Bioclimatic Planning in Greece: Energy efficiency and application directions

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Bioclimatic Planning in Greece: Energy efficiency and application directions

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ALTENER is the non-technological program for the promotion of renewable sources energy (RES) in the European Union. It is a program of the General Directorate for the Transport and Energy (DG TREN, formerly DG XVII) of the European Commission, which finances actions for the dissemination of alternative forms of energy, especially renewable ones its sources. These actions aim to significantly increase the contribution of RES to energy balance of the European Union.

CONTENTS

PROLOGUE

The "greenhouse effect" is mainly due to carbon dioxide (CO_2) and other gases that come from burning conventional fuels for energy production. These gases burden her human health, threaten the planet's ecosystems and cause the earth's temperature to rise, with devastating consequences for the environment and the economy.

The building sector shows a high rate of increase in energy consumption. The reduction of consumption energy and the utilization of renewable energy sources in buildings is particularly important, as above from 40% of the energy consumed in Europe is used to service buildings, while the fuels for the production of the required energy (thermal and electrical) are responsible for the largest part (50%) of the emissions of gases that intensify the greenhouse effect in the atmosphere. Within of the effort for sustainable development, a significant reduction in energy consumption and, therefore, CO_2 emissions can be achieved to a large extent through bioclimatic planning and energy technologies in the built environment. In Greece, it is estimated that it is technically possible to reduce it of energy consumed in the buildings at a rate of at least 30% of the current total consumption. This information

material is intended to convey experience from existing applications. of bioclimatic design in Greece presenting the parameters that influence the performance of bioclimatic buildings and passive solar systems and energy saving techniques that are applied to them, through the analysis of existing cases in various regions of the country.

Particular emphasis is placed on energy efficiency and the potential of bioclimatic design and of "passive" technologies applied to buildings, providing the most important directions for the correct their application, so that bioclimatic design becomes more easily the "property" of architects and be incorporated into their daily practice.

The material presented concerns the results of analytical measurements, energy records and simulations of buildings carried out within the framework of the K.P.S. project. – E.P.E.-Measure 3.1.4: "Energy performance of passive systems in bioclimatic buildings in Greece" prepared by K.A.P.E. the years 1999 and 2000.

1 BIOCLIMATIC DESIGN AND PASSIVE SOLAR SYSTEMS

1.1 INTRODUCTION

Bioclimatic architecture is about design of buildings and spaces (indoor and outdoor-outdoor) based on the local climate, with the aim of ensuring thermal conditions and visual comfort, utilizing the solar energy and other environmental resources but also its natural phenomena climate. Basic elements of of bioclimatic design are passive systems are integrated where into buildings with the aim of utilization of environmental resources for heating, cooling and lighting of buildings.

The utilization of solar energy and environmental sources (in general) through the P.H.S. is achieved within its framework overall thermal function of the building and the relationship between the building and the environment. And the thermal function of a building is one dynamic state, which:

¾ depends on local climatic and environmental conditions parameters (sunshine, outside temperature air, relative humidity, wind, vegetation, shading from other buildings), but also the conditions of use of the building (residence, offices, hospitals, etc.) and

¾ is based on the corresponding energy behavior of of its structural elements and (by extension) of of integrated passive solar systems, but also the energy profile resulting from its operation building.

Bioclimatic design – although it is integrated in architecture that characterizes every place on earth – considered by many to be a new "vision" in architecture and is related to ecology more than energy and the savings it can bring. Despite this, the bioclimatic architecture has constituted in the last decades basic approach to the construction of buildings worldwide, while in more states is now a key design criterion of small and large buildings which is taken into account by all the architect and engineer researchers. And this, because of lower energy requirements for heating, the cooling and the lighting of the buildings resulting from the practice of bioclimatic architecture and multiple benefits that they entail: energy (saving and thermal/optical comfort), economic (reduction of E/M installation costs), environmental (reduction of pollutants) and social.

The energy benefit resulting from its application of bioclimatic design is attributed in the following ways: ¾ energy

saving from the significant reduction of losses due to the improved protection of the shell and behavior of structural elements,

¾ production of thermal energy (heat) through solar panels of direct or indirect profit systems with a contribution to thermal needs of the attachment areas and partial coverage the heating requirements of the building,

¾ creating thermal comfort conditions and reducing them requirements regarding the thermostat setting (in lower temperatures in winter and higher in summer),

¾ maintaining the internal air temperature at levels high in winter (and correspondingly low in summer), with resulting in the reduction of the load to cover the energy requirements from the auxiliary systems vs the use of the building.

Contrary to the "solar" design, the degree to which the bioclimatic design today takes advantage of local climate variations, which provides a flexibility in the ways architectural expression and application possibilities through very simple techniques and interventions up to complex passives solar systems, a fact that is also proven by recording of bioclimatic buildings in Greece. It isn't embedded in the architecture of most distinguished architects and researchers in Greece – with projects examples (or experiments) that are models applications of bioclimatic architecture of which not only we learn today, but they demonstrate the and multiple benefits that they arise from coexistence with it environment and climate.

The performance of bioclimatic design depends on many parameters, which makes it "sensitive" to external and non-technical factors. For this reason, **basic criteria** for the application of bioclimatic design must be:

¾ the simplicity of using the applications and the avoidance of complex passive systems and techniques,

¾ the small contribution of its user building in the operation of systems,

¾ the use of widely applied systems,

¾ the technical-economic use energy efficient technologies.

1.2 PASSIVE SUNSETS SYSTEMS AND TECHNIQUES

With the aim of reducing needs heating, cooling and lighting, the improvement of the microclimate, the reduction of the environmental impacts from operation of buildings and housing sets as well as the collateral thermal and visual comfort, o bioclimatic planning is based on maximum exploitation of solar energy and environmental sources. Includes different per thermal season techniques and focuses on two levels of planning: urban and architecture.

Passive heating and cooling systems are systems which utilize natural sources (sun, wind, etc.) for heating or cooling the building without mechanical intervention means. Their operation is based on the exchange of energy with the environment and includes both appropriate storage and distribution of energy within the spaces. The liabilities systems are structural elements of the building and are included in bioclimatic planning. As for passive systems they are assisted by a mechanical system of small low consumption (e.g. fan) are called hybrids. Her goal selection and dimensioning of passive systems is the improvement of thermal comfort with simultaneous savings energy for as long a period of the year as possible.

Passive solar systems are attached to building facades with south orientation, with the possibility of deviation up to 30° east or west of clear South.

Passive solar heating systems

Passive solar heating systems collect solar energy energy, store it in the form of heat and distribute it in space. The most common passive solar system (system direct profit) is based on the exploitation of windows appropriate orientation. All passive solar systems they require orientation approximately south, so that there is solar incidence on openings during the longest period of the day the winter. In addition, they must be combined with her required thermal protection (thermal insulation) and the required thermal mass of the building, which also stores delivers the heat to the space with a time lag, thus smoothing the temperature distribution within the twenty four hours. Passive solar systems, finally, should in the summer to be combined with sun protection and often with possibility of ventilation.

Categories of passive heating systems

À System of immediate profit

À Indirect profit systems - Solar walls

a. Thermal storage walls (indirect gain)

9 simple mass walls (non-thermo-siphonic flow, no boxes) either solid, or consisting of containers which contain water or phase change materials

9 Trombe-Michel mass walls (thermo-siphon flow, with slots at the top and bottom)

b. Thermosiphon panel (isolated gain)

À Indirect profit system - Solar space (greenhouse)

À Indirect profit system - Solar patio

À Isolated gain systems - Thermosiphonic panel (outside the building envelope)

Special shell protection and reduction systems thermal load

Apart from passive solar systems, there are several systems applied for natural cooling, which they also work positively in the winter, enhancing thermal insulation capacity of the building envelope, such as. À

Radiation barrier

À Ventilated shell

À Planted roof.

Passive systems and natural cooling techniques

The operation of passive cooling systems and techniques is based on four strategies of bioclimatic design:

in the reduction of solar and thermal gains in the enclosure of the building

in the rejection of heat from inside the building to the natural environment (to the air by convection / conduction, to the earth by conduction, to the sky by radiation, to water by evaporation)

in utilizing the heat capacity of the building as "regulator" of the internal temperature

in improving the thermal comfort of the occupants, regardless from the cooling of the building itself, affecting the environmental parameters in the interior spaces.

Categories of passive systems and physical techniques cooling

A. SUN PROTECTION - THERMAL PROTECTION

À Shading of openings

À Reflective coatings on external surfaces

À Radiation barrier

À Planted roof

B. NATURAL VENTILATION

À Through natural ventilation (day or night) À Hybrid ventilation (ceiling fans and others) À Chimney or ventilation tower (natural draft) À Solar chimney

À Ventilated shell

C. COOLING THROUGH SOILS

À Submerged or semi-submerged buildings

À Underground duct system (soil-air exchangers)

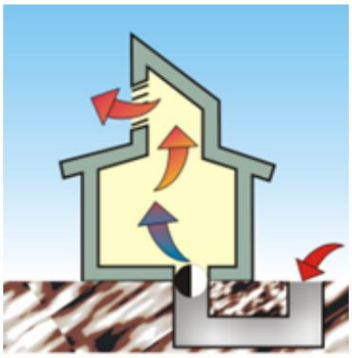
D. COOLING THROUGH NIGHT RADIATION

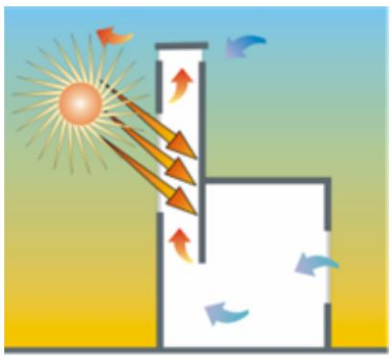
À Metallic radiator

E. EVAPORATIVE COOLING

À Cooling tower

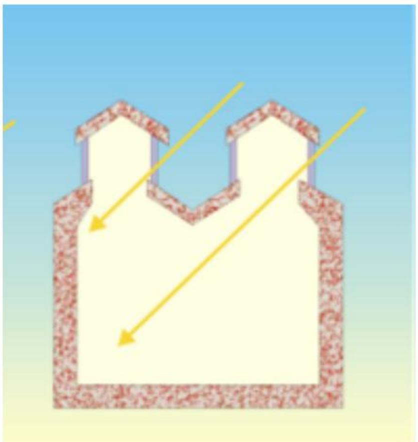
À Evaporative cooling units (direct, indirect or combined exhaust)

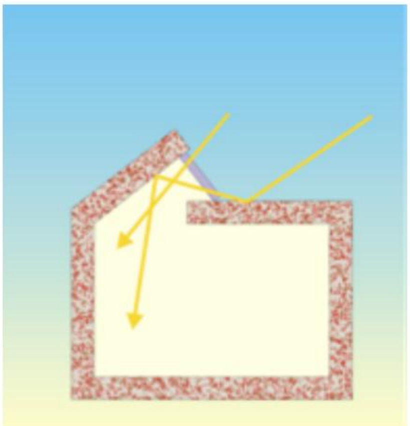


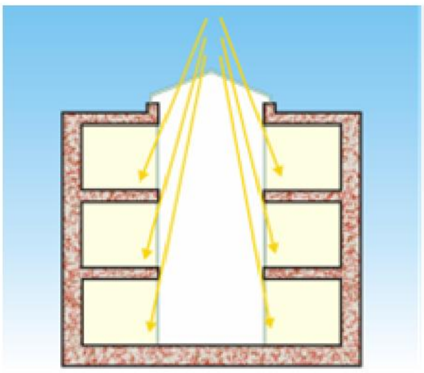


Natural lighting systems and techniques

Natural lighting aims to achieve visual comfort inside the buildings, but also to generally improve the living conditions inside the spaces, combining light, view, ventilation, utilization and regulation of the incoming solar energy. Of particular importance in the design of natural lighting systems is the greatest possible coverage of lighting requirements from natural light, depending on the use of the building and the work carried out inside the premises.







In order to make use of natural lighting for the benefit of the building with the aim of ensuring visual comfort, a sufficient quantity (illumination level) and even distribution should be ensured in the internal operational spaces, through the appropriate systems and techniques, in order to avoid sharp variations in the level, which cause a "dazzle" phenomenon. Both the adequacy and the distribution of the lighting depend on the geometric elements of the space and the openings, but also on the photometric characteristics of the opaque surfaces (color / texture) and the glazing (transmittance / reflectivity).

Natural lighting system means the whole:

• Glass panel or other light-permeable element • Frame

• Shading arrangement (whether structural element or otherwise)

Accordingly, the various techniques applied in the system or in the interior space increase the performance of the system and improve the conditions of visual comfort.

