Historic Buildings and Energy Efficiency

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Introduction

The recent European Directive (2012/27/UE) underlines that obtaining significant results in terms of the requirements to reduce greenhouse gas (GHG) emissions and increase the energy production from renewable sources is impossible if the existing

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building stock is not improved. In other words, it is not sufficient to design and construct new buildings with nearly zero consumption. Taking into consideration the fact that several countries, including Italy, have building stock which is very old, this issue becomes rather critical, especially in light of European and national policies. More specifically, in Italy, 50 per cent of the existing building stock was built at a time when laws concerning energy use did not exist. Out of this stock, 22 per cent is in a bad condition, but also, of the 70 per cent built after World War II, just 2 per cent has acceptable levels of energy performance.[1] In addition to the urgent need to comply with European and national regulations in terms of energy performance standards, a further complexity is added in the case of the historic building stock since it is imperative that conservation of the values of historic buildings co-exists with modern energy interventions. It is worth stressing at this point that, in Europe, only 30 per cent of the existing building stock is considered to be historical.[2] As a result, the adaptation of existing buildings, specifically those identified as part of the cultural heritage, always poses a key threat: transformation could cause an unexpected decrease in their values (artistic, historic, social, economic, etc.). Therefore, if we want to reach the proposed energy-efficiency targets, it is essential to review this challenge in the historic built environment.

The *ratio* of legislation

Interestingly, the European Union standards (Directive 2002/91/CE EPBD and 2010/31/UE EPBD recast)[3] did not affect the policies of designing new buildings or upgrading existing ones. In view of this, it is worth exploring first the legislative framework of Italy, which is used as the case study for this paper, before proceeding with an analysis of the simulation models that were used to assess the energy performance of historic buildings.

In Italy, a prescriptive law concerning the refurbishment or restoration of a surface smaller than 1,000 m^2 (for instance, houses in historical centres) imposes restrictive U-values (identifying heat loss due to transmission through building surfaces) concerning the most important thermal parameters for describing the overall energy performance of a building.[4] As mentioned above, Italian legislation, in accordance with European Directives, seeks to improve the thermal performance of the building envelope with rigid U-value limits for individual parts of it (windows, roofs, walls, etc.) without the possibility of evaluating the global improvement in performance by ‘treating or adding’ what is typical for ancient buildings. Therefore, the final result only can be substitution of parts with new ones with higher performances and new materials. When this is not possible due to conservation needs, the alternative offered is the introduction of deregulation: in most of the European laws the buildings included in the cultural heritage classification are eligible for exclusion due to their historical or cultural relevance. What seems to be, at first glance, a good solution (but actually is not, as I will try to explain in this paper), is actually a consequence of the aforementioned prescriptive approach. In other words, all buildings (old, new, listed, or unlisted) must guarantee the same performance and when it is not possible to reach the highest levels (e.g. obtain the U-value defined by the standards) the alternative is to do nothing. Instead, deregulation should be seen more as an opportunity for a conscious approach than a way — as often happens — in which to avoid problems.

The energy behaviour of historic buildings could be achieved in respect of conservation practices, by applying the same approach currently used in Italian earthquake regulations: not requiring an old building to achieve the same level of safety as a new one, but demonstrating an improvement in its seismic capability. The same happens in the field of overcoming architectural barriers and also in the regulations concerning the safety in case of fire, whereby the idea of an 'equivalent safety', compared with the one required by law, has been introduced. The application of European standards in old, listed buildings is thus highly problematic and further complicated by the limitations of current tools used to evaluate the energy use of historic buildings since, as I will argue, the tools were developed for modern buildings initially and are 'blindly' applied to the historic building stock.

The current criteria, parameters, and tools for energy evaluation

The thermal losses for heat transmission of the opaque envelope play an important role in the energy balance of buildings.[5] In Italy, currently, thermal performance based on U-value may be estimated using different methods. The simplified method is used only for energy assessment of existing buildings where a rigorous calculation, based on inspections or other more reliable sources, is not possible.[6] The abacus of masonry structures provides guidance on the main wall technologies.[7] An analytic calculation is used where the stratigraphy of the masonry is known.[8] *In situ* measurement is applied where it is not possible to make destructive tests to determine the properties of the construction elements.[9] The first two methods, based on Italian standards, define the U-values related to compositions, materials, and thicknesses of different construction techniques. The simplified method standardises the U-values for five typologies of walls (brick walls plastered on both surfaces, stone walls plastered on both surfaces, semi-solid bricks or tuff, concrete walls without insulation, and cavity brick walls). In view of this, only two of them (bricks and stone walls) can be considered for ancient masonries. In the first case, the standard thicknesses are 15–60 cm, while, in the second case, they are 30–60 cm, which are both too small for ancient walls. The standard U-values consider only a few historical constructive technologies and, normally, the thermal properties refer to new construction materials. Therefore, these data are insufficient compared to actual case studies of historic buildings.

The abacus of masonry structures considers most historic building technologies related to ancient construction (brick, stone, mixed materials, tuff, wall-carved stone, and ancient stone and brick walls) and there are no limits for thicknesses. Nevertheless, the thermal performances of materials refer to new construction. Furthermore, information about the characteristics of the stone is not provided.

The analytic calculation according to international standards[10] requires detailed information on the stratigraphy and properties of the individual materials. For a new building the data on thermal conductivity, vapour-pressure resistance, and other thermo-physical properties have to be certified by the manufacturers, while, for existing buildings, these data are missing. The information must be taken from a database developed for current materials and construction techniques.[11] These data do not correspond to the characteristics of historic buildings, especially concerning the properties of different materials (conductivity, vapour-pressure resistance, density, thermal masses, etc.), construction techniques (with or without mortar), and the role of moisture and internal humidity. There is a great deal of variation in the U-values of brick walls in relation to thermal conductivity of building materials.

In brick masonry, the percentage of mortar does not affect the final U-value (± 3–4 per cent) due to the similar thermo-physical properties of bricks (0.72 W/mK with a density of 1,800 kg/m^3) and mortar (0.9 W/mK).[12] Variation in the U-values of stone walls in relation to the thermal conductivity of materials is not so wide, but the average thermal conductivity is different in European and Italian standards (EN 1745: 2012 and UNI 10361: 1994).

The effect of the presence of air has not been considered and it does not greatly affect walls with stone blocks which are perfectly square; however, as irregularly sized blocks are common in old buildings it is necessary to consider the impact of air on the final U-values. Research was carried out to quantify the percentage of mortar and air on walls located in the Lombardy region which had been made using the same construction technique.[13] The percentage of mortar and especially air affects the final U-values (± 8–10 per cent considering only mortar, but much more also considering air) (Figures 1 and 2).

Furthermore, old masonries often contain a high percentage of water, but the procedure of analytical calculation does not consider the effect of the presence inside the component on final energy performance. At the same time, in mixed walls, it is difficult to know (and therefore to calculate) the correct stratigraphy due to the many possibilities of composition and variation of materials. When the stratigraphy of walls is not known, the real U-values only can be measured with heat-flow meter (HFM) measurement, which is non-destructive testing (NDT) that permits determination of the thermal transmission properties of the envelope.

In order to verify the suitability of the standard and calculated U-values of walls, in our research at Politecnico di Milano we carried out a series of experimental measurements according to international standards[14] on a representative part of the whole element. *In situ* measurements were taken from twenty-two historic buildings — the majority listed — with solid masonries made of stone, bricks, and mixed materials, built in different historical ages with different thicknesses, materials, internal humidity levels, and types of damage. The selected case studies are representative of the historical construction techniques prevailing in the Lombardy region (Figure 3 and Table 1).

Our study compared the national standards with the U-values calculated and measured *in situ* in each of the twenty-two cases. The results obtained differ depending on the types of wall but, in all cases, the measured U-values of ancient walls were better than both the standard and calculated ones. For brick walls, it could be argued that

FIGURE 1 Section of a stone wall showing the presence and quantity of stone, mortar, and vacuum.

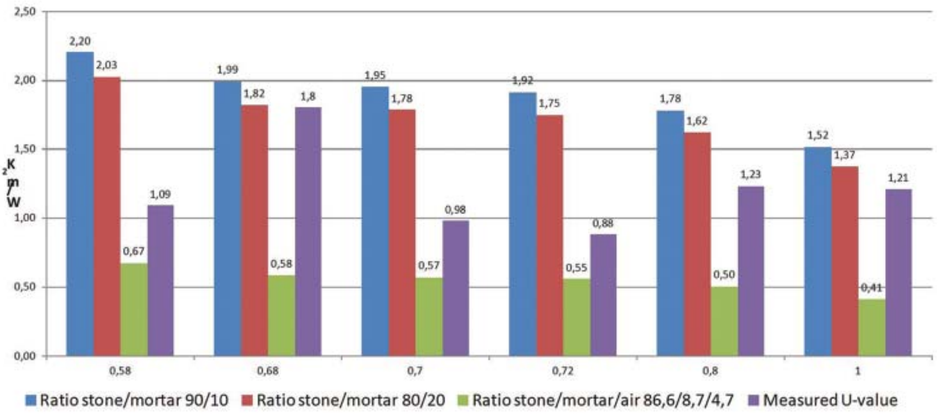

FIGURE 2 Effect of the presence of mortar and air on U-value calculations for stone walls with different thicknesses.

it is not convenient to utilise standard and calculated U-values because they excessively overestimate the thermal losses of the opaque envelope. The real performance is better by up to 3–56 per cent compared to standard data and 2–57 per cent compared to calculated data.

In stone walls, it was not possible to make a similar analysis because the thermal properties of stones are very different. The U-values calculated using the Italian standards were based on the average value of thermal conductivity of stones and did not coincide with the characteristics of the case study stones (Moltrasio stone); also the standard thicknesses were too low. However, also in this case, the results showed that U-values were always lower in comparison with standard ones, showing that historic buildings ‘work’ better.[15]

The analysis did not reveal statistically significant correlations between historical ages and thermal performances of masonry due to the fact that the same old techniques have been used over very long periods. As shown above, construction techniques are the most important thermal parameter for describing the overall energy performance of a building. However, the correct U-values of historic structures are still unknown and, because of this fact, use of energy simulation software is problematic since imprecise parameters are inserted.

Evaluating energy simulation software

Subsequently, the research focused on an evaluation of the current different available energy software to test their abilities to simulate historic buildings properly. The software were tested on three churches: San Rocco in Cornaredo (built between 1451 and 1524), the Church of the Purification of Santa Maria in Caronno Pertusella (built between 1483 and 1500), and Santo Stefano Oratory in Lentate sul Seveso (1369), all of which are located in the Province of Milan (Figure 4). The churches were chosen because their shapes were simple and thus it was easier to conduct the simulation. In addition, the chosen examples represent different building technologies allowing a useful comparison.

First, the energy consumption of each church was measured using the electricity and gas bills for one year. At the same time, a deep diagnostic study was carried out

FIGURE 3 Examples of case studies.

(Table 2). The collected data informed the applicability of the simulation software. The systems for assessing the energy performance of buildings currently available are static, semi-dynamic, and dynamic. Each software type uses a specific algorithm for the calculations, has a different input mode, and can produce different typologies of output. In general, more powerful and complete software requires more detailed and precise information.

The simplified programs realise an energy assessment in a stationary regime considering a limited number of inputs. They are used for energy labelling in order to compare the different performances with standard conditions of use. The simulation may be realised with simplified (synthetic method) or complex (analytic method)

TABLE 1

THE CASE STUDIES, THEIR LOCATIONS, PERIODS OF CONSTRUCTION, ACTUAL DESTINATION, AND DIMENSIONS OF THE MEASURED WALL

Edificio	Località	Epoca costruttiva muratura analizzata	Destinazione d'uso dell'ambiente in cui è stato installato lo strumento	Spessore muratura analizzata (m)
Palazzo a ringhiera	Milano	XIX secolo	Abitazione	0.46
Chiesa di San Rocco	Cornaredo (MI)	XV secolo	Chiesa	0.46
Convento del Carrobiolo	Monza	XVI secolo	Convento	0.52
Chiesa della Purificazione	Caronno Pertusella (VA)	XVIII secolo	Chiesa	0.52
Museo di Scienza e Tecnologia	Milano	XVI secolo	Ufficio	0.54
Palazzo ad uso civile	Milano	XIX secolo	Abitazione	0.58
Basilica di S. Giovanni Battista	Monza	XIII secolo	Chiesa	0.60
Istituto dei Ciechi	Milano	XIX secolo	Ufficio	0.64/0.80
Politecnico	Milano	XX secolo	Ufficio	0.65
Palazzo Reale	Milano	XIV secolo	Ufficio	0.67
Villa Reale	Milano	XVIII secolo	Sala espositiva	0.68
Oratorio di S. Stefano	Lentate sul Seveso (MB)	XIV secolo	Chiesa	0.70
Pinacoteca di Brera	Milano	XVI secolo	Sala espositiva	1.10
Villa Olmo	Como	XIX secolo	Sala espositiva	0.56
Palazzo Giovio	Como	XVI secolo	Ufficio	0.58
Palazzo Erba Odescalchi	Como	XIV secolo	Biblioteca	0.68
Palazzo Natta	Como	XVI secolo	Ufficio	0.70
Palazzo Volpi	Como	XVII secolo	Sala espositiva	0.72
Chiesa di S. Francesco	Como	XIV secolo	Chiesa	0.80
Palazzo Cernezzi	Como	XVI secolo	Ufficio	1.00
Monastero di S. Maria del Lavello	Calolziocorte (LC)	XVI secolo	Ufficio	0.50
Palazzo del collegio dei Padri Barnabiti in S. Alessandro	Milano	XVII secolo	Università	0.40

NOTE: The first part of the table concerns brick walls, the second stone walls, and the third mixed walls.

procedures, which differ according to the quantity and accuracy of data requested. In the synthetic method, the technological data of the envelope and plants can be obtained by using a simplified determination, abacus of masonry structures, analytic calculation, or *in situ* measures. In the analytic method, the data can be obtained by using diagnostic tests. The correctness and accuracy of the input data, of course, are of fundamental importance for determining the final results.

The concluding result from our simulations is that the software simulate only partially the real performance of buildings, because they have a standard heating period, prefixed data for internal and external air temperatures, and do not consider the periodic changes of temperature and the way in which the churches are really used.

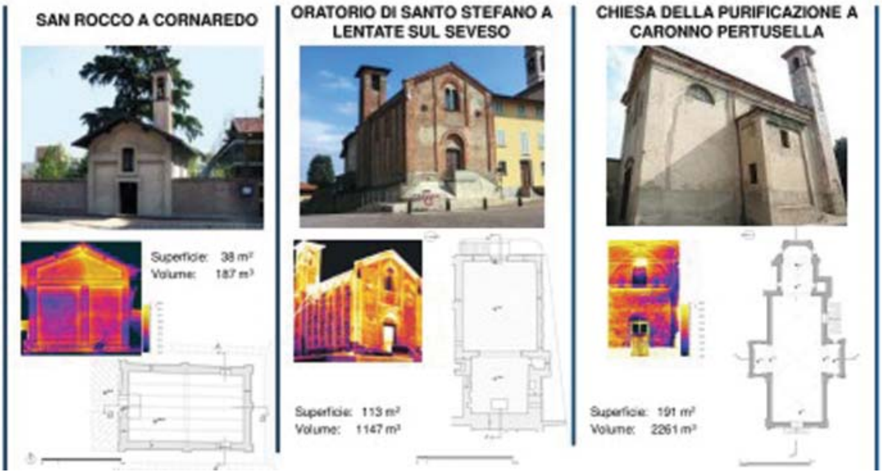

FIGURE 4 The three case studies with thermograms, surveys, and dimensions of surface and volume.

TABLE 2

DIAGNOSTICS PERFORMED ON THE CASE-STUDY BUILDINGS

Test	Cornaredo	Caronno Pertrusella	Lentate sul Seveso
Historical analyses	X	X	X
Survey	X	X	X
Relief	X	X	X
IR thermography	X	X	X
Gravimetric tests	X	-	X
Analysis of mortars and plasters	X	-	X
Psychometric tests (T°C/RH)	-	-	X
T and RH monitoring	1 outside 1 inside	1 outside 3 inside	1 outside 2 inside
HFM	X	X	X
Energy bills	X	X	X

NOTE: IR - Infrared; T - Temperature; RH - Relative Humidity; HFM - Heat Flux Measurement.

The semi-dynamic software (also called sketch design software) performs in-between the simplified and detailed simulation tools. It requires a simplified input in terms of climatic data, geometry, and building description, while also taking into account the thermal inertia, but has a limited range for data input of the envelope and plants (which are strongly referenced by modern building technologies). Other problems relate to the impossibility of considering unheated buildings and difficulties with determining the moisture level of walls and natural ventilation rate.

Finally, the dynamic simulation software analyses in detail the contributions of thermal inertia of walls, variability of outside temperature, solar radiation, natural ventilation, and user management. Detailed data have to be used for describing climatic conditions, geometry, and building properties.

Results of the energy simulation

The simulations were carried out through the use of DOCETpro 2010 (static software), Casanova (sketch design), and BEST Openstudio (dynamic software which works with the EnergyPlus engine). Particularly, the simulations were realised in the subsequent conditions. The static software was used for three simulations based on the synthetic method using standard and measured U-values and analytic methods. The sketch design software and the dynamic software (which involved standard and real management data) were then used. Due to the existing monitored data (annual energy bills, air temperature, and relative humidity collected hourly for more than one year), it was possible to compare the software output with the real collected data and to verify the differences (Figures 5 and 6).

In general, the software overestimated the real energy consumption (Figure 7), which indicates the limitations of the static simulation software when applied to historic buildings. Some of these limitations included:

- presence of standard climatic databases
- difficulties with modelling complex shapes (i.e. domes, vaults, etc.)
- difficulties with simulating buildings without heating systems
- presence of established internal temperatures (20°C in winter and 26°C in summer)
- lack of consideration of the lighting systems.

Due to these limitations, the static software greatly overestimated the results compared to the real energy consumption. For example, the Church of San Rocco — the only unheated building — had the highest energy consumption according to the simulations. These simulations, in fact, define the energy needs that the heating system must provide for, while maintaining the prefixed internal temperature (20°C), which is something that never happens in this type of building in reality.

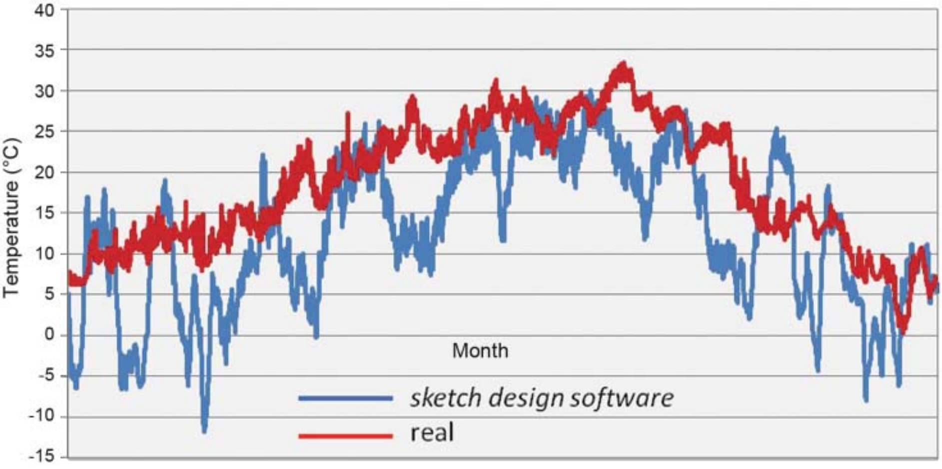

FIGURE 5 Example of the comparison between real monitored data and those calculated using the sketch design software, in the Church of the Purification of Santa Maria in Caronno Pertusella.

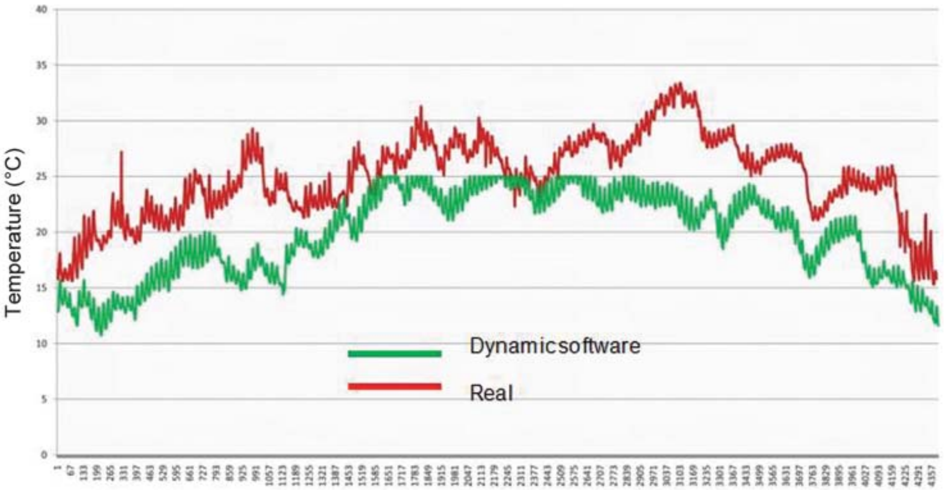

FIGURE 6 Example of the comparison between real monitored data and those calculated using the dynamic software, in the Church of the Purification of Santa Maria in Caronno Pertusella.

In the other two buildings, the worst results were obtained through the synthetic method (with differences from consumption in the range of 52–63 per cent), requiring significant simplifications for the data input, both for the envelope and plants. The deviation from the real energy bills decreased by 7–10 per cent by changing standards and measured U-values.

The static evaluation realised by the analytic method (using measured U-values) modelled much better, showing a difference from consumption in the range of 22–38 per cent. The better quality of the results is due to the higher precision of the data requested for heating and air-conditioning systems.

The sketch design software had very few reliable results for historic buildings (the difference from consumption was in the range of 28–75 per cent). This is due to the fact that climatic databases referred only to the most important Italian cities (Rome and Milan) although there was a provision for importing climatic data. In addition, other limitations included:

- the ability to simulate only simple shapes (square and rectangle)
- presence of limited ranges of U-values
- necessity of entering the same thermal performances for windows placed on the same facade of the building
- difficulties with coring out simulations of buildings without heating systems
- presence of limited ranges of data input for heating and cooling systems (which strongly referred to modern building technologies), and
- simplified management data and internal gains.

Furthermore, this experiment showed that only the dynamic software, in real conditions, overestimated slightly the energy performance of the heated churches (10–24 per cent). The software models simultaneously estimated thermal, electrical, air flow, and user management data, providing a comprehensive energy assessment of all the parameters that characterise the energy balance of the building, both in winter

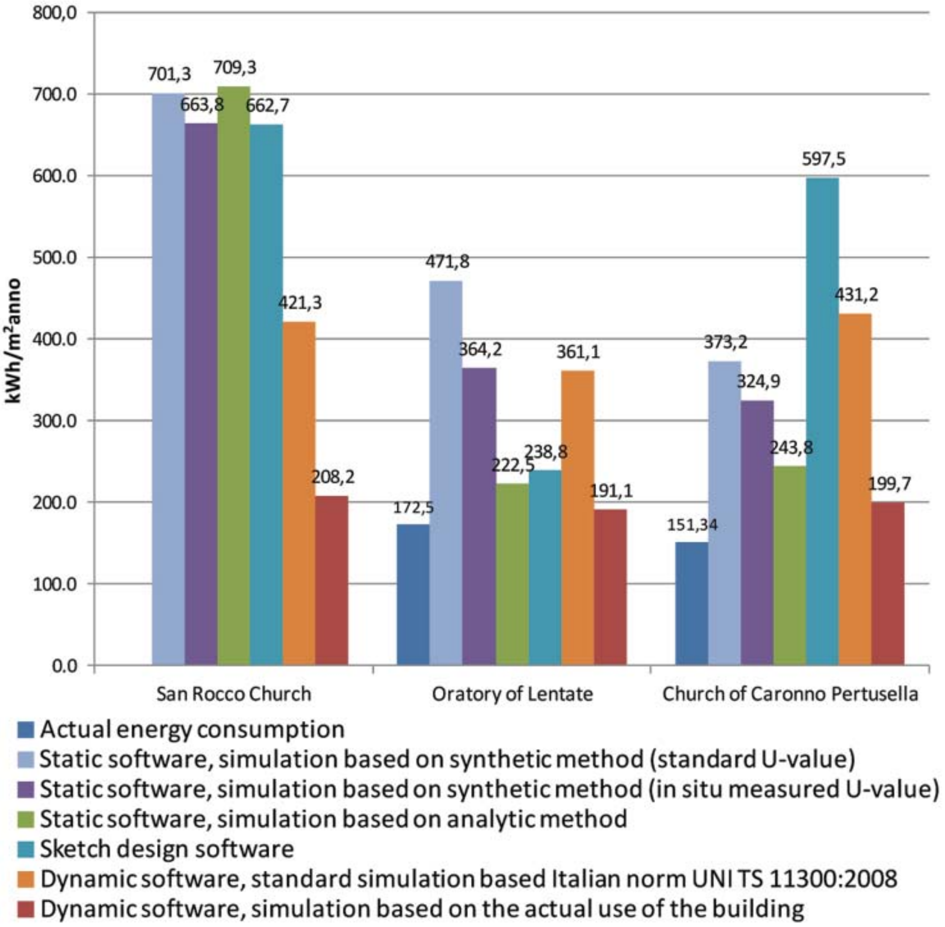

FIGURE 7 Comparison of real energy bills and energy consumptions simulated using static, semi-dynamic, and dynamic software.

and summer. The dynamic software allowed non-standard data to be entered regarding the ground temperature, considering the effect of storage and the release of heat produced by the ground. In unheated or weakly heated buildings this fact is very important because, considering standard temperature, the floor appears as a 'hot plate'. Also, only using dynamic software made it possible to consider the presence of structures huddled next to the building — very common in urban centres — which leads to a positive energy effect, particularly when the walls have a reduced thickness (< 50 cm). Finally, with dynamic software it is also possible to verify the role of management data for improving energy efficiency.

In the dynamic simulation of a historic construction, the main problems are related to the level of precision of the input data required for the simulation (especially for the building envelope and air flow). Standard databases, construction schedules, and reference literature, however, are inappropriate for these buildings. For this reason, it is necessary to create specific databases, based on *in situ* measurements of the important parameters, such as thermal transmittance, thermal inertia, and conductivity of envelope materials; role of the humidity rating in increasing the U-value of walls; air flow rate; and energetic performances of energy supply systems. In particular, the main difficulties concern the calculation and measurement of air leakages through the building envelope.[16]

What does the case study analysis tell us about the issue of energy efficiency in historic buildings?

The results of the simulation studies illustrate that there is great uncertainty in terms of the characteristics and behaviour of historic buildings. This uncertainty raises the question of our ability to design appropriate energy-efficient interventions. This reinforces even further my argument that, in the case of the historic building stock, it is more preferable to accept that the required energy-performance standards are possibly unachievable and energy efficiency should be improved through maintenance and use of less-intrusive methods (i.e. heavy curtains, closing of shutters, etc.) (Figure 8). For instance, as has been shown in research conducted by English Heritage, in the case of windows, if the U-value of a single-glazed window is nearly 48, the U-value with secondary glazing will be in the range 2.9–3.4, and the U-value of a single-glazed window with night shutters will be nearly 3.0.[17] I have quoted the case of windows because several countries experience a similar phenomenon with the systematic replacement of traditional windows (Figure 9). Due to the incentives linked to potential energy savings coupled with a widespread lack of knowledge among stakeholders, this situation is producing extensive and uncritical substitution of building elements, especially in historical centres, where stringent control — possible for monumental buildings — is difficult to pursue, or is just excluded from policies. This raises the following question: Is the substitution of old parts of historic buildings a sustainable policy?

A sustainable policy? The case of replacement of traditional windows

The uncritical application of regulations already has led to disastrous consequences. For example, Directive 93/76/EEC Energy Efficiency (SAVE) was later repealed because its purpose was driven by economic incentives associated with the replacement of windows in buildings that have always been energy efficient. This situation has resulted in the loss of many traditional windows in several countries including Hungary, Finland, Norway, and the UK. Similarly, in Italy, the replacement of windows counts for almost half of the total replaced elements of all the buildings that have obtained incentives for energy efficiency, as can be seen in a recent report which states that: ‘the massive usage of window replacements does not involve significant energy savings in the context of the various interventions’.[18] The average annual savings achieved, by this type of work, in fact, show that replacement of windows has the lowest savings (2.6 MWh). Translated into monetary terms, this is between €80 and €125 per year, with payback achieved in 12–15 years.[19]

The Italian Ministry of Economic Development and Italian National Agency for New Technologies, Energy, and Sustainable Economic Development (ENEA) are proposing a revision of the incentive mechanism as ‘it is not appropriate to claim for above the line performance of the transmittances at our latitudes with risk of fake or

FIGURE 8 A house in Milan with secondary glazing.
Source: Farina, P.M. ed. 2003. Dal restauro alla manutenzione. Dimore Reali in Europa. Atti del Convegno Internazionale di Studi, Monza — Milano, 12–15 October 2000. Il Prato, Saonara, Padova

useless benefits, without paying attention to walls, floors and roofs as well'.[20] The key aspects that must be considered are certainly not the ones that come from conservators of historic buildings. First, the need for improving the thermal comfort while reducing energy bills is one of the key elements that drive property owners to replace their windows. Second, there is blatant abuse regarding the replacement of windows in terms of a simple cost/benefit analysis. While addressing the question from the point of view of savings, in a purely economic sense, it should be noted that historical centres (which constitute the fabric of the Italian territory) — once depleted of their characteristics and transformed into chaotic current buildings — will no longer generate economic benefits resulting from tourism. The third main reason for intervention, which should be seriously considered, is environmental sustainability. In this regard, research carried out in Norway based on quantitative data concluded that the adoption of new, more-efficient windows can increase CO_2 emissions in the atmosphere, due to the entire production cycle, including the cost of extraction, production, use, disposal of the old, and new materials.[21] It then becomes clear that something is profoundly jarring within these arguments on environmental sustainability and the current way of addressing this issue. Finally, the most important issue to be discussed for a historic building conservator is the great underestimation of the meaning — in terms of the history of material culture — of ancient windows, or other parts of the construction. Indeed, it could be argued that windows are important historical witnesses. They can inform the evolution of design intention and technical possibilities, as well as regional traditions in the use and processing of materials,

FIGURE 9 Substitution of windows in historic buildings: an example from Kent.
Source: Carbonara, G. ed. 2001. Restauro Architettonico e Impianti. Torino: UTET

social structures, and habits. Hence, there should be the assumption that preserving ancient windows means that 'with the transmission of a quantity of information to future generations, the qualities given by the correlation between windows, facades and interiors are preserved and an economical use of resources is ensured'.[22]

Re-reading the ancient wisdom of those who manufactured windows is one way in which 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 centuries-old 'know-how', as demonstrated by the aforementioned Norwegian research, has produced windows which have the capability of a 250-year period of service, even when exposed to fierce weather conditions.

What the analysis above indicates is that conservation and energy-efficiency requirements can be in conflict. However, there are innovative ways in which synergy can be found. For instance, 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 those related to the displacement of features and integration of alternative energy sources.[23]

Conclusion

The key problems in deploying strategies for improving energy efficiency in built heritage concern the difficulties of balancing different needs (conservation, comparison with the performance of elements of efficient contemporary buildings, choice of parameters for comparison, etc.), limitations of actual tools for efficiency diagnostics, and our current limited knowledge about historical buildings. In order to achieve energy targets it is inevitable that different elements of old architectural structures will be replaced, however, this should take into consideration the following three aspects. First, the *sustainability aspect* needs to be thought about more holistically. As the example of windows indicates, heritage elements of a building structure can be more sustainable from an environmental, economic, and cultural perspective than modern interventions. The second aspect, *efficiency and efficacy*, considers that it is not appropriate to claim for above-the-line performance of the transmittances of some elements without paying attention to walls, floors, and roofs as well. In addition, since historic buildings behave differently in comparison with new ones, new interventions can increase decay (for instance, old walls need to breathe). Finally, *balancing different needs and values* is a critical aspect. The issue of rendering historic buildings energy efficient interrelates with how owners and managers value buildings. Aesthetic and integrity values seem to be the priority when determining the right type of energy-efficiency interventions. However, the needs of users (such as human comfort) are often neglected in this process. This consideration opens the discussion on a different level of the debate, which is particularly vivid at present in Italy, where the issue of substitution of materials and elements of a historical structure crashes into the concept of preserving if possible all parts of the structure. The Italian culture of restoration considers it necessary to maintain the historical existing elements, which are full of unique memory, cultural, and social values.

It seems that by now a comprehensive theoretical work that analyses in depth the close relationship between sustainability and conservation is still lacking. Moreover, a vision that takes into account the most recent approaches in conservation, which provide procedural strategies and put emphasis on the importance of management, control, and preventive maintenance, with the aim of reaching higher-level energy efficiency in the historical building, is also missing. A lack of critical thinking and limited knowledge of how historic materials behave have led to oversimplified simulations intended to model the energy usage and energy performance of a historic structure. Such oversimplified simulations will result in false decision-making processes which will impose risks not only regarding conservation of the historic fabric but also for the health of occupants and users. This paper calls for the development of a systematic database of accurate information (including energy and historic information) about the historic building stock which could inform accurate and meaningful simulations as well as energy-efficient interventions.

Notes

[1] Maranzana, C. & Zappa, A. 2010. Edifici storici sostenibili. *Costruire*, 355 (IV) April (2011): 86–93.

[2] European Commission. 2010. *Energy-Efficient Buildings PPP Multi-Annual Roadmap and Longer Term Strategy*. European Commission e-book.

[3] Directive 2002/91/CE EPBD and 2010/31/UE EPBD recast.

[4] Legislative Decree 192/2005 and 311/2006.

[5] See EN ISO 13790, 2008.

[6] UNI TS 11300-1: 2008.

[7] UNI TS 11300-1: 2008.

[8] UNI EN ISO 6946: 2008.

[9] ISO 9869: 1994.

[10] UNI EN ISO 6946: 2008.

[11] UNI 10351: 1994; UNI 10355: 1994; EN 1745: 2012.

[12] Lucchi, E. & Pracchi, V. eds. 2013. *Efficienza energetica e patrimonio costruito. La sfida del miglioramento delle prestazioni nell'edilizia storica*. Santarcangelo di Romagna: Maggioli.

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