LESSONS LEARNED FROM THE PEFKI SOLAR VILLAGE IN ATHENS, NEARLY 20 YEARS ON.

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ABSTRACT

Solar Village 3 in Pefki, Athens, was part of an ambitious program, with active and passive solar systems providing space and water heating for 1750 inhabitants, designed in the early 80's, and inhabited from the late 80's.
This paper focuses on passive solar systems applied to a number of the buildings. A survey highlighted the cases of trombe water benches and conservatories as the most frequently, poorly operated systems. Over time this led to a lack of belief by the occupants in the passive systems.
Building simulation indicated a much higher cooling load than originally designed for, combined with recent warmer summers and poor maintenance and operation, have led to the present case that many homes have installed air conditioning.
Plans for district heating will improve heating provision for residents and reduce CO_2 emissions but a lack of a maintenance strategy for the passive systems will surely lead to their increased neglect.

1. INTRODUCTION

Solar Village 3 in Pefki, Athens, was the result of an intergovernmental agreement between the relevant government departments of Greece and Germany, with the participation of the Greek Workers' Housing Organization (OEK) (1), it benefited from EU funds being part of a demonstration project.
The design competition was held between 1978 and 1981, and won by Tombazis Architects (2). Construction started in 1984 and was concluded in 1988. The housing scheme consists of: 435 apartments distributed in 25 buildings, an energy and solar information centre, commercial and community facilities, and a central public open square.
The village is organized in neighbourhoods, each one with its own playground, separated by streets, and arranged in a herring bone pattern.
Apart from the materials used in the active and passive energy systems, the remaining construction materials and methods employed were conventional. The project was intended to demonstrate that solar houses do not have to differ from conventional ones.
On completion houses were awarded to eligible families by lottery, and occupation started from the end of 1988 (3). The agreement included a very low rent for the inhabitants for about 15 years (i.e. 60 Euro/month), after which the ownership of the houses would pass to them. This handover is currently still in negotiation, meanwhile maintenance of central electro-mechanical installations and the issuing of energy bills is still being performed by OEK.

1.1 Main environmental strategies

There are a few main strategies that run throughout the village, these are as follows:

- The majority of main elevations, openings, terraces and balconies are south facing. Flats are arranged on an east-west long axis. Northern openings are restricted to a minimum to reduce heat losses in winter. No East or West openings exist, to avoid high solar gains in summer.
- Increased insulation levels (100mm) to reduce heating loads (further than those required by building regulations 4). Exterior insulation is used over walls and concrete frame to eliminate thermal bridges. The upper and lower surfaces of balcony slabs were also insulated.
- Double glazed windows with night insulation shutters.
- High thermal mass of building shell used to offset temperature differences between day and night.
- Overheating can be avoided by provision of external shading during summer, with blinds, awnings, overhangs, and plants.
- Natural cooling is achieved through the narrow plans of the flats and the North and South openings that provide cross ventilation.

- Arrangement and distances between the buildings ensure optimum daylight levels and solar heat gains during winter
- All the various buildings are designed and arranged in space in order to provide a protective “barrier” against cold north winds
- Except for the 3 bed homes, the remaining homes all have bedrooms that are south orientated. Living rooms are dual aspect (north and south) for cross ventilation, while kitchens and bathrooms are on the north side.

2. DESCRIPTION OF PASSIVE SOLAR SYSTEMS IN PEFKI SOLAR VILLAGE

In this paper only the homes with passive solar features are considered, (4 of the total 25 buildings consisting of 34 flats). These buildings have space heating from a combination of the most up to date passive solar systems (conservatories, thermal storage walls, trombe walls, thermo-siphonic panels). For Domestic Hot Water (DHW) autonomous, thermo-siphonic solar systems (flat plate collectors) are used in 3 out of the 4 buildings. In the fourth building, a 3 storey apartment building, DHW is supplied by a central system.

In all these houses in winter, the solar energy falls directly on floors, walls and ceilings, after passing through large glass surfaces. Solar energy is stored by the buildings’ high thermal mass; solar collectors located on the roofs, provide energy for water heating. Selected autonomous, passive solar systems are integrated in the design. These systems are briefly described below.

