Design
Vegetation also contributes to the microclimate of the house. The incident radiation in the building depends heavily on the trees or shrubs surrounding the building. Vegetation does not only interfere with solar radiation but also with the speed of winds directed towards the building. Trees offer year-round protection, and they prevent the sun during the winter along with providing better shelter in the summer and much less in winter. But even their bare branches can block the flow of the wind to some extent. The placement of trees around the building is not accidental as there is an optimal distance between them to achieve good ventilation.



Ill.105 Vegetation as Sun Protection

# Vegetation - Evaporation
Evaporation occurs when the water vapor pressure on the surface is higher than the partial vapor pressure in the adjacent atmosphere. If this surface is under a building or vegetation shade, this process improves. Evaporation is a process that is promoted in bioclimatic design to a certain degree both in human factor and in the building so that it does not create mold. Evaporative cooling techniques are separated into hybrid and passive. Hybrid techniques are based on equipment to provide cooling, while passive systems involve evapotranspiration through vegetation, fountains or small lakes.

## Vegetation - Green Roof

The green roof is a modern perspective in which the vegetation is not only on the ground but also applied to the roof of the building. The benefits are many, since it initially improves the microclimate of the urban environment. Allows energy savings during heating or cooling of the building at different times due to its thermal insulation properties. This also leads to a reduction in the temperature of the wider urban environment through increased planting. At the same time, it contributes to the better management of rainwater and the containment of suspended dust and other harmful atmospheric pollutants. The planted roof can also be offered as a place for entertainment and relaxation. A basic prerequisite for creating the roof is proper waterproofing and anti-radical protection

## The Water Element in Urban Fabric

Water elements in a city can complement the flow of wind and contribute significantly to the damping of the urban fabric, influencing local and wider microclimate. This is because water has a much higher heat capacity than all other building components used in a city. Typically, it has two to three times higher heat capacity than materials such as concrete, bricks etc.

A large area of water (eg. sea, river, lake) can stabilize the temperature of a city. At the same time, aquatic elements within the urban fabric, such as fountains, artificial lakes, streams, are an effective strategy for local (or general) improvement of the urban microclimate. This is due to the evaporation cooling that water surfaces can provide.

Generally, the process of evaporation cooling can describe as follows: Water absorbs most of the solar radiation incident to it. At the same time, evaporation from the surface of the water is activated, resulting in atmospheric temperature moderation. In the evening, the diffusion of stored energy compensates for heat loss through radiation and helps evaporation throughout the night. So, unlike the common building blocks of a city, the green and the water element play a very important role, since when heated they do not emit heat but cool the air

Finally, it must be noted that the effect of a water surface on the cooling is a function of its extent and its volume. Also, bioclimaticity and landscape aesthetics are enhanced using running water (waterfalls, fountains, jets, etc.) combined with horizontal surfaces. While combining all these with the flow of wind, the best possible result can be achieved, since the hot masses of the wind that flows can cool and cool parts of the urban fabric.



Ill.106,107,108 Water Element in Building

Ill.109 Water Element in Town

# Examples

This section will examine how some of those bioclimatic optimisation techniques can be utilised in modern society of Cyprus. The plans of both buildings can be seen below and include floor plans, views and sections and photographs.

## Bioclimatic Residence in Dali
## General Information

This building is a small home, designed by the Civil Engineer-designer Michalis Michael. The goal is to build a low-cost home in order to save energy while operating and utilize all the energy gains naturally provided in the area to create the right thermal comfort.

## Home Layout

The ground floor consists of the Iliakos, the living room, the kitchen, two rooms, a toilet, garages and warehouses. The house is to be built on the northern part of the site and has mainly south orientation. The indoor area is 109 m2 and the outside covered areas are 58 m2. On the south side are deciduous trees, while on the north side are shrubs and cypress trees. The entrance is located on the east side.

## Bioclimatic Analysis:
## Iliakos

This house has a solar room inspired by the traditional architecture of Cyprus, which is located on the south side of the building to earn solar gains all the time. The glazing of the solar room space is quite high, while its roof is independent of the rest of the building, it is made of glass and upper movable shades. These moving sun shades on the roof during the summer period have the ability to bend during the day to avoid direct vertical radiation and thus avoid overheating. At night, these shades can be opened to release the heat stored in the morning in the atmosphere to cool the building. In winter, these sunshades are inversely invoked by the summer, they have the ability to protect the shell from the rain and maintain the desired temperature level inside. The sun's rays at this time can penetrate directly to the room due to the sun's inclination, as opposed to the summer, so a mass wall (concrete) in the living room was placed so that it heats and exposes heat during the rest of the day. The solar room with the living room is separated by a moving inner partition glass and is used accordingly so as not to leave the temperature created to penetrate the rest of the building easily.

