468: An Energy Autonomous Building

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Abstract

Palaio Phalero is a southeast coastal suburb approximately 10km away from the centre of Athens. It is a high-density residential municipality with buildings of 5-8 storeys high. Following years of research the construction of the area's first energy autonomous building was recently implemented with solar energy and geothermy replacing the use of oil and natural gas. The major goal of this project was to eliminate the necessity for external purchased energy while taking on board other requirements/constraints such as environmental indoor conditions, economic effectiveness and urban integration. The building is six storeys high with residential/office space and has "a centralized automation system with advanced control programming for optimal energy management". This paper is concerned with the project's use of energy efficient technologies that include passive low energy design, hot water generation for heating and cooling, photovoltaic panels, solar-assisted desiccant cooling, seasonal thermal storage in reinforced concrete tanks. An outline of their effectiveness and level of integration within the building fabric is undertaken together with an assessment of the apartment block's operation and financial aspects.

Keywords: energy, solar, geothermal, building

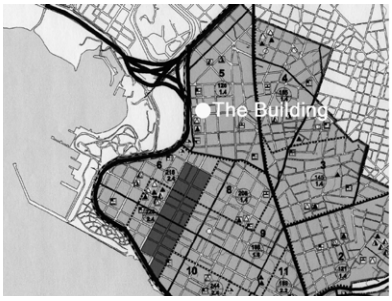

Fig 1. P. Phalero Suburb/Plan [1]

Fig 2. Aerial View of Area and Building [2]

1. Introduction and Background

Oil, natural gas and coal will continue to provide the energy requirements of the European Union countries as well as influence their economies. There are growing concerns that include the production and use of fossil fuels, oil and gas prices, the environment and climate change. All this has contributed to an increase in the research and development of clean energy technologies in addition to a EU mandate, which depicts that every member state should increase energy efficiency and reduce global warming emissions.

In Greece the main priorities for sustainable development include the promotion of renewable energy sources (RES) and combating climate change. National legislation (EU directive 2001/77) has passed Law 3468/2006 that indicates a target of 20.1% set for 2010 for electricity production from RES [3,4]. Greece's renewable energy production is assuredly and rapidly on the rise, partly driven by pressure from the European Union and partly due to the realization of the economic and commercial opportunities involved. Fortunately the falling price of renewable energy technologies/products is giving rise to the increased application of new strategies and projects, the results of which will be more apparent within the next few years.

One of these projects is a recently finished building block located in the Athens area of Palaio Phalero, which is a southeast coastal residential suburb, approximately 10km away from the centre of the capital, located next to Phalero Bay and bordering three other municipalities (Fig.1&2) [5]. Today this area is a high-density suburban residential municipality of 64,759 inhabitants (2001 Census) [6]. Buildings are usually 5-8 storeys high, with balconies and small gardens. The increasing pressure for housing over the years created by the incoming population is evident in the area's almost total urbanisation. Blocks of flats are now the area's dominant building feature having replaced most mansions and their large gardens [5,7]. These building blocks are thirsty energy consumers contributing to the greenhouse effect/climate change.

Fig 3. View of Building

In this context and over four years ago, miscellaneous Hellenic design/engineering disciplines, research establishments, academic institutions and a private company specialising in energy saving systems came together to produce a unique building block that would eventually cost very little to run while taking on board occupant comfort requirements, use renewable energy sources, engage in passive energy design, provide a research backdrop for the creation of an efficient energy autonomous/environmentally friendly building and blend in the existing urban surroundings (Fig.2&3). The owners of this building have indicated that this project represents "a pilot implementation of the solutions for integrated energy design of autonomous buildings" [2].

The participants of this combined public-private venture were the National Center for Scientific Research "Demokritos", the National Technical University of Athens, the Aristotle University of Thessaloniki and the company SOL Energy Hellas S.A which owns and occupies the building block. The project, implemented almost a year ago, is within the framework of a research program instigated by the Hellenic Ministry of Development. The benefits of such a project and its associated technologies/applications will be outlined briefly in this paper. A quantitative analysis will follow, in a second paper, within the next few months and following the one-year anniversary of the building's operation.

2. Building for Climate

Greece has a typical Mediterranean climate, temperate with mild/wet winters and hot/dry summers with long periods of sunshine all through the year. The warmest period is towards the end of July and beginning of August when mean maximum temperatures range between 29-35 degrees Celsius. These high temperatures are tempered by cool sea breezes and northern winds from the Aegean [7]. The comprehension of the climatic and microclimatic conditions of the location made possible the design and development of a climatically responsive building while providing an appropriate internal environment for its occupants even under extreme climatic conditions.

The utilization of integrated energy design, a process that brings together design/engineering disciplines for the production of buildings, helped in the implementation of this block, which uses among others energy saving applications and makes use of solar/geothermal energy sources that replace fossil fuels. It also drastically reduces operating expenses, provides thermal comfort and control over the internal environment.

