

University of Applied Sciences and Arts
of Southern Switzerland

SUPSI



Solar Energy Application Centre
The Netherlands

Building Integrated
Photovoltaics:
Product overview
for solar building skins

Status Report
2017

SUPSI – Swiss BIPV Competence Centre

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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 and EnergieSchweiz, 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.

Solar Energy Application Centre, SEAC

Menno van den Donker, Finn Vossen, Wiep Folkerts

The Solar Energy Application Centre (SEAC) is a knowledge centre on solar energy systems and applications. SEAC was founded in 2012 on the initiative of ECN, TNO and Holland Solar and is located in Eindhoven, The Netherlands. The scope of SEAC is the field of solar energy systems & applications, which includes photovoltaic systems and solar thermal applications. The technical expertise of SEAC is strongly focused on three key R&D areas: benchmarking, field testing and techno-financial modeling for solar energy systems & applications. The website www.seac.cc offers many reports on BIPV and related topics.

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, but also for conventional building products.

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 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 regular building component and a BIPV component.

Another dominant market factor in the new era is the fact that high-rise multi-storey buildings simply do not have enough roof area to meet the energy performance requirements. 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 drivers 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 and to the way of working in construction industry. This movement will eventually lead to a transition from BIPV as a customized product to BIPV as a

commodity product for the building skin. An interesting illustration (or driver, depending on perspective) of this transition is the recent announcement of the Tesla Solar Roof, a product of SolarCity, a Tesla owned company. Demonstrations of the product have attracted a substantial attention. Tesla is clearly not the first company to launch a solar roof tile product, but media coverage for this product has been larger than ever before.

This does not take away the pregnant question whether a solar roof tile is indeed the solution that will win the market. One could even argue that a solar roof tile is essentially a retrograde product that shows lack of creativity. Similar to that the first cars resembled carriages and the first electric bulbs resembled candlesticks. Possible disadvantages of a solar roof tile approach are evident: many small components, large labour cost, many electrical connections and a challenge on robustness due to the many connectors.

Other actors in the market put their believe therefore on the large area solutions, that facilitate full roof solutions as well as large area façade solutions in BIPV. What is the winning strategy? Time will tell.



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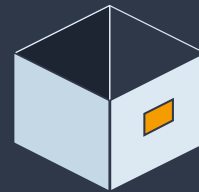
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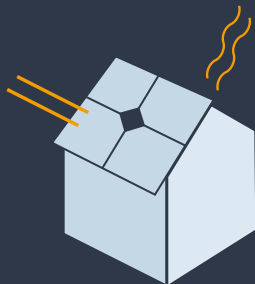
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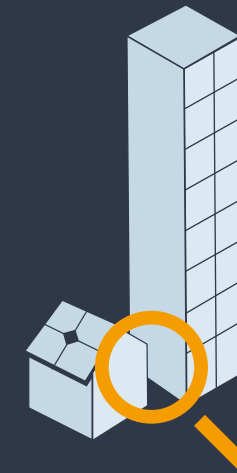
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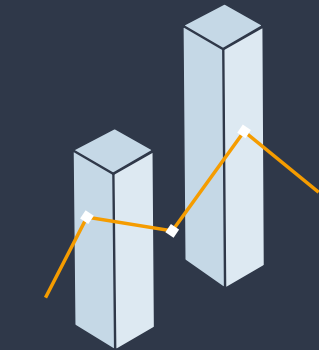
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Management summary

Building Integrated Photovoltaics (BIPV) is about multi-functional building elements that generate electricity. BIPV is an emerging sector in the PV market and shows very promising market perspectives worldwide [2].

Today, about 40% of the global energy demand is consumed in residential and commercial buildings. Therefore the building sector is one of the main targets of European and global policies on mitigating climate change. These policies translate into regulations and laws on energy performance of buildings (new buildings and renovations). Improved energy performance can be obtained through energy efficiency measures and by implementing renewables. As the regulations become more ambitious on the way towards (near) zero energy buildings, the application of PV on buildings is expanding and becomes more and more a part of the architectural concept.

In this perspective BIPV represents a strategic part of the future building vision. BIPV brings the worlds of construction and photovoltaics together with all the challenges and chances inherent to such a change of paradigm. Aesthetics and technology, energy efficiency and functionality, flexibility and reliability are not in conflict anymore but they are part of the same concept. After more than 20 years of R&D [3], a true market segment for BIPV has emerged with very interesting products for the building envelope and elegant showcase projects. The birth of this market has been based on an enormous progress in BIPV technology development (cost-wise and performance-wise), together with the vision of some leading architects and industries. Today the European market of BIPV systems for buildings is supported by more than 100 suppliers of commercially available products.

