University of Applied Sciences and Arts
of Southern Switzerland

SUPSI

Solar Energy Application Centre
The Netherlands

BIPV Product Overview for Solar Façades and Roofs

BIPV Status Report 2015, SUPSI - SEAC

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PREFACE

After several turbulent years, the market for Photovoltaics (PV) now entered a more mature phase. Prices have stabilized, market volumes show a healthy growth and national support schemes are being reduced or redefined. At the same time we see an interesting market segment emerging: Building Integrated Photovoltaics (BIPV). It is expected that the European BIPV market will experience a rapid growth in the years to come. Its key market driver is the European Directive 2010/31/EU [1].

In BIPV applications, photovoltaic modules, available as flat or flexible surfaces, realized with cells or laminates, are integrated into any element of the building envelope. Due to their features (size, flexibility, shape and appearance), BIPV is particularly suitable for being "designed". In fact, these photovoltaic elements can be used together with materials that are common in architecture, such as glass or metal, in opaque as well as in semitransparent surfaces. This is particularly true for roof systems where solar cells are incorporated in conventional building components such as shingles or terracotta tiles.

Manufacturers today can provide the building sector with a variety of interesting products, ready to be used by architects and planners. Nevertheless, adoption and application of BIPV by the building sector is relatively slow. Its potential is not well known by architects, and from the economical point of view, its affordability is not sufficiently demonstrated.

The purpose of this report is to inform architects, stakeholders and technicians with a comprehensive overview on the capabilities, potentials, specifications and strengths of PV in the building skin. We present a general overview on the available systems, prices, technologies and application ranges. The report concludes with some leading project examples. This report is the collaborative work between the Swiss BIPV Competence Centre of SUPSI (Switzerland) and the Solar Energy Application Centre (SEAC, The Netherlands).

The **Swiss BiPV Competence Centre of SUPSI** was created in 2005 within the Institute for Applied Sustainability to the Built Environment (ISAAC). It aims to combine the competences of the department of Architecture of the University of Applied Sciences and Arts of Southern Switzerland (SUPSI) with those of ISAAC, offering a new and appropriate approach to photovoltaics for architects. Applied research, training and professional advice are the pillars on which it founds its activities. The www.bipv.ch website, supported by the Swiss Federal Office of Energy, is one of the communication platforms of the Swiss BiPV Competence Centre. Here you can find essential information concerning PV technology integration in buildings and different projects realized both in Switzerland and abroad. Moreover, one has access to a comprehensive overview of manufacturers, suppliers and installers covering a wide range of BIPV solutions.

The **Solar Energy Application Centre (SEAC)** is a cooperation of knowledge institutes in The Netherlands, founded in 2012 on the initiative of ECN, TNO and Holland Solar. The scope of SEAC is the field of solar energy systems & applications, which includes photovoltaic systems and solar thermal applications. The technical expertise of the SEAC is strongly focused on three key R&D areas: benchmarking, field testing and techno-financial modeling of solar energy systems & applications. The SEAC covers these and other topics in close cooperation with ECN, TNO, Utrecht University, Technical University Delft, Technical University Eindhoven, Wageningen University and Zuyd University of Applied Sciences.

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MANAGEMENT SUMMARY

Building Integrated Photovoltaics (BIPV) is about multifunctional building elements that generate electricity. BIPV therefore brings the worlds of construction and photovoltaics together with all the challenges and chances inherent to such a change of paradigm. After more than 20 years of R&D [2], the market for building-integrated photovoltaics (BIPV) has kicked off with very interesting products and elegant showcase projects. The birth of this market has been based on an enormous progress in PV technology development (cost-wise and performance-wise), together with the vision of some leading architects and industries. Today the European BIPV market is supported by approximately 200 commercially available products.

The SUPSI-SEAC report 2015 gives a comprehensive overview of BIPV, its product classification, its price levels, its available products and its example projects.

The report starts off with an adapted classification of BIPV systems according to the most recent developments in the market. We believe that this classification system serves the purpose of understanding the market segmentation and the product segmentation in BIPV. Three main application areas are distinguished: Pitched roofs, flat & curved roofs and façades. The application areas are sub-divided into thirteen different product categories. A short description and a photograph of an application is given per product category.

Next, in chapter 2 we investigate the price levels for the various product categories. The investigation was made by asking Dutch and Swiss BIPV installers to quote on a fictional building. PV products were found to be priced about 200 €/m^2 above conventional roof products like tiles or shingles. In façade systems, this is different. PV products were priced very similar to conventional façades made from materials like wood, stone or glass. A major factor in the price levels of the BIPV applications was whether standard size PV panels or non-standard size PV panels were used. In the first case BIPV pricing could come close to conventional PV pricing. In the second case the price could be a factor 3 higher than conventional PV applications.

In chapter 3 we present our updated database of BIPV products available. It consists of 108 BIPV products that are commercially available in Europe, with a focus on the Dutch and Swiss markets. The database evolved out of the networks of SEAC and SUPSI together with results of our internet search and trade fair visits.

In earlier publications, the market analysis made through the database of the SUPSI website [3] and the published BIPV report by SEAC [4] showed that the most common products for roof applications were “In-roof mounting systems”, while “solar glazing” and “cold façades” (”cladding”) represented the majority of façade applications. In this new analysis, we find that the most abundantly populated product categories are “Full roof solution” and “Solar glazing”. The least occupied product groups are “PV membranes”, “Metal panels” and “Warm façades”.

Judging from the sheer amount of products available, rooftop applications have the largest market share within BIPV. In the utility and commercial segments, façade BIPV systems are expected to gain importance. The key market driver for this segment is the European Directive 2010/31/EU [1], which states that each new building should be made ‘nearly zero energy’ from 2020 onwards. Façade PV systems are essential to meet this demand, as in many utility and commercial buildings the roof is simply not large enough to generate all the required energy.

The dominant PV technology in BIPV is found to be crystalline silicon (c-Si). Nonetheless, relatively high market shares for thin film technology of up to 25% are found. Thin film PV technology is getting significant attention especially in façade systems, because of its homogeneous color (black) appearance and a lower price per m^2.

A potential market opportunity lies in lightweight flexible thin film products for application on curved surfaces and flat roofs with small weight capacity. Many example projects can be found, but commercially available products are not easy to find, and do not appear in this year’s database.

In chapter 4, eight examples of BIPV projects are described from various product categories and application areas. We hope these existing projects will serve as catalysts, from which more architects, construction companies and end-users will get stimulated to apply BIPV solutions in their buildings.

Finally, we wish to look ahead towards a successful BIPV future. In our vision, the further development of the BIPV market in Europe will depend on a number of key factors. Three of those factors are related to a stable predictable market situation:

- A stable and predictable roadmap of building directives and regulations: BIPV as the way to meet energy regulations for buildings and at the same time satisfy value drivers in the building industry (investor's value, architectural quality, comfort);
- Development of European harmonized standards, technical rules and building codes in order to allow BIPV products to address the complete European market;
- A stable and predictable roadmap of financial incentives (market stimulation) for PV application in general.

Other success factors are related to product positioning, supply chain and cooperation between sectors:

- Concerted efforts by players in the BIPV supply chain to work together in accordance with a collaborative and integral design/building process. BIPV will require not only a technological integration but an integration in the whole building process;
- Smart engineering and manufacturing of BIPV products such that low cost (€/Wp as well as €/m^2) can be combined with the high mix requirements from the building market. In the meantime, a way to approach the price-challenge would be to sell BIPV in a "irrational way". That is as a feel-good product, a fashion product and/or a status product. This will take the buying decision away from considerations like payback time.
- A broad support and acceptance of the central BIPV vision: i.e. that BIPV can be considered as a building material producing energy;

Europe is a front runner in policy development on sustainability (building codes, incentives). Furthermore the European industry is well positioned as a supplier of high mix product offerings based on smart engineering and innovative technology. Therefore we believe that BIPV is a very promising product-market combination for European industry!

FIGURE 1. PV FULL ROOF IN A PITCHED. PLUSENERGIEBAU (PEB) TRUFFER, KÜSNACHT/ZH, ARCHITECT: BELLEVUE STUDIO S.A.R.L.. NORMAN FOSTER SOLAR AWARD-DIPLOM 2011 AT SWISS SOLAR PRIZE (SOURCE: WWW.SOLARAGENTUR.CH , WWW.BIPV.CH)

1 CLASSIFICATION OF BIPV SYSTEMS

The acronym **BIPV** refers to systems and concepts in which the building element has an additional function, namely producing electricity. This dual functionality has the promise of reducing the initial investment costs, material costs and labor expenses in comparison to traditional PV solutions where PV modules don't replace traditional building elements. At the building scale two main types of integration can be identified.

A *functional integration* refers to the role of the PV modules in the building. For this reason we can speak about multi-functionality or double function criteria. Photovoltaic 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 305/2011. Thus the building performance of the BIPV module is required for the integrity of the building's functionality.

The *aesthetical integration,* on the other hand, refers to the architectural concept, its appearance, these are harder to define in a unique way. The aesthetical integration has to be understood as capability of the PV solution to define the linguistic/morphological rules governing the signs, the structure and the composition of the building's architectural language. In contemporary architecture the appearance is one of the first factors of recognizability. In order for "Solar Architecture" to be successful it has to comply with the architectural standards of today.

Various definitions of BIPV have been adopted in literature, international and also in national systems for feed-in-tariffs [3-8]. There is no general consensus within the PV community about the different categories of BIPV. In our attempt to provide a conclusive view on the many faces of BIPV applications, we combined the various approaches from literature into one comprehensive product categorization for BIPV systems as shown in Table 1.

FIGURE 2: EXAMPLES OF BIPV IN THE REFURBISHMENT OF EXISTING BUILDINGS AWARDED WITH THE SWISS SOLAR PRIZE. (LEFT) WEIBER FAMILY HOUSE IN HORGEN, ZURICH (CH), RYCHENER PARTNER AG ARCHITECTS (SOURCE: RYCHENER PARTNER AG ARCHITECTS). (RIGHT) POSITIVE ENERGY HOUSE IN INNERBERG, CANTON OF BERNA (CH).

Application area	SUPSI[1]	SEAC[2]	BCC[3]	SUNRISE[4]	ABIO[5]	This report
Pitched roofs	• Tiles • Metal panels	• In-roof systems • Small solar tiles-shingles-slates • Large solar tiles-shingles-slates	• Roofing	• Standard in-roof systems • Solar tiles and shingles • Flexible laminates	• Solar Tiles • Opaque flat/sloped roof • Transparent roof • Multipurpose roof • Roof element	**• In-roof mounting systems • Full roof solutions • Small tiles-shingles-slates • Large tiles-shingles-slates • Metal panels • Solar glazing**
Flat & curved roofs	• Roof (Glass) • PV membranes	• Skylights and semi-transparent roof systems • Flexible laminates	• Glazing	• Semi-transparent solution • Flexible laminates	• Opaque flexible roof • Transparent flexible roof	**• Metal panels • Solar membranes • Solar glazing**
Façades	• Façade (Elements) • Façade (Glass) • Shading systems	• Cladding systems • Semi-transparent systems • Louver systems	• Glazing • Sun-shading	• Cladding systems	• Façade elements • Continuous façade systems • Windows • Shading systems • Multipurpose façade	**• Accessories • Warm façade • Cold façade • Solar glazing**
Other application	• Urban structures		• Architectural fabrics		• Urban furniture • BIPV custom design	

TABLE 1: BIPV CLASSIFICATION CRITERIA FROM LITERATURE AS COMPARED TO THIS REPORT, WITH THE SOURCES:
[1] SUPSI CLASSIFICATION AS IS USED ON *WWW.BIPV.CH* IN 2014 [3].
[2] K. SINAPIS AND M.N. VAN DEN DONKER "BIPV REPORT 2013", ONLINE AVAILABLE AT WWW.SEAC.CC [4]
[3] BCC RESEARCH ENERGY & RESOURCES REPORT [6]
[4] REPORT FROM THE EU FUNDED SUNRISE PROJECT [7]
[5] PUBLICATION BY THE ABIO INSTITUTE, MADRID [8]

The three main application areas of Pitched roofs, Flat & curved roofs and Façades are shortly described below.

