Evaluation of refurbishment alternatives for an Italian vernacular building considering architectural heritage, energy efficiency and costs

Original
Evaluation of refurbishment alternatives for an Italian vernacular building considering architectural heritage, energy efficiency and costs / Becchio, Cristina; Corgnati, STEFANO PAOLO; Spigliantini, Giorgia. - In: ENERGY PROCEDIA. - ISSN 1876-6102. - 133:(2017), pp. 401-411. [10.1016/j.egypro.2017.09.370]

Availability:
This version is available at: 11583/2687773 since: 2017-10-26T15:25:36Z

Publisher:
Elsevier

Published
DOI:10.1016/j.egypro.2017.09.370

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 133 (2017) 401–411

Energy Procedia

www.elsevier.com/locate/procedia

Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area, 12-13 May 2017, Matera, Italy

Evaluation of refurbishment alternatives for an Italian vernacular building considering architectural heritage, energy efficiency and costs

Becchio Cristina[a]*, Corgnati Stefano Paolo[b], Giorgia Spigliantini[b]

[a]*TEBE Research Group, Department of Regional and Urban Studies and Planning (DIST), Politecnico di Torino, Viale Mattioli 39, 10125 Torino, Italy*
[b]*TEBE Research Group, Energy Department (DENERG), Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy*

Abstract

Despite the majority of legislative requirements in terms of energy performances is not addressed to historical buildings, there is an increasing consciousness on their relevance to reach the European CO_2 emissions' reduction goals. This paper engages the theme of traditional buildings' refurbishment, with a view to the necessity of a conscious intervention in terms of heritage preservation, energy efficiency and financial viability. In particular, the research analyzed a real case study of a rural building located in North Italy; the main objective of the study is to compare two different refurbishment scenarios by simultaneously considering architectural, energy and financial aspects.

Peer-review under responsibility of the scientific committee of the Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area

Keywords: Energy retrofit; cost-optimal analysis; vernacular architecture, architectural heritage.

1. Introduction

The necessity to conserve historical buildings have always been dictated by the moral commitment to transfer the knowledge of what history left to future generations. Today, the conservation of this kind of historical evidences

* Corresponding author. Tel.: +39 0110904524
E-mail address: cristina.becchio@polito.it

1876-6102 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the scientific committee of the Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area
10.1016/j.egypro.2017.09.370

is usually conceived with a view to their valorization that involves the adaptation of these buildings to the current necessities, both in cultural and legislative terms. In this framework, conservation and valorization have nowadays to deal with the current financial crisis and the environmental emergency. To comply these necessities, international authorities has already elaborated operative plans and legislative measures at several levels. The European Union (EU) handled the issue of sustainability by providing a long-term framework to Member States (MS). In 2011, the "Roadmap for moving to a competitive low-carbon economy in 2050" was released, expressing the view to achieve an 80% reduction of EU's GHG emissions by 2050 (compared with 1990 levels) [1]. For this purpose, the contribution of buildings is crucial; indeed, the same document showed that in this sector GHG emissions could be reduced up to 90% by 2050 (compared to 1990 levels). Despite the majority of legislative requirements in terms of energy performances are not addressed to historical buildings, they have a great influence to reach these goals. Indeed, several statistical data show that 14% of the European building stock dates from before 1920 and this percentage could dramatically grow in some historical cities. In Bologna (Italy), for example, around 80% of city center's buildings was built before 1949 [2]. Beside general long-term strategies, EU Commission set out specific targets to achieve high energy performances in buildings. In particular, two legislative measures have been taken; the Energy Performance of Buildings Directive 2002/91/EC [3] and its recast version (2010) [4]. Specifically, EPBD recast introduced the concept of nearly-zero energy building (nZEB) and a methodology to define national targets for this kind of buildings, called cost-optimal analysis. The cost-optimal analysis was described in 2012 by EU's Guidelines [5] and allowed Member States defining national requirements adopting a similar approach but also following their specific building stock features and financial situations. Moreover, EPBD recast set out the minimum energy performance requirements should be set with a view to achieve cost-optimal levels for buildings and building elements. A cost-optimal level represents the energy performance level which leads to the lowest cost during the estimated economic lifecycle. According to EU instructions, it has to be calculated through the global cost method from the European Standard EN 15459:2007 [6]. The great potentiality of this methodology lies in the possibility to individuate an ideal solution that considers both energy and financial evaluation. For this reason, recently some studies explored the possibility to use it as a decision-making tool for single design cases, but there are not experimentations on historical buildings yet. Currently, heritage preservation and energy efficiency measures are often conceived as mutually exclusive purposes. Instead, it should be considered that energy retrofit measures could contribute to historical buildings' preservation by enhancing their livability and financial sustainability, improving structural protection and enhancing comfort for occupants. The main objective of this study is to compare two different refurbishment scenarios by exploiting the potentialities of cost-optimal analysis in order to simultaneously consider architectural, energy and financial aspects [7], [8]. The research adopted a real case study, a traditional rural building located in North Italy for which the private owner asked for an energy retrofit and a building's refurbishment to open a small lodging establishment. The refurbishment alternatives were elaborated in order to obtain a large discrepancy in investment costs and design solutions. In particular, the “high investment scenario” aimed at obtaining high energy performances with a less architectural conservative approach, while the “low investment scenario” aimed at accomplishing the national energy requirements minimizing the interventions on the architectural fabric. Regarding the energy and financial characteristics of the alternatives, the comparison between the scenarios was made through the cost-optimal methodology. In particular, the energy performances were assessed by a dynamic simulation software, while the financial analysis was developed using the global cost method according to the EU standard 15459:2007 [6]. In a second phase, a partial review of the global cost formula was proposed and applied in order to include specific peculiarities of the case study. This modification proposal was made for two main reasons. First, since this methodology was conceived for national authorities, its use as decision-making tool for specific cases could request a more holistic approach. Moreover, historical buildings are usually characterized by specific necessities and conservation priorities, so cost-optimal levels identified at national level will not be necessarily cost-optimal for every single building or investor. In this case, using the cost-optimal methodology as decision-making tool, the analysis should include other elements of evaluation. Indeed, considering the lodging activity, beyond the environmental implication the private investor will be interested in recovery the initial investment, privilege the more financially-convenient solution and the future possible incomings. Finally, by comparing the results of the previous analysis, some considerations were made about the use of cost-optimal methodology as a decision-making tool for single design cases and regarding the two design scenarios by focusing on conservation, architectural heritage, energy and financial aspects.