2.1 Indirect gain - 2 storey thermal storage walls (trombe or water walls)

In these systems 60% or more of the solar energy is absorbed by a concrete wall of high thermal storage capacity (300mm thickness). Its external surface is painted black, absorbing solar energy behind a glass pane. The thermal storage material can also be water. The thermal mass of the walls absorbs the heat and then reradiates it into the rooms, when the indoor temperature drops.

2.2 Direct solar gain- water benches

These are low elements painted with absorbing paint and filled with water for thermal mass, and are situated under the windows. They have an insulated shutter, providing shading during the summer period and night insulation during winter.

2.3 Expanded indirect gain (conservatory, trombe walls)

This system is based on trombe wall properties, but the heat storing gap between the glass pane and the wall is, in this case, a whole new space, a conservatory. This system is less efficient; however it provides an attractive new space in the dwelling.

The heat stored is distributed to the house by radiation from the thermally massive wall, or by convection, when the glass doors of the living room are opened.

2.4 Expanded indirect gain (1½ storey conservatory, water walls)

The conservatory of this system is larger (1½ storeys), allowing the storage of solar energy in water walls that extend on all South walls of the ground floor and almost half of the first floor. The thermal storage in this case is water, used as a variation to the previous system for comparison reasons (3).

2.5 Isolated gain (thermo-siphonic air panels to hollow-core slabs)

In this system, solar energy is absorbed and stored in thermo-siphonic panels, which are similar in structure to trombe walls. The external surface of the wall features a glass pane, an air gap and then a selective heat absorbing material. Solar radiation heats the trapped air; this air is controlled thermostatically and delivered directly to the heated space through ducts and openings on the floors or ceilings (hollow-core slabs). The air then returns to the air panel, to complete a full cycle.

2.6 Expanded isolated gain (heat transfer cycle: conservatory to hollow-core slabs)

In these flats, the air heated by the sun in the conservatory is conveyed to the dwelling, by going first to an air plenum with adequate thermal storage capacity (hollow-core slabs). Due to thermo-siphonic effect, it is transferred through the floor, reaching all spaces of the dwelling, and finally back to the conservatory to complete the cycle.

2.7 Combination of systems in the three storey apartment building

Three distinct systems, a combination of two or more of the previously described systems, are applied in the three storey highly passive apartment building. The ground floor has a direct gain system with water benches. The first floor has a conservatory equipped with water walls. The second floor has a trombe wall (thermally massive) in the bedrooms and a thermo-siphonic panel in the living room.

3. CLIMATE CHANGE

Since the time of the original design, global climate change has become an important issue. Athens has a Mediterranean type climate with mild winters and hot summers; however, even here, some evidence is appearing that suggests that over the timescale between design date and now there have been changes in the Athens climate.

Data from (5) shows an increase in maximum temperatures of approximately +2 °C between the periods (1978-1983) and (1999-2004).

A report from the National Observatory of Athens (6) supports such a consideration, noting a continuous tendency in Greece for warmer summers that has appeared from mid-1970’s up to the present, with 1999 being the warmest year of the century for Athens. In Athens, the frequency of maximum daily temperatures exceeding 35-38°C in the last 3 years is the highest for at least 100 years. However, “no similar change has been found in the frequency of occurrence of cold extremes.”

These issues appear increasingly frequently in newspapers and magazines in Greece (7), implicating global warming and urbanization for the increase of temperatures in summer and consequently, on higher energy consumption for air conditioning.

4. RESIDENT SURVEY

Residents of the buildings with passive solar features were surveyed in July 2005 in the form of written questionnaires that were distributed to each family; 20 of the 34 homes responded.

Most families moved in, between 1988 and 1992. Therefore one can assume that they attended the first “seminar” about the systems, and were informed on how they work and how they should be used to allow them to save both energy and money. Some mentioned the original printed user’s guide they were given, but nobody was actually able to present it.

The majority of occupants are now aged 46-60 and have two or more children. The majority of families (55%) claim that they always use the passive systems, however a significant percentage (30%) admit that they never use them, their reasons include that they are “time consuming” or “useless in terms of energy saving”.