The SUPSI-SEAC report 2017 gives a comprehensive overview of BIPV, its product classification, its available products and emerging trends, its example projects and its price levels.

The report starts off with a reference classification of BIPV systems according to the most recent developments in the market. We believe that this cataloguing system serves the purpose of understanding the market and the product segmentation in BIPV. The application areas are divided into ten different product categories.

Next, in chapter 2 we present our updated database of BIPV products available. It consists of 114 BIPV products that are commercially offered 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 collaborations with industries. Rooftop applications have the largest amount of product offerings in BIPV. BIPV systems for façades are a runner up, and expected to gain more and more importance in the coming years.

It is particularly interesting to note that the BIPV market is dynamic. Indeed one out of three BIPV products in our database appeared on the market within the last two years, replacing others that disappeared for various reasons (costs, technology maturity, specific regulations, company takeovers and name changes).

The dominant PV technology in BIPV is found to be crystalline silicon (c-Si). Nonetheless, a relatively high percentage of the product offerings uses thin film (TF) PV technology. One relevant factor is the better aesthetics of thin film PV modules compared to regular c-Si modules. Another relevant factor is that thin film modules are generally sold at a lower price per m² which improves the competitiveness compared to conventional façade cladding materials. It is interesting to follow the trend of the thin film PV market share in BIPV façades, as the aesthetic advantage of thin film PV modules might get weakened by the introduction of colored PV modules.

In chapter 3 we describe some main technology trends that we believe could represent a new significant market segment within the next 5 years.

A potential market opportunity can be recognized in: prefab mounted BIPV systems, colored systems, solar glazing and lightweight systems. Even though some example projects already exist, commercially available products are not yet easy to find since many of these technologies are the result of recent research projects or new start-up/spin-off, as only few products appear in this year's database.

Chapter 4 presents five BIPV buildings representing various product categories and application areas. We believe that these realized projects, demonstrating that PV for building is aesthetical, feasible and affordable, will serve as catalysts, stimulating more architects, construction companies and end-users to apply BIPV solutions in their buildings.

In the final chapter we investigate and discuss the topic of the price levels and cost assessment for the various BIPV product categories, starting from the input arisen as a result of the market survey conducted, mainly for the Dutch/Benelux and Swiss markets, involving producers, suppliers as well as installers of BIPV products.

In our vision, the further development of the BIPV market in Europe will depend on a number of key factors. Two of these 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 national/local building codes in order to clearly allow BIPV products to address the complete European market;

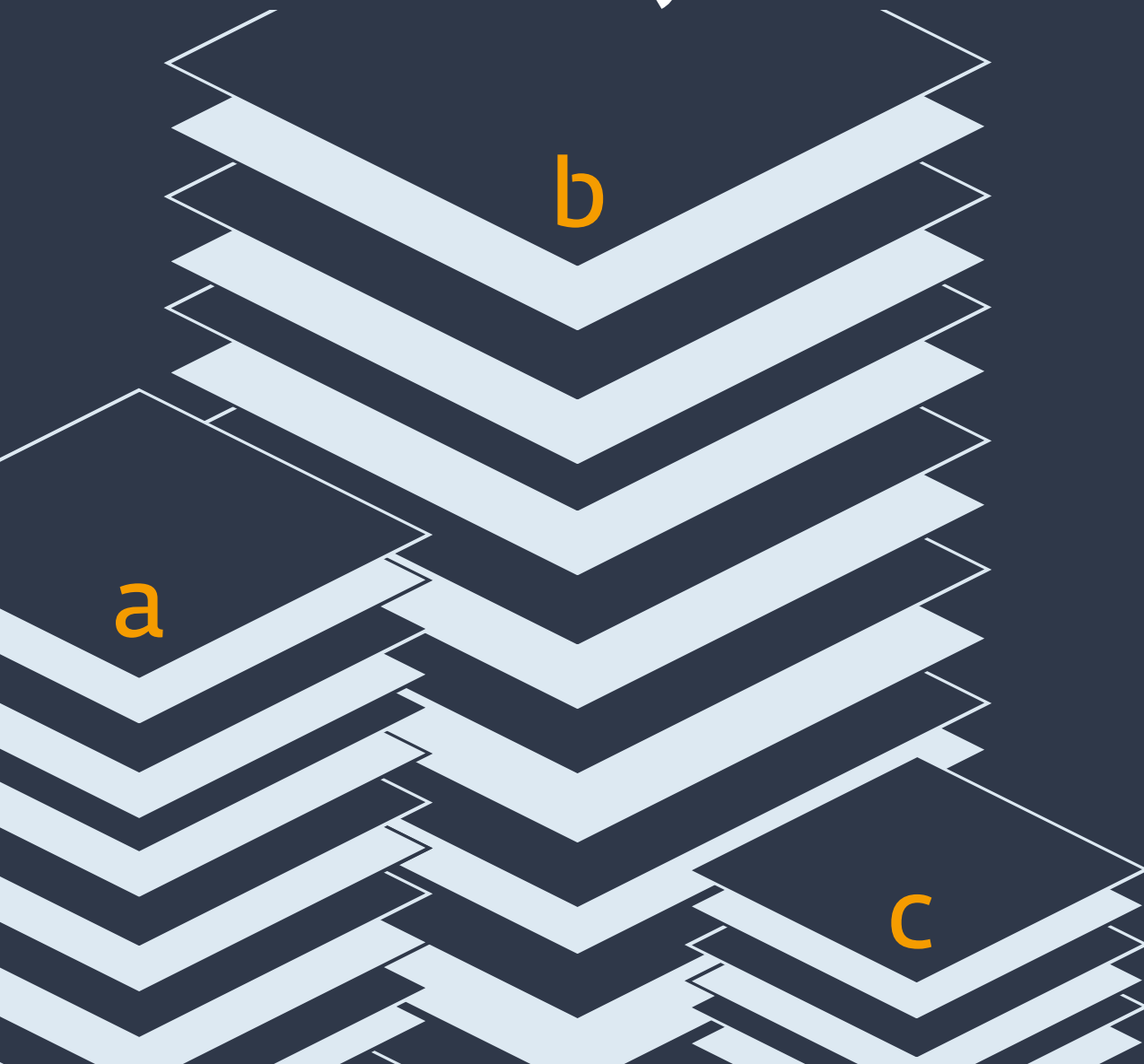
The three other success factors are related to product positioning, supply chain and cooperation between sectors:

- A broad support and acceptance of the central BIPV vision: BIPV has to be considered by architects as part of the building skin and a material to introduce a new semantics in contemporary architecture.
- Smart engineering and manufacturing of BIPV products such as the combination of mass-customization and cost-effectiveness from electro-technical and building field with energy efficiency, reliability and aesthetics.
- 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 innovation but mainly an integration/innovation in the whole building process;

The purpose of this report is to inform architects, stakeholders and technicians with a comprehensive overview on the capabilities, specifications and value propositions of PV integrated in the building skin. We expect that this report will contribute in better underlining some main aspects as currently in discussion in the BIPV field and in supporting this sector.



1 Classification of BIPV systems



The acronym BIPV technically refers to systems and concepts in which the photovoltaic element has 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 is evolved in the years through gradual steps of innovation, resulting in a progressive technological transfer of PV technology in the building technical elements, from addition of PV in already existing elements, up to the layering of the building skin with active parts or new integration concepts where PV is part of a unique concept.

A functional definition refers to the structural or physical role of the PV modules in the building skin. In this definition, 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 definition of BIPV refers to the architectural concept: this is harder (and maybe impossible) to define in a unique way. It can be considered as the

potential of the PV material/component/system to define the linguistic/morphological rules governing the signs, the structure and the composition of the building's architectural language.

"An acceptance of solar technology in construction by the general public can only be achieved by means of convincing visual ideas and examples"

"Renewable forms of energy present an opportunity to make life in cities more attractive"

Thomas Herzog - Excerpt from the European Charter for Solar Energy in Architecture and Urban Planning 1994-1995 [4]

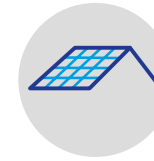
"My expectation is that such panels will be integrated into the very fabric of the walls and roof and the shape or form of the buildings will also be sculpted by the solar cycle to maximize the input of its energy. I've never seen a conflict between the pursuit of aesthetic delight and high performance in terms of sustainability"

Lord Norman Foster - 2010 [5]



Various functional and aesthetic definitions of BIPV have been adopted in literature, international standards and also national feed-in-tariffs classifications. There is no general consensus within the PV community about the different categories of BIPV, since different criteria can be adopted. In the previous edition of our status report we have derived a comprehensive definition set that we will further expand upon in this report. Namely, one additional category was added: Prefab PV systems. The categories "metal panels" and "PV membranes" have been merged and are now called "lightweight" products. This approach has also been used for the categories "small tiles" and "large tiles", which are now merged into one category called "tiles".

Considering the growing market share of BIPV, the progress in standardization (EN 50583-2016, Parts 1 and 2) 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 it is becoming a mature building element as well.



The two main application areas: roof and façades which are shortly described below.

