“TERPSITHEA” SUSTAINABLE HOUSING PROJECT IN PORTO RAFTI, GREECE

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ABSTRACT

The paper reports on a housing project developed by Beis & Associates relatively the installation of green roofs and roof ponds at a sea side residence in Porto Rafti, Greece. The objective was to explore the abilities of this building type to reduce non-renewable energy consumption and hence to obtain an environmental character. Houses in Porto Rafti consume large amount of energy in order to cool during the hot period in summer. Roof is generally the most exposed element of the building’s external envelop to the solar radiation. The paper supports the implementation of green roofs and roof ponds to aid the housing sector in dissipating the excess heat gains. In order to test the thermal performance of the house and thus the benefits of using green roofs in housing projects, simulations have been done by using TAS software. The first step was to create the reference building as a base case which is the model including the implementation of the Greek regulations for thermal insulation. Afterwards, an exploration of the installation of green roof, natural ventilation and Low E glazing with argon in the windows was done. Finally, an examination of roof ponds, by literature review, was done. Conclusively, roof ponds and green roofs can help houses in Porto Rafti to reduce the annual loads and energy consumption.

1. INTRODUCTION

Porto Rafti is the seaside section of the municipality of Markopoulo Mesogeias. It surrounds the Porto Rafti Bay in the east coast of Attica. It is located 38 km from the city centre of Athens, Greece. The population of Porto Rafti is estimated to be approximately 10,000 habitants with a prediction to rise to 45,000 residents by 2030. Thus, the demand of permanent residence is increasing rapidly. Houses in Porto Rafti consume large amount of energy in order to cool during the warm period in summer. “Terpsithea” is a sustainable sea-side housing project, done by Beis & Associates, comprising of two individual residences. The aim of the project is to point out the abilities of this building type to reduce non renewable energy consumption. Furthermore, the aim of the project is to promote sustainability in order to help expanding housing sector in Porto Rafti to obtain environmental character.

2. CONTEXT

2.1 Climate

Weather data for Porto Rafti city (37.51°N 24.01°E) were obtained using an appropriate internet weather database for various Greek cities. Porto Rafti has a typical Mediterranean climate, characterized by mild, wet winters and hot, dry summers. Figure 1, highlights three distinct periods: a six – month period of cold weather (November to April inclusive) characterized by daily mean

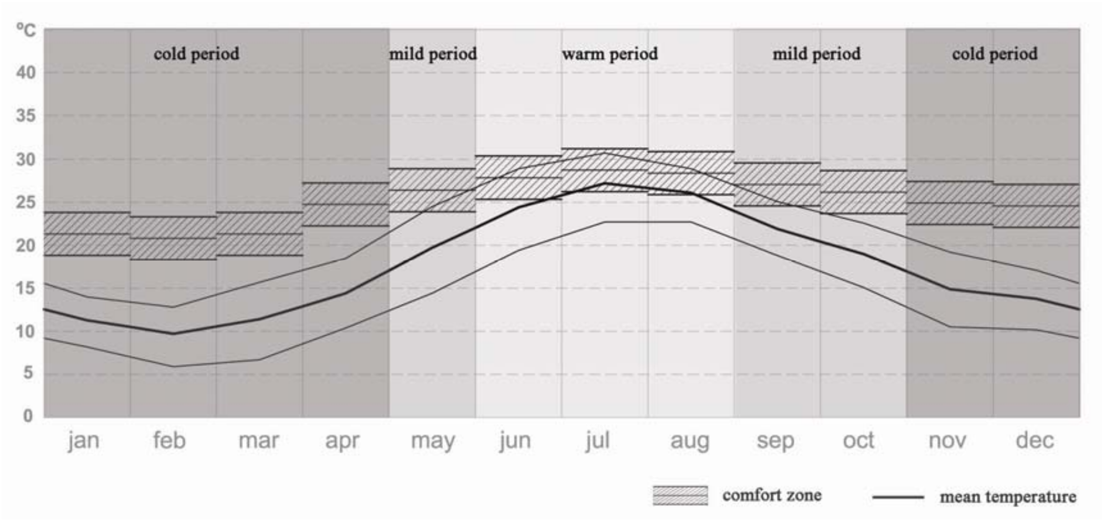

Figure 1: Monthly mean temperatures in Porto Rafti, Greece.

temperatures below 15 °C; a mild period (May, September and October) with mean temperatures of 19-21.9°C, and a warm - hot period (June to August inclusive) with mean temperatures of 24.4-27.2 °C. However, during the warm period there are two months, July and August, which are extremely hot months and the maximum mean temperature is above 30 °C. Thus, during this period of the year, the building is expected to have high cooling demands. Finally, the mean relative humidity varies throughout the year from 37% in July to 70% in December.

