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Energy analysis and refurbishment proposals for public housing in the city of Bari, Italy

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HIGHLIGHTS

- An evaluation of the energy needs of existing buildings in a city in Southern Italy is provided.
- Possible refurbishment strategies are evaluated.
- An economic analysis is carried out to understand the feasibility of interventions.
- An estimate on an urban scale of the energy-saving potential of public housing in Bari is provided.

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ABSTRACT

From the perspectives of the energy and the environment, building stock should be considered a useful resource in the struggle against greenhouse gas emissions and scarcity of energy resources.

The aim of this work is to provide an example of the application of a methodology to evaluate the energy needs of the building stock of a city and to determine the possible strategies for energy planning.

This paper aims to obtain an estimate, on an urban scale, of the energy needs and CO_2 emissions of the public residential buildings of Bari. This estimate is achieved by evaluating the critical issues of the built heritage, the most common architectural typologies and the heating systems in the territory of the city of Bari in southern Italy, as well as the possible strategies for upgrading energy efficiency, through the combined use of energy software and geo-referenced systems. Furthermore, several possible interventions are assumed to improve the energy performance of buildings in not only environmental terms but also economic terms through the instrument of cost–benefit analysis. The ultimate goal is to compare the different intervention strategies to determine which demonstrate greater cost effectiveness and feasibility for future energy planning.

1. Introduction

It is widely recognised that one of the strategies to resolve the problems of greenhouse gas emissions and scarcity of resources is energy conservation. Currently, partly because of the economic crisis, climate change and the continuous increase of the welfare needs of the population, the consumption of non-renewable energy sources has increased substantially, especially in the construction sector.

In Europe, energy-saving policies in the civil sector have been adopted in all of the energy action plans born from the transposition of Directive 2002/91/EC concerning the energy performance of buildings, and especially from Directive 2006/32/EC on energy services. The same European Directive on Energy Efficiency 2012/27/UE aims to increase the rate of building renovation (European Union, 2012). Moreover, since 2007, the European Union has adopted the document “Energy for a changing world”, unilaterally committing to reduce its CO_2 emissions by 20% by 2020 to increase the level of energy efficiency by 20% and for the use of renewable energy sources in the total energy mix to be 20%. The European Union Action Plan for Energy Efficiency included, as a priority, the creation of a Covenant of Mayors to actively engage European cities in the path toward energy and environmental sustainability to combine measures at the local and regional levels and to promote effective actions against climate change (European Union, 2010).

According to the European Union, local authorities must take responsibility for the fight against climate change in an effort to anticipate the sustainability objectives that European Union has set.

In this context, the Sustainable Energy Action Plan (SEAP) is the key document that defines the energy policies that municipalities

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Nomenclature

Symbol Quantity Unit

A_f Heated floor area m^2
CO_2 CO_2 emissions kg/m^2a
c_t Specific cost of gas at the *t*-th year €/kWh
DPP Discounted payback period year
EP_H Energy performance index in the heating season kWh/m^2a
$\Delta EP_{H,j}$ Energy performance index differential of the *j*-th action between before and after refurbishment kWh/m^2a
I_j Initial investment of the *j*-th action of refurbishment €
i Discount rate %
$Q_{H,nd}$ Building energy need for heating kWh
$Q_{H,p}$ Primary energy demand for heating kWh
R_{jt} Economic benefit at the *t*-th year for the *j*-th action of refurbishment €
t Time year
U Thermal transmittance W/m^2K
U_g Thermal transmittance of window glass W/m^2K
U_w Thermal transmittance of window W/m^2K
N Life cycle of the investment year
NPV Net present value €
$\eta_{H,g}$ Heating system seasonal efficiency %

intend to take to achieve the objectives of 20-20-20.

The SEAP is an important instrument in dealing with the local community because it contains the actions that both the authorities and citizens must undertake. Moreover, the Action Plan would allow the authorities to systematise and harmonise the various activities that are implemented or planned for the future. The regular monitoring of the actions could check the performance of the plan over time, at least from the point of view of energy and of environmental performances.

