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Ranking cost effective energy conservation measures for heating in Hellenic residential buildings

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ABSTRACT

Residential buildings comprise the biggest segment of the European building stock and they are responsible for the majority of the building's sector energy consumption and CO_2 emissions. This paper documents the potential benefits and sets the priorities of individual energy conservation measures (ECMs) to reduce heating energy consumption in Hellenic residential buildings, including space heating and domestic hot water production. The analysis is facilitated by using the available Hellenic typology for residential buildings that consists of 24 typical buildings, derived after a classification in three construction periods, two building sizes and four climate zones. The focus is mainly on the implementation of ECMs that have low first-cost investment and short payback period. In order to prioritize ECMs that would be most attractive to building owners, two ranking criteria are used, namely primary heating energy savings and payback period. Finally, the preliminary results are used to provide an insight on the potential abatement of CO_2 emissions for the national residential building stock.

1. Introduction

The building sector has a large energy and environmental footprint, since it is responsible for about 40% of global energy used, and as much as one-third of global greenhouse gas emissions, both in developed and developing countries [1]. A substantial share of the buildings stock in Europe is older than 50 years, with many buildings today being over hundred years old. From an energy performance point-of-view, this constitutes a grim reality and clearly implies that the majority of European buildings will need some kind of refurbishment to the thermal envelope and the electromechanical (E/M) installations to meet the new energy efficiency standards for buildings.

In Europe, residential buildings account for 75% of the total building stock, with 64% single family houses and 36% multi-family houses (apartment blocks) [2]. In 2010, households in the European Union (EU-27) were responsible for 26.6% of the total final energy consumption, reaching 307.3 million tonnes of oil equivalent (Mtoe). Over the past decade (2000–2010), energy consumption in the residential sector increased by 5%. Energy consumption in households is mainly for heating, cooling, hot water, cooking and appliances. The dominant energy end-use is space heating, accounting for around 70% of total final energy use. The share of fuels to the total final energy consumption in households is dominated by natural gas (39%), followed by electrical energy (24%), oil products (14%), renewable energy sources like solar heat, biomass, geothermal and wastes (13%), derived heat (7%) and solid fuels (4%) [3]. Between 2000 and 2010, the consumption of oil products dropped by 24% and the consumption of derived heat by 3%, while the consumption of all other fuels increased, i.e. renewables by 37%, followed by electricity (18%), solid fuels (10%) and natural gas (6%).

In Greece, the final energy consumption in Hellenic households reached 4.63 Mtoe in 2010 or 24.3% of the total [3]. The share of fuels is dominated by oil products (42%), electrical energy (34%), renewables (17%), natural gas (5%) and derived heat (1%). Over the past decade (2000–2010), the total energy consumption increased by 3.1%. The highest increase was recorded in electricity (26%) and the introduction of natural gas in the energy mix and use by households, while the use of oil products fell by 22% and renewables by 5%.

Hellenic residential buildings consume over 50% of the electricity and over 90% of the thermal energy required by the entire Hellenic building sector [3]. In a recent study using operational data from a representative sample of about 180 Hellenic residential buildings [4], including apartment buildings and single dwellings, the annual final total energy consumption for residential buildings is reported to range from 43 to 348 kWh/m^2. The large variation is

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due to differences in location and weather conditions, operational characteristics and E/M installations, along with deviations from the desirable indoor environmental quality.

The main legislative instrument for improving energy performance of buildings throughout Europe is the EPBD European Directive 2002/91/EC and its recast (Directive 2010/31/EC). In Greece, EPBD transposition was enacted in 2008 by a national law (N.3661/2008). A follow-up regulation on the energy performance in the building sector (commonly referred to as KENAK) was issued in 2010 and outlines the general calculation method and overall approach that is in accordance to European standards. The main contents of the national regulation are reviewed in [5]. Recently, a new law (N.4122/2013) was introduced, as a first step for transposition of the EPBD recast, which replaced N.3661/08 and consolidates several revisions that were introduced through various satellite legislative efforts.

In addition, transposition of the European Directive 2006/32/EC on energy end-use efficiency and energy services that took effect in June 2010 by the national law N.3855/2010, there is a national obligation to implement various energy conservation measures (ECMs) in all energy end-use sectors, including buildings, in order to achieve by 2016 an overall national indicative target of 9% energy conservation. For the building sector, this implies about 1 Mtoe energy savings compared to 2007 data [5].