2.2 Comfort

In order to reduce the use of air – conditioning and hence the energy consumption, it is essential to decrease the temperature difference between indoors and outdoors. This will require the acceptance of adaptive standards of thermal comfort.

Table 1: Comfort zone

Month	*Tmean (Tm)*	*Tn - 2.5K*	*Auliciems Tn=17.8 + 0.31 Tm*	*Tn + 2.5K*
jan	11.3	18.80	21.30	23.80
feb	9.7	18.31	20.81	23.31
mar	11.4	18.83	21.33	23.83
apr	14.4	19.76	22.26	24.76
may	19.7	21.41	23.91	26.41
jun	24.4	22.86	25.36	27.86
jul	27.2	23.73	26.23	28.73
aug	26.1	23.39	25.89	28.39
sep	21.9	22.09	24.59	27.09
oct	19	21.19	23.69	26.19
nov	14.9	19.92	22.42	24.92
dec	13.8	19.58	22.08	24.58

According to (Szokolay, 2008) the temperature limits of this comfort zone can be taken to the Tn (neutrality temperature) for 90 % acceptability from (Tn – 2.5) °C to (Tn + 2.5) °C. Table 1 illustrates the variation of indoor comfort zone for the climate of Porto Rafti. Throughout the year comfort zone varies from 18.31 °C to 28.73 °C. When the temperature inside the residence is below 18.31 °C heating demand will be required; conversely, when the temperature indoors is above comfort zone cooling demand will be need. Conclusively, it can be argued that the interior space of the house can provide general comfort requirements to the occupants when it is heated and cooled according to the new extended comfort zone of (18 – 28) °C.

3. OVERVIEW OF "TERPSITHEA" HOUSING PROJECT

"Terpsithea" is a sustainable sea side housing project which comprises two individual dwellings. Each dwelling is a maisonette, side by side single family homes, and consists of two floors and a basement. The area of each residence is approximately 270 m², which includes the basement. The occupied spaces are developed into two levels; the ground floor and the first floor, while the basement is used as a garage and storage area. Therefore, the occupied area of each house is approximately 170 m². The ground floor contains spaces for the daytime, such as, living room, dining room and kitchen; whereas, bedrooms are situated in the first floor to maximise efficiency.