2. The case study

The real case study analyzed in this research is a traditional rural building located in Livorno Ferraris (Italy). The urban context in which the building is located is a low density residential area very close to the countryside. In this area, as well as the whole Piedmont, the case study building typology is highly diffused and often characterized by the necessity of refurbishment and energy retrofit. In these terms, this research represents also an exemplar insight on rural buildings' energy retrofit opportunities. The building, built in the late XIX Century, is a two floors fabric (Fig. 1 shows part of the metric survey). Several minor interventions, e.g. the replacement of old windows, adapted the building to the current necessities and partially compromised the original architectural identity. Nowadays, the edifice is divided into two main parts; one is inhabited while the other hosts a warehouse and the ancient granary. The attic is non-heated and only partially usable. The fabric was constructed with traditional techniques and materials. As a large part of the traditional rural heritage in Piedmont region, the building has a brick structure in which the high thickness of the walls (40 cm) determine a high thermal mass. Another building feature is that the North wall is almost all opaque (there is only one window at ground floor), because the building adjoins another property. For this reason, ventilation and lighting of internal environment have been one of the main concerns of the architectural design scenarios.

Fig. 1. Metric survey of the case study south elevation.

3. Methodology

With the aim to implement the cost-optimal analysis as decision-making tool between design alternatives, two architectural and energy design scenarios were proposed for the case study. These scenarios are principally distinguished by the amount of the initial investment cost. Indeed, they were developed in architectural and energy terms in order to obtain two "extreme cases" of high and low investment costs. The analysis of energy performances was made by the dynamic software EnergyPlus. Then, as already expressed, a financial analysis was made through the global cost method. Successively, a partially-reviewed global cost formula was used including in the analysis additional aspects like the activity's earnings and tax deductions related to the investment cost. Finally, the results of the financial analysis were compared.

3.1. The high investment and low investment scenarios

In architectural and energy terms, the scenarios follow the previous mentioned aim to distinguish a high and a low investment approach in order to obtain different market offers for the accommodation activity. The high investment (HI) alternative pursued the objective to collocate the future lodging activity in a medium-high market sector; the building architectural arrangement chased the maximum-profit approach. Indeed, a raise of the building fabric was previewed in order to make the attic completely habitable. The final configuration of the building consisted of four bedrooms and a common space for breakfast and relax. All the major modification of the architectural appearance previewed by the design are distinguishable from the original elements, protecting the historical evidence of the building. In the low investment (LI) scenario the aim was to pursues a more conservative approach. The dual division of the fabric was maintained distinguishing a common part from the bedrooms-zone that consists in three rooms (Fig. 2).