## Openings

The most openings in the building are on the south side, very few and small in the east and west, while in the north there is a very small window just for ventilation. This reduces unwanted radiation as well as heat transfer from the building to the environment. Also, the glass panes that are outside of the Solar room are heat-insulated, double-spaced and therefore with a low permeability coefficient to avoid overheating and direct radiation inside the building

## Wind Turbine

The wind turbine inside the building is an important bioclimatic element in modern architecture. This turbine has a glazing on the south face, a ventilator on the north, while the other two sides are closed.



In this way, in the summer, the small glass pane is covered by the protrusion without letting the sunlight penetrate it and heat the space. The building's internal air is heated and uplifted, having the opportunity to escape through the turbine fan, allowing the air to flow through the openings and exits from the stove giving cooler conditions to the building. In winter, the sun rays penetrate the glasshouse and hit a mass wall to offer more heating gradually, since it will slowly dissipate the heat inward while the ventilator remains closed.

## Housing-Pedestal-Ceiling

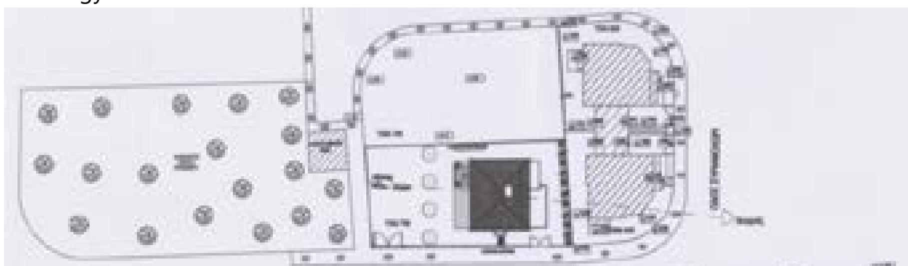
The shell of the building is constructed by adopting another element of Traditional Architecture, the plinth, building material that offers thermal insulation in the building and will be coated with thermal insulation for additional strength and thermal insulation. The building is protected from the northern, cold winds prevailing in the winter as the walls on the north side are thicker in order to reduce the heat transfer while there are two storehouses and the garage to reduce the losses to a greater extent. Also there will be no slope but individual foundations with the ground at a higher point so that the floor temperature of the building is closer to the soil temperature. Finally, the roof will be made with light-colored tiles to reflect much of the sun's radiation, especially during the summer season where the sun is perpendicular to the building and there is less burden

## Creating Microclimate

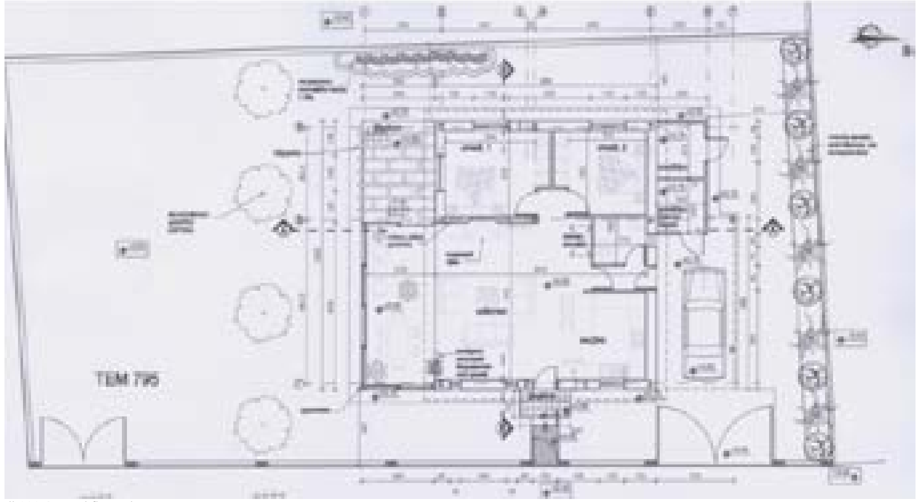
Another important element of this residence is the creation of an appropriate microclimate in the yard of the building so that the tenants enjoy mainly cool summer conditions. The veranda is on the south side and is shaded during the summer season by the vineyard, a part of the traditional heritage, which is designed to be on the pergola, while in the winter the vine shoots its leaves. It is also shaded by the deciduous trees that will be placed in the south (poplar trees). The additional element of dew is the fountain located in front of the west side terrace to take advantage of the western wind, which will rest on the water and then be fed with moisture and offer cooler conditions on the veranda. The vegetation in the building is completed using a thick barrier of bushes and cypress trees to cut the intensity of winter winds

