# Historical buildings: energy performance and enhancement

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## 1. Introduction

The issue of energy efficiency arises as a result of rethinking the use of non-renewable sources and it is linked to economic and political factors and, in a wider sense, it has the purpose of ensuring sustainable choices. Due to the fact that 30% of the existing buildings are classified as historic heritage[1], as underlined in the last European Directive[2], it is very important to find effective policies not only for the construction of new buildings with low energy consumptions, but also with the refurbishment of the existing ones.

Improving the performance of buildings with particular values is very complex because it is necessary to balance different requirements. It is also useful to recall that the concept of “value” has been enriched by many meanings and nuances, well beyond overcoming and limiting categories that define the singularity of a few number of monumental objects. The paper will briefly outline how this problem is considered, in order to highlight weaknesses and threats that have already produced unnecessary losses and replacements of the characteristic elements of the historical heritage. The challenge of improving energy efficiency in historical buildings can be achieved only through the construction of a more relevant framework.

## 2. Potentiality of ancient buildings

Differently from a lot of post-war buildings, the ancient buildings are characterized not only by “weaknesses” but also by many “strengths”. The latter have been built in periods in which the heating, ventilation and air-conditioning (HVAC) plants were not in existence. For this reason, they have to take full advantages of the available natural resources. The empirical knowledge of our predecessors, therefore, included the ability of using building exposition, natural ventilation, conformation of the ground, presence of water and vegetation in order to achieve the maximum benefits in the mitigation of the indoor climatic conditions. This aim was achieved also through the shape of the building and the contribution of constructive system of walls, floors and roofs, realized with insulating and porous materials. The thermal mass and the high thickness of the envelope facilitates the liveability during the entire year. The microclimatic regulation is also reached through the different size of the windows in various orientations and the use of “functional additions” such as porches, galleries and pergolas that provide heat protection in summer, at the same time, allow the winter sun to warm the walls. Also the splays of the windows are not identical but they are inclined in a different way, to better catch the prevailing winds. Finally, the internal microclimate is also improved through simple solutions such as covering the floors directly with straw or grass in contact with the ground, raising the beds on wooden platforms, using tissues on walls (or arazzi and tapestries in important spaces), having inside shutters and heavy curtains on the windows. Similarly, the outdoor staircase avoids the unwanted heat transfer, on the contrary the wooden structure of flo-

ors transmits the heat to the upper rooms usually unheated. These examples are known and recalling them isn't nostalgia, but simply they indicate that the ancient buildings have great potentialities.
The current tendency not to consider the differences and try to resolve the issue in purely technical terms, leads to an excessive intervention or probable occurrence of future deteriorations. For example, the thermal transmittance of ancient masonries provide a clear idea: the heat flux meter measurement realized in situ on 21 old buildings (66 measurements) shows a higher thermal performance (up to 25%) compared with national standards (standard UNI TS 11300:2008)[3]. In stone walls, the gap is more pronounced, probably because the internal presence of voids and air is not considered. In the brick masonries, the deviation is probably due to the different porosity between ancient and modern bricks, those are produced in a different way. The ancient walls, therefore, behave better than our thinking based on daily experience. This leads to the obvious consideration concerning the poor knowledge of constructive characteristics and energetic performances of ancient buildings and the enormous importance of a correct evaluation. We see the repetition of mistakes already made in the past, for example in the field of structural consolidation where the lack of knowledge of the behaviour of ancient architecture led the over abundance of interventions, with errors and damages today unfortunately marked. The long debate has recently led to an intervention logic defined for improvement, enhancing the existing resources without thinking of carrying out any adjustment to achieve performance similar to those required for new buildings[4].

**3. Legislative framework**

A second important point in this framework concerns the legislation that governs the field of intervention to increase energy efficiency. In fact this is an important mirror to understand how the issue is perceived. In a nutshell, it must be stressed that there is no differentiation in the tools and interventions for ancient and modern buildings, if not for the possibility of derogation. The Italian law (literally adapted from European Directives) specifies that the buildings included in the cultural heritage classification are specifically excluded from the regulations when the intervention produces an unacceptable alteration of their aspect[5]. The recent legislative changes also eliminated this step, supporting the "deregulation" for listed buildings.
The use of deregulation of course tends to solve the conflict between conservation and thermal requirements, but that should be seen more as an opportunity for a conscious approach, and not a way - as often happens - to remove the problems. If the aim is rather to take up the challenge of improving energy efficiency to ensure a long-lasting use of the historic buildings, this should be achieved without losing the richness of values that they possess. The energy behaviour of historical artefacts could be achieved in more appropriate way, and in respect of conservation practices, applying the same approach currently used in Italy in regard to the seismic regulations: an old building does not require to achieve the same level of safety (transmittance efficiency in this case) of a new building. Nevertheless, they require the demonstration of an

improvement in the seismic worthiness. In other laws, i.e. the one regarding the problem of the architecture barriers, the use of the derogation is intended more precisely: it promotes alternative solutions compared to those imposed, however, keeping fix the goal to achieve. Also, in the anti-fire legislation, there is the possibility of achieving a level of “equivalent safety” through the use of active and passive measures. However, in this specific context, we are not considering yet in the same way. There are two possibilities: making interventions respecting the prescriptive measures or no interventions.
The Italian law imposes the minimum requirements for energy performance (both for the heating and air conditioning) for the refurbishment of buildings having the surfaces higher than 1000 $m^2$. On the other hand, the law imposes the minimum requirements of the thermal transmittance of any elements under refurbishment if the surface of intervention (total or localized refurbishment, extraordinary maintenance) is smaller than 1000 $m^2$. In general, updating a single building is an intervention belonging to the second category (typically the refurbishment of a building in a historical district).
The energy balance of a wide and totally refurbished building should be evaluated globally, this way it is possible to maintain elements and parts with different levels of performances, because they make up for their application. Instead, in the case of small surfaces of intervention, it is possible to upgrade the energy efficiency only in this way: to increase the efficiency of the single element under refurbishment (roof, windows, masonry, etc.) up to the acceptable U-values (which are strictly defined by law), without any possibility to evaluate the global improvement of the building performances by “treating or adding” lacks and excellence. Therefore, the final results can only be the substitution of parts of the existing buildings with high performances elements and materials.

## 4. Historical centers

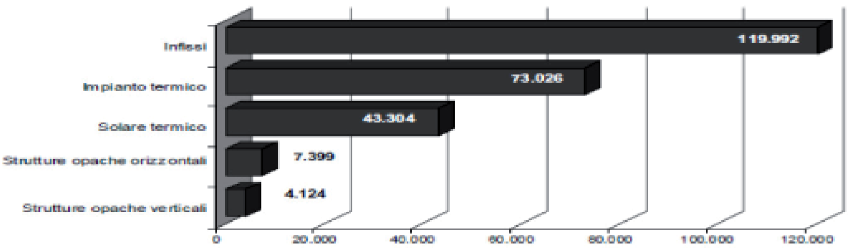
As we have seen, in a listed building it is possible to apply the derogation tool, but in the historical centres, the situation is most paradoxical. The protection activities, which the state reserves to itself through its members operating in the territory (the *Soprintendenza*), cannot be exercised where a planning instrument of government land was realised before 1985, except where a landscape bond must be respected. Urban planning and building regulations, in practise, defines what is allowed or not. The analysis of about 30 municipal planning instruments, identified as especially virtuous by a recent report of *Legambiente*[6], shows the absence of policies that define different rules for the buildings of historical centres. The municipalities are considered virtuous for the system of volumetric incentives or of reward for reducing taxes when the energy efficiency has been improved, without any concern for the protection, or a mindless rush to define lower transmittance limits. In the historical centres, a strategy must be defined to obtain a sensible and integrated energy improvement, without turning the fabric into a chaotic current building stock. Needless to prohibit the use of photovoltaics (PV) in town centres, rather it is possible to think the appropriate ways of integration or to study their placement. Also, in these areas, it is necessary to design different heat distribution systems. Therefore, in the historic centres, a coordinated policy is missing to indicate strategies and opportunities that cannot be reduced with volume incentives in order to compensate a behaviour deemed virtuous, as the replacement of windows.

## 5. Tax incentives for the replacement of traditional windows

The inappropriate application of regulations has already proved to provide disastrous results, as in the case of the Directive 93/76/EEC on Energy Efficiency (SAVE), later repealed, whose purpose was the economic incentives for the replacement of windows in buildings already energy efficient. This has resulted in the loss of many traditional windows in Hungary, Finland, Norway, United Kingdom, etc. (Fig.1).

Fig.1 - Old removed windows. (photo by Roger Curtis)

In Italy as well the incentives linked to potential energy savings lack effective regulation and the necessary corrective measures to address different specificities. Coupled with the widespread lack of knowledge among stakeholders, this is producing extensive and inappropriate replacement of building elements. Moreover, Italy is in a condition similar to the one of other European countries: replacements of fixtures are almost half of the total replaced elements of all the buildings that have obtained incentives for energy efficiency (Fig. 2). A recent report ("Analysis of the socio - economic impact of 55% tax deductions for upgrading the energy efficiency of existing buildings")[7] says that "the massive usage of windows replacements does not involve significant energy savings in the context of the various interventions." (Fig. 3).
The average annual savings achieved, by type of work, in fact shows that replacement of windows has the lowest energy saving (2.6 MWh). Translated into monetary terms this is about 164 € (source ENEA) or between 80 and 125 € (source CRESME), with payback achieved in 12 -15 years. The Italian



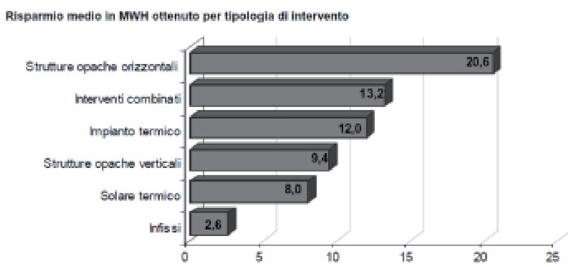




Fig.2 - Retrofit actions on buildings in 2008 (source: CRESME, July 2010); Fig.3 - Average savings in MHV per type of intervention (source: CRESME, July 2010)

Ministry of Economic Development was proposing a revision of the incentives mechanism as “it is not appropriate to claim for above the line performance of the transmittances at our latitudes with risk of fake or useless benefits, without paying attention to walls, floors and roofs as well”.

## 6 .A sustainable policy?

Another main reason for intervention should be seriously considered is environmental sustainability. In this regard, a research carried out in Norway[8] based on quantitative data, concluded that the adoption of new more efficient windows can reduce the energy consumption throughout their entire life cycle, at the cost of eight times increase in $CO_2$ emission in the atmosphere, due to the entire production cycle, including the cost of extraction, production, use, disposal of the old and new materials (Table 1).

| | Electricity GJ | Fossil GJ | Total GJ | $CO_2$ g | $SO_2$ g | $NO_x$ g | VOC g |
|---|---|---|---|---|---|---|---|
| **Old windows with single glazed inner frame** | | | | | | | |
| Production and replacement | 1 | 3 | 4 | 87058 | 451 | 1953 | 182 |
| Use | 12524 | | 12525 | | | | |
| Dismantling/Demolition | | 0 | 0 | 114 | 0 | 2 | 0 |
| Total | 12525 | 3 | 12529 | 87172 | 451 | 1955 | 182 |
| **Old windows with double glazed inner frame** | | | | | | | |
| Production and replacement | 2 | 5 | 8 | 130196 | 793 | 3594 | 247 |
| Use | 11993 | | 11993 | | | | |
| Dismantling/Demolition | | 0 | 0 | 194 | 0 | 3 | 1 |
| Total | 11995 | 5 | 12001 | 130390 | 794 | 3597 | 248 |
| **Coupled double glazed windows** | | | | | | | |
| Production and replacement | 12 | 26 | 39 | 713457 | 3978 | 17451 | 1408 |
| Use | 12002 | | 12002 | | | | |
| Dismantling/Demolition | | 0 | 0 | 1057 | 1 | 17 | 3 |
| Total | | 26 | 12041 | 714513 | 3979 | 17468 | 1411 |
| **Energy windows with Argon** | | | | | | | |
| Production and replacement | 13 | 21 | 35 | 766169 | 3450 | 13750 | 1678 |
| Use | 11878 | | 11878 | | | | |
| Dismantling/Demolition | | 0 | 0 | 1032 | 1 | 16 | 3 |
| Total | 11891 | 21 | 11913 | 767201 | 3451 | 13766 | 1681 |

Table 1 Energy and environmental impact from windows from a period of 90 years (source: Fosdal, 1996)

It appears clear that something is profoundly jarring within these arguments on environmental sustainability and the current way of addressing this issue. Moreover, another aspect of our modern deleterious cultural climate emerges from the examination of the case concerning the windows. The lack of maintenance and management practices, that was rather a common practice in the past, because of preserving something that could not be replaced. Figure 4 reproduced below, which comes from studies offered by English Heritage, shows how simple actions and objects (heavy curtains, close the shutters, double windows, etc.) are highly effective methods for improving the energy behaviour of windows.

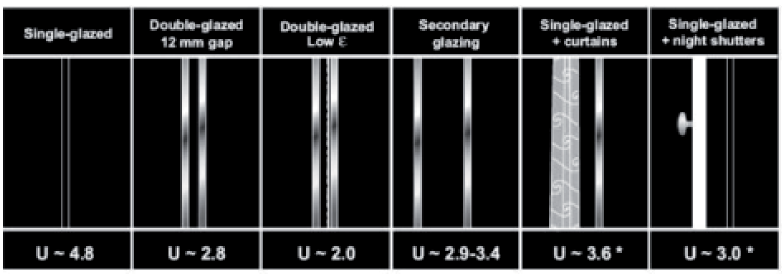



Fig.4 - Comparison of U-values of several type of windows (source: English Heritage, 2008)

Finally, the most important issue to be discussed for a conservator of existing buildings is the great underestimation of the meaning - in terms of the history of material culture - of the ancient window frames. “Windows are important historical witnesses. They can tell about a variety of aspects, such as the evolution of design intention and technical possibilities, regional traditions in the use and processing of materials, social structures and habits”[9], hence the assumption that preserving the windows means that “with the transmission of a quantity of information to future generations, the qualities given by the correlation between windows, façades and interiors are preserved and an economical use of resources is ensured”.
Re-reading the ancient wisdom of those who manufactured windows and doors means to understand the necessary qualities of wood, its different seasoning, the intriguing history of timber manufacturing and glass production, as well as the craftsmanship of their producers. A “know-how” produced by centuries-old traditions that allows, as demonstrated by the aforementioned Norwegian research, windows with a capability of 250-years period service, even if exposed to fierce weather conditions. Also constant care and maintenance are the result of an ancient knowledge. Modern fixtures that characterize the architecture of the Modern Movement, wrongly considered impossible to maintain, have different technical problems, but identical at conceptual level. In this regard the refurbishment on the building of the Bauhaus in Dessau, allowed an improvement in the overall energy balance with a limited replacement of windows, thanks to the synergy of different strategies, especially related to the displacement of features and the integration of alternative energy sources[10].

**7. Tools for the evaluation of thermal behaviour of the ancient buildings**

Therefore, not only an appropriate legislative framework is needed but also “ad hoc” calculation tools and methods, a knowledge of historical building techniques and materials behaviour are essential. An accurate audit, as a matter of fact, is the first step to identify the suitable intervention. Also, retrofit actions based on an incorrect understanding of the energy performances can cause serious physical damage and possible legal claims. Moreover, current criteria, parameters and tools for energy evaluation are thought mainly for modern buildings. Therefore, the weaknesses regard the lack of suitable information on building techniques, materials (it is difficult to know and therefore to calculate the correct stratigraphy due to the many possibilities of composition and variation of materials), the difficulty of entering data related to ventilation, moisture contents, surface mass etc. of the structures. As a result, these calculation tools have a low flexibility to the application on historical buildings, and their modelling is not reliable apart from adjusting the inputs appropriately to obtain results close to the experimental data, and this requires the tight collaboration between the experts of restoration and building physics. The most common calculation tools, both static and dynamic software, use the same evaluation methods and parameters for modern and ancient constructions. The dynamic software is better than other tools for assessing energy performance of historical buildings. Unfortunately, it does not contain sufficient library of information regarding the technical terms and the properties of historical elements and their interaction. This necessitates to create and develop new specific database of the construction techniques used in historical buildings[11]. A more adherent energy evaluation may calibrate the retrofit actions, avoiding strategies or technological solutions that can have negative effects on it.

**8. Energy retrofitting**

As explained, a reliable assessment of the energy efficiency of historical buildings results only from the application of experimental diagnostic. To determine the real performances of the building, together with the collection of the documentation on the consumption and use, the energy audit is required. Nevertheless, in the common practice, the energy audit is preferable and it's the only assessment that the professionals achieve, because the diagnostic is considered an additional cost to reach the same goal, that is the evaluation of energy consumption. The standard does not require to detect the weak elements to possibly improve, therefore, the final digit of the consumption is enough to classify the building. As shown, the standard requirements mislead the professionals evaluation from the overall assessment of the buildings.

The way the problem is defined, it is not difficult to imagine that the actions to obtain high energy efficiency must be tailored to the real needs little or even incorrect, such as internal insulation, interior plasters or ECTIS in the interior side of the masonry. The application of interior plasters with high thermal performance seems to have a wider appreciation, obviously only in the case where the existing plaster has not any historical and artistic value. Nonetheless, the application of an interior insulation changes the thermal behaviour of the masonry: during the winter, insulation prevents heat accumulation in the mass of the wall, that is one of the advantage of the old masonry, therefore the exchange between the air inside the room and the wall becomes faster. During the summer, the solar radiation propagating across the masonry reaches the interior insulation, and then the interior, increasing the air temperature inside the room. Hence, it is possible to keep constant air temperature of inside rooms only by increasing the use of cooling plant, and consequently, increasing the cost for heating/cooling. Therefore, the interior insulation increases the comfort but increases also the cost to keep it constant. For this reason, this intervention is recommendable only if the building is used occasionally. A removable device that could be installed during the winter and removed in summer could join the advantage of insulation layers and thermal inertia of historical masonry, but the market does not offer this solution yet. At last, the insulation has to be transpiring, permitting the exchanges of water/vapour from the masonry to the air inside the room. As it is a well-known criticality also for the contemporary buildings, for the ancient ones is even more critical because of the higher porosity of the materials traditionally employed.

There is a risk of using automatic procedures, that may be valid in new buildings, but that has little sense for the historic ones. We have already seen the case of the replacement of the windows, that has a modest contribution to a real energy improvement, except within a wider arc of calibrated interventions. Similarly, the widespread practice to insulate the roof is not always necessary

in large buildings or churches. In a very large and very high spaces, also, does not make sense to heat the whole environment, but only what you need with a radiant system that contributes to the thermal comfort to the height of 2 meters. Of course, it is necessary to remember that in addition to the actions on the building it is possible to consider the design of the surrounding space. In this sense, the ancient centres are models to be rediscovered. Particularly, the integration with natural elements, such as vegetable and water, will prove to be valuable aids.
Finally, the idea behind the legislation should be quashed: that in case of historical buildings with values, since you cannot do everything, it is better not to do anything. As De Santoli refers: “Even in the most critical cases ... where it is not possible to operate on the envelope is still possible to work on improving energy efficiency. For example, you may provide energy production systems and high-efficiency technologies for monitoring and managing the most appropriate”[12].

## 10. Conclusions

As a matter of fact, the knowledge of the energetic behaviour of old buildings has not yet been studied in an adequate way with respect to their complexity, nor there is an agreement about the ways of upgrading general performances taking care of cultural values. At present, common practices are set without following any guideline and shared priority. It seems that at the moment a comprehensive theoretical work that analyses in depth the close relationship between sustainability and conservation is still lacking. As well as a vision that takes into account the most recent approaches in conservation, that provides procedural strategies, emphasis in the importance of management, control and preventive maintenance, with the aim to reach a higher energy efficiency in the historical buildings. It is time to collect and use the suggestions that come from the past, when sustainability was a matter of life or death, and to invest in it our advanced technology for creating new systems, elements and behaviours for ensuring the best use of our present and future.

Notes

[1] See: European Commission, 2010, *Energy-Efficient Buildings Multi-Annual Roadmap And Longer Term Strategy*, European Commission, Bruxelles.

[2] See: European Directive 2012/27/UE.

[3] See:

- R.S. Adhikari, V. Pracchi, A. Rogora, E. Rosina, 2011, *La valutazione delle prestazioni energetiche negli edifici storici: sperimentazioni in corso*, «Progetto sostenibile», n. 28, pp.20-27.
- R.S. Adhikari, E. Longo, V. Pracchi, A. Rogora, E. Rosina, G. Schippa, 2011a, *Energy behaviour in historical buildings: limits and potentials for the project evaluation*, in PLEA 2011, Conference Proceedings of the 27th Conference on Passive and Low Energy Architecture, Louvain-la-Neuve, Belgium, pp. 515-520.
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*Transmittance of the Opaque Vertical Walls in the Historical Buildings*, in Juan Reiser, Cecilia Jiménez and Susana Biondi Antúnez de Mayolo, Proceedings of 28th International PLEA Conference "Opportunities, Limits & Needs".
- P. Baker, 2011, *U-values and traditional buildings. In situ measurements and their comparisons to calculated values. Historic Scotland*, Historic Scotland, Edinburgh.- European Project SECHURBA, *Sustainable Energy Communities in Historic Urban Areas*, www.sechurba.eu.

[4] See: Art. 29 of Law number 42 issued on 22 of January 2004 "In the case of real property, situated in declared earthquake areas in accordance with current legislation, the restoration includes the intervention of structural improvement" and Guidelines for the evaluation and reduction of seismic risk for the cultural heritage aligned with the new technical standards for buildings (d.m. 14 Jannuary 2008).

[5] See: D.Lgs. 311/2006 Art. 3 comma 3.

[6] See: Legambiente, 2013, *Comuni Rinnovabili*, Legambiente, Roma.

[7] See: CRESME, 2010, *"Analysis of the socio - economic impact of 55% tax deductions for upgrading the energy efficiency of existing buildings"*, CRESME, Milano.

[8] See: S. Fossdal, 1996, *Windows in existing buildings - maintenance, upgrading or replacement?,* Project report.

[9] See: B. Furrer, 2003, *Le finestre degli edifici storici*, Commissione Federale dei Monumenti Storici.

[10] See: Stefanie Schneider e Yvonne Tenschert, 2011, *Bauhaus Dessau Foundation*, Dessau.

[11] See:
- R.S. Adhikari, E. Lucchi, V. Pracchi, 2012, *Efficienza energetica dell'edilizia storica. I sistemi di valutazione statica e dinamica: caratteristiche, limiti e potenzialità*, in Atti del 30° Convegno Nazionale AICARR "Oltre la certificazione energetica: progettazione e gestione del sistema edificio impianto per ottimizzare il comfort ed i consumi energetici reali", Bologna 19 October 2012, AICARR, Milano, pp. 77-90.
- R.S. Adhikari, E. Lucchi, V. Pracchi, E. Rosina, 2013, *Static and Dynamic Evaluation Methods for Energy Efficiency in Historical Buildings*, in Proceedings of 29th International PLEA Conference "Sustainable Architecture for a Renewable Future", Monaco 10-12 September 2013.
- R.S. Adhikari, E. Lucchi, V. Pracchi, 2013, *Energy Modeling of Historic Buildings: Applicability, Problems and Compared Results*, in Proceedings of 3rd European Workshop on Cultural Heritage Preservation (EWCHP), Bolzano 16-17 September 2013.

[12] L. de Santoli, 2010, *Efficienza energetica degli edifici storici*, AICARR Journal, April.