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Environmental and energy impact of the EPBD in residential buildings in hot and temperate Mediterranean zones: The case of Spain

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ABSTRACT

The residential sector in the European Union accounts for 25.4% of the final energy consumption and 20.8% of the CO_2 emissions. Greater savings and efficiency in the sector are expected through the Energy Performance of Buildings Directive (EPBD). In the case of Spain, this directive is implemented through the Basic Energy-Saving Document of the Technical Building Code (CTE-DB-HE). This study presents an energy and environmental analysis of the EPBD implementation and evolution toward nearly zero-energy buildings (NZEBs) in a multi-family housing block. The locations of the studied building span 24 cities representative of the hot and temperate climate zones in Spain. This study complements a similar study conducted for the cold climate zones in Spain. The evolution of the regulation is studied through 5 cases and 3 proposals that seek to achieve NZEBs. The results reveal that reductions of more than 50% in energy demand, more than 68% in non-renewable primary energy consumption and more than 65% in CO_2 emissions are achieved with the current regulation. In addition, this article shows how the CTE-DB-HE can evolve to achieve NZEBs.

1. Introduction

The total final energy consumption in the European Union is 1084 million tons of oil equivalent (Mtoe). The building construction sector is responsible for 38.9% of this consumption, whereas the residential sector consumes 275.2 Mtoe of energy (25.4%) [1]. In addition, the European Union emits 3447.6 million tons (Mt) of CO_2, of which the residential sector is responsible for 715.7 Mt CO_2 (20.8%) [2]. One of the sectors with the greatest potential for energy savings and improvement, in which more measures can be implemented, is the residential sector. According to the International Energy Agency (IEA) [3], 10.4% of the energy consumption in the residential sector is covered by energy efficiency policies. In this regard, the energy efficiency directives applicable to this sector in the European Union are the Energy Performance of Buildings Directive (EPBD) 2010 [4], the consolidated version of EPBD 2002 [5], and the Energy Efficiency Directive (EED) 2012 [6]. The studies in Refs. [7,8] were performed at an international level and compared the residential sector energy consumption of different countries. The relationships between residential energy consumption and income in EU-28 countries were analyzed in Ref. [9], whereas fuel and energy transition possibilities and their sustainable development in compliance with EU policy were analyzed in Ref. [10]. In addition [11,12] studied how to achieve the objectives of renewable energies in Europe 2020. Focusing on the residential sector of Spain, in Ref. [13], both the final energy consumption and the primary energy consumption were analyzed, and energy indicators were created to establish the degree of compliance with the 2020 European objectives.

EPDB 2010 [4] proposes a general methodology for the calculation of the energy efficiency of buildings using energy performance certificates (EPCs). The primary energy consumption and CO_2 emissions of the residential sector can be determined based on the data in the EPCs [14]. Each Member State has adapted and implemented the EPBD [15]. The Mediterranean countries of southern Europe have the problem that different methods are being used to obtain their EPCs, even though their climates are similar [16]. These EPCs have been used to analyze and increase knowledge of the energy and environmental aspects of the residential sector in Portugal [17], Spain [18], France [19], Italy [20], Greece [21], Cyprus [22] and Turkey [23]. Additionally, the building codes and standards derived from the implementation of [4,5] regulate and limit

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Abbreviations

COP	Coefficient of Performance
CTE-DB-HE	Basic Document for Energy Saving of the Technical Building Code (Documento Básico de Ahorro de Energía del Código Técnico de la Edificación)
DHW	Domestic Hot Water
ED	Energy Demand
EED	Energy Efficiency Directive
EER	Energy Efficiency Ratio
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
FEC	Final Energy Consumption
IDAE	Institute for Diversification and Saving of Energy (Instituto para la Diversificación y Ahorro de la Energía)
NRPEC	Non-Renewable Primary Energy Consumption
NZEB	Nearly Zero-Energy Building
RITE	Regulation of Thermal Installations in Buildings (Reglamento de Instalaciones Térmicas en los Edificios)
SCOP	Seasonal Coefficient of Performance
SEER	Seasonal Energy Efficiency Ratio
SPF	Seasonal Performance Factor
WCZ	Winter Climate Zone

the thermal transmittance value of the thermal envelope of buildings [24]. The energy and environmental consequences of their implementation in the residential sector were analyzed in Portugal [25], Spain [26], Italy [27], Greece [28], Cyprus [29] and Turkey [30], and with these studies, further progress in the definition of the nearly zero-energy building (NZEB) has been made.