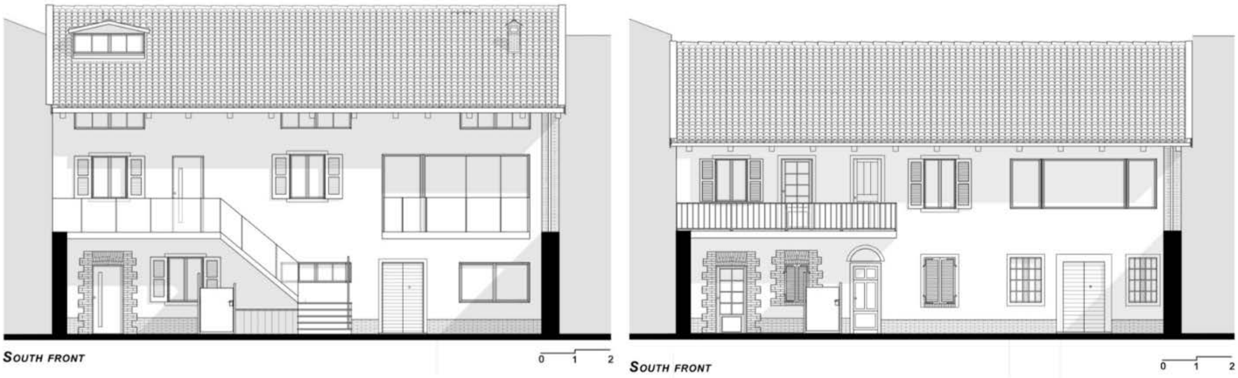


Fig. 2. Architectural design of south façade in the high investment scenario (on the left) and in the low investment one (on the right).

The two alternatives showed a consistent difference in heated surface, because the attic in the low investment scenario was not heated. With the aim to ameliorate ventilation and natural lighting of rooms, both scenarios provided windows located about 2 meters above the floor level, according with the Italian Civil Code. The energy-design of these scenarios took into account building envelope and HVAC systems. Coherently with the previous-declared financial features, the HI scenario produced higher initial costs, but satisfied more ambitious targets in terms of energy performances and GHG emissions. A retrofit of the envelope was provided for both alternatives, although with different performance objectives. In particular, the local legislative requirements were adopted [9] as reference for components thermal transmittance targets. The mandatory level was pursued by the LI scenario, while the HI chased the more ambitious second level. For both alternatives the starting point was the existent building configuration. Also technological choices for energy retrofit were the same, varying only the thickness of the insulation. Opaque envelope operations involved ground floor, external walls and the roof. The ground floor was insulated and a ventilation space was introduced, exterior insulation in mineral wool was adopted for exterior walls and the existing roof was substituted with a ventilated and insulated one. The insulation of external walls was pursued because the architectural evidence of the building would not be compromised; the appearance of walls with plasters remained the same for both scenarios. For transparent envelope different glazing systems were adopted, changing glass type but choosing PVC frames for both. New windows were chosen because the existent ones were not original, so their conservation and restoration was not suitable. Glasses chosen for HI scenario were triple panes with low emissivity coatings filled with krypton, while for LI scenario were double panes with low emissivity coating filled with air. In Table 1 building components performances are listed for HI and LI scenarios.

Table 1. Transmittance of building components.

Building Component	Components thermal transmittance for HI scenario [W/m^2K]	Components thermal transmittance for LI scenario [W/m^2K]
Roof	0.14	0.17
External walls	0.14	0.22
Ground Floor	0.14	0.24
Glass	0.5	1.5
Window	0.82	1.46
Walls versus unheated spaces	0.14	0.28

HVAC system choices were made complying the general approach. The HI scenario was elaborated following the strong idea to obtain a completely electric building. Moreover, using all available surfaces to install photovoltaic panels, the objective was to cover energy needs as much as possible and minimize CO_2 emissions. On the other hand, the low-investment scenario was characterized principally by the aim to lower the financial effort for systems and maintenance, but also fulfill the local legislative requirements and guarantee adequate level of comfort for the lodging activity. In terms of generation, a water-to-water heat pump (COP=3.8, EER=3.5) was adopted for HI scenario. The LI alternative instead, opted for two different generation systems for heating and cooling. A condensing boiler (η=0.99) was adopted for heating system, while a multi-split system (EER=3.5) was chosen to satisfy cooling energy needs. Despite the very low amount of energy needs for cooling, a system was still adopted in order to offer an appreciated service for the accommodation activity. In terms of regulation, the HI scenario looked to occupants' comfort by opting for operative temperature thermostats, while the LI was equipped with external and indoor probes thermostats. Moreover, terminal devices chosen for HI scenario were low temperature radiant floor panels, while for LI high temperature terminals (radiators) were adopted. In regard to ventilation system, the HI alternative opted for a mechanical ventilation system to ensure a constant adequate air quality, while in LI natural ventilation was previewed. Finally, focusing on Renewable Energy Sources (RES), the objectives of HI and LI scenarios were widely different. Indeed, as already mentioned, the HI scenario aimed at electrical autonomy, while LI scenario opted to only respect the legislative minimum requirements for renewable sources. The minimum size of thermal solar panels in Italy is established at regional level; in particular, they have to cover the 60% of the annual energy needs (in primary energy) for domestic hot water (DHW) [10]. For both scenarios, thermal solar panels were adopted in order to satisfy the minimum size above mentioned; the remaining 40% of annual energy needs for DHW was covered by an electrical boiler. The minimum size of photovoltaic (PV) system was calculated following the methodology given at national level [11]. In either cases, the minimum size resulted 1.81 kW_{peak}. Following the objectives previously described, HI scenario opted for using all the available surface on the roof to install photovoltaic panels. This way, the system resulted 12.4 kW_{peak}, covering about 77% of the total electricity uses. In LI scenario instead, a 2kW_{peak} PV system was provided, covering about 38% of the total electricity consumption.

