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Influence of envelope design in the optimization of the operational energy costs of a multi-family building

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Abstract

The international efforts for improving energy efficiency in buildings and reducing their environmental impact also constitute a challenge for working against the risk of energy poverty. The work aims to test a methodology for optimizing the operational costs of the different flats of a multi-family building for social housing. The method combines the use of TRNSYS building energy simulation program with GenOpt Generic Optimization program in a so-called simulation-based optimization method.
A typical floor of a real case study building was modeled and the energy costs for heating and cooling due to the variation of design variables related to the building envelope was studied. The optimization led to reduce the total operational costs of the flats by the range 17%-23%. The different share of heating, cooling, ventilation and DHW in the total operational costs was studied and resulted differences in energy rating and costs between flats were analyzed.

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Keywords: simulation-based optimization; multi-family building; social housing; TRNSYS; GenOpt; particle swarm; flats; operational costs

1. Introduction

In the residential sector. improving the energy efficiency of new and existing buildings can be useful not only for contrasting CO_2 emissions and climate change, but also for working against the risk of energy poverty for low-income households. It has been proved that financial problems may oblige people to consume less energy, leading to the incomplete satisfaction of their needs [1]. As reported in [2], it can be observed that during the financial crisis of 2007– 2012 in Europe, the energy consumption of residential buildings has decreased by 4%, while in countries with

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a deeper economic problem like Portugal, Slovakia and Ireland the corresponding decrease was 16%, 22% and 22% respectively. In Italy, it is estimated that between 5% and 20% of households was in energy poverty in 2012 [3].

This problem is frequent for multi-family buildings. In 2014, 5 out of every 10 persons in Italy lived in flats [4]. Within a more comprehensive approach towards the implementation of economic sustainability principles [5], it emerges the importance of considering the effect of the design strategies in the total energy demand of multi-family buildings and their related operational costs, even more so if addressed to low-income households. In fact, reduced exposure to energy price fluctuations gives the user a feeling of control and increased certainty to be able to keep the needed level of comfort while maintaining economic affordability. Furthermore, especially in case of social housing, reducing the differences between flats within the same building leads to highest equality between families.

The use of tools able to evaluate and optimize the building energy performance by analyzing a great number of different design configurations is emerging as a powerful method for supporting this design process [6].

1.1. Scope of the work

The aim of the work is to apply a simulation-based optimization methodology [7] to assess the potential reduction of the annual operational energy costs for heating and cooling of a multi-family building for social housing in Italy.

The optimization process focuses on energy efficiency measures able to reduce the operational costs for heating and cooling of each flat of the case study floor. With the addition of the costs related to DHW and ventilation fans, the work also evaluates the potential reduction of the total energy costs (for heating, cooling, DHW, ventilation) due to the adopted optimization process.

2. Case study

In order to study a multi-family building that is representative of recent social housing intervention in Italy, a real building located in Cremona was selected. Because of its features that are recurrent in similar buildings throughout Italy, the analysis can be potentially replicated in other Italian contexts.

It has a C shaped plan around a common inner courtyard. Each block has different number of storeys. The building has a concrete structure and a well-insulated envelope. External wall is made of bricks (30cm) and external thermal insulation (10 cm) with a thermal transmittance U equal to 0.26 W/m^2K. Transparent surfaces are double low-e glass windows with metal frame, having mean thermal transmittance equal to 1.45 W/m^2K and a solar factor equal to 0.59. Some windows are shaded by external loggias, a typical feature of the Italian architecture.

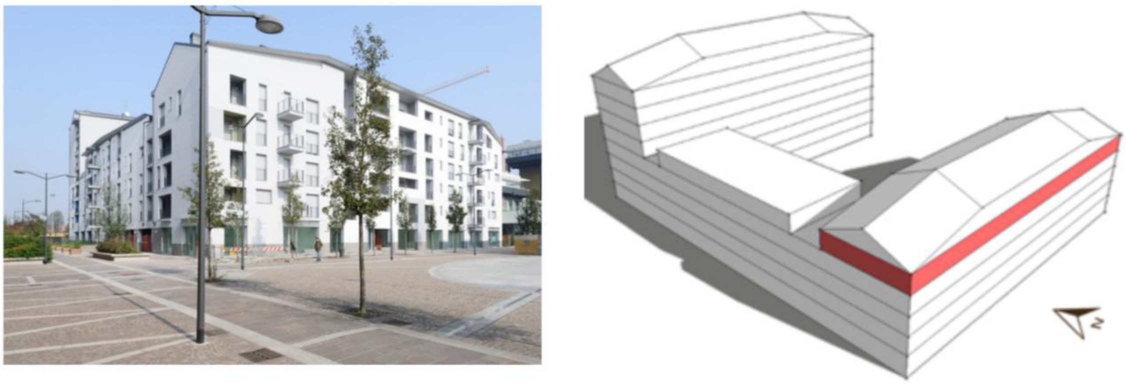

Fig. 1. (a) The multi-family building (b) The case study floor

The building is connected to a district-heating network supplied by a municipal solid waste incinerator that delivers hot water for heating (total primary energy conversion factor declared by the supplier equal to 0.62). There are radiant panels as heating terminals. The total seasonal efficiency ratio of the heating system is equal to 0.88.

A gas boiler produces DHW (energy efficiency ratio 0.85, primary energy conversion factor 1.05).

A mechanical ventilation system with a heat exchanger with an efficiency equal to 0.50 is also present.