CATEGORIES OF SYSTEMS

• Openings in vertical masonry • Roof openings • Atriums • Skylights

NATURAL LIGHTING SYSTEMS AND TECHNIQUES

a. Glass panes

• Colored and reflective panes • Absorption panes • Low-e emission panes • Electrochromic • Photochromic • Thermochromic

b. Prismatic light-transmitting elements

c. Transparent insulating materials

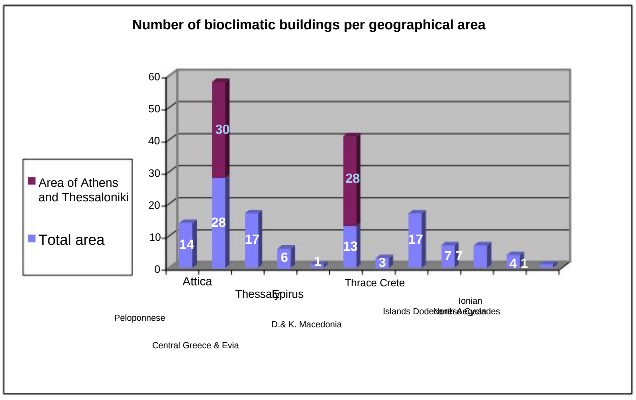
d. Reflectors (Lighting Shelves)

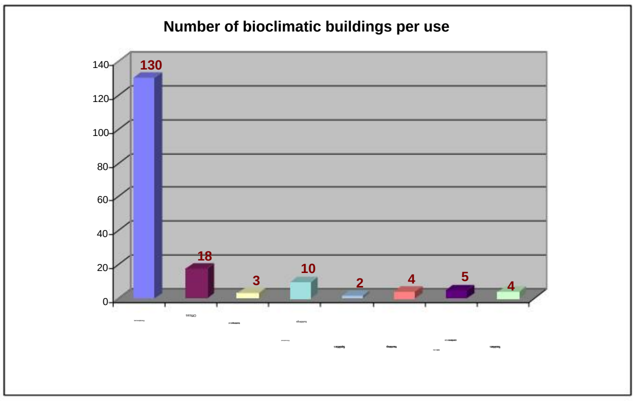
e. Reflective blinds

2 APPLICATIONS AND PERFORMANCE OF BIOCLIMATIC DESIGN IN GREECE

2.1 BIOCLIMATIC PLANNING APPLICATIONS IN GREECE

According to the results of the project, in Greece today there are approximately 180 applications of bioclimatic buildings, of which 2 are residential complexes. Of these, the largest number of buildings is located in the region of Attica (58 cases including the Solar Village) and in Macedonia (41 cases of buildings). With an average number of applications, bioclimatic buildings have been recorded in the rest of Central Greece (17), Crete (17) and Epirus (17), Peloponnese (14) and less in the rest of the regions.





The application of passive systems in the shell of buildings for increased profits from the utilization of solar energy, mainly concerns the residential sector of low height (one-two floors). The use of passive systems for heating and cooling in other building uses has not been particularly applied. In Greece, only in the last decade has bioclimatic design started to be applied to buildings of the tertiary sector, in the context of a more comprehensive new approach to design. Thus, of the buildings already registered, 74% of the cases concern residential buildings, while a more detailed breakdown into uses of the tertiary sector gives the highest percentages in office and education buildings.

2.2 PASSIVE SYSTEMS APPLIED TO buildings

The use of passive systems in bioclimatic buildings in Greece is used during the winter period mainly to save energy and improve comfort conditions, while in the summer period mainly to ensure thermal comfort (since it concerns mostly non-air-conditioned buildings) through simple methods and techniques natural cooling.

Of the systems and techniques that have been more widely applied in bioclimatic buildings, the main place is occupied by simple techniques for maximizing the southern openings (passive systems of direct solar gain for heating), which appear in 81% of the buildings (exclusively in 11%) and use solar spaces of indirect profit (mainly greenhouses, which appear in 42% of buildings). Solar walls (Trombe, mass and thermosiphon panels), appear in 27% of the buildings recorded. Of the solar walls, 68% are Trombe walls, 11% mass walls, 4% water walls and 17% thermosiphon panels. In only one case is there a rock bed, which

works in combination with
thermostatic panel. Furthermore, the increased thermal insulation, h differentiated conventional non-construction of external walls, planted roofs and minimization of the northern openings offer additional protection in winter.

Correspondingly for the summer season, shading, the minimization of the west openings and cross ventilation are main physical techniques of cooling that appear in all of them almost cases sun protection were recorded. The where

achieved externally or internally shading systems and specifically, special sun protection systems reported in 29% of cases and planting of the surrounding area in 9% of cases.

Other passive systems that have been implemented in Greece are the solar patios, roof skylights to improve the conditions natural lighting, cooling chimneys and ground pipes. It should be noted that natural ventilation, although not is particularly noted by scholars, it is applied to set of buildings.

2.3 ENERGY EFFICIENCY OF BIOCLIMATIC DESIGN IN GREECE

According to the results of the project and the simulations especially those prepared on the basis of those recorded actual conditions of use of the buildings, the energy ones consumptions arising for the heating of bioclimates of residences (buildings of continuous use) in the A' climate zone they range from 25 to 42 kWh/m2 , in the B climate zone from 28 to 55 kWh/m2 , while in the C climate zone from 44 to 90 kWh/m2 annually. It is estimated that in relation to the usual conventional buildings built after 1979 (year of application of the Regulation Thermal insulation) bioclimatic buildings show savings energy of the order of 30%, while in relation to the past insulated buildings the corresponding energy saving amounts to percentage of the order of 80%.

The results of the project show that the saving of energy brought about by the utilization of solar energy for heating of buildings is particularly important – regardless of use of bioclimatic buildings. However, it is a parameter design, which must be combined in parallel with the reception sun protection and shading measures, to reduce solar radiation profits during the summer season (and therefore, cooling needs).

In addition to the significant thermal benefits of direct systems profit, the contribution of other indirect profit systems to overall energy behavior of bioclimatic buildings is equally important.

In particular, the simulation analysis shows that in existing condition of the buildings:

greenhouses yield up to 30%.

thermal storage (solar) walls can bring energy savings of over 40% in buildings houses in the A and B climate zones, while in the C climate zone reaches 12%.

Energy saving due to **increased southerly** of **openings** depends on the surface of the openings, but and the overall function of the building (insulation, internal gains, climate of the area, etc.). In some cases, the increased glass surface, due to the large night losses of heat in areas with cold nights, contributes to the increase of the building's heating load. This phenomenon can be limited by the use of night insulation in the openings.

Greenhouses **(solar spaces)** are the most widespread passive solar system in buildings in Greece. Their performance it depends on their size and how they are used and it is similarly in all 3 climatic zones of the country.

All greenhouses have a shading system, either outside or inside internal and have openable sections for summer ventilation their. This summer protection of the greenhouses has as resulting in no particular thermal load on it building from the greenhouses. In most cases the Greenhouses have an opaque roof, or their roof is completely shaded during the summer months. The thermal load from the roof is important in the summer, and for this reason, greenhouses with an opaque roof are recommended.

The performance of **solar walls** depends on their size in relation to the building, but also on the use of the building. Thermal storage walls and thermosiphon panels are small in size and have a small contribution to the energy performance of buildings.

Solar walls, when not shaded and ventilated, generally burden the building in the summer. However, they can also contribute positively if they are shaded, particularly and if they are utilized for the natural ventilation of the building.

DIFFERENTIATION OF CONSTRUCTION OR USE FROM STUDY

The implementation of the study of a building with proper construction and application of construction techniques and passive systems is an important performance parameter of bioclimatic design. In most of the cases of buildings studied, the deviation of the final construction from the original design of the building is the main factor responsible for the reduced performance of the P.H.S.

In general, small deviations of the design from the construction (e.g. modifications to the construction of the roof or the masonry), imply small deviations of the energy behavior of the building. Changing the size of openings, incorporating or non-passive systems, poor quality construction (e.g. insufficient insulation), but especially poor operation of passive systems and the building (e.g. excessive winter ventilation, shading of passive systems, inactivity of the solar walls) lead to significant deviations of the energy behavior of the building from the expected one.

Particularly important is the effect of the incorrect application of the study on the behavior of the building in the summer months, where significant overheating often occurs. This phenomenon is due to insufficient shading or ventilation. It is very common to see windows and other openings that were intended to be opened either being permanently constructed or sealed by the users, or simply remaining closed. Also, external shades are manufactured differently than intended or not at all. Characteristic examples are the two schools, in Rethymno and Andros, where, due to insufficient shading and ventilation, in September the internal temperature in the classrooms reaches 30o C and 34o C respectively, which would not exceed 27.5o C and 30o C respectively, if the buildings were functioning properly.

According to assessments that emerged from the project, the main factor leading to the under-implementation and misuse of passive systems is the ignorance or lack of interest of the users regarding the operation of passive systems.

THERMAL COMFORT

It is characteristic that in all the homes of the sample in all climate zones there is no installation of an air conditioning system, since natural cooling systems and techniques (shading and natural ventilation) are applied. Some buildings have ceiling fans, which are rarely used at all. When the shading and ventilation systems work properly and therefore efficiently, there are no overheating problems, as can be seen from the testimonies of the occupants and from the data of all the energy records, even when the outside temperatures are high. Outside-inside temperature differences of up to 10o C have been observed in the summer.

Another important conclusion that emerged from the energy records and especially the on-site visit to the buildings and the testimonies of the users, is the fact that during the summer thermal comfort is achieved at fairly high temperatures, when adequate ventilation is applied to the buildings. The comfort temperatures in these buildings, when there is natural ventilation and especially vertical ventilation, reach up to 31.5o C. However, in buildings with inefficient ventilation and shading, the comfort limits are much lower (below 29o C), resulting in thermal discomfort of the occupants.

SUN PROTECTION

Sun protection in bioclimatic buildings is an integral element of their proper operation and a basic condition for ensuring thermal comfort conditions in the buildings during the summer season. Sun protection in Greece is achieved both with the structural elements of the building (e.g. cantilevers) and with shades. There are usually fixed or movable external shades. Although movables are often recommended by designers, during construction in many cases fixed shading blinds are installed. External blinds and shutters are also used, as well as internal curtains, usually in combination with some external shading.

In greenhouses there are usually fabric rolls, which are external or internal, while their roof (as mentioned above) is completely shaded. Accordingly, solar walls are often shaded with external roller shutters.

VENTILATION

Natural ventilation is applied in all bioclimatic buildings, with the result that relatively low temperatures inside the buildings and thermal comfort conditions are observed in most cases during the summer season. In cases where ventilation is not applied (for reasons of construction or misuse), overheating is usually observed. At the same time, the limits of thermal comfort are significantly reduced. The natural ventilation of buildings, which is generally applied during the night, is achieved either through openings, or with openings at the height of the building, when the phenomenon of natural attraction is observed, resulting in more air changes per hour. The reduction of the cooling load due to natural ventilation reaches up to 75%, which in practice means (for residential buildings at least) that the need to use an air conditioning system is removed, as evidenced by all the energy records. It should also be noted that in bioclimatic energy recording buildings, even when ceiling fans are present, they are rarely used.

PASSIVE SYSTEMS AND TECHNIQUES E.E. ON THE ROOF

Often in bioclimatic buildings, passive heating or cooling systems and load reduction techniques are applied to the roof of the building, such as: the ventilated roof, the application of solar or wind chimneys, and the planted roof. The ventilated roof and the planted roof reduce both the heating load and the cooling load of the building, and in addition improve the thermal comfort conditions inside the buildings. The solar chimney, if it works properly, reduces the heating and cooling load of the building, but when it does not work properly (it is not combined with sufficient opening of windows for proper ventilation), it burdens the building thermally in the summer. The wind chimney contributes to the reduction of the building's cooling load and to the improvement of thermal comfort conditions, due to increased ventilation, and in winter, it slightly increases the heating load.

3 CONCLUSIONS – GUIDELINES FOR THE SUCCESSFUL IMPLEMENTATION OF BIOCLIMATE DESI

The particularly mild climate in Greece, the increased sunshine and the cool summer winds are climatic factors that allow the possibility of designing buildings with low energy consumption, with passive techniques and without the requirement of systems that increase construction costs (either passive or hybrid).

As it emerges from the project, but also as is well known, the greatest energy savings result from correct and rational planning – in terms of the location and orientation of the building, the size, orientation and position of the openings, the protection of the shell (thermal insulation, wind protection and sun protection) – which is also the most basic factor that researchers must take into account.

Thus, the performance of a technique (or even a passive system), while related to the climatic area of application, depends in particular on the overall construction of the building and the contribution of the remaining structural elements (amount of thermal mass, percentage of openings, points of the shell where the thermal losses etc.) but also the comfort requirements set by the users of the building. In other words, it is possible, while the appropriate (for an area) system has been provided, if it is not studied with calculation and analysis of the entire shell, it may not yield the expected benefits. Accordingly, deviations in its construction and its incorrect use by users can lead to reduced energy benefits or even a negative function.

From the experience so far in this practice, a key factor for the selection of techniques in bioclimatic planning is the simplicity in the use of the proposed technique. On the one hand, the contribution of building users is a very basic parameter of the efficient operation of passive techniques and systems, on the other hand, the complexity of a system can sometimes have a negative effect on the performance of the system.

In particular, as it emerges from the project, there are four parameters of the *successful performance* of bioclimatic planning:

1. Correct planning and rational selection of techniques

More generally, it is proposed to apply basic principles of bioclimatic design, ensuring optimal insolation of the building for heating in the winter, and ventilation possibilities for cooling in the summer, as well as the choice of simple protection techniques and systems for the utilization of environmental sources.

Basic benefits are provided by the protection of the shell (reduction of heat losses in winter and solar gains in summer), by the selection of suitable construction materials for the building for improved thermal capacity and thermal insulation, but also by the use of non-conventional construction techniques (ventilated structural elements, radiators, radiation barriers, additional insulation, etc.).

Natural cooling with cross ventilation and other techniques is suitable for all climatic regions of Greece, contributing to significant energy savings for cooling up to 100% in northern climatic regions (for residential buildings). Sun **protection** of the building is a necessary condition for the application of natural cooling techniques , while night ventilation is also recommended for uses in buildings of the tertiary sector.

Another factor that must always be taken into account is the cost of the system. The benefit resulting from passive techniques and systems can present great differences, depending on the type, use and size of the building, the climatic region, the structural system of the application area, etc. Thus, it is necessary for the researcher to choose systems and techniques after analyzing the cost / benefit relationship, so that the cost of the application does not exceed the potential benefits and the payback time of the system is short.

2. Correct implementation of the systems during construction

The implementation of the study of a building with proper construction and application of construction techniques and passive systems is the second performance parameter of bioclimatic design. In most of the cases of bioclimatic buildings in Greece, the deviation of the final construction from the original design of the building is the main factor responsible for the reduced performance of the P.H.S. This deviation, which is due either to manufacturing errors and omissions, or to user decisions, can reverse the behavior of the systems and the entire building, resulting in worse conditions (increased energy consumption and reduced thermal comfort) than in a conventional building without passive systems.

