Oil free, low energy heating and cooling of an apartment in Litochoro, Greece

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ABSTRACT: Rising fuel costs, combined with concern for the environment, leads more and more people towards alternative sources of energy to heat, cool and light their homes. In Greece, "green energy" is still far from mainstream, as only a few financial incentives to encourage investment in this field have been offered. Although lack of familiarity and high initial costs prevent householders from "greening" their new or existing homes, there are some interesting case-studies that can lead by example.

The current paper describes a 100m^2 apartment in Litochoro, northern Greece, which uses a ground source heat pump, combined with solar collectors, for heating, cooling and hot water supply. This geosolar system is used in tandem with underfloor heating, with flooring materials that have high thermal mass, to increase efficiency even more. Orientation of the spaces as well as thermal insulation and shading also play an important role in the energy performance of the building.

Detailed monitoring of building's energy consumption for heating, cooling and hot water supply started in October 2011 and has already covered two heating periods and a cooling one. The energy consumption for heating, cooling and hot water supply is compared to the estimated heating and cooling loads simulated in software, but also to reported petrol consumption in similar apartments in Litochoro. The savings emerged to be great and the payback period for the "unconventional" part of the installation (boreholes, mechanical equipment, solar collectors, underfloor system) is calculated to be about 9,5 years.

Keywords: Ground source heat pump; solar collectors; underfloor heating system

INTRODUCTION

The apartment under study is part of a three-story house in Litochoro, northern Greece (Fig. 1-3), which was designed in 2009 to house two families. The owners of the apartments had agreed on adopting some bioclimatic design techniques, in order to achieve thermal comfort with the minimum energy consumption. These included:

- Southern orientation of most main spaces
- Sufficient insulation on all external walls (Fig. 6)
- Proper shading, when needed (as described later)
- Exploitation of daylight
- Use of a highly efficient geosolar system in combination with underfloor heating/cooling

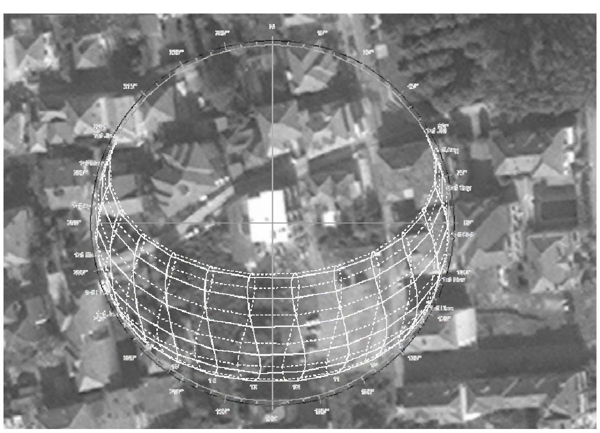


Figure 1: Sun-path diagram on the site.

Figure 2: South facade.

Figure 3: North (and partly east) facade.

The building was ready to be occupied in autumn 2011. Each family uses one floor (first and second), whereas the ground floor houses a small office, a parking place and the mechanical equipment. Detailed monitoring of building's energy consumption for heating, cooling and hot water supply started immediately. In this paper, *only the upper floor is analysed and presented*, as far as its energy performance is concerned (Fig. 4).

The most important ally in the low energy consumption of the building is undoubtedly the ground source heat pump, combined with solar collectors. A ground source heat pump (GSHP) is a central heating and/or cooling system that pumps heat to or from the ground, using the earth as a heat source (in the winter) or a heat sink (in the summer). In Greece, the first GSHP system was installed in the 80s and even today only a small number of case studies can be detected. The Centre for Renewable Energy Sources (CRES) in Athens is one of the 10 partners from 7 European countries in SEPEMO project (SEasonal PErformance factor and MOnitoring for heat pump systems in the building sector). In the framework of this project, monitoring of some GSHP installations has proven their high efficiency and short pay-back periods [1].

Figure 4: Second floor plan (the apartment under study).

DESCRIPTION OF THE APARTMENT

As it can be seen in Fig. 4, most of the main spaces face the south. The living room in the north faces the street, with view of both Mount Olympus and the sea. Large horizontal overhangs around the building provide shading. These are sufficient for protecting the south openings in summer; nevertheless eastern windows in the living room and kitchen need extra protection from overheating. This is provided by movable external vertical blinds (Fig 5a). Even the eastern openings of the staircase are protected by internal movable translucent blinds (Fig 5b). Apart from the usual openings, daylight exploitation is achieved through a roof opening (skylight) in the main bathroom (Fig. 5c). The fact that it is operable, offers the possibility of enhanced ventilation and, when possible, natural cooling.

a b c

Figure 5: Details of the apartment that affect its energy performance.
a: Movable external vertical blinds (living room windows of the east facade) b: Internal movable translucent blinds (staircase windows of the east facade) c: Roof opening (skylight) in the main bathroom.