The total annual thermal energy requirements of the building are 376MWh. Emphasis is placed on the largest energy uses (cooling and heating) and includes appropriate features to improve energy efficiency in the chosen design of this 600m2 above ground/600m2 below ground building. This mixed-use six storey high (plus two basement floors) typical Athenian block uses passive/solar thermal systems that are incorporated onto the building (Fig.3&4). Various technologies are developed and integrated in the building block such as "hot water generation by high-efficiency flat-plate solar collectors for heating and air-conditioning, seasonal thermal storage in non-metallic tanks, solar cooling (absorption technology), solar-assisted desiccant cooling, shallow geothermal energy-geothermal heat pumps, passive energy design, in-wall and under-floor heating and cooling, pre-air-conditioning fresh air through double-element central air-conditioning units, P/V panels, automation system with advanced control programming for optimal energy management" [2].

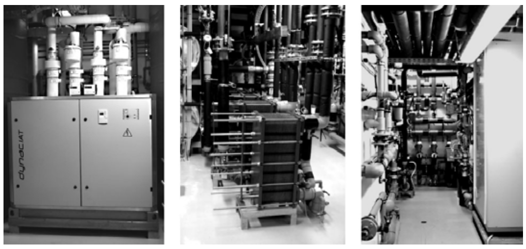

Fig 4. Basement View

Bioclimatic design principles have been implemented, such as heat/cold protection of the building all year round using techniques, which are applied to the external envelope, in particular adequate insulation and air tightness of the building/openings. The building shell has "external thermal insulation fixed with metallic corners and plastic plugs leaving a 2cm gap between the outer shell and bearing structure of the building. Double-glazing panels of low emittance/high reflectance have been placed (Optitherm SN layer, in-between Argon gas and Optilam Phon layer) with a total thickness of 31mm and an overall U-value coefficient = 1.1W/m2K" [2]. Thermal break aluminium frames have been chosen consisting of "an inner and outer profile interconnected by EPDM plugs of low thermo-conductivity in order to avoid thermal bridges" [2]. Additional protection of the building, from the summer sun, is achieved by shading devices, overhanging balconies, vegetation, reflective colours/surfaces (Fig.5).

Fig 5. Building Garden View

Internally and on every floor there are in-wall and in-floor polyethylene heat exchangers/pipes the operation of which is recorded under different temperature scenarios controlled by the sensors of an automation system. They provide summer cooling/winter heating in an invisible/noiseless manner and can intake/discharge energy from thermal storage tanks. The peripheral air-conditioning systems in place (fan coil/central units) preheat/cool fresh air and complement the polyethylene heat exchangers when/if required.

There are sensors which monitor carbon monoxide, temperature and humidity levels throughout the building. The appropriate operation/management of the solar air-conditioning system (solar field, hot/cold water non-metallic thermal stores, absorption chiller) achieves optimum seasonal efficiency. There is a dehumidification desiccant system, which uses solid dehydrates and hot water (produced from the solar field) in order to dehumidify the internal environment. The occupants can control the temperature of individual rooms.

Fig 6. Building's Solar Collectors/Field

An installation of 30 solar collectors with a southern orientation (solar field's total area 84.6m2) has been placed on the roof of the building (Fig.6). These collectors comply with a variety of international standards and are environmentally friendly. The solar field has an optimal inclination according to the seasonal thermal requirements of the block. Additionally various elements such as temperature sensors and regulating valves are installed on the solar field in order to investigate efficiency/operation under different conditions and requirements such as "summer operation for hot water generation at high temperatures (85-90°C) to be used in an absorption chiller (Br-Li), operation for hot water generation at moderate temperatures to charge the seasonal thermal tanks, winter operation for hot water generation to meet space heating requirements" [2].

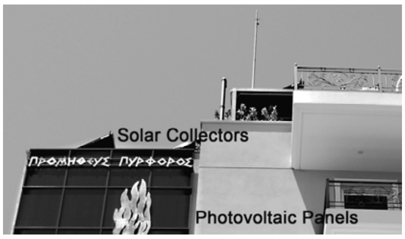

Fig 7. P/V Panels (Front Façade View)

Photovoltaic panels (44 P/V amorphous silicate of 100W each - total power of 4,4kW) are positioned on the eastern façade of the building in order to generate energy even under cloudy conditions/overcast sky (Fig.7). Their efficiency at high temperatures, when compared to other types, as well as their location (limited exposure to the sun during the day) were the main reasons behind their choice. Two inverters "convert direct current into 230V - 50Hz alternating current, which is then forwarded via a meter to the electricity mains" [2]. It has been estimated that the annual energy production of this system is 3,245kWh and that the annual financial return is 1,298 euros (0,4 euros/kWh in 2007) [2].

