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A supporting method for defining energy strategies in the building sector at urban scale

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HIGHLIGHTS

- The need and effectiveness of proper energy policies at urban level was stated.
- References and barriers in data collection and data elaboration for city energy performance were described.
- A methodology to estimate energy consumption of existing buildings was developed.
- Successful tests at city and district level were carried out, referring to Milan.
- Further developments and improvements of the work were indicated.

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ABSTRACT

Energy policies at the urban level may result in long lasting effects and can successfully influence the energy performances of an urban system if we consider the whole built environment and focus on the energy renovation process in existing buildings. Undoubtedly, cities have a high level of complexity, especially considering problems related to obtaining suitable information about a building's energy performance and consumption.

This study developed a methodology able to characterize the energy performance of the built environment in a city or neighbourhood and to evaluate the effects of different energy strategies. The methodology was designed to be as simple as possible, not time consuming and applicable to all Italian towns, as well as elsewhere, if basic building information are available; the main phases of the methodology were the collection and analysis of the available data about the built environment and the implementation of a Geographic Information Systems (GIS) city buildings database. To test the developed tool, the city of Milan was considered as a case study.

The authors hope that this methodology will be able to support energy policies at the urban level, taking into account the approaches of different stakeholders to develop low carbon models of settlements.

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1. Introduction

It is well documented that energy consumption is the largest contributor to carbon dioxide (CO_2) emissions and the leading cause of climate change and that cities are the main energy consumers in the world. On the European continent, cities are currently responsible for approximately 70% of the overall primary European energy consumption, and this share is expected to increase to 75% by 2030 (European Institute for Energy Research (EIFER), 2012a, 2012b). Further, UNCHS (2001a) stated that, in 2001, the level of urbanization in Europe was 74.6%, and it is predicted that this value will reach 82% (UNCHS, 2001b).

As defined by European Directive 31 (European Parliament Council, 2010), member States shall ensure that, by 31 December 2020, all new buildings will be close to zero-energy buildings. However, in Italy, the number of existing buildings is very high compared to the number of new ones; approximately 60% of existing buildings were built before the 1970s (CRESME, 2010; ISTAT, 2001, 2006, 2012) and before Law 373/1976, "Standards for the containment of energy consumption for thermal use in buildings" (Parlamento Italiano, 1976), the first regulation concerning energy conservation in buildings. The reduction of energy demand in existing buildings represents the main challenge in improving the global energy system.

Furthermore, it should be noted that, beginning with the EPBD—Energy Performance Buildings Directive (2002), major efforts were directed to improve the energy performance of buildings, though the energy system of a city as a whole was not considered. Models for planning scenarios (Manfren et al., 2011) that consider

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global environmental targets and policy constraints (e.g., renewable energy quota (Directive 2002/91/EC, 2002)) are also required.

Indeed, large building stock evaluations can be extremely complex and time consuming, both because of the extent of required information and because of the recourse to audit campaigns, simulation and monitoring techniques. Fortunately, the rapid development of computational power and information technologies, such as Geographic Information Systems (GIS), could support evaluations and decision making on the urban and regional scales about the complexity of the related energy system.

Large building stock evaluations still represent a challenging topic and are currently covered by many studies aimed at investigating energy consumption mainly in the residential buildings sector, as shown in the works of Tommerup and Svendsen (2006), Dascalòaki et al. (2010), Theodoridou et al. (2011a, 2011b, 2012) and Panayiotoua et al. (2010). The work of Fracastoro and Serraino (2011) focuses on Italian realty and proposes an analytical procedure for the "Statistical Distribution of Residential Buildings" (E-SDOB), although it is only applicable at the national or regional scale. Moreover, the work of Ballarini and Corrado (2009) investigates the potential of energy saving actions in existing buildings in Turin (in Italy) by chronological and typological categorizations using the application of the calculation methods specified in the EPBD—Energy Performance Buildings Directive (2002). Because finding a tool for analysing a city's energy consumption, which is related to the age and the characteristics of existing buildings, can be very difficult, Fabbri et al. (2012) try to investigate, particularly among existing buildings, the energy performances of historical buildings, which represent a special case of buildings. Indeed, they suggest the creation of a tool able to evaluate the energy behaviour and plant system installation in the restoration process of historical buildings.

