Energy 98 (2016) 284–295

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Mapping the energy performance of hellenic residential buildings from EPC (energy performance certificate) data

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ARTICLE INFO

Article history:
Received 22 September 2015
Received in revised form
8 December 2015
Accepted 27 December 2015
Available online 6 February 2016

Keywords:
Energy performance certificates
Energy consumption
Energy conservation measures
Energy savings
CO_2 emissions
Residential buildings

ABSTRACT

Residential buildings are the vast majority of the building sector and play a significant role in the energy and environmental footprint of the whole building stock. This paper presents an overview of the energy performance of the existing Hellenic residential building stock, by exploiting data from the EPCs (energy performance certificates) of buildings issued in accordance to national EPBD (energy performance in buildings directive) provisions. The analysis is performed for different building size (i.e. single- and multi-family houses), construction periods and locations (i.e. at the four national climate zones). In addition, implemented energy conservation measures are investigated in order to define the most common refurbishment actions for each building type. According to 650,000 EPCs that have been issued in Greece by August 2015, 15% are for single-family houses and 85% for multi-family houses (buildings or building units). About 34% of the residential buildings are ranked at the lowest energy class-G, while only 3% are ranked in energy class-B or higher. The average calculated primary energy is 261.6kWh/m^2 and the average CO_2 emissions 70.3 kg/m^2. Replacing the windows is the most popular retrofit action, followed by the installation of solar collectors for domestic hot water.

1. Introduction

The Hellenic building stock is estimated at about 4.1 million exclusive-use buildings, of which 79% are residential buildings according to the most recent building Census data [1]. Residential buildings in Greece consume over half of the electricity and over 90% of the thermal energy required by the Hellenic building sector, reaching 3.8 Mtoe or 24.8% of the total final energy use in 2013, compared to 4.5 Mtoe or 24.1% in 2000 [2].

1.1. National transpositions of EU directives

A national obligation to implement various ECMs (energy conservation measures) in all energy end-use sectors, including buildings, was introduced in 2010 for the transposition of the European Directive 2006/32/EC on energy end-use efficiency and energy services. Accordingly, the goal is to achieve by 2016 an overall national indicative target of 9% energy savings compared with the average final energy use of 2001–2005. For the building sector, this implies about 1 Mtoe energy savings. The EED (energy efficiency directive) (EED 2012/27/EU) was recently transposed in to national law (N.4342/2015) in early-November 2015. However, its full implementation will probably be further delayed, considering the struggle for developing the necessary ministerial decisions, regulations, administrative provisions and supporting tools.

According to the national energy efficiency action plan [3], the 2014–2020 cumulative total energy savings target is set to 3.33 Mtoe (38.8 TWh) or approximately 19.3% of the total final energy consumption in 2012, with total new annual savings equal with 902.1 ktoe (10.5 TWh) in 2020. Amongst the various policies, ECMs in buildings have the most significant contribution (about 58%) towards meeting these national goals. In particular for the residential sector, where most measures are applied, the accumulated energy savings for the period 2014–2020 are estimated equal to 1932 ktoe while the annual final energy savings in the year 2020 are estimated to about 523 ktoe (as a result of subsidized energy upgrades and ECMs in buildings, smart metering etc.).

To reach these ambitious targets, to improve living conditions and lower the operating cost of dwellings, there is a need to

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http://dx.doi.org/10.1016/j.energy.2015.12.137
0360-5442/

aggressively support the implementation of ECMs in existing buildings. This is a major challenge, considering that only half of the Hellenic dwellings have some kind of envelope thermal insulation [4] although HDD (heating degree-days) in Greece range from 600 in the south to over 2600 HDD in the northern parts of the country. Only 16% have double glazing and thermally insulated external walls. Double glazing is common in new buildings and the most frequent refurbishment activity in existing buildings, encountered in about 43% of the dwelling stock.

The first HBTIR (Hellenic building thermal insulation regulation) was introduced in 1980. National transposition of the EPBD (energy performance in buildings directive) was enforced in 2010 [5] by introducing the national regulation on the energy performance of buildings - KENAK [6]. The regulation introduced more strict building thermal insulation regulations and more efficient HVAC installations, through a series of four technical guidelines that govern implementation. For example, the U-value for external vertical walls in contact with outdoor air was 0.7 W/m^2 K with HBTIR and is reduced with KENAK by 14%–43% depending on location at four national climate zones. Minimum specifications for the building's HVAC installations include, for example, use of outdoor temperature compensation systems, zone thermostatic control, along with heat recovery for central air-handling-units, energy efficient lighting for non-residential buildings, etc. For domestic hot water production, all new buildings should cover 60% of the load from renewables in accordance to KENAK and a national law (N.3851/2010) that transposed the European RED (renewable energy directive) (RED 2009/28/EC).

