The energy improvement of monumental buildings. An investigation protocol and case studies

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Abstract

Improving the energy efficiency of important buildings is a complex operation that requires skill and care due to the inherent specificity of the preservation actions and increase of the contextual performances. It is difficult to propose an intervention-type or a code of practice as for ordinary buildings, because every monumental artefact has a peculiar typological-dimensional conformation as well as different formal and technological details. It is therefore always necessary to carry out an specific assessment that should be developed on a case by case basis, but within a framework of shared orientations, which the scientific community continually refines, due to technological innovations and new usable materials. Essentially, if each project is specifically related to the values of the asset, criteria and logical-operative means are established so as to retrace the achievement of the objectives aimed at upgrading the energy efficiency, while respecting the characteristics of the building.

In this paper, starting with a review of the current problems on the subject of the energy improvement of historic buildings, the main normative references are discussed, as well as the most recent European guidelines and orientations. These orientations and guidelines are methodologically consistent with the study protocol that is proposed and from which emerges the centrality of both the compositional and technical solutions that are planned for the property, and the results from the economic-financial evaluation.

The case study of the Convento dello Spirito Santo in Pellezzano (SA), developed in relation to the selection of interventions that are technically compatible with the historical and architectural value of the building, highlights how on-site tests are essential so as to create a database that may be useful for improving the general intervention principles as part of a continuous feedback process and source of any subsequent corrections. This is followed by using new technologies with the ability to satisfactorily increase the energy performance of the building but without compromising its monumental integrity.

1. INTRODUCTION

The data on energy consumption in Europe show how the construction sector is responsible for 40% of the total energy produced and around 50% of air pollutant emissions[1]. To counter this trend and achieve the objectives of the Kyoto Protocol, from 1997 until the recent UN Climate

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[1] Source: EURAC (Accademia Europea di Bolzano).

Change Conference in Paris in 2015, interventions need to be carried out in the construction sector by increasing the performance of new buildings as well as rehabilitating existing ones. It is evident that imposing energy consumption limits only to new constructions is not enough. In fact, if a good energy retrofit strategy [1, 2] can lead to a reduction of greenhouse gas emissions by up to 70-80%, a requalification intervention could be useful in improving the thermal comfort conditions so as to increase the value of the building as well and avoid the demand for new buildings that consume soil. The recovery of existing buildings should therefore be considered within the wider context of the European urban regeneration policies that, by 2050, intend to pursue the containment of soil occupation up to a factor near to zero.

19,15% of the buildings in Italy were built before 1919 and, of these, the Ministry for Cultural Heritage and Activities (MiBAC) has surveyed over 46,000 assets of constrained architectural heritage. It is a heritage of considerable size, whose energy demand is connected to the housing envelope characteristics, the type of construction, the intended use and the obsolescence of the systems. To include improving energy efficiency as part of the restoration project of monumental buildings, interventions to reduce consumption and environmental pollution may not only be important, but also a way to increase the possibilities for valorisation and reuse. To ensure that the measures can effectively be realized, the technical study of the investment must be accompanied by an adequate analysis of the economic-financial feasibility, so as to verify its sustainability with respect to the private investor, and – with increasing frequency – to the community.

2. ENERGY IMPROVEMENT AND PRESERVATION OF MONUMENTAL BUILDINGS

2.1 The open issue of the intervention criteria

When it has to do with property value, renovation work must take into account multiple needs, including performance and conservation, along with energy saving and preservation of the historical and architectural features. According to a study by the *Building Performance Institute of Europe* (BPIE)[2], "moderate" interventions can also be carried out on historic buildings in order to reduce energy consumption and CO_2 emissions within the set limits by 2050. It should be noted that among all the possible solutions, there are always some energy efficiency ones adaptable to the historic building. The crucial question is understanding what performance level can be achieved, not only due to the difficulty in modelling the actual energy behaviour, but also the problematic application of interventions that respect the historical and aesthetic identity of the building. According to the most important International Restoration Charters, whenever a cultural property is affected by an intervention project, it is necessary to protect it from being altered[3] and transmit it to future generations in the same state by implementing improvement and not impactful interventions.

In terms of energy, on the one hand, the intended use dictates the requirements regardless of the characteristics related to the constraint, while on the other, specific rules that clarify how to intervene on historic buildings are still being waited for. European directives have so far not given due weight to architectural heritage, especially in Italy, while it has become an important issue considering the number of properties with these characteristics.

It is also worth highlighting how at the 1996 Helsinki conference, the theme was discussed, with a resolution for the management of cultural heritage within a framework of sustainable development, based on public-private practices aimed at architectural preservation as well as the assessment of possible energy performances. However, no precise intervention guidelines were drawn up. Even in the following international conferences the need for a sustainable perspective for historic buildings was highlighted, but these proposals have still to be transformed into prescriptive regulations.

