ENERGY SAVINGS IN BUILDING RESTORATION - AN APPLICATIVE CASE

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Abstract
Italy has a historical and architectural heritage which consists mainly of buildings built in different historical period.
These buildings are today characterized by some aspects of functional distribution and comfort, which need rehabilitation. This is related to the change thinking on a more comfortable distribution of spaces, and improving the sustainability of buildings. These issues have spurred the study of methods to improve the distribution of spaces, the performance of indoor comfort and the energy efficiency in the full respect of materiality and aesthetics of the building. Therefore, the aim of this rehabilitation is improving the indoor comfort, the energy efficiency and the environmental performance of existing buildings, but it is also to choose more carefully the most environmentally sustainable materials for the restructuring. In this work, a case study of rehabilitation of a historical school building sited in the city of Palermo in Italy is reported.

Keywords: *School building, energy performance of building, building restoration.*

Introduction
Sustainable restoration requires a new attitude throughout the process of refurbishment projects and concerns intentions, attitudes and roles of different actors: inhabitants, designers, construction companies and public administrations.
This is a process that begins with the need for carrying out renovation of the existing, which aims to preserve the architectural qualities, existing cultural and social hardship, it also takes care to reduce the impact on the environment, health and improving occupant comfort, always compatible with economic and management aspects.
Therefore, a sustainable restoration should also aim to improve energy performance of building. Since a decade, The European Community has implemented policies on the energy saving in buildings.
On the 16 December 2002, in fact, the European Parliament enacted the Directive 2002/91/EC (EPBD), the main legislation on the energy performance of building in European Union (EU). Recently, the European Parliament passed the EPBD recast, which requires higher energy performances. Therefore the EPBD recast states that "Buildings occupied by public authorities and buildings frequently visited by the public should set an example by showing that environmental and energy considerations are being taken into account and furthermore those buildings should be subject to energy certification on a regular basis" (DIRECTIVE 2002/91/EC). Consistent with this, the educational buildings play a meaningful role.
In literature there are numerous international studies on the energy efficiency and indoor environmental quality of educational building (Dascalaki and Sermpetzoglou, 2011; Desideri and proietti, 2002; Corgnati, 2008; Theodosiou and Ordoumpozanis, 2008, Butala and Novak, 1999). Other studies, however, propose tools to improve energy efficiency in educational buildings (ASHRAE, 2008; EPA-NR Project, 2007).
A primary school, belonging to the school park of the municipality of Palermo, will be here considered for interventions regarding the renewal of the energy performances and rehabilitation of the indoor conditions.

These interventions refer to the policy adopted by the Italian Government in reference to EPB Directive. Different interventions involving the envelope (the glazed part and outer wall, in particularly) are taken into account respecting the original constructive typology.
Guidelines for the rehabilitation of the school will move through the following main steps:

- analysis of the outdoor conditions, referring to the shadow map on the façades;
- analysis of the indoor conditions, referring to the thermal and hygrometry, eventually to the acoustic and to the lighting situations;
- evaluation of the feasibility of interventions on the envelope;
- evaluation of the indoor conditions and of the energy consumption performed by the building, following the previous interventions.

Different interventions are combined to constitute some action scenarios which were analysed and compared by means of suitable indicators concerning energy and economic issues.

Historical school buildings

During the whole nineteenth century the school building type had a quick evolution because of the development of regulations.
This evolution was also caused by the development of the pedagogical theories, which come from Dewey and Montessori to the most modern ones.
There were two real booms of the construction of school buildings in Italy: one was in years 1920-1940, after the first world war, when the diffusion of illiteracy became unbearable for a modern state; the second one was after the second world war when people moved from countryside to town.
For all these reasons and for the current need of school buildings, we use both contemporary and historical building.
In particular in old town centre is often necessary to use historical building, which adapt to surrounding context, but does not often comply the current requirements of indoor comfort and energy efficiency. Therefore, in all the old Italian town centre, historical school buildings are actually used. The functional distribution is in any case the “barrack layout”, with a central corridor and the classrooms on one side or on either side.
They are generally characterized by a masonry structure, which is the original one, while, in many cases, the wooden floor has been replaced with brick and concrete one.
The main issues of building restoration are usually:

- deteriorated facades and roofs;
- deteriorated windows and doors;
- thermal bridges (e.g. after replacement of the floor);
- obsolete equipment (air conditioning system, electrical system, etc.).