In addition to these works, the recent study by Dall'O' et al. (2012) presents a methodology for the energy performance classification of residential building stocks at the urban scale.

As will be better explained in Section 2, our study takes into account the Italian context and aims to overcome the lack of accurate and detailed data about the built environment of a city (e.g., the data derived from audit campaigns), to give the necessary importance to the characteristics of the Italian heritage in the retrofit process and to support the energy policies at the city level on the basis of the data available for all the Italian cities. Moreover, it has to be stressed that our methodology takes into account both the residential and commercial buildings of a city, and the sources of energy consumption include heating, cooling, cooking, domestic hot water, lights and appliances.

2. Methodology

As mentioned in the previous section, the methodology aims at estimating the energy consumption of all buildings (residential and commercial) of an Italian city to find the energy uses (heating, cooling, cooking, domestic hot water, lights and equipment) and to simulate the effects of energy policies related to the improvement of energy efficiency (both for building envelopes and for building systems and plants) and related to the implementation of cogeneration systems and renewable sources. To be practical, this approach requires perforce audits and monitoring campaigns, which usually consume many time and economic resources. This approach is based mainly on statistical data and other simple information (i.e., buildings' construction periods, morphological and technological building characteristics and use of the buildings) generally available for Italian cities.

As will be explained in Sections 2.1 and 2.4, the main phases implemented in the development of the methodology regard the collection of data about the buildings, characterisation of the building stocks, implementation of a GIS building database, evaluation of the city buildings' energy performance and definition and assessment of scenarios for decreasing energy consumption.

2.1. Main references for data collection

We analysed the available information on the technical and performance characteristics of a large building stock. This information is available for each Italian city from the National Census database (ISTAT, 2001, 2006, 2012) and from the buildings' map. However, all this information was not originally provided for energy performance evaluations. In fact, the National Census database (ISTAT, 2001, 2006, 2012) provides information about the population, buildings, houses and dwellings aggregated for a census tract, a geographic area that usually coincides with the limits of a block and represents the smallest territorial unit for which the Census data are available.

The buildings' map, taken from an aerial photogrammetric survey and available at the technical departments of the municipalities, provides information about the lay-out, dimensions (area, perimeter and eaves height of buildings) and distribution of the buildings.

It is necessary to implement such information by also taking into account the literature data and the national standards addressing energy characterizations; for example, as will be better explained in Section 2.3, the building envelope materials, which depend on the construction period, were assigned with reference to the literature data (CNR, 1982).

As previously mentioned, the buildings' systems and plants were also considered, taking into account the typical efficiencies of heating systems reported in UNI TS 11300-2, (2008) and the typical efficiencies of cooling systems reported in UNI TS 11300-3, (2010) to evaluate the energy performances of existing buildings. Further, the standard UNI TS 11300-2 (2008) was considered in order to assign reference data for cooking and domestic hot water consumptions.

2.2. Characterisation of the building stock

After data collection, the first operational phase was dedicated to the characterisation of the building stocks. Because data for the development of the methodology (Section 2.1) cannot be directly used for defining energy performance, they need to be elaborated and processed in order to create a supporting tool, which should include both the dimensional data (area, perimeter and eaves height of the buildings) at the building level and the information available only at the census tract level (number of buildings realized in the construction period as reported by the National Census and the relative technology, type of systems and plants, etc.).

For these reasons, it was necessary to overlap the ISTAT census cartography (Fig. 1) with the buildings' map (Fig. 2).

Linking the census information with the buildings' geometric data (Fig. 3), it was possible to create a fundamental tool to develop the following: a geographic database containing two layers (one representing the buildings and one representing the ISTAT census cartography in which buildings fall) (for a sample area representation, see Fig. 4).

The subsequent data elaboration was aimed at determining the prevailing age for each census tract (Fig. 5) according to the National Census classification, illustrated in Table 1.

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