– **Pitched roofs**

A pitched/sloped opaque roof is made up of angled and sloped parts. This method of construction is common all over the world: it is known as a "discontinuous" roof due to the presence of small elements (tiles, slates, etc.). Simultaneously these small elements have to hold the main physical building properties such as water tightness. Due to the size of the roof, easiness of install and inclination and orientation towards the sun, the roof is perfectly suitable for PV. A lot of constructive solutions have been developed over the last years, moving from a first generation PV system (building applied photovoltaic, BAPV) towards the most recent watertight solar tiles where PV modules replace the traditional tiling layer. Categories within this application area include solar glazing, in-roof mounting systems, full roof solutions, large tiles small tiles, and metal panels. These categories are described in more detail below.

- **Flat & curved roofs**

A flat or curved roof, also known as "continuous roof", is characterized by an uninterrupted layer with the main function to be water resistant. Usually membranes are used as a water barrier. In the first applications, the PV was mainly placed on top of the roof. Lightweight and self-bearing systems represent the second generation of PV applications. Flexible membranes, solar floors and other solutions can easily be used for integrating PV in the building envelope. Categories within this application area include solar glazing, metal panels and PV membranes. These categories are described in more detail below.

- **Façades**

Increasing requirements regarding energy efficiency in buildings results in a growth of PV applications in the façade segment. PV acts as a substitute for traditional materials in most common façade systems (e.g. cold façade or curtain walls), both opaque or transparent. Moreover, in transparent façades PV has a key role with respect to the comfort of the indoor microclimate (for reducing overheating in summer and allowing solar gains in winter). Besides it enhances the comfort due to an increase of natural lighting. Categories within this application area include solar glazing, accessories, warm façades and cold façades. These categories are described in more detail below.

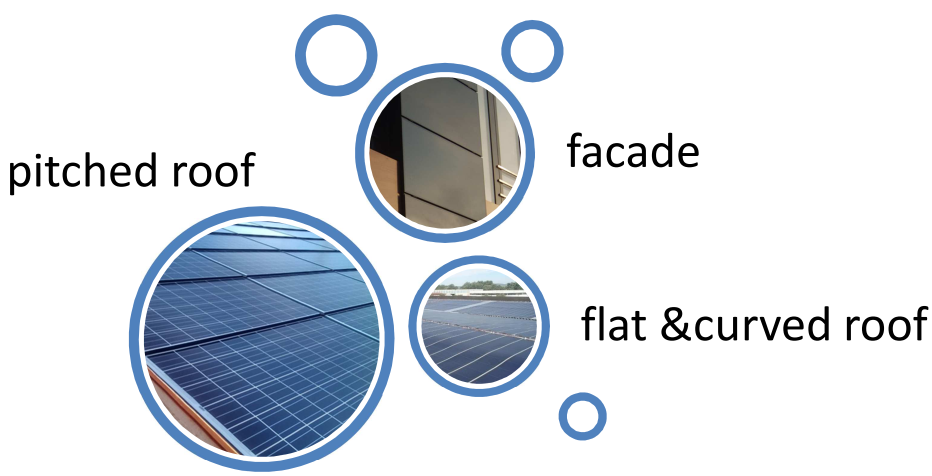


FIGURE 3: EXAMPLES OF BIPV CLASSES CONSIDERED IN THE REPORT. PITCHED ROOF (SOURCE: SI-POWER INDACH). FLAT ROOF (SOURCE: GENERALMEMBRANE). FAÇADE (SOURCE: KREIRE GIRKE ARCHITEKTEN)

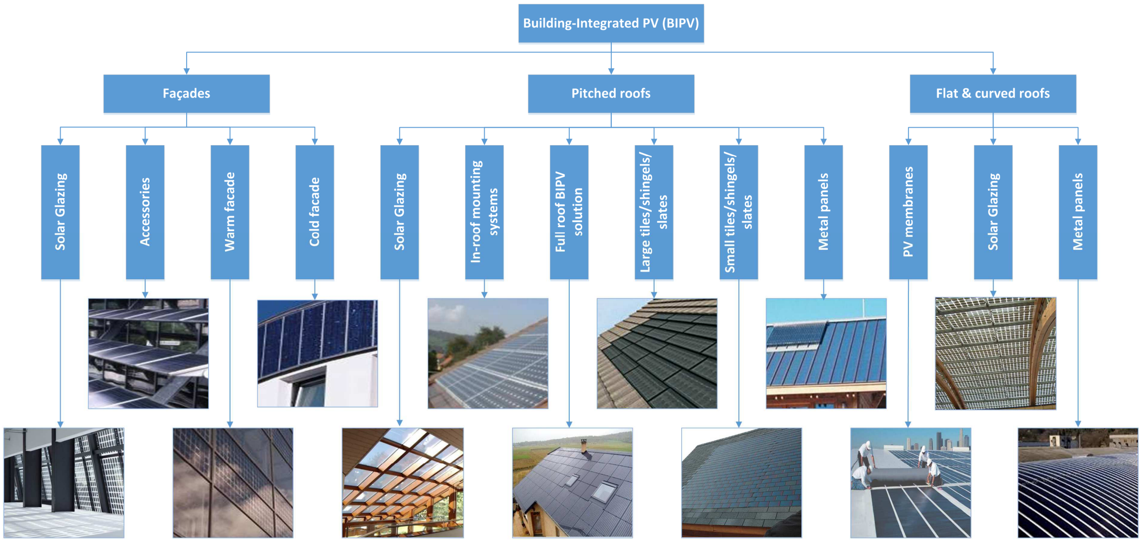


FIGURE 4: THE BIPV SEGMENTATION USED THROUGHOUT THIS REPORT

Considering the growing market share of BIPV, the progress in standardization (prEN 50583-CENELEC) and the tightening regulations with respect to CPR (Construction Product Regulation n.305/2011), we can state that a BIPV component is not merely an electrical device but is becoming a mature building element as well.

IN-ROOF MOUNTING SYSTEMS (PARTIALLY INTEGRATED)

In-roof mounting systems are used to install standard PV modules in sloped roofs. Usually only a part of the roof is covered by PV since the system is based on standardized components/mounting components. Specials such as dummies, customizable parts for geometrically complex shapes are not provided. The solar panels are inserted in a geometrically defined portion of the roof next to the conventional roofing material (e.g. roof tiling).

FIGURE 5. EXAMPLES OF IN-ROOF MOUNTING SYSTEMS ARE USED IN SLOPED ROOFS (SOURCE: RENUSOL INTERSOLE)

FULL ROOF SOLUTION (GLASS ROOF)

The *full roof solution* includes cases that offer a full solar roof concept, where the roof surface is exclusively and specifically conceived as a solar collector for energy production. Thus PV doesn't represent an "insertion" within an already defined surface but it is a characterizing factor of the technology and the design involving both an aesthetical and functional/constructive integration since the early design phase (EDP). This whole concept concerns both the building construction technology and architectural language. Accordingly, these solutions often include 'dummies', flashings, metal works, sub-structures, roof components, etc. since the BIPV system becomes the protagonist of the whole roof and the correct interaction with the building skin becomes a basic requirement. Special mounting systems are often developed (e.g. modules with special frames, borders, joints and connections) and a well-defined installation procedure is defined in order to meet all the building requirements (such as water tightness, mechanical resistance, etc).

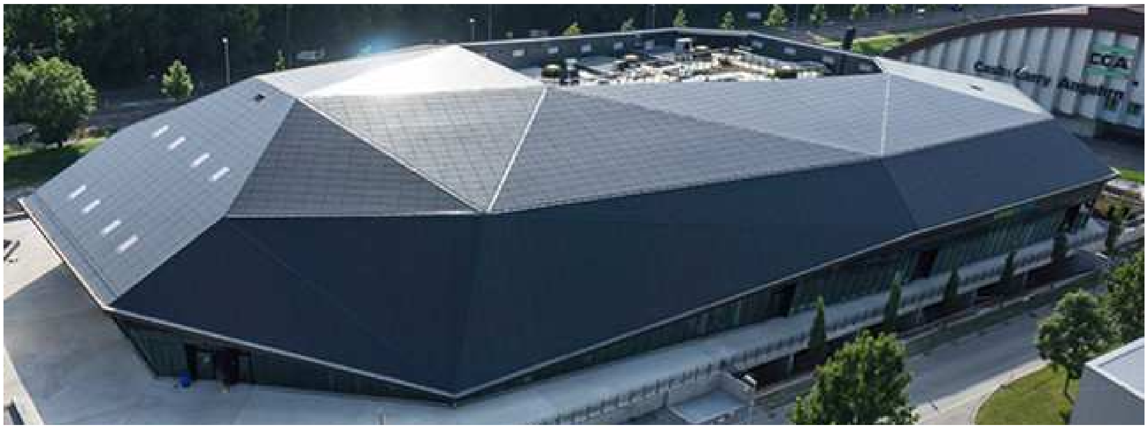


Figure 6: Umwelt Arena, Spreitenbach, Zurich. BIPV covers over 57,048 square feet of the arena's rooftop and holds the possibility of generating 540,000 kWh of solar energy every year (source: Meyer Burger).

LARGE SIZED SOLAR TILES / SHINGLES / SLATES

This system is usually designed to resemble the conventional 'roof tile' with a solar PV tiling. The panel height is modular to the roof tile's rows. Size of the modules is usually >0.5 m^2. They can be glazed or foil-based. Commonly only a part or the whole roof is used for PV. The solar panels are mounted in between original roofing elements (e.g. conventional roof tiles). Note that if a flat, black conventional roof tile would be chosen, the solar tiles would blend in perfectly with the rest of the roof.

FIGURE 7. LARGE SIZED TILES (SOURCES: WWW.NEWROOF-HYBRID.COM)

SMALL SIZED SOLAR TILE / SHINGLES / SLATES

This systems, in contrast to the “large solar tiles” category, are usually characterized by a module size <0.5 m^2. Both height and width of the panels are adapted to the conventional roof tile that becomes itself the PV element. There are several varieties, semi-rigid and systems using various thin film solar cell technologies. Commonly only a part or the whole roof is used for PV, using the same sub-structure as the mounting system.

FIGURE 8. SMALL SIZED TILES (SOURCES: PANOTRON, FORNACE FONTI)

METAL PANELS

Typically flexible laminates are used with metal panels both in pitched roofs and in curved roofs. The market offers a plenty of types with different materials (steel, copper, zinc, etc…), joint’s technology, sizes and performances.

