



Comparative analysis of various heating systems for residential buildings in Mediterranean climate



Georgios Martinopoulos^{a,*}, Konstantinos T. Papakostas^b, Agis M. Papadopoulos^b

^a International Hellenic University, School of Science and Technology, EL, 57001 Thessaloniki, Greece

^b Aristotle University of Thessaloniki, Dept. of Mechanical Engineering, EL, 54124 Thessaloniki, Greece

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ABSTRACT

Scope of the study is to compare the heating systems most commonly used in the Greek residential sector, by using the equipment's efficiency and the lifecycle cost as criteria. As the majority of buildings were constructed prior to the introduction of mandatory thermal insulation in 1979, space heating is the major cause of energy consumption in residential buildings. This fact, combined with the ongoing economic recession and the high cost of energy carriers, has led to a rapid increase of households not being able to cope with rising heating expenses. Consequently, the cost of energy has become over the past years the dominant factor when determining the selection of a heating system, often placing the system's efficiency or environmental aspects in the background. A variety of technologies has become available on the market, with each heating system having distinct advantages and disadvantages, and it is therefore necessary to examine the alternatives paying particular attention to their running costs. In that sense, when selecting the appropriate heating system, be it for a new dwelling or in particular when replacing an existing one, understanding the main operational features of the different systems, their pros and cons, their efficiency ratings and running costs, is essential. This study aims to facilitate this selection by describing and comparing different heating systems for the statistically representative three floor, multi-family apartment building, built according to the latest Greek energy efficiency regulation. A sensitivity analysis has been carried out for the four climatic zones in which Greece is subdivided with climatic conditions similar to those found throughout the Mediterranean. The systems' overall performance is evaluated based on their total lifecycle cost as well as the environmental burden associated with the fuel used.

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1. Introduction

Buildings constitute worldwide one of the biggest energy consumers with 32% of the total final energy consumption, while in terms of primary energy consumption they represent around 40% in most countries, according to the International Energy Agency. In the United States commercial and residential buildings use almost 41% of the total primary energy consumption [1]. The same trend is also evident in Europe as the building sector accounts for 40.7% of the total final energy consumption (1103.8 million tons of oil equivalent in 2013) in EU-28 of which 295.8 million tons of oil equivalent in residential buildings and 152.3 in non-residential buildings. Space heating represents 69% of total household con-

sumption, followed by water heating at 11% for 2013 [2]. Moreover, residential buildings are the fourth largest source of CO₂ emissions in the EU and account for 9.9% of total emissions according to the latest available data, while emissions from non-residential buildings are ranked fifth and account for 3.9% of the total CO₂ emissions in EU-27 [2].

The residential sector in Greece was responsible for approximately 30% of the total final energy consumption in 2013 [3,4]. According to a recent survey [5], every household in the country consumes, on average, 10.2 MWh of thermal energy, for space heating, hot water production and cooking and 3.75 MWh of electricity for the various electrical appliances.

According to the same survey, almost every house (98.9%) in Greece has some form of space heating with the majority using diesel heating oil (Type 2 diesel) as their fuel of choice and electricity, natural gas and biomass following with less than 12% each. As most buildings date before the 1980's they are either not thermally insulated at all or are only insufficiently insulated, as some

* Corresponding author.

E-mail addresses: g.martinopoulos@ihu.edu.gr, gmartinop@gmail.com (G. Martinopoulos), dinpap@eng.auth.gr (K.T. Papakostas), agis@eng.auth.gr (A.M. Papadopoulos).

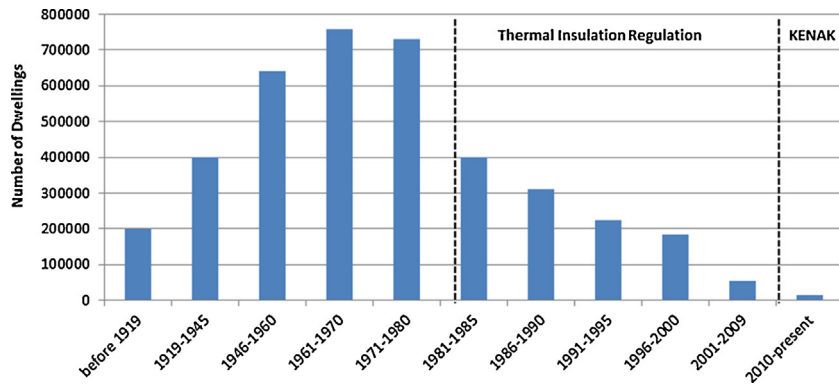


Fig. 1. Distribution of the Greek residential building stock with respect to its age.