3.2. Energy evaluation

The energy evaluation of the design scenarios was conducted by EnergyPlus, a dynamic energy simulation tool. The geometric model was elaborated by Open Studio, a cross-platform and open source plug-in for the software Google SketchUp. DHW energy needs and consumptions were calculated following the UNI EN 11300-2 [12] methodology. In a first phase, building operational parameters like occupancy, lighting and electrical appliances were simulated considering standard data from standards. In particular, focusing on lighting, minimum requirements of illuminance were established following the UNI 10380 [13]; for bedrooms the minimum requirement is 100 lux, while for collective spaces is 200 lux. Then, for both scenarios, a LED lighting system (with a power of 3 W/m^2) was provided. The artificial lighting system was set in order to turn on if the illuminance measured in ambient by a crepuscular sensor is below the minimum requirement settled and people are present (basing on the occupancy schedules). About equipment, the EN 15232 [14] was considered in order to establish reference levels of power for this particular building type. Having opted for the category hotels, the power value is 4W/m^2. Occupancy was implemented considering firstly the UNI 10339 [15] in order to establish a crowding index of 0.2 people/m^2, secondly the EN 15232 [14] to elaborate occupancy schedules. Finally, activity levels of human beings were established basing on UNI EN ISO 7730 [16].

3.3. Financial analysis: standard global cost calculation

The design scenarios were firstly analyzed through the standard global cost method. According to the European Standard EN 15459 (EN, 2007) the global cost formula can be written as in Equation 1:

$$\mathbf{C_g(\tau) = C_I + C_g \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \times R_d(i)\right) - V_{f,\tau}(j)\right]} \tag{1}$$

where $C_g(\tau)$ corresponds to the global cost referred to starting year τ_0; C_I is the initial investment cost; $C_{a,j}(j)$ is the annual cost for component j at the year i (including running costs and replacement costs); $R_d(i)$ is the discount rate for year i; $V_{f,\tau}(j)$ is the final value of the component j at the end of the calculation period (referring to the starting year τ_0). In particular, global cost method specificity consists in the use of a uniform calculation period. In this analysis a calculation period of 30 years and a discount rate of 4% were adopted. Specifically, the initial investment cost was calculated through an estimative calculation of the retrofit operations (including expenses to purchase the systems). Prices were extrapolated by the Piedmont Region price list [17]. Annual costs include energy costs, maintenance costs and replacement costs, calculated considering the UNI EN 15459 appendix [6]. To calculate energy expenses, the tariffs were extrapolated by the AEEG (the Italian authority for electricity and gas) [18]. In particular, for the high-investment scenario the electricity tariff for energy was specific for customers with heat-pump systems; it was a dual-hourly tariff of about 0.177€/kWh and 0.172 €/kWh (each valid for 12 hours/day). For the low-investment scenario instead, energy tariff for electricity was 0.125€/kWh, while for natural gas it was 0.486€/m^3. Moreover, accomplishing the EU EPBD Guidelines [5] and the objective to foster the development of post carbon buildings, an evaluation of costs related to CO_2 emissions was made. Therefore, an annual calculation of CO_2 emissions was implemented adopting the medium national emission factors of the different fuels and the financial tariffs indicated in EPBD Guidelines [5]. In particular, these costs are expressed in €/t_{CO2}, with different steps until 2025 (20€/t_{CO2}), 2030 (35€/t_{CO2}) and after (50€/t_{CO2}).

3.4. Financial analysis: reviewed global cost calculation

Following the principles previously described, the modified global cost formula includes expected earnings of the activity for the two scenarios and the tax deductions obtainable in the specific temporal contingencies of this intervention. The general aim of this modified approach was to obtain more holistic and realistic predictions, so while in the previous analysis the standard approach was used following the directive, this reviewed formula aim to give to the investor specific information contextualized in the financial market in which its activity will be inserted. As summary, the reviewed global cost formula can be written as in Eq. 2:

$$\mathbf{C_g(\tau) = C_I - \sum V_{td,i}(j) + \sum_j \left[\sum_{i=1}^{\tau}\left[\left(C_{a,i}(j) - V_{e,i}\right) \times R_d(i)\right)\right] - V_{f,\tau}(j)\right]} \quad (2)$$