FIGURE 9. METAL PV PANELS (SOURCE: KALZIP, TEGOLA CANADESE)

PV MEMBRANES

The major technological families of flexible PV products are: thin film silicon, thin film CI(G)S and thin film organic-PV (OPV). The manufacturer of this product usually attaches the PV flexible laminates in a building element (such as watertight membranes, tents) or directly applies the PV flexible laminates onto the complete roof (e.g. flat roof).

FIGURE 10. PV MEMBRANES EMBEDDED IN A FLAT ROOF COVER (SOURCE: WEKA DAKSYSTEMEN).

SOLAR GLAZING

These glazed PV laminates are often made by crystalline silicon cells with adjusted spacing or by laser grooved thin film which provides filtered vision. In buildings they are often used as windows or as a curtain wall semi-transparent system, designed with extruded aluminum frames (but also steel, woods, etc.) in-filled with glass. They can also be used as roof parts, so-called 'skylights'. Since it is part of the building envelope, parameters related to solar gain control, such as thermal and visual comfort have to be controlled when using highly-glazed curtain walls. The transparent functional layer (glass) is replaced with PV glazed panes, whilst the load-bearing part is equipped for the electric wirings passages. The cell's pattern and assembly can provide the proper solar and daylighting control replacing the traditional external louvers and defining a particular architectural appearance of the façade.

These structures usually combine glass-glass PV laminates with adjustable light transmission, stimulating the architectural design of light and shadow. Skylights are used in flat roofs, pitched roofs, and sometimes in the top area of the façade.

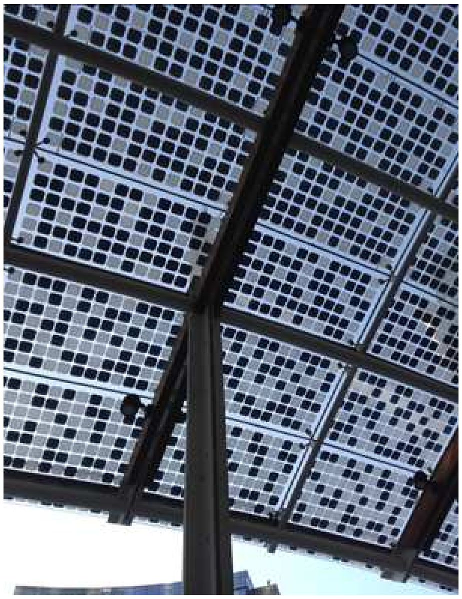



FIGURE 11. PORTA NUOVA MILANO - PIAZZA AULENTI (SOURCE: ENERGY GLASS)

FIGURE 12. *THE "HERON TOWER" IN LONDON WITH THE SEMI-TRANSPARENT DOBLE SKIN -BIPV FAÇADE (PICTURE: P. BONOMO).*

WARM FACADE

A warm façade is typically a continuous building envelope system in which the outer walls are non-structural. A warm façade fulfils all building envelope requirements such as load bearing, thermal insulation, weatherproofing and noise insulation. Since it is the building skin system, the parameters related to solar gain control such as thermal and visual comfort have to be controlled when using highly-glazed curtain walls. In this case a warm façade matches a solar glazing. In general a warm façade can also be represented by an opaque curtain wall or by an insulating cladding panel (e.g. PV + thermal insulation without an air gap) where there is no ventilation (see fig.13).

FIGURE 13. WARM FAÇADE BIPV SOLUTION, MONTE ROSA HUT (ZERMATT, SWITZERLAND) (ARCHITECT: ETH STUDIO MONTE ROSA)

COLD FAÇADE

This facade system typically consists of a load-bearing sub-frame, an air gap and a cladding panel. In summer, heat from the sun is dissipated thanks to the cavity that is naturally ventilated through bottom and top openings. This is the reason why it is also called “cold façade”. Many constructive models and technological solutions are available. The solar modules can be integrated as a building cladding like a conventional façade material. Usually an air gap is created between the external elements, accordingly to the building model of the ventilated façade. So it offers cooling for the wall and improves the efficiency of the modules.

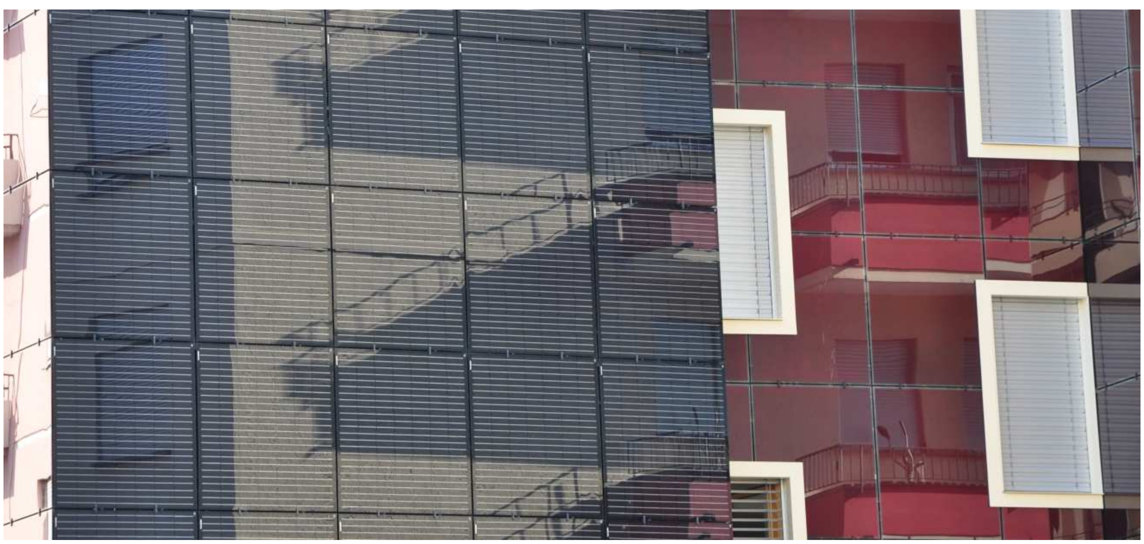


FIGURE 14. PALAZZO POSITIVO IN CHIASSO (SWITZERLAND), REFURBISHMENT WITH A BIPV COLD FACADE (SOURCE: F. FRONTINI, SUPSI)

ACCESSORIES

In particular larger buildings may have several ‘solar accessories’ integrated in the design. These accessories may include balconies, shading systems and several other smaller systems. Shading systems are the most commonly used accessory. The control of the indoor microclimate, especially in glazed façade systems, usually requires the use of shading devices aimed to select the solar radiation for ensuring the thermos-hygrometric and visual wellbeing through a proper use of the natural lighting. Shading devices may be of various type: applied on roof or façade; external, interposed (e.g. in double skins) or internal; fix or tracking (manually or electrically); vertical, horizontal or oriented; lamellar, micro-lamellar, sail, grid; curtain or blind; mobile screen or panels; with special element (selective glass, solar film, prismatic glass). Solar cells can be easily laminated in this construction offering a perfect way to utilize the shadow function with electricity production.

FIGURE 15. TEXTILE PV ARCHITECTURE, SOFT HOUSE, IBA HAMBURGKENNEDY & VIOLICH ARCHITECTURE (SOURCE: WWW.IBA-HAMBURG.DE/)

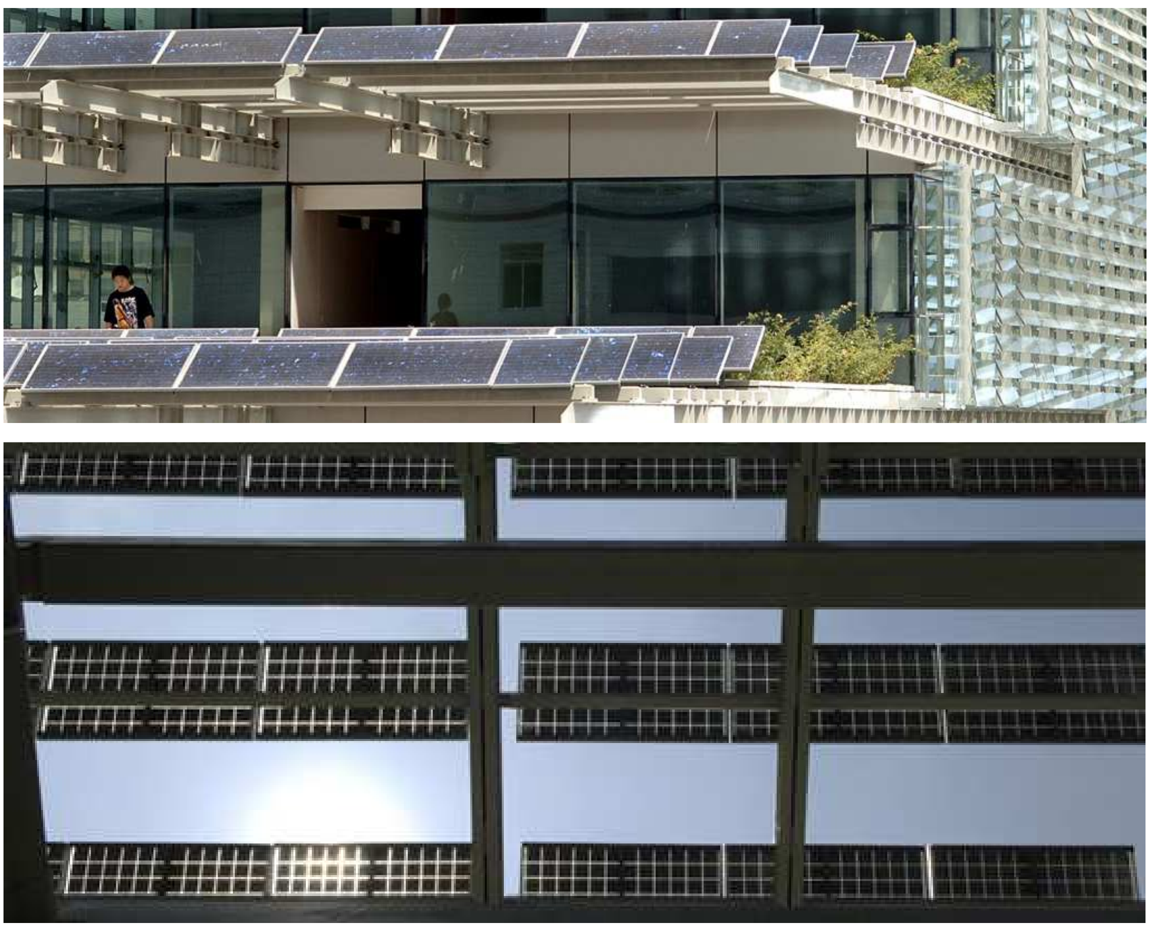


FIGURE 16. PV SHADINGS IN THE SIEEB BUILDING, BEJING, MARIO CUCINELLA ARCHITECTS (SOURCE: WWW.SINOITAENVIRONMENT.ORG/)

2 BIPV PRICE SURVEY

Although BIPV is often described as aesthetically more appealing than BAPV, it is also perceived as expensive. But how expensive is it really? And can ‘substitutional costs’ cancel out this higher price setting for BIPV products? The purpose of this chapter is to shed some light on this matter and to inform architects, stakeholders and technicians on the different price levels of PV added and integrated in buildings. To this end a review is included of a recent study published by SUPSI and SEAC [9].

