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Fighting energy poverty by going underground

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Abstract

The inadequate coverage of energy needs in the residential sector, known as energy poverty, is a primary socio-economic problem, worldwide. Especially in Greece, under the pressure of the recent economic crisis, households face serious difficulties in meeting sufficiently their energy needs. We will show that one long-term way to minimize energy consumption, and therefore, tackle energy poverty, is the turn to underground constructions. Although underground built space can offer important benefits in terms of energy demand and consumption, underground residences have been largely regarded as unusual, far from the common residence type. However, in Greece and especially in Greek islands, underground residences have been often used in order to deal with extreme heat, during summer. Moreover, since 2012, underground constructions have been introduced as a special residence type by the Greek building regulation, thus facilitating the expansion of such practice. In this paper, the benefits of an underground residence in terms of energy poverty are being examined. More specifically, energy consumption required to achieve desired energy standards is calculated both for an earth-sheltered and an aboveground residence of similar characteristics in Greece. In this way, an indicative energy poverty ratio is calculated for the two residence types. The different climatic conditions throughout the country have been taken into consideration, by examining different Climatic zones. The findings show lower energy poverty ratios in the case of the underground residence at all climatic zones. In other words, a household living in an underground dwelling can more easily meet its energy needs compared to another one living in an aboveground dwelling. Hence, the analysis shows that modern architecture design should more systematically turn to underground constructions, incorporating the advantages of bioclimatic performance and energy savings.
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1. Introduction

The inadequate energy coverage emerges as a crucial socio-economic problem of recent years, worldwide. Global energy demand is continually increasing and is expected to increase by nearly 30% from 2013 to 2040, according to the central World Energy Outlook scenario [1]. At the same time, the global economic situation is characterized by great instability, with fuel prices going through constant fluctuations. This trend results in the current energy problem, in which households face difficulties in meeting sufficiently their energy needs (space heating and all other domestic energy needs) and suffer from energy poverty. A practical way to measure energy poverty has been that of UK, which regards a household as energy poor if it is needed to spend more than 10% of its income for domestic energy expenditure, in order to have an adequately warm home [2]. An adequately warm home is the one maintaining 21°C in the living room and 18°C in the rest of the house [2].

Globally, 1.2 billion people have no access to electricity and more than 2.7 billion people keep on cooking with biomass, which causes harmful indoor air pollution [3]. The problem is also severe within Europe as well, affecting approximately 10-15% of the European population [4], with Greece, Bulgaria and Cyprus being first on the list of the most energy poor countries. For the case of Greece, the recent economic crisis -since 2009- has deteriorated the energy poverty issue, with substantial variations in fuel prices, numerous arrears in electricity bills and drastic reduction in households' incomes [5].

The Greek residential sector represents over 29% of the whole final energy consumption (5.04 Mtoe), of which almost 64% is used for space heating, as shown on Table 1 [6].

Table 1. Percentage distribution of the total energy consumption by end-use.

End use of energy consumption	Percent
Space heating	63.7%
Domestic hot water	5.7%
Cooking	17.3%
Space cooling	1.3%
Lighting	1.7%
Appliances and equipment	10.2%

It is noteworthy that 41% of the dwellings are thermally unprotected, as built prior to 1980, when the first Building Thermal Insulation Regulation was enacted in Greece. In fact, the basic thermal regulations approaching the European standards (KENAK Regulation) were introduced just a few years ago, in 2010. It has been reported that Greek households present the highest energy consumption in Europe, while also being significantly higher even from countries with very cold climates, such as the Nordic countries [7].

2. Underground space living

Underground space has been used as a safe haven since ancient times, providing protection to people against enemies and climatic conditions. Through the course of time, energy gains of underground space have turned underground constructions as a good alternative for handling extreme climatic conditions and reducing energy losses. Notable examples of underground dwellings can be seen all over the world. The heritage of "cave dwellings" has been preserved in several regions, such as Guyaju (China), Matmata (Tunisia), Cappadocia (Turkey), Kandovan (Iran), Sassi di Matera (Italy), Guadix and Granada (Spain), Santorini (Greece) and Coober Pedy (an underground town in Australia). Apart from the old, traditional cave dwellings, modern earth-sheltered dwellings can be found in certain regions, such as Base Valley (Japan), Oxford Gardens (London), Therme Vals region (Switzerland) etc. Representative examples are shown on Figures 1 and 2. In Greece, several projects including modern earth-sheltered houses in islands (i.e. Kea, Ios, Milos, Crete) are currently under construction, as only in 2012 the Greek state

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