where, in addition to eq. (1), $V_{td,i}(j)$ corresponds to the obtainable tax deduction for the component j; $V_{e,i}$ is the annual expected earning of the accommodation activity. Expected earnings of the activity were calculated firstly elaborating a market survey of similar activities in Piedmont region. Then, considering similar accommodation proposal, two different tariffs were quantified for the scenarios (81€/person*night for the HI scenario and 64€/person*night for the LI scenario). In order to calculate the expected annual profit, standard expenses of the activity like rooms cleaning and hosts' breakfasts were taken into account. Successively, a realistic prediction of profit was made considering a statistical data, namely an annual occupation rate of accommodation activities in Piedmont elaborated by ISTAT (the Italian Institution for Statistical Analysis). The obtained previewed profit for the two scenarios was quite different, due to different tariffs and the quantity of rooms previewed by the two design alternatives. Following a similar approach, a more realistic prevision for energy consumptions was attempted. Considering the already-mentioned statistical data about occupation in accommodation activities, the energy models were modified working on operational parameters (occupancy, lighting, equipment, HVAC systems schedules), in a way that systems function only when occupants are present. Tax deductions were calculated according to the Italian Stability Law. In particular, at that time two types of tax deductions were compatible with the case study; the first was the so-called Eco-bonus [19] that included some ex- penses for the energy retrofit, the other concerned refurbishment operations in general [20]. The so-called Eco-Bonus, is a 65% tax deduction obtainable if the operations that have to be deducted allow the building to respect a primary energy for heating limit that has to be calculated following the regulation's instructions. In this first category operations on opaque and transparent envelope were considered (e.g. insulation, changing of glazing system), systems (heat pump for HI scenario and condensing boiler for LI) and thermal solar panels for both scenarios. In order to profit of the second incentive (for building refurbishment), that amount to 50% of tax deduction calculated basing on the sustained expenses, the mechanism is easier; the regulation reports a list of operation allowable. In this second category of tax deduction operations like the elevation of the building fabric for HI scenario and the integration of a new staircase in LI were considered, mechanical ventilation system for HI and multi-split system for LI, and PV panels for both scenarios.

4. Results

4.1. Energy evaluation results

Starting from the evaluation of building retrofit's design, a comparison between energy-related results of the two scenarios is developed below. As already described, the HI scenario was characterized by more ambitious performances related to building envelope. Indeed, the following graph (Fig. 3) shows a wide difference between energy needs for space heating and a very low need for space cooling for both scenarios.

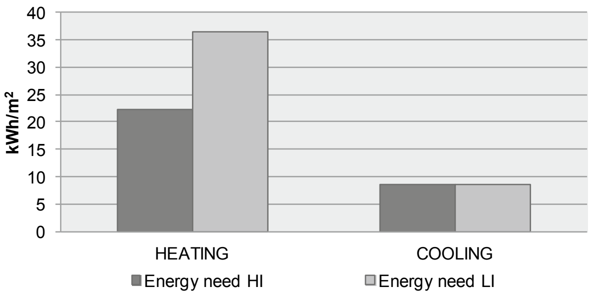


Fig. 3. Energy needs for space heating and cooling for the two different design scenarios.

Considering the previously described HVAC system choices, energy simulation results in terms of standard total energy consumption subdivided for end uses are showed in Figure 4. Since the equipment and lighting legislative references were the same, the consumptions for these categories resulted quite similar in LI and HI scenarios. However, since the HI scenario has a bigger transparent surface in respect to the LI, the graph shows a little discrepancy. Owing to the presence of mechanical ventilation system, fans and pumps energy consumption is remarkably higher in HI configuration. Finally, heating-related consumptions are widely lower in HI scenario, while for cooling the multi-split system resulted less energy-costly. The previous information considered the so-called standard energy consumption. However, in the same figure standard and realistic consumptions were compared.