4.1 Response for each system

A closer look at the answers shows “never use” responses refer mainly to the water benches. A question about ease of use suggests occupants understand how to use them but find their performance to be “bad” or “mediocre”.

Although the majority claim to use the passive systems, only 10% of responses consider any system as “good”, with most answers rating them as mediocre or even bad, see table 1 (8). Almost the same “bad” performance is attributed to houses with conservatories, though some users said they can contribute to energy efficiency.

TABLE 1: HOW WOULD YOU RATE THE PASSIVE SYSTEMS PERFORMANCE?

	Good	Mediocre	Bad
Thermo-siphonic panels		2	
Trombe wall	1	3	
Water Bench		2	3
Conservatory with water or trombe wall	1	3	3
Water wall		2	

Concerning the response for awnings (not shown here), things are less clear. In summer, most inhabitants (90%) say that they always use them, meaning they have them lowered most of the time to provide shading. In winter, however, a surprisingly high percentage seem to keep them lowered (65% always, 20% sometimes), thus blocking and inactivating the passive systems operation. One can assume that most of them behave like that either for privacy reasons, insufficient knowledge of the systems or simply because of negligence.

4.2 Air conditioning and other heating and cooling methods

The “negative” way the residents look at the passive systems is clearly reflected in their turn to air conditioning (a/c) systems. 90% of the homes surveyed are using air conditioning systems, with 60% of units installed between 1999 and 2004 (8). A small percentage (15%) have had an a/c unit installed since 1992-1994.

Apart from a/c units, 60% of the houses are also using a variety of other, additional means for heating or cooling:

- For heating: electric heaters (25%), fireplaces (5%), gas heaters (20%), halogen heaters (5%) or combinations, ie. gas heater & fireplace (5%)
- For cooling: electric fans (25%)

4.3 Conservatories

The majority of the families use conservatories as living spaces (86%). Most have been turned into an “extra” playroom or children’s room. Others are used as storage spaces, with furniture (units with shelves, desks, closets) placed against the thermal walls and on the floor, minimizing the absorption of solar energy.

4.4 Thermal comfort

In questions about thermal comfort conditions (when heating or cooling is provided by the passive systems only), overall evaluation is:

- Winter: 45% bad, 40% mediocre, 15% good
- Summer: 35% bad, 50% mediocre, 15% good

A large percentage of those dissatisfied in both periods have homes with both water benches and conservatories (8).

By examining the results in more detail we find that living rooms were found to be cold in winter (80%), bedrooms were also found to be cold (65%). In 2-storey houses bedrooms are on the first floor and have more exposed surfaces.

Half the sample state that underheating is a major problem in winter (50% always). Overheating occurs occasionally in summer (70% sometimes) when external temperatures rise significantly.

Overall design evaluation

The majority of the occupants consider their house to be “good” aesthetically. They think the same about its layout and the arrangement and distribution of spaces (8). Concerning storage spaces, 45% rate them “bad” and another 20% “mediocre”, most do not have a separate storage space, apart from closets in bedrooms and kitchen.

4.5 Overall satisfaction with the house

Despite a few homes with significant problems including,

- Awnings that have broken and have never been replaced
- Dampness caused from leakage of the water bench system
- Broken roller blinds (insulated shutters) in trombe walls

35% seem satisfied with their homes, and 60% rate them “mediocre”. However it is clear that there is dissatisfaction in terms of thermal comfort, and some distrust of the passive systems, this obviously affects their overall opinion about their house.

4.6 Future use

When questioned about the future, only 40% would be willing to keep the passive systems operating in the future, 30% would be pleased with occasional operation (perhaps supplemental to other, conventional systems), 30% would not mind if the systems did not exist in the future.

5. MONITORING SURVEY

Apartment UBC05 was monitored, for two periods: 1-7 April, and 14-26 July 2005. This is a two storey house, with conservatory, thermal storage walls on the ground floor (living room) and trombe walls with insulated roller blinds on the first floor (bedrooms). It has no air conditioning installed. For supplementary heating in winter, electric resistance heaters were provided. The residents claimed that they did not use them during the monitoring period.