The “La Masa” school

The “La Masa” school is placed in an urban area that was expanding in the early years 1900s (see Fig. 1 and Fig. 2).

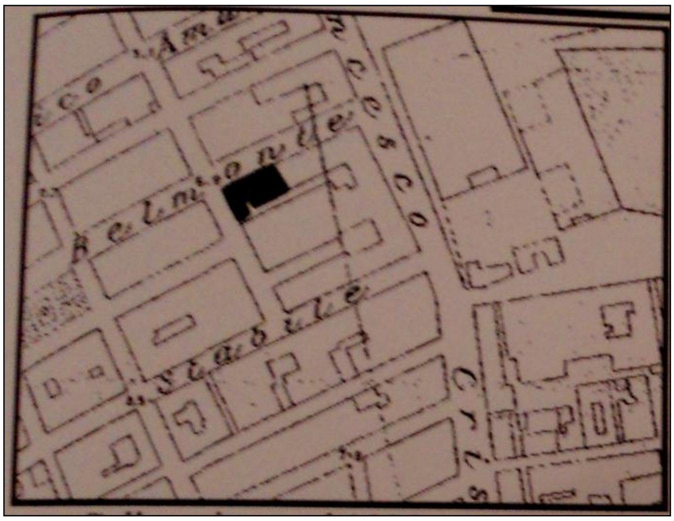

Figure 1: Urban plan (1939) (Archive of the office contract, Municipality of Palermo).

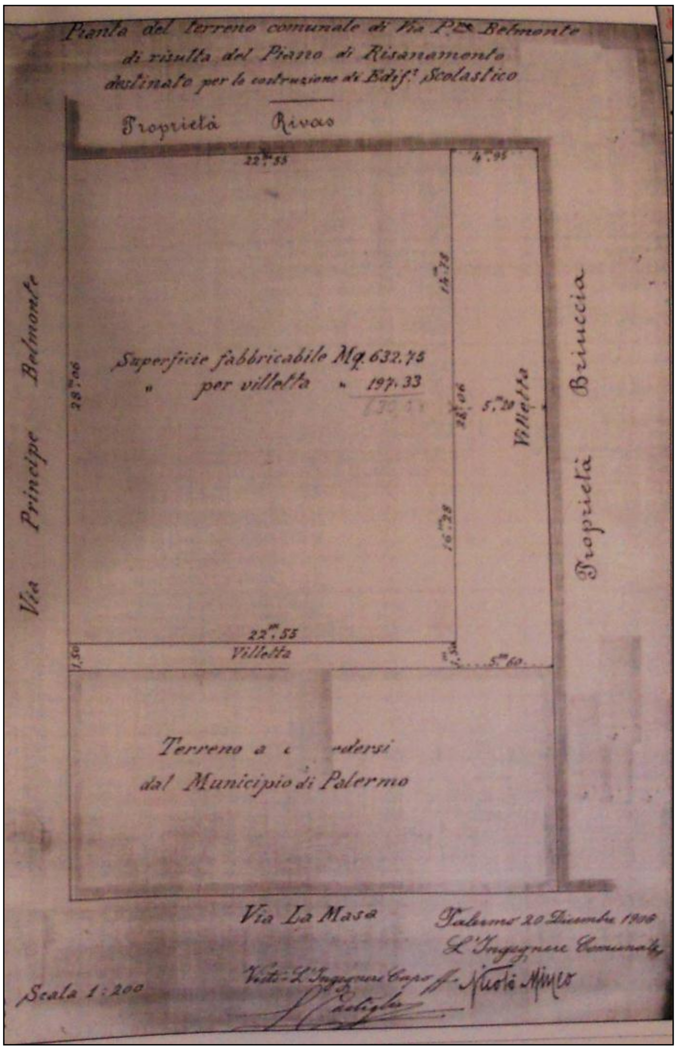

Figure 2: Location of area (1908) (Archive of the office contract, Municipality of Palermo).