All external walls, as well as the internal ones adjacent to the staircase, are insulated with 5cm of extruded polystyrene, which are placed between two layers of brickwork (9cm each), with an air gap of 5cm on one side (Fig. 6).

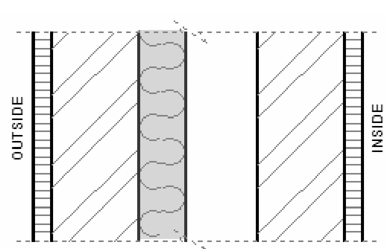
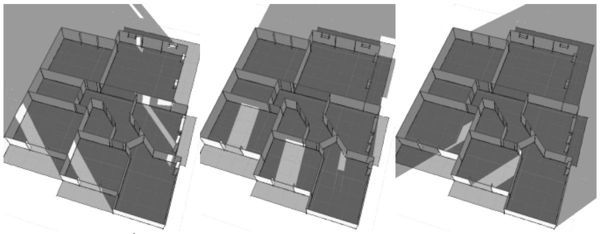
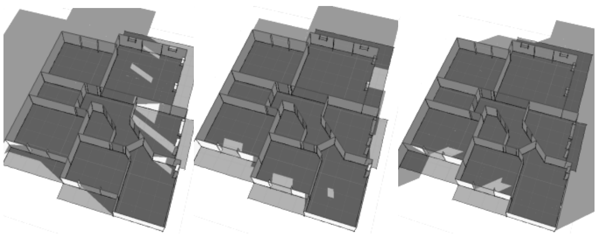


Figure 6: Schematic section of external walls.

The apartment takes advantage of the direct solar gains in winter (Fig. 7), where as it avoids them in summer, through proper shading.



21st of December, at 9:00, 12:00 and 15:00



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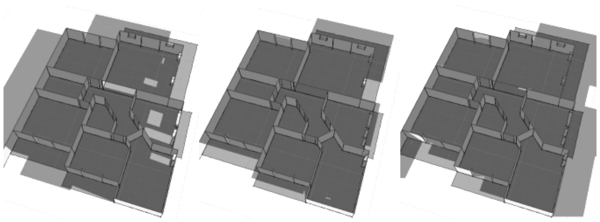

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Figure 7: Shading study on characteristic days.

CLIMATIC DATA

Litochoro is located at the base of Mount Olympus, on the western shore of Thermaic Gulf (4klm from the sea), at an average elevation of 300 meters. Its climate is Mediterranean, with hot/dry summers and cold/humid winters.

Throughout the hottest month of July, daytime temperatures will generally reach highs of around 35°C, whereas at night the average minimum temperature drops down to around 18°C. The average daily relative humidity in summer is around 49%. In winter, daytime temperatures will generally reach highs of around 9°C, whereas at night the average minimum temperature drops down to around 0°C. The average daily relative humidity in winter is around 80% [2].

Analytical weather data for the years 2011-2013 (for the period that monitoring of the building's energy performance took place) are recorded for Dion [3], a small village located at a 7.5km distance from Litochoro, at an elevation of 50m. They can be seen in Figures 11-12, in combination with the recorded energy consumption.

THE GEO-SOLAR SYSTEM

The apartment is heated and cooled by a closed loop geothermal heat pump system (Fig. 8). The main components of the system are three borehole heat exchangers that cover the needs of the whole building (100m depth each one), a heat pump and solar collectors (two units, with a total absorbent surface of 4,46m^2) [4]. This geosolar system is used in tandem with underfloor heating. Flooring materials have high thermal mass (ceramic tiles), to increase efficiency even more.