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 into perspective. The prices of conventional building materials were also included for further reference. The price study focused on end-user prices in the Benelux and the Swiss market, excluding VAT. 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 prices for conventional roofing applications were obtained using Dutch databases on building price information. Regarding BAPV roofing systems, 8 installers participated in the survey. To ensure validity and reliability of the pricing data, a reference roof with a standardized PV system size was used. The BAPV systems were projected to be installed on top of concrete tiles which represented the cheapest and most common conventional roofing material in the Netherlands. The reported m^2 price includes roof tiles and PV system prices added up. Regarding the BIPV roofing systems, 44 parties participated in the survey. Sufficient participants were found for the BIPV categories of “in-roof mounting systems” and “full roof solutions”. In addition, we combined the categories of “small tiles/shingles/slates” and “large tile/shingles/slates” to form a merged category “BIPV tiles”. The number of participants per product group are stated in Table 1.

	Product group	# Participants in price survey
Roof	BAPV system and roof tiles	8
	In-roof mounting system	23
	Full roof solution	11
	BIPV tiles	11
	PV membranes	-
	Metal panels	-
	Solar glazing	-
Facade	Cold façade	2
	Warm façade	-
	Accessories	2
	Solar glazing	-
	Total	**44**

TABLE 1. NUMBER OF PARTICIPANTS IN THE PRODUCT SURVEY WITH BIPV SOLUTIONS FOR A ROOF.

The prices for conventional façade applications were obtained using Swiss databases on building price information. Regarding the BIPV façade systems, only 4 parties participated in the survey. The market of BIPV façade systems in Switzerland and Benelux is relatively small and there is still a large cost variety depending on the building type and application. A lot of producers and installers have not replied to the submitted price survey. A frequently used argument is the demanded discretion by the customer regarding the project costs. This may be explained considering that very often BIPV facades have been experimented in pilot-demonstrative projects so that the cost was specifically linked to the context and influenced by building size, technology adopted, owners policy, etc. Thus the absence of a well-established market influenced this phase of research. Only some smaller producers or installers provided some cost data: the main reason was to promote and advertise BIPV demonstrative buildings showing their cost-effectiveness also at a small-medium scale (residential multi-storey building e.g.). Table 1 shows the distribution of the participants. Survey participants were found for Accessories and Cold Façade.

By means of a box-and-whisker plot the price range, 25%, 75% quartiles, and median within each product group were displayed. Figure 17 shows the results of the price survey including the conventional roofing materials. The costs (€/m²) in the figure can be separated in conventional roofing materials and PV systems (both BAPV as well as three types of BIPV product groups).

The figure shows a significant price range for the different conventional roofing materials. The price of concrete and ceramic tiles varied between 30 €/m² for cheap concrete tiles to almost 75 €/m² for expensive ceramic tiles. This can be explained by the type and brand of roof tile used. Furthermore the size of the roof and the installer experience have an impact on the price per square meter. Investigating the roof slates we see an even wider price range that varies between almost 75 €/m² to o 125 €/m². The prices of different slate materials play an important role here. For metal roofing the price range can be explained mainly by the thickness of metal and how they are finished. Degreased and painted metal sheets are more expensive. The final conventional roofing material considered is thatch roofing which costs between 85€ and 105€ per square meter.

The PV products were all priced roughly 200 €/m^2 higher than the conventional roofing materials. The BAPV system price varied between 225 and 300 €/m² (Note: This price range includes the roof tile underneath the PV panels, as these are required to make the roof water-tight in BAPV systems). For the in-roof mounting system the price varies between 350 €/m² and almost 500 €/m². For the BIPV tiles the price varied between 225 and 500 €/m². For the 'full roof solution' category, the price ranged from 200 €/m² to almost 650 €/m².

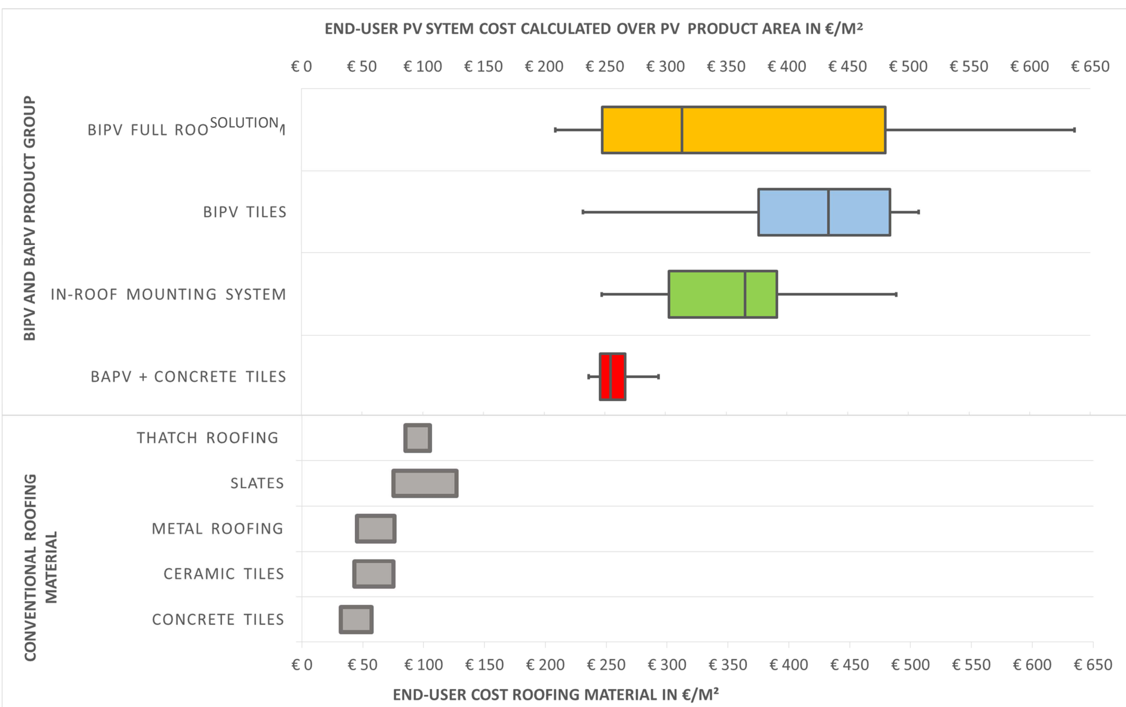


FIGURE 17. A BENCHMARK OF THE CONDUCTED PRICE SURVEY, COMPARING CONVENTIONAL ROOFING MATERIALS WITH BAPV AND BIPV ROOFING SOLUTIONS. THE PRICE IS DEFINED AS THE END-USER PRICE AND MEASURED IN €/M².

Figure 18. A benchmark of the conducted price survey, comparing conventional façade materials with BIPV façade solutions. The price is defined as the end-user price and measured in €/m².Figure 18 displays the results of the price survey (€/m²) which compares conventional façade systems with some BIPV solutions. Conventional façade technologies include fibrocement, brick-ceramic, metal, stone, wood, window and curtain walls. Prices range all the way from 30-50 €/m^2 for a low cost fibre-cement façade (similar to a traditional plaster) to 1.100 €/m^2 for a special curtain wall (e.g. self-lighted, interactive façade, etc.). The price of the BIPV

systems varied from 100-150 €/m^2 for a thin film PV cold façade (with a really simple sub-structures and a low-efficiency solar technology) to 750 €/m^2 for a high end PV solar shading system. This indicates the following important conclusion: for façades a very interesting price point has been obtained, as BIPV systems are very comparable in price with conventional façade materials. Low cost BIPV façade strengthen the promise of BIPV because these applications are cost-wise suitable as a substitute for the conventional façade solutions.

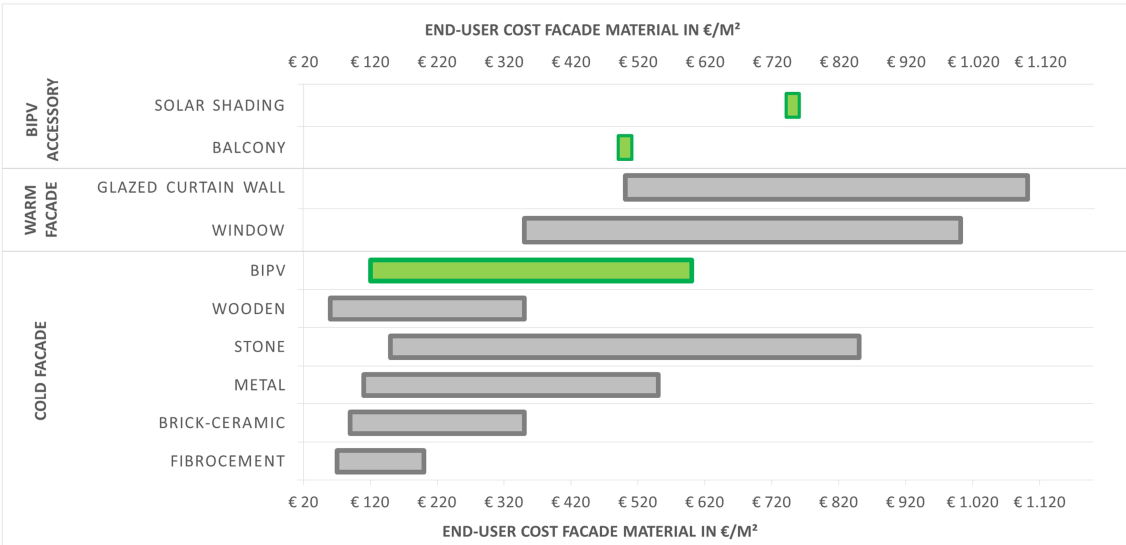


FIGURE 18. A BENCHMARK OF THE CONDUCTED PRICE SURVEY, COMPARING CONVENTIONAL FAÇADE MATERIALS WITH BIPV FAÇADE SOLUTIONS. THE PRICE IS DEFINED AS THE END-USER PRICE AND MEASURED IN €/M².

In conclusion, we reported on a price study from which the following key insights can be gained:

- BIPV in-roof systems, BIPV tiles and BIPV full roof solutions are already widespread available. More than 44 participants responded to the survey.
- BIPV metal panels, BIPV membranes, BIPV skylights and BIPV façades are specialized and customized niche products for which it is difficult to find participants in a price survey.
- BIPV roof products are still priced about 200 €/m^2 above conventional roof products. These added costs should be paid back by the electricity sales.
- BIPV full roof solutions are a highly promising emerging field of technology, as several products were already found to be lower priced than the alternative of roof tiles topped with conventional BAPV systems.
- BIPV façades are a highly promising emerging field, as the products were priced very similar to conventional façade materials. This holds the promise of 'PV for free', *e.g.* a building with BIPV built without any added costs compared to a conventional building.

For future research and development, it will be of particular interest to focus on the price composition and improvement possibilities for BIPV full roof solutions and BIPV façades. In addition, it might be worthwhile to explore BIPV membranes and BIPV metal roofs as only little price information is available on those technologies so far. New technologies in PV field are also interesting BIPV field both in industry and building experimentation.

