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Topic 6.3 Building, Infrastructure and Landscape Applications

BIPV AFFORDABILITY

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ABSTRACT:
Several recent international surveys [1], [2] carried out among BIPV stakeholders reveals that one of the main barriers for the wide-spread of BIPV (building integrated photovoltaic) systems is the high cost.
The economic issue is still perceived as a barrier by architects and contractors, who are the main BIPV stakeholders.
On the other hand, the drastic cost breakdown of PV in recent years has enormously decreased BIPV prices leading to cost competitiveness with standard building materials.
It is thus essential to increase trust of architects, investors and financers stakeholders, showing business cases and real stories. Architects perception is highly influenced by "tangible examples" and real experiences more than by theoretical calculations.
This paper shows 16 realized BIPV projects as business case studies, providing information on their final user costs.
The case studies were selected among more than 40 examples collected in a local "call for case study", in order to represent "ordinary BIPV high quality" examples, including several kind of integration typologies representing both private and public sector. Our investigation field is not on "extraordinary, archistar-designed" BIPV projects, but on "ordinary BIPV high quality", meaning BIPV cases with high quality which have high replication potential overall Europe.
The economic matter is tackled from two different perspectives: the "PV" perspective –normalizing the cost to kWp, and the "building" perspective –normalizing the cost to m^2.
Results show that the cost of the analyzed BIPV systems, which construction year lays between 2004 and 2015, ranges (i) from 2.500 €/kWp to 8.300 €/kWp, with an average of around 5.500€/kWp and (ii) from 300 €/m^2 to 1.300 €/m^2, with an average of around 600 €/m^2. A clear decreasing trend is shown for the last decade (from 2004 to 2015) with values of ~8.000 €/kWp and ~950 €/m^2 in 2004 and of ~3.300 €/kWp and ~400 €/m^2 in 2015.
Looking in particular at the "building" perspective (which might be more interesting for architects), it is shown that the BIPV system capital cost lays in an acceptable range and it is even cheaper than some standard passive building materials [3] (e.g. glazed curtain walls, stone and others). This, without even considering the pay-back time period, which ranges from 4 to 11 years for the presented case studies and which is "infinite" for standard passive solutions (without taking into consideration energy savings).
These tangible examples demonstrate that, despite the economic issue is still perceived as a barrier for the wide spread of BIPV systems [1], [2], the use of PV in architecture is instead absolutely viable for many cases.

1 INTRODUCTION

Several definitions of BIPV have been adopted in literature and there is no univocal consensus within the PV community and the building sector about BIPV categorization and criteria (examples of criteria and definitions can be found in [4]–[6]). At international level, the recent standard EN 50583-1:2016 "Photovoltaics in buildings" [7], states that photovoltaic modules are considered to be building-integrated, if the PV modules form a construction product providing a function as defined in the European Construction Product Regulation CPR 305/2011 [8].
The meaning of the acronym BIPV in this publication, is intended in a broader meaning compared to the EN standard definition and in particular refers to a triple concept of integration: technology, aesthetic and energy integration. Technology integration is meant as the capability of the PV system to be "multifunctional" (as intended in the EN Standard) and aesthetic refers to the architectural appealing. The energy integration refers to the capability of a PV system to interact with the building and district energy system in order to maximize the local use of the produced electricity. This is in our view a quite important aspect which is often not considered in the traditional BIPV definitions.
In fact, despite the existing "BIPV" definitions, we believe that in order to succeed in the BIPV system design, all three aspects must be considered. The selected BIPV cases studies are considered respondent to this triple concept.

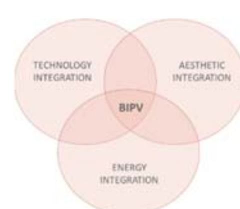

Figure 1: BIPV integration concept

2 CASE STUDIES SELECTION METHODOLOGY

In order to collect the most representative case studies for our investigation (i.e. ordinary BIPV high quality examples), a local "call for case studies" was launched by contacting most of the engineers, architects and professionals of Trentino Alto Adige region through several channels (projects contact list, Engineers and Architect associations). This region has been very active in recent years in the BIPV field by boosting PV use and building energy efficiency through several measures: incentive schemes, dedicated policies, awareness raising, guidelines development and public engagement in the use of PV in public buildings.

Out of more than 40 collected cases, the best ones were selected through an internal workshop involving 19 Eurac collaborators, forming a "selection group". The selection was based on two main criteria, i.e. "overall impression/global approach" and "lesson learnt". The collaborators were asked to evaluate each case study by considering the following aspects:

- Overall impression / global approach, considering both technology and aesthetic integration, in particular:
  - the way PV integrated in the whole concept of the building and contributes to/preserve architectural quality;
  - the whole building concept;
  - surface texture, composition of visible materials, correlations of colours, details (especially successful new designs)/joints/fixing.
- Lesson learnt, also considering the energy integration, according to the following questions:
  - Is it an interesting experiment of PV integration?
  - Is there something to learn about it?
  - Are there innovative architectural concepts, original solutions, original applications?

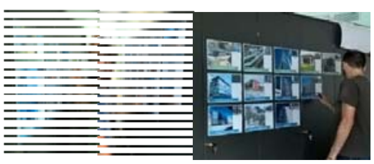

Figure 2: Pictures of the workshop for the selection process

The cases getting a score higher than 20 marks were selected and included in this paper, meaning that the great majority of the "selection group" found the project interesting and inspirational for architects, as "ordinary BIPV high quality" examples (according to the BIPV definition given in the introduction).

In this way, 19 best case studies were selected.

For each of the selected case studies, a questionnaire was performed to collect information from at least one of the involved stakeholders (e.g. architect, owner, PV system electrical designer, installer, general contractor). Out of these 19, we could collect information and authorizations to publish on "cost issues" just from 16 of them.

3 CASE STUDIES OVERVIEW

The case studies were categorized according to the EN standard 50583:2016 "Photovoltaics in buildings" [9], as shown in Figure 3.

Figure 3: "Photovoltaics in buildings" categories according to [9]

The categories schematized in Figure 3 can be described as follows (from left to right):

- Category A: Sloped, roof-integrated, not accessible from within the building
- Category B: Sloped, roof-integrated, accessible from within the building
- Category C: Non-sloped (vertically) mounted not accessible from within the building
- Category D: Non-sloped (vertically) mounted accessible from within the building
- Category E: Externally integrated, accessible or not accessible from within the building

BIPV Case study	Architectural system	Standard category	Ownership
1	Semi-transparent roof	B	Private
2	Opaque tilted roof	A	Public
3	Semi-transparent roof	B	Private
4	External semi-transparent device	E	Private
5	Semi-transparent roof	B	Private
6	Opaque tilted roof	A	Private
7	External opaque device	E	Private
8	Opaque tilted roof	A	Private
9	Opaque cold façade	C	Private
10	External semi-transparent device	E	Public
11	Opaque tilted roof	A	Private
12	Opaque cold façade, semi-transparent façade	C, D	Public
13	Opaque cold façade	C	Public
14	Semi-transparent roof-façade	B, D	Private
15	Opaque cold façade	C	Public
16	Opaque tilted roof	A	Public

Table I: Case studies characterization according to their BIPV architectural system

Among the selected case studies, examples of different type of building typologies are presented, including office, residential, agricultural, industrial, community, religious, commercial and transportation buildings.
Several architectural integration are shown, including opaque and semi-transparent roof, warm, cold and double skin facades as well as external devices such as parapets and solar shading elements. The most predominant are façade and roof systems.
Different kind of ownerships (private and public) are also represented, giving an overview on different approaches to the BIPV matter, especially regarding the decision making related to economic issues.

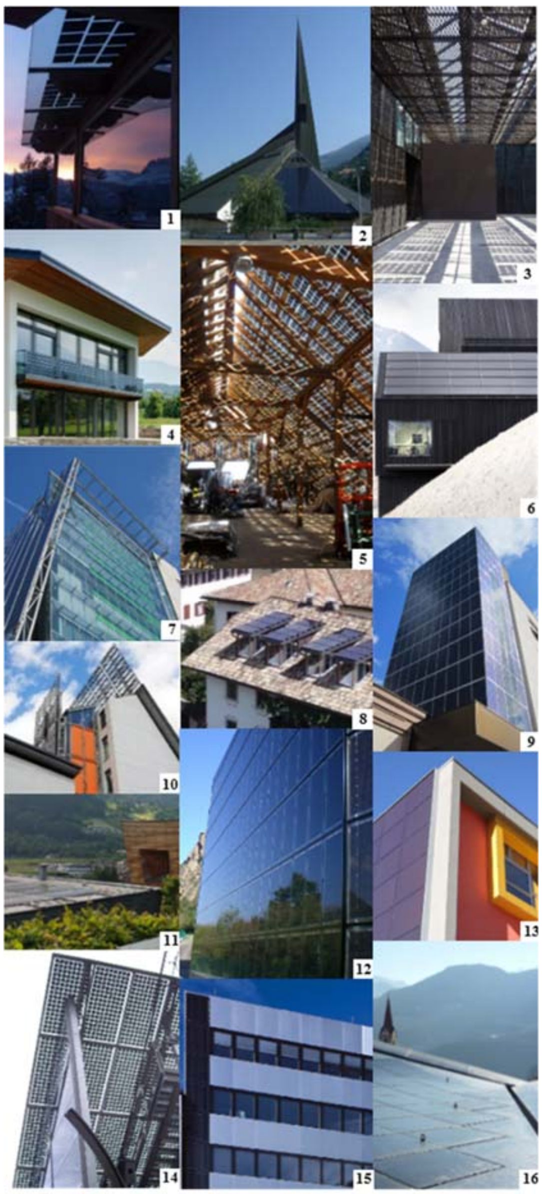

Figure 4: Pictures of analyzed case studies

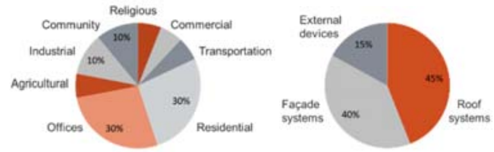

Figure 5: Building typologies and architectural integration types presented in the case studies

Regarding the PV modules, the crystalline technology is the mostly used, being applied in around 80% of the analysed case studies. Most of the systems are made using standard modules (only 30% are made with costume-made modules), showing that in many cases appealing BIPV systems can be realized without the need of customization.
A more detailed case studies description is insert in [12].

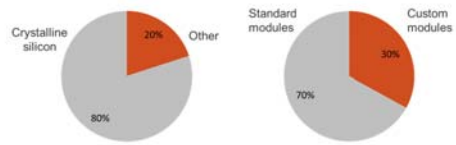

Figure 6: PV technologies and module types presented in the case studies

4 RESULTS

Figure 7 and Figure 8 show a summary of the cost of each BIPV system, looking at the same issue from two different perspectives (i.e. the "PV" perspective and the "BUILDING" perspective).
Figure 7 normalizes the BIPV systems cost to the nominal power (€/kWp), an indicator which is always used in the "PV sector". The cost of the analyzed BIPV systems ranges from 2.500 €/kWp to 8.300 €/kWp, with an average of around 5.500€/kWp, considering that the analyzed systems were built in the decade between 2004 and 2015.
This variation can be ascribed to several factors, such as the type of technological integration, type of components and, mostly important, the construction year, since the PV cost has seen an impressive decrease in the last few years.
In particular, looking at the technological integration types, the following average values are found:

- Opaque cold façade: ~7.900 €/kWp
- Semi-transparent roof-façade: ~5.100 €/kWp
- External device: ~4.900 €/kWp
- Opaque tilted roof: ~4.400 €/kWp

In order to look at the economic matter from another perspective, the cost has been normalized to the envelope covered surface (€/m^2), thus using an indicator which is normally used in the "BUILDING sector" (see Figure 8). The cost of the analyzed BIPV systems ranges from 300 €/m^2 to 1.300 €/m^2, with an average of around 600 €/m^2.
In particular, looking at the technological integration types, the following average values are found:

- Opaque cold façade: ~ 850 €/m^2
- Opaque tilted roof: ~ 600 €/m^2
- Semi-transparent roof-façade: ~ 500 €/m^2

- External device: ~ 500 €/m²

As the €/kWp index, the cost variation can be ascribed to several factors. In particular, this time a crucial role is played by the PV module efficiency. For this reason, looking at this indicator might be misleading but it is very useful to compare the BIPV system cost with standard building materials. It demonstrates that in fact, the BIPV system capital cost lays in an acceptable range and it is even cheaper than some standard passive building materials [3] (e.g. glazed curtain walls, stone and others). This, without even considering the pay-back time period, which ranges from 4 to 11 years for the presented case studies (this information was not available for all cases) and which is "infinite" for standard passive solutions (without taking into consideration energy savings).

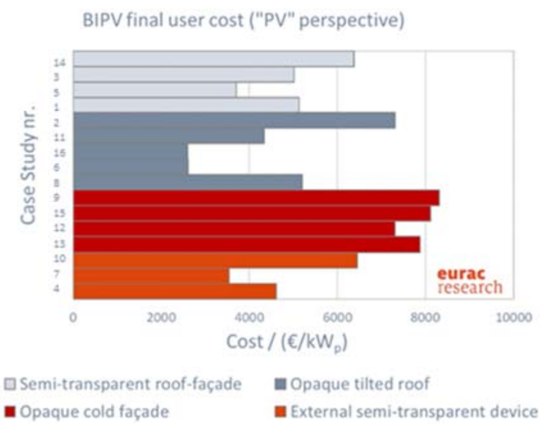

Figure 7: Final user costs of the analysed BIPV systems, normalized to the system nominal power

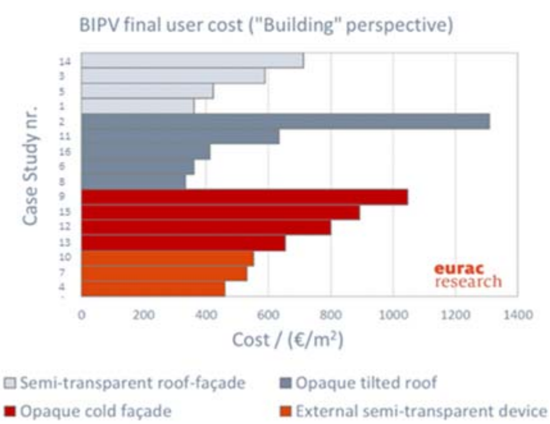

Figure 8: Final user costs of the analysed BIPV systems, normalized to the envelope covered surface

As mentioned above, the cost variation is very much influenced by the construction year, since the PV cost has seen an impressive decrease in the last few years. Figure 9 and Figure 10 show the trend over the years of the final user BIPV systems cost, considering the "PV" and "Building" perspective.

A clear decreasing trend is shown for the last decade (from 2004 to 2015) with values of ~8.000 €/kWp and ~950 €/m² in 2004 and of ~3.300 €/kWp and ~400 €/m² in 2015.

By comparing this data with standard not integrated PV systems, we might conclude that the "BIPV" trend cost in 2015, corresponding to 3.300€, is not too far from a ground-PV solution (considering a base line cost of around 2.500 €/kWp, typical of small plants in the last recent years).

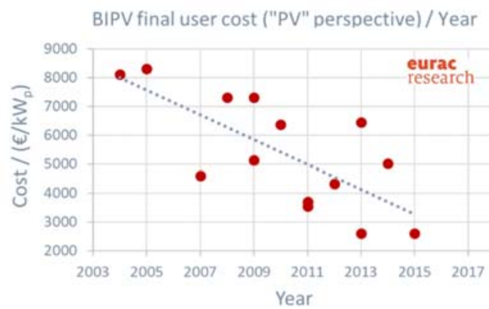

Figure 9: Final user costs of the analysed BIPV systems per construction year, normalized to the system nominal power

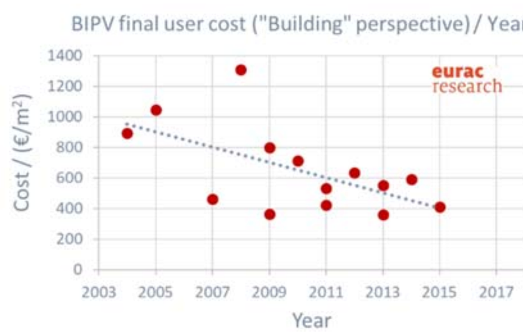

Figure 10: Final user costs of the analysed BIPV systems per construction year, normalized to the envelope covered surface

5 CONCLUSIONS

These tangible examples demonstrate that, despite the economic issue is still perceived as a barrier for the wide spread of BIPV systems [1], [2], the use of PV in architecture is instead absolutely viable from this point of view. A clear decreasing trend over the years during the last decade is shown in Figure 9 and Figure 10.

Even if some incentive schemes are over in Europe (e.g. the "Conto Energia" for Italy, which lasted from 2005 until 2013), they have paved the way to an irreversible process that cannot be stopped anymore. At Italian level, the current support schemes, relies mainly on two measures: tax credit, which allows to rescue 50% of the capital cost in 10 years, and the "net billing scheme" managed by GSE, which valorizes from an economic point of view delivered to the grid.

The economic viability of BIPV systems is thus preserved, even if we can somehow read a conceptual shift in the way to reward it: with the "Conto Energia" the formal and technological integration was mainly boosted (through a higher contribution foreseen for "innovative BIPV"), while, with the current schemes, the energy integration is mostly pursued, in order to maximize the energy match between the produced and consumed energy.

This energy integration will become more and more important to cope with new ways to conceive buildings and their energy provision. In fact, also thanks to the EU policy oriented to promote the NZEB (nearly zero energy buildings) concept and RES (renewable energy sources) exploitation [10], [11], buildings are becoming more than just stand-alone units using energy from the grid. They are becoming micro energy hubs consuming, producing, storing and supplying energy, thus transforming the EU energy market, shifting from centralised, fossil-fuel based, national systems towards a decentralised, renewable, interconnected and variable system.

In this context, PV integration is irrevocably destined to play an essential role in the years to come and, learning from the experience gathered in realized projects, BIPV systems will have the opportunity to improve in all three aspects of its soul (technological, formal and energy).

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