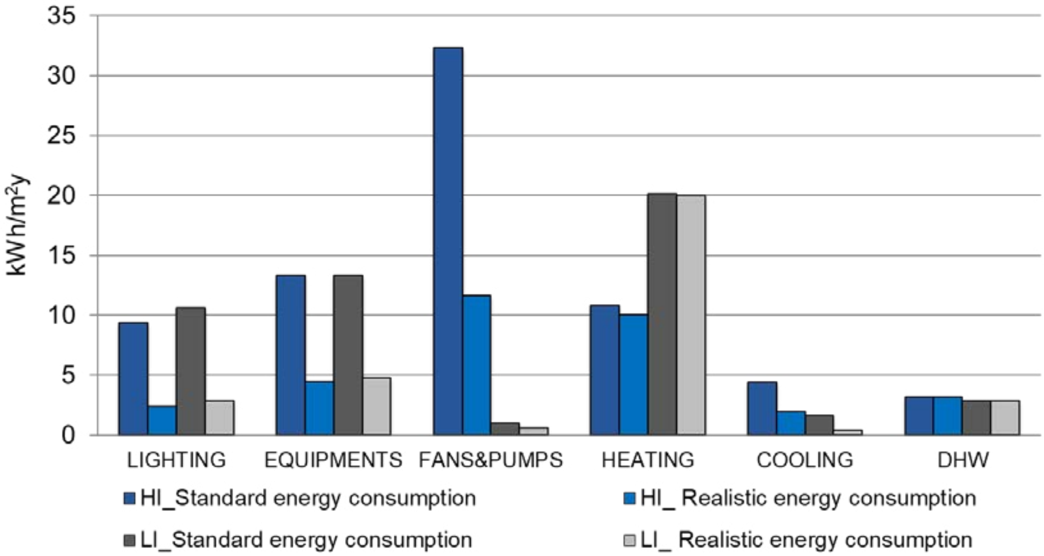


Fig. 4. Standard and realistic energy consumptions subdivided for the different end uses for HI and LI scenarios.

Realistic consumption was calculated as previously described according to statistical data. Figure 4 shows the direct comparison between the standard and the realistic calculation for each scenario. Considering a realistic occupancy rate of the building, lighting and equipment energy consumption is drastically reduced. Similarly, since the mechanical ventilation is activated only if occupants are present, fans and pumps consumption in HI configuration resulted remarkably lower with realistic approach. Space heating and cooling consumptions were not significantly lowered with the realistic approach, because the energy need to re-heat or re-cool the entire building after a non-occupation period resulted almost similar to the standard conditions one. Another notable consequence of adopting realistic approach was that differently from the standard calculation, the exploitation of renewable sources resulted in completely satisfying electricity needs of both scenarios (Fig. 5). Particularly, for the HI alternative this means that the building would probably result not only energetically autonomous, but also energy-positive.

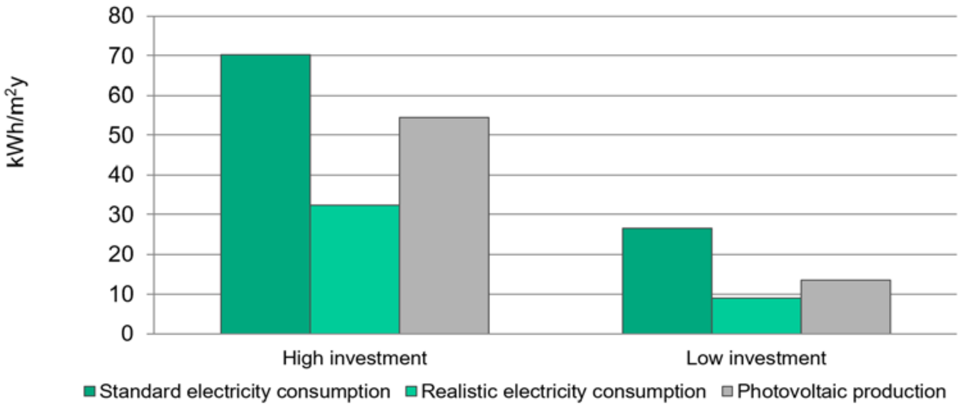


Fig. 5. Exploitation of photovoltaic system considering standard and realistic electricity consumptions for HI and LI scenario.

Similar considerations could be made for CO_2 emissions. Indeed, if the LI scenario resulted electrically-independent, its realistic emissions would be due only to condensing boiler's gas consumption. HI scenario's emissions instead, being energetically autonomous, would be technically reduced to zero (Fig. 6).

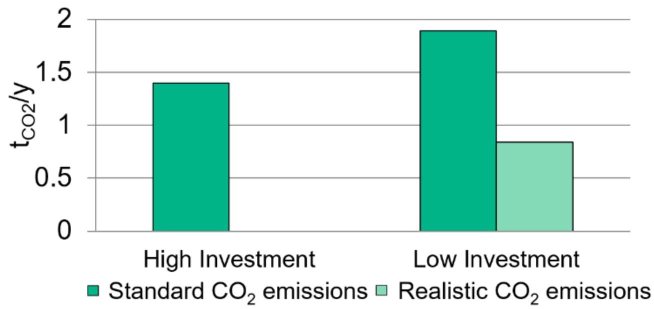


Fig. 6. CO_2 emissions analysys considering standard and realistic consumptions for HI and LI scenario.

4.2. Financial evaluation results

As previously described, the financial aspect of initial investment guided the entire elaboration of the two scenario alternatives in order to compare them and give to the customer sufficient and complete information in order to choose between them. Therefore, the financial analysis results represent the cornerstone of the entire work. The two design scenarios were firstly analyzed through the standard global cost formula and then its partial modification was provided in order to implement a more holistic approach and adopt a profit perspective for the private investor.