We see that PV technology today is mostly economic driven and therefore a crucial factor for its success. If the first goal is surely to minimize the initial investment, also other factors are more and more showing an economic relevance during the life-cycle such as an adequate maintenance, the energy management/optimization and the quality of modules and its installation (e.g. degradation, damages, etc. affecting energy production and durability). In BIPV applications PV becomes an integrated part of the building skin that cannot be singularly considered in terms of architecture, technology, performance, energy behavior or costs. Accordingly a more accurate evaluation of the cost-effectiveness could also consider all the costs and benefits in the life-cycle. We suggest references [10-13] for further reading on this topic.

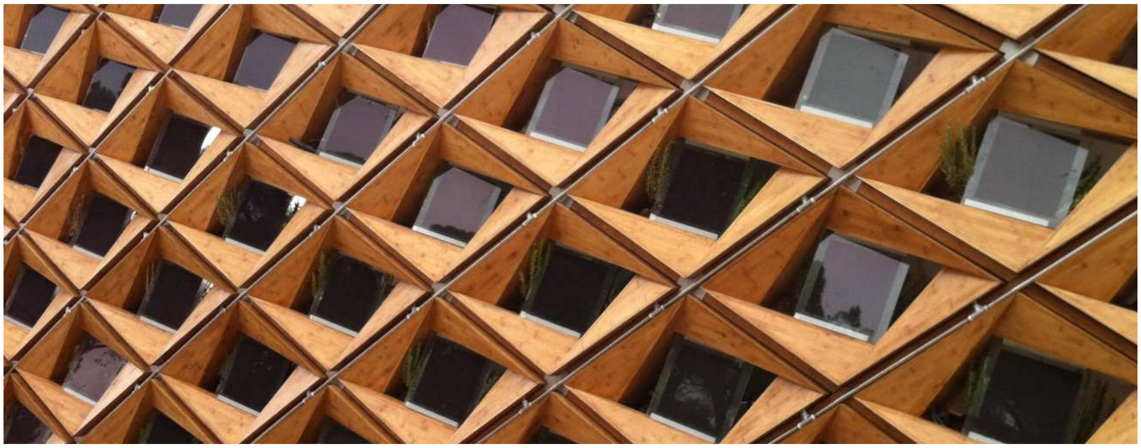


FIGURE 19: A COMPLEX BIPV FACADE IN THE SOLAR DECATHLON “PARA ECO HOUSE” (SOURCE: C. POLO, SUPSI)

3 BIPV PRODUCTS DATABASE

This chapter holds a list of BIPV products divided over the different categories earlier defined in this report. The chapter focuses mainly on the manufacturers and installers based in Europe, and more particularly on systems commercially available in the Swiss and Dutch/Benelux markets. The list of products is obtained by merging existing databases of the SUPSI website www.bipv.ch [3] and the SEAC BIPV report [4], complemented by an internet search and BIPV trade fair visits.

First, in Figure 20 we give an overview of the amount of products found per BIPV product category. The most common product group is the full roof solution. Products for solar glazings follow with a significantly lower percentage. PV membranes currently do not seem to be offered frequently for BiPV applications. Twice as much products for pitched, flat and curved roofs were found as products for façades, indicating that the roof market is currently significantly bigger than the façade market.

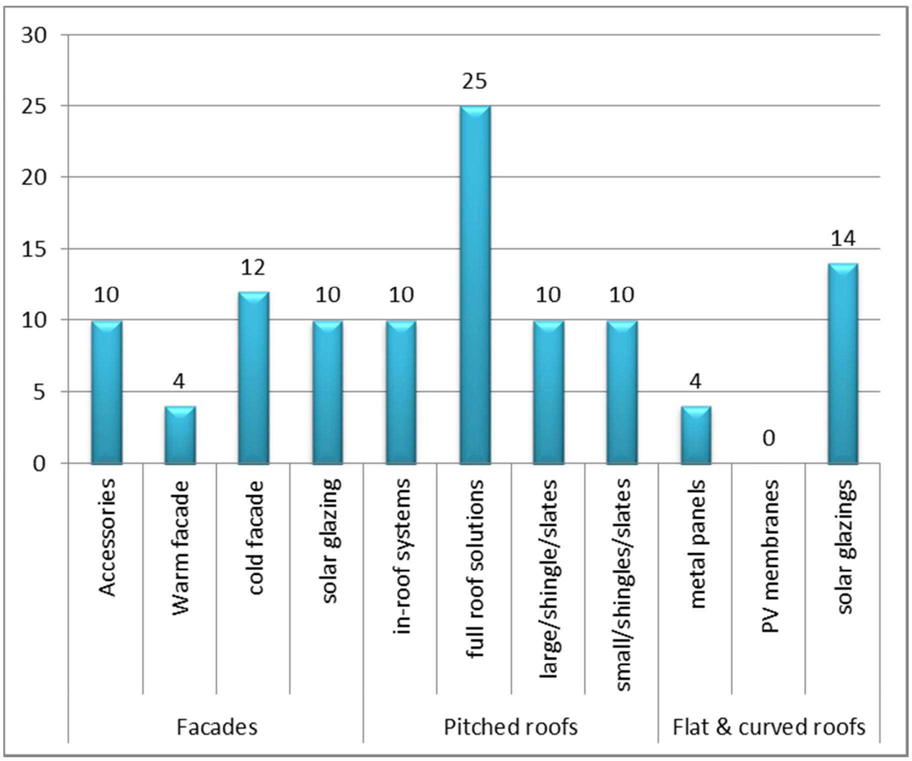


FIGURE 20. DISTRIBUTION OF LISTED PRODUCTS ACCORDING TO THE DIFFERENT CATEGORIES. RESULTS OF THE MARKET SURVEY PRESENTED IN TERMS OF THE OCCURRENCE OF PRODUCT GROUPS.

Next, in Figure 21 we give an overview of the PV technology used within the found products, with a focus on the technology share of ‘crystalline silicon’ versus the ‘thin film’. We found that 15-22% of the BIPV products for roofs and 8-29% of the BIPV products for façades were using the 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 thin film technology [14]. We propose the possible explanation for the success of thin film PV technology in BIPV to be due to two key reasons: (1) the all-black, aesthetic appearance and (2) the low price/m^2, and associated high relative substitutional costs when saving out conventional building materials.

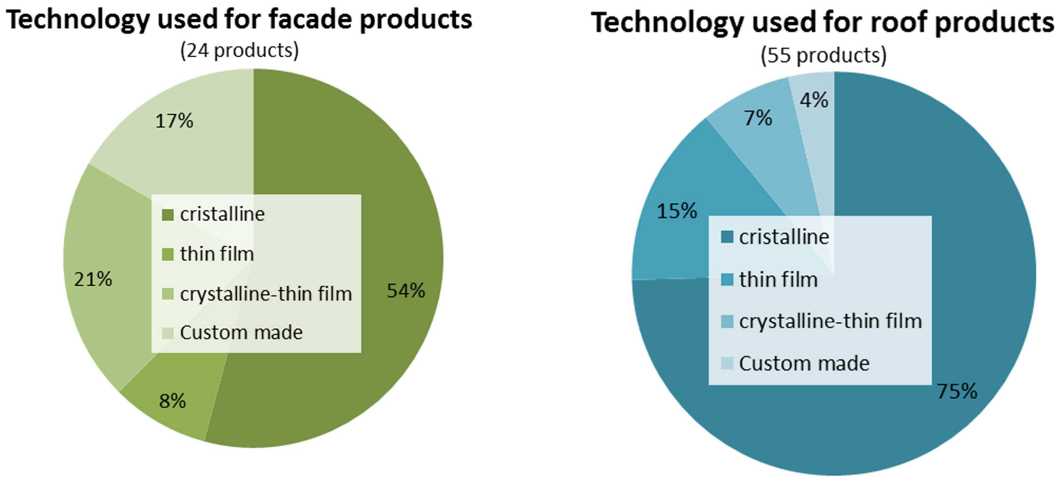
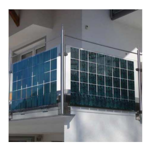
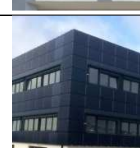
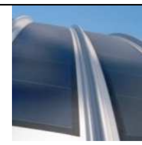
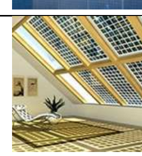
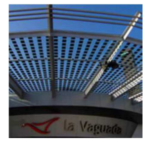
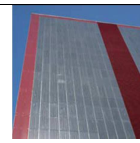


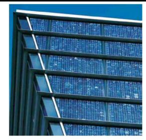
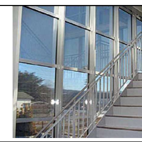
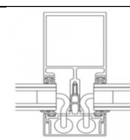
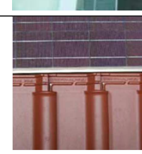
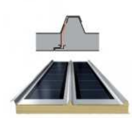
FIGURE 21. PIE CHARTS OF THE TECHNOLOGY USED IN THE ROOF AND FAÇADE APPLICATION AREAS.

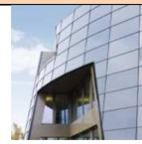
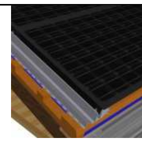
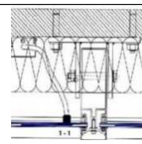
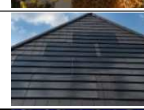
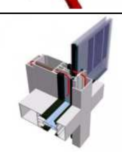
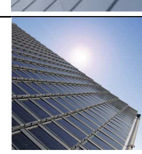
Finally, we present the list of available products in Table 2 below. Note that more information on these products can be found by clicking the provided hyperlink on the right most column, or by visiting the website www.bipv.ch.

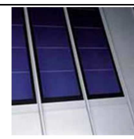
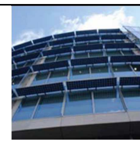
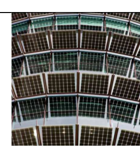
N	Company name	Country of origin	Product name	PV technology	Product picture	Application class	Hyperlink
1	Abakus Solar AG	Germany	Peakin	Mono / Multicrystalline / Thin film 200-220 W		Accessories	www.abakus-solar.com
2	Abakus Solar AG	Germany	Peakin	Mono / Multicrystallino 200-220 W		Skylight / Solar glazing	www.abakus-solar.com
3	Aerspire	Nether-lands	AER	Monocrystalline 260 W		Full roof solution	www.aerspire.com
4	Asola Technologies GmbH	Germany	VITRUM Balcony	Monocrystalline 120 W		Accessories	www.asola-tech.de
5	Asola Technologies GmbH	Germany	VITRUM Super	Multicrystalline 160 W		Cold Facade	www.asola-tech.de
6	Asola Technologies GmbH	Germany	VITRUM Carport	Monocrystalline 80-160 W		Skylight / Solar glazing	www.asola-tech.de
7	BeauSolar	Nether-lands	BEAUsolar®	Mono / Multicrystalline / Thin film variable		Full roof solution	www.beausolar.eu