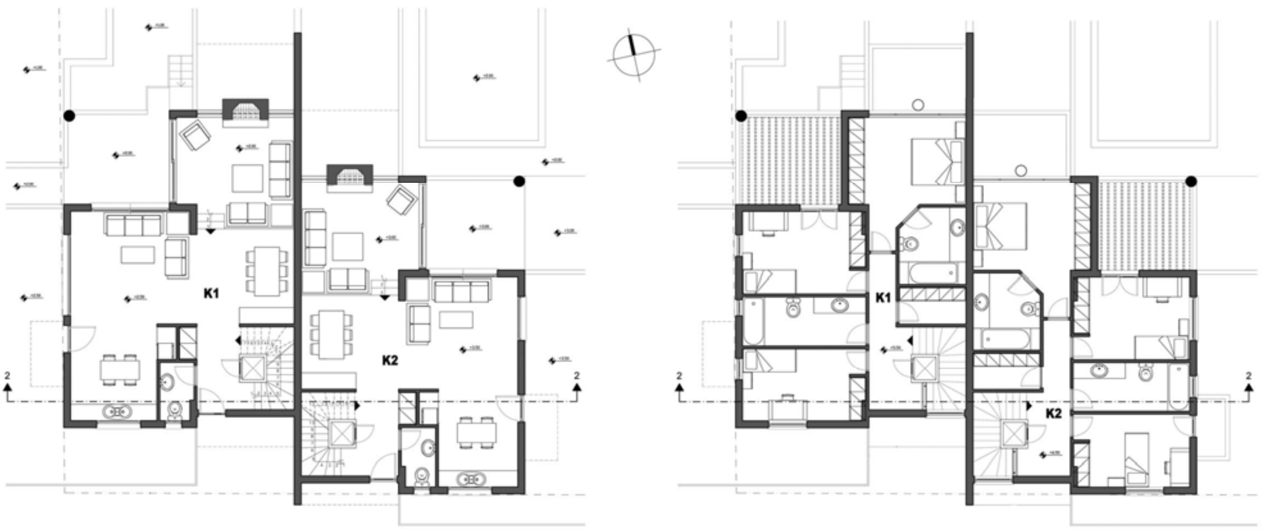

Figure 2: ground floor and first floor plans

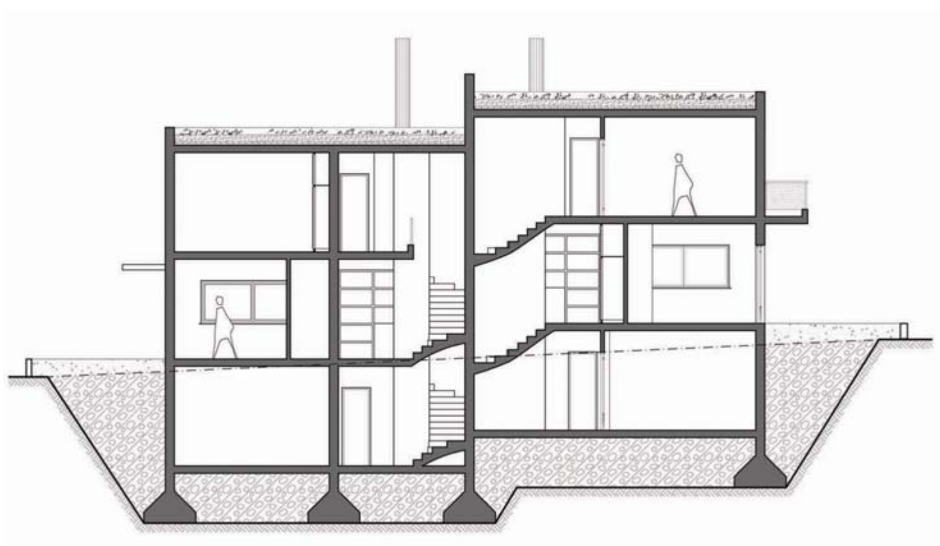

Figure 3: Building section

"Terpsithea's" housing project objective is to improve the building's thermal performance compared to a typical construction, which applies the Greek regulations for thermal insulation. The primary objective is to reduce the cooling loads, which are substantial. In order to reduce Terpsithea's cooling loads by environmental means, passive strategies are tested in Tas thermal simulation software. Such strategies are the installation of *green roof* (Case 1*)*, the addition of *nocturnal convective cooling* (Case 2) and the use of *Low E glazing with argon* (Case 3). Finally, a study of the potential of *roof pond* is introduced.

4. THERMAL PERFORMANCE

4.1 Methodology

Dynamic thermal simulation software EDSL TAS (version 9.0.9d) was used to build a geometrically precise model of the "Terpsithea" housing project. Thermal properties of the materials were assigned according to the existing national standards to all construction elements. Internal conditions and the building schedule were allocated as well as the weather file of the climate of Porto Rafti.

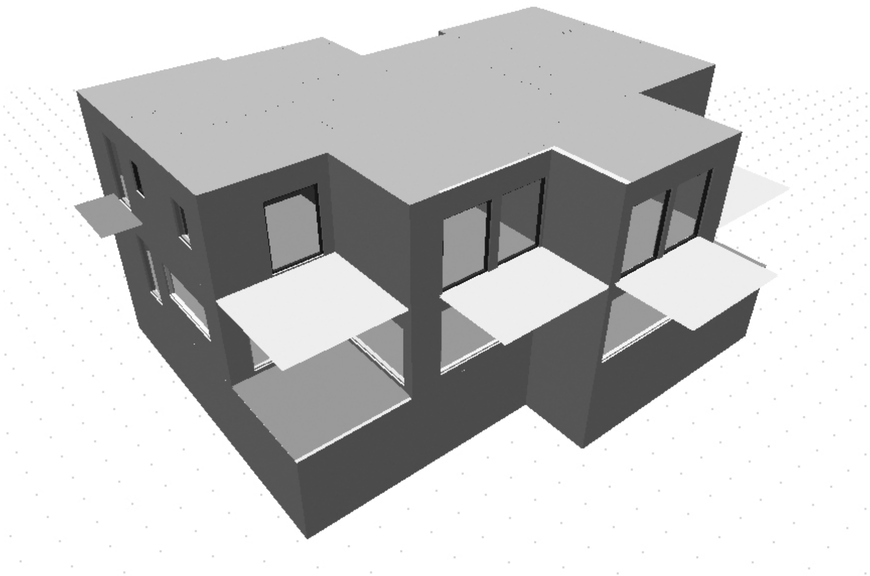

Figure 4: 3D model in Tas

The model of Terpsithea is a box shaped configuration. It consists of three floors; the basement the ground floor and the first floor. Six zones were set for the simulation; two in each floor. The focus will be on the ground floor and the first floor, because they are the occupied floors as previously mentioned.