A qualitative and quantitative assessment of the available national data on the Hellenic residential building stock and its energy-related characteristics, are defined in [6]. Several priorities for ECMs in Hellenic residential buildings are presented through the implementation of a realistic and effective national action plan in order to reduce the environmental impact from CO_2 emissions. However, existing buildings continue to be upgraded at a very low rate, although several published research findings have demonstrated major benefits [7]. Apparently, this is going to be an even greater challenge for meeting the goals outlined by the EPBD recast that mandates EU member states to encourage more major renovations and achieve significantly higher improvements in energy performance than "normal" renovations.

The decision as to which ECM should be used for a particular building, is a multi-objective optimization problem subject to many constraints and limitations, such as specific building characteristics (e.g. building services types and efficiency, construction of thermal envelope), specific project targets, and finally it is all usually driven by the available budget. The effectiveness of a building retrofit is also dependent on building-specific information, such as geographic location, building type, size, age, occupancy schedule, operation and maintenance, and also energy related like type of fuels and utility rates.

This paper presents an overview of the potential benefits and the priorities of building energy conservation strategies to reduce heating energy consumption, including space heating and domestic hot water (DHW) production. The analysis is facilitated by using the available Hellenic typology for residential buildings. The preliminary results provide an insight on the energy conservation potential of the national residential building stock. The focus is mainly on the implementation of ECMs that have low first-cost investment and short payback period. Accordingly, the intent is to prioritize ECMs that would be most attractive to building owners and could easily be introduced in the market.

2. Building typologies

Building typologies can be used for the assessment of the energy performance of individual buildings, groups of buildings and even for the evaluation of the impact of energy conservation scenarios on the entire building stock. The term "building typology" describes a classification of buildings according to some specific characteristic energy related properties. A harmonised structure of European building typologies (TABULA) for residential buildings has been developed that includes model buildings with representative energy-related characteristics of their construction and technical systems and installations, representative of a country's building stock [8]. TABULA focuses on energy consumption for space heating (SH) and domestic hot water production (DHW), which constitute the main energy consuming end-uses in the residential sector. The buildings considered are permanent dwellings, with continuous occupancy throughout the year and do not include summer (vacation) dwellings.

The classification of buildings for the Hellenic residential building sector was based on three main parameters: building construction period, building size and climate zone. According to the building construction period three categories were defined: T1-Buildings constructed before 1980, considered without thermal insulation, since they were constructed before the implementation of the first Hellenic Building Thermal Insulation Regulation (HBTIR); T2-Buildings constructed during the period 1981–2000, considered partially or insufficiently insulated and T3-Buildings constructed after 2000, considered properly thermally insulated according to HBTIR, although they are not in compliance with the new thermal regulation (KENAK) introduced in 2010.

According to the building size, two categories were defined: SFH – single family houses, including low-rise buildings with one or two floors and MFH – multi-family houses, including apartment buildings. Finally, according to the climate zone, four categories were defined, in line with the four climate zones defined in KENAK depending on the heating degree days (HDD): ZA – climate zone A (601–1100 HDD), ZB – climate zone B (1101–1600 HDD), ZC – climate zone C (1601–2200 HDD) and ZD – climate zone D (2201–2620 HDD).

The classification of Hellenic residential buildings resulted in a total of 24 different typology classes, with an example building assigned to each one of them. Details on the thermal characteristics of the building envelope and installed systems in the Hellenic typology buildings are elaborated in [9].

The example buildings of the Hellenic typology may not reflect the typical characteristics of their class, due to specific characteristics of their initial construction or possible retrofit measures to their envelope (e.g. replacement of windows) and/or heating systems over the years. Thus, "typical buildings" were defined for each of the 24 typology classes. The typical buildings have the same geometry as the example buildings, but different energy-related characteristics. The thermal characteristics of the typical buildings' envelope as well as the installed space heating and DHW system characteristics were derived as weighted averages using the frequencies of occurrence per building class, reflecting the construction and renovation trends in Greece over the years [9].

3. Calculations

For each typical building, calculations were performed to assess the existing condition as well as the potential of various ECMs. The calculations were performed using the official national software [10], commonly referred to as TEE-KENAK. The software was developed for the assessment of the energy performance of buildings, using the asset rating method, in accordance to the European standards.

More specific, the calculations for space heating demand and energy consumption are based on the quasi-steady state monthly method, in line with [11]. The DHW demand is calculated according to [12]. According to the national calculation methodology and technical guidelines, several assumptions are used in order to