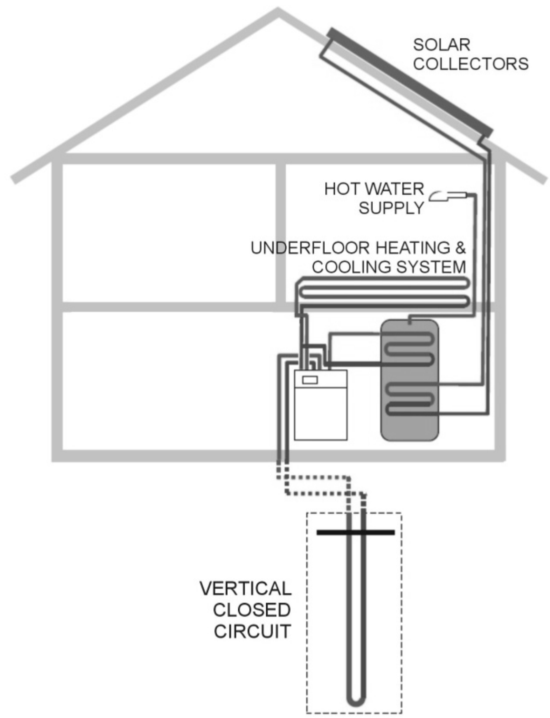

Figure 8: Schematic drawing of the geo-solar system that provides the house with heating, cooling and hot water for everyday use, all year round.
Redesign of the original image in CLIVET Techn. Bulletin [5]

The model of the water-to-water geothermal heat pump is Clivet 51, with R410A as a refrigerant. Its nominal capacity for heating is 15,7 kW and for cooling 13,1 kW. The nominal COP is 4,13, while EER is also 4,13. These data [5] are related to the following conditions:

- internal exchanger water: 12/7°C
- external exchanger water: 30/35°C

In reality, the temperature of the water supplied to the underfloor system is 45°C in winter and 13°C in summer.

The underfloor system used is Buderus Logafix PUR-THERM® and the digital thermostats placed in every room, except for the bathroom and WC, are Siemens REV13.

Finally, the two solar collectors that were placed on the south side of the roof are Buderus Logasol SKE 2.0, 2,23m^2 each. They provide all the hot water supply needed by the occupants around the year.

a b

Figure 9: Photographs of the mechanical equipment.
a: Buffer tank of 150lt and boiler of 200lt
b: The Clivet 51 heat pump (15,7 kW heating capacity)

ENERGY CONSUMPTION

Detailed monitoring of building's energy consumption for heating, cooling and hot water supply started in October 2011 and still goes on. It covered two heating periods and a cooling one. The first winter (2011-2012) has been one of the coldest ever in the whole region of Pieria. It should be noted that for about a month Litochoro was covered by a layer of snow, about 10-30cm thick. On the contrary, the winter that followed (2012-2013) has been one of the warmest in Greece. It did not snow at all in Litochoro, which was something very rare. On the other hand, the summer of 2012 could be considered as a relatively hot summer in Litochoro, with temperatures often reaching 40°C.

In order to assess the recorded data, it was compared to estimated annual heating and cooling loads, simulated in Autodesk® Ecotect® Analysis software [6] (Fig. 10). The apartment was divided in nine thermal zones, as shown in Fig. 7 and was simulated with its actual construction characteristics. No attempt was made to simulate the novel systems (geosolar, underfloor), since the aim has been to come up with the thermal and cooling loads of a conventional house. The climatic data used for Litochoro was created in Meteonorm 6.1 software [7]. It should be noted that Ecotect's results do not include the energy needed for hot water supply. This energy is taken into account in Table 1.

In the simulation, the comfort band was set between 19°C and 26°C for the master bedroom, while for the rest of the thermal zones the desired temperature in winter was set to 20°C. These temperatures correspond to the actual setpoints of the digital thermostats in every room of the apartment.

The actual energy consumption recorder for the periods mentioned before is shown in Fig. 11 & 12.

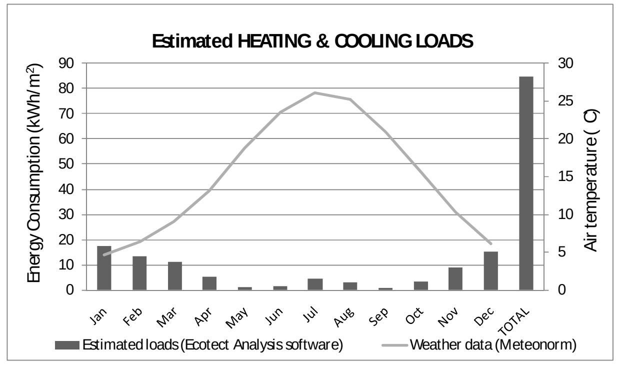

Figure 10: Estimated annual heating and cooling loads, simulated in Autodesk® Ecotect® Analysis software, combined with average monthly air temperature, derived by Meteonorm.