4.2 Base case evolution

The first task was to calibrate the performance of the base case integrating the Greek regulations. The overall ventilation rate (both infiltration and ventilation) for the building for the whole year is set 1 ach. Assuming that the value for infiltration rate is 0.5 ach and it remains steady the whole day, the rest 0.5 ach is ventilation and follows the building's schedule. Also, thermostat's setpoints were calibrated according to the new comfort zone; 18°C for heating and 28°C for cooling. Later on, annual thermal and cooling loads of the base case are compared with corresponding loads of the other cases. Table 2 shows which variable is changing according to different parametric studies.

Table 2: Building envelope and other variables

	Building envelope	*infiltration (ach)*	*ventilation (ach)*	*U external walls (W/m²K)*	*U roof (W/m²K)*	*U glass (W/m²K)*
	Base Case (BC)	0.5	0.5	0.5	0.45	2.94
Case 1	BC + green roof	0.5	0.5	0.5	*0.34*	2.94
Case 2	Case 1+ NCC	0.5	*5*	0.5	0.34	2.94
Case 3	Case 2 + Low E glazing	0.5	5	0.5	0.34	*2.12*

Figure 5 illustrates the annual heating and cooling loads for the base case. Annual cooling loads are much higher than heating loads; therefore revealing the necessity to cool down our buildings. At this point, it is important to mention that annual loads do not represent the energy input for the building. The energy input depends on the coefficient of performance (COP) of the air-conditioning system.

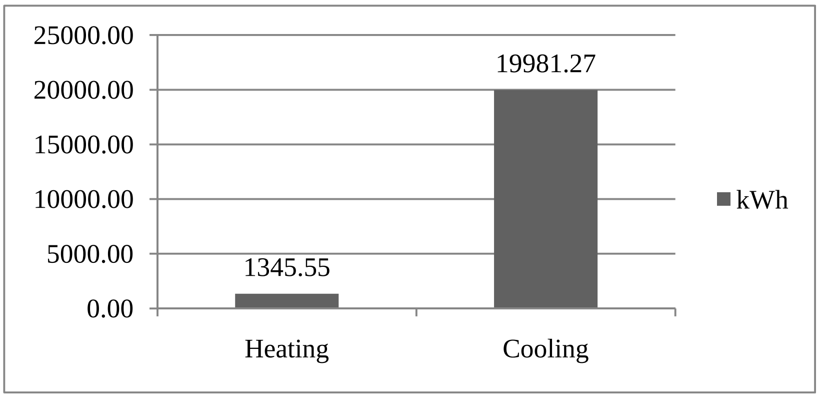

Figure 5: Annual heating and cooling loads for Base Case in kWh.

4.3 Green roof

The installation of green roof to buildings is technically and practically well established in USA, Japan, Germany and Sweden. According to (Spala et al. 2007) green roofs can offer a sustainable green surface by improving urban climate, minimising heat island effects and simultaneously producing biodiversity. Also, planted roofs can provide additional environmental benefits, such as, the absorption of carbon dioxide and the alleviation of heat stress due to temperature fluctuations on roofing (Yannas et al. 2006). In order to test and improve Terpsithea's thermal performance the green roof is applied to the model.

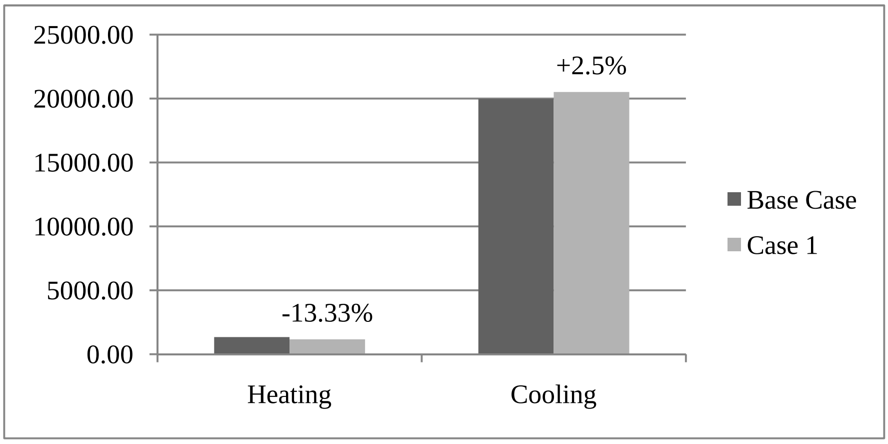

Figure 6: Annual heating and cooling loads for Base Case and Case 1 in kWh.