Starting from the analysis of the information contained in the SEAP, the Municipality is able to identify the priority areas and actions to be implemented to achieve the objectives of reducing CO_2 emissions and, consequently, to plan a set of actual measures in terms of the expected energy savings, scheduling, and assignment of responsibilities, both with respect to the financial aspects for the pursuit of long-term energy policies. The issues considered in the SEAP concern the various sectors of the Municipality, so any future development at the urban level should take into account the provisions of the Plan of Action.

Many studies and international research projects (FP7 SEMANCO project, 2011) have been performed to analyse the refurbishment of the existing residential building stock of several countries in the EU from the energetic, environmental and economic points of view. Singh et al. (2013) consider the city of Liege and take into account different parameters (buildings age, structures, type of heating system, type of fuel used, built-up area, adjacency, insulation of roofs and walls and energy consumption); their study concludes that approximately 69% of the buildings that were constructed before 1945 require serious renovation to improve the roof and external wall insulation level. Theodoridou et al. (2011) provided detailed information on the residential urban building stock, as determined in a field study in typical large and smaller Greek cities. Given the complexity of the Greek building sector, the rather limited interest demonstrated by the owners of the buildings, and a series of legal and administrative hurdles considering energy renovation measures, these researchers concluded that it will not be an easy task to implement the urgently needed energy renovation policies. Sartori et al. (2009) developed a model for studying the effect of three hypothetical approaches in reducing the electricity and energy demand in the Norwegian building stock: wide diffusion of thermal carriers, heat pumps and conservation measures. Adopting conservation measures on a large scale does allow for reduction of both electricity and total energy demand from the present day levels while the building stock continues to grow. Ástmarsson et al. (2013) investigated how regulatory changes and contractual solutions can help solve the landlord/tenant dilemma in relation to sustainable renovation of residential buildings. These researchers indicated that when the interests of landlords and tenants are misaligned, one of the greatest barriers hindering the development of sustainable renovation of residential buildings in Europe is realised.

Currently, it is known that 40% of the energy used in Italy is essentially used to heat, cool, illuminate and ventilate buildings. Furthermore, existing buildings are far from efficient, but are becoming increasingly important in the fight against environmental and climate problems because they represent the vast majority of the Italian building stock in a country with a very small proportion of building area.

For this reason, it is essential to assess the energy needs of the existing buildings. Several models (Sathaye and Sanstad, 2004; Theodoridou et al., 2012) used to assess the energy needs can be divided into three categories:

– Bottom-up models: these models start from the study of the energy consumption of individual buildings, assessed in detail in every aspect, and then the results are extended to the entire neighbourhood or city to assess the energy consumption or energy savings in the renovation of the buildings.
– Top-down models: these models start from data concerning energy consumption on an urban scale, compare it with the climate data and data from censuses or statistical surveys, and then obtain the average consumption of the buildings. From a larger scale, top-down models achieve a scale of detail suitable to compare different economic variables, but they are unable to distinguish the variations in consumption and the distributions of emissions in the urban space.
– Hybrid models: these models study the energy needs of standard buildings and adapt them to assess the energy consumption on the urban scale, using detailed spatial representations of the building stock, so that it is possible to associate with each building its own consumption and to obtain an estimate that is sufficiently accurate on a global level.

This paper uses the last methodology, providing a real application example and possible energy-saving strategies.

2. Methods

The aim of this work was to provide an example application of a methodology adopted today for optimal energy planning. In fact, increasing numbers of studies are being devoted to understanding the trends of energy efficiency in cities and European countries (Bosseboeuf, 2009) and to improve the study of methods to obtain estimates of the true energy needs through the classification of buildings according to the periods of construction, air-conditioning systems and construction characteristics (Corgnati et al., 2008;