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A methodology for the energy performance classification of residential building stock on an urban scale

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ABSTRACT

An understanding of the energy performance in buildings in an entire municipality or an entire district is important for sustainable energy planning strategies that accelerate the energy renovation process in existing buildings that are not energy efficient.

The methodology described in this paper is largely based on information that is already available on building stock (i.e., cartographic documentation, thematic maps, geometric data and others). Data regarding the energy performance of buildings are collected using energy audits on sample buildings, which are selected using a statistical approach. Using the tools in a GIS platform, the integration of two data sources allows for a low cost, comprehensive framework of the energy performance of buildings. This methodology was tested in a medium sized town in the Lombardy region (Italy), and the results are discussed in this paper.

1. Introduction

The main objective of the energy certification of buildings, which was introduced in the European Union by EPBD – Energy Performance Buildings Directive [1], is to provide clear guidelines for energy performance of buildings to improve the energetic quality of new buildings and existing building stocks.

The rules for the implementation of EPBD in Italy were defined by Legislative Decree 192/05 [2] and, in particular, by the national guidelines for energy certification [3], which were published in 2010.

The Italian constitution considers energy usage to be a matter that should be governed by states or by regions; for this reason, some regions, including the Lombardy region, have implemented the EPBD independently through regional laws. The rules for the energy certification of buildings in Lombardy are regulated by Regional Law 24 [4] and subsequent decrees [5,6]. Energy certification is mandatory in Lombardy when selling or leasing buildings.

According to [7], there have been approximately two million estimated energy certificates issued in Italy. To date, approximately 450,000 of these certificates have been issued in the Lombardy region.

The implementation of an archive of regional energy certificates using the mandatory certification is useful and important; however, the process is quite slow. According to [8], the residential building stock of Lombardy is composed of approximately 4,600,478 apartments. Because 450,000 energy certificates were issued over four years (2007–2011), it will take approximately 40 years to achieve a comprehensive framework.

The objective of this study is to define a tool that allows public institutions, particularly municipalities, to create a comprehensive database of the energy performance of buildings on an urban setting. The proposed procedure allows for relatively quick and cheap pre-energy certification of all buildings in a local context. As the buildings are certified according to official procedures, the information contained in the database can be naturally replaced. The use of a GIS platform through the implementation of a WEB-GIS plug-in facilitates access to the data via the WEB.

This work is part of a series of studies conducted by a group of researchers in the Research Unit "Innovative technologies for energy management in construction" of the BEST (Building Environment Science and Technology) Department of Politecnico di Milano. The purpose of this line of research is to develop methods and strategies that accelerate the movement towards better energy sustainability on an urban level.

The methodology presented was applied for the first time in 2006 in a municipality near Milan called Carugate. This municipality is famous, at a national level, because it is the first that has

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Nomenclature

Symbols

EP_H	specific primary energy for winter heating (kWh/m^2)
EP_W	specific primary energy for hot water supply (kWh/m^2)
S	surface (m^2)
U	U-value (W/(m^2 K))
V	volume (m^3)
S/V	surface/volume coefficient (m^{-1})

Abbreviations and acronyms

EPBD	Energy Performance Building Directive, 2002/91/CE
DD	Degree-Days (°C days)
DHW	domestic hot water
PV	photovoltaic
CEN	European Committee for Standardisation
GIS	Geographic(al) Information System
SEAP	Sustainable Energy Action Plan
CENED	Certificazione ENErgetica degli EDifici (energy certification of buildings)
DXF	Drawing Exchange Format

introduced, in 2004, a building code with mandatory rules aimed at a sustainable improvement of energy efficiency in the building sector (e.g., reduction of U values for external walls, windows and roofs, the use of solar systems for hot water supplies, reduction of the use of DHW, etc.). Carugate's building regulations introduced the concept of mandatory energy certification even before this procedure was implemented in the Lombardy region (for more on this subject, see [9]). This research was also an opportunity to carry on other works; in particular [10,11], relate to this project.