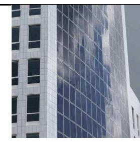
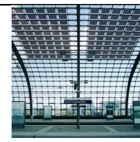
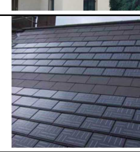
N	Company name	Country of origin	Product name	PV technology	Product picture	Application class	Hyperlink
8	Brandoni Solare	Italy	Aeternum	Multicrystalline 130-155 W		Full roof BiPV	www.brandonisolare.com
9	Büro Dach & Wand	Switzerland	Kalzip Aluplus Solar	Thin Film (triple junction) 68-144 W		Metal panels	www.kalzip.com/kalzip
10	ClickCon GmbH & Co.KG	Switzerland	ClickPlain Indach Montagesystem	Mounting system		Full roof BiPV	www.clickcon.eu
11	Colt International	Switzerland	Shadovoltaic	Mono / Multicrystalline n.d.		Accessories	www.colt-info.de
12	Colt International	Germany	Solarer fensterladen	Mono / Multicrystalline Custom made		Accessories	www.astrid-schneider-gruen.de
13	Creteq	Nether-lands	Zigzag solar	Monocrystalline variable 38,5 – 40,5 W		Accessories	www.zigzagsolar.nl
14	Electro-sol	Switzerland	Intersole SE	Mounting system		In-roof mounting systems	www.electrosol.ch
15	EnergyGlass	Italy	EnergyGlass BiPV Module	Mono / Multicrystalline / Thin film Custom made		Solar glazing	www.energyglass.eu/pagine/pagina.aspx?&L=IT
16	EnergyGlass	Italy	EnergyGlass BiPV Module	Mono / Multicrystalline / Thin film Custom made		Skylight / Solar glazing	www.energyglass.eu/pagine/pagina.aspx?&L=IT
17	Ernst Schweizer Metalbau	Switzerland	Solrif	Mounting system		Full roof BiPV	https://www.schweizer-metallbau.ch/de/home.html
18	Ertex Solar	Austria	VSG-insulating glass module and VSG	Mono / Multicrystalline Custom made		Solar glazing	www.ertex-solar.at

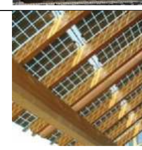
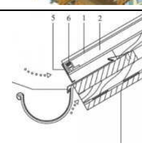
N	Company name	Country of origin	Product name	PV technology	Product picture	Application class	Hyperlink
19	Ertex Solar	Austria	VSG-insulating glass module and VSG	Mono / Multicrystalline Custom made		Skylight / Solar glazing	www.ertex-solar.at
20	ERTL GLAS AG / Ertex Solar	Austria	VSG Modules	Mono / Multicrystalline Custom made		Cold Facade	www.ertex-solar.at
21	FATH Solar GmbH	Germany	FATH EnergyRoof	Mono / Multicrystalline 250-265 W 265 W		Full roof BiPV	www.fath-solar.com
22	Fischerwerke GmbH &Co. KG	Germany	Undercut point fixing system	Mounting system		Warm facade	www.fischer.de/Home.aspx
23	Fornace Fonti srl	Switzerland	Tegole DF2-DF3 in cotto	Mono / Multicrystallino 8 / 12 W		Small sized Solar tiles - Shingles	www.fornacefonti.it/it/
24	Galaxy Energy GmbH	Germany	Galaxy Energy Indachsystem	Monocrystalline 185-270 W		Skylight / Solar glazing	www.galaxy-energy.com
25	Gielleplast	Italy	Giellenergy-Tile	Monocrystalline 8 W		Small sized Solar tiles - Shingles	www.giellenergy-tile.eu
26	Helvetic Energy	Switzerland	Aldo Voltaik / Aldo+ Voltaik	Mono / Multicrystalline 280-298 W		In-roof mounting systems	www.helvetic-energy.ch
27	Imerys	France	Tuile photovoltaïque Imerys	Monocrystalline 66 W		Small sized Solar tiles - Shingles	www.panneau-solaire-tuile-photovoltaique.fr
28	Jansen/Schüco	Switzerland	Shüco Prosol	Mono / Multicrystalline / Thin film n.d.		Accessories	www.jansen.com
29	Jansen/Schüco	Switzerland	Schüco Prosol	Mono / Multicrystalline / Thin film n.d.		Solar glazing	www.jansen.com

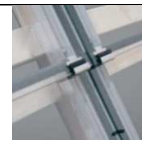
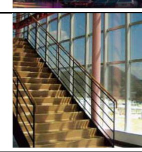
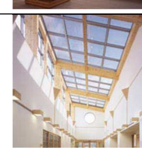
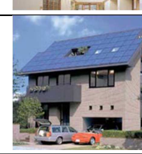
N	Company name	Country of origin	Product name	PV technology	Product picture	Application class	Hyperlink
30	Jansen/Schüco	Switzerland	Schüco Prosol	Mono / Multi-crystalline / Thin film n.d.		Cold Facade	www.jansen.com
31	Jansen/Schüco	Switzerland	Schüco Prosol	Mono / Multi-crystalline / Thin film n.d.		Skylight / Solar glazing	www.jansen.com
32	Jansen/Schüco	Switzerland	Schüco MPE 210 Indach	Mounting system n.d.		Full roof BiPV	www.jansen.com
33	Kaneka	Belgium	See-Trough PV module	Thin film (triple junction) 44-55 W		Solar glazing	www.kaneka-solar.com
34	Kaneka	Belgium	See-Trough PV module	Thin film (triple junction) 44-55 W		Skylight / Solar glazing	www.kaneka-solar.com
35	Kawneer North America	USA	1600 PowerShade	Multicrystalline 75 W		Accessories	www.kawneer.com/kawneer/north_america/en/info_page/home.asp
36	Kawneer North America	USA	AA 110 Photovoltaic	Mounting system		Warm facade	www.alcoa.com/global/en/home.asp
37	Längle Glas	Austria	Al-Wall	Mounting system		Cold Facade	www.langleglas.com/en/home/
38	LOF Solar	Taiwan	High efficiency color solar cell	Mono / Multicrystalline 49 W		Large sized Solar tiles - Shingles	www.lofsolar.com
39	Marcegaglia Building	Italy	Brollo Solar	Thin film (triple junction) 68-144 W		Metal panels	www.marcegaglia.com
40	Mecosun	France	MV3	Mounting system		Full roof BiPV	www.mecosun.fr/fr/

N	Company name	Country of origin	Product name	PV technology	Product picture	Application class	Hyperlink
41	Megasol Energie	Switzerland	Megasol Swiss Premium Mono	Monocrystalline 255-280 W		Cold Facade	www.megasol.ch
42	Megasol Energie	Switzerland	Megasol Swiss Premium Transluzid	Monocrystalline 255-280 W		Skylight / Solar glazing	www.megasol.ch
43	Megasol Energie	Switzerland	Megasol NICER	Mono / Multicrystalline 200-270 W		Full roof BiPV	www.megasol.ch
44	Metra Regusa e Alcover	Italy	Metra Polyedra Sky 50	Mounting system		Cold Facade	www.alcover.it
45	Meyer Burger	Switzerland	Megaslate	Monocrystalline 185 W		Full roof BiPV	www.meyerburger.com
46	Mijn energiefabriek	Nether-lands	In-dak Easy-in	Mounting system		In-roof mounting systems	www.mijnenergiefabriek.nl
47	Monier	Nether-lands	Monier VI90	Monocrystalline 95 W		Large sized Solar tiles - Shingles	www.monier.nl
48	Montavent GmbH	Switzerland	Montavent Indach	Mounting system		In-roof mounting systems	www.montavent.ch/index.php/en/
49	Naps Systems	Finland	Naps Solar Sunshade system	Mounting system		Accessories	www.napssystems.com
50	Naps Systems	Finland	Naps Solar Glazing System	Mounting system		Warm facade	www.napssystems.com
51	NaturHaus Solar GmbH	Germany	nD-System	Mounting system		Full roof BiPV	www.nd-system.de
52	Panotron	Switzerland	Solarziegel	Monocrystalline 95 W		Small sized Solar tiles - Shingles	www.gasserceramic.ch

N	Company name	Country of origin	Product name	PV technology	Product picture	Application class	Hyperlink
53	Rheinzink	Switzerland	QuickStep solar PV	Mono / Multicrystalline 68 W		Large sized Solar tiles – Shingles	www.rheinzink.ch
54	Rheinzink	Switzerland	Klick-Leiste Solar PV	Thin Film (triple junction) 68 W		Metal panels	www.rheinzink.ch
55	Rheinzink	Switzerland	Stehfalz	Thin film (triple junction) 68 W		Metal panels	www.rheinzink.ch
56	Romag Ltd	UK	PowerGlaz	Mono / Multicrystalline 165-235 W		Accessories	www.romag.co.uk
57	Romag Ltd	UK	PowerGlaz	Mono / MUlticrystalline 165-235 W		Cold Facade	www.romag.co.uk
58	Romag Ltd	UK	PowerGlaz	Mono / Multicrystalline 165-235 W		Skylight / Solar glazing	www.romag.co.uk
59	Roto Sunroof GmbH	Germany	Sunroof SRP	Monocrystalline 270-285 W		In-roof mounting systems	www.roto-dachfenster.de
60	Sapa Building System	Switzerland	Sapa Solar	Mounting system		Warm facade	www.sapagroup.com
61	Sapa Building System	Switzerland	Sapa Solar	Mono / Mulricrystalline / Thin film Custom made		Cold Facade	www.sapagroup.com/en/Sapa-Building-system-Group/
62	Sapa Building System	Switzerland	Sapa Solar	Mono / Multicrystalline / Thin film Custom made		Skylight / Solar glazing	www.sapagroup.com/en/Sapa-Building-system-Group/
63	Scheuten Glas	Netherlands	Optisol Shade	Multicrystalline 93-350 W		Accessories	www.scheuten.com

N	Company name	Country of origin	Product name	PV technology	Product picture	Application class	Hyperlink
64	Scheuten Glas	Netherlands	Optisol Screen	Multicrystalline 186-497 W		Solar glazing	www.scheuten.com
65	Scheuten Glas	Netherlands	Optisol Skin	Monocrystalline 72-288 W		Cold Facade	www.scheuten.com
66	Scheuten Glas	Netherlands	Optisol Sky	Multicrystalline 152-380 W		Skylight / Solar glazing	www.scheuten.com
67	Schletter GmbH	Germany	BiPV 2--11	Mounting system		In-roof mounting systems	www.schletter.de
68	Schletter Solarmontagesysteme	Germany	Plandach 5	Mounting system		Full roof BiPV	www.schletter.de
69	SolteQ Group	Germany	SolteQ Quad38	Monocrystalline 38,5 – 40,5 W		Large sized Solar tiles - Shingles	www.solteq.eu
70	SCX solar B.V.	Netherlands	SCX soloroof	Thin film/ Mono /Multicrystalline (Variable) W		Full roof solution	www.scx-solar.eu
71	SED Productionsgesmbh	Austria	Solardachstein	Multicrystalline 45-48 8W		Small sized Solar tiles - Shingles	www.solardachstein.com
72	Si Module GmbH	Germany	SI-Power Indach	Monocrystalline 270-275 W		Full roof BiPV	www.si-module.com
73	Smartroof NV	Belgium	Neosolpan	Monocrystalline 13 W		Small sized Solar tiles - Shingles	www.smartroof.be
74	Société d'Energie Solaire SES	Switzerland	Sunstyle	Monocrystalline 98 W		Full roof BiPV / Solar tiles – Shingles	www.solairesuisse.ch
75	Société d'Energie Solaire SES	Switzerland	Swisstile	Multicrystalline 18 W		Small sized Solar tiles - Shingles	www.societe-energie-solaire.com/en/