Figure 6 shows the installation of the green roof to Terphithea dwellings reduced annual heating loads by approximately 13 % but increased annual cooling loads by some 2 %. This means that because roof insulation has been increased, the internal loads during the warm period cannot dissipate easily through the roof. The above results are similar to another study in terms of green roof utilization (Niachou et al. 2001), which indicated the impact of the green roof on the energy savings of the well-insulated buildings is almost less than 2 %. In order to dissipate the excess internal loads, a higher ventilation rate is needed especially during the night.

4.4 Ventilation

Night ventilation during the warm period can help the building to dissipate excess heat gains. After (Givoni, 1994), for this effect, the building should not be ventilated during the daytime to prevent the interior being heated by the hotter outdoor air. Thus, ventilation is added to the model (Case 2) during the night. The new ventilation rate for the model is 5 ach.

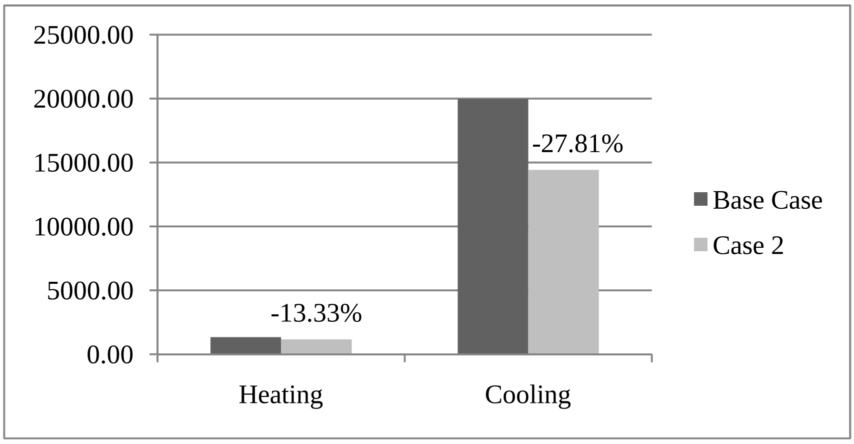

Figure 7: Annual heating and cooling loads for Base Case and Case 2 in kWh.

Figure 7 indicates that the installation of green roof in addition with night ventilation during warm period reduces the annual cooling loads by some 28 %. Total energy savings for Terpsithea residences in terms of heating and cooling loads are decreasing significantly by almost 27 %.

4.5 Low E glazing

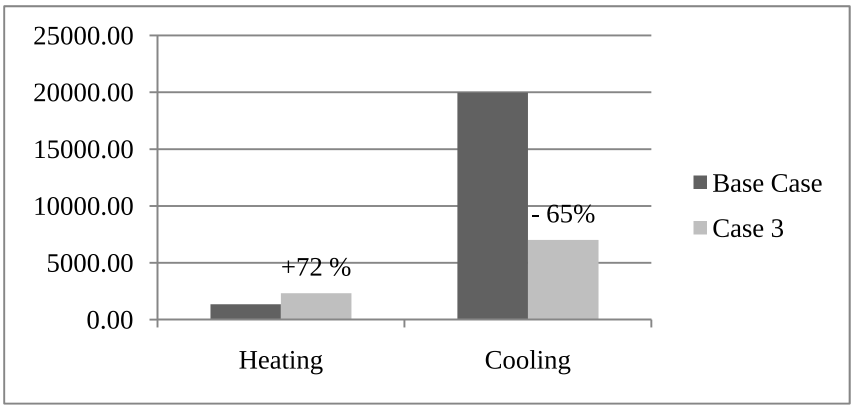

Figure 8: Annual heating and cooling loads for Base Case and Case 3 in kWh.