In some cases, in that of the *Energy Performance of Buildings Directive* (EPBD), strong contrasting elements have been detected between energy efficiency and environmental protection, despite the *European Working Group on EU Directives and Cultural Heritage* having worked for years on the possible impacts that European legislation may have on the EU's architectural heritage. For example, in Directive 93/76/ EEC *Energy Efficiency*, now repealed by Directive 2006/32/ EC, substantial interventions on the envelopes of historic buildings were recommended, such as the mandatory changing of windows, to achieve very high standards.

Thanks to the work of associations such as *English Heritage* or *Historic Scotland*[4], it has been recently

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[2] BPIE is a non-profit European Institute dedicated to spreading knowledge in the field of energy saving in buildings policies.

[3] This does not mean that we should implement a mere preservation process, without some "appropriate" alteration of the existing building, for example, in terms of reintegrating gaps, removal of superfluous or even improving performance. From the Amsterdam Declaration of 1975 followed by the same restoration charter, it also shows clearly that the idea of restoration as mummification is absolutely outdated and that by the search for functions that permit the use of good cannot be ignored, according to the known concept of "integrated conservation".

[4] *Building Regulations and Historic Buildings: Balancing the needs for energy conservation with those of building conservation*: an Interim Guidance Note on the application of Part L, English Heritage, 2004. *Energy conservation in traditional buildings*, English Heritage, 2008. *Improving the thermal performance of traditional windows*, Historic Scotland by Glasgow Caledonian University, Glasgow 2008. *Energy Efficiency in traditional homes*, Historic Scotland, Edinburgh, 2007. *Windows, Managing Change in the Historic Environment*, Historic Scotland, Edinburgh, 2009.

realised that research should support the European Community to ensure that the efficiency improvement techniques do not compromise historic buildings, but rather allow for the conservation of form, materials and construction techniques, as well as minor construction, provided the historical value is recognised [3, 4, 5]. The methodological criteria being elaborated and which have had widespread scientific recognition are based on the implementation of interventions that are configured as part of *energy improvement*, similarly to what has been introduced in the structural framework for the consolidation of historic buildings, representing an alternative to *energy adjustment*, since it is not constrained to a rigid fulfilment of the rules, but rather to increasing the performance up to the limit resulting from the preservation.

The principle is to not distort the characteristics of the property [6, 7, 8], that is to say the structure, the decorating elements, the materials, construction techniques, etc., but to intervene in a way that respects the preservation criteria and, at the same time, that as efficiently as possible reduces consumption and protects the environment [9, 10].

2.2 The Ministry of Cultural Heritage Guidelines

In Italy, there is an exemption of energy adjustments for cultural buildings, as set out by Decree n. 192 dated August 19, 2005, but the changes introduced by Law 90/2013, as a result of the implementation of Directive 2010/31/EU, have made the application of this exception subject only to those cases where it is established that compliance with the requirements involves a substantial change in the nature or appearance of the listed building, with emphasis on the historical, artistic and landscape profiles[5]. This does not imply it does not have to be carried out, but rather that the provisions relating to the certification of the energy performance and controls on the heating systems still apply, while all the other retrofits must be reviewed by the Superintendent who, in carrying out the institutional task of preservation, evaluates what interventions are feasible of every individual case and which are in conflict with the preservation and conservation requirements.

To deal with this condition of regulatory uncertainty and to allow for the uniformity of judgments, MiBACT has issued guidelines[6] which provide guidance for the evaluation and improvement of the energy performance of cultural heritage. This has also been done with the intent to provide operational guidance to both planners and officials of the Superintendence. The proposed methodology is particularly interesting, with it placing an essential premise on the *historical reading of interventions on the building*, based on:

- documentary and archival sources;
- bibliographical sources;
- direct observation of the building in its entirety (from the foundations to the roofing, to the surrounding context).

Through this historical reading, it will be possible to:

1. temporally reconstruct the building phases of the building and any subsequent interventions up to the modern day;
2. retrace its intended use over time;
3. study, detect and verify the original systems, historical or existing;
4. identify the materials and building technologies adopted, in relation to the local building traditions and climate data of the site in question;
5. identify any previous interventions aimed at improving the energy performance of the building, with a critical assessment of their effectiveness.

A geometrical and technological survey is equally important, since it allows to obtain a correct reconstruction of the dimensions, as well as identify the various stages of the construction history, the structural elements of the existing installations and materials. An extended survey of the urban context where the building is located also allows to obtain information regarding the environmental factors, such as exposure, daylight and surroundings.

The preliminary survey is followed by a *correct energy audit*, i.e. an assessment of the energy performance taking into account the climatic aspects of the area, the thermal insulation level of the building envelope, its own power generation systems, the technical characteristics and installation of the systems and the microclimate of the interior.

Only after this extensive knowledge has been acquired, is it possible to define the *energy improvement,* intervention proposals, which can be of various types, but in principle defined according to the following general criteria:

- the thermal energy required for heating or cooling can be reduced by limiting the flow of ventilation air or, for example, through the use of self-producing systems from renewable sources (solar thermal panels, geothermal heat pumps) or also with passive interventions on the dispersive surfaces of the building;
- the consumption of electricity can be reduced by using LED lighting integrated with natural lighting technology.