3. Correct use and operation of the building and systems

The contribution of the users of the bioclimatic buildings is a key non-technical factor on which the performance of the P.H.S. depends to a very large extent. and of the building shell itself.

For all P.H.S. and shell techniques to save energy there is a degree of necessity for user input. This factor should be a key criterion for researchers when choosing systems and techniques, as in most cases a reduced contribution is expected from that required during the operation and use of the building.

In most cases of buildings in the tertiary sector, the efficient operation of passive systems requires the installation of control and automation systems, as it is difficult or impossible for the user to contribute to the operation of the systems.

4. Adequate maintenance

Maintenance is the last parameter to ensure the optimal performance of bioclimatic buildings with passive systems and other techniques. Although the P.H.S. operate mainly without the intervention of mechanical means, maintenance (as a factor on which the operation of almost all systems and facilities depends) contributes to their long-term operation without reduced performance. The main reasons for maintenance are dust, the age of transparent materials, age of frames, rust and others, which are usually created with time and the use and operation of the systems

4 ENERGY ANALYSIS OF 8 (EIGHT) BIOCLIMATIC BUILDINGS IN GREECE

The buildings presented were studied within the framework of the E.P.E. project. Measure 3.1.4. "Energy performance of passive systems in bioclimates buildings". They are typical examples of buildings, from the study of which conclusions were drawn about the operation of the passives solar systems. In these buildings energy was carried out recording and energy analysis with the method of simulation and in one of them and analytical measurements, based on the common methodology that followed in the project for 30 buildings under study.

For each building, the energy requirements for heating and cooling as well as the temperature conditions arising in existing construction and use of the building and compared with various scenarios. The basic scenario is what is labeled as "CONVENTIONAL CONSTRUCTION", which refers to the same building as it would otherwise be there were passive solar systems built into it. Must be here it should be noted that even in this case the buildings are considered bioclimatic and present reduced energy requirements in relation with the usual 'conventional' buildings. The other scenarios considered by case concern the construction and operation of individual systems, so that it is possible to draw conclusions not only for the overall operation of the building, but also for the contribution of each one system or technique applied to it.

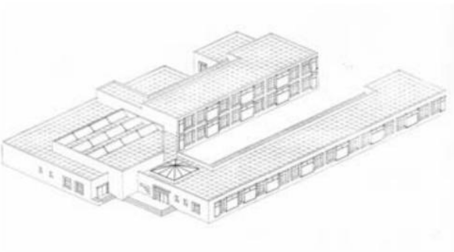
In particular, buildings designed by architects:

1. Alexander Capon
2. Michalis Souvatzidis
3. Margarita Konstantinidou
4. Thanos Collar
5. Elli Georgiadou
6. Thymio and Nicoleta Saliachi
7. Giannis Kalligeris
8. Alexandros Topazis and associates

SCHOOL IN ANDROS

Researcher: A. Capon
Year of construction:
1989 Building area: 899
Area of heated spaces: 513.5 m2
Number of floors: 1
Passive Solar Systems: •
Immediate profit
• Trombe walls

Natural Cooling: •
Translucent ventilation
Anticipated thermal insulation: 10cm polystyrene



The most basic element, which characterizes this case, is that the existing building presents significant differences in function in relation to the ones foreseen in the study, which is due to poor construction, but also misuse and maintenance.

BUILDING CONSTRUCTION	HEATING LOAD			COOLING LOAD		
	GJ KWh/m2 % GJ KWh/m2 %					
CONTRACT CONSTRUCTION	33.15	17.93	-	0.02	0.01	-
CURRENT SITUATION	22.84	12.36 -31.10 15.98			8.65 75995	
ARCHITECTURE STUDY	9.42	5.10 -71.57 0.08			0.04 257.14	

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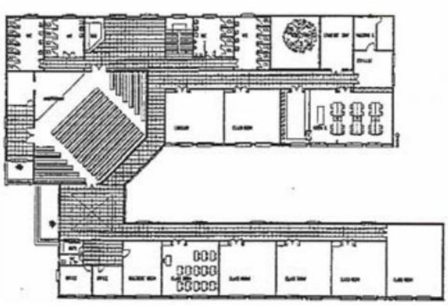
PERFORMANCE OF PASSIVE SYSTEMS	LOAD HEATING		COOLING LOAD	
	GJ	KWh/m2 GJ KWh/m2		
EXISTING SITUATION WITH WALLS TROMBE AND ASCIASTA SOUTH OPENINGS	22.84	12.36	15.98	8.65
EXISTING CONDITION WITH CURTAINS ON SOUTHERN OPENINGS	41.87	22.65	15.98	8.65
EXISTING SITUATION WITHOUT WALLS TROMBE	87.94	47.57	0.01	0.01
ARCHITECTURAL STUDY WITH TROMBE WALL 9.42		5.10	0.08	0.04
ARCHITECTURAL STUDY WITHOUT A WALL TROMBE	30.15	16.31	0.02	0.01



TYPICAL FLOOR PLAN

In particular, the differentiation of the existing state of the building from the study, due to construction and use, concerns the following:

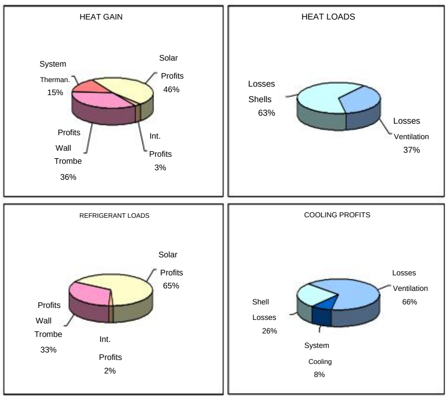
• The construction quality of the building is very poor, resulting in uncontrolled infiltration of air from cracks and fissures, which leads to large heat losses in winter.

• The insulation has been damaged, due to poor construction, with result in not yielding.

• Trombe walls underperform in winter because they don't work the lockers satisfactorily. In the summer there are no verticals awnings to shade the Trombe walls, which have been torn as well have not been replaced. And the ventilation slots in the wall (horizontal opening section of the wall glass), which are necessary to avoid excess heat, no they can be opened as the guide is placed in front of them of the shading awning. The consequence of the above is overheating of the wall and the adjacent room during the period cooling.

• The north ventilation skylights of the halls do not open, as they do not there is a system for easy opening from a lower point with consequence of not being able to adequately ventilate the building.

• While on the windows the researcher had foreseen venetian blinds for reducing glare, curtains were finally installed.



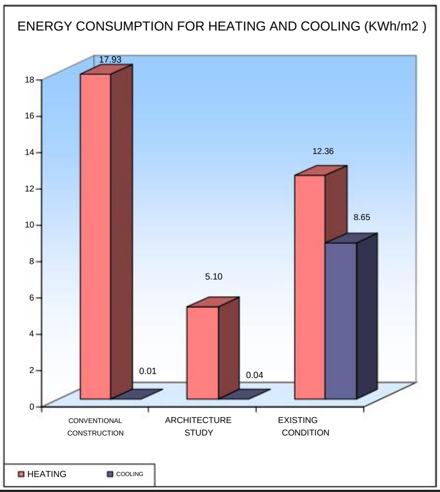
ENERGY BALANCE

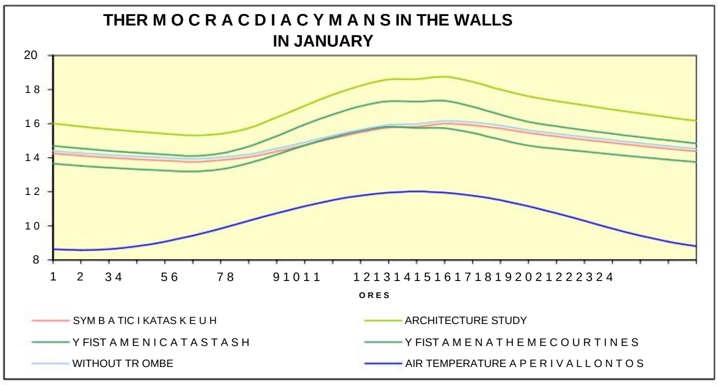
The energy saving from the building, as foreseen by the study amounts to 71.6% for the heating period, an amount which falls to 30% due to the existing construction and operation of the building. Despite its moderate function, the Trombe wall, yields significant heat benefits, reducing the thermal load of the building by 68.7% and increasing the internal temperature by 1.5o C at least a typical day of it January. Its operation would raise its temperature by 3o C of space if it had been applied correctly n architectural study. In the present state the internal temperatures him January during the hours teaching range from approximately 15 to 17o C, (as shown by simulation of the building).

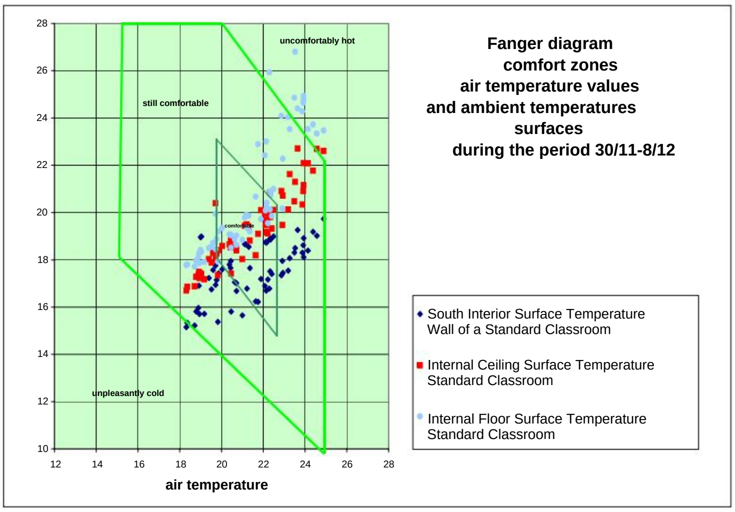
During the winter period of measurements (December 1999) the temperatures in room is within the limits of thermal comfort, as Fanger's diagram shows without auxiliary heating operating. The Trombe walls work satisfactorily raising the average air temperature to hall during its hours of use. Thus, while temperature variation of the air ambient is 10o C (8-18o C), h variation in the room is only 5o C (19-24o C). It is observed that even on the days when solar radiation is at low levels, the walls perform well, keeping it minimum room temperature above the 17o C. In maintaining the conditions of these, the direct also contributes adjunctively profit.

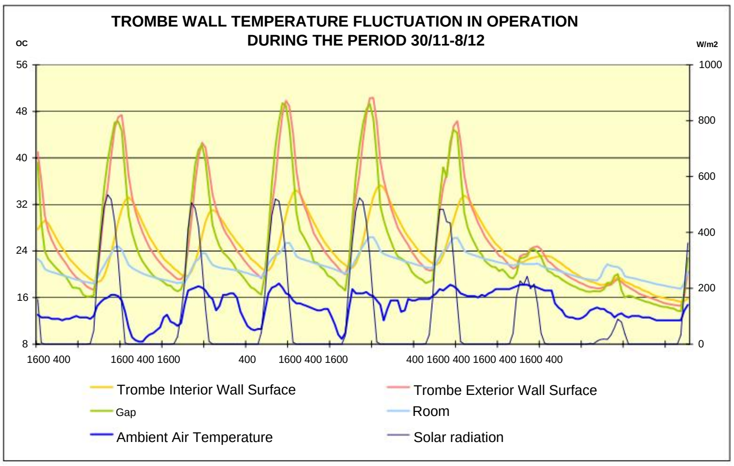
From the energy balance of the building for the heating period, seems to be the important one contribution of both the Trombe wall, and of direct solar gains: solar gains cover 64% of the balance, profits from the Trombe wall 27%, while the auxiliary heating only 7%.

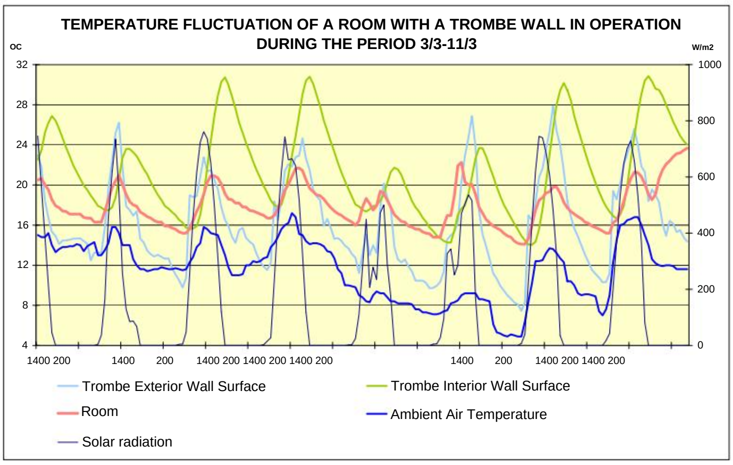
During the energy recording it was observed that in the rooms facing south orientation, are present in the windows curtains, which remain permanently closed due to her problem glare. Considering this situation operation, it turns out different behavior of the building in the winter in existing situation, from the one initially was calculated and even more differentiated from the architectural study. Her presence of inner curtain has as a result the increasing the thermal load of the existing one construction by approximately 83%. Respectively its energy balance also changes building, as solar gains are reduced to 46%, the heating system covers 15%, while the percentage contribution of the walls increases Trombe. The almost doubling of the load heating of the building in the winter, from presence and only the curtains at windows, could be avoided with the intended use by the researcher of horizontal mobile blinds.