N	Company name	Country of origin	Product name	PV technology	Product picture	Application class	Hyperlink
76	Solarcentury	England	C21e	Monocrystalline 50 W		Large sized Solar tiles - Shingles	www.solarcentury.com/nl
77	SolarMarkt GmbH	Switzerland	Arres Solar	Mounting system		Full roof BiPV	www.solarmarkt.ch
78	Solarwatt	Germany	Glass-Glass Modules	Monocrystalline 130-140 W		Solar glazing	www.solarwatt.de/de/startseite/
79	Solarwatt	Germany	M125-32/p110-32 GEG LK	Mono / Multicrystalline 110-124 W		Cold Facade	www.solarwatt.de/de/startseite/
80	Solarwatt	Germany	Glass-Glass Modules	Monocrystalline 130-140 W		Skylight / Solar glazing	www.solarwatt.de/de/startseite/
81	SolarWorld	Germany	Energiedach	Mounting system		Full roof BiPV	www.solarworld.de
82	Solstis	Switzerland	Oryon	Mono / Multicrystalline 130-220 W		Full roof BiPV	www.solstis.ch/en/
83	Soltech	Germany	PV-TEC 2000	Mounting system		Full roof BiPV	www.solartechniken.de/
84	SOLTERRA SA	Switzerland	Solterra TI	Mounting system		Full roof BiPV	www.solterra.ch/
85	Solus engineering	Belgium	Solus Zonnedakpan SE_F.B.S.	Monocrystalline 18 W		Small sized Solar tiles - Shingles	solusengineering.com/
86	Stafier Solar Systems	Nether-lands	Stafier Standaard	Mounting system		In-roof mounting systems	stafiersolar.com/
87	Stafier Solar Systems	Nether-lands	Stafier premium	Monocrystalline 93 W		Large sized Solar tiles - Shingles	stafiersolar.com/

N	Company name	Country of origin	Product name	PV technology	Product picture	Application class	Hyperlink
88	Star Unity	Switzerland	Sunny Tile	Monocrystalline / Thin film 6.5 W (mc) / 2 W (tf)		Small sized Solar tiles - Shingles	www.starunity.ch/deutsch/frame_d.htm
89	Sun Technincs Fabrisolar AG	Switzerland	STG 30	Mounting system		In-roof mounting systems	www.suntechnics.ch
90	SUNAGE	Switzerland	SUNAGE Capillary Comb 60/6	Monocrystalline 265-290 W		Full roof BiPV	www.sunage.ch
91	SUN-Integration SAS	France	Integ PV	Mounting system		In-roof mounting systems	www.sun-integration.com
92	SUNOVATION GmbH	Germany	eFORM Arc	Mono / Multicrystalline 50-650 W		Solar glazing	www.sunovation.de
93	Suntech	UK	Light thru type	Mono / Multicrystalline 80-736 W		Solar glazing	www.suntech-power.com
94	Suntech	Switzerland	Suntech See Thru	Thin film 42-52 W		Solar glazing	www.suntech-power.com
95	Suntech	UK	Light thru type	Mono / Multicrystalline 80-736 W		Skylight / Solar glazing	www.suntech-power.com
96	Suntech	Switzerland	Suntech See Thru	Thin film 42-52 W		Skylight / Solar glazing	www.suntech-power.com
97	Suntech	Switzerland	Just Roof	Monocrystalline 90-190 W		Full roof BiPV	www.sunergic.com
98	SunTechnics Fabrisolar	Switzerland	Sunjoule	Multicrystalline 17-32-34 W		Large sized Solar tiles – Shingles	www.suntechnics.ch

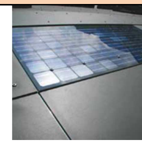
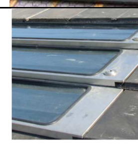
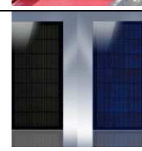
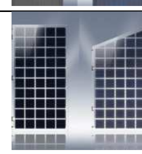
N	Company name	Country of origin	Product name	PV technology -	Product picture	Application class	Hyperlink
99	SunTechnics Fabrisolar, Eternit	Switzerland	Integral Plan	Monocrystalline 355 W		Full roof BiPV	www.suntechnics.ch
100	Synroof	Nether-lands	Sneldekker Solarpan	Monocrystalline 35 W		Large sized Solar tiles - Shingles	www.synroof.nl
101	Synroof	Nether-lands	WS24 Solarpan	Monocrystalline 44 W		Large sized Solar tiles - Shingles	www.synroof.nl
102	Tegola Solare New Roof s.r.l.	Italy	Tegola solare New Roof	Monocrystalline 70 W		Large sized Solar tiles - Shingles	www.newroof-hybrid.com
103	Tritec	Switzerland	Tri-roof	Mounting system		Full roof BiPV	www.tritec-energy.com/en/
104	UNOVATION GmbH	Germany	eFORM Color	Mono / Multicrystalline 50-650 W		Cold Facade	www.sunovation.de
105	UNOVATION GmbH	Germany	eFORM Crystal	Mono / Multicrystalline 50-650 W		Solar glazing	www.sunovation.de
106	Wyss Aluhit	Switzerland	Aluhit	Mounting system		Cold Facade	www.wyssag.com/wyssag_com/
107	Zep BV.	Nether-lands	Ceramic Solar Rooftile	Cigs 6.5 W (mc) / 2 W (tf)		Small sized Solar tiles – Shingles	www.zepbv.nl
108	Zonnepanelen -Parkstad	Nether-lands	LOCI	CdTe 80 W		Full roof solution	www.zonnepanelen-parkstad.nl

TABLE 2. LIST OF BIPV PRODUCTS FOR THE BUILDING ENVELOPE. VISIT THE WEBSITE WEBSITE WWW.BIPV.CH FOR MORE INFORMATION ON THESE PRODUCTS.

4 BIPV PROJECT EXAMPLES

To map the progress and innovation in the emerging BIPV market, we describe multiple BIPV roofing and façade projects in this chapter. There are also projects where a combination of both roof and façade BIPV solutions are incorporated in one project.

BIPV in-roof mounting system by Stafier (The Netherlands, 2014)

This roofing project included the renovation of 29 terraced dwellings in Maarn, The Netherlands. The investor here is the “Spoorweg” pension fund. The complete building envelope is being replaced by a new one within 5 days. Stafier developed a BIPV in-roof solution called “Stafier Standaard”, here one side of the roof is partly covered with modules. The remaining roof area on the PV side is finished using conventional roofing tiles. The other roof side is completely filled with conventional tiles. The modules can be integrated both portrait and landscape. Next, there is a square module to increase the freedom regarding module positioning. Another feature in this concept is the option to include a porthole window in the BIPV roof solution.

FIGURE 22. STAFIER STANDAARD AS AN IN-ROOF MOUNTING SYSTEM (MAARN, THE NETHERLANDS), 29 TERRACED DWELLINGS

Full roof BIPV solution by SCX Solar (The Netherlands, 2014)

This roofing project entailed the renovation of 75 dwellings in Tilburg. In 25 days each, the terraced houses were completely demolished and newly built according to new energy standards. SCX solar was the company that supplied the BIPV full roof solution called the “SCX Soloroof”. Flashings are used as finishing material to cover every possible dimension. In total 138 modules of 200Wp, 726 modules of 250Wp, and 752 modules of 260Wp panels were installed. The construction of each roof envelope had to be initiated and completed in one day. Moreover, exactly the twelfth day in the building process. The customer here is a housing association.

FIGURE 23. SCX SOLOROOF AS BIPV FULL ROOF SOLUTION (TILBURG, THE NETHERLANDS), 75 TERRACED DWELLINGS

Full roof BIPV solution by SunTechnics Fabrisolar AG (Switzerland, 2007)

The “Marché International Support Office” is said to be the first office building in Switzerland achieving a “zero energy balance”. The materials used for the supporting structure and building skin combine standard timber construction methods, innovative PCM technology and photovoltaics. The entire surface of the mono-pitched roof supplies 100% of the required power. The entire roof slope facing south with an inclination of 12° is covered with photovoltaic modules. The anthracite panels, form a homogeneous roofing that does not require an additional layer for the watertightness. The solar roof is composed by glazed PV modules, which are relatively small in size and are anthracite-colored, creating an aesthetically pleasing roof surface that is exemplary in its elegance and establishes a benchmark in the environment.

FIGURE 24. BIPV FULL ROOF SOLUTION, MARCHÈ INTERNATIONAL SUPPORT OFFICE (KEMPTTHAL, SWITZERLAND), (ARCHITECT: *BEAT KÄMPFEN)*

Combined skylight and warm façade BIPV solution by Flabeg Solar International (Germany, 1999)

The Mont-Cenis glazed shell accommodates a "building within a building" with a length of 180 m, a width of 72 m and a height of 16 m. A total of 20,640 m² glass has been laid in aluminum frames. Of this, 10,000 m² are fitted with solar cells (for a total peak power of about 1 MW) allowing that all areas in the interior open spaces and inside the buildings are optimally lit and shaded. For this purpose, solar modules with a density ranging between 53 and 93 % (output 190 to 420 wp) were used. The "solar field" also supplies the necessary shading for the hall. Light reflectors in front of the windows of the inside spaces intensify the supply of daylight to the rear areas.

FIGURE 25. COMBINED SKYLIGHT AND WARM FAÇADE BIPV, MONT-CENIS ACADEMY (HERNE, GERMANY), (ARCHITECT: *JOURDA ET PERRAUDIN)*

Combined roof, warm façade and balcony BIPV solution by Gasser Gebäude AG and MGT-esys GmbH (Switzerland, 2009)

This eight-story apartment building is located in Chiasso, Switzerland. This building is for the largest part covered by photovoltaic modules. The existing building was built in 1965 and has been recently refurbished according to the Minergie and Passivhaus protocols so that a massive reduction of the heat losses through the high-insulation of the building envelope was required. By covering almost the entire façade, the building owner achieved the plus-energy target thanks to the solar production considering that, for a high rise building, the roof space is not sufficient. For this reason, all the four facades play an important role in the energy production with a peak power of 45.9 kWp (façade) and 6.7 kWp (balcony). Thus the cladding elements of the Palazzo Positivo are transformed in an energetic skin integrating glazed thin-film and monocrystalline modules. In addition, a 51.8 kWp plant was installed on the garage roof and on the main roof. Blind (dummy) components are installed on the corners, the openings and in the shady parts of the facades. The aesthetical characterization of this re-cladding is provided by the PV integration in the vertical skin. This building represents a demonstrative case, unique in its kind, where PV becomes a constructive and architectural building material in a cost-effective way. The use of a thin-film amorphous-Si technology with a low power density of about 50 W/m2 results in a very-low end-user price for the BIPV system with a price of around 120 €/m2 (including mounting system). Also different interesting aspects related to self-consumption emerges thanks to the different orientation of PV modules. It was calculated a surplus of energy production of about 4800 kWh compared to total consumption estimated.