The methodology, which was updated in some places due to regulatory updates, is offered as a tool for quality control management and efficiency in the SEAP (Sustainable Energy Action Plan) promoted by some municipalities in the Lombardy region under the framework of the EU Project "Covenant of Mayors".

2. Description of the methodology

2.1. Methods for assessing energy performance at a local and regional level

The evaluation of the energy performance of existing building stock at the regional or local level has long been debated by many researchers. The proposed approaches obviously differ.

An evaluation of the energy consumption of European apartment buildings was carried out by Balaras et al. [12]. The data on heating energy consumption used in the study were collected through 193 European residential building audits in five countries. Data was analysed in order to assess the influence of envelope thermal insulation, age and condition of heating system. The study also explores aspects of regulations and strategies in terms of energy efficiency promoted in Europe. Many studies consider the method for assessing the energy performance of building stocks within specific Countries. Tommerup and Svendsen [13] gives a short account of the technical energy-saving possibilities that are present in existing dwellings in the Danish residential building stock. Detailed calculations have been performed on two typical buildings, representing the residential building stock, and then an assessment of the total energy-saving potential is performed on the basis of the calculations. A specific approach for data collection and analysis of building stock and its energy performance is given by Dascaloaki et al. [14]. The Hellenic database included a sample of 250 buildings from different regions in Greece, with a breakdown that is representative of the national building stock. The aim of the work is to provide a tool to manage the process of building and labeling certification promoted by the Directive 91/2002. The database includes a total of 255 parameters covering a wide, yet realistic, range of building characteristics.

The characteristics and the energy behaviour of the residential building stock of Cyprus are examined in the work of Panayotou [15]. The database of the Cyprus residential building stock, about 500 buildings, is built on the basis of Statistics of Constructions and Housing in order to classify the buildings according to the climatic zone, type, age and size of the housing units. For these buildings the energy performance (operational rating) was based on a formulated questionnaire. For a smaller sample of 20 selected houses a detailed simulation was made using SBEM Cy, which is the software provided by the Cyprus Energy Service for assessing the energy performance of buildings in Cyprus.

A statistical analysis of the Greek residential building stock is the approach used by Theodoridou et al. [16], that provide detailed information on the residential urban building stock thanks to a field study in typical big and small Greek cities.

Another example of statistical approach is given by Caldera et al. [17]. In this case the analysed data come from a sample of 50 multifamily residential buildings of the local social housing company in Turin, built in different periods between the end of the 19th century and the end of the last century.

A comparison between two different approaches, top–down and bottom–up, for the modeling of residential sector energy consumption, is given by Swan and Ugursal [18]. The top–down approach treats the residential sector as an energy sink and is not concerned with individual end-uses, while the bottom–up approach extrapolates the estimated energy consumption of a representative set of individual houses to regional and national levels, and consists of two distinct methodologies. As regards bottom–up approach, the paper evaluates both the statistical method and the engineering method.

Fracastoro and Serraino [19] propose an analytical methodology to determine the statistical distribution of residential buildings according to primary energy consumption for heating purposes at a regional or national scale (Italy). The main source of data required is still the National Italian Census, integrated by energy standards and laws, literature and a few data taken from the authors' experience and in situ analysis.

Ballarini and Corrado [20] analysed the potential of energy conservation actions in existing buildings in Turin by a chronological and typological categorizations and using the European Standard.

The common goal of the various methods is to provide the most complete and comprehensive framework of the characteristics of the energy efficiency of existing building stock. The proposed approach can be classified as a mixed method, i.e., a method that integrates the statistical and individual building approaches.

2.2. Brief explanation of the approach

The methodology is outlined in the flowchart in Fig. 1. The central part of the diagram shows the different phases of the process; the actors involved are reported on the left, and the activities and tools are on the right.

2.2.1. Documentation retrieval

This phase includes the collection of all information that may be useful for analysis, for example, site maps, aerial photogrammetric surveys and building cadastral data. This information is usually provided by the technical departments of municipalities, from the historical archives of the buildings or from land registers (buildings