Potentialities and criticalities of different retrofit guidelines in their application on different case studies

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Abstract – The paper aims to investigate criticalities and potentialities of the Italian Cultural Heritage Ministry's Guidelines (October 2015) and the European Guidelines for Improving Energy Performance of Historic Buildings (EN 16883 – June 2017), comparing and applying them to selected case studies.

The documents represent an instrument to help public authorities and designers to follow an iterative retrofit process; in both cases it is possible to notice some difficulties in their technical application. Thus, we have identified their critical and positive features through the case studies assessment.

The scope is to underline possible issues and to suggest new solutions in both cases, improving the existing guidelines with other targets to obtain a calibrated evaluation method, which could guide the retrofit project.

Keywords – historic buildings retrofit; Italian Cultural Heritage Retrofit Guidelines; EN 16883 Guidelines

1. INTRODUCTION

The reason to analyze the European Guidelines EN 16883 [1] and the Italian 'Guidelines for the improvement of energy efficiency in cultural heritage' [2] is to check how they address the design process, defining suitable interventions for the retrofitting of historic buildings.

Heritage buildings need special protection actions; hence improvements must be carefully weighed to balance conservation needs and increase performance [3]. The two documents mentioned above are not mandatory, but they are worth knowing and analyzing. The goal is to help the stakeholders involved in the process (whether designers or heritage authorities) in a well-thought assessment of possible solutions, before their implementation.

The purpose of this paper is to check these documents, through their application to different case studies, to explore potentialities and limits and, if possible, to suggest improvements.

1.1 EUROPEAN AND ITALIAN GUIDELINES

The two guidelines are certainly different, although they have the same purpose. The European standard is synthetic and aims to guide the lecturer in the proposed procedure; the Italian one is very long and structured as a book.

In EN 16883, despite its brevity, important concepts are highlighted. Among them, a few main concepts are the importance to pay attention not only to exceptional buildings, but also to ancient city centers, focusing on authenticity – integrity – significance of the building, considered as an entirety. It is also specified that “Maintenance is the best conservation measure” and that in this field also “non-standard measures could be considered”.

In contrast, the Italian guidelines are a collection of restoration theory concepts (as the important distinction between improvement and adaptation, borrowed from the Italian Guidelines for the seismic vulnerability assessment of historic buildings) and technical parts to support people in performing energy diagnosis.

The text is divided in three sections: knowledge of contexts (including environmental quality assessment for historic buildings); energy efficiency assessment (in this part the retrofit procedure flowchart is exposed) and energy efficiency improvement (which includes a description of possible retrofit interventions, a paragraph about maintenance costs and a collection of best practices).

The last section is followed by supplementary technical sheets (some of which dedicated to photovoltaic insertion). This part of the volume also refers to non-standard solutions (e.g. fixing a second window in contact with the first instead of modifying the existing one), underlining that choices should be made considering the preservation of the heritage values. Other retrofit measures linked to the exploitation of the environment are also quoted (e.g. the use of trees and water in dry climate for comfort purposes). The goal of these sheets is to ‘wisely’ consider a range of possible measures, focusing on innovative materials and explaining pros and cons of each retrofit technique. However, we will see that one of the main shortcomings is an imperfect integration between theoretical and technical parts.

1.2 CASE STUDIES

To compare the two guidelines and understand their potential, we applied them on three case studies, different for climatic conditions, installations and use. The first two cases (Verga’s House and Pepoli Museum) are situated in Sicily. The third one (Rebecco house) is situated in the historic centre of a mountain village in Lombardy. All of them are protected with different legal constraints (see Table 1).

2. APPLICATION OF EN 16883 GUIDELINES ON CASE STUDIES

2.1 STEP 1: BUILDING SURVEY AND ASSESSMENT (CHAPTER 7)

The procedure consists of six steps and must be carried out by a multidisciplinary team. The first step is structured in nine points as a collection of information about the building, useful to address the next stage of the planning process.

The first three points collect general data (historical, constructive, legal); the fourth point asks to highlight opportunities to reinstate lost or hidden character-defining elements (e.g. restoring the original window / replace an identical one), conservation priorities or constraints on behalf of the local heritage authorities,

Table 1. Case studies

Case Studies	***(1) -Verga's House***	***(2) -Pepoli Museum***	***(3) -Rebecco House***
			
Building information	Listed house-museum in a three-level palace 350 m²	Listed museum and library with courtyard on two levels 1350 m²	Old abandoned farmstead on two levels 90 m²
	18th century 1980 restoration works	14th century 2013 restoration works	18th century neglected
Location and Climate zone	Catania (Sicily) city centre	Trapani (Sicily) outskirts	Lavone (Lombardy mountain
	B – 833 HDD	B – 810 HDD	F– 3227 HDD
Building description and condition survey	Lava stone masonry walls; paper wall inside	Sandstone walls with plaster finishing	Stone walls with plaster finishing inside
	vaults cover the pitched wood roof	vaults cover the insula-ted pitched wood roof	broken pitched roof with tiles and wood structure
	wooden window frames with single glass	wooden window frames with single glass and shutters	wooden window frames with single glass; chimney
	19th century furniture; moisture problems	new exposition area in glass; good condition	no pavement; air leakage; moisture problems
Plant and lighting system	Split systems; halogen lamps	Split systems+ HVAC&R; halogen lamps	No plants; no lamps.
Energy performance	By audit and bills data	By audit and bills data	Static and dynamic simulation
	167.73 kWh/m²	152.49 kWh/m²	540.00 / 275.90 kWh/m²

to understand the limitations of the intervention to define where, how much and how to intervene. There is a risk that there will be too much focus on the single building node rather than on a set of calibrated actions, which should constitute the purpose of the procedure.

In the following two points (5-6) it is required to define the intended use and to map the building's condition. In our opinion, it would be more effective to reorganize the order of points 4-5-6, proceeding first with the 'Mapping building's condition and environmental influences' (point 6), then with the definition of the 'Intended Future Use' (point 5) and finally with the definition of opportunities, meant as improvement actions, well-balanced both on conditions and needs of the building (point 4). Accordingly, we have defined opportunities as improvement suggestions for each case study:

- Case (1): interventions could be limited to roof and fixtures, due to ancient finishing. Microclimate control might be provided to preserve existing collec-tions;
- Case (2): it might be considered to add trees in the courtyard creating shade for the new glazed-in exhibition area during the summer season, as well as adding curtains or solar control window films, to avoid thermal shock damage for collections;

- Case (3): it might be possible to improve and restore loft hatch and ground-level to mitigate internal conditions and limit infiltrations.

Point 7 requires the energy performance assessment, that could be done by an energy walk-through audit, by an analysis of energy use and consumptions (asset rating) [4] or by calculating the energy performance in-depth (tailored rating) [5]. It's important to underline the guidelines' remark on calculation methods' difference: for historic buildings, a tailored method is recommended because it allows evaluating non-standard conditions with case-by-case variable input data, whilst a standard calculation method is more limiting due to its simplifications. In our opinion, this part should be highlighted to alert against interventions based on reductive approaches. Our case studies are examples of application of these different methods: the performance of cases 1 and 2 has been assessed by the Energy Authority of the Sicilian Region, analyzing their energy bills (asset rating). The real consumptions were compared with calculation data, extracting by using a static simulation software (MC4) in standard conditions: results led to a difference of 8–10 percent in favour of the measured data. This difference is attributable to the simplification of the static software, not suitable for the evaluation of the thermo-physical behaviour of historical buildings. With a static calculation method, although results are quickly produced, there are numerous issues, such as lack of adequate databases and inability to define more complex parameters (infiltration rate, internal gains and weather data) [6].

Energy performance of case 3 has been evaluated both with a static simulation software (CENED+, freely provided by Lombardy region) and a dynamic one (EnergyPlus) to compare the two methods results. This case study has a singularity: it has no HVAC system which can be a common condition in historic buildings. The CENED+ software cannot run in free-floating conditions: it is structured for energy audit and labelling of modern constructions, this means that it considered a false implant as default. Furthermore, input data were entered from the general database, which is not properly targeted for historic buildings. Hence, an approximate result was obtained quickly, in terms of global primary energy (540 kWh/m^2). In contrast, the dynamic evaluation tool has allowed modelling each input parameter:1 detailed data were included both for describing climatic conditions, geometry and building properties. As output, building energy requirement could be verified (275.90 kWh/m^2 – equivalent to half of those simulated with the standard method). It has also been possible to evaluate other parameters, useful for a complete evaluation of performance needs, such as infiltration losses, relative humidity, surface temperature, solar gain and daylight luminance to verify comfort needs. Although dynamic simulation involves more time compared to the static one, it gives more accurate data.

According to our findings, a correct energy performance assessment is important to make decisions in the following phases on retrofit options. The limit of both

1 Four thermal zones have been identified (room 1, room 2, loft hatch and ground level), imposing for the two rooms +20 °C for heating period and +26 °C for cooling period with an infiltration rate of 4 changes/hour, due to the high air leakage. Climate data: Collio meteo station (Brescia).

methods is found in the correctness and accuracy of the input data that must be calibrated on measured data [7]. However, the output data must also be evaluated properly, according to the building needs and use. The guidelines are not necessarily directed towards one or the other method; however, one must be more explicit about their pros and cons.

2.2 STEP 2–3: OBJECTIVES AND END OF PROCESS (IF NEEDED) (CHAPTERS 8–9)

The second phase of the procedure requires defining objectives and targets according to the priority criteria that address the project in the planning phase. Before this step, it is mandatory to define some criteria, upon which future action lines should be based. Objectives are specific and refer to individual cases and are therefore variable, whilst some guiding criteria could be of general validity, referring to the need of protection. In Figure 1 we propose possible criteria, subdivided into different fields (Heritage, Efficiency and Users), to which single objectives are referred for each case [8].

At this point, after the second step, it is possible to interrupt the process, although no scenario has been proposed or verified too. In our opinion, this possibility should be postponed in the downstream of the flow chart. Prior to excluding measures, it will be necessary to evaluate their effectiveness to decide whether to apply them or not. Hence, even in the most critical cases where it is not possible to work on the building envelope, it is still possible to improve energy efficiency, with high-performing energy production systems and appropriate management technologies [9].

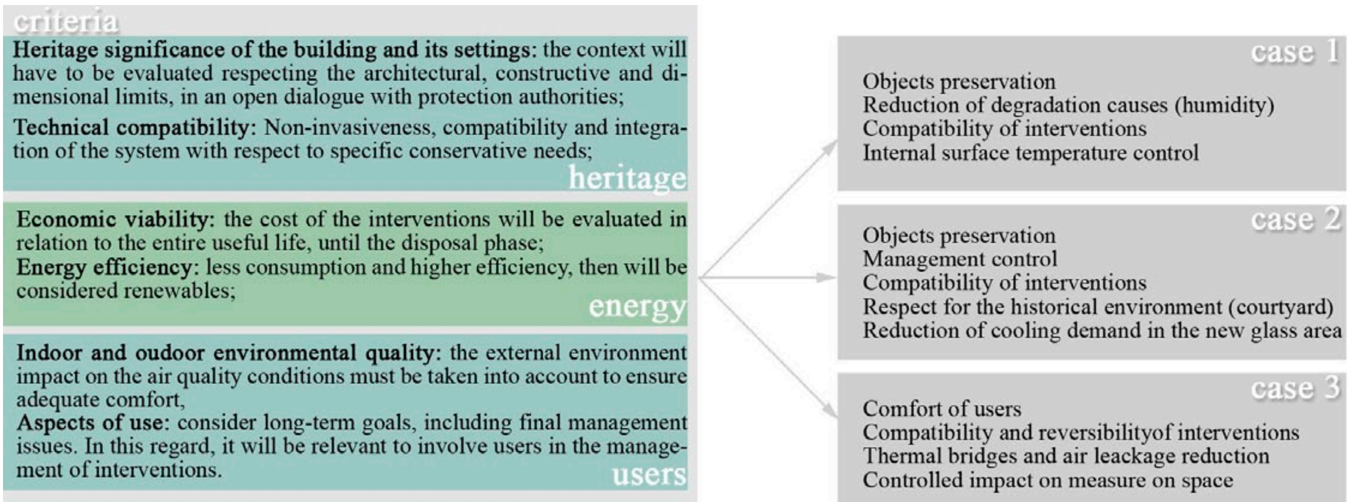

Figure 1. Criteria and objectives

2.3 STEP 4: SELECTION OF MEASURES AND ASSESSMENT OF PACKAGES (CHAPTER 10)

The fourth step provides for the definition of retrofit measures. Starting from a list of common ones for the three cases, they have been divided into three categories: interventions on the building (e.g. wall insulation, window refurbishment, etc.), interventions on the HVAC system and user involvement and building management. For each case, the most appropriate options were selected from those listed (e.g. in case 1, given the presence of antique finishing, work on floors and walls were excluded, but interventions such as system replacements, building automation control, curtains, etc. could be considered). In the guidelines, it is expected that retrofit actions are individually evaluated and grouped together afterwards. However, assessing them singularly does not make it possible to evaluate linked effects given by the whole system, further extending the verification times. At this stage, it is therefore preferred to combine them in packages (e.g. in the case 3: package 1='refurbishment' includes removal operations of degradation and roof improvement, to limit the problems of water infiltration presence).

For the evaluation of the selected packages, a risk-benefit analysis is proposed. The assessment can be made on a five-level scale through the examination of qualitative data (risk of material and spatial impact, influence on the use, etc.) and quantitative ones (energy performance, comfort data, payback time, GHG emissions, etc.). Some critical aspects of the method – highlighted from the comparison among the three cases – are shown below:

- We assessed the same group of measures in two climatic contexts, to check if specific problems related to different conditions were highlighted by the procedure. The combined interventions 'thermal-insulating plaster + windows substitution' were tested, both in climate zone B, case 2, and climate zone F, case 3. In both risk evaluations, the result does not change, although there are clear differences. According to that, it was considered to add a set of categories to underline specific issues: 'overheating', and 'insufficient ventilation' for the case study number 2, 'interstitial condensation' for the number 3. This means that to correctly assess the effects of interventions, perhaps it would

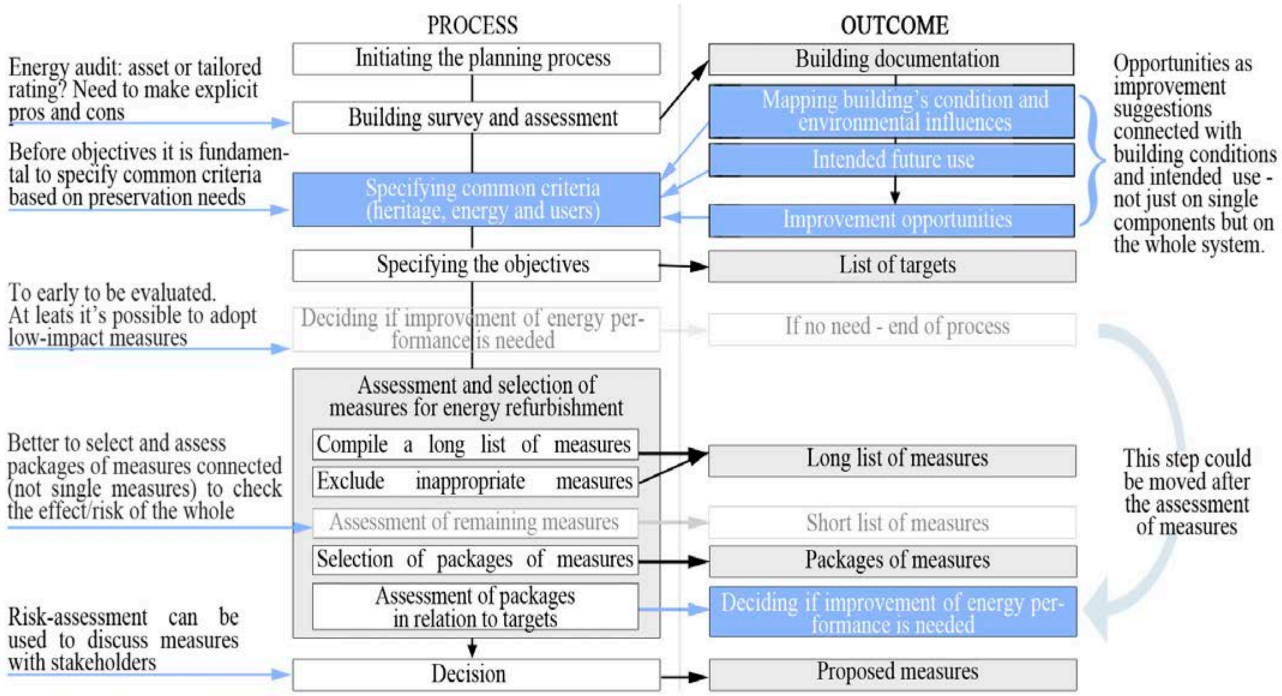

Figure 2. European Guidelines flowchart showing the proposed procedure with comments.

be necessary to define specific risk parameters, considering for example climate zone or future use of the building;

- The measures have to be designed in relation to the objectives previously set out. For example, in assessing the introduction of a ventilation system in case 1 and 2, having to preserve the art collections, the jeopardy of deterioration of the objects should be verified before.

After evaluating the packages of measures for the three examples, it was not possible to have a clear vision of the results at the end of the process. As the guidelines mention: "This method should not be seen as a mechanical tool that provides an answer" (chapter 10.2), but it's meant to allow a transparent dialogue to make a decision on intervention. Thus, the assessment procedure represents a possible basis of work to discuss different proposals with the team and all the stakeholders, according to criteria and objectives, established case-by-case [10].

3. APPLICATION OF ITALIAN GUIDELINES ON CASE STUDIES

The guidelines' proposed procedure provides a waterfall model with five steps. The first step is the collection of building data (geometrical, architectonic, structural, etc.) as in the European guidelines. This part will be functional to the energy assessment, which will take into account local legislation and standards [11]. Who will be in charge to do the energy performance analysis will define its level of detail (standard, asset or tailored analysis according to the Italian standards UNI TS 11300:2014); the decision will depend on the availability of resources and time, causing different output data quality. At the end of this step, the final goal is to reach the evaluation of the Primary Energy (EP) of the building. Later, possible measures have to be selected. Once possible interventions are established, the performance of EP after implementation will be evaluated for each of them. The value of primary energy before and after each measure should therefore be compared. If the intervention has led to a reduction of primary energy (EP '<EP), it will be possible to proceed with its realization, otherwise it is mandatory to restart the procedure, redesigning the retrofit measures [12].

As is evident, the application of this procedure on the three case studies, has led to a comparison of performance data, before and after, without providing elements in terms of compatibility of the historic building. Looking at the case 1, for example, a substitution of existing windows (historic wooden frame with single glass to PVC window frame with double low-e glass) would result in a reduction of primary energy, but would have impact on the whole system, such as an overheating risk in the rooms (with a 100 % discomfort index), a visual impact risk, as well as the irreversibility of the intervention. So, in the suggested process, retrofit projects seem only limited to a building parts replacement [13]. A data analysis phase and a selection of criteria for guiding the interventions are missing, differently from the European equivalent.

Scrolling through the pages of the Italian document, however, there are numerous ideas for a careful evaluation of the interventions (e.g. from the environmental quality assessment to comfort parameters, from glare criteria to the suggestion of non-standard measures to intervene in museums). We notice that the process

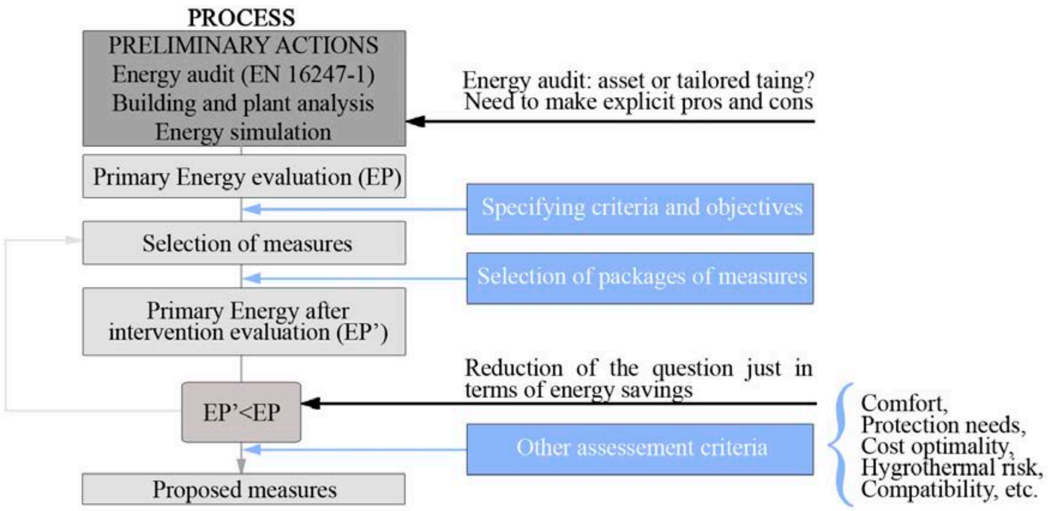

Figure 3. Mibact Guidelines flowchart showing the proposed procedure with comments.

needs to be enriched in a more organic way, integrating those criteria that are expressed in the other part of the guidelines, focusing more on the needs of historic buildings.

4. CONCLUSIONS

In both guidelines, the first part is dedicated to the building survey and data collection, meant as the lecture and evaluation of possibilities and constraints for a retrofit action (identifying where and how to intervene). However, the building should also be examined considering its thermo-physical behavior for taking advantage of the acquired knowledge during the further elaboration of the project [14]. This could be done studying in detail materials, structure and degradation forms and causes (often related to the presence of water).

The analysis of the energy performance assessment that we have done, highlighted issues due to the different methods choice. In the future, the research should focus not only on the already mentioned lack of data about historic buildings, but also on simulation tools and on the importance of estimating benefits and drawbacks, associated with the introduction of new devices.

Before starting with next steps of the retrofit decision-making, it would be necessary to introduce a list of previously defined criteria and objectives, which we aim to achieve in the assessment of retrofit measures. The difference among criteria and objectives is that criteria are valid as guiding principles to address the retrofit project, whilst objectives are differently defined for each case study. The set of them would be useful to check the congruence of all retrofit measures according to the preservation needs [15]. Alternatively, this check of congruence could be postponed to the last phase of the risk assessment, which is the most important to be examined. Absent in the Italian document, this one plays a central role in the European guidelines, where in our opinion, it should deserve some calibration. In fact, if the assessment is compiled by a multidisciplinary team, it would be as a multicriteria evaluation, in which each actor considers the single choice according to his point of view. Hence, for example, a window replacement could be positive if considered from an energy expert's point of view, but negative for an expert in heritage protection.

A way to compare all stakeholders' requirements could be to adopt a multicriteria chart model, which allows to consider the historic building's conservation needs and to easily organize the assessment of different options. Each criterion shall have a score, from 1 to 5 (as in the European case), which can be modified with multiplication coefficients. Weights could result from a comparison among the criteria, determining which ones are the most often successful and then assigning them proportional multipliers. The aim has to be not to define just a classification, but to bring out the issues to evaluate in a multidisciplinary context. In the Italian document, an attempt to weigh the criteria is found in the attached technical sheets, in which some examples of interventions are evaluated according to the categories of invasiveness, reversibility and compatibility. However, it's possible to notice different ways to interpret the same kind of interventions (e.g. the substitution of an existing roof with a new one is considered reversible in one case study and not reversible in another one).

One more important issue is that the building impact assessment should consider no single measures, but the whole, considering their effects on the microclimatic change. To avoid the most frequent mistakes, some recommendations could be added in the process before proceeding with the intervention, promoting awareness of possible repercussions on the building:

- Do not exceed the intervention, pursuing the logic of adjustment (i.e. compliance with standards requirement, suitable for modern construction), by renouncing interventions that, in absolute terms, may upgrade more, but have excessive impact [16]. Hence, the aim of an improvement action is not "doing everything", but "doing only what you need, where you need it", moving from the idea of 'Best Available Technology' to 'Best Allowed Technology';
- Take into account the building thermal properties: historic buildings have a different behaviour compared to those of new constructions. Their thermal capability guarantees fair performance, especially in hot climates. It is counterproductive to "seal" these buildings because of their need to "breathe" [17];
- Strengthen the existing building resources before promoting new interventions (e.g. restoring natural ventilation, enhance walls mass, etc.);
- Do not propose interventions not suited for the climatic context. Italy is constantly facing the negative effects of interventions, done to achieve a better performance without paying attention to the climate (e.g. massive adoption of insulation as retrofit intervention both in the north and in the south of the country);
- Consider the different climate needs choosing the most suitable measures. In temperate climate, appropriate materials should be chosen to mitigate the effects of both summer and winter demands, avoiding the adoption of materials with low phase displacement and attenuation. In hot climate, suitable

measures should be adopted to reduce cooling demand mostly in summer period like a shade system;

- Take into account users' comfort needs [18]. This is one of the weak points of both documents. First of all, it is necessary that interventions should be carefully evaluated on the basis of comfort parameters (hygro-thermal, visual, acoustic), to avoid repairs in the future (e.g. if the building is overly sealed, probably it would be necessary to add air conditioning and forced ventilation, leading also to a cost increase, as well as an environmental damage, that will reduce the advantages);
- Avoid considering savings as a simple saving of money or energy (sustainability does not mean spending less). Improving the performance also means avoiding degradation, not losing important and delicate parts (such as paintings, frescoes, wooden works, etc.), postponing restoration works. A cost-benefit analysis should be considered in a broad sense, including the entire useful life cycle of components or interventions.

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