This area is characterized by high traffic density and is very close to the port of Palermo (see Fig. 3).

Figure 3: Geographical location of the school in the town of Palermo.

The “La Masa” school has a complex history. It was originally built in 1908, with a plan drafted by Municipal administration in 1906. The designers were the Eng. N. Mineo and Eng. L. Castiglia (Archive of the office contract, Municipality of Palermo).

The early ‘900 was a difficult period for educational institutions because of shortage of school building. Until then, the education was indeed given by clergymen in monasteries or in private homes.

For this reason, for the first time in 1904 in Palermo, school buildings were designed with only purpose of using them as school.

The plan of the “La Masa” school building of the year 1908 indicated a two-storey building, with 5 classrooms in each floor. The constructive features, as it is possible to read on the appraisal cost estimates, were:

- Shapeless stones foundations;
- Small ashlars stone (from Aspra town, close to Palermo town);
- Concrete casting floors;
- H-beams of iron and clay tiles for the floors;
- Wood trussed for the roof.

With the coming of fascism, to impart education become a fundamental role of the State, and the construction of school buildings was significantly increased.

The style of the schools of this period is specific to the regime, it had to be the emblem of the state power.

In 1929 the “La Masa” school was enlarged with the addition of a storey in order to obtain 14 classroom (see Fig. 4). The materials and techniques adopted were the same as the original construction.

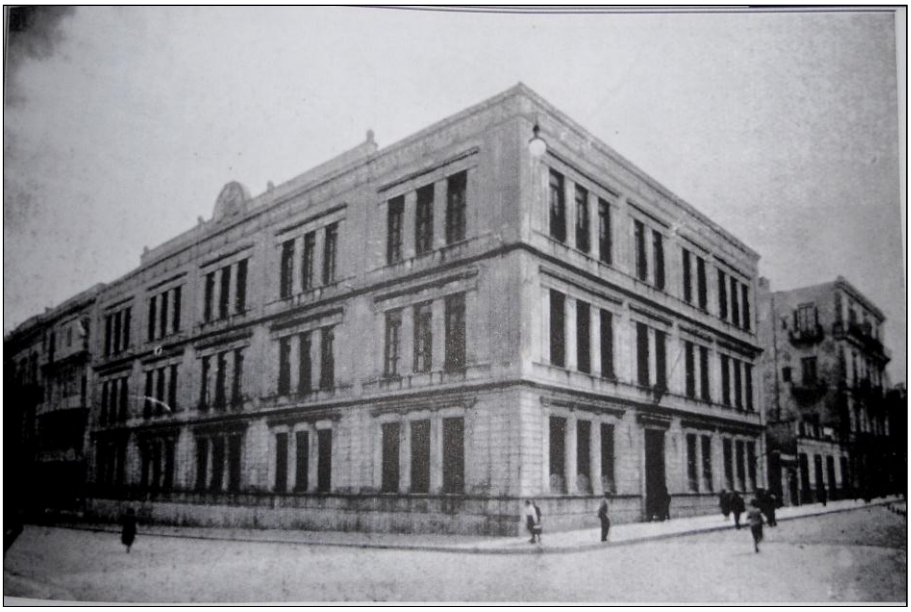

Figure 4: The school after the addition of a storey (1930) (Archive of the office contract, Municipality of Palermo).

The Second World War had disastrous consequences for Palermo, the bombings indeed leaved it with many areas totally destroyed.
The “La Masa” school building was partially destroyed and rebuilt in 1947, as we can read on a manuscript kept in the archive of the real estate of the Municipality of Palermo:
“…school built in 1928-29, almost entirely destroyed by the war and the jackals .”
The “La Masa” school building has today the design of 1947, with some modifies which were necessaries for legal compliances.
In 1947 the wooden floors have been replaced with brick and concrete floors, and a part of the structure with reinforced concrete. The outside ornaments are not longer and the current appearance of the building is much more austere and simple (see Fig. 5 and Fig.6).