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[5] Article 3 sets out, in paragraphs 3, 3-bis and 3-bis.1, that historic buildings must comply with the EPBD requirements for the energy certification and the operation, maintenance and inspection of the technical systems, except authorization from the Superintendent for Architectural and Landscape Heritage, on the evaluation of possible alterations and impairments that such adjustments can make to the historic building.

[6] Site MiBACT: www.beap.beniculturali.it (section regulation).

3. THE CENTRALITY OF THE ECONOMIC-FINANCIAL EVALUATION. A STUDY PROTOCOL

It is widely recognised in current literature that the judgment on the execution of an investment project is not possible without a detailed economic-financial evaluation. This also applies to monumental buildings.

Research has focused on defining a model for the thermodynamic characterisation, economic analysis, selecting of projects for the redevelopment of historic buildings, as well as measuring the environmental benefits which are generated over time by virtue of such interventions [11]. The protocol appears consistent with the issues raised so far and in relation to what is called for in the Ministry of Cultural Heritage guidelines. This is in light of the stages of the study and with the model proposed (Fig. 1).

The selection of technologically advanced interventions, compatible with the historical building, can be planned through a protocol that takes into account its historical background and specific technical characteristics, in addition to the climatic data of the place, the geometric-dimensional, thermo-physics of the building envelope and performance of the systems (stage I). This information, implemented in a software according to the UNI TS 11300 regulations, allow for the thermodynamic modelling and its calibration (stage II-III). The critical issues are then identified through non or slightly destructive techniques, so as to select the possible interventions to be implemented (Phase IV-V). The decision on the investments to be made is taken while considering the results of cost-benefit analysis, which reflects the positive effects related to the financial benefits in terms of energy efficiency and building renovation (VI-VII phase). Finally, it is possible to monetarily quantify the equivalent reduction of CO_2 emissions through the social cost of carbon, SCC (Phase VIII), and – even by multi-criteria logic – other specific social, cultural or environmental effects.

4. A CASE-STUDY OF THE FORMER CONVENTO DELLO SPIRITO SANTO IN PELLEZZANO (SA)

The structure of the study protocol described above is set out in order to define the most technically and economically effective design solutions for the improvement of the energy performance of monumental buildings.

4.1 Background

The Convento dello Spirito Santo is in the municipality of Pellezzano in the province of Salerno, in a strategic geographical position, looking out over both the Valle dell'Irno and the Sele, towards the Gulf of Salerno and the Amalfi Coast. According to some historians[7], due to its location, it was originally a fortress and defended the roads of the area. It was probably part of the defence system created by the Anjou to protect the city of Salerno and consisted of the imposing castles of Sarno, Mercato S. Severino, Roccapiemonte and S. Liberatore di Cava. The restoration works carried out in 2003 have confirmed this hypothesis, through an architectural reading of the construction phases and transformations that have made it possible to highlight some significant building elements, such as the tower, the cisterns and the internal *curtis murata*, different from the classic walled cloisters of the convents of the time, which are typical of military garrisons (Fig. 2).

The few historical documents available report that the monastery was established by the Augustinians of St. Mary Colloreto (XVI century), belonging to the homonymous Calabrian congregation who enjoyed the patronage of the feudal lord Pietro Antonio Sanseverino. It is during this period that the ancient fortress was transformed and converted into a religious building (Fig. 3), consisting of:

a. church;

b. chapter house, sacristy, dormitory, dining hall and kitchen, all around the main cloister;

c. infirmary, guest house, library and writing room, around an inner courtyard;

d. granaries, ovens, stables;

e. gardens and vegetable gardens.

The monastery was organised so as to include a number of public spaces, currently found in in the basement with access from the outside. The cells, as places of meditation and prayer, were located on the first and second floors and looked out onto a covered porch inside the cloister. An analysis of the materials found on site makes it possible to assume that the second floor was made at a different time so as to satisfy the growing needs of the friars. This hypothesis is supported by the presence of a second well in the cloister that is joined to the cistern. Another element that confirms this hypothesis is the smaller thickness of the wall, as well as the facts that they are made from a poorer quality stone. The rooms in the basement, specifically the dining hall with a barrel vault with lunettes, can be dated between 1400 and 1500; similar items can also be found in the civil buildings of the capital of the province (see the entrance hall of Palazzo Guardati in Via Tasso in Salerno).

On April 15, 1604, the Hermits of Colloreto joined the Augustinian Order and founded a church dedicated to the

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[7] Cosimato, D., *La Valle dell'Irno. Il territorio dei comuni di Baronissi e Pellezzano*, Baronissi, 1987; Polverino, E. (a cura di), *Il Comune di Pellezzano nella Valle dell'Irno*, Coperchia-Pellezzano, 1992.