## Mechanical Construction Elements

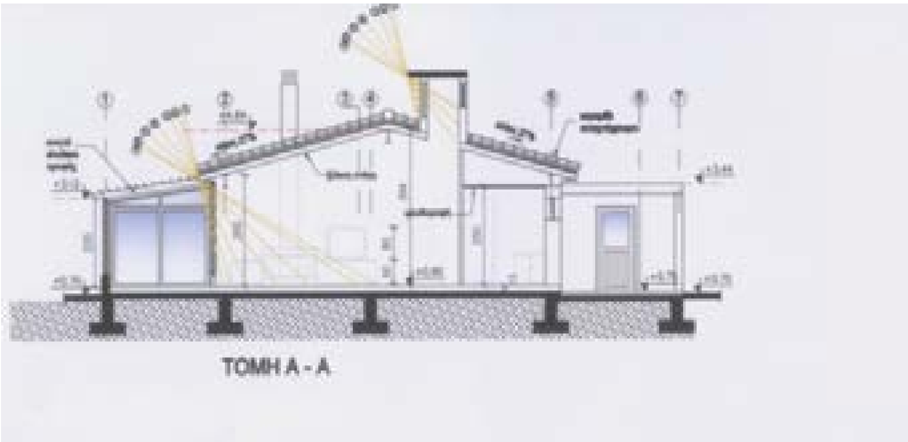
The building is designed to be a low-energy house for this purpose and the design requires some mechanical components such as an energy fireplace, solar thermal panels for water heating and photovoltaic panels. Traditional elements along with modern techniques are an appropriate design for building a progressive bioclimatic house that has many benefits to residents and the environment in general, saving large amounts of energy.



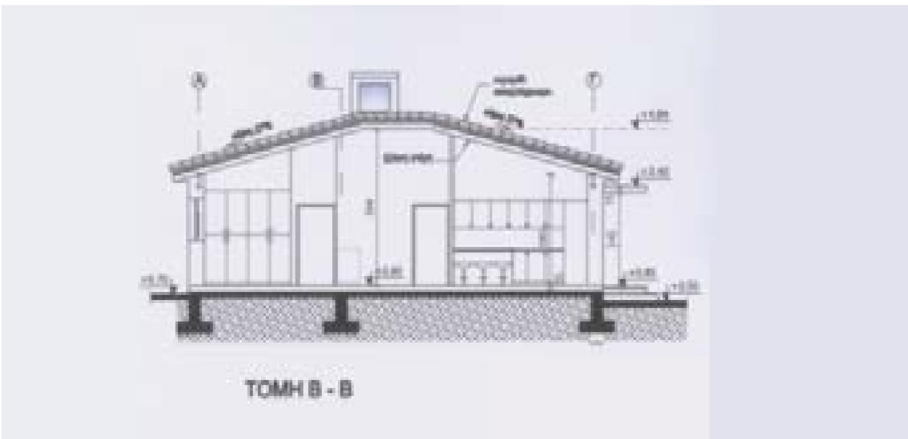
Ill.110 Site plan



Ill.111 Ground floor Plan



Ill.112 Section AA'



Ill.113 Section BB'



Ill.114 East View

Ill.115 South View

Ill.116 West View

Ill.117 North View

## Bioclimatic Residence in Dali 2
## General Information

The residence in Idalion is in a corner site adjacent to a public green space. The architects Yannis Agisilaou and George Kalavas adapted this house to the conditions of the area, while creating suitable spaces to meet the needs of a large family.

## Home Layout

The house is formed in the Γ-shaped space and consists of the "makrinari" and "Dixori" rooms, which come from the Traditional Architecture of Cyprus. The Dixori is the kitchen and the living room, while the backyard is the office, spaces that are distributed around the inner courtyard of the building, while the three bedrooms are formed on the floor. The area of the plot is 375 m2, the area of the building 190 m2 and 40 m2 of the basement.