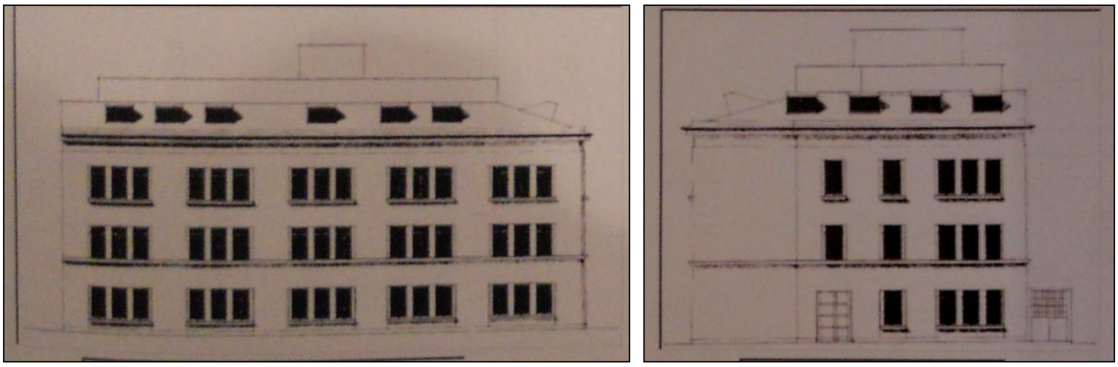

Figure 5: Façades of the “La Masa” school (after 1947).

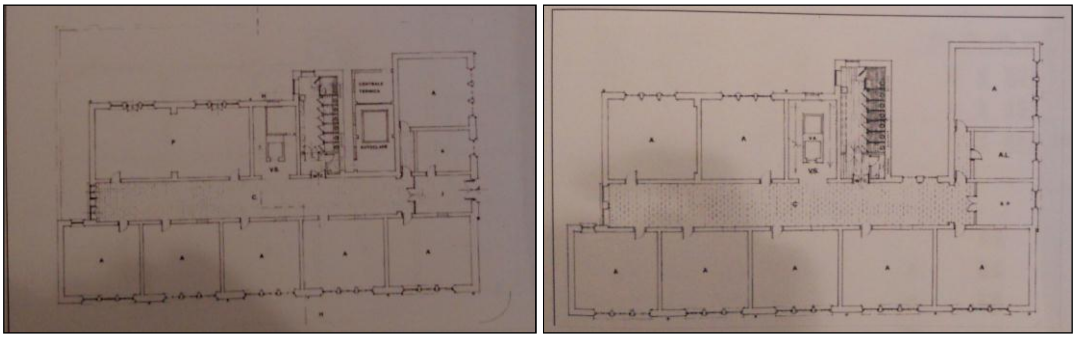

Figure 6: Plans of the “La Masa” school (after 1947): first and second floor.

In the 1990, the school was refurbished and was checked the structural integrity of building (see Fig.7).

Figure 7: Photography of the school façade in 1990.

The elements that currently make up the envelope of the school building are:

- foundations: stonework;
- vertical load-bearing structures: ashlar stone of the Aspra site (near Palermo);
- horizontal structures: reinforced concrete;
- roof: a usable flat part and a pitched part (wood trusses and Marseilles tiles);
- staircase: reinforced concrete;
- external frames: wood and double-glazed with two kind of opening (shutter or transom);
- interior finishing materials: linoleum on the floor surfaces and marble grit staircase.