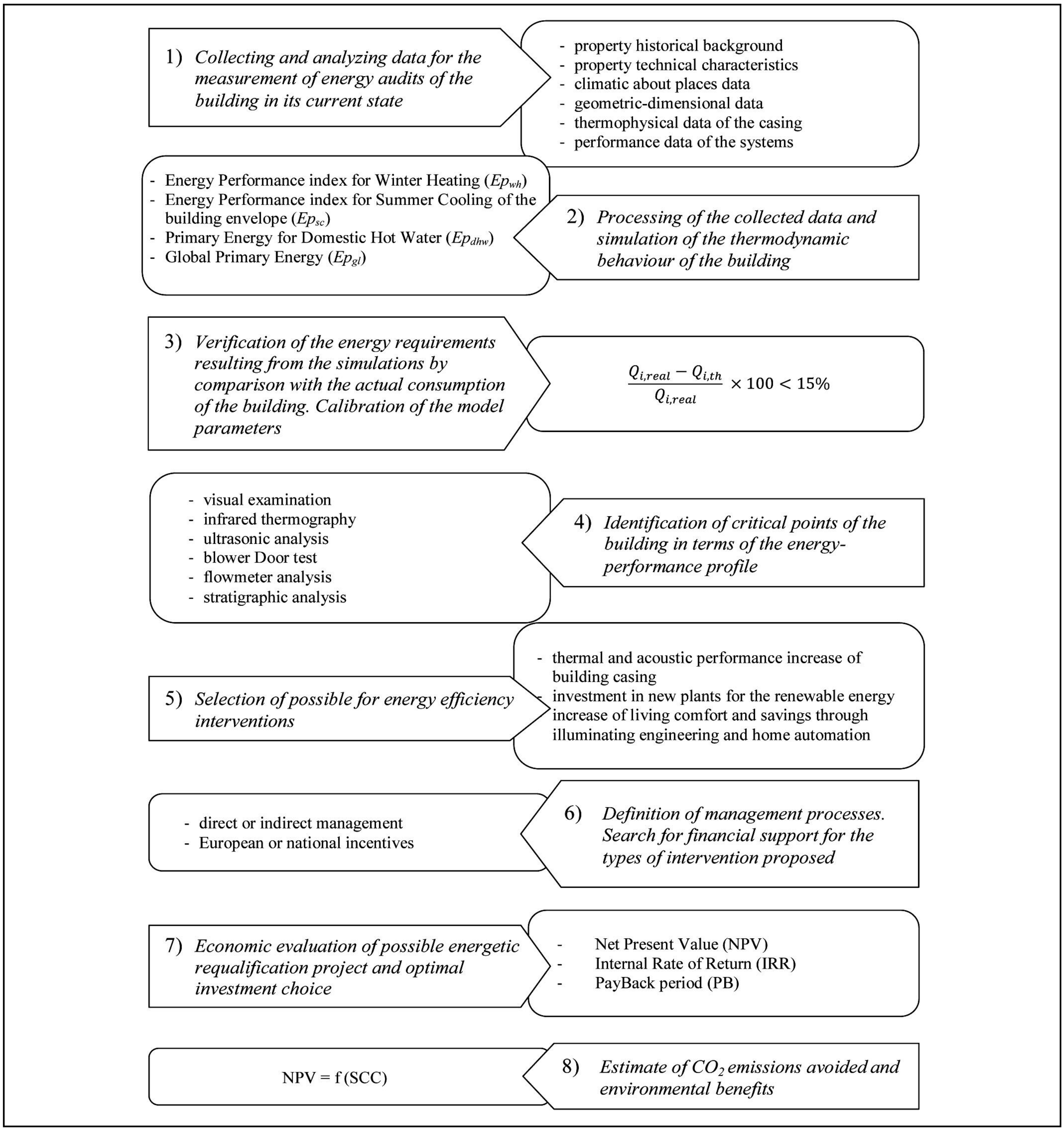

Figure 1 - *Stages of the study protocol*

Holy Spirit. On August 28, 1653 the monastery was abolished through the implementation of the *Instaurandae regularis disciplinae* bull issued by Pope Innocent X. Between 1600 and 1700, the monastery was transformed into a retreat and inhabited by an ascetic, with the local people still frequenting it. In the first half of the nineteenth century, with the implementation of the Napoleonic laws, the complex was no longer under ecclesiastical jurisdiction and it became part of the Institutes of Charity, known as the Luoghi Pii, managed by the State. The church and monastery were abandoned until the second half of the nineteenth century, when it

Figure 2 - *The Convento dello Spirito Santo in Pellezzano (SA) after the restoration work carried out between 2003-2007*

became part of the Congregation of Charity run by the local council, with a welfare function.

In the 1950s, it was frequented only on Easter Monday, and after a long period of neglect, in 2003, the restoration work began, with it being reopened in 2007 and a new use, that of a museum. From 2013, the local council approved and realised the works set out by the energy efficiency project, giving the ancient Convento dello Spirito Santo, the new function of museum and conference centre. The redevelopment project, funded under the Interregional Operational Programme "Renewable Energy and Energy Efficiency", 2007-2013 ERDF, is based on three main lines of action:

1. redevelopment of the adjacent public spaces;
2. improvement of the energy efficiency of the existing housing envelope;
3. restructuring and replacement/integration of existing electrical and air conditioning systems.