In Case 3 Low E glazing with argon replaces the double glazing of the Base Case. Moreover, Case 3, is the combination of Case 2 with Low E glazing to the openings. Through thermal performance simulations it is indicated that Case2 has the ability to reduce an estimated 65 % of the cooling loads (fig.8). On the other hand heating loads are increased and became almost double compared to the base case. It is proven that Low E glazing blocks the solar radiation and lowers the ability of the building to be heated from the sun during the cold period. Nevertheless, the impact to the overall energy saving is more than 56 %.

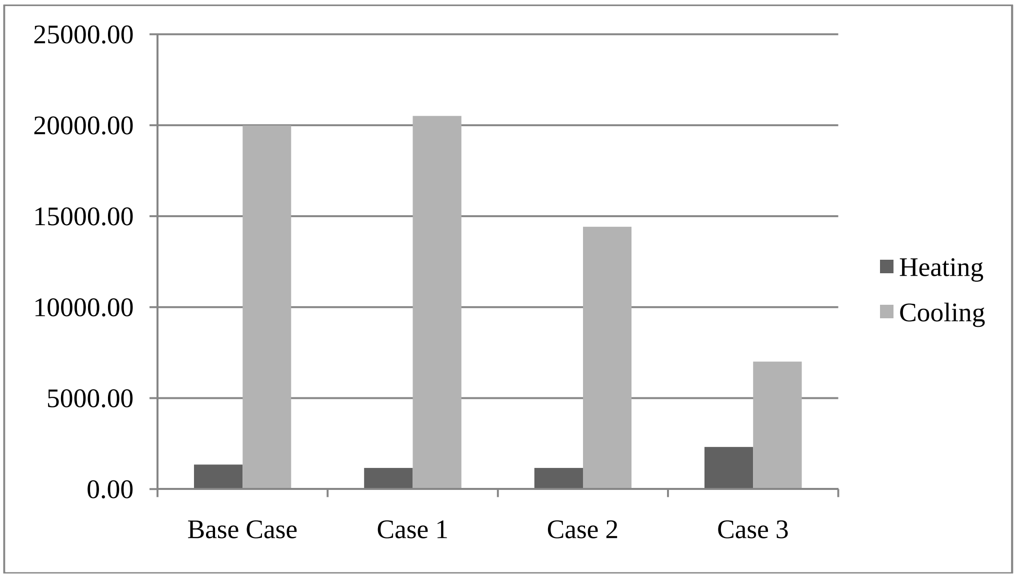

Figure 9: Annual heating and cooling loads for Terpsithea sustainable housing project in kWh.

Figure 9 shows the comparison between the four cases. In terms of thermal performance, Terpsithea dwellings can consume almost half the energy compared to a typical housing construction in Porto Rafti. The studies revealed that the green roofs have to be combined with natural ventilation during the night in order to achieve improved results indoors. Also, Low E glazing with argon has the ability to reduce a large percentage of the cooling loads, but it doubles the heating loads. The overall energy saving in Case 3 is dramatically high.

5. ROOF PONDS

Despite the annual cooling loads have reduced by some 65 %, it is important to explore the ability to further cool down the building. Roof ponds as a passive strategy can affect the thermal behaviour of single storey buildings or the thermal performance of the building's last floor. According to (Yannas et al. 2006), there is a potential to reduce cooling loads by 41.6%, when the building utilizes a roof pond with depth 0.3 m. Thus, by installing roof pond instead of green roof Terpsitea's cooling loads will be reduced 1.5 times more than the Case 2 and the building will have better thermal behaviour. Contrastingly, in terms of inserting a roof pond, the roof must support 200 – 400 Kg/m², which means that the construction will be more expensive.

6. CONCLUSIONS

In regards to the energy performance of Terpsithea housing project in Porto Rafti, Greece, this paper demonstrated options to increase energy efficiency in homes in Porto Rafti. Through thermal performance simulations and with the incorporation of literature review, the study has indicated that Terpsithea has the potential to reduce non-renewable energy consumption by applying either a green roof with night convective cooling or roof ponds. Furthermore, the integration of Low E glazing with argon has meaningful impact to building's thermal performance. The above strategies are compatible with the climate of Porto Rafti. In a similar way the housing sector in Porto Rafti can obtain an environmental character by using environmental means. Finally, Terpsithea sustainable housing project can be a paradigm of how sustainable design can lead to better buildings for the occupants and the environment. Architects have to consider environmental parameters to their initial design and occupants have to learn how to occupy the house in a more efficient way.

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