## Bioclimatic Analysis:
## Orientation-Openings

The front facade of the building is located to the north while the inner courtyard is located on the south side. Most openings of the building are facing the inner courtyard in order to have the most sunshine light. Also, it stops the direct sunlight in the summer with suitably designed overhangs. Large opening are also on the north-eastern side, which would normally lead to thermal losses from the building, but in this case the area of the glass pane contains, from the inside, shades to stop further sunshine, for reasons of privacy but also to limit the heat that escapes from the inside of the building to the environment. The mounted glass panes are double coated with aluminium in their gap, which reflect the infrared radiation to the environment during the summer, while reflecting the thermal radiation coming from the inner walls back to the space.

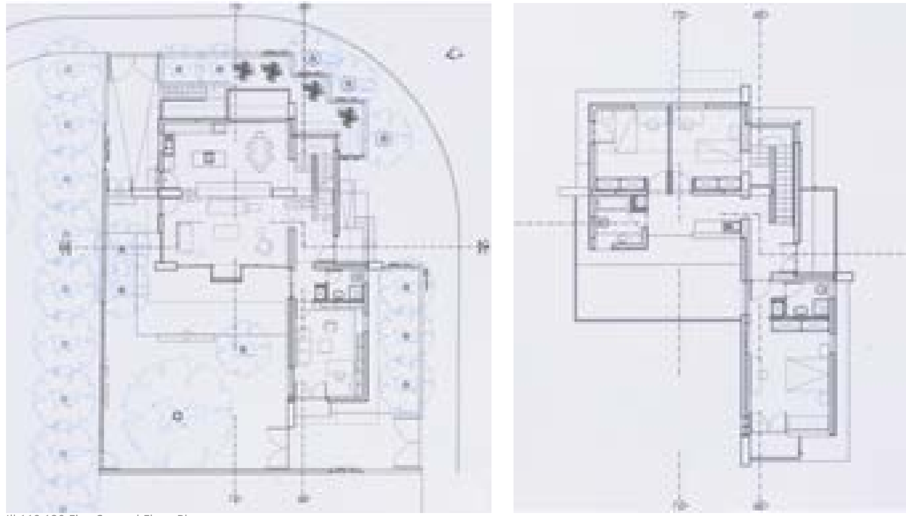
## Inner Courtyard-Vegetation

Traditional elements that make up this home are not only in the interior design, but also in the inner courtyard and in the vegetation. The interior courtyard of the residence, which face south, is suitable for creating a microclimate thermally comfortable to the occupants by placing vegetation, referring to a traditional inner courtyard. The vegetation on the west side, outside the fence, is densely made of pine trees and can protect the building from the frozen air while offering privacy.

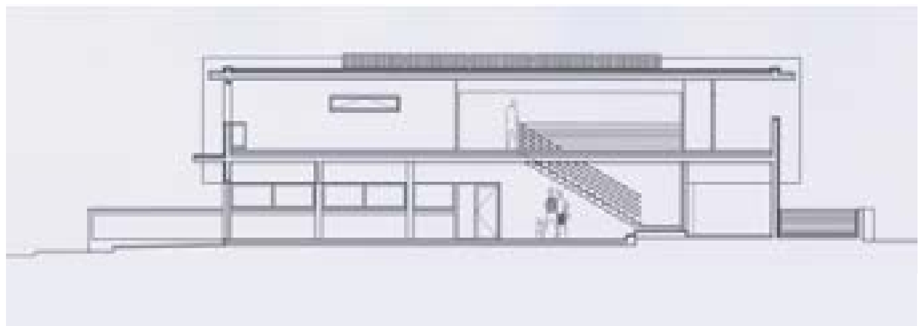
## Building Enclosure-Thermal Insulation

The building envelope is well insulated with 5cm of extruded polystyrene on the outside, and the same polystyrene is placed on top above the slab. The "fairface" walls are 40cm thick. These walls have the ability to absorb the radiation and emit heat later. Their outer side blocks the outside heat to penetrate the inside of the building while their inner side absorbs heat from the sun during the winter when the sun visors of the north-eastern glazing are open and re-emit it back into the interior. The colour of the house is white to reflect much of the solar radiation. This residence is the result of a combination of traditional and modern bioclimatic elements. The evolution of the experience and wisdom of traditional knowledge make the home properly shaped in this area, taking the natural features of the landscape to create the desirable living conditions without the need for mechanical engineering.

