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Simplified model to determine the energy demand of existing buildings. Case study of social housing in Zaragoza, Spain

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ABSTRACT

The refurbishment of residential buildings is fundamental to fulfil the EU's CO_2 emissions and energy savings objectives. Social housing estates built during the Spanish post-war period are vulnerable areas in Spanish cities that require public economic investment for their urban regeneration, and to refurbish their buildings. Public economic resources must center on the buildings that most require these actions, which are precisely those with a higher energy demand. This article proposes a simplified model to predict heating and cooling energy demands of buildings with no insulating material layer in their envelopes, which was conducted based on the case study of social housing buildings built in the Spanish city of Zaragoza between 1945 and 1975. The model obtained herein predicts the cooling and heating energy demands of buildings from only knowing a few inputs that are easily obtained, and is useful for the energy characterisation of large residential stocks without the need of dynamic simulation.

1. Introduction

The residential building sector in the EU is responsible for more than 21% of all energy consumed [1]. Nowadays, regulations require new energy-saving buildings to be built. However, in some countries like Spain, fewer new buildings are being built, and efforts must be made to fulfil energy refurbishment objectives.

To fulfil the greater energy efficiency and lower greenhouse gas emissions objectives, energy improvements must be made to existing buildings as they will remain on the market for many years to come. In Spain, most of the existing building stock, i.e., 56% of all buildings [2], were erected before the 1979 Basic Building Regulations on Thermal Conditions in Buildings (NBE-CT, in Spanish) [3] came into force. These regulations were the first in Spain on taking measures to make energy savings to be applied to new buildings in the residential sector. Current regulation The Basic Document "Energy Saving HE1- Limitation of the energy demand" of the Technical Building Code [4], indicates requirements for newly constructed buildings, as well as for works of considerable magnitude to be done on existing buildings. Nevertheless, no legislation exists that obliges existing buildings to be refurbished, which is why public organisations must promote the renewal of the existing building stock. Efforts should be made to limit energy consumption by refurbishing buildings to reduce the energy they consume and to make them comparable to newly constructed buildings. Besides, it makes sense to prioritise buildings with a higher energy demand as they will be the ones to make more savings and higher profitability.

Refurbishing buildings in the urban regeneration context helps fulfil energy savings objectives, cut CO_2 emissions and revitalise the areas where they are located. The Europe 2020 strategy consists in five main objectives that Member States have to fulfil by 2020 in the following areas: employment, R&D, climate change and sustainable energy, education, and fight against poverty and social exclusion [5]. Urban regeneration contributes to two of these objectives: on the one hand, climate change and urban sustainability since refurbishing buildings, as indicated herein, reduces energy consumption and cuts greenhouse gas emissions; on the other hand, fight against poverty and social exclusion as neighbourhoods affect families and children [6,7].

From Europe, investments in renewing the existing building stock are being urged [8], and in Spain the Refurbishment, Regeneration and Urban Renewal Act refers to obtaining and updating maps and censuses of deteriorated areas or buildings in need of refurbishment [9]. This is why making information available about diagnosing building stocks to the EU and Public Administrations in Spain is so important.

Public economic investments in urban refurbishment and regeneration must center on the most unfavourable areas and,

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among them, the buildings that most require such actions. In Spanish cities, deteriorated areas generally concentrate in old quarters, and also in the old housing estates built during the Spanish post-war period. In the Spanish city of Zaragoza, the old workers districts have begun to be studied, known as Urban Estates of Interest (UEI). These estates are groups of buildings constructed during the protection regime period that covered 1945–1965, now characterised by high-density buildings, poor-quality buildings, poor-quality environment in public places and selective population loss [10]. Most of the buildings have load-bearing walls and therefore their façades are significantly massive. Neither the façades nor the roofs have a layer of insulating material since they were built before any thermal regulating existed in Spain. It has to be stated that sporadic investments have been made to refurbish and regenerate these UIE with excellent results [11], but the economic conditions that promoted them have changed.

Nowadays, public investments are limited and should focus on buildings that most require them. For refurbishments promoted by public organisations, or those financed with public resources, to address buildings with a greater energy improvement capacity, we need to know their energy consumption and potential savings. Given the large number of existing blocks and the difficulty of studying each one in detail, a simplified evaluation methodology is proposed to estimate energy demand in primary energy terms (kW h/year m^2) to give priority to certain refurbishments over others.