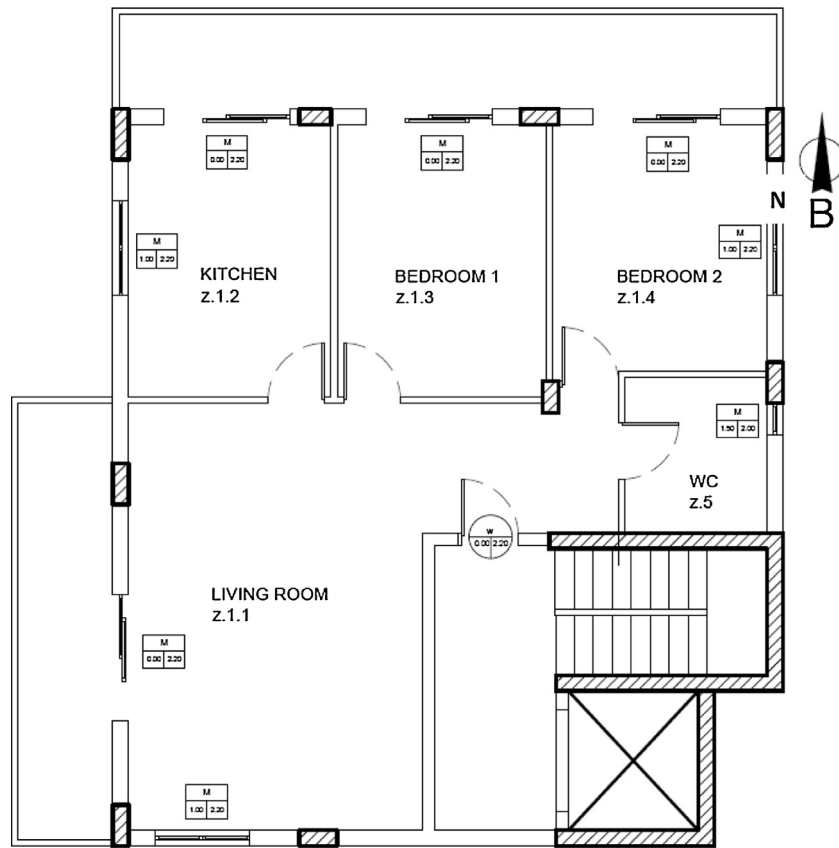


Fig. 2. Floor plan of the reference multi-family building.

refurbishment measures, like replacement of windows with new double glazed ones or retrofitting of insulation, especially on the roofs, have been implemented in older buildings since the early 2000s [6]. In most parts of the country a home's heating and cooling system are its largest energy user, so it's important to have an efficient, economical and reliable system.

A number of different studies have dealt with the energy consumption of households and its correlation with various socio-economic parameters for various countries worldwide [7–10]. In these studies the main parameters that were considered were the average household size, their income and the thermal characteristics of the building. In other studies, various heating systems were compared and evaluated with the use of exergy and environmental analysis [11,12], while others focused on the spatial and temporal allocation of energy conversion to match the heat demand of residential end users [13] or on specific types of heating systems

[14]. For Greece in particular, previous studies include the statistical analysis of the Greek building stock with emphasis on the cities of Northern Greece [15] the investigation of the energy, environmental and financial benefits, from the exploitation of forest and agricultural biomass residues for heating in buildings [16], an assessment of energy, economic and environmental performance of heating systems in Greek buildings [17] in the mid-2000, the effect of climatic conditions on the design optimization of heat pump systems [18], as well as the economic evaluation of energy saving measures [19]. According to the Greek Regulation for the Energy Performance of Buildings (KENAK) that was introduced in 2010 [20], as well as Directive 2009/28/EC [21], Greece, in line with all member states in EU, should increase the use of renewable energy sources along with energy efficiency and savings by 20% until 2020. Nevertheless, during the last six years Greece is facing a severe economic recession, which is characterized by a reduction

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