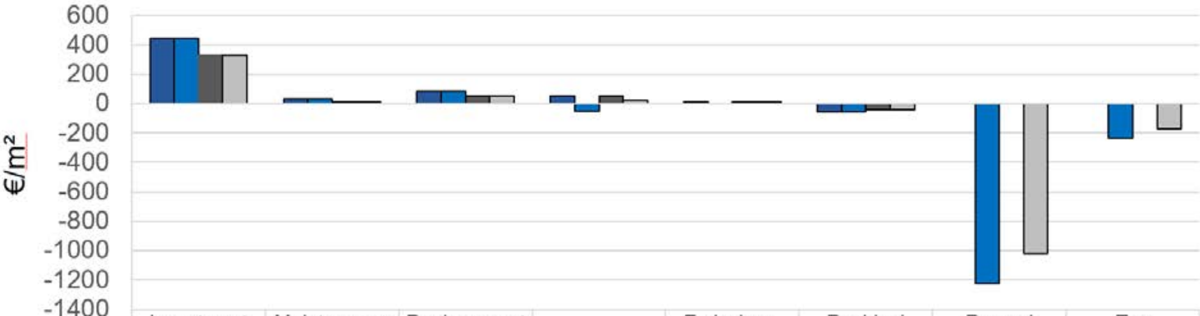
The following graph (Fig. 7) shows the amount of considered costs in standard and reviewed global cost method, directly comparing the impact of high and low investment scenarios.

Comparing the standard and the modified approach, there is no difference in the investment, maintenance and replacement costs. Observing the breakdown analysis of Figure 7, it's undeniable that these mentioned voices of cost are all bigger in the high investment scenario than in the low investment one.

Moreover, the energy-related costs were here calculated in standard terms. HI scenario didn't produced a considerable difference, because considering standard consumes the photovoltaic system covers only 77% of the total electric-energy demand. Thus, in this first analysis HI scenario produced a considerably higher global cost.

The modified approach gives place to cash flows in which expected earnings from the lodging activity resulted very influential; in the standard global cost approach this income is null because it's not taken into account. Another important observation concerns energy costs. Indeed, considering the more realistic data based on statistical survey, the HI scenario results energetically-autonomous and capable to export in the grid the electricity produced by photovoltaic system. This exportation generates an income; consequently, the high investment scenario valued with the realistic approach is the only one that is characterized by a value and not a cost related to energy consumptions. The LI scenario valued with the realistic approach results only electrically-autonomous thank to the PV production, but the choice to provide a condensing boiler for heating generation determines non-eliminable costs for natural gas. Indeed, the electricity surplus in Italy is subordinate to a particular contract with the Italian manager of energy services (GSE) that calculate a six-month contribution for the energy exported in the grid. The tariff considered for little producers (PV systems until 1MW of electrical nominal power) amounts to 39€/MWh for the year 2015 [21].

Another significant element was represented by tax deductions that lowered initial investment costs in significant extent.



	Investment cost	Maintenance costs	Replacement costs	Energy costs	Emissions costs	Residual value	Rooms' earnings	Tax deduction
HI_ Standard	445	30	85	52	3	-55		
HI_Realistic	445	30	85	-51	0	-55	-1222	-235
LI_ Standard	328	6	52	55	5	-42		
LI_ Realistic	328	6	52	22	2	-42	-1020	-173

Fig. 7. Breakdown costs analysis adopting the standard and realistic approach for HI and LI scenario.

The final results are reported in Table 2. The table allows to simultaneously consider energy-related and financial aspects of the two scenarios and also evaluate the impact of the two employed approaches, the standard and the realistic one. It's worth noting that using the realistic approach and applying the modified global cost formula, the final choice of the private investor could vary a lot. Indeed, adopting the modified global cost formula, for both scenarios the global cost is characterized by a negative value that represents an income. Moreover, the HI scenario conducts to a higher income; the more ambitious solution (both energetically and environmentally) results favorable.

Table 2. Results of the standard and the modified global cost method for HI and LI scenario.

Scenarios	Standard global cost calculation		Modified global cost calculation	
	Primary Energy [kWh/m^2]	Global cost [€/m^2]	Primary Energy [kWh/m^2]	Global cost [€/m^2]
HI scenario	32	1490	0	-1802
LI scenario	54	1348	11	-1632

5. Conclusions

This paper deals with the opportunity to concentrate efforts in refurbishing traditional and historical buildings with a view to implement conservation and valorization necessities with a cost-optimal approach. To this effect, a real case study was considered and two refurbishment scenarios were developed with the aim to obtain two very different alternatives in terms of financial efforts. The architectural scenarios design followed two different approaches; the low investment (LI) scenario privileged the conservation of the building as it arrived to the present time, while the high investment (HI) scenario opted for the partial modification of building's internal distribution and the fabric itself maximizing the future profit opportunities. For both scenarios, it is important to observe that the architectural identity of the building was respected. In coherence with this approach, the energy design of retrofit solutions was more challenging for the HI scenario, while the LI aimed at respecting legislative restrictions while reducing financial effort. The energy and financial features of the retrofit designs were evaluated first with a standard approach and then with a more realistic approach. In terms of energy evaluation in the first case, standard operational parameters were used while in the second case the operational parameters were fixed according with statistical data related to accommodation activities like the one introduced in the retrofitted building. Concerning the financial valuation, in the standard approach the global cost formula as proposed by the EN 15459 was used, while a partial modification of the method was proposed in the realistic approach in order to implement a profit perspective and a more holistic description of single design scenario.

