Energy efficiency in historic buildings

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1. ENERGY EFFICIENCY IN HISTORIC BUILDINGS

The particularity of cultural heritage and its interaction with the theme of energy efficiency has often been analysed either for the purposes of integrating climate control systems in listed buildings, which can be quite a complicated problem [ASHRAE, 2003] [CIBSE, 2002], or in the framework of the conservation of cultural heritage, using approaches which at times can be overly sectoral – [Tetreault, 2003]. Within the broad definition of cultural heritage (Fig. 1), energy issues need to be considered, firstly, in relation to buildings of historical and cultural importance, an important category as regards energy consumption [De Santoli, 2009]. In this case, therefore, we shall speak of the *historic building*, i.e. a building that has value as a historical landmark and as a testimony of cultural heritage. See also [EHS, 2004] [Jokilehto, 2007] for an operational definition of a historic building. An analysis of the distribution of Italy's real estate provides an indication of the high incidence of buildings built before the middle of last century.

In the case of historic buildings, complete lack of compliance with the European directive 92/CE/2002 is not acceptable. In fact, even in the most delicate cases, such as when decorated surfaces or fixtures of particular value make it impossible for work to be carried out on the building envelope, it is still possible to improve energy efficiency, sometimes quite effectively, using, for example, efficient energy production systems, renewable energy systems and appropriate monitoring and management technologies, while respecting the historical, artistic and landscape values of the buildings.

Directive 2002/91/EC on energy efficiency in buildings, recognizing the particularity of cultural heritage, in Article 4, paragraph 3 states that "*Member States may decide not to set or apply the requirements introduced for buildings and monuments officially protected as part of a designated environment or because of their special architectural or historic merit, where compliance with the requirements would unacceptably alter their character or appearance*". These indications were included in Legislative Decree 192/05 and then Legislative Decree 311/06, which in Article 6 states that "*This decree does not apply to [...] buildings that fall under the regulations of Part II and Article 136, paragraph 1, letters b) and c) of Legislative Decree 22 January 2004, No 42, listed under cultural heritage and landscape, when the requirements involve an unacceptable alteration of their character or appearance, especially their historical or artistic characteristics; (...)*". In fact, buildings of particular value are not required to comply with energy efficiency requirements as specified by law if producing an unacceptable alteration to the building. This does not mean that the goal of energy efficiency should not be pursued for historic buildings; in these cases even small improvements in energy efficiency would be acceptable.

It is the duty of the Ministry of Heritage and Culture to identify a single code of conduct for the approval or rejection of energy efficiency interventions on historic buildings, especially now that there is legislation providing incentives, such as for the generation of electricity from photovoltaic panels, depending on the degree of architectural integration achieved [DM 02/19/2007, Feed-in tariff]

According to this criterion a system is fully integrated when it replaces a structural part of the building; this could lead to negative impacts not only on the appearance of historic buildings but also their material consistency, leading to the unacceptable replacement of old bearing structures, with often minimal improvements in energy efficiency.

In fact, in most cases the best course of action when carrying out work to improve energy efficiency is to reduce as much as possible negative impacts the appearance of the buildings; improvements can be quantified in terms of reduced primary energy consumption.

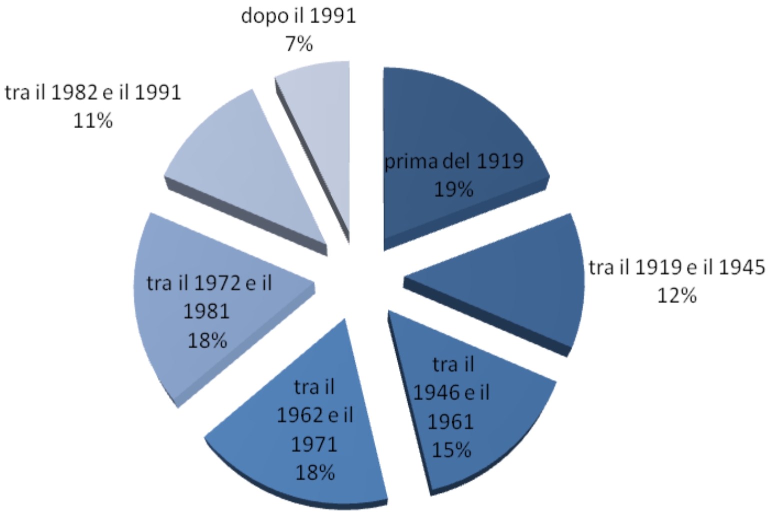

Figure 1 - Classification of Italian residential buildings by date of construction (Source XIV Housing Census, 2001)

2. THE PROTECTION OF HISTORIC BUILDINGS

Energy efficiency work on historic buildings should be carried out bearing in mind the significance of the protection of cultural heritage.

The Code for Cultural Heritage and Landscape (Legislative Decree No 42 January 22, 2004), Article 1c, 2, states: *"The protection and promotion of cultural heritage contributes to the preservation of the memory of the national community and its territory, and promotes the development of culture."* This opens a debate on the significance of energy efficiency and its value in the context of cultural heritage: efficiency interventions should not be understood in terms of mediating conflicting needs (conservation-innovation), but as an instrument for attaining protection objectives.

A benchmark for the implementation of a proper policy for the protection of heritage is, among others, the 1964 Venice Charter, for both the monument itself and its environment; the Charter extends the concept of monument also to works which, albeit of a modest nature, have acquired over the centuries a marked cultural value. Territorial planning, involving the drafting of landscape plans, must be conducted in accordance with the principle of preserving diversity and avoiding changes to the landscape.

In October 2000, the Landscape Convention was signed in Florence by 27 European countries. The document codified a shared view of "landscape" and defined what actions may be taken to "protect", "manage" and "plan" landscape. Landscape is a complex mix of natural features and randomly placed or planned man-made landmarks, which together establish the identity of a place. It is the perception of this identity that differentiates land from "landscape."

In particular, "landscape management" means work undertaken, from the perspective of sustainable development, to ensure landscape governance, orienting and harmonizing the transformation produced by social, economic and environmental development processes. Included in this is the pursuit of energy efficiency.

Thus, it is important to include any territorial interventions (and therefore also interventions on historic buildings) within a context of planning and design, because any territorial transformation, if not planned and programmed, risks damaging the landscape. It is, therefore necessary, to develop appropriate tools for the planning and design of interventions.

3. PRINCIPLES FOR THE INTEGRATION OF INTERVENTIONS

The Ministry of Heritage and Culture promoted the elaboration of "Guidelines for the efficient use of energy in cultural heritage" [various authors, in press]. They provide guidelines for assessing and improving energy performance in protected cultural heritage, referring also to Italian regulations on energy conservation and the energy efficiency of buildings. They are intended to provide guidance not only to project designers but also the regional offices of the Culture Ministry. The former are given guidelines for assessing the existing energy performance of historical buildings and for designing interventions to improve energy efficiency, conceptually similar to those for unlisted buildings, but tailored to the needs and specificities of cultural heritage. In addition, the Culture Ministry's regional offices for the protection of cultural heritage are given guidelines for assessing, as objectively as possible, both energy efficiency and the degree of conservation guaranteed by the intervention.

The energy performance of a building defined by Legislative Decree no. 192/05 and subsequently Legislative Decree 311/06 as "*the amount of energy actually consumed or required to meet the different needs arising from a standard use of a building,*", is assessed using the EP performance index, which takes account of annual primary energy demand for a unit surface area or volume of the building in question. The calculation of primary energy includes, of course, improvements in the characteristics of the building envelope and the use of renewable sources.

As mentioned earlier, any project for the improvement of the energy efficiency of a historic building must indicate the level of technological and landscape integration at different scales of study: microscale (building-systems), mesoscale (street, square), and macroscale (land). The DPCM Technical Annex 12/12/2005 (*landscape report*) makes no explicit mention of this, but the need for different scales of study is found in many guidelines elaborated in both Italy and abroad. For technological integration, in its broad sense, reference can be made to feed-in tariffs, which identify two levels of integration (partial or total).

For the application of these principles, the guidelines refer to existing regulations involving non binding methods, which, given the nature of progress, may be subject to changes and updates.

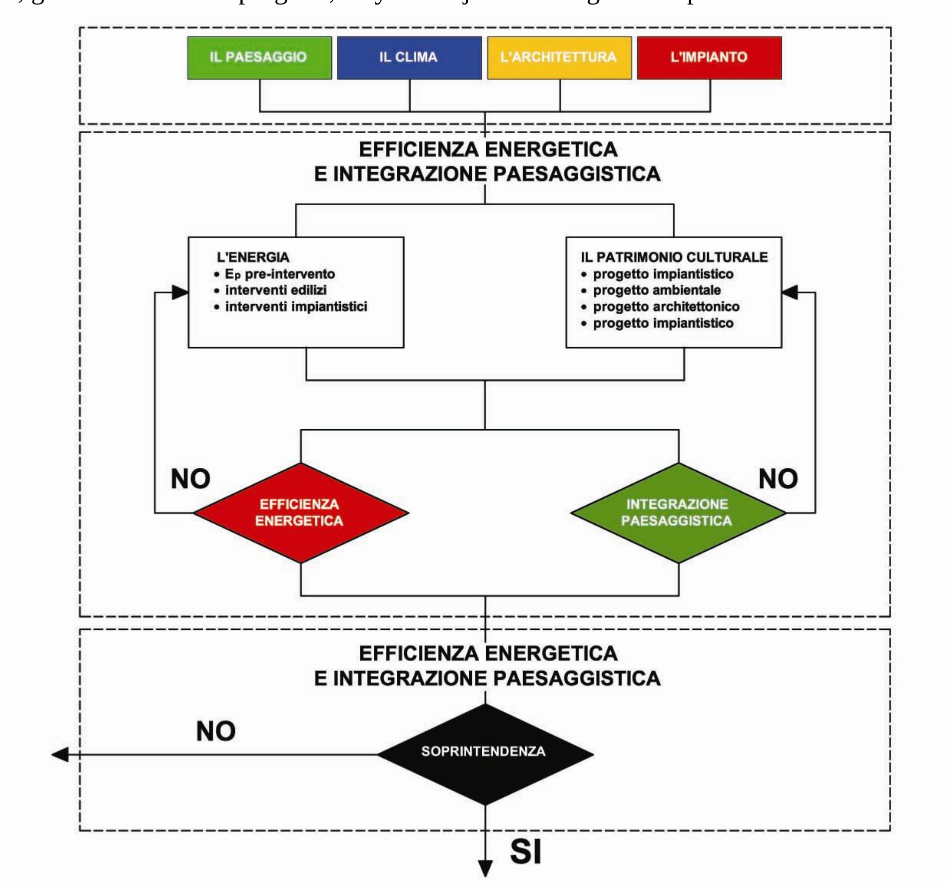

Figure 2 - The chart used in the Guidelines for energy efficiency in cultural heritage

The guidelines are ideally structured along a logical path that the designer should follow in elaborating a proposal for energy efficiency improvement to be submitted to a regional office (Figure 3).

The project should be clearly structured around the theme of energy, defining a range of possible strategies aimed at improving energy efficiency as regards both the building envelope and energy generation.

On the basis of the different project proposals, the post intervention energy situation is identified, specifying single energy performance values, so that they may be compared with the pre-existing situation.

From the viewpoint of technological and landscape integration, interventions that do not involve some degree of integration are unacceptable. The tool used for this assessment is an integration level matrix, compiled by the project designer on the basis of the documentation produced.

Integration is assessed at different intervention scales, in accordance with the following criteria:

- Technological (degree of structural replacement)
- Type (vertical and/or horizontal),
- £impact on landscape (morphological, formal and chromatic).

The matrix, compiled by the project designer, is assessed by the Regional Office and is the information summarized therein is then compared to the energy assessment result.

4. IN-DEPTH KNOWLEDGE

Energy efficiency can be used as a protection instrument only through in-depth knowledge of the target object (see also Figure 3).

Improved energy performance of historic buildings is usually achieved by modifying the architectural organism, which often can significantly impact the characteristics that define its cultural value. Much of the cultural heritage of our country is dotted around the country and sometimes made up of a group of buildings, which, although not of major importance, together define the specificity and historical memory of a particular place. It is an extremely fragile system, which is vulnerable to even small changes as regards exterior building morphology and colour. This is why it is important for the designer to gain an awareness of the work involved through in-depth knowledge of the building to understand fully the nature of the construction and the role it plays in the landscape. Improvements in energy efficiency should, therefore, be designed to preserve the qualities that define the character of the historic building, which in some cases may also be subject to the restrictions set in Legislative Decree 42/2004.

The learning process must begin with a survey of the geometrical, structural, material and stratigraphic characteristics of the historic building, together with an analysis of the pre-existing climate control systems and the requirements related to the present needs of the use made of the building, thereby ensuring a shared awareness among the project designers involved in the process of controlled modification of cultural heritage.

With good knowledge of the evolutionary process of the architectural organism and the technological systems adopted in the historical building, the following typologies can be distinguished:

- Existing obsolete systems;
- Existing malfunctioning or faulty systems to be replaced or removed;
- Obsolete systems of historical interest, which for this reason should be preserved and in some cases integrated into the new system.

The third typology leads us to reflect on the assessment of historical value through knowledge of the evolutionary process of climate control systems in the history of technology and architecture.

The technological-historical heritage of climate control systems can be compatible with the criteria used by ICOMOS for the inclusion of a particular site in the *World Heritage List*[1]. One could suppose that a historic system, as a precursor of future applications, deserves to be preserved in the same way as a historical building, not only because of the interaction between it and the building, but also because of its testimonial value within the history of technology.

These principles are particularly important in the case of historic industrial buildings, in which the systems and the technology are an essential part of the architecture. A study of the ruins of an old industrial area could never produce completely satisfactory results if it did not start with an analysis of the equipment and technologies found at that particular site.

Although in non-industrial buildings, old systems play a different role, we should not overlook the testimonial value of the technological aspects of historic buildings, taking them into account when analyzing the evolutionary process of the building.

A particularly important aspect in the diagnosis of a building (such as degradation, materials, static consistency, etc) is the geometry, to understand how easy or difficult it will be to install a system, a vital process that links the learning phase to the design phase of the energy performance improvement project. A technical drawing should show the building's stress points and motion points, as defined below:

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[1] The sites in the *World Heritage List* must, in addition to the criteria of authenticity, comply with one or more criteria from a list of 6 criteria for cultural sites and 4 criteria for natural sites. Cultural sites have to:

- to represent a masterpiece of human creative genius
- to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design;
- to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared;
- to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history;
- to be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change;
- to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (this criterion should preferably be used in conjunction with other criteria);

- Invariable areas: the parts of the building where it would be difficult to make any alternations for many different reasons, the presence of bearing structures, elements of special value, or deterioration. These conditions can arise, therefore, when alterations cannot be made without causing damage to the building;
- Changeable areas: parts of the building which can be used to host new elements, suitable for laying pipes and wires of different systems. The survey should highlight, then, passages, paths, wells, flues and all other types of openings, before an assessment is made of what they could host.

5. THE IMPROVEMENT OF ENERGY PERFORMANCE

The assessment of a historic building's overall energy performance must be done both before and after the proposed interventions. Among the interventions analysed to calculate primary energy, the guidelines include those on the building envelope, those regarding energy production systems, and those concerning renewable energy sources.

The energy performance of a building is the annual amount of energy actually consumed or expected to be required to meet the different needs arising from a standard use of the building, including winter and summer air-conditioning, hot water production for sanitary systems, ventilation and lighting.

Overall building energy performance is expressed through the global energy performance index *EPgl*, which is annual global energy expressed in terms of primary energy referred to the gross volume of the building:

$$EPgl = EPci + EPacs + EPce + EPill$$

where:

EPci: is the energy performance index for winter heating;

EPacs: the energy performance index for the production of hot water;

EPce: the energy performance index for summer air conditioning;

EPill: the energy performance index for artificial lighting.

In the case of historic buildings, all indices are expressed in kWh/m^3year.

The calculation of building energy performance indices are based on the method described in the technical standards and subsequent amendments [UNI TS 11300].

Given the increasing use of energy for cooling buildings, these aspects should also be taken into account in the preparation of UNI TS 11300 Part 3, currently in the discussion phase, on the calculation of primary energy for summer cooling.

On the basis of proposals for energy efficiency improvement, an evaluation should be made of the post intervention building energy performance situation, with the specific identification of single energy performance index values, so that they may be compared with those referring to the prior situation.

Interventions that do not produce a certain percentage of total primary energy saving, depending on the size of the building under consideration, should not be submitted.

A matrix is also used for the evaluation of primary energy savings, compiled by the project designer on the basis of the documentation produced, to be assessed by regional office and is the information contained in it is compared to the result of the integration assessment.

CONCLUSIONS

The complex nature of the interaction between cultural heritage and energy efficiency, even when only referred to historic buildings, has led to the emergence of difference and separate types of expertise, creating counterproductive conflicts between innovation and conservation. To overcome this conflict a different approach must be used by both project designers, who must pursue the objective of well-defined landscape integration, and by those working in conservation, who should consider energy efficiency as a powerful instrument to boost protection. The hope is, therefore, that an instrument to implement this process can be defined.