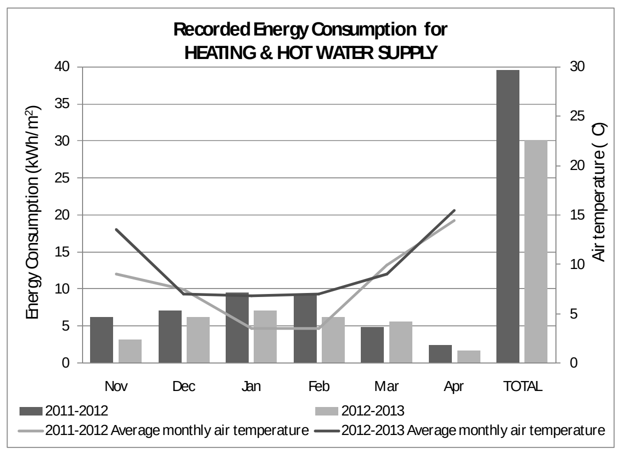

Figure 11: Recorded energy consumption for heating and hot water supply in winter 2011-2012, combined with average monthly air temperature.

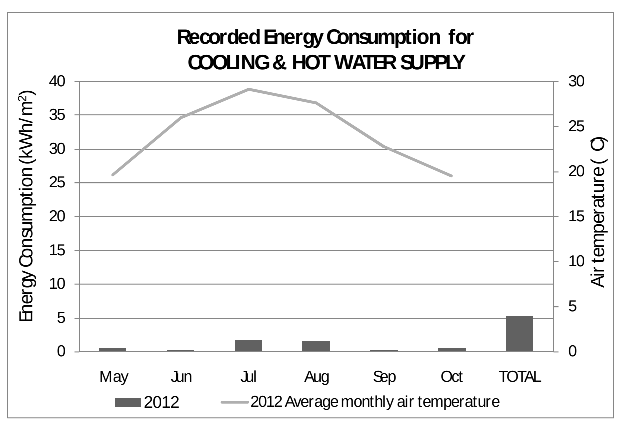

Figure 12: Recorded energy consumption for cooling and hot water supply in summer 2012, combined with average monthly air temperature.

The comparison between estimated energy consumption and recorded data (from November 2011 until October 2012) is demonstrated in Table 1. The total estimated amount was calculated by adding a predicted amount of energy used for hot water supply (38.7 kWh/m^2 for a four member family, according to *TEE KENAK*, the official national software for energy performance calculations) to Ecotect's heating and cooling loads. The conversion factor used for the calculation of the primary energy was 2.9 for electricity and 1.1 for petrol, according to TOTEE 20701-1/2010 Technical Instructions *"Detailed national standards of the parameters for the calculation of the energy performance of buildings and the issuance of the Energy Performance Certificate"*. According to Table 1, there are great energy savings by using the innovative (for Greek standards) geosolar system, in tandem with underfloor heating/cooling.

Table 1: Comparison between estimated (simulated in Ecotect Analysis software) and recorded energy consumption.

Cases	Simulated data (conventional house)	Recorded data (real house)	Savings
Annual Energy Consumption (kWh/m^2)	165.11	44.91	72.8%
Annual *Primary* Energy Consumption (kWh/m^2)	259.64	130.24	49.84%

The extra cost for the "unconventional" part of the installation (boreholes, mechanical equipment, solar collectors, underfloor system) was 15.000 €. Taking into account that the cost of 1kWh is about 0,11€ and that, during the winter of 2011-2012, 1lt of petrol cost about 1€, the pay-back period is calculated to be 9.5 years. (Calorific value of petrol = 10.08 kWh/lt and burner's COP = 0.85). Nevertheless, it should be noted that since 2012 the cost of oil has risen to 1,30€/lt, which means that the "green" investment is even more profitable.

It is also worth mentioning that informal interviews with local citizens revealed that houses of the same size needed more or less 2.000lt of petrol in winter 2012-2013, which correspond to 2.000€, where as the occupants of the apartment under study only paid 407€ for heating *and* hot water supply.

CONCLUSION

This study has taken a step in the direction of studying ways in which contemporary buildings can save energy. This was done by examining the energy performance of an apartment in Litochoro, northern Greece, which uses a geosolar system, composed of a ground source heat pump and solar collectors. From comparing the recorded energy consumption for heating, cooling and hot water supply to the estimated heating and cooling loads (simulated in software) but also to reported petrol consumption in other apartments in Litochoro, it emerged that the energy savings are of great importance. The payback period for the "unconventional" part of the installation (boreholes, mechanical equipment, solar collectors, underfloor system) is calculated to be about 9,5 years, which proves that this kind of investments is very profitable in Greece, given the current fuel costs and economic status.

Monitoring of the building's energy consumption will continue, in order to determine the exact payback period.

It is hoped that the current case study will lead by example, so that "green energy" becomes the rule rather than the exception in Greece.

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