4.2 The energy efficiency measures

The investigation in preparation of the design choices, and in the absence of specific documentation, was essentially based on the *on-site* reading of the building and the data collected during the execution of the previous work carried out between 2003 and 2007. The metric survey, already available, was assessed and updated, with additional information being added, making it possible to have more detailed knowledge. The investigation aimed to understand in greater detail the following aspects:

- relief the stratigraphy of the building and the constituent materials of the various sub-systems (housing envelopes, horizontal elements, etc.).
- identify the thermal bridges and areas where interstitial or superficial condensation could occur;
- detect any discontinuity of the wall sections, as well as the presence of any cavaedium;
- analyse the system elements and their efficiency;

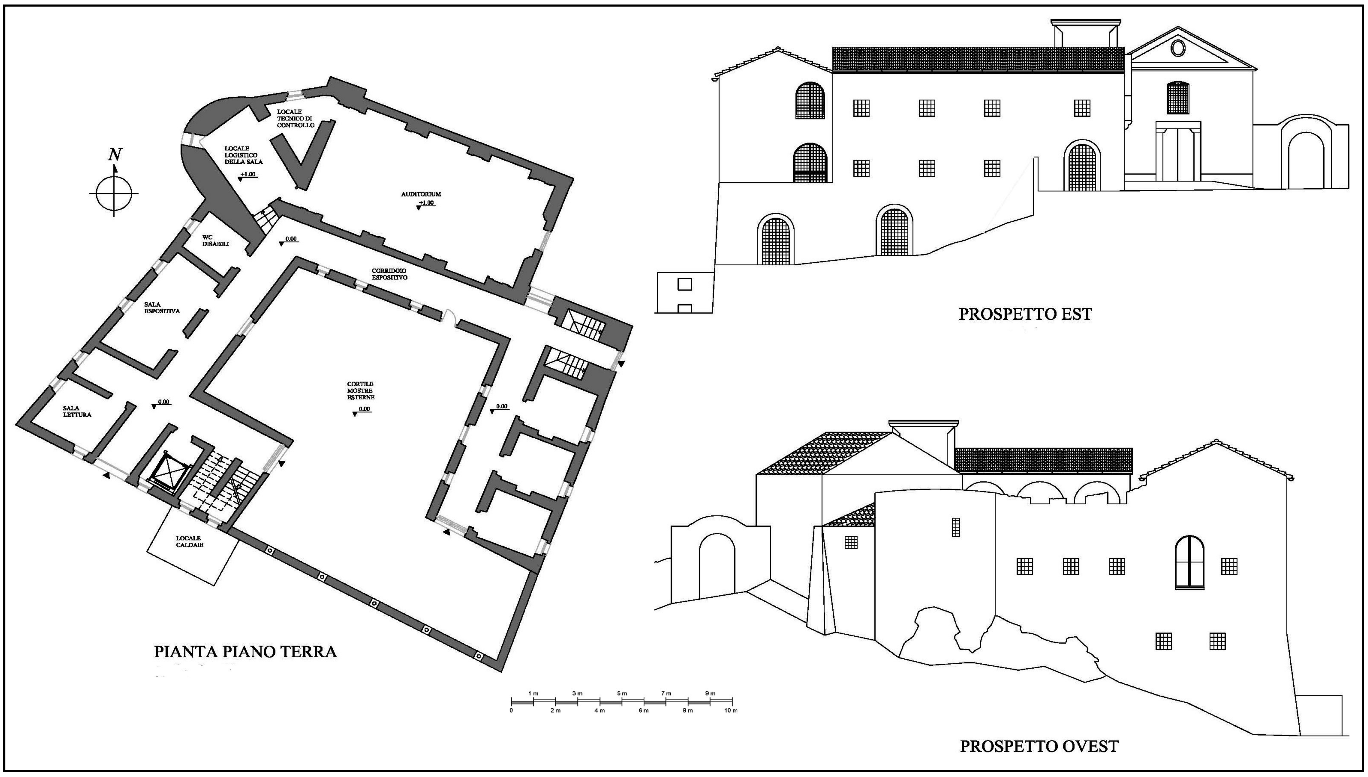

Figure 3 - *Ground floor plan, east and west elevations of the Convent*

- study the degraded parts for any detached, aging or obsolescence material (plaster, wood elements, etc.).

Based on these preliminary findings and the available documents, including the reports of the local Superintendent of Salerno, the interventions were designed on the assumption of full compliance with the historic and architectural characteristics. They were divided into two main categories: the first based on improving the performance of the building envelope, which also included the deteriorated parts (a "passive" approach); the second consisted of the revision and implementation of the systems (an "active" approach).

As part of the *first macro-category*, the work was carried out relating in general to:

- the elimination of all the pipes and cables on the facade and the simultaneous removal of accretions on the external faces of the structure;
- re-plastering the worst parts, repainting the facades with hydrophobic and insulating paint;

while regarding the improvement of the energy performance:

- insulation of the roof with rock wool insulation panels;
- replacement of windows [12] with high energy performance elements (the windows had been replaced during the first intervention of 2003);
- renovation of the floors in natural glazed terracotta tiles and revision of the "floor" heating.

The *second macro-category* used the most resources, but at the same time entailed a significant reduction of energy consumption, concerning measures for increasing the efficiency of the systems:

- realization of a thermal tri-generation system with the use of geothermal energy;
- replacement of existing lamps with LED lighting with high luminous efficiency and low energy consumption.

The design criteria can be mainly attributed to the principles of *minimal intervention*, *minimally invasive* and *reversible*, while trying to use what innovative system technologies are available so as to increase performance.

The building in question, being in a state of advanced degradation in the early 2000s, had already been the subject of a previous work, with the restoration of some missing structural parts and replacement of some decorative elements. Therefore, solutions were adopted that would not overlapped with the previous works, in order to maintain the *recognisability* of the interventions as much as possible and the *respect of the authenticity* still present. According to this approach, "light" interventions were carried out, which ruled out the insulation of the façade with insulation boards (highly functional in containing dispersions), in order not to alter the stone wall structure.

However, it was possible to remove the existing floor (laid new in 2007), given its low value, and replace it with terracotta tiles made in the area in ancient wood-burning ovens in accordance with traditional artisan production methods. The replacement of the windows (also installed in 2007), with triple glass low thermal transmittance ones was possible since the existing ones did not present any noteworthy characteristics.

The solutions for the systems were designed in full compliance with the historic and architectural value [13], based on apparently conflicting criteria:

- with a logic that hides items by placing them in the structures and masking them with finishing elements. This applies, for example, to the radiant floor panels (Fig. 4), part of the concealed air shafts or pipes, the holes in the subsoil for the geothermal probes;
- with criteria aimed at highlighting the system elements, deliberately showing each component, so as to clearly mark each part added (Fig. 5).

The geothermal energy intervention, associated with the tri-generation, avoided using alternative energy sources,

Figure 4 - *"Floor" heating system (left) and LED lighting (right)*

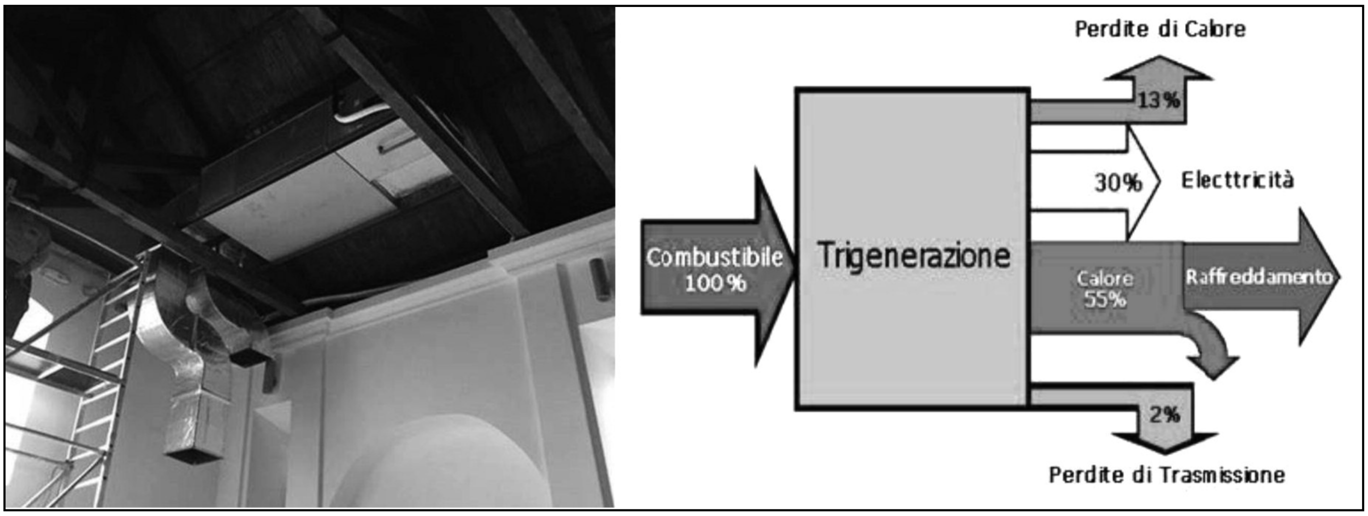

Figure 5 - *Tri-generation system (hot and cool air conducts and operation diagram)*

such as photovoltaic and solar thermal systems, which inevitably would have had a less respectful impact on the characteristics of the building and the place. The eventual use of a photovoltaic system would have only been possible with the relocation of the panels to the surrounding area (a sort of island), which, however, in this case, would have poorly adapted to an environment of valued landscapes.

The geothermal systems[8], in addition to contributing to the reduction of energy consumption, allow for a wider applicability for particularly energy-intensive buildings and whose regeneration is subjected to a series of limitations and constraints, not only related to the importance of the article, but also to the environmental context.

The technology adopted does not allow to completely avoid the use of fossil fuel sources, but rather their more effective exploitation: geothermal energy contributes in part to the contribution of energy for tri-generation, which allows to produce electricity, heat and cooling with energy efficiencies higher than in conventional production systems. Geothermal probes were inserted into the ground, at a depth of 120 metres, by means of drilling, with a diameter of about 15 cm, on the east side external to the building at a minimum distance of about 8-10 metres.

Even with the protection constraints present, the results achieved were satisfactory, as highlighted by the Energy Performance Certificate (EPA) developed *ante* and *post-works*, by means of which it is demonstrated that, compared with an initial consumption of 28,057 kWh/(m^3year), there is a final consumption of 4,510 kWh/(m^3year), going from class G to class A.

4.3 The financial analysis

A Cost-Benefit Analysis (CBA) was carried out, which requires the estimate of the costs (investment and management) and revenues (savings on consumption). From the time schedule, the execution time of the works was estimated at one year: seven months for the construction work, insulating the exterior walls and terraces, pitched roof insulation, relaying the indoor flooring, restoration and painting the interior surfaces, replacing the window frames; 3 months for installing the systems (tri-generation with methane, geothermal, air conditioning with thermo-convectors, electric); 2 months to install the consumption monitoring system, the central control and final testing.

The initial full operation phase is relatively short, with the results of energy efficiency being tangible immediately with the systems coming into operation.

Since this is a building of public interest, the period of analysis was extended up to 35 years [14].

From the bill of quantities, the investment costs were estimated at € 862,659.82. This excluded VAT, but included labour and security costs (Tab. 1).

Periodic maintenance was also planned, including the replacement of both the tri-generation plant engine, as well as the LED light bulbs (respectively € 85,000 and € 2,000 every 15 years).

Following the execution of the works, the overall energy consumption was reduced from 28,057 kWh/(m^3year) up to 4,510 kWh/(m^3year), with an annual saving amounting to € 3,843.70. Additional savings result from the unpaid

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[8] The theme of "geothermal energy for historic buildings" was the subject of a European research project that began in 2015, entitled "Cheap and Efficient Application of reliable Ground Source Heat exchangers and PumpS", as part of the Horizon 2020 program, with the participation of the CNR -Isac (Institute of Atmospheric and Climate Science).

Table 1- *Intervention costs*

Intervention		Costs [€]
A.1.1. Tri-generation and geothermal heating system		466,891.38
A.1.2. Electrical system		53,450.00
A.1.3. Construction work		216,127.48
A.1.4. Consumption monitoring system		15,000.00
A.1. Total amount of work and supplies based on auction		751,468.86
A.2. Safety costs not subject to discount		22,544.07
A. Total work and supplies (A1+A2)		*774,012.93*
B.1. Technical costs, including social security contributions		75,146.89
B.2. Energy Audit	10.000,00	
B.3. Promotion interventions	3.500,00	
B. Total amount available to Administration (B1+B2+B3)		*88,646.89*
Total investment (A+B)		***862,659.82***

costs for the routine maintenance of incandescent bulbs (€ 400 year).

In view of the pre-programmed regular maintenance, the residual value of the project after 35 years was equal to the sum of 70% of the investment cost for the heating system with tri-generation and geothermal energy, and 20% of the cost for the other systems and construction works.

The estimate was made assuming a discount rate of 4%[9], as suggested in the *Guide to Cost-Benefit Analysis of Investment Projects*, 2015 [15]. The results of the Cost-Benefit Analysis are expressed through the criterion of the Net Present Value (NPV), which amounted to € 144,981.86.

This increases if the value of avoided CO_2 emissions is taken into account. In fact, the annual carbon dioxide CO_{2eq} emissions before and after the intervention amount to:

$$CO_{2eq}\text{ (pre-intervention)} = 7{,}753\ kg/m^3 year,$$

$$CO_{2eq}\text{ (post-intervention)} = 0{,}214\ kg/m^3 year.$$

With a consequent reduction of emissions to the extent of:

$$\text{reduction } CO_{2eq} = 0{,}007539\ t/m^3 year \times 2.100\ m^3 = \\ = 15{,}83\ t/year.$$

The Social Cost of Carbon (SCC) for each tonne produced varies from 61.00 to 2011$/t in the first year of the analysis period, up to almost 103.00 to 2011$ /t in the 35th year [16, 17]. The value in dollars in 2011 are discounted based on the average inflation rate for the period. The dollar/Euro exchange rate is 0.8736.

Table 2 summarizes the terms of the CBA including the benefits arising from lower CO_2 emissions. This results in a NPV of € 165,175.56, with an increase of 13.93% compared to the value previously calculated.

5. CONCLUSIONS

Energy efficiency projects of monumental buildings must reconcile conservation requirements and performance increases. Unlike ordinary buildings, defining an intervention type or code of practice is an arduous task, since every precious artefact presents peculiarities related to a constructive history, sometimes stratified over centuries, as well as unique and irreproducible decorative elements. Each case requires a specific study, along with other field expertise, appropriately evaluated, that then become important when updating the general framework of guidelines and standards to which the single initiative, in turn, must comply with.

The work highlights two seemingly opposing aspects. On the one hand, the need to carry out an specific analysis on the monumental building, in accordance with its historical, artistic, architectural and environmental characteristics, as well as in relation to the symbolic and social value it can have for the community. While, on the other, there is the opportunity to carry out studies and define the project activities within specific criteria, shared by the scientific community, legislation as well as market participants.

The theoretical and normative analyses explain how a study protocol could be possible, starting from the

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[9] In the *Guide to Cost-Benefit Analysis of Investment Projects*: "According to Article 19 (Discounting of cash flows) of Commission Delegated Regulation (EU) No 480/2014, for the programming period 2014-2020, the European Commission recommends that a 4% discount rate in real terms is considered as the reference parameter for the real opportunity cost of capital in the long term".

Table 2 - *Estimate of lower CO2 emissions and total cash flows*

Years	Cash flows [€]	SCC [2011$/t]	SCC [2016$/t]	Total saving SCC [$]	Total saving SCC [€]	Total cash flows [€]	Total discounted cash flows [€]
1	0,00	61.00	64.20	0,00	0,00	0,00	0,00
2	4,243.70	62.40	65.67	1,039.56	908,16	5,151.86	4,763.18
3	4,243.70	63.80	67.15	1,062.98	928,62	5,172.32	4,598.18
4	4,243.70	65.20	68.62	1,086.25	948,95	5,192.65	4,438.70
5	4,243.70	66.60	70.09	1,109.52	969,28	5,212.98	4,284.69
6	4,243.70	68.00	71.57	1,132.95	989,75	5,233.45	4,136.07
7	4,243.70	69.20	72.83	1,152.90	1,007.17	5,250.87	3,990.23
8	4,243.70	70.40	74.09	1,172.84	1,024.60	5,268.30	3,849.49
9	4,243.70	71.60	75.36	1,192.95	1,042.16	5,285.86	3,713.78
10	4,243.70	72.80	76.62	1,212.89	1,059.58	5,303.28	3,582.71
11	4,243.70	74.00	77.88	1,232.84	1.077.01	5,320.71	3,456.23
12	4,243.70	75.20	79.14	1,252.79	1,094.43	5,338.13	3,334.18
13	4,243.70	76.40	80.41	1,272.89	1,112.00	5,355.70	3,216.49
14	4,243.70	77.60	81.67	1,292.84	1,129.42	5,373.12	3,102.84
15	4,243.70	78.80	82.93	1,312.78	1,146.85	5,390.55	2,993.18
16	-82,756.30	80.00	84.20	1,332.89	1,164.41	-81,591.89	-43,562.58
17	4,243.70	81.00	85.25	1,349.51	1,178.93	5,422.63	2,783.83
18	4,243.70	82.00	86.30	1,366.13	1,193.45	5,437.15	2,683.93
19	4,243.70	83.00	87.35	1,382.75	1,207.97	5,451.67	2,587.59
20	4,243.70	84.00	88.41	1,399.53	1,222.63	5,466.33	2,494.76
21	4,243.70	85.00	89.46	1,416.15	1,237.15	5,480.85	2,405.18
22	4,243.70	86.40	90.93	1,439.42	1,257.48	5,501.18	2,321.25
23	4,243.70	87.80	92.40	1,462.69	1,277.81	5,521.51	2,240.22
24	4,243.70	89.20	93.88	1,486.12	1,298.27	5,541.97	2,162.04
25	4,243.70	90.60	95.35	1,509.39	1,318.60	5,562.30	2,086.51
26	4,243.70	92.00	96.82	1,532.66	1,338.93	5,582.63	2,013.60
27	4,243.70	93.20	98.09	1,552.76	1,356.50	5,600.20	1,942.24
28	4,243.70	94.40	99.35	1,572.71	1,373.92	5,617.62	1,873.35
29	4,243.70	95.60	100.61	1,592.66	1,391.34	5,635.04	1,806.89
30	4,243.70	96.80	101.88	1,612.76	1,408.91	5,652.61	1,742.80
31	-82,756.30	98.00	103.14	1,632.71	1,426.33	-81,329.97	-24,111.10
32	4,243.70	99.20	104.40	1,652.65	1,443.76	5,687.46	1,621.25
33	4,243.70	100.40	105.67	1,672.76	1,461.32	5,705.02	1,563.71
34	4,243.70	101.60	106.93	1,692.70	1,478.74	5,722.44	1,508.16
35	564,972.58	102.80	108.19	1,712.65	1,496.17	566,468.75	143,551.95

historical, technical-dimensional characteristics as well as the energy audit of the building, aimed at the most effective selection of the work to be carried out, emphasizing the economic-financial results of the investment as well in view of new and more profitable uses.

In addition, the case study showed how to proceed in selecting concrete actions to improve the energy performance of the Convento dello Spirito Santo in Pellezzano (SA), while respecting the constraints that are present when the object of investment is a monumental building.

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