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Economic efficiency of social housing thermal upgrade in Mediterranean climate

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ABSTRACT

The age of European existing building stock and the very low growth rate make energy retrofit a critical issue at the moment. The spreading of good practices is strongly hampered by their cost effectiveness.

National legislation thermal requirements for retrofitting works play a fundamental role. If they are too strict, the initial economic investment could be too high if compared with energy savings achievable.

The paper refers to a case study of improving fabric thermal performance of stone masonry buildings located in Cagliari – Italy. They were built in 1950s.

The economic feasibility of different energy efficiency retrofits is evaluated. Two different scenarios are analyzed: the former according to the earlier Italian legislation (valid from 2006 to 2008), the latter according to the latest and strictest measures (valid from 2010).

The results show that heavy thermal performance upgrades, even though compulsory, are not completely cost-effective in a mild Mediterranean climate area as far as payback time is concerned. National subsidy policies can improve the economic return on the investment. The impact of present Italian incentives has also been evaluated.

1. Introduction

Statistical studies show that nearly 76% of Italian dwellings were built before 1981, and 49% are more than 50 years old. The average annual increase in new dwellings in the 1981–2011 period was only 1% [1].

These values are above the European average. The existing residential building stock in Europe has more or less the same annual growth trend which is estimated at 1.3%, 70% are more than 30 years old and 35% are more than 50 years old [2,3]. The data highlight how much the Italian building stock has aged.

Although the first building legislation on energy performance was adopted in 1976 [4] and an update was proposed in 1991 [5], energy consumption in the residential sector did not decrease. In 2005 the Directive EPBD 2002/91 was adopted [6,7]. In the same period a decrease in the growth trend of Energy consumption from 0.8% to 0.4% [8].

It is evident that the low growth of new high performance dwellings is not enough to invert the growing consumption trend; it is instead necessary to adopt effective retrofit solutions for existing buildings.

As other authors have already point out, there are many obstacles to the diffusion of good practices. One of the main issues is the cost-effectiveness of home energy retrofits [9].

In particular, the literature review highlights some critical issues:

- national legislation can be too strict and prescribe energy efficiency requirements that make retrofits cost-ineffective for homeowners [10,11];
- the price of energy is artificially low because the social costs of production are often hidden and not charged directly on users' bills [9,12–14];
- uncertainties concerning the future price of energy make the economic feasibility analysis of works quite difficult [15,16]; and
- public subsidies are necessary to reduce payback time and increase economic benefits for investors [9,14].

These issues are extremely important and also the recent EPBD 2010/31 [17] highlights that "Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels. (omissis) Member States shall take the necessary measures to ensure that when buildings undergo major renovation, the energy performance of the building or the renovated part thereof is upgraded in order to meet minimum energy performance requirements in so far as this is technically, functionally and economically feasible. (omissis)".

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Nomenclature

I_j	initial investment of the *j*-esim work combination (€)
R_{jt}	economic benefit at the *t* year (€)
i	constant discount rate (%)
N	life cycle of investment (years)
$Q_{H,c,p}$	primary energy use for heating before retrofit intervention (kWh per year)
$Q_{H,c,j}$	primary energy use for heating after the *j*-esim retrofit work combination (kWh per year)
c_t	specific cost of gas at the *t* year (€/kWh)
ΔI_j	initial investment differential of the j-esim work combination between Scenario 2 and 1 (€)
ΔR_j	economic benefit differential of the j-esim work combination between Scenario 2 and 1 (€)
IROR	internal rate of return (%)
PBT	payback time (years)
NPV	net present value (€)
t	time (years)
λ	thermal conductivity (W/mK)

Codes

EW1	4 cm thermal insulating perlite and silica plaster, $\lambda = 0.066$
EW2	8 cm rockwool board external insulation, $\lambda = 0.04$
R1	4 cm PUR board external insulation, $\lambda = 0.035$
R2	7 cm PUR board external insulation, $\lambda = 0.035$
W1	thermal-break aluminum frame + 4/12/4 glazing (air-filled)
W2:	thermal-break aluminum frame + 4/12/4 low-e glazing (air-filled)
BLDG	building

Different requirements are established by Italian Decree Law 192/05 to reduce energy consumption of existing retrofitted buildings. Among these the upgrade of building fabric thermal transmittance has undoubtedly the highest economic impact.

Even stricter standards have been adopted since 2006, as is shown in Table 1.

The paper refers to a case study of improving fabric thermal performance of stone masonry buildings located in Cagliari – Italy. The economic feasibility of different energy efficiency retrofits is evaluated.

Two different scenarios are analyzed: the former according to the earlier Italian legislation [18] (valid from 2006 to 2008), the latter according to the latest measures (valid from 2010).

The results show that heavy thermal performance upgrades, even though compulsory, are not completely cost-effective in a mild Mediterranean climate area as far as payback time is concerned. National subsidy policies can improve the economic return on the investment. Their impact has also been evaluated in the following.

The results can also have interesting applications in other European areas. As shown in [19] Cagliari's climate is similar to the whole Mediterranean coastal area from Gibraltar to Cyprus. This region is characterized by heating degree days <1500 and cooling degree days ≥500. Main Mediterranean European Countries, such as Spain and Greece, have been pursuing similar incentives policies in the last years [20,21]. Even if the subsides are different from Italian ones (that consist mainly in tax incentives), the methodology proposed in the paper can be transposed also in different contexts, once construction costs and discount rates are known.

Table 2
The main geometrical data of the three case studies.

	Bldg I	Bldg II	Bldg III
Net floor area [m^2]	768	194	518
Gross heated volume (V) [m^3]	3052	787	2165
Gross fabric area (S) [m^2]	1819	614	1297
S/V	0.60	0.78	0.60

2. Description of case studies

2.1. The buildings

Cagliari's Sant'Elia district is an old suburb of social housing. It was built in the 1950s to provide affordable dwellings for local fishermen after the destruction inflicted by World War II bombing raids.

It comprises 50 buildings of which 9 are semi-detached houses, 12 are multi-storey buildings and 29 are terraced houses. These building types are a very representative sample of Italian social housing in the 1950s.

A case study is proposed for each of them (Fig. 1).

The main geometrical data of the three case studies are shown in Table 2.

The site (39°13′N lat.; 9°7′E long.) faces the shore of the Gulf of Cagliari. The climate is strongly influenced by the Mediterranean Sea. The number of heating degree days is 990 (calculated according to [22]), the average annual temperature is 17.3 °C, the average temperatures of the coldest and hottest months are 10.2 and 25.3 °C [23].

The original building fabric had very poor thermal performance if compared with present legal standards (see "before works" column in Table 4). The external stone masonry walls were not insulated, roofs were simple concrete slabs and hollow-core clay blocks and timber frame single-glazed windows; no HVAC systems were installed. In 2005, the Municipality of Cagliari undertook a renovation program that is still ongoing. Works to upgrade the fabric thermal performance of dwellings were performed according to Italian legislation [18]. Since planning permission was earlier than 2008 the least strict energy requirements were prescribed (Table 1). A detailed description of energy saving upgrades actually made on the buildings is indicated with W1, R1 and EW1 codes in the following.

2.2. The retrofit scenarios

The paper analyzes two different retrofit scenarios for each of the three buildings case study. The former (Scenario 1) refers to

Table 1
U-value limits according to decree law no. 192/05, Annex C, for the city of Cagliari.

U-value limits (W/m^2 K)			
	From 1st January 2006	From 1st January 2008	From 1st January 2010
External walls	0.57	0.46	0.40
Roofs	0.55	0.42	0.38
Windows	3.30	3.00	2.60