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# ACCEPTANCE OF BUILDING INTEGRATED PHOTOVOLTAIC (BIPV) IN HERITAGE BUILDINGS AND LANDSCAPES: POTENTIALS, BARRIER AND ASSESSMENT CRITERIA

## ABSTRACT

The paper refers to the application of Building Integrated Photovoltaic (BIPV) systems for the renovation of heritage buildings and urban landscapes, preserving their historic, material, aesthetic and natural values as well as lowering energy bills, increasing comfort, and improving their technical quality in terms of economic and environmental sustainability. Several criteria for the compatible use of BIPV systems in heritage context are proposed, also taking into account the perspective of architectural preservation, legislative framework, research projects, and the scientific literature. The research is structured in the following steps: (i) examination of existing criteria for acceptable use of BIPV on heritage sites; (ii) examination of the theory of architectural preservation and restoration; (iii) identification of a set of criteria for compatible insertion of BIPV; and (iv) assessment of these criteria on case studies. The study shows new opportunities of inserting new and emerging solar products in these contexts, especially thanks to the advanced customization possibilities to preserve their values by resembling other known building materials.

**KEYWORDS**: BIPV; Photovoltaics systems; Historic buildings; Historic centers; Heritage landscape

## 1. INTRODUCTION

Improving energy efficiency in historic heritage, preserving their values and characters, is a topic of great importance, even considering that historic buildings constitute a considerable part of the European (EU) building stock. The promotion of Renewable Energy Sources (RES) has an important role in this process, thanks to the the Directive 2018/844 has introduced the concept of nearly zero-energy buildings (NZEBs) [1] for new buildings and for existing buildings subjects to major renovations. Also, Switzerland moves in this direction. Even if it is not always possible to comply with current energy standards, it is considered essential trying to improve their energy efficiency as much as possible [2]. At EU and international level this topic is gaining importance in recent years. Proofs of this increasing interest is the constant growth of funded project at European level [3; 4; 5; 6; 7; 8]. At international level, the main aim of the International Energy Agency (IEA) Task 59 [9] is to find conservation-compatible energy retrofit approaches and technologies for historic (not necessarily protected) buildings with low energy efficiency and comfort levels, also considering the integration of renewable solar resources. Different methodologies and decision-making tools to determine the correct approach for energy retrofitting and management of historical buildings have been investigated so far in EU Research Projects [3; 4; 5; 6; 7; 8; 10]. The final aim of most of these projects focused on reducing primary energy consumptions as much as possible, to improve the level thermal and acoustic conditions, quality of the internal air and natural lighting conditions, as well as preserving the historic architectural and landscape values and minimizing the environmental impacts. The aim is to look for a balance between different needs. Similarly, the International Scientific Committee on Energy and Sustainability within ICOMOS and the new EU standard EN 16883 set the importance of consider a consensual and uniform approach to be implemented [11]. The integration between solar energy systems and building components appears very critical in sensitive historic contexts, especially for the protection of their constitutive materials, aesthetical appearance and historical values. In the recent past, the installation of photovoltaic (PV) and solar thermal (ST) systems was not recommendable for historic buildings, to preserve the valuable fronts and roofs, especially considering traditional PV panels. On the contrary, nowadays, the use of integrated solar systems within these types of context to enhance energy efficiency becomes increasingly possible due to the very high compatibility of new products. These products, thanks to advanced customization with low reflecting and special glasses, colors, patterns and innovative low-cost treatments, can be designed to appear similar to traditional architectonic materials [12], as already demonstrated in some research projects [3; 4; 5; 6; 7; 8] and activities carried out within IEA SHC program [13]. The most popular strategy is the insertion of Building Integrated Photovoltaics (BIPV) systems into building components, despite the above-mentioned architectural barriers. The integration of these systems in roofs was studied departing from existing guidelines and less visually intrusive commercial products [3; 8]. The commitment of local and heritage authorities was introduced as an important step to find unexplored solutions (i.e. localization on alternative structures close by heritage sites) [3; 4]. Otherwise, BIPV market is dynamic and characterized by a wide spectrum of new architectural products for [14; 15]. These products are suitable for the application in heritage context with minor alterations of the original integrity or harming the aesthetics or cultural value of roofs, facades, skylights and windows [8; 12; 14; 15; 16; 17]. The installation of solar technologies in these sensitive contexts has not an unanimous approval in scientific circles and the motivations could be different from the point of view of conservatives. The reasons for which being somewhat diverse [15].Alongside evaluations of a technical-economic nature and considerations relevant to effectiveness and efficiency, the installation of solar - supplied devices clearly contrasts with the “slippery” project to safeguard cultural and material values, juxtaposing different weights unlikely to find common ground [14]. However, a shared framework on the acceptability and compatibility of these products on historical contexts and sensible landscape is still missing. This depends substantially on multiple meanings that can be attributed to terms such as integrity, alteration, aesthetic and historical values and in the balance among aims.

## 2. AIMS AND METHODOLOGY

The paper aims at proposing a set of shared criteria on the application of BIPV systems for the renovation of heritage buildings and landscapes, preserving their material, aesthetic, and natural values as well as lowering energy bills, increasing comfort, and improving their technical quality. On the one hand, it is possible to evaluate the efficiency and the effectiveness of an energy retrofitting intervention from the quantitative point of view (in terms of energy and economic savings). On the other hand, it is more difficult to express an assessment from a qualitative point of view, especially in the case of listed building. The assessment of these interventions should take into consideration how much is lost, in terms of material culture and historical value, and how much is gained, in terms of energy improvements and sustainability, as well as perceptive impacts on buildings contexts and landscapes. However, material loss and energy saving are two entities that are difficult to measure among themselves. It is therefore necessary to overcome this dichotomy recurring to a systemic approach that could optimize and not maximize one system over the other. The methodology is based on the literature review, the comparative analysis of technical legislation and the proposition of a set of quantity-quality criteria. While the comparative analysis of legislative framework is rather simple, more difficult is the formulation of a set of shared criteria for the compatible use of BIPV on historic buildings and urban landscapes. It was therefore necessary to open a light on different philosophies and methodologies to approach architectural conservation and restoration. The research is structured in the following steps: (i) examination of existing criteria for acceptable use of BIPV on heritage contexts in the legislative framework; (ii) examination of the point of view of architectural restorers and conservators; (iii) identification of a set of criteria for compatible insertion of BIPV with particular attention to visual impacts; and (iv) application of these criteria on case studies.

## 3. CRITERIA FOR COMPATIBLE BIPV APPLICATION

### 3.1. Criteria from the legislative framework

EU and Switzerland legislations emphasize the key role of combining energy efficiency and RES integration in the building sector. RES are mandatory for the retrofit of existing buildings, providing correct inclination and orientation [1]. This measure is not mandatory for listed buildings, when it can have an impact on the aesthetic value of the building [**Error! Reference source not found.**]. Important building renovations (in terms of surfaces involved or energy consumption reduced) require a coverage of 50% for the energy produced for domestic hot water, heating and cooling through RES [**Error! Reference source not found.**]. It should also be noted that these energy sources are one of the requisites needed for the achievement of the Nearly Zero Energy Buildings [**Error! Reference source not found.**]. In general, the integration of BIPV in the landscape is encouraged reducing its aesthetical impact and without ruin the heritage structures or natural sites [1; **Error! Reference source not found.**]. The systems must be coplanar to the roof, not protrude, and present a compact shape with a low rate reflection. Several EU Countries defined national guidelines that include BIPV installation in sensitive buildings and landscapes [1]. Specificity, the guidelines suggests several examples of best practices, but only in few cases specific aesthetic or technical criteria for their assessment. Heritage authorizations are mandatory for RES installation on cultural heritage, particularly for historical and rural buildings, historical towns and settlements, areas of landscape protection. In this case the final advice of the Heritage Office for Cultural Heritage is required. As stated, legislative framework in the different countries could approach the topic in a different way. Nowadays , the authorities and the legal entities are taking positions with a more open-mind approach. Initially, they established basic criteria and guidelines to respect. Recently, the tendency is to greater permissibility, pushing to municipalities in searching appropriate and compatibility solutions with the landscape and constructive characteristics of the urban areas and analysing specific and singular cases in detail, when necessary. Furthermore, some important methodological premises lie at the basis of these reflections. This situation is evident also from technical recommendations: (i) to ensure the maximum material preservation it is preferable to intervene on traditional buildings if quite degraded or in state of collapse, where completely new roofing is required; (ii) to minimize the alteration to a landscape it is desirable to intervene on shelters, arbours, service access volumes annexed to the buildings rather than on buildings which fully embody traditional characteristics; (iii) in urban landscape, it is preferable to intervene on buildings already compromised by blatant, modifying stages or on recent buildings, in which materials and building techniques are often employed already different from traditional architecture regulations [18].

### 3.2. A common ground for discussion: multiple attitudes in architectural preservation and restoration

Sustainability and historical heritage, both material and immaterial, seem to belong to increasingly tangent (and interactive) spheres. This new condition may contribute to overturn cultural reference both in terms of technical attitude and conservation/restoration principles. Since more than two Centuries, Europe is discussing about the fate of an impressive amount of ancient monuments, of poor but meaningful buildings, of urban fabrics and of rural hamlets that survived from the past and still characterize our territories and built landscapes [19]. During the XIX century, the two recognized ‘fathers’ of the modern restoration theories elaborated two opposite ideas about the attitude to be adopted in relation with the traces of the past that still influence our debates. Eugène Emmanuel Viollet-le-Duc clearly declared that restoration was a modern word for a modern thing and that “[…] *restoring it is not preserving a building, but it could mean to bring it again to a state of wholeness that could have never been existed in a given moment*” [20]. With a completely different approach, but agreeing on the modern essence and origin of the problem, John Ruskin asserted that “[…] *restoration is a lie; the worst lie which is accompanied by the destruction of the beloved artefact accompanied by the fake description of the destroyed thing”* [21]. Nowadays all over Europe it is possible to identify more or less codified theoretical-doctrinal positions in accordance with Ruskin’s or Viollet’s thoughts, synthetized in the following points: (i) the so named “*stylistic restoration”*, focussed on the construction of a “history of styles”, by selecting those parts of a monument that are considered consistent with the prevalent architectural language recognized in the building; (ii) the presumed “*philological restoration”* [22] recognized the essence of the monument considered as a document and stated the necessity to valorise all the signs of succeeding phases of its history; (iii) the so-called "*critical and creative restoration"* [23], that implies the critical identification of the outstanding aesthetical values of a monument, its 'true form' as the result of a genius's creation. A parallel and more complex version of this approach brought afterwards to the fundamental definition of the treatment of the so-called lacunae, i.e. the voids existing within a figurative texture, in order to re-establish not the original and lost unity but only the potential one, still suggested by the survived and remaining parts of the masterpiece of art and thus deciding which instance should prevail between the historical and the aesthetical one [24]. Finally, (iv) the usually identified as the modern "*preservative approach"* gave then the greatest relevance to the permanence of the existing artefacts, recognised and accepted in their irreducible complexity and contradictoriness, with no aspiration in transforming the existing buildings to match a coherent idea of them but trying to safeguard all the past interpretations already embedded in the body of the monument and the possibility for future ones [19]. In order to be effective in the safeguard of this legacy, we should overcome the simple struggle between the extreme terms of the traditional debate. If the choice of 'how' to intervene on existing buildings is a matter of decision, we must assume all the responsibilities about it, renouncing to invoke metaphysical or legal reasons in order to diminish the role we play in determining the real impact of our ideas and proposals. [25]. Material conservation, minimization of impacts, protection of the landscape are the indispensable objectives of any new intervention. Whatever the attitude to critical, stylistic or conservative restoration we can identify criticalities connected to impacts on historical, landscape and environmental context, substantially summed up below: (i) visible intrusion, given recipient chromatic characteristics, their shape, reflecting surface (generally contrasting with morphological surfaces, matter and already existing colours); (ii) modification of soil structure, minute territorial soil formation, vegetation etc.; (iii) replacing of existing materials and loss of matter characteristics in traditional architectural presence; (iv) alteration of social perception of the places. On these critical points, together with the results of previous investigation on legislative framework, the identification of acceptable criteria could be based [18].

## 4. IDENTIFICATION OF A SET OF CRITERIA AND BIPV APPLICATION IN CASE STUDIES

The compatibility criteria for architecture and landscape safeguarding, considering factors affecting the visibility and impacts, could be sub-divided into: (i) "localizing" (focusing on territorial vocations, panoramas, building and morphological characteristics of the network but also on the real conditions of minor building preservation); (ii) "quantitative" (depending on whether it is a question of isolated systems or repeatable/groupings, considering, hence, the question of scale, with implications for the so-called cumulative factor); and (iii) "qualitative" (relating to the morphology of the device, its colour, the possibility to mitigate on the visual impact). The factors affecting "quantity" (surface extent, rapport with roof, width, height and slope) and "quality" type (shape in relation to the context, colour, texture, anchoring, arrangement and alignment) are closely interdependent. Hence, compatibility criteria must be read not so much, and not only, as an independent but as an integrated method as they take into consideration principally the type of context and its visibility [25]. The first principle in evaluation of intervention admissibility is the maximum surface extension of the panels on the roof. Roofing rapport limit (surface of pitched roof/surface of panels) common to most technical regulations is 40% but there are specific situations with a lower degree of tolerance (15%), with the further indication of the option of covering only one slope. In small isolated or grouped rural buildings, considering the narrow dimension of their roof, a dimensional relationship contained to respect 40% would reduce the surface available for panel installation to limit an energy production – in short totally ineffective! It is, hence, not unthinkable to propose integrated solutions covering the whole pitched roof, with careful reflection on employable materials, colour and panel shape, the way they are positioned, aligned and anchored, criteria all of a quality nature and, therefore, more difficult to classify. Example of maximum surface extension interventions are shown in Figure 1 and 2. In any case, elements of a quantity nature are to be evaluated alongside "scale" and the cumulative effect issuing from repeated intervention on the landscape, the latter causing greater alteration detection and upsetting proportion equilibria. Effects of cumulative interventions are shown in Figure 3. As concerns shape, the arrangement of solar panels on triangular pitched roofs approaches the critical; the roofs poorly adapt to the fixing of a device, or a group of devices of generally rectangular shape. Consequently, panel-laying may be incompatible, unless geometrically adaptable shaped panels are employed ("laser cut"); in the case of covering the entire roof, be it triangular or rectangular, a fringe band of traditional roof covering could opportunely be left intact. The market today boasts different materials (rigid or flexible panels) and colour schemes (coloured panes, semi-transparent panes of glass) which constitute a valid alternative for better landscape compatibility versus traditional photovoltaic panel – the drawback being slow performance and high cost (Figure 4).

Figure 1: Example on solar BIPV integration in a Glaserhaus, built in 1765 in Affoltern in the Emmental / BE (CH). Left picture shows the front view of the house from 1765, in the last decades mostly uninhabited before the renovation. Right picture the illustrates the Plus Energy renovated building using BIPV solar technology in the roof, where tradition, modernity, sustainability and aesthetics complement each other and significantly improve the urban landscape (Source: Swiss solar prize 2016 and SUPSI-BFE database)

Figure 2: The 1939 built residence Villa Carlotta in Orselina / TI (CH), was recently renovated. The old oil heating has been replaced with a 38 kW heat pump solar-powered (BIPV in roof) with six geothermal probes ranging from 140 to 165 m in depth. The entire 350 $m^2$ roof area was equipped with a 51 kW PV system which covers the total energy requirement 87% (Source: Swiss solar prize 2018)

Figure 3: MFH-Multi-Family House, SanierunG Feldbergstrasse 4+6 BS (CH). Refurbishment of two houses in the protected area of Basel-Stadt. The solar roof on the south side provides more energy than is necessary for heating and hot water (Source: Swiss solar prize 2009, Viridén+Partner AG Zurich)

Figure 4: The Ecuvillens / FR (CH) rural house pilot project, dating back to 1859, uses clay-colored modules developed by the CSEM and Issol for sites protected by cultural heritage (Source: Swiss solar prize 2018)

The arrangement of the panels in relation to the lay of the pitched roof is another factor to be considered carefully. As to simple overlapping, it is preferable to select solar device integration with the roof surface material of the whole pitch, made possible in intervention of complete reroofing. To permit roof visibility, on the edges of the roof it is advisable to retain a fringe surface strip in traditional material. In the case of partial pitch covering, another delicate factor affecting the intervention impact is the method of panel grouping and aligning: care for detail, especially at the junction between panels and roof covering, remains indeed one of the most delicate aspects in relation to intervention detection.

The application of fortuitous and irregular types should be avoided in favour of solutions retaining or improving the building’s proportional status freeing, for example, the part of the roof nearest the eaves and assembling the panels close to the ridge - even if this might contradict some of the technical canons examined. Co-planarity of the panels to the pitch, referring to alignment, regular shape, grouping and precision in integrated installation, is another point for roofing panel interaction. When, in the case of total surface reroofing, elements of small dimensions are chosen (tiles or solar curved tiles, for example) other factors to be considered besides efficiency (certainly less so than in the case of panels) are the type of material and texture, in keeping with the method of solar element laying (Figures 5; 6). Available pitch surface area certainly affects the quantity of the solar or photovoltaic product to be laid and, consequently, visibility or mimesis; technology, moreover, is making great strides towards the almost total invisibility of solar cells.

Figure 5: The refurbishment and addition of new building in the Doragno Castle, Rovio / TI (CH). It uses a BIPV on the roof (16’000 kWh/y), testing an innovative and sustainable solutions for multifunctional building envelope to achieve NZE standard, using ST and PV modules (Source: deltaZERO SA Architects, pictures Luciano Carugo)

Figure 6: Hotel des Associations, Neuchâtel / NE (CH). The building is located in a ISOS protected area. Based on special and opaque modules, it integrates perfectly with the entire roof surface and preserves the historic character of the building (Sources: Swiss solar prize 2015).

## 5. CONCLUSIONS

A first analysis where made to identify compatibility criteria for architecture and landscape safeguarding, when integrate solar systems in heritage buildings or in protected urban landscapes, considering factors affecting the visibility and impacts. In parallel, in the growing sector of sustainable architecture, solar energy represents one of the main challenges that are progressively changing the building sector with the tangible revolution of solar architecture. The possibilities of new and emerging solar products, unfortunately not yet well-introduced in the market, thanks to the advanced customization possibilities (for example, low-reflection and special glasses, colors, patterns, different shapes and sizes) will offer new opportunities to better insert into contexts of special heritage protection buildings to preserve their cultural and essential values.

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