Our study objective was to develop a simplified method that predicts the heating and cooling energy demand of social housing buildings that considers the thermal inertia of the non-insulated elements of the envelope, at the scale of housing block, by only knowing some variables of buildings that are easily obtained, without the need of simulating them since this would be very time-consuming. This model is useful for the Public Administration in Spain, and it will also be of help in other European countries with this construction typology, since they will count with a simple method to quickly obtain objective information about the energy demand of a large stock of residential buildings, which will be helpful in prioritising their refurbishment.

2. State of the art

In this study the energy demand of buildings in primary energy terms (kW h/year m^2) is the energy-related criterion used to give priority to the refurbishment of certain buildings over others. Other parameters could also be used, such as the energy consumption, the CO_2/year m^2 emissions associated to such energy consumption, or the energy classifications that derive from the former. These three other alternative parameters are energy consumption-based parameters.

The studies pursuing the energy characterisation of existing building stocks rely mostly on consumption-based parameters. Some of these studies in the literature propose evaluation methodologies to estimate annual energy consumptions that start with overall energy consumptions data and share them among buildings according to specific building typology parameters. For example, in the studies that analyse the whole building stock in Europe, the energy consumption and CO_2 emissions of such a large and heterogeneous set of data is shared among buildings according to statistical-based data related to country, climate zone, building typology or age [12] [13]. The studies at city scale estimate the energy consumption of the built stock according to statistical data about building typology, envelope thermal characteristics, heat production units, energy carriers and use of renewables [14,15]. In any case, these energy consumption-based studies have the disadvantage that, as calculations are based on proportionally sharing the official energy consumptions according to the building, envelope or installation typologies, specific residential block factors such as orientation or social factors affecting energy consumption are ignored.

User behaviour – a social factor – is considered key to energy efficiency of existing buildings [16] as well as orientation. For this reason, the studies that proportionally share energy consumptions according to statistical census data are not considered appropriate for the objective of this paper since our aim is to find a method to predict energy efficiency for a given building typology (old social housing) requiring sufficient precision to differentiate behaviours at the residential block scale. Whereas the previously mentioned studies provide rough energy data about country- or city-scale residential building stocks, our intention is to provide more accurate data about a given residential typology that is found in European cities and has been identified as a key residential typology to be refurbished due to its high consumptions [17].

Energy poverty in Spain is a genuine and growing problem [18]. The percentage of homes unable to maintain a suitable temperature increased by 22% from 2012 to 2014, and is now estimated at 11% [19]. It is reasonably assumed that this percentage is higher in vulnerable areas. Energy demand decreasing strategies work better for people suffering from energy poverty than consumption decreasing ones [20]. Besides energy poverty, building's heating and cooling systems will also affect energy consumption, and there is no available and reliable data about this matter for the residential stock in Spain. So conducting a study into the energy characteristics of buildings by means of their energy demand, that is, the energy they require for their interiors to be comfortably enjoyed by occupants, was considered a more appropriate measure than using any energy consumption-related parameter. Demand depends basically on climate and the building's characteristics, and is independent of the performance of heating systems and social factors. This is why it was considered a more reliable criterion.

Various models have been designed to forecast the heat demand of buildings. They use regression models to predict the energy demand of residential buildings [21–23], office buildings [24] or commercial buildings [25]. The energy prediction models are based on extended databases obtained by dynamic simulations. The inputs for the models include building shape factors, building orientation aspects, building construction characteristics, windows ratios, and climate. These models have been developed to support early design stages of new buildings whose envelopes have insulating material. In the case of building refurbishment, especially in post-war social housing, the thermal envelope is not insulated and thus the model must include different inputs. Most of these buildings have a great thermal inertia that taken into account together with heat transfer coefficients are the most important quantitative parameters for designing energy-efficient exterior walls and roofs [26].

Therefore, the novelty of this paper consists of using an energy demand criterion to characterise the existing building stock – instead of the most commonly used energy consumption related ones – and of including as input data for the prediction model the thermal inertia of the building envelope with no insulating material.

3. Methodology

Simulation tools were used from which demand data were obtained. To calculate energy demand, the General Option Technical Building Code Energy Savings (CTE DB HE) Method was used, formalised through the Unified LIDER-CALENER (HULC by its Spanish acronym) software application tool, version 20151113 (0.9.1431.1016), of compulsory use in Spain since 14 January 2016. This tool was used instead of other simulation software because it is the official tool employed in Spain. The heating and cooling

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