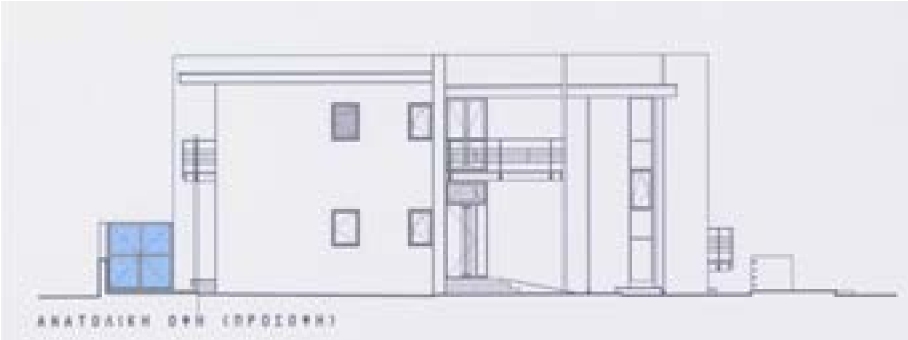
Ill.118 Site plan



Ill.119,120 First,Second Floor Plans



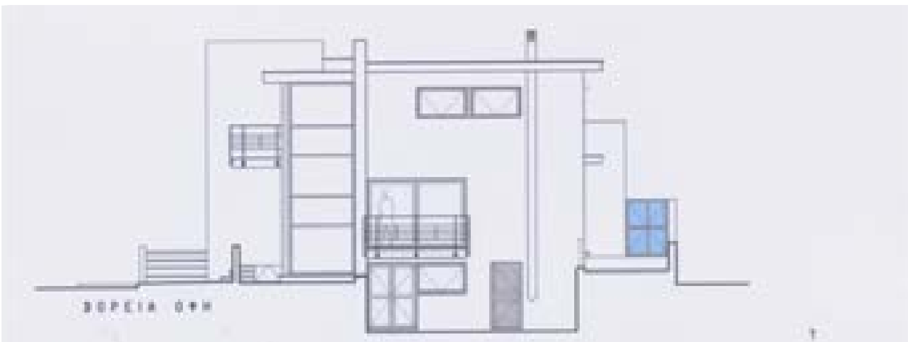
Ill.121 Section



Ill.122 East View

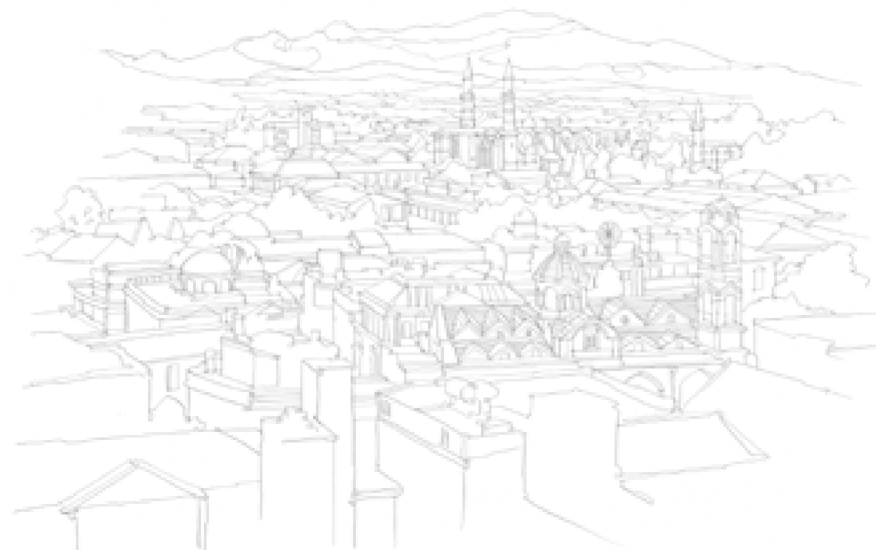
Ill.123 South View

Ill.109 West View



Ill.124 North View


Ill.125,126,127,129 Building Illustrations


Ill.130 Nicosia Sketch

# Conclusion

The aim of the book was to address some of the societal issues that arised in the 21st century in Cyprus, how these affected the architectural design and functionality and how one can best utilise some techniques that were pivotal in the past but nowadays have been neglected. It specifically concentrated in the bioclimatic aspects that were main decision makers in architectural design in Cyprus historical-architecture and how they can be adapted to the modern society. With reference of creating more sustainable, economically affordable living conditions for a Cypriot citizen.

# Future Research

It is important to consider that future researchers should explore in further detail the applicability of such bioclimatic elements in modern society as the climatic conditions of the island in alignment with the economic situation might differ significantly in a time-span of 5-10 years. Future researchers should also take into consideration some of the limitations of this report and accordingly adapt their study.



Ill.131 Limassol Rejuvenation Project Master plan

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