The building block also uses shallow geothermal energy/technologies for the supply/storage of thermal energy. A (water-to-water) ground source heat pump connects to two circuit systems that can operate independently. The open circuit consists of a flat plate heat exchanger and two groundwater wells located under the building (one is needed to extract groundwater and the other to return it into the same aquifer from which it is produced). The closed circuit consists of a horizontal ground heat exchanger connected in parallel with five loops. The heat pump "is connected to two buffer tanks and distributes hot and cold water to them in sequence" [2]. The tanks operate alternately depending on the season" [2]. When the operating temperature of the block's heating system is lower, the GSHP's energy performance is better (in-floor/in-wall heating systems need low operating temperature). Additionally higher operation temperature in the cooling system enhances energy performance (ceiling/in-wall cooling systems are used).

The bespoke computerized building management system (BMS) installed has a software program configured in a hierarchical manner (Fig.8). The system manages the environmental temperature, CO2 levels and humidity within the block. It monitors/controls the heating/cooling systems, manages the systems that distribute air throughout the building, controls the mixture of heating/cooling to achieve the desired room temperature, uses the most efficient technology to achieve a specific task, controls the backup mechanisms if ever required, saves energy by undertaking a specific action among others. In general the building management system monitors, controls and records the electromechanical functions of the block. The information produced is also invaluable for the research side of the project.

Fig 8. The BMS (Basement)

The BMS plays a critical role in the block's energy demand management. Two of its main functions are to maintain, throughout the year, a constant (building) internal temperature of 23-25 degrees Celsius irrespective of the external conditions, and manage thermal storage while keeping an eye on the operating technologies. These are utilized according to the BMS' assessment of the building's daily energy requirement, 95% of which is covered by solar/geothermal technologies, while 15% of the remaining 5%, is covered by photovoltaics and rest by the national grid.

3. Financial Aspects

In general the falling price of renewable energy technologies/products is giving rise to the increased application of new strategies and projects. This type of project, driven by environmental and economic considerations, took four years to develop and implement. Financial resources came from both the private and public sectors (SOL Energy Hellas S.A and the Hellenic State / European Union). The building block started operations almost a year ago and had a total construction cost of under one and a half million euros (Fig.9&10).

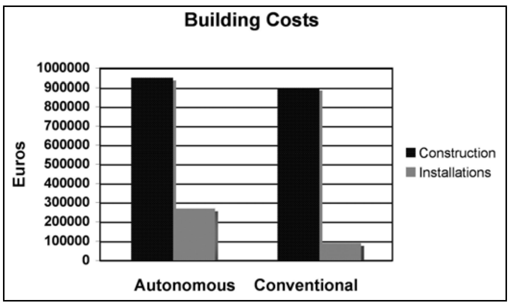

Fig 9. Building Costs

From studies/research implemented it is anticipated that just over eight years are needed to recover the money paid for the installations, after that energy needs for heating and cooling will be effectively cost free.

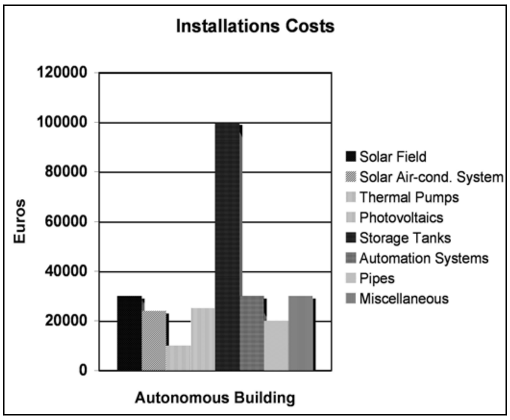

Fig 10. Building Installations Costs

Although this is a pilot building, the construction costs including installations are only 23% larger than those of an equivalent conventional block. This means, when compared to the past, that the application of these technologies is beginning to be economically viable.

4. Conclusion

The existence of an environmentally/occupant friendly and over 95% energy autonomous building is possible without relaying on conventional energy sources to run it, therefore fossil fuels are not used which translates into zero emissions. The building's yearly seasonal cooling/heating energy demands are supplied by solar and/or geothermal energy technologies/installations (within a bioclimatic framework). All are controlled by a bespoke building management system which also provides information that helps towards better energy efficiency, depicts major environmental and eventual great financial cost savings, as well as assists towards the development of better applications and products. This is a showcase building block that uses a multiplicity of technologies largely for research and demonstrative purposes. In reality in a similar building purely designed to satisfy client requirements the appropriate technologies would be selected for the site, location and purpose reducing installation costs.

5. Acknowledgements

The author wishes to thank SOL Energy Hellas S.A for the provision of invaluable information, documentation, publications but most of all their time and expertise.

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