In winter, the living room benefits from the conservatory and is warmer than the south bedroom of the first floor (+2 ºC). The trombe walls on the first floor (bedroom) were totally shaded, therefore inactive.

The residents were satisfied with overall mean temperatures of 19-19.5ºC, probably adopting high clothing levels.

In summer, the spaces appear to follow the external temperature fluctuations (mean 28.22ºC, max 33.6ºC) at nighttime they drop to 25-27ºC, during the day, they rise though remain 1-2ºC cooler than outside. The living room is apparently cooler than the bedroom. However, temperatures ranging between 27-32ºC for both spaces cannot be considered satisfactory.

6. MODELLING EXERCISE

In order to further examine the internal environmental conditions in the passive houses, the environmental conditions of apartment UBC05 were also modelled using TAS dynamic thermal building simulation software (9).

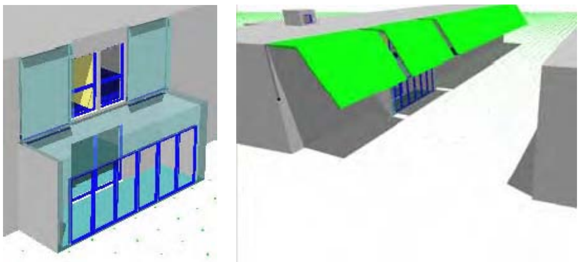

Fig. 1: TAS model views

Weather data for Athens featuring a warm summer (max. temp. 39.3ºC) was selected. Appropriate selections were made for air change rate, ventilation, occupancy schedules and gains from heating and lighting, see figure 1 and (8) for full details.

6.1 Simulation

The house was tested for different periods throughout the year. The main features being tested were as follows:

- The effect of solar shading
- The effect of passive systems (trombe walls, conservatory)
- The effect of night insulation on the passive systems
- The effect of opening up the conservatory to the exterior in summer
- The effect of awnings

6.2 Simulation Results

From the simulations, given ideal operation, the house was found to be capable of achieving reasonably comfortable internal temperatures for most of the year. However, results for cloudy winter days or hot summer ones suggest that some form of heating or cooling is required for each period to achieve comfort temperatures.

An annual heating load per unit floor area of 18-20kWh/m² (total treated floor area =100 m^2), slightly lower than that of the original design specifications was calculated for the base case.

To achieve satisfactory thermal comfort and economy, awnings are needed during the whole summer period. In this case, the resulting cooling load of 36 kWh/m² (see table 2) was high, compared to the 5.7 kWh/m² predicted in the original design.

TABLE 2: MODELLED ANNUAL LOADS COMPARISON GRAPH

	Winter Heating (kWh/m^2)	Summer Cooling (kWh/m^2)
No Shading	18.3	63.0
Night insulation	21.3	62.1
Awnings	30.2	35.6

The shading and evaporative cooling effects of trees and plants, or of night ventilation during the summer period weren't modelled, despite this, the comparative results can be considered representative of the real situation.

It was found that passive systems can be effective during the winter, providing thermally comfortable conditions, on sunny days no extra heating load is required. The basic requirement for this however is that the residents keep the South elevation totally unshaded, in order to maximize solar gains.

In summer, the shading provided did not appear to be effective enough, temperatures above 30°C were noticed on very warm days, requiring extra cooling.

Assuming that night ventilation can be effective in real conditions, and also that summer breezes can provide a cooling effect, the thermal comfort could be acceptable and the assumed cooling load could be reduced.

However, considering current and future climate changes as mentioned earlier, the issue of summer cooling appears to be of higher importance than the original design had premised.

7. CONCLUSIONS

This paper presents a thorough study of the Solar Village's performance and evolution over the years that have passed since its first inhabitation, focusing on the passive homes of the settlement.

A number of different factors were shown to affect the intended outcome of the design, which proved to be quite complicated for all the different groups involved, mainly the residents of the settlement and the official supervisor for the energy systems, OEK.