Energy performance analysis

In order to assess the energy performance of school building (only heating season), we use the method described in UNI TS 11300 Italian standard (parts 1 and 2) (UNI TS 11300-1, 2008; UNI TS 11300-2, 2008). The method proposed by this Italian standard is the same of the monthly method described in ISO 13790 standard (EN ISO 13790,

2008). The Italian standard includes a lots of thermo physical data of several building materials used in Italy. The part 1 of the Italian standard shows the method in order to calculate the energy need for heating and cooling with mainly reference to the characteristics of building envelope, while the part 2 describes the method in order to assess the energy use for space heating and domestic hot water.
The main geometric characteristics of building are reported in Table 1.

Table 1: Main geometric characteristics of "La Masa" school building.

Floor	Gross conditioned area (m^2)	Gross conditioned Volume (m^3)	Useful conditioned area (m^2)	Useful conditioned Volume (m^3)	Area of external wall (m^2)
First	847.89	4281.84	720.89	3496.32	808.51
Second	847.89	4281.84	658.29	3192.71	798.91
Third	847.89	4281.84	658.29	3192.71	798.91
Fourth	241.98	1222.00	133.29	646.46	477.03
Fifth	17.40	56.55	6.83	20.82	79.56
Overall	**2803.05**	**14124.08**	**2177.59**	**10549.00**	**2962.91**

The thermal transmittance of opaque and glazed building elements were calculated by means of methods reported in EN ISO 6946 standard (EN ISO 6946, 2007) (e.g. see Table 2) and in EN ISO 10077-1 standard (EN ISO 10077-1, 2006) respectively.
The heat loss by thermal bridges was calculated taking into account the method described by EN ISO 14683 standard (EN ISO 14683, 2007).

Table 2: Calculation of thermal transmittance of one type of external wall (thickness 60 cm).

N. layer	Description	Thickness s (m)	Thermal conductivity λ ($W\ m^{-1}\ K^{-1}$)	Thermal resistance R ($m^2\ K\ W^{-1}$)
1	Internal thermal surface resistance			0.13
2	Internal plaster	0.02	0.7	0.03
3	Cement mortar	0.05	1.4	0.04
4	Tufa stone	0.45	0.63	0.71
5	Cement mortar	0.05	1.4	0.04
6	External plaster	0.03	0.9	0.03
7	External thermal surface resistance			0.04
	Overall thermal resistance ($m^2\ K\ W^{-1}$)			**1.02**
	Thermal transmittance ($W\ m^{-2}\ K^{-1}$)			**0.98**

The building was divided into calculation conditioned zones at temperature of 20°C (see Fig. 8):

- first floor – Zone n. 1 (ground floor);
- second floor – Zone n. 2;
- third floor – Zone n. 3;
- forth floor – Zone n. 4;
- fifth floor – Zone n. 5.

The attic and the boiler room are unconditioned areas.

Figure 8: Cross section of building and thermal zones.

Moreover, there are external obstructions (especially surrounding buildings) which shade the façades of the school building.
To perform the energy calculation by means of a simplified quasi-steady state calculation method (proposed by EN ISO 13790), it is necessary known the internal thermal capacity of conditioned areas; in this case study it is 165 (kJ/K) per square meter.
The results relate to the calculation period of heating season (December 1 – March 31) set by Italian legislation. The climatic data were taken by the UNI 10349 Italian standard (UNI 10349, 1994). Table 3 and Fig. 9 report the results of calculation of energy need for heating with reference to the building envelope

Table 3: Energy need for heating with reference to the building envelope.

	$Q_{h,env}$ (MJ)				
Zone	**Dec**	**Jan**	**Feb**	**Mar**	**Total**
Zone 1	70144	85536	70823	60437	286940
Zone 2	52966	64827	53124	44458	215375
Zone 3	66746	81458	67121	56852	272177
Zone 4	30851	37041	30305	25636	123834
Zone 5	4508	5355	4343	3686	17892
All zone	**225214**	**274218**	**225716**	**191068**	**916217**