Roofs

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. Other important properties are e.g. fire repellent, storm wind proof, low audible noise from rain showers, and good acoustic damping. 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

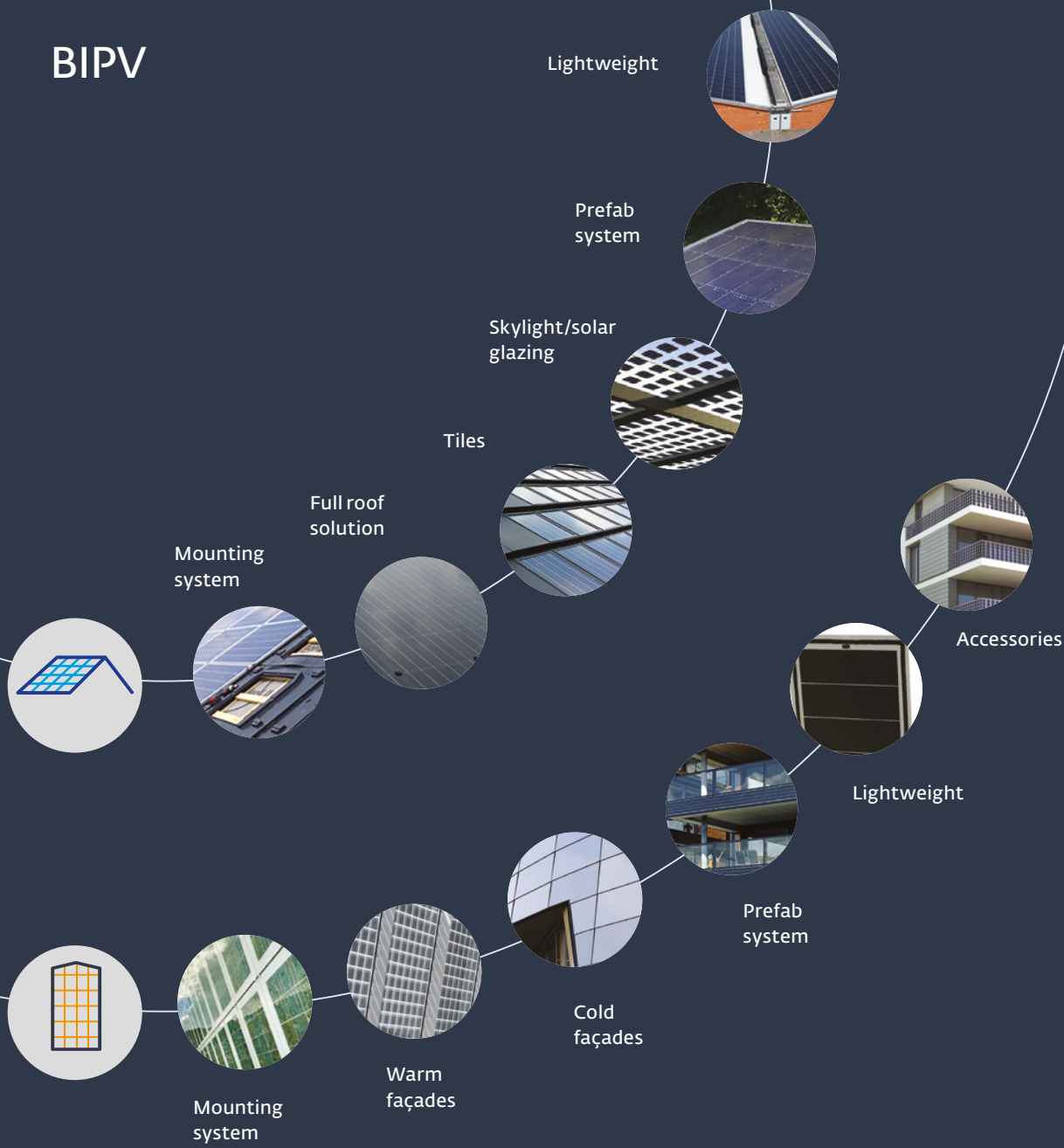
A flat or curved roof, also known as "continuous roof", is characterized by an uninterrupted layer with the main function to be water resistant. Usually membranes are used as a water barrier. In the first applications, the PV was mainly placed on top of the roof. Lightweight and self-bearing systems 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.

BIPV



The BIPV segmentation use throughout this report

Considering the growing market share of BIPV, the progress in standardization (EN 50583-2016, Parts 1 and 2) 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 it is becoming a mature building element as well.

Mounting systems (partially integrated)



In-roof mounting systems are used to install conventional PV modules in sloped roofs with a standardized kit of components such as frames, clamps, watertight layers, etc. Usually only a part of the roof is covered by PV since the system is based on standardized elements that cannot be adapted to single roof features such as morphology, pitches size, irