BIPV PRODUCTS OVERVIEW FOR SOLAR BUILDING SKIN (SUBTOPIC 6.3 / BUILDING, INFRASTRUCTURE AND LANDSCAPE APPLICATIONS)

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ABSTRACT: In this paper, the authors report on a jointly conducted analysis of the current status of the BIPV market by giving a comprehensive overview on the available products, the current trends of technological innovation, the application ranges and a survey on the price levels. For this purpose a market survey was conducted among the various stakeholders in the BIPV sector, including manufacturers, installers and BIPV product suppliers. The survey focused on different application areas: roof and façade systems including both crystalline and thin film technologies. The market survey was conducted for the European market, with emphasis on The Netherlands and Switzerland. The most frequent products investigated were PV tiles and full roof solution (mainly for residential roofs). Although crystalline silicon technology was most commonly used, thin film technologies gained considerable share as well as façade systems. The data from the price survey showed that BIPV systems for the building skin can be executed at very similar costs than projects involving conventional building products.

Keywords: BIPV, building integration, multifunctional component, architecture, database

1 PREFACE

The BIPV market in Europe is in a transition. The past decades of a slowly emerging BIPV market have been characterized by the original dominant value of BIPV: a building that communicates an image of sustainability and innovation. As BIPV is more expensive than straightforward application of a PV system on a roof (BAPV), the appropriate question is always: what is the value that justifies this additional cost? In the past years this value in most cases was: image. The message that is communicated by the building: a message of sustainability, responsibility and even idealism. Payback time or return on investment have not been the major parameters in the decision process for applying BIPV.

This is changing now. In most European countries the new regulations on energy performance in buildings, derived from the EPDB 2010 [1], have been defined and the time for the regulations to become mandatory is very near. The energy performance regulations are now taking over as the main driving factor for the BIPV market. And that has huge consequences. Instead of BIPV finding its value in only being visible and supporting an image, the main value of BIPV products now becomes to be invisible. In other words: we do not want to see anymore the difference between a building component and a BIPV component both in aesthetical and construction terms.

Another dominant market factor in the new era is the fact that high-rise buildings (such as multifamily residential blocks) simply do not have enough roof area to meet the energy performance requirements, by using conventional PV modules. This leads the building designer naturally to the use of the façade for applying BIPV, which is a central part of the architectural concept.

This change in market driver has led to an intensified research and development aiming to create BIPV products that come in a variety of colours and sizes, while at the same time the manufacturing of the BIPV ideally should be as close as possible to existing building components, to its requirements and to the way of working in construction industry.

2 CLASSIFICATION OF BIPV SYSTEMS

The acronym BIPV technically refers to systems and concepts in which the photovoltaic element carries an additional building functionality, namely replacing an element of the building skin. The use of PV in the building sector opened up questions: re-imagine the envelope of solar buildings both in aesthetics and technology. The relationship between PV and construction has evolved in the years through gradual steps of innovation, resulting in a progressive technological transfer in the building technical elements, from addition of PV in conventional building elements, to the layering of the building skin with active cladding parts up to new integration concepts where PV is part of a unitary building envelope.

2.1 A basic concept: BIPV as a building component

Multifunctionality [2] refers to the functional or physical role of the PV modules in the building skin. In this definition, PV modules are considered to be building integrated if they represent a component of the building envelope providing a function as defined in the European Construction Product Regulation CPR (Construction Product Regulation n.305/2011) [3]. Thus the building performance of the BIPV module is required for the integrity of the building's functionality. Considering the growing market share of BIPV, the progress in standardization (EN 50583-2016, Parts 1 and 2) [4] and the tightening regulations with respect to CPR, we can state that a BIPV component is not merely an electrical device but it is becoming a mature building element as well.

2.2 Beyond functionalism, BIPV architecture.

BIPV also refers to the architectural concept: like any other building material, the potential of PV is its materiality and the opportunity to define the linguistic/morphological rules governing the signs, the structure and the composition of the architectural language. A large repertoire of examples is progressively

showing the aesthetical innovation in contemporary architecture due to a solar design.

3 BIPV PRODUCTS DATABASE

The research methodology is founded on the analysis of a database collecting mainly products by manufacturers and installers based in Europe, focusing on systems commercially available in the Swiss and Dutch/Benelux markets. The SUPSI website www.bipv.ch and the SEAC-SUPSI BIPV status report of 2015 [5] served as basis for the products list. We removed products that were withdrawn from the market since 2015 and added new products that entered the market until today. This was executed through an internet web search, interviews with industries and trade fair visits. For more detailed definitions the complete report is available [6].

3.1 Product overview

Figure 1 shows the overview of the products grouped for BIPV categories. The most common product group is that of solar tiles (any size) immediately followed by the full roof solution. In 2015 this trend was already visible even though full roof systems where slightly more common than solar tiles. Products for rain-screen façades, where the photovoltaic module is used as a building cladding, and skylight/solar glazing follow with a significantly lower percentage. Products for roofs are much numerous compared to those for façades indicating that the roof market is currently wider than the façade market. It has to be remarked that products described as solar glazing for roofs are generally marketed also with a curtain wall variant.

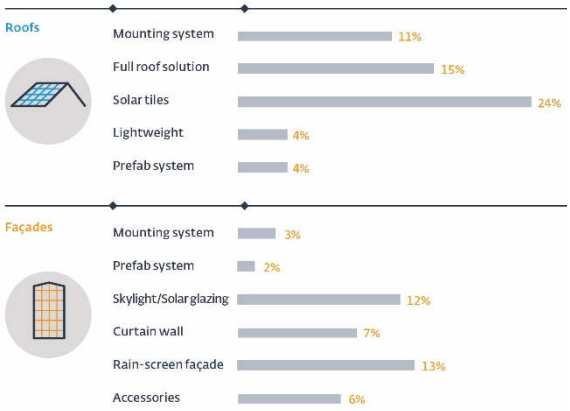

Figure 1: Results of the market survey presented in terms of the occurrence of product groups. Distribution of BIPV products according to different categories.

2.1 Used PV technology

The 8% of the BIPV products for roofs and 44% of the BIPV products for façades resulted to be using thin film technology. This is a very high technology share for thin film, when considering that only about 5% of all worldwide available PV module types are made using this technology [7]. We suggest the possible explanation for the success of thin film in BIPV, especially on façades, to be due to two key reasons: first of all the aesthetic appearance and secondly the low price/m^2, associated to the high relative substitutional costs when saving out conventional building materials.

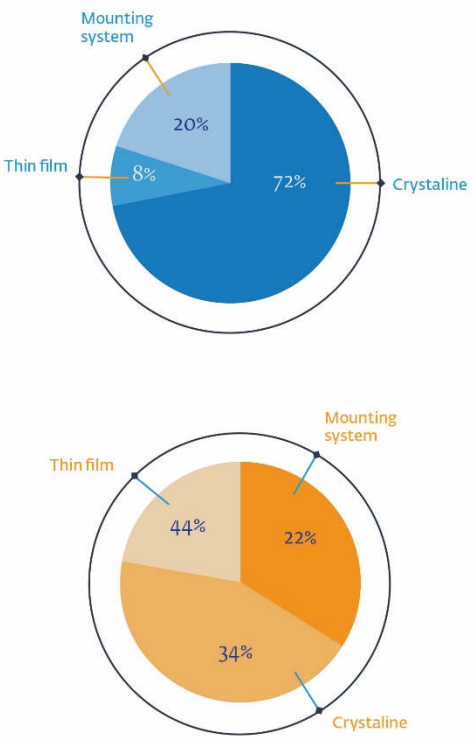

Figure 2: Pie charts of the technology used in the roof (top) and façade (bottom) BIPV application areas

During the data collection phase it was noticeable how products appeared and disappeared on the market in a consistent manner. About 35% of the companies listed in the current edition did not offer their products two years ago. Since the list only marginally grew (from 108 to 114 products) this means that also about 35% of the companies listed in the previous edition, stopped their activities or no longer offer BIPV products.

4 BIPV TECHNOLOGY TRENDS

The process of photovoltaic transfer in building ranges between new and tradition. In architecture, the replacement of an existing material with a new one is usually accompanied by the permanence of tradition looking both at architectural languages and technical systems. This slow process of innovation is linked both to new technology and new design models which can be related to morphological aspects, building skin image or construction and so on.

Regarding the building envelope, for example, the physical flexibility and lightness of thin film permit to incorporate PV in ultrathin and lightweight skins or membranes. The innovative trends such as Luminescent Solar Concentrators (LSC), new technologies (e.g. DSSC) or some treatments for glass are opening the scenario of a new language of photoactive technologies towards a colored or “invisible” PV and indoor PV |7].

The technological transfer of PV in the architecture field is changing building skin design approaches and opening new challenges. The industry makes available a plenty of products for building application: multi-functionality, cost-effectiveness, mass customization and other paradigms are ensuring a growing penetration on the real market. Thus, along with functional and construction aspects, definitely BIPV is today one of the new

fundamentals for the contemporary innovation in architecture.

4.1 Prefab mounted BIPV

Using prefab elements brings a lots of advantages in building process: along with a better quality control of the construction component, it allows a fast building mounting and e.g., in case of renovation, lets people to stay inside their homes.

In some prefab systems the whole process of design, manufacturing and implementation is performed industrially.

These products are not only serially produced but are also more and more mass-customizable and, in case of BIPV cladding, it is possible to select: colour, stratigraphy (e.g. insulation thickness), dimensions, ratio transparency/opacity, types of interior and exterior layer, total thickness and fixing system. Consequently a successful integration of PV is possible thanks to advanced solutions where mass-production and flexibility are strategically optimized.

4.2 Coloured or patterned façades

The colouring of PV, namely its ability to be camouflaged or "designed", has been considered an essential requirement for market acceptance of PV façades in recent years.

In a BIPV glass façade, the conventional PV appearance can be camouflaged behind coloured patterns that completely dissimulate the original materiality of the PV cells. This involves a "shading" over the PV cells and a consequent reduction of the energy production that needs to be carefully optimized in order to obtain an energy efficient customization. Namely the challenge to optimally balance the aesthetical quality with the energy and electrical efficiency, reliability and safety is one of the drivers of innovation in the BIPV sector. Different customization techniques can be identified in the current developments [8].

Colouring and pattern of PV panels may occur by several different methods and treatments applied mainly on:

- the cells and backsheet
- the front glass
- an intermediate foil

Figure 3: A BIPV white module obtained through a laminated color foil with diffuse reflector (Solaxess).

4.3 Solar glazing

The combination of glass and photovoltaics seems to match well in terms of both aesthetics and functionality of the building skin and the "BIPV glass" market is expected to grow in the forthcoming years.

There are various technological routes to manufacture active solar glazing:

- Crystalline silicon glass-glass modules
- Crystalline silicon cell strips
- Thin film solar cell strips
- Thin film solar strips hidden by a lens system
- Luminescent solar concentrators
- Thin absorber layers

Figure 4: Thin film solar cell strips (Onyx).

4.4 Lightweight systems

Two techniques can be distinguished: modules based on thin-film technology and modules based on crystalline silicon technology. In general, thin film flexible panels have a smaller curvature radius and are more robust under continuous bending, flapping and moving conditions. They would therefore be a good choice for applications on tents, membranes, corrugated sheets, etc. Crystalline silicon flexible lightweight panels are higher efficient than their thin film counterparts, but less flexible and sometimes less good looking. They would therefore be a good choice for 'invisible' applications with a permanent fixture, such as flat roofs. New approaches are emerging to obtain such innovative applications [9].

5 BIPV PRICE SURVEY

A market survey was conducted through an on-line web form that was sent to producers, suppliers as well as installers of BIPV products. The market survey was conducted mainly for the Dutch/Benelux and Swiss markets.

The survey was sent out to about 120 contacts from which we collected 35 respondents. Roof solutions collected more feedback than façade products. This was probably because these kinds of systems have been on the market for a while and they are characterized by quite distinct cost levels associated with almost completely standardized mounting systems. If BIPV roof solutions are seeking to be as similar as possible to standard roofing applications, façade products are instead focusing more on tailored made building engineering solutions (rain-screen façade, curtain wall), especially in case of existing buildings, so that in most cases the price levels are still uncertain and less definable or, as mentioned before, cannot be really generalized from specific contexts.

Product group	# Participants in price survey
BAPV system and roof tiles	7
In-roof mounting system	4
Full roof solution	7
BIPV tiles	7
PV membranes	3
Metal panels	-
Solar glazing	-
Rain-screen façade	3
Curtain wall	-
Accessories	-
Solar glazing	4
Total	35

Table 1: Number of participants in the product survey with BIPV solutions for a roof or a façade.

In-roof mounting system, BIPV tiles and BIPV full roof solutions are already widespread available while BIPV metal panels, BIPV membranes, BIPV skylights and BIPV façades are still niche products for which it is difficult to rely in a consistent number of participants in the price survey.

The market of BIPV façade systems in Switzerland and Benelux, even though a relevant trend of increase is tangible, is still relatively small and there is a large cost variety depending on the building type, building skin application and on the specific context of intervention.

5.1 Costs: from LCOE to €/m^2

The reviewed price survey covered both BIPV and BAPV applications. The results on BAPV systems were included in order to have a benchmark and reference of the BIPV products but the main goal was to consider the prices of conventional building materials for further reference. The price study focused on end-user prices in the Benelux and the Swiss market, excluding VAT, thus obtaining an "average" European reference cost. The end-user prices are converted to €/m^2, which is the end-user PV system cost calculated over the area that the PV systems covers on the roof or façade. Using this unit of €/m^2 it is possible to directly compare various PV technologies to conventional building materials.

The ranges of cost are displayed in fig. 5. For façade systems is indicated the cost for providing only the cladding panel whilst for the roof is indicated the final cost. The grey bars represent the share of the costs that is avoided because the conventional building material (passive element) is replaced. The black bars represent the true additional costs that contractors need to spend in order to apply PV functionality in their building skin. The total cost results from the sum of both. The error bars show the full range (min-max) of all the different quotes.

Financially, a BIPV system becomes feasible in most of cases when BIPV replaces conventional building cladding elements (curtain wall, marble, etc.) and cost-effectiveness can be demonstrated taking into account the whole building envelope system. E.g. it is particularly interesting to use prefab elements or integrated solutions which allow to optimize not only the cost but also the timing and the complexity of the installation. In this case the technical and process costs can be evaluated together.

As mentioned before in a façade system (rain-screen façade, curtain wall, etc.) the BIPV cost is strongly affected by specific building factors that are the main drivers for cost-effectiveness and it cannot be easily generalized.

Moreover the cost of a BIPV unitized façade systems, which includes the supply of all the cladding elements, substructures, fixings, joints, connections, etc. (excluding insulation) as well as the needed building and electrical equipment (and usually also the installation of the system itself), cannot be compared with cases where the BIPV cladding is self-contained (it can be removed or replaced) from the rest of the façade system (typically, this is the case of a BIPV module that can be mounted as a façade cladding). In the second scenario the price is more similar to a conventional PV module.

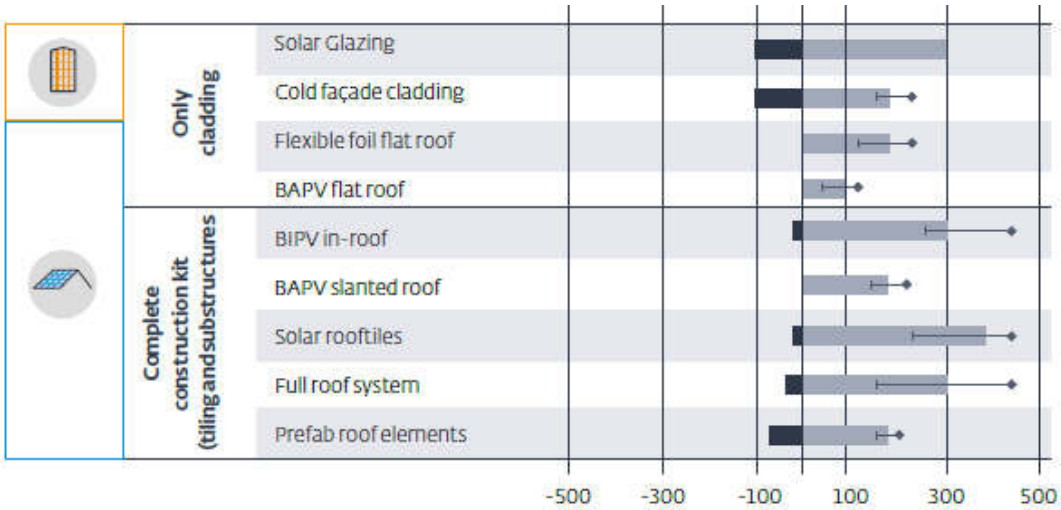

Figure 5: Cost of BIPV as resulted from the survey.

5.2 Cost of complete BIPV roof tiling construction

The graph refers to the final cost of a complete roof tiling construction, including mounting, transportation and other additional costs. This cost includes both the roof tiling and the mounting system (clamp, metal ducts, etc.). It shows a significant price range for the different conventional roofing materials.

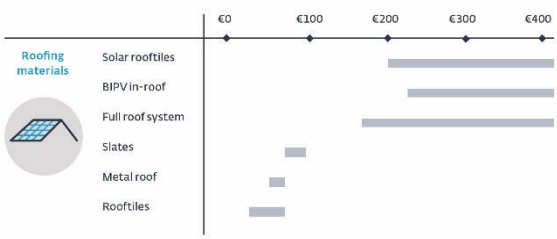

Figure 6: Cost of BIPV roof tiling compared to other roofing materials used in conventional pitched roof.

5.3 Cost of façade cladding

The prices for conventional façade applications were obtained using Swiss databases on building price information.

The next graph specifically refers to the cost of the cladding, namely the outer material layer that represents the exterior wall. The costs of the substructures, fixings and insulation are excluded. Only in case of curtain walls it is considered the cost of the whole system (including mounting and shading elements). Not to consider these variables could lead to confusing evaluations on costs.

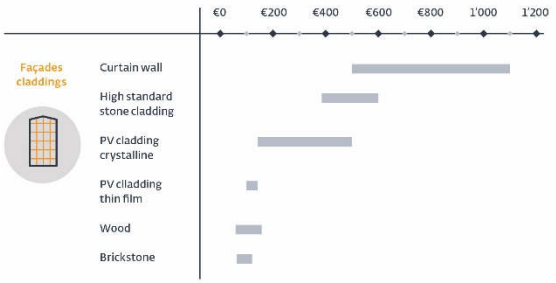

Figure 7: PV costs compared to other cladding materials used in the built environment as façade cladding materials.

Figure 7 provides only some reference ranges, which are not substitutive of an ad-hoc request of quotation for a specific building project. The cost per square meter is influenced by various factors such as: the global size of the project, the building typology and the window to wall ratio, the planned type of substructure (wood, aluminium, steel) which has a major influence on the durability of the installation itself, but also on the complexity of the technical details (the simpler, the cheaper), the size of the modules, the form of the façade (more or less articulated) from which it depends the possibility of using a modular system that is clearly simpler and usually lower priced compared to a custom made product. In case of transparent façades it could be necessary to plan an integrated shading system which could influence significantly the final cost of the BIPV installation.

In general the design, and consequently the required aesthetics, greatly affects the cost of the cladding layer. For example, the size and weight of the cladding element influences the characteristics of the substructure.

The market analysis indicates the following important conclusion: for façades a very interesting price point has been obtained, since BIPV systems are very comparable in price with conventional façade materials/systems and extra-costs to make it active are no higher than extra-costs for BIPV roofs! BIPV façades strengthen the promise of BIPV because these applications are cost-wise suitable as a substitute for the conventional solutions. This holds the promise of 'PV for free' in building contexts where façades are already quite expensive (unitized façade, curtain wall, rain-screen façade, etc.).

6 CONCLUSIONS

Compared to the previous BIPV Status Report, a greater product diversification is taking place even though the most common categories are still roof related (solar tiles and full roof solutions) indicating that this market is still significantly bigger than the façade market. Some of these new products appeared on the market also as a result of innovation projects supported at a national or European level.

Regarding the BIPV trends we expect that 'Invisible PV' will become a driving approach in the development of new products and that new technologies focusing on blending PV panels in buildings design will enter the market. Multi-functionality, cost effectiveness, mass customization and other paradigms are ensuring a growing penetration of the technology itself, but beyond functional and energy aspects: BIPV is slowly becoming part of the architectural concept!

Summarizing the considerations obtained through an online price survey we can affirm that standardized prices per square meter do not exist neither in building nor in BIPV, and suppliers are generally unwilling to share pricing information apart from very specific price quotations. Nonetheless, thanks to the participation of approx. 35 companies, we can conclude that BIPV is affordable and that the extra cost compared to a wide range of conventional building materials, especially on the high-end spectrum, is limited. However, there was no big price drop compared to 2 years ago. BIPV volumes remain low and no economy-of-scale effects are observed yet.

Overall, the BIPV sector is in a healthy shape. Many attractive products are available, reliable and offered at a competitive price. Good examples of aesthetically pleasing and affordable BIPV buildings can be found and are more and more entering the ordinary building stock. Normative approaches for product qualification are quite clear as well. It is time for the demand side to catch up and allow the suppliers of BIPV products to enlarge their market and realize economies-of-scale. We hope that this report helps to create awareness in the building and PV sector and positively add to the direly needed enlargement of the market.

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