1.2. EPCs in Greece

According to EPBD and the national provisions of KENAK, EPCs (energy performance certificates) are being issued in Greece as of January 2011 and they are valid for up to ten years. The EPC (energy performance certificate) is compulsory for all buildings that are being sold and for entire buildings that are being rented out for the first time to a new tenant. The EPC for a building unit (e.g. an apartment) that is being rented out for the first time to a new tenant was initiated in January 2012. A certified energy inspector performs the building energy audit to collects all relevant data, which are then submitted to the official national electronic registry (www.buildingcert.gr) for issuing a certificate.

The Hellenic EPC is a two-page document [5]. It includes general building data, the building's energy class (based on an asset rating, using letter grades for ranking with a “G” the lowest performance buildings, up to “A+” designating best performance), annual calculated and actual (if available) final and primary energy consumption, CO_2 emissions, an optional evaluation of indoor environmental quality, breakdown of energy carriers and different end-uses, and up to three cost effective recommendations for improving the building's energy performance with calculated energy savings and payback period. In the normative calculations, primary energy is estimated using the national conversion factors according to KENAK for different energy carriers, i.e. 2.9 for electricity, 1.1 for heating oil and 1.05 for natural gas. The carbon emissions are estimated using the following national conversion factors: i.e. 0.989 $kgCO_2/kWh$ for electricity, 0.264 $kgCO_2/kWh$ for heating oil and 0.196 $kgCO_2/kWh$ for natural gas.

The value of data from EPCs is progressively recognized as a valuable resource for understanding the energy related performance and other characteristics of regional and national building stocks [7,8], especially in countries where previously such data was unavailable [9]. Other approaches have also managed to couple commonly available information on a regional building stock (e.g. cartographic documentation, geometric data) with data from short energy audits of representative buildings, using a GIS platform to assess the energy performance of buildings [10], while others use targeted short surveys to collect and analyze energy use data [11].

In addition, the EPC is an instrument for assessing different ECMs [12,13], but the challenge still remains to encourage and facilitate their implementation [8], especially under adverse economic conditions [14]. In Greece, a set of financial incentives, with co-financing from the European Union, was initiated in 2011 for the implementation of ECMs in residential buildings, via the “Energy Efficiency at Household Buildings” (commonly referred to as Exoikonomo) program (http://exoikonomisi.ypeka.gr). An eligible residence is a detached house, a block of flats or a building unit (apartment). Various social and financial criteria apply in order for building owners to qualify for different incentives (e.g. 15–75% grants and the remaining as interest-free loans). Relevant to this work, it is mandated that an EPC is issued before and after the works in order to document that the energy class is at least “D” in the existing condition and a second energy inspection after the implementation of the works to verify the achievement of minimum energy performance improvements aimed by the program, i.e. the upgrade by at least one energy class or annual primary energy savings by more than the 30%.

1.3. Methodology

Using available national Census and statistical survey data, the first comprehensive classification scheme taking in to account the building size, age and location, along with an elaborate assessment of potential energy savings in the Hellenic residential building stock was presented in Ref. [15]. The work was performed to support national efforts during the early 2000 for assessing the policies for the abatement of CO_2 emissions in the residential and tertiary sectors in Greece. The greatest obstacle encountered at that time and to a certain extent continues even today, was the lack of detailed data on the characteristics of the existing building stock beyond the standard Census data and on the actual energy consumption. This gap of knowledge is progressively being bridged by the progress of building energy audits, performance certification, along with regular inspections of heating and air-conditioning systems in buildings.

This paper presents an overview of residential buildings’ energy performance exploiting EPC data. The results provide an insight on the existing condition of Hellenic buildings, as well as the potential energy savings. The focus is mainly on implemented ECMs, from the EPCs issued for the refurbishment of residential buildings under the national Exoikonomo program.

For the assessment of the buildings' energy performance, actual data were used (e.g. type of building, age, climate zone, total and heated area), as well as calculated data (e.g. energy class ranking, primary energy consumption, CO_2 emissions, fuel type, proposed ECMs, energy savings and payback period). ECMs taken into account are grouped into three categories. The first one includes the interventions on buildings' thermal envelope aiming to minimize heating loads, while securing the appropriate indoor environmental quality conditions. The second group of interventions targets the buildings’ heating systems in order to increase their efficiency and minimize the fuel consumption. The third category includes the interventions of integrating renewables and hybrid systems aiming to reduce the use of electricity.

During the analysis, a first rough quality control of the available data was performed in order to ensure the validity of the results. The analysis is facilitated by using the available TABULA Hellenic typology for residential buildings [16]. The typologies were developed following a common methodological structure consisting of a classification scheme grouping buildings according to their size,