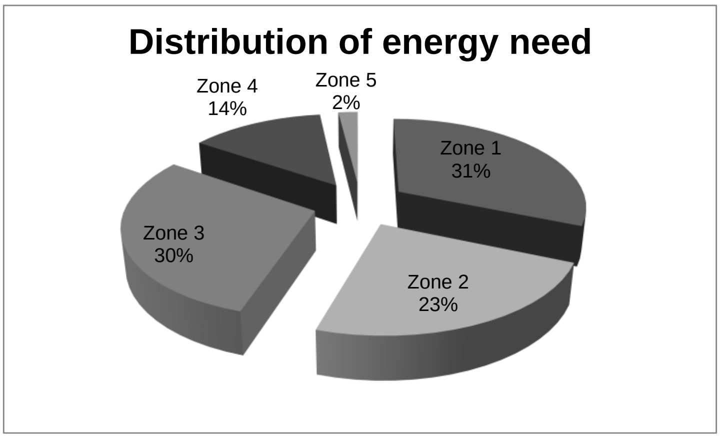

Figure 9: Percentage distribution of energy need for heating

It is certainly more useful to know the energy need per cubic meter that, in this case, is equal to 64,9 MJ/m^3. The Figure 10 shows the trend of the energy need per cubic meter during the heating season.

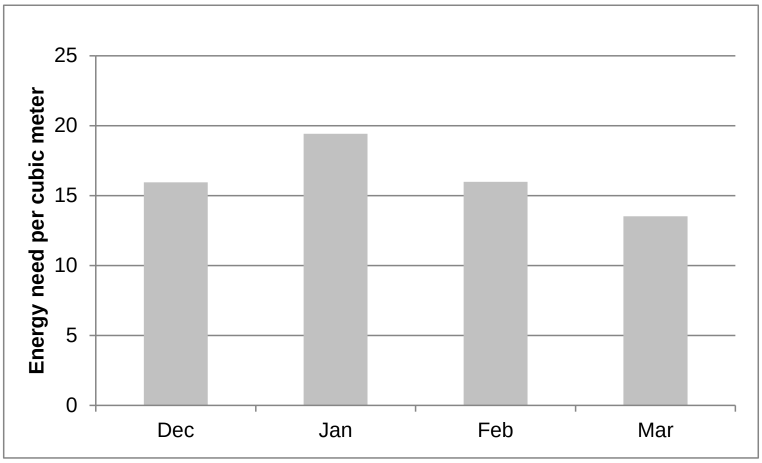

Figure 10: Percentage distribution of energy need for heating

The school is equipped with an air conditioning system consisting of a AHU, air ducts, air outlets and a boiler fueled by natural gas. The boiler room is located on ground floor. The efficiencies of the four subsystems that constitute the HVAC system are:

- 0.9 for the emission system (air inlet);
- 0.93 for control system (on/off type);
- 0.938 for distribution system;
- 0.86 for generation system (boiler).

The electrical energy need for auxiliary equipment of air conditioning system is equal to 828.34 kWh_{el}, that is equal to 1837.11 kWh (converted to primary energy), instead the primary energy use for winter heating is equal to 378774.45 kWh.
The average seasonal efficiency of the air conditioning system for winter heating is supplied by following relation:

$$\eta_h = \frac{Q_{h,env}}{Q_{p,h}} = 0.672$$

where:

- $Q_{h,env}$ is the energy need for heating with reference to the building envelope (equal to 916217MJ or 254504.76 kWh);
- $Q_{p,h}$ is the energy use for winter heating (equal to 378774.45 kWh);

The Energy Performance index for the winter heating is supplied by following equation:

$$EP_{heating} = \frac{Q_{h,env}}{\eta_h \cdot V_{gross}} = 26.82 \ \frac{\text{kWh}}{\text{m}^3}$$

where: V_{gross} is the gross volume of the school building (equal to 14124.08 m^3).
According to the “D.Lgs 192/05” Italian law [20], the Energy Performance index for the winter heating of this building should not exceed 4.78 kWh/m^3.

Proposed rehabilitation actions

After evaluating the energy performance of building, we hypothesized some possible action scenarios.

We have considered the following possible interventions:

1) thermal insulation of:
   a) the roof;
   b) vertical walls;
   c) the floor of ground floor;
   d) false ceiling (adjacent to unconditioned area).
2) Replacement of:
   a) glazed surfaces;
   b) boiler (with another more efficient).

