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Existing buildings and HVAC systems: incidence of innovative surface finishes on the energy requirements

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Abstract

A great portion of the global energy consumption depends on existing buildings. So, energy saving and related CO_2 emission reduction are important measures. This paper analyses the incidence of innovative surface finishes on the cooling and heating energy demand of existing buildings. These easy and cheap measures preserve the little living spaces, limited height and the architectural/chromatic characteristics. The analysis is conducted for various European cities, by using a dynamic energy simulation software. The primary energy required by the HVAC systems on seasonal and annual basis is evaluated and relevant energy saving (up to 21% on annual basis) is obtained. Finally, a technical-economic analysis is performed and interesting payback values are obtained (2.5-11 years in the best cases; 2–10 years, when a tax deduction of 35% is considered).

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Keywords: building envelope; existing buildings; surface finishes; energy saving; HVAC systems

1. Introduction

In Europe, the building energy requirement is about 40% of the global energy demand. So, the EPBD recast [1] promotes energy saving in buildings and use of passive solutions. In Bellia et al. [2-3], a passive strategy based on suitable solar shading devices allows relevant reductions of the energy demand for air conditioning. A great problem is represented by the large number of historic buildings, characterised by low energy performances (Filippi [4]). The global warming (Cotana et al. [5]), the urban heat islands (Santamouris [6], Xu et al. [7]) and the cooling energy requirements of buildings (Synnefa et al. [8]) can be mitigated by means of the Albedo control, which consists in reflecting to the space the shortwave incident radiation. Ascione et al. [9] study the influence of the surface finishes on the energy requirements of the buildings. Relevant summer energy saving in school buildings (Synnefa et al. [10]) and in commercial buildings (Levinson et al. [11]) is also shown. In Pisello et al. [12], the proposed high reflective tiles for

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pitched roofs allow reducing the cooling demand of about 50% for historic residential buildings. The effects of innovative cool and low-emissivity paints are studied in Marino et al. [13]. The use of external innovative finishes on pitched roofs and walls of existing attics reduces the cooling energy requirements (up to 60%) and increases the heating energy demand (up to 10%).

The analysis reported in [13] is extended in the present paper: also the case of insulated building envelope is considered, as well as different configurations of HVAC systems and various efficiency values of the different national electric systems. The case study is an existing attic modelled with properties typical of the historical buildings, depending on the various countries (TABULA Project [14]). Traditional HVAC systems for existing residential buildings are considered. The analysis is conducted for various European cities, through a dynamic energy simulation software (Design Builder [15]) based on EnergyPlus code. The paper analyses the energy saving for heating and cooling, and the payback values obtainable by applying simple innovative surface finishes on the opaque surfaces of an existing attic. It is important to highlight that the proposed retrofitting measures are easy and cheap; moreover, they allow the preservation of the little living spaces, limited height and architectural/chromatic characteristics.

Nomenclature

α absorptance (ND)

ε emissivity (ND)

ρ reflectance (ND)

η_{gl} seasonal global efficiency of the heating system (ND)

$\eta_{thermoelectric}$ efficiency of the national electric system (ND)

Subscripts: **c**=cooling, **h**=heating, **y**=yearly

COP coefficient of performance (ND)

EPBD European Energy Performances Building Directive

HVAC heating, ventilation and air conditioning

PE primary energy (kWh/m^{2}y)

SEER seasonal energy efficiency ratio (ND)

SPB simple payback time (number of years)

TE thermal energy needs of building envelope (kWh/m^{2}y)

U thermal transmittance (W/m^{2}K)

PA Palermo **RM** Rome **MI** Milan **SV** Seville **PS** Paris **BE** Berlin

2. The proposed innovative surface finishes, the methodology and the case study

The traditional coatings herein considered as reference case are the following: internal white plaster with high $\varepsilon_{infrared}$ (0.9); red tiles on the pitched roof with high $\varepsilon_{infrared}$ (0.9) and low solar reflectance ρ_{solar} (0.3–0.4); external plaster with medium α_{solar} (0.3–0.4) and high $\varepsilon_{infrared}$ (0.9).

The innovative coatings are characterized as follows: red tile cool paint on pitched roof (ρ_{solar} =0.79; $\varepsilon_{infrared}$ = 0.89); white cool plaster on external surfaces of the vertical walls (ρ_{solar}=0.88; $\varepsilon_{infrared}$=0.9); low far-infrared emissivity plaster on internal surfaces of the building ($\varepsilon_{infrared}$=0.62), realized with traditional plaster and ceramic nanospheres. This innovative internal plaster increases the internal surface thermal