# Exploitation of solar energy in buildings, particularly in the natural and low energy heating and cooling. The case study of an energy–efficient residence in Nikaia, Larissa

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ABSTRACT

This work is concerned with the exploitation of solar energy in the buildings with the use of passive and active systems. The system in study is an energy-efficient residence in Nikaia, near Larissa. The house consists of two apartments that have been both fitted with active and passive solar systems. The climate in Larissa is well known for its high temperatures during the summertime and for that the application of solar energy cooling becomes very appropriate. The work contains analysis of the climate and energy requirements of a typical residence house in the region of Larissa. There is an analysis of the elements of the residence system in study and an economic analysis of the benefits from the solar energy in use. It becomes apparent that the buildings we live in are the continuation of the environment in which they have been built and have a constant relationship of action and reaction with it.

## 1. INTRODUCTION

The buildings where we live in are the continuation of the space in which they have been built and have a constant relationship of action and reaction with their environment. During the summer the air goes through their skin refreshing the inside air and in the winter they get warmer by the sun.

Unfortunately, in Greece we do not take care of the environment our buildings are built in. They act more like obstacles than like a physical continuation of their space. This happens because the last decades in Greece the building construction was massive and rapid. There was no care taken for the environment, not even the general building rules that the engineers had to follow.

It is very important for an architect who wants to design a building, first to take into consideration its orientation and of then the climatic conditions of the region. Also, the thermal needs of the building must be estimates and its thermal balance measured. Following these steps, passive or active systems for the exploitation of solar energy are embodied in the building.

## 2. CLIMATE

The residence is situated at the northeast side of Thessaly, in the municipality of Nikaia. Nikaia is located 10 kilometers away from Larissa and its latitude is $39^0$ 38' North and its longitude is $22^0$ 25' East.

In particular, the data that we are interested in so as to have a more integrated view of the climate conditions in the region are: the temperature, the humidity, the wind, the solar radiation and the rain. For the region of Larissa the data is available at the site of the Center of Renewable Energy Sources.

- The average air temperature is $15.73^0$C, the absolute maximum temperature is $34.09^0$C and the absolute minimum temperature is –$2.55^0$C.
- The average sunlight is 205 hours/month.
- The average monthly rainfall is 35.27 mm/month.
- The average speed of the wind is 1.23 m/sec and in Nikaia there are usually northeast winds.

### *Microclimate*

The microclimate refers to the restricted area of

Figure 1: Northeast view of the house.

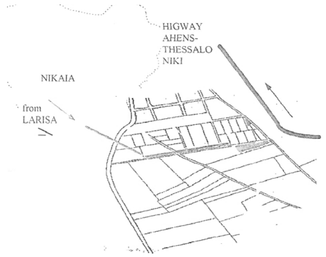


Figure 2: Site plan.

the house. Its topographical layout affects its microclimate.

The residence is situated on the slope of a hill at about 117 m height and has a panoramic view of the city of Larissa. The field in which the house is built is a rectangle, its size is about 5000 square meters and is situated at the northwest side of the hill that enjoys the sun the most hours of the day. The mountains Olympus and Kissavos affect the climate of the area. In addition, the Aegean Sea affects the temperature and the humidity of the winds. The orientation of the building helps in the exploitation of the advantages of the microclimate during the whole year.

For few days of the year there are east and northeast winds. The winter is rather cold but not for a long period, the spring and the autumn are rather rainy the last years while the summer is hot with high humidity.

The ground and the vegetation also affect the microclimate. The size of the field is 5000 square meters, it is sloppy and orientated to the northwest. A great part of the field is covered with grass. It is the part around the house where are located sitting places and flowerbeds. The rest of the field is covered with spear grass and trees. The vegetation improves the sun protection of the house during the summer months. At the southwest side of the building there are deciduous trees, such as sycamores and poplars that shade the south façade in the summer but let the sun enter the house in the winter.

The continuous soaring of the field implements at a lower temperature during the summer months because of the extra humidity. In addition, there is constructed a small lake at the west side of the house which also affects the microclimate because of the humidity that creates.

## 3. RESIDENCE AND COURTYARD

The residence is organized in a southwest-orientated field. It is a box and its larger sides face the north and the south. It is a double house with a two-bedroom flat at its first level and a four-bedroom one at its second and third level.

On the first level (semi basement) is situated the smaller flat (Fig. 3). Its total area is about 90 square meters and includes a bathroom between the two rooms, a kitchen and a living room. This flat covers about half part of the semi basement. At the other half are organized the boiler-room, a stockroom and a fridge room. This side of the level is almost in the earth.

The four family house starts at the first level (basement) where are organized the kitchen, the living room, a bathroom and a guests room (Fig. 4). On the upper level, are the three bedrooms and a bathroom (Fig. 5). The aim of the designer was the flats to have straight access to the garden. The area of the big flat is 230 square meters, 90 square meters for the upper level and 140 square meters for the level with the kitchen and the living room. The inner staircase connects the two flats.

The planning of the inner rooms follows the rules of the orientation. More specific, at the south side are situated the kitchen and the living room at both the first level and the second level, and at the third level the two of the three bedrooms with the bathroom between them. In the middle of the north side is the staircase. Because of the slope the stockroom, the boiler room and the fridge room at the first level are almost in the earth.

What is quite characteristic about this residence is its extremely big south windows. These windows exploit the sunlight during the winter and the spaces that are behind them are full of light. In addition, the windows on the east and west side are also quite big for the same reason. All these windows provide shutters with insulation to protect the house from the sunlight during the summer. It is important to notice that the sun gains of these windows at the summer are

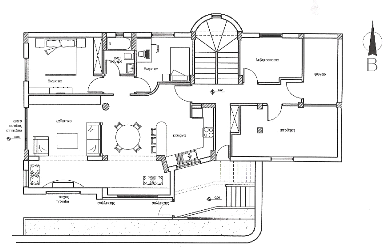

Figure 3: Plan of the first level.

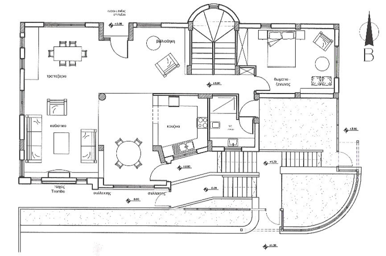

Figure 4: Plan of the second level.

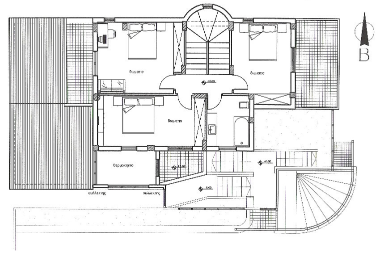

Figure 5: Plan of the third level.

the lesser except for the ones at the north side.

*3.1 Thermal mass*

The Trombe wall is situated at the south façade and is constructed by stone. The wall is double in height (Fig. 6). It starts at the first level of the house, ends at the upper layer of the second level and neighbors with the kitchen and the living room at both levels.

The thickness of the wall is 50 cm, its width is 2 meters and its height is 6 meters. The fact that the wall is built by stone increases its thermal capacity and makes its surface rather abundant which also increases its thermal absorbency. The wall covers part of the south façade of the semi basement and basement. Outside of the thermal wall is situated a glass frame about 10 cm in front of the wall living a gap where air can flow and get in the house by holes on the wall or get out by wholes on the glass. During

Figure 6: The Trombe wall.

the winter the air inside the gap is warmed up by the sun and turned into the house. In the summer the air is guided outside the gap drawing away the air of the inner house. The air pocket is refreshed by new air and this leads to a constant stream which reduces the inside temperature.

The function of the Trombe wall is the same for both levels. The only differentiation for its operation is between summer and winter, and day and night. During the winter the aim of the system is to heat the inner space while, during the summer the aim is to cool it.

*3.2 Greenhouses*

There are two greenhouses planned for the needs of the house. A small one at the south facade on the third level in front of a bedroom, and a bigger one on the southeast side of the house, which starts at the second level and reaches the roof.

The solar radiation that is collected in the greenhouses warms up their inside air and the walls of the house that are in touch with these spaces. So the insertion of the warm air into the house is accomplished either by the walls, or by the doors and the windows between the house and the greenhouses, or through some air floodgates situated on the walls. At the third level the greenhouse is in contact with only one of the three bedrooms, the warm air reaches the other spaces through air-ducts.

The greenhouses contribute to the most efficient exploitation of the solar energy. In addition, they provide interior spaces of great thermal comfort full of sunlight. In this residence both the greenhouses are used as garden sitting rooms.

*3.3 Rock-bed system for warm and cool air using air-solar collectors*

On the south side of the house are situated four air collectors (Fig. 7) that start from the semi-basement and end up to the roof of the house. These are black surfaces with great capacity of heat absorption that are covered with glass. Every collector converts the sun radiation to thermal energy and heats the air between the black surface and the single glass. The warm air is brought into the house either through air-ducts or through an under-floor storage deposit, the rock bed.

During the summer cool air is brought into the rock bed through air-ducts, decreases its temperature and is stirred out through the solar air collectors (Fig. 8). The rock bed is situated underneath the floor of the semi basement and is about 80 cm deep. It is stuffed with stones, big ones for the bottom of the storage and some smaller for the top (Fig. 9). In the perimeter of the building are constructed 10 perpendiculars conductors that connect the horizontal ducts of the storage deposit and drive the air to the conductors.

The warm air of the collectors is steered in the deposit where gets cooler and moves back to the collectors. This way the storage deposit gets warmer and refers its heat to the house. It is very important to keep in low rates the humidity of the air that gets into the rock bed so as to avoid condensation of water vapors, bringing out fungi and the creation of malodor.

Figure 7: The solar-air collectors.

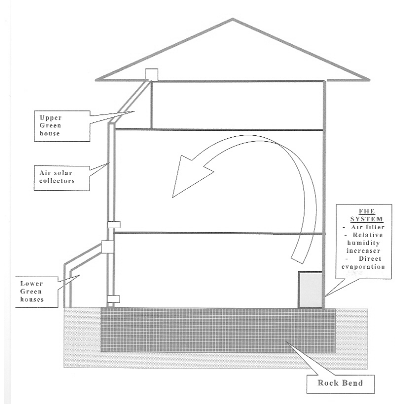


Figure 8: The cooling process.

Figure 9: Rock bed.

*3.4 Fire places*

On the inner side of the thermal wall are constructed two fireplaces, which are connected on a common double chimney. The first one is situated on the semi basement and sends hot water at the conventional heating system and the other is located on the basement sends hot air to the bedrooms or the living room of the bigger flat. The thermal mass and the fireplaces cooperate exchanging heat during their function (Fig. 10).

*3.5 Electric power production using fuel cells*

On the southeast side of the house is situated a system of FC cells that are able of producing 2 kw electric power. The devices that where chosen to be supplied by these sources of energy are the fridge, the television, the circulators, and 10 illuminants of low consumption.

*3.6 Solar energy for hot water*

In order to provide hot water a solar system is forerun. Two boilers, one of 160 lit capacity and the other of 200 lit. constitute the solar system. The surface of each solar-water collector is about 6 $m^2$. The function of the system will be

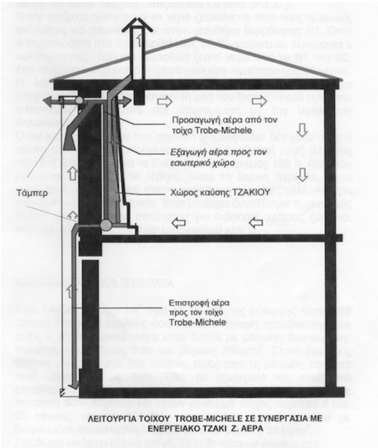


Figure 10: The fire place in cooperation with the Trombe wall.

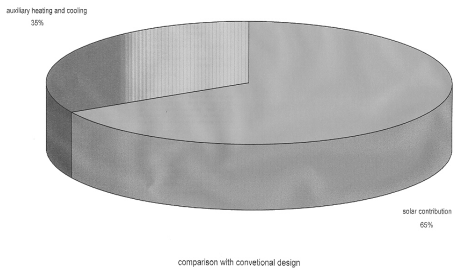


Figure 11: Comparison with conventional design.

automatically programmed.

*3.7 Construction*

The house is constructed from reinforced concrete and infill masonry with 50mm of polystyrene insulation internally in external walls and the roof. The roof is finished in traditional wood-frame. The floor is made of concrete and is finished with tiles. The greenhouses are made of aluminum frame with 6mm single glazing.

The Trombe wall is made of stone. The gray surface of the wall turns away the overheating that is noticed during the summer in the ones with a black surface behind the glass frame.

*3.8 Performance of passive solar design*

The energy required for space heating has been reduced by 65% compared with a conventional house with the same use (Fig. 11).

*3.9 Cost effectiveness*

The over cost of the solar features and auxiliary heating system has been estimated at 15.000 euros at 2000 prices. Considering the auxiliary energy savings achieved, this gives a simple payback period of 10 years.

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