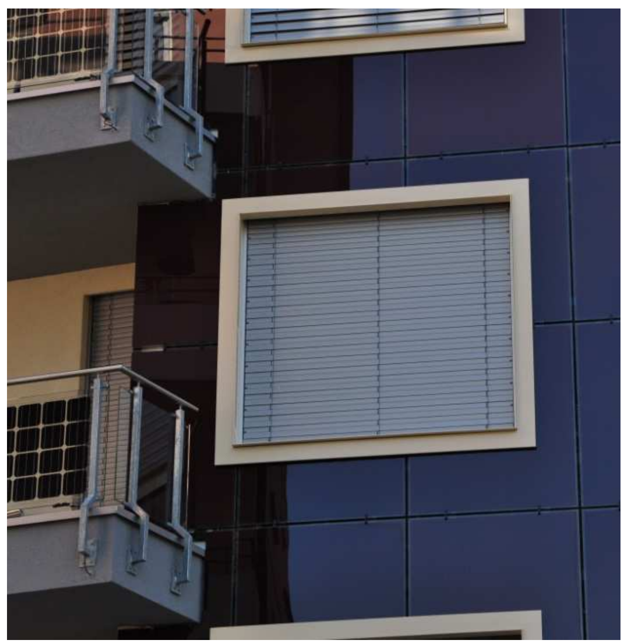


FIGURE 26. WARM FAÇADE BIPV SOLUTION, PALAZZO POSITIVO (CHIASSO, SWITZERLAND) (ARCHITECT: TOUR BAUMANAGEMENT AG, BAD RAGAZ, PICTURES: F. FRONTINI, SUPSI)

Warm façade BIPV solution (Switzerland, 2009)

The defining feature of the architectural concept for the New Monte Rosa Hut is its splendid isolation within Alpine landscape, in an extreme climatic location far from easy supply networks. The new hut therefore had to be as autonomous as possible and independent from the external environment. These requirements had a direct impact on the planning . The photovoltaic panels are integrated in the facade of the building adding a double function to the building's envelope and introducing an interesting dialog with shimmering aluminium claddings. The building looks like a glazed crystal at 2,883 meters above sea level, and it is almost completely self-sufficient. The autonomous alpine shelter was designed by the Department of Architecture at the Swiss Federal Technical University in Zurich (ETH).

FIGURE 27. WARM FAÇADE BIPV SOLUTION, MONTE ROSA HUT (ZERMATT, SWITZERLAND) (ARCHITECT: *ETH STUDIO MONTE ROSA)*

Cold façade BIPV solution by MGT-esys GmbH (Switzerland, 2009)

The new Minergie residential building is located at an altitude of 1050 m above sea level, in the ski center of Laax (Graubunden Canton in Switzerland). The south facade is characterized by the integration of PV modules with high efficiency monocrystalline cells. The cold façade system manufactured by the Austrian producer MGT esys, was installed onto a wooden substructure allowing an appropriate ventilations of the panels. The solar facade is equipped with a special mechanical anchoring system that is invisible from the outside. The architectural language is characterized by the grey appearance of the solar cladding obtained by the all-black modules. This creates a uniform striped effect similar to the wooden cladding of the other facades. The PV system which is grid connected produces enough electricity to meet the energy demand of the apartments.

FIGURE 28. WARM FAÇADE BIPV SOLUTION, CASA SOLARA (LAAX, SWITZERLAND) (ARCHITECT: *GIOVANNI CERFEDA)*

Cold façade BIPV solution by White architects and Solkompaniet (Sweden, 2013)

The residential building Frodeparken in Uppsala has a distinctive architecture and is one of the city highlights. The 90 meter arched building houses 70 apartments and combines its architecture with a favorable energy profile. The 1800 integrated solar panels cover the complete façade (675 m^2). The installed power is 100 kWp which produces is 70.000 kWh per annum. Enough electricity to power the elevators, lighting and ventilation. The panels are black thin film CIGS modules and are produced in Germany by Solibro GmbH. The size of the CIGS module was leading for the design of this building. In a way, this is an illustration of one of the major bottlenecks for a breakthrough in BIPV: the fact that low cost solutions are based on a standard panel size, while architectural solutions often require non-standard sizes. In this case the façade has been redesigned based on the size of the modules. The photos show how well the modules blend into the building and dictate its aesthetics.

FIGURE 29. COLD FAÇADE BIPV SOLUTION, FRODEPARKEN (UPPSALA, SWEDEN) (ARCHITECT: *WHITE ARCHITECTS)*

CONCLUSIONS

In this report a synthetic overview on the capabilities, potentials, specifications and strengths of PV in buildings (Building Integrated Photovoltaics, BIPV) has been discussed to inform architects, stakeholders and technicians about this growing field.

Key conclusions that can be drawn from the report:

- Today the European BIPV market is supported by approximately 200 commercially available products, of which 108 are listed in this report. The products are well-distributed over 3 application areas and 13 product categories. The most abundantly populated product categories are “Full roof solution” and “Solar glazing”. The least occupied product groups are “PV membranes”, “Metal panels” and “Warm façades”.
- BIPV roof products are priced about 200 €/m^2 above conventional roof products. Several products in the BIPV full roof solution category were found to be lower priced than the alternative of roof tiles topped with conventional BAPV systems, making these products the most cost-effective PV solution for newly built or renovated houses.
- BIPV façades are a highly promising application area, as the found products were priced very similar to conventional façade materials. This holds the promise of ‘PV for free’, e.g. a building with BIPV built without any added costs compared to a conventional building.
- Within the BIPV market, rooftop BIPV has the largest product availability and this situation is expected to prolong for the next five years at least. However especially in the utility and commercial segments, façade BIPV systems are expected to gain importance. The key market driver for this segment is the European Directive 2010/31/EU [1], which states that each new building should be made ‘nearly zero energy’ from 2020 onwards. Façade PV systems are essential to meet this demand, as in many utility and commercial buildings the roof is simply not large enough to generate all the required energy.
- The dominant PV technology in BIPV today is crystalline silicon (c-Si). Thin film PV technology has a share of 10-25%, which is significantly higher than in the conventional, non-integrated PV market. The proposed reason why thin film PV is relatively more popular in BIPV applications, is its homogeneous color (black) appearance and its lower price per m^2.
- BIPV projects are slowly becoming known throughout Europe. Good examples of BIPV projects can be found in most countries. Eight examples of BIPV projects were described and shown in this report. We hope the existing projects will serve as catalysts, from which more architects, construction companies and end-users will get stimulated to apply BIPV solutions in their buildings.

Many international references of BIPV worldwide today show the wide range of chances and opportunities for solar energy in “sustainable architecture”. The increasing demand of nearly-Zero Energy Buildings is contributing to change the building skin from a passive barrier towards a sensible, active and adaptive layer. BIPV is a growing sector in industry, market and people awareness: the multi-functionality of PV is by now recognized as a pre-requisite that is gradually stimulating product and building systems' innovation. The industry today makes available a plenty of PV products for building and a wide range of possibility can be satisfied in terms of aesthetics and performance. Multi-functionality, prefabrication, standardization, mass-customization, aesthetic and cost-effectiveness are the main pillars on which the development of BIPV systems is evolving. Thus neither the technological feasibility nor the aesthetics of BIPV are the main problem today. There are other reasons because BIPV still remains a niche market. Excluding costs and conflicting building codes, regarding which some solutions have already been traced out or are under development, perhaps the main reason is the additional effort required for all the actors in the value-chain. In this perspective a different concept of “integration” should be investigated involving a higher level of complexity (technological, constructive, energetic, performance, aesthetic, economic, etc.) as well as an interdisciplinary and a collaborative approach both in the design and in the building process.

As an outlook, we see that the following items deserve attention in the years to come:

- Concerted efforts by players in the BIPV supply chain to work together in accordance with a collaborative and integral design/building process. BIPV will require not only a technological integration but an integration in the whole building process;
- Smart engineering and manufacturing of BIPV products such that low cost (€/Wp as well as €/m^2) can be combined with the high mix requirements from the building market;
- A broad support and acceptance of the central BIPV vision: i.e. that BIPV can be considered as a building material producing energy;

DISCLAIMER

PICTURE SOURCES

The images illustrated in this report are used for only educational and scientific purposes without any discrimination, commercial use or other scopes. Following the sources and links are listed (accessed February 2015)

Figure 1. Schweizer Solarpreis 2011, p.56 http://www.solaragentur.ch/sites/default/files/Solarpreis/Solarpreis2011/g-11-10-06_solarpreispublikation_truffer.pdf

Figure 2. Schweizer Solarpreis 2013, p.41(Link: http://www.solaragentur.ch/sites/default/files/g-13-09-17_solarpreispublikation_2013_def_ka_weibel_horgen.pdf). Schweizer Solarpreis 2012, p.53 http://solaragentur.ch/dokumente//G-12-09-24_Klein-Solarpreispublikation_2012-DEF.pdf)

Figure 3. SI-Power Indach (www.bipv.ch, http://www.si-module.com/); General Membrane (www.generalmembrane.it/); Krehl.Girke Architekten (http://www.krehlgirke.de/)

Figure 4. SEAC-SUPSI

Figure 5. Renusol Intersole (http://www.renusol.com/en/pv-mounting-solutions/intersole.html)

Figure 6. Meyer Burger Technology AG (www.meyerburger.ch)

Figure 7. www.newroof-hybrid.com

Figure 8. http://www.realize-energysystems.com/produkte/panotron-solarenergiesystem/index.html, www.fornacefonti.it

Figure 9. http://www.kalzip.com/kalzip/, http://www.tegolacanadese.com/

Figure 10. http://www.energyglass.eu/pagine/pagina.aspx?&L=IT

Figure 11. www.iba-hamburg.de/

Figure 12. P. Bonomo

Figure 13. https://www.ethz.ch/de/news-und-veranstaltungen/medien/bildergalerie/neue-monte-rosa-huette.html

Figure 14 F. Frontini, SUPSI

Figure 15 www.sinoitaenvironment.org/, http://www.mcarchitects.it/

Figure 16, 17: SEAC, SUPSI

Figure 18: C. Polo, SUPSI

Figure 19: SEAC, SUPSI

Figure 20: SUPSI

Figure 21: SEAC, SUPSI

Figure 22: http://www.stafiersolar.com/portfolio-item/stafier-standaard/

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Figure 26: F. Frontini, SUPSI

Figure 27: https://www.ethz.ch/de/news-und-veranstaltungen/medien/bildergalerie/neue-monte-rosa-huette.html

Figure 28: F. Frontini, SUPSI

Figure 29: White Architects, http://www.white.se/en/project/308-frodeparken

Figure 30: F. Frontini, SUPSI

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FIGURE 30. THE WEBSITE WWW.BIPV.CH IS ONE OF THE COMMUNICATION MEANS OF THE SWISS BIPV COMPETENCE CENTRE. HERE YOU FIND ESSENTIAL INFORMATION CONCERNING PV TECHNOLOGY INTEGRATION IN BUILDINGS AND DIFFERENT PROJECTS REALIZED BOTH IN SWITZERLAND AND ABROAD. MOREOVER, YOU CAN CONSULT A LARGE **DATABASE OF BIPV MODULES AND FASTENING SYSTEMS** COLLECTING THE MAIN PRODUCT'S INFORMATION IN A DATASHEET. THE WEBSITE IS AN ACTIVE INTERFACE OPENED TOWARDS DIFFERENT STAKEHOLDERS THANKS TO THE POSSIBILITY TO UPLOAD AND STORE YOUR BIPV EXAMPLES (ARCHITECTS, INSTALLERS, OWNERS, ETC.) OR PRODUCTS (MANUFACTURERS, SUPPLIERS, INSTALLERS, ETC.) AS WELL AS TO THE TECHNOLOGICAL/CLIENT SUPPORT THROUGH THE CONTACT INFO@BIPV.CH.