Summarizing the results, through the previous analysis a private investor could receive some essential information to opt for one scenario rather than another, from the initial investment entity to the long-term convenience. Relevant information derived from the modified global cost formula. Indeed, following the more realistic approach, the apparently disadvantaged HI scenario resulted the favorable one. In the same considered period, HI scenario resulted energy autonomous and capable to export electricity producing, consequently, a financial earning. In financial terms, the HI scenario produced a higher income due to the accommodation activity, despite the initial investment costs were remarkably higher.

In conclusion, results obtained by adopting the modified global cost formula encourage, in general, having a more holistic approach in historical buildings refurbishment designs especially if there is a change of building use. Future research should concentrate on its implementation in order to make it more usable also at professional level.

References

[1] European Parliament, EPBD Recast. Directive 2010/31/EU of the European Parliament and of Council of 19 May 2010 on the energy performance of buildings (recast). Official Journal of the European Union; 2010.

[2] Troi A, Zeno B, Energy Efficiency Solutions for Historic Buildings, a handbook. Brussels: Birkhauser; 2014.

[3] European Parliament, EPBD. Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings. Official Journal of the European Union; 2002.

[4] European Parliament, EPBD Recast. Directive 2010/31/EU of the European Parliament and of Council of 19 May 2010 on the energy performance of buildings (recast). Official Journal of the European Union; 2010.

[5] European Parliament, EPBD Guidelines (2012/C 115/01). Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU. Official Journal of the European Union; 2012.

[6] EN, EN 15459:2007 Standard. Brussels: European Committee for Standardization; 2012.

[7] Becchio C, Corgnati SP, Orlietti L, Spigliantini G, Proposal for a modified cost- optimal approach by introducing benefits evaluation. Energy Procedia 2015;82:445- 451.

[8] Becchio C, Bottero M, Corgnati SP, Dell'Anna F, A MCDA-Based Approach for Evaluating Alternative Requalification Strategies for a Net-Zero Energy District (nZED). In: Multiple Criteria Decision Making: Applications in Management and Engineering / Zopounidis C., Doumpos. New York: M. Springer International Publishing Switzerland; 2016. p. 189-211.

[9] Energy and Ambient Agency of Turin, Allegato Energetico ambientale al regolamento edilizio della città di Torino. Allegato alla

deliberazione n. 2010- 08963/38. Torino: Energy and Ambient Agency of Turin; 2009.
[10] Piedmont Region, DGR 11969/2009 n. 46-11968. Aggiornamento del Piano regionale per il risanamento e la tutela della qualità dell'aria - Stralcio di piano per il riscaldamento ambientale e il condizionamento e disposizioni attuative in materia di rendimento energetico nell'edilizia ai sensi dell'articolo n.21 della legge regionale 28 maggio 2007, n.13 "Disposizioni in materia di rendimento energetico nell'edilizia". Turin: Piedmont Region; 2009.
[11] Italian Republic, Dlgs 28/2011. Attuazione della direttiva 2009/28/CE sulla promozione dell'uso dell'energia da fonti rinnovabili, recante modifica e successiva abrogazione delle direttive 2001/77/CE e 2003/30/CE. Gazzetta ufficiale della Repubblica Italiana. Rome: Italian Republic; 2001.
[12] UNI, UNI TS 11300-2: 2014. Standard. Milan: Italian Unification Body; 2014.
[13] UNI, UNI 10380:1994 Standard. Milan: Italian Unification Body; 1994.
[14] EN, EN 15232:2012 Standard. Brussels: European Committee for Standardization; 2012.
[15] UNI, UNI 10339:1995 Standard. Milan: Italian Unification Body; 1995.
[16] ISO, ISO 7730:2007 Standard. Brussels: International Standards Organization; 2007.
[17] Piedmont Region, Prezzi di riferimento per pere e lavori pubblici nella regione Piemonte. Edizione dicembre 2014-valevole per il 2015. Turin: Piedmont Region; 2015.
[18] Italian authority for Energy. Tariffe. http://www.autorita.energia.it/it/tagSearch?tag=tariffe. Web source. 13th October, 2015.
[19] Italian revenue Agency, Le agevolazioni fiscali per il risparmio energetico. Rome: Italian revenue Agency; 2015.
[20] Italian revenue Agency, Ristrutturazioni Edilizie: le agevolazioni fiscali. Rome: Italian revenue Agency; 2015.
[21] Italian gestor of energy services. Scambio sul posto. http://www.gse.it/it/Ritiro%20e%20scambio/Scambio%20sul%20posto/Pages/default.aspx. Web source. 25th September 2015.