EPBD 2002 [5] was adopted into Spanish law by the Basic Energy-Saving Document of the Technical Building Code (CTE-DB-HE 2006) [31], and this required a new Regulation of Thermal Installations in Buildings (RITE) [32] and a basic procedure for the energy efficiency certification of buildings [33]. CTE-DB-HE 2006 [31] was progressively modified with [34,35], resulting in CTE-DB-HE 2009 [31,34,35]. Subsequently, a major update occurred in 2013 with the adoption of EPBD 2010 [4], and CTE-DB-HE 2013 [36,37] was generated, which increased the requirements of CTE-DB-HE 2009 [31,34,35]. This core document contains the following basic requirements for the residential sector: (i) CTE-DB-HE0 on the limitation of energy consumption; (ii) CTE-DB-HE1 on the limitation of energy demand; (iii) CTE-DB-HE2 on the performance of thermal installations, developed in the different revisions of the RITE [38]; and (iv) CTE-DB-HE4 on the minimum solar contribution for domestic hot water (DHW). CTE-DB-HE1 limits the heating and cooling energy demand of new residential building construction and regulates the thermal transmittance of the thermal envelope of the building. Whereas CTE-DB-HE1 2009 requires the energy demand to be lower than that of the reference building that corresponds to the climate zone, CTE-DB-HE1 2013 sets more stringent limits that depend on the winter climate zone and habitable area. Both CTE-DB-HE4 2009 and CTE-DB-HE4 2013 require a minimum solar contribution to meet the DHW demands of the building. The main change of CTE-DB-HE 2013 [36,37] is CTE-DB-HE0, which establishes a limit on non-renewable primary energy consumption that depends on the winter climate zone and the habitable area. The implementation of NZEBs in Europe has been slow and difficult in the countries of Southern Europe [39]. In fact, the definition of an NZEB appears for the first time in Spain in the last modification of CTE-DB-HE 2013 [36,37] in June 2017 [40]: all new buildings that meet the requirements of CTE-DB-HE 2013 [36,37,40] are considered NZEBs. In addition, when the EED 2012 [6] took effect, the basic procedure for the certification of energy efficiency [41] was changed by Ref. [42]. [42] included the requirement that as of 31 December 2020, all future new residential buildings must be NZEBs, always according to the CTE-DB-HE in force at any given time. For the upcoming CTE-DB-HE 2018 in Ref. [26], it was proposed that NZEBs will be those that achieve an A rating in terms of both non-renewable primary energy consumption and CO_2 emissions.

The aim of this study is to examine the evolution of CTE-DB-HE from an energy and environmental standpoint, using a multi-family housing block located in the most representative cities of the hot and temperate climate zones of Spain (22 provincial capitals and 2 autonomous cities). To accomplish this, five cases are studied: the conditions of the building stock in 2008 [43], buildings with the maximum thermal transmittance indicated in CTE-DB-HE 2009 [31,34,35], buildings that meet CTE-DB-HE 2009 [31,34,35], buildings with the maximum thermal transmittances indicated in CTE-DB-HE 2013 [36,37,40] and buildings that meet CTE-DB-HE 2013 [36,37,40]. Thus, the previous study in Ref. [26] for the cold climate zones of Spain is complemented. In addition, different proposals to achieve NZEBs in the hot and temperate climate zones are evaluated. This study, combined with [26], provides a clear picture of the EPBD implementation in Spain. This paper is structured as follows. Section 2 describes the studied building; the methodology used for the evaluation of the energy and environmental parameters is explained, taking into account the evolution of the applicable regulations; the various cases for study are listed; and, finally, proposals to achieve NZEBs are presented. Section 3 presents the results and discussion for all the cities selected for the different cases along with the impact of the regulations and the different proposals to achieve NZEBs. Finally, the most important conclusions are presented in Section 4.

2. Methodology

2.1. Description of the building

The multi-family housing block studied was used for a similar study performed for cold climate zones in the Mediterranean [26]. It consists of a ground floor and five stories. Its base is 22 m by 22 m, which equals an area of 484 m^2. The height of each story is 3 m. The main façade is oriented to the north. Fig. 1 shows the typical floor plan. On the ground floor is the entrance and an area for retail space. Each of the five floors has 4 types of apartments: apartment A has 3 bedrooms and a size of 100.05 m^2; apartment B has 3 bedrooms and a size of 101.93 m^2; apartment C has 4 bedrooms and a size of 137.64 m^2; and apartment D has 3 bedrooms and a size of 103.69 m^2. Table 1 lists the spaces that make up each type of apartment.

2.2. Climate zones

In Spain, there are 15 climate zones, depending on the severity of summer and winter climate according to CTE-DB-HE1 2013. The winter climate severity determines the heating energy demand and is represented by a letter (α, A, B, C, D, and E) that ranges from α for the least severe winter climate to E for the most severe winter climate. In contrast, the summer climate severity determines the cooling energy demand and is represented by a number that ranges from 1 for the least severe summer climate to 4 for the most severe summer climate. Fig. 2 shows all the climate zones for the different