These interventions were grouped in four possible action scenarios, as reported in Table 4.

Table 4. Proposed action scenarios.

Scenario	Thermal insulation				Replacement	
	Roof	Vertical walls	Ground floor	False ceilings	Glazed surfaces	Boiler
1	X	X	X			
2	X	X		X	X	
3	X	X				X
4	X	X		X	X	X

The proposed action scenarios influence considerably the energy consumption of building; in fact, these actions reduce the energy consumption between 38.5% to 55.1%. However, none of these actions is able to cut down the energy consumption so much so that the Energy Performance index goes below the law limit value (see Fig. 11).

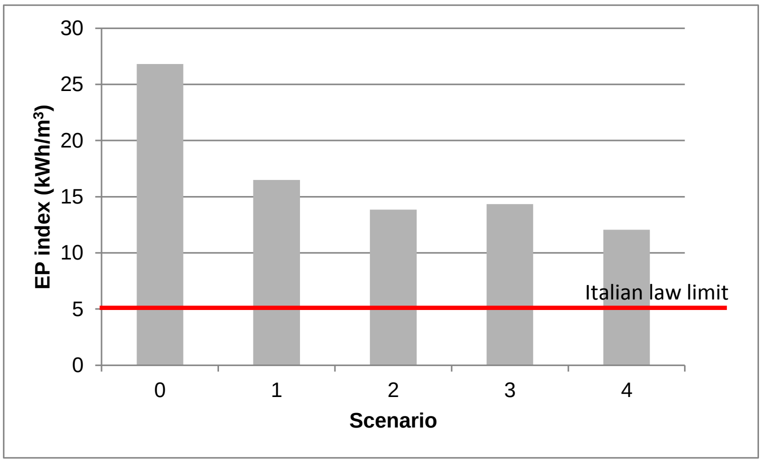

Figure 11: Graph of the EP index of various scenarios.

With regard to financial statement analysis, the payback times of action scenarios are assessed in order to evaluate the profit of each scenario (see Fig. 12).

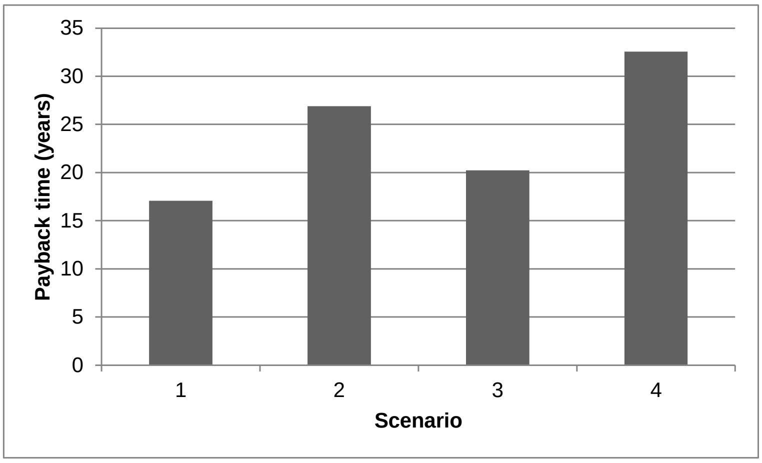

Figure 12: Graph of the payback time of various scenarios.

The scenarios 2 and 4 are necessary to achieve the level of insulation required by Italian law "D.Lgs 192/05" (ITALIAN DECREE n.192, 2005), but both of them are not economically viable even unacceptable (payback times are longer than the useful life of interventions); on the contrary, the scenarios 1 and 3 are economically viable.

Conclusions

The case study highlights the importance of energy audit in order to choose the more advantageous interventions. In fact, the energy audit allows to know the degradation of the building (envelope and equipment) and to single out the possible action scenarios. Finally, the energy audit is intended as an instrument of necessary knowledge to draw up a refurbished plan that is not only related to the planning of timely maintenance.

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