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Application of energy rating methods to the existing building stock: Analysis of some residential buildings in Turin

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ABSTRACT

The objective of this work is to contribute to the recent standardisation activity, finalized to apply the Energy Performance of Buildings Directive (EPBD). Through the energy assessment of some residential buildings in Turin (Italy), the work investigates the application of the calculation methods that have been specified in the recent European standard for the so-called "standard energy rating". A comparison of the "calculated energy rating" with the "measured energy rating" is used to investigate the effect of user behaviour and weather conditions. Moreover, in order to draft the energy certificate and make an appropriate classification, the last part of the work investigates the way to find energy reference values of the building stock, through the study of the correlation between the input and the output data of an energy rating and the comparison of the analysed buildings.

1. Introduction

The building sector is one of the main protagonists in environmental problems because of the exploitation of non-renewable resources, the use of soil and the energy consumption during the whole life cycle of a building. The negative effects on the environment include both resource consumption and pollution; in the building sector, the latter factor causes the largest impact. In 2000, it was estimated that 45% of the energy produced in Europe was used in the building sector and 50% of air pollution was caused by this sector. The European *Energy Performance of Buildings Directive* 2002/91/EC (EPBD) [1] has the aim of promoting the reduction of carbon dioxide emissions, according to the limits established in the Kyoto Protocol. In order to reach this target, the EPBD foresees a substantial contribution to the energy performance (EP) of buildings, and requires the Member States to provide regulations to comply. In particular, the following actions are considered: the adoption and the application of a methodology to calculate the energy performance of buildings (i.e. primary energy use for heating, air-conditioning, ventilation, hot water supply and lighting); the adoption of necessary measures to ensure that minimum energy performance requirements for buildings are set; the adoption of an energy performance certificate that includes reference values and recommendations for the improvement of the energy performance; the adoption of measures to establish a regular inspection of boilers and air-conditioning systems.

Italy transposed the EPBD through *Legislative Decree 2005/08/19 no. 192* [2] and *Legislative Decree 2006/12/29 no. 311* [3]: the latter contains integrations and modifications of the former. As regards the minimum energy performance requirements, *Legislative Decree 311/2006* provides a gradual implementation according to the type of building work. The same is provided for the application of the energy certification, which is scheduled according to the year of selling and to the building size. Italian regulations also introduce an energy qualification, which is preliminary to the energy certification and which reports some information about the building (typology, construction, etc.) and the value of the calculated energy performance indicator (only space heating is considered). This qualification also gives useful information on the solutions adopted to improve energy efficiency, comparing it with the minimum energy performance requirements fixed by law.

As regards the EP calculation methodology, Italian legislation specifies the elements that have to be considered and requires that the calculation methods must guarantee results that conform to the best technical rules, i.e. those defined by the standardisation bodies, such as the *European Committee for Standardization* (CEN).

In the European and national context, the specialists have already prepared the energy performance calculation methodology whose scheme is represented in Fig. 1. The application of this methodology is required to draft the energy certificate and compare the energy performance of a building with the minimum requirements. The energy assessment is also useful

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Nomenclature

A	area (m^2)
b	temperature adjustment factor (-)
C	specific heat capacity (MJ/kg K)
$f_{W,ls,d}$	hot water heat loss coefficient for distribution (-)
DD	degree days (°C d)
F	fraction (-)
g_n	total solar energy transmittance factor, normal incidence (-)
H	heat transfer coefficient (W/K)
Q	energy (MJ)
t	duration of the calculation step (Ms)
U	thermal transmittance (W/m^2 K)
V	volume (m^3)

Greek symbols

η	dimensionless utilization factor, system efficiency (-)
θ	temperature (°C)
ρ	density (kg/m^3)
Φ	heat flow rate, thermal power (W)

Subscripts

adj	adjusted
C	cooling
ctr	control of the internal temperature
d	distribution system
e	external (temperature), envelope
em	emission system
F	frame
f	floor
g	glass
gen	generation system
gn	gains
H	heating
int	internal (heat gains, temperature)
ls	losses
mn	mean
nd	need
O	cold water (entering the domestic hot water system)
p	primary
s	storage system
set	set-point
sol	solar (heat gains)
sup	supply system
sys	system
tr	transmission (heat transfer)
u	adjacent unconditioned space
ve	ventilation (heat transfer)
W	hot water (delivered)
w	window

to find reference values of existing constructions (i.e. the average energy use of the building stock), so that a classification of the energy performance can be made and placed inside the energy certificate.

The work presented in this article contributes to these targets, through the application and the validation of the new energy rating methods. The analysis of the energy performance is made on some buildings in Turin (Italy), each one built in a different decade of the second postwar period. Then, in the second part of the work, the main parameters of each building that influence the calculated energy performance indicators are investigated, in order to find the reference consumption values for other buildings and to obtain knowledge on the energy behaviour of the building stock in a regional context.

2. The energy rating methods and the calculation of the energy performance

European Standard EN 15603:2008 [5] proposes different energy rating methods. The evaluation of the energy performance of buildings is based on the weighted sum of the calculated, or measured, use of energy carriers (for heating, cooling, ventilation, domestic hot water and lighting). The two principal types of energy rating are the "calculated energy rating" (i.e. energy rating based on calculations) and the "measured energy rating" (or "operational rating", i.e. energy rating based on real energy use data, measurements or utility bills). The "calculated energy rating" is classified as "tailored energy rating" (i.e. energy rating based on actual data for the building, climate and occupancy) or "standard energy rating" (or "asset energy rating", i.e. energy rating based on actual data for the building and standard use data set). The type of rating is chosen according to the purpose or the utility [6]. For instance, "tailored energy rating" is finalized to optimisation, validation and retrofit planning; instead, "standard energy rating" is applied, above all, in order to draw up an energy performance certificate. The energy certification of buildings requires a method that is applicable both to new buildings and to existing ones and that considers them in an equivalent way, focusing attention more on building features than on their management. Many studies have been developed on several energy ratings, by creating and applying methods to predict annual building energy costs [7], to evaluate the quality of the given results and the process [8], to establish energy benchmark values and to plan energy efficiency improvements of the building stock [9], etc.

A methodology to calculate a standard energy use for space heating and cooling is provided in European Standard EN ISO 13790:2008 [10]. This standard presents a coherent set of calculation methods with different levels of detail (seasonal, monthly, simple hourly and detailed simulation method) of the energy use for space heating and cooling of a building and the influence of recoverable thermal losses of building systems, such as the heating and cooling system. The main inputs needed for this standard are the followings: transmission and ventilation properties; heat gains from internal heat sources; solar properties; climatic data; description of building and building components, systems and use; comfort requirements (set-point temperatures and ventilation rates); data related to the heating, cooling, hot water, ventilation and lighting systems; partition of building into different zones for the calculation (different systems may require different zones); energy losses dissipated and recoverable or recovered in the building; air flow rate and temperature of ventilation supply air; controls. The main outputs of this standard are the annual energy needs for space heating and cooling, the annual energy use for space heating and cooling and the length of the heating and cooling seasons. Other outputs are monthly values of energy needs and energy use, and monthly values of the main elements in the energy balance, i.e. transmission heat losses, ventilation heat losses, internal heat gains, solar heat gains. Additional outputs are the contribution of passive solar gains and system losses (from heating, cooling, hot water, ventilation and lighting systems) recovered in the building.