It was undoubtedly obvious from the very beginning of the settlement's inhabitation that the residents' behaviour would be the most decisive factor, especially in the passive systems operation, as it demanded their direct involvement and affection.

In the first sociological and monitoring surveys carried out soon after first occupancy, there were significant indications that the occupants had not absorbed enough from the instructional seminars. A number of them used the conservatories as living spaces, ventilated other spaces excessively or kept the awnings lowered in winter.

Occupants never fully appreciated or believed in bioclimatic principles and the importance of their energy saving to the environment. On the contrary, it seems as if they always had a feeling of being experimental guinea pigs and "hostages" to OEK supervision. Unsurprisingly perhaps, the present condition of the settlement indicates that things have got worse over time, and today a large number of occupants have totally abandoned the passive systems.

The problem with ownership of the houses, led to many maintenance problems remaining without attention for long periods. Occupants wouldn't pay for what they might consider as "useless" solar systems for the sake of a stranger's experiments.

Previous monitoring, the questionnaire survey and the simulation process show that certain aspects of the original design can work well, able to provide satisfactory thermal comfort conditions and saving energy. Under certain conditions of proper operation, it was shown that a typical passive house can achieve comfortable temperature levels during sunny winter days, and have a low heating load for the entire winter period (18-22.5kWh/m²).

In summer, it was found that the cooling load is six times higher than that originally predicted. The original design strategy for summer was based on natural ventilation techniques, which work well for most mild days. However, simulation and measurements show on hotter days, ventilation alone is not enough to reduce the temperatures to comfortable conditions.

The fact that the houses had quite small storage spaces, and that most of the families grew to have two or more children, created extension needs. Conservatories were the easiest solution to this space problem, as they were the ideal size for an extra room. Occupation of these had two negative consequences: the inactivation of the passive system and the creation of extra heating demand, for this new (un-insulated) living space.

The trombe benches had some design disadvantages: they had a relatively small surface area, and were considered less efficient. Their location at the lowest part of the elevation could not prevent their shading by furniture or plants on the floor close to them. Even a chair in front of them would severely minimize their efficiency. Finally, the insulated shutter provided was quite impractical (due to its low location and its opening technique: inclination). That may be the reason most residents always kept them shut, causing the benches to be inactive.

It might be an extreme consideration, but at current prices, a resident could pay less money for a small a/c unit for his living room, than to replace a torn or broken awning (also the a/c installation could be faster and easier).

Finally, a common problem for many houses was dampness on North facing walls due to construction failure (this is a contractor's failure rather than the design team). This problem is irrelevant to the passive systems operation and performance; however it somehow contributed to the occupants' distrust towards the house's qualities in a more general way, helping to provoke the neglect of the passive systems.

A positive change for the summer microclimate through the years that have passed is the growth of surrounding greenery and associated shading. However it remains a fact that the cooling load in summer is higher than was initially predicted. The temptation to install air conditioning is increased further by decreasing prices for the a/c units themselves.

No concern is shown in the new proposed maintenance program for passive energy systems. They will continue to exist, but it is almost certain that if no measures are taken, they will eventually deteriorate and be totally abandoned considering the previous experience and distrust of their value by the residents.

Modelling indicates that the passive systems can work, if operated properly. At this critical time, perhaps a new "educational" seminar period would be useful. The occupants should be again informed on how the systems can contribute to energy saving.

Another important issue, the need for cooling, is not highlighted in the new OEK plans. The new district heating network that will be installed could be modified and also include provision for cooling. Since the majority of houses appear to prefer a/c rather than the original natural ventilation, a central cooling plant could be a highly efficient and economical solution rather than individual domestic units.

The research and demonstration character of the project still remains; it is still the only one of its size in Greece although more than 15 years have passed. All involved parties should protect this particular character, ensuring that the settlement can continue to act as a showcase for energy saving techniques that can contribute to comfortable homes and a green and friendly environment. Perhaps the new generation of families that live there, with proper information and education, can retain and secure the sustainable future of passive homes and their energy saving solar systems, thus promoting similar environmentally friendly solutions for future housing schemes and urban planning.

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