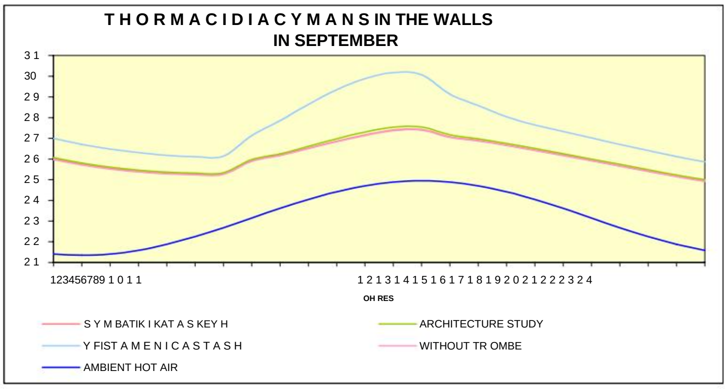
The best solution in terms of operation, but mainly maintenance, would be the installation of Venetian blinds in between in the panes of the south windows to combine passive heating with solar gains, avoiding glare with deflection of the sun's rays, but also protection against wear due to use.

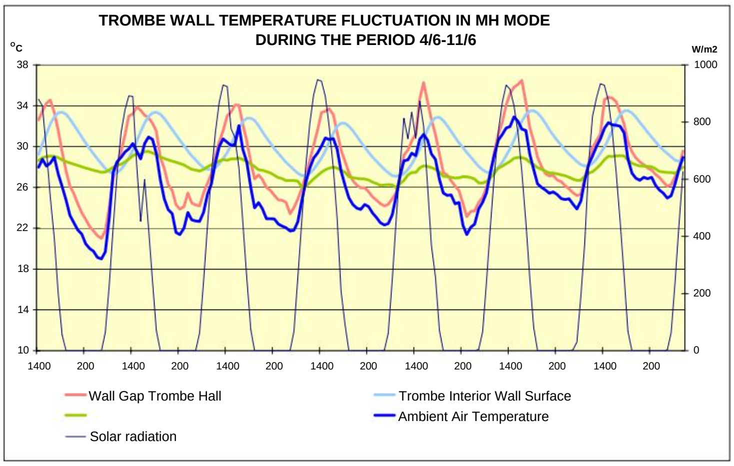
September, which is the busiest month thermally, the presence of the Trombe wall, as it works, raises the temperature to rooms by about 2.5o C, when and internal temperatures up to and 30o C. According to the simulation analysis, if the Trombe wall worked right, it wouldn't raise the temperature any higher by 0.2o C, resulting in temperatures in the room not to exceed 27.5o C.

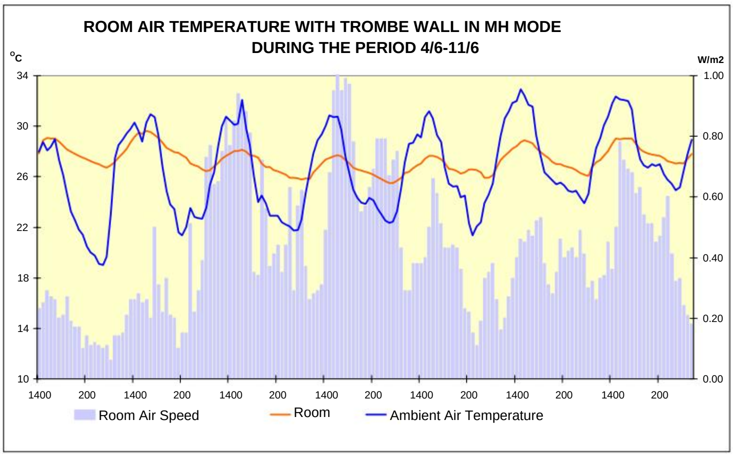
At the same time, the air temperatures during measurements of the summer period (June 4-11 1999) are marginal in the thermal zone comfort, as well as inside the room there are relatively high wind speeds.

The temperature variation inside of the hall during the twenty-four hours is small (only 1.5 oC), when indeed the outside temperature has one range of variation 10o C. The small one variation proves that it does not become sufficient night ventilation. Indeed, in the wings of the rooms, the northern ventilation skylights do not they are usually opened, for one thing because they are not easy to approach them, and on the other hand because when they open, their opening is limited from the air heaters that are installed right in front of them.

The temperatures developed at Trombe walls are particularly high and burden the internal conditions increasing the temperature inside of the hall. The high temperatures are due to the non-shading of the walls (as the outer wall awnings are damaged), but also in non-discharge of the wall from the ventilation slots (obstructed by its guides shading system).







RESIDENCE IN ATTIKO ALSOS

Researcher: M. Souvatzidis
Year of construction:
1993 Apartment size: 159.4 m2
Area of heated spaces: 153.7 m2
Number of building floors:
5 Passive Solar Systems: •
Direct profit • Greenhouse
integrated into the building
Natural Cooling: •
Shading of openings
• Transverse and vertical night ventilation
Masonry: Exposed road masonry inside and outside, with
Thermoblock and 5cm insulation in between.

The owner and user of the building is the researcher himself. The home is part of the building, which is structured on five levels and occupies the last three levels, while the remaining levels they are the researcher's office and other apartments.

The building is in an area of Athens with a continuous structure, it has southeast orientation, with large southern openings and greenhouse. The greenhouse is part of the living room of the residence. During the day, the greenhouse and the living room are one space, while during the night there is a roll with internal insulation that separates the greenhouse from the rest of the space.

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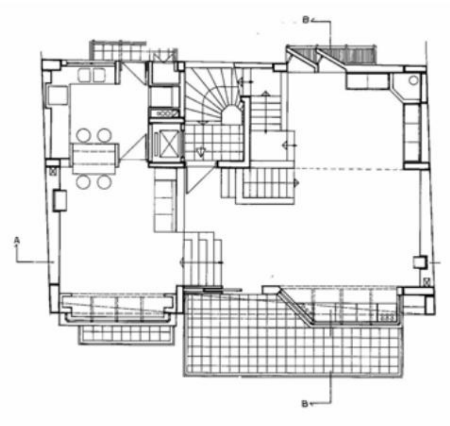


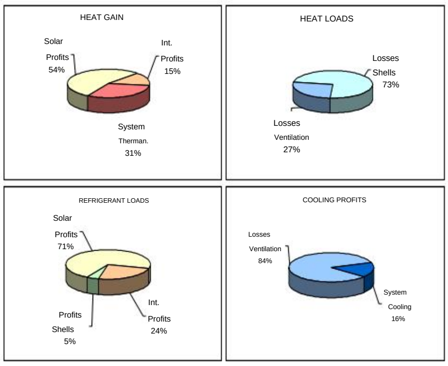
FLOOR PLAN

Externally, the openings are shaded with horizontal, louvered shades. THE blinds are oriented towards the south and their inclination is this which allows the maximum insolation of the openings during the winter period. Internally, the openings are shaded with verticals light colored blinds.

The layout of the house in levels facilitates vertical ventilation. For better ventilation of the house, small ones have been installed exhaust fans of the hot air that is concentrated in the upper ones flat.

On the roof of the building there are sections which are planted, while the a larger part of the roof is shaded by corresponding horizontal shades with those that shade the openings. Finally, in a section of the house and in a solar collector has been placed in contact with it, as a result, the this section should essentially have a minimum thermal load, as the solar energy is absorbed by the collector.

BUILDING FORM	HEATING LOAD			COOLING LOAD		
	GJ	KWh/m2	%	GJ	KWh/m2	%
CONTRACT CONSTRUCTION	20.32	35.41	-	6.20	10.80	-
CURRENT SITUATION	17.93	31.24	-11.76	7.14	12.43	15.12



Energy balance

From the energy balance of the building it follows that the solar gains constitute 54% of the total thermal gains, while the auxiliary heating covers 31%.

In general, the residence has limited heating requirements. Such as the researcher-user mentioned, the heating of the space for short periods of time intervals during the day has the effect of being maintained the temperature within the limits of thermal comfort.

SHELL CONSTRUCTION	LOAD HEATING		COOLING LOAD	
	GJ	KWh/m2	GJ	KWh/m2
SHADES, GREENHOUSE, SPECIAL MASONRY 17.93		31.24	7.14	12.43
WITHOUT SHADE	17.93	31.24	7.96	13.87
WITHOUT GREENHOUSE	20.69	36.06	5.52	9.62
WITH TYPICAL MASONRY	19.16	33.40	7.28	12.68

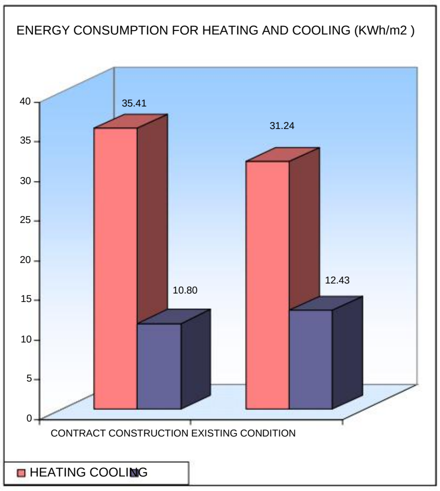
The use of concrete masonry and the greenhouse contribute to energy saving for heating of the order of 13%. From the table showing the energy requirements for heating and cooling, it follows that the greenhouse has a very small contribution to saving energy for the heating period, since the greatest saving energy results from the overall design of the building. In addition, the greenhouse puts a slight burden on the building in the summer, raising the temperature of the adjacent space by up to 1o C.

During the summer season, temperatures reach 30o C inside the house, as shown by the simulations. As it emerged from the user's testimony, this temperature is tolerable in the building and there is no need for air conditioning in the premises.

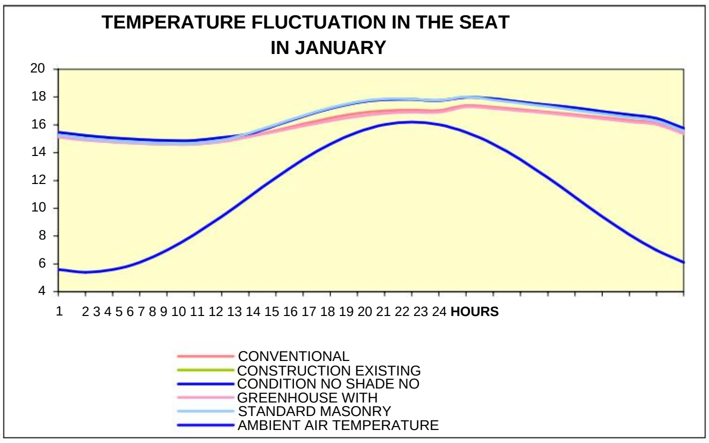
The temperatures measured inside the house during the energy recording had a 10o C difference with the outside air temperature. Specifically, while the outside temperature was close to 42o C, the temperature in the living area was 31.5o C. It should be noted that although a temperature of 31.5o C is not considered to be within thermal comfort limits, with at this temperature, those present in the building felt thermal comfort.

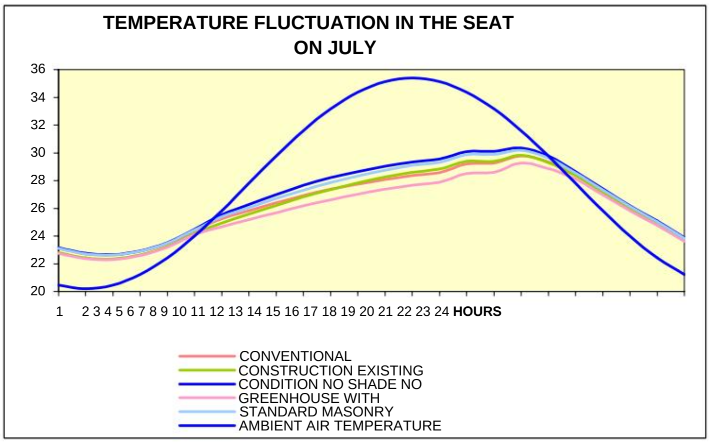
The operation of the small fans to remove the hot air and the existence of open openings in the roof result in a noticeable improvement of the conditions inside the room. The use of shades results in a 10% reduction in cooling needs.

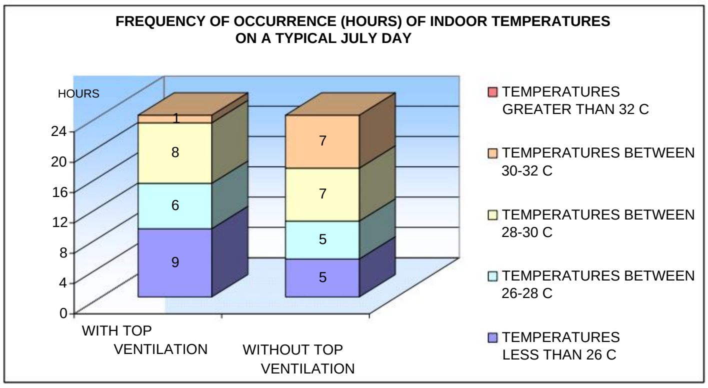
The application of the specific masonry has positive, albeit small, results both during the heating period and during the cooling period.



The masonry that has been applied to the residence yields thermal gains and discharges at a lower rate than standard masonry. As a result, during the winter period, higher temperatures are created in the space at night than when standard masonry was applied, while during the day they fluctuate at the same levels. During the summer season, the opposite happens. During the day, higher temperatures are experienced with conventional masonry, while during the afternoon and night hours, almost the same temperatures in the residence.

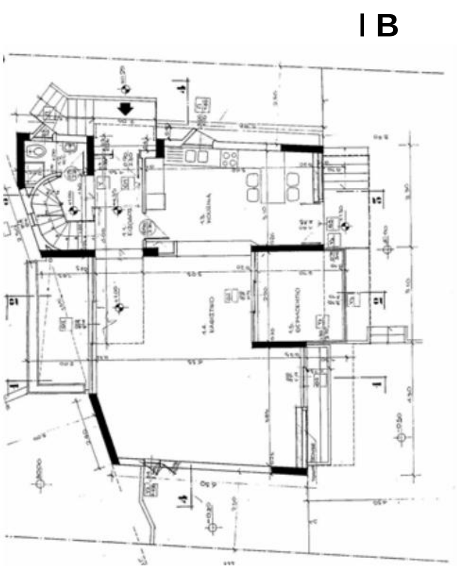






RESIDENCE IN KIFISIA

Researcher: M. Konstantinidou
Year of construction:
1995 Building area: 208.1m2
Area of heated spaces: 133.2 m2
Number of floors: 2+basement
Passive Solar Systems: •
Direct profit • Greenhouse
integrated into the building
Natural Cooling: •
Shading of openings
• Greenhouse shading and ventilation
• Transverse and vertical night ventilation



FLOOR PLAN

The residence in Kifissia presents a low heating load, due to basic elements of its design: compact volume and large direct profit exposures. Solar gains in this case cover 53% of the heat balance during the heating period, while auxiliary heating 38%.

BUILDING CONSTRUCTION	HEATING LOAD			COOLING LOAD		
	GJ	KWh/m2	%	GJ	KWh/m2	%
CONVENTION BUILDING	34.97	46.68	-	1.41	6.52	-
CURRENT SITUATION	35.19	46.98	0.64	1.44	6.66	2.06
ARCHITECTURE STUDY	31.09	41.50	-11.08	1.43	6.61	1.28

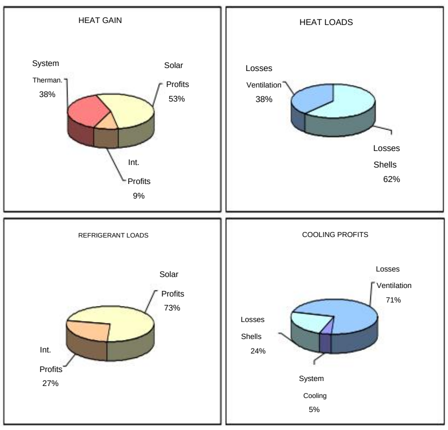
The existing construction presents significant differences from the architectural study, which have a similar effect on energy behavior of the building.

• The study envisaged Trombe walls, which were not built.

• The study also provided for the construction of an attached greenhouse in the building, which was finally built integrated and works as a "sunny" (direct profit system).

The greenhouse (sunroom) has opening glass windows, at a 75° slope as and side doors. It also has constant shading horizontally (cantilever) and has the possibility of full shading with an awning, which however provides the possibility of ventilation, as it is located at a distance from them panes of glass.

GREENHOUSE OPERATION	LOAD HEATING		COOLING LOAD	
	GJ	KWh/m2	GJ	KWh/m2
INTEGRATED GREENHOUSE 35.19		46.98	1.44	6.66
ATTACHED GREENHOUSE 33.48		44.69	1.25	5.80
WITHOUT GREENHOUSE	34.97	46.68	1.41	6.52



Energy balance

EFFECT OF IHO Y TROMB ON THE BUILDING ME THERM GARDEN	F O PT IO THERM ANSIS		F O PTIO PS HYXIS	
	GJ	KW h/m2	GJ	KW h/m2
WITH T O IHO TRO M BE	31.09	41.50	1.43	6.61
HO RIS T O IHO TRO M BE	33.48	44.69	1.25	5.80
WITH IHO TRO M BE, HO RIS GREENHOUSE	33.90	45.25	1.70	7.87

From the sensitivity analysis done with simulations, it emerged that the building as constructed presents a burden in relation to one same building without passive systems (conventional) by a small percentage (0.6% increased heating load), while the building was as it originally was studied would save 12.5% energy for heating in relation to conventional. The existing greenhouse burdens the building thermally, because, although it directly raises the temperature of the space, it presents large losses to the external environment during its night winter, while summer has little better behavior than this of the original study.

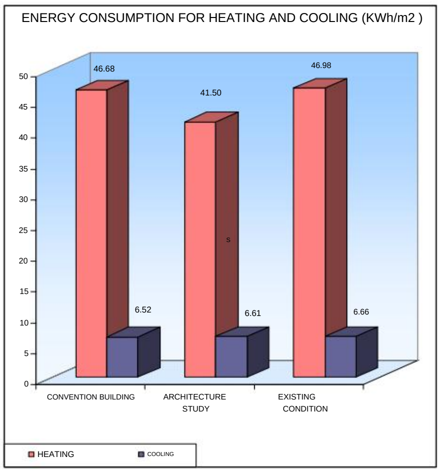
The greenhouse, as initially studied, would save heating energy of the order of 4.5%, while the Trombe wall 3%. In addition, the Trombe wall would contribute to increasing the temperature by 2o C and in addition to improving the thermal comfort in the adjacent space in winter, due to its high surface temperature resulting in heat radiation to the space. In the summer it must necessarily be shaded.

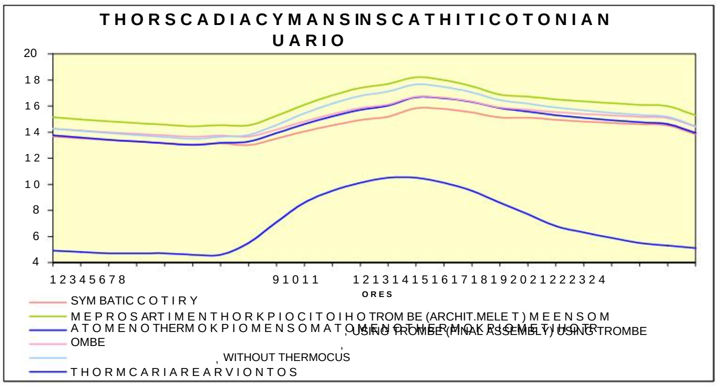
In general, these passive systems put little burden on the building in the summer, raising the temperature in the adjacent space by less than 1o C.

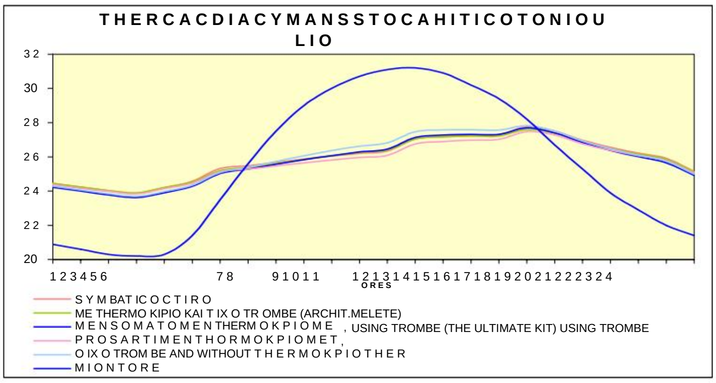
The operation of the existing greenhouse, as it is shaded and ventilated, does not burden the building.

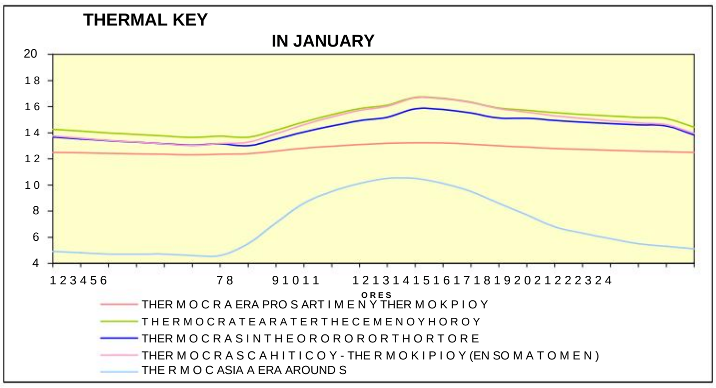
The natural cooling systems have been implemented as was the original study. The openings of the building are shaded with cantilevers and external sliding shutters. In the roof of the staircase there is a south-facing opening, which functions as a wind chimney, facilitating the ventilation of the building with the phenomenon of natural attraction, which implies the unloading of the building from the heat, but also greater thermal comfort.

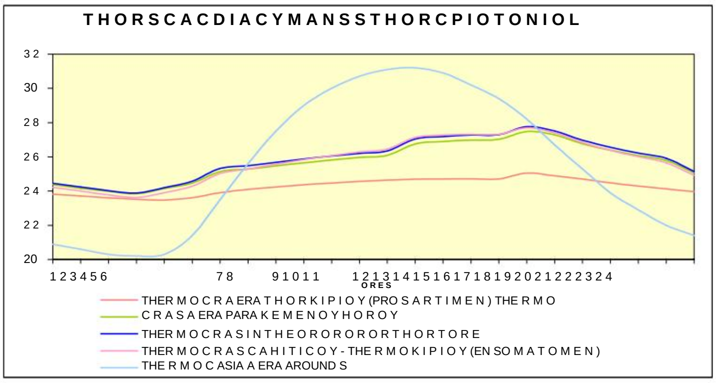
Thermal comfort prevails in the building, as the room temperatures are below 27.5o C, while the outside temperature reaches 31o C.











RESIDENCE IN MALESINA

Researcher: Th. Yakas
Year of construction:
1989 Building area: 226.3 m2
Area of heated spaces: 180.8 m2
Number of floors: 2 + basement
Passive Solar Systems: •
Greenhouse at a height of two floors
• Direct profit
Natural Cooling: •
Shading openings • Night
ventilation
• Greenhouse ventilation and shading
Insulation:
Masonry: 10 cm fiberglass
Ceiling: 10cm polystyrene

INTERIOR VIEW OF GREENHOUSE

BUILDING CONSTRUCTION	HEATING LOAD			COOLING LOAD		
	GJ	KWh/m2	%	GJ	KWh/m2	%
CONTRACT CONSTRUCTION	34.73	53.36	-	5.99	9.20	-
CURRENT SITUATION	21.30	32.73	-38.65 5.29		8.13	-11.70

In the building there is a greenhouse, which occupies a height of two floors. The greenhouse on the ground floor is in contact with the living room, while on floor with the main bedroom of the building. At floor height the greenhouse bears perimeter on the outer sides of the balcony in shape P, providing access to its opening glass panels collection surface. The roof of the greenhouse (an extension of of the building's roof) protrudes and completely shadows its upper part (per floor height) in the summer months. At the ground floor level, the greenhouse has french shutters for shading, as the cantilever does not shadows The communication of the greenhouse with the adjacent areas it is done through internal windows, which remain open in winter open during the day and close at night. The summer remain closed.

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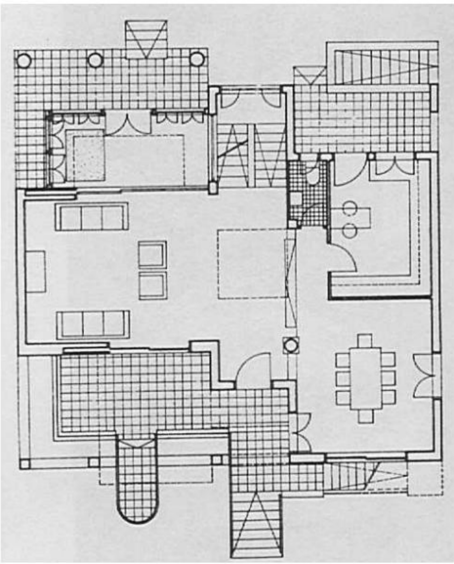
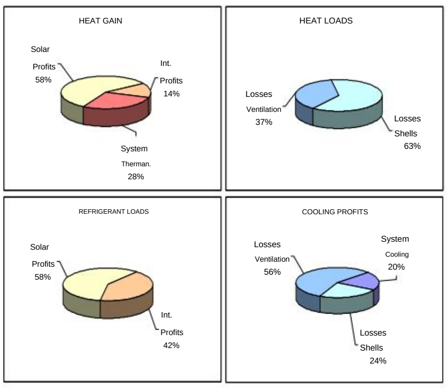


ground floor plan

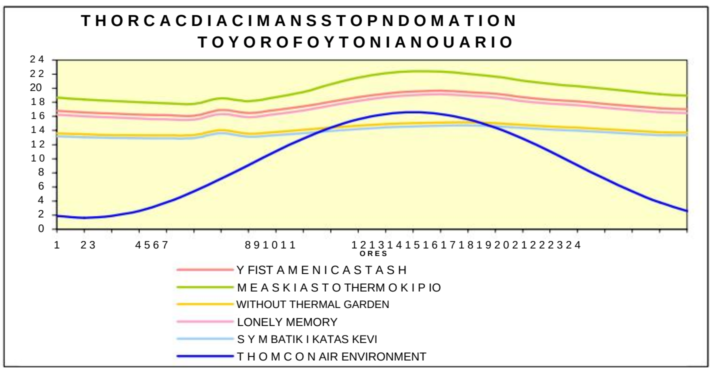
CONSTRUCTION AND OPERATION OF GREENHOUSE	LOAD HEATING		COOLING LOAD	
	GJ	KWh/m2	GJ	KWh/m2
GREENHOUSE WITH SHADE AND CONVENTIONAL ROOF (CONCRETE)	21.30	32.73	5.29	8.13
GREENHOUSE WITHOUT SHADE AND WITH ROOF FROM GLASS PANELS	16.78	25.78	26.95	41.41
WITHOUT GREENHOUSE	29.85	45.87	5.50	8.44

SHELL CONSTRUCTION	LOAD HEATING		LOAD COOLING	
	GJ	KWh/m2	GJ	KWh/m2
WITH INCREASED INSULATION	21.30	32.73	5.29	8.13
WITH GREENHOUSE AND STANDARD INSULATION	25.65	39.41	5.77	8.87

From the energy balance of the building it follows that the solar gains cover 58% of the total heating needs, while the auxiliary heating system about 28%.

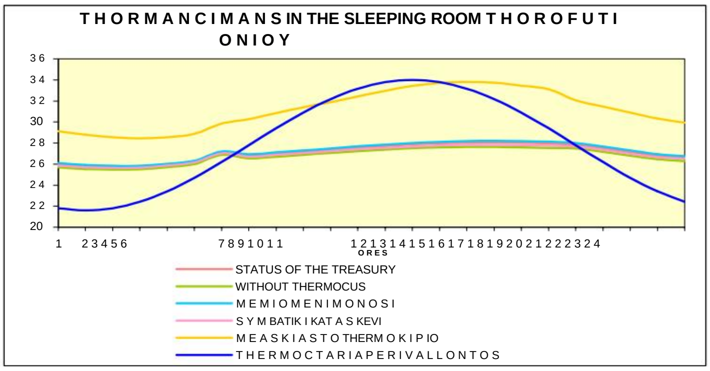


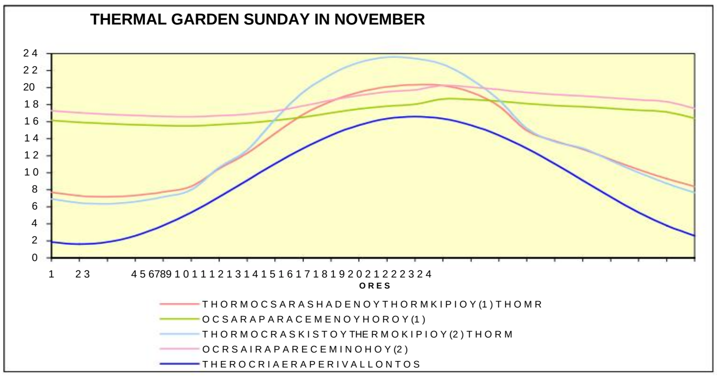
Energy balance



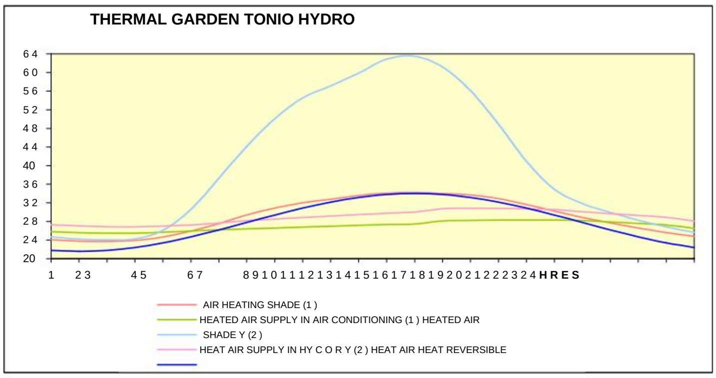
During the winter the greenhouse contributes to its reduction demand rate by 28.6%. In the summer, the greenhouse is also ventilated externally shaded by French shutters on the ground floor, and by a cantilever (overhang of the roof) on the floor and thus the building is not thermally burdened in the summer months. On the contrary, it shows a very slightly improved behavior, due to the shading. It is observed that in the summer in the greenhouse the air temperature is only 1o C higher than the outside temperature.

Although the shading of the greenhouse imposes a thermal burden on the building in winter and some intermediate periods (since the greenhouse has no solar gains from its roof), in summer it has a significant positive effect. Unshaded operation of the greenhouse in the summer results in an increase in cooling needs by 5 times as well as an increase in the temperature in the adjacent area of the ground floor by 1.5o C, and the floor by 5 C. That is, the temperature of the room should be around 34o C. It is typical that the air temperature inside the asciato greenhouse reaches 64o C, while the outside air temperature does not exceed 33o C.



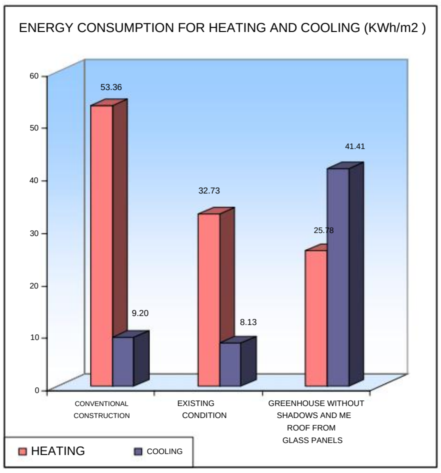


With the existing greenhouse operation, of the temperatures in the areas of the residence are below 28o C.



The increased insulation of the shell contributes to a reduction of the heating load by 17% and the cooling load by 8.4%.

The fact that there is no overheating problem in the residence in the summer is also due to the occupants who operate the ceiling fans in the bedrooms.



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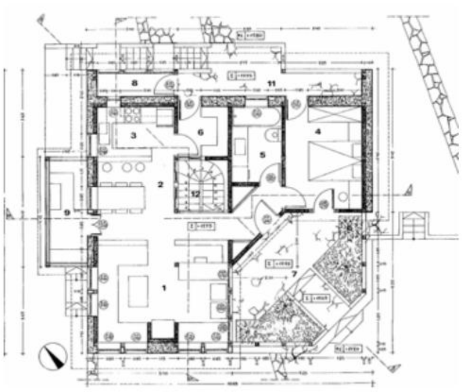
RESIDENCE IN PELIOS

Researcher: E. Georgiadou
Year of construction:
1997 Building area: 157.5 m2
Area of heated spaces: 89.9 m2
Number of floors: 2+attic
Passive Solar Systems: •
Greenhouse
• Direct profit (windows + skylights) Natural
Cooling: • Transverse and vertical
ventilation • Greenhouse ventilation

Masonry: Two 15 cm thick Thermoblock with 10 cm air gap, total thickness 45 cm Roof: Wooden roof with Heraklith insulation 7.5 cm thick

The residence in Pelion has particularly low consumptions heating period, both due to design and passives systems, but mainly due to the behavior of the users. It is characteristic that the only auxiliary heating system is two wood stoves (one in the living room and one in the greenhouse). You must also note that the study had morphological limitations due to traditional character of the region.



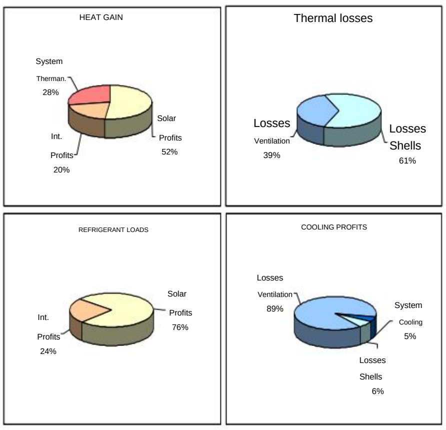
ground floor plan

BUILDING CONSTRUCTION	HEATING LOAD			COOLING LOAD		
	GJ KWh/m2 % GJ KWh/m2 %					
CONTRACT CONSTRUCTION	20.57	63.57	-	1.25	3.85	-
CURRENT SITUATION	17.62	54.44 -14.36 2.19			6.77	75.92

During the energy simulation of the building, the setting of the thermostat for the heating system it was considered at 19o C, following the suggestion of tenants.

From the energy balance it follows that the solar gains are the 52% of the total thermal gains of the building, while the auxiliary heating covers 28%.

GREENHOUSE OPERATION	LOAD HEATING		COOLING LOAD	
	GJ	KWh/m2 GJ KWh/m2		
SCENARIO 1	17.62	54.44	2.19	6.77
SCENARIO 2	17.78	54.95	2.19	6.77
WITHOUT AUXILIARY HEATING SYSTEM IN GREENHOUSE, SCENARIO 1	16.60	51.28	2.19	6.77
WITHOUT GREENHOUSE	20.39	63.01	1.23	3.81



Energy balance

SHELL CONSTRUCTION	LOAD HEATING		COOLING LOAD	
	GJ	KWh/m2 GJ KWh/m2		
MASONRY WITH THERMOBLOCK	17.62	54.44	2.19	6.77
TYPICAL MASONRY	17.00	52.53	1.70	5.24

The greenhouse contributes 13.6% to the reduction of the heat load, although it has a limited number of openings (solid apron 65 cm high and part only of the pitched roof of glass fence), which was done for reasons to protect the building from summer overheating. The greenhouse essentially functions as a part of the building with direct profit because it is used as the main space in the winter and is heated certain hours only.

The greenhouse has been examined in terms of the efficiency of its operation with two operating scenarios:

1. With all openings to the interior open at during the day, so that there is an immediate benefit of them solar gains in the premises.

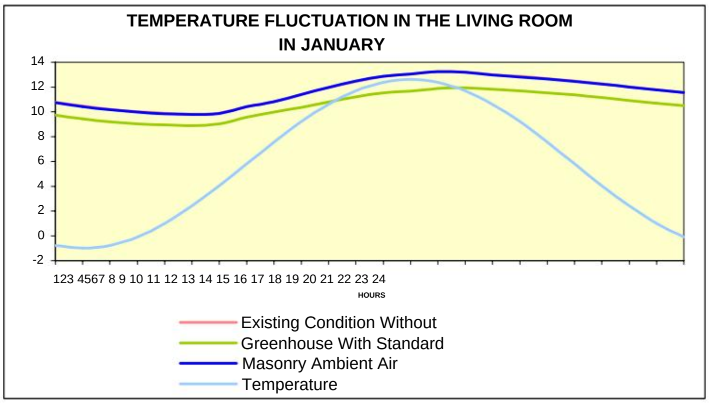
2. With a few openings open, so that the greenhouse is heated more and to gradually deliver the heat to the space.

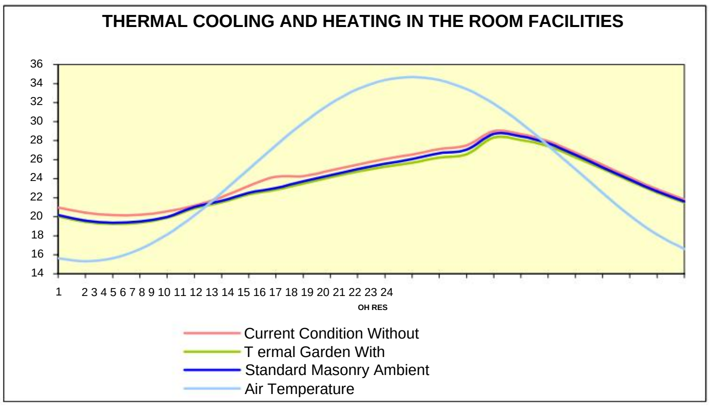
From the results of the simulation it follows that the two scenarios do not show a substantial difference, although the former shows slightly improved performance.

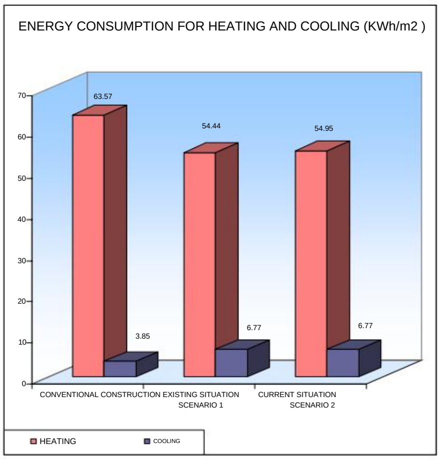
The special Thermoblock masonry, in relation to the standard masonry, seems to perform slightly less, which leads to the conclusion that the thermal insulation and thermal storage capacity of this masonry in the specific climate is not satisfactory, but it could show better results if it had slightly greater thickness.

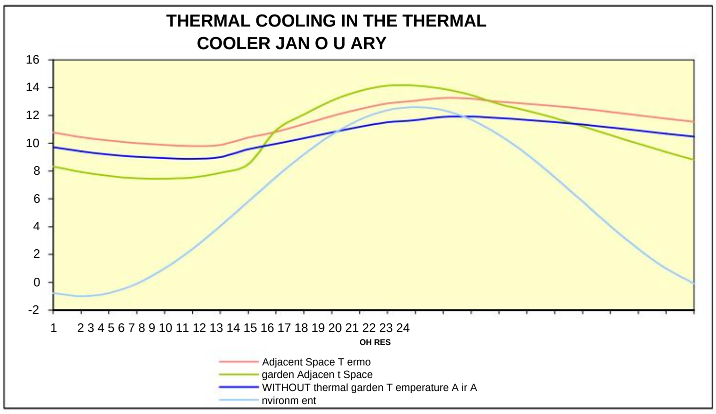
The auxiliary heating system (wood stove) performs adequately throughout the building. The consumption of wood for heating per year is very low (4 tons per year) compared to other buildings in the area, although the climate of the area is particularly cold in winter. It is also characteristic that the tenants stated that in the attic bedroom high temperatures are observed in winter (26-27o C), which is attributed to the accumulation of hot air, due to stratification.

In the summer, overheating is not observed in any space, as the transverse and vertical ventilation creates a discharge of excess heat and an increased air current. Nevertheless, as can be seen from the simulations, the greenhouse thermally burdens the building (40% burden on the theoretical cooling load and internal temperatures of the building at the limits of thermal comfort). The users of the building, however, confirm that they do not have an overheating problem in the summer.









RESIDENCES IN TRIKALA

Researchers: T. Saliachis, N. Saliachis
Year of construction:
1996 Building area: 267.7 m2
Area of heated spaces: 204.0 m2
Number of floors: 2+basement
Passive Solar Systems: •
Direct gain (windows, roof opening, small sunroom) Natural Cooling:
• Shading of vertical openings • Transverse and vertical ventilation

The residence, located in an area with no dense construction, presents, as reported by the users, low energy consumption for heating, although the loads resulting from the simulation are relatively high, due to the cold climate in winter (about 85 kWh/m2).

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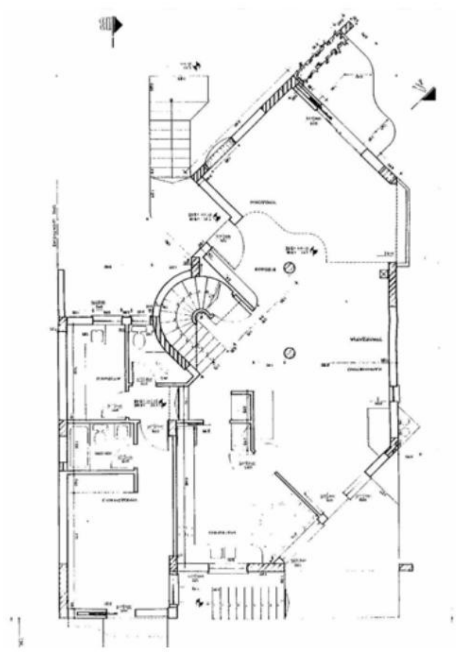


ground floor plan

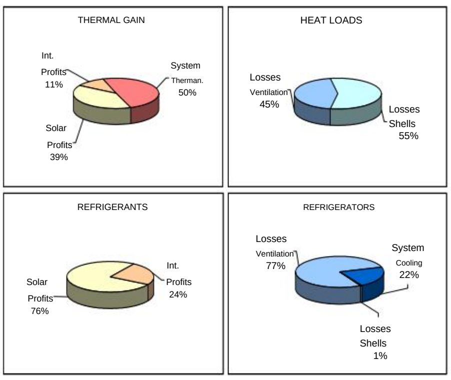
BUILDING CONSTRUCTION	HEATING LOAD			COOLING LOAD		
	GJ KWh/m2 % GJ KWh/m2 %					
CONTRACT CONSTRUCTION	68.57	83.73	-	2.83	3.45	-
CURRENT SITUATION	69.25	84.56	0.99	7.35	8.98	160

From the energy balance it follows that the solar gains in winter constitute 39% of the total thermal gains, while the auxiliary heating covers 50%.

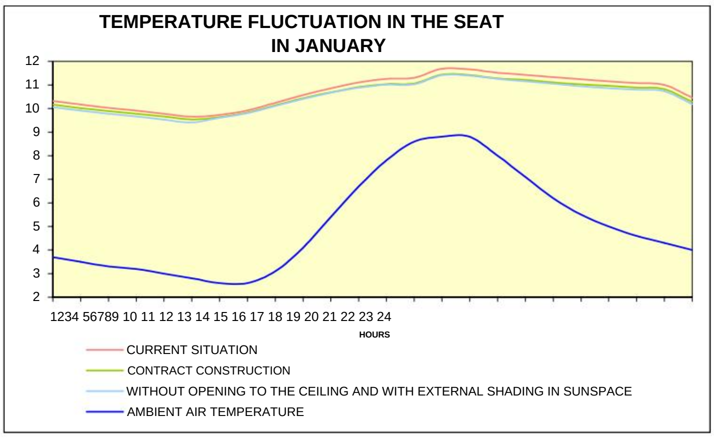
INSTANT PROFIT MODE	LOAD HEATING		COOLING LOAD	
	GJ KWh/m2 GJ KWh/m2			
ROOF OPENING AND SUNSHINE ASKIASTA 69.25		84.56	7.35	8.98
INTERNAL SHADING IN THE ROOF OPENING 69.25		84.58	3.38	4.12
SHADING SYSTEM IN LIAKOTO	70.24	85.77	7.33	8.95
WITHOUT THE ROOF OPENING AND WITH SYSTEM SHADOW IN LIAKOTO	69.67	85.07	1.60	1.95

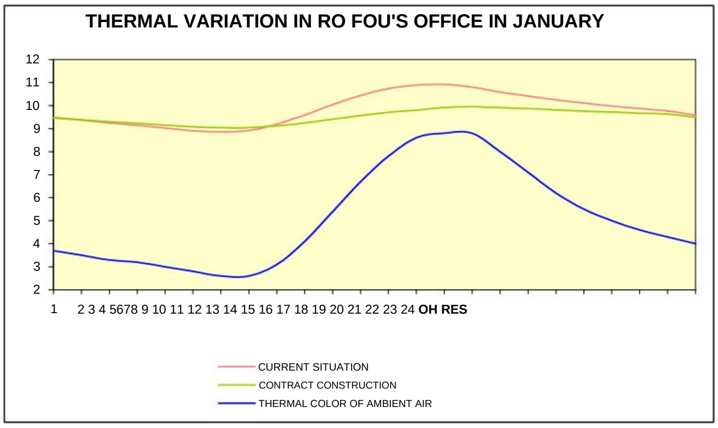
A special architectural element of the house is the roof opening, the which is hemispherical, covered with a polycarbonate sheet, which carries opening section at its top. There is also a small "sunny" of the south orientation, total area of approximately 7.5 m2 , in which an insulating quilt is placed on the outside, as nighttime thermal insulation winter.

The roof opening has little effect on the total heating load, increasing it by 1%. This small increase is due to the fact that, due to the low temperatures of the region, it presents many thermal losses during the night, which neutralize the daily earnings. His positive contribution in the winter can be found in improvement of thermal comfort conditions in the adjacent area (staircase and open office space), but in the summer there is corresponding overheating, when it remains closed.

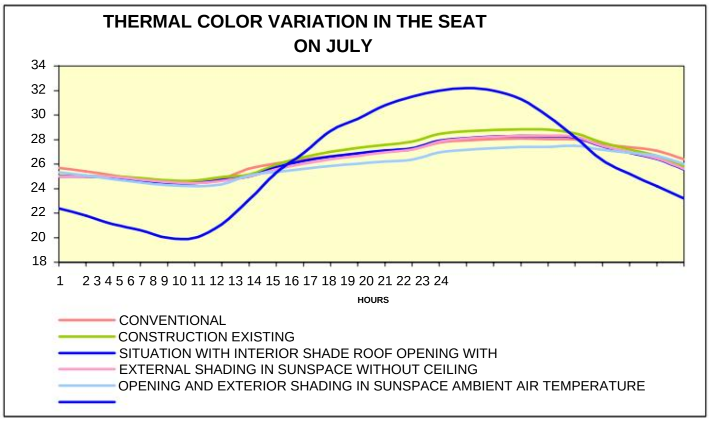


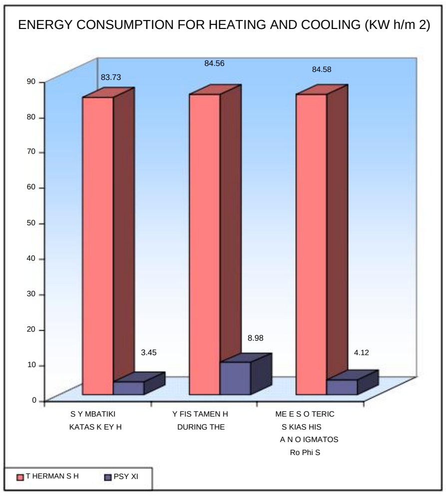
Energy balance

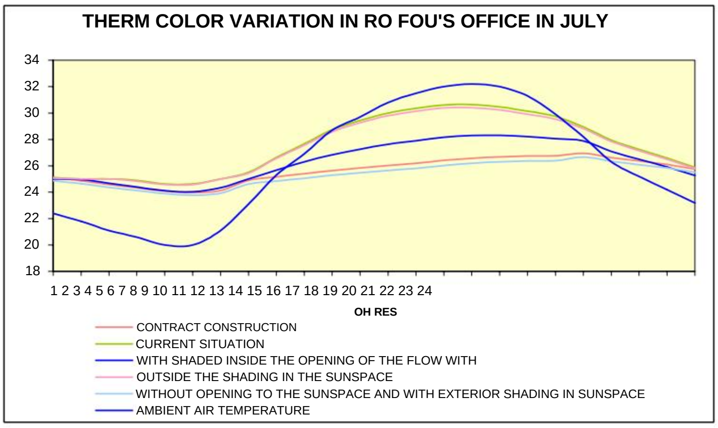




An important phenomenon in this residence is that the passive solar systems of the building affect the adjacent spaces, while in the bedrooms both on the ground floor and on the first floor, the effect is negligible. This phenomenon, demonstrated by the simulation, is largely due to the fact that the warm air circulates both due to stratification and due to natural attraction in the interior of the building and not in the adjacent bedrooms.

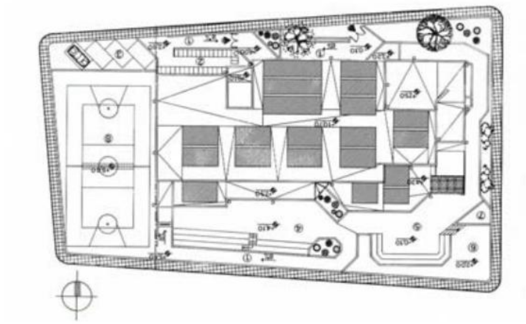






SCHOOL IN RETHYMNO

Researcher: I. Kalligeris
Year of construction:
1987 Building area: 1430.4 m2
Area of heated spaces: 893.7 m2
Number of floors: 3
Passive Solar Systems: •
Direct profit (windows + skylights) •
Greenhouse attached to two rooms
Natural Cooling: •
Shading of openings (horizontal louvered external shades) •
Transverse and vertical ventilation



FLOOR PLAN OF A SCHOOL COMPLEX

BUILDING CONSTRUCTION	HEATING LOAD			COOLING LOAD		
	GJ	KWh/m2	%	GJ	KWh/m2	%
CONTRACTUAL STATUS	32.68	10.16	-	25.33	7.87	-
CURRENT SITUATION	34.53	10.73	5.65	33.45	10.40	32.09
ARCHITECTURE STUDY	21.64	6.73	-33.79	16.31	5.07	-35.59

The school is a typical example of its differentiation construction from the study, resulting in large deviations in energy behavior of the building, in this case its reversal behavior of the building's passive systems.

OPERATION OF PASSIVE SYSTEMS	LOAD HEATING		LOAD COOLING	
	GJ	KWh/m2	GJ	KWh/m2
BUILDING WITH GREENHOUSE AND SHADE	21.64	6.73	16.31	5.07
BUILDING WITHOUT GREENHOUSE	35.85	11.14	12.08	3.76
BUILDING WITHOUT SHADE STUFF FEGITES	21.64	6.73	18.75	5.83

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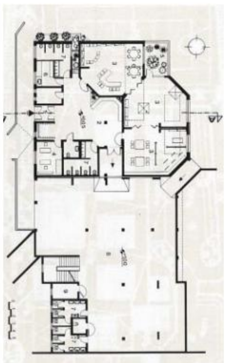
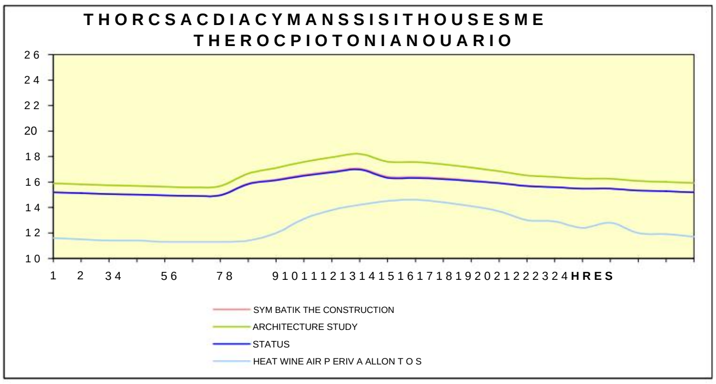
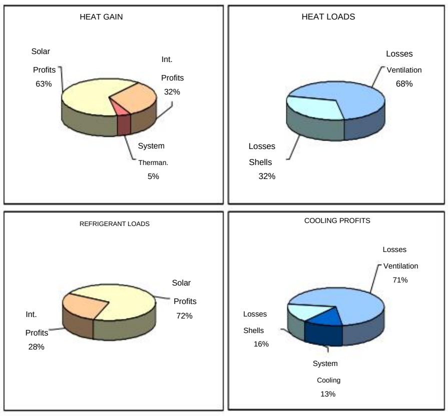


GROUND FLOOR FLOOR FLOOR FLOOR

In particular for the winter period, while the architectural study would have as a result of 33.8% energy saving in the winter and a reduction of cooling needs by 36%, with the existing construction and operation we have an increase in heating needs by 5.65% and cooling needs by 32%, in relation to the building without the passive systems.





Energy balance

The most important differences of the construction from the study are:

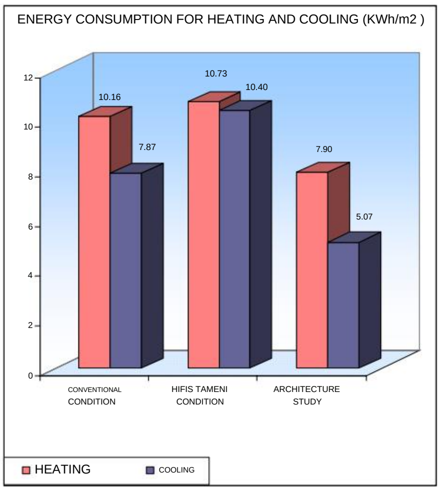
- The skylights, while they were originally made openable, due to poor construction have been sealed.
- Shades on skylights and windows while they were designed folding, they were built firmly, they have not been destroyed in one a significant percentage of them. This results in insufficient shading of the openings, but also its incomplete protection polycarbonate sheet of the skylights from weather conditions, which led to the aging of the material (clouding and yellowing).
- The study provided for openings (windows) to the corridor for through ventilation which do not work (some remain open, others closed regardless of season and time).
- The greenhouse remains isolated from the halls (the communication openings remain closed), but also presents

deterioration (clouding and yellowing, due to the aging of polycarbonate sheets) resulting in the reduction of solar gains in the room in winter.

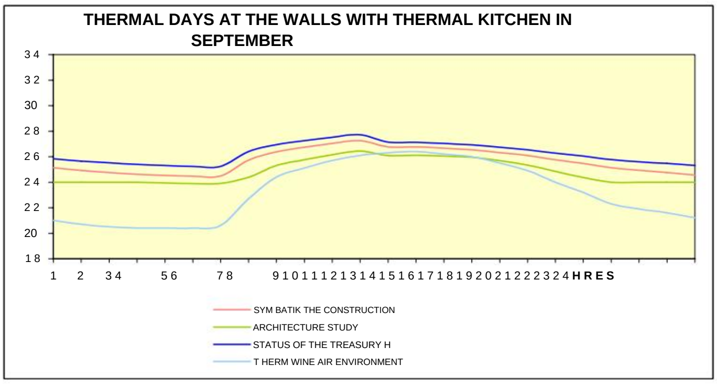
From the energy balance of the existing building, it follows that the solar gains make up 63% of the thermal gains, while the auxiliary heating covers only 5%, and in the summer the thermal gains are due to 72% of the solar gains.

In the school rooms with skylights, as can be seen from the simulation, high winter temperatures are present. In January, the temperature changes varies in the existing building from 18 oC to 23o C, while if the study were applied it would be from 20o C to 25.5o C, (ie the rooms would not need auxiliary heating). As it follows from the simulation analysis, the building in its theoretical conventional form without skylights, presents a lower temperature variation, as it has a smaller increase in temperature per hour than the two cases above where there are skylights, which provide thermal (solar) gains to the room. The internal temperature of the room in this case ranges from 20 oC to 23o C.

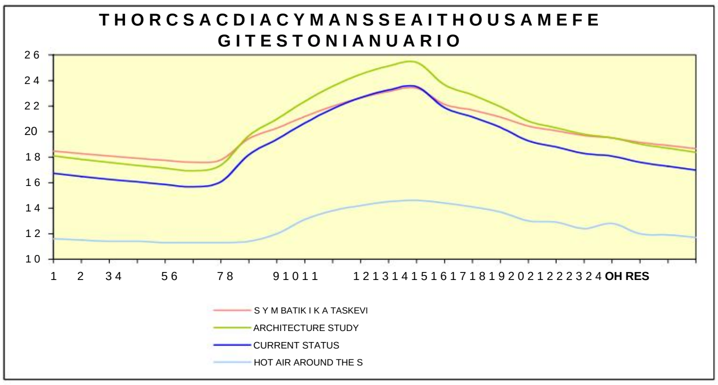
The simulation shows that both in June and September the greenhouse with the appropriate operation would not burden the building thermally, while in January it would raise the internal temperature of the space by 1.5o C.

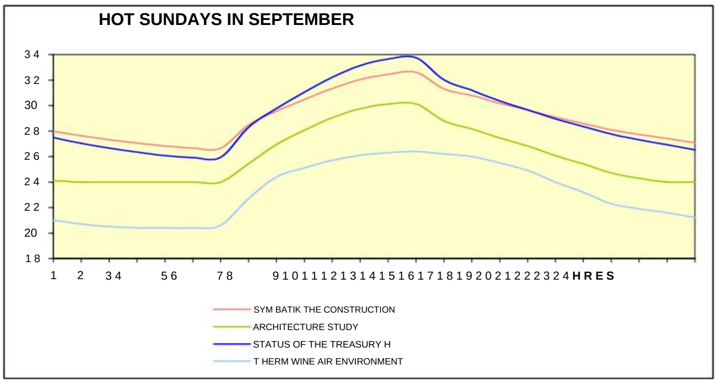


The most critical month in terms of heat load is



September (in July and August the school does not operate and therefore the behavior of the building was not examined in these months). In the current situation, significant overheating occurs, as the indoor temperature in the rooms reaches 34o C (which would reach 32o C in the conventional building and 30o C if the architectural study had been applied correctly). In the room bordering the greenhouse, much lower temperatures are observed and within comfort limits, as this room has small solar gains (no skylights) and is also semi-underground.





OFFICES-WORKSHOPS IN PIKERMI, ATTICA

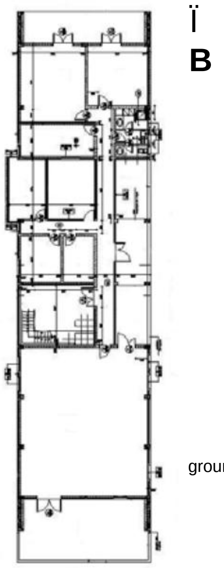
Researcher: Studies, Office of Studies A.N. Topaz
Year of construction:
2000 Building area: 268.5 m2
Area of heated spaces: 215 m2
Number of floors:
Passive Solar Systems: •
Direct profit (windows + skylights) • Patio

Natural Cooling: •
Transverse and vertical ventilation

The building, which houses the Photovoltaic Laboratory of KOPE, is arranged on the north-south axis, due to the shape of the plot, the however, its main aspect is the small southern one, 10.5m long, while the eastern and west side have a length of 36.5m. For its sun exposure and natural lighting building, an atrium has been created inside and skylights on the top section of the vertical southern masonry.

CONSTRUCTION	LOAD HEATING			LOAD COOLING		
	GJ	KWh/m2	% GJ		KWh/m2	%
CONTRACT CONSTRUCTION	10.90	14.08	-	89.46	115.64	-
CURRENT SITUATION	22.25	28.76	104.20	67.43	87.17	-24.62

An important parameter in the design of the building was the provision of adequate and good quality natural lighting, a fact that has as resulting in the reduction of the building's artificial lighting needs.



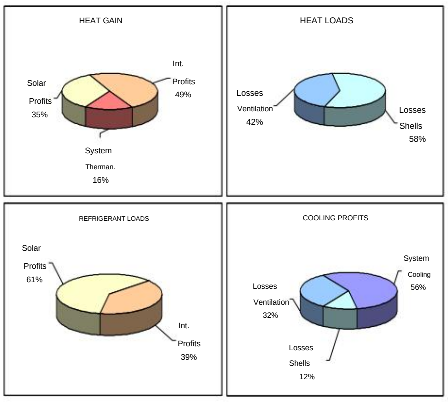
ground floor plan

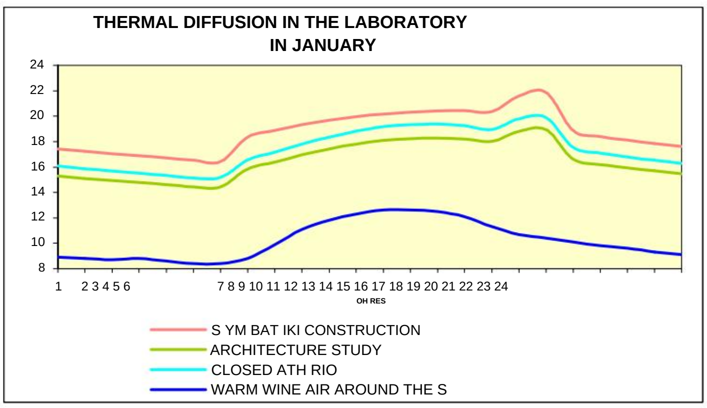
OPERATION OF COOLING SYSTEMS	COOLING LOAD	
	GJ	KWh/m2
WITH TOP VENTILATION, WITHOUT SHADING SYSTEM	67.43	87.17
WITH TOP VENTILATION AND SHADING SYSTEM INSIDE	55.50	71.74
WITHOUT CEILING VENTILATION AND SHADING SYSTEM	69.24	89.50
WITH NIGHT FORCED VENTILATION, WITHOUT SHADING	59.15	76.46
WITH INTERNAL SHADING SYSTEM AND NIGHT FORCED VENTILATION	49.86	64.46

SHELL CONSTRUCTION	HEATING LOAD			COOLING LOAD		
	GJ	KWh/m2	%	GJ	KWh/m2	%
WITH OPEN PATIO	22.25	28.76	-	22.25	28.76	-
WITH CLOSED PATIO	11.00	14.21	-50.58	107.42	138.86	382.81

Energy balance

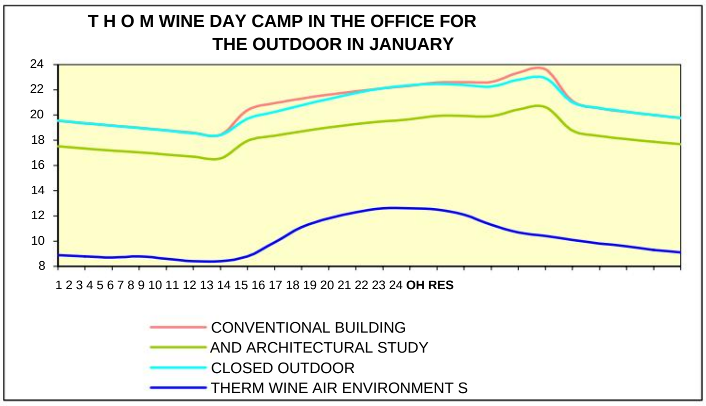
This building has very low energy needs for heating, both due to its use (high thermal gains) and due to design and construction. From the energy balance for during the heating period it follows that the solar gains make up 35% of it heat balance, the internal profits 49%, while the auxiliary heating is required to cover 16%. The internal temperature without the system heating would reach 20o C on a typical January day. THE resulting internal temperature is lower in laboratories (drops to 16o C during the first hours of operation of the building), while in the office facing the patio, due to more interior and solar gains are above 18o C during the building's operating hours.

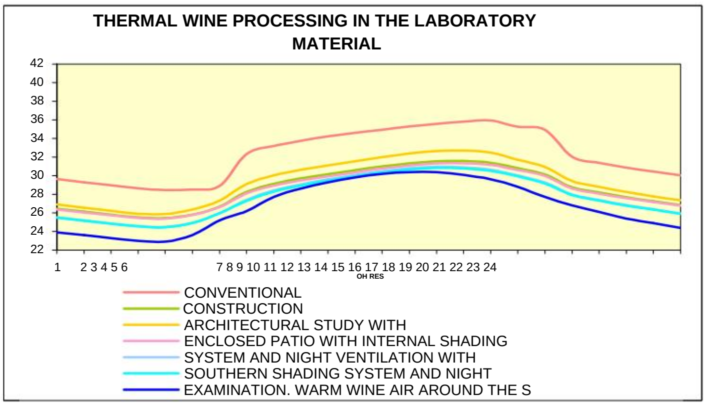


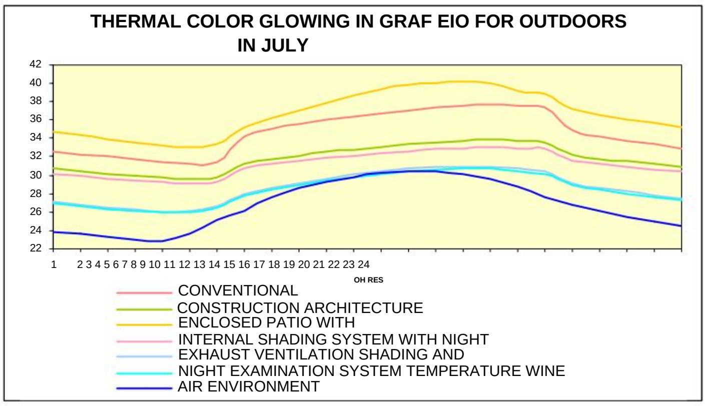


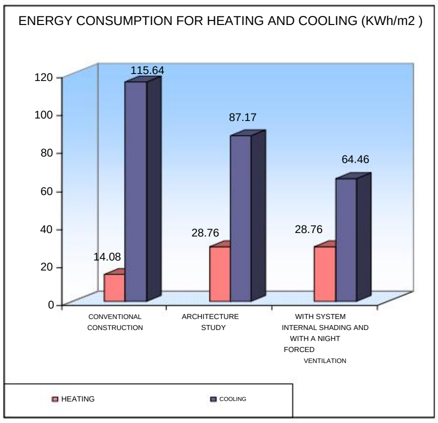
Conversely in summer, due to the internal gains, the building presents high cooling requirements, as the internal temperature without the auxiliary system would reach 33o C in the office area and 31o C in the laboratory, on a typical July day.

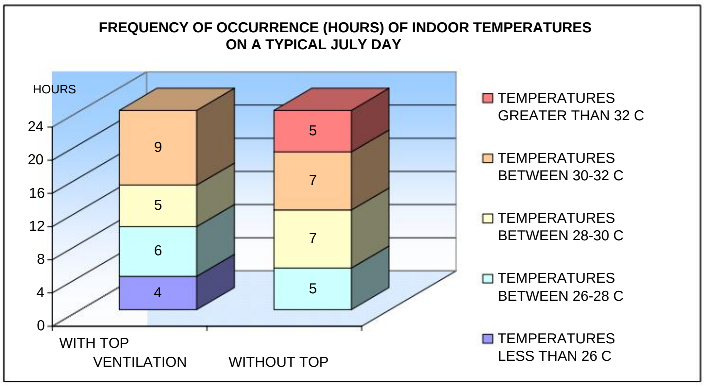
From the analysis of the building with simulation it follows that the building without the presence of the skylights (conventional construction) would have even lower heating requirements, approximately 50% less than the existing building, but the cooling requirements would increase by 24%, due to of increased thermal gains from the greater number of lights in operation and from the inability of vertical ventilation, resulting in the development of internal temperatures in July to 37o C in the office and 36o C in the laboratory. In addition, the existence of skylights is necessary for the natural lighting of the building. The possibility of vertical night ventilation of the building is important, which reduces the cooling load of the building by approximately 3%. With the forced night ventilation of the building (10 air changes per hour), there is an additional energy saving of 12%. The effect of an internal shading system of all the glazing in the building during the cooling period was investigated. This solution results in an energy saving of 18% and a reduction of the internal temperature, when the system is not operating in July, by at least 0.5o C in the office facing the patio. The combination of shading and forced ventilation will contribute to an energy saving of 26% compared to the existing operation of the building, reducing the internal temperature of the building by at least 2o C in the office, and almost 1o C in the laboratory. Finally, the energy behavior of the building was investigated with the atrium closed with glass panels on its roof, provided that it is shaded and ventilated in the summer. Although it significantly reduces heating needs by 50%, it increases the cooling load by 60% and is therefore not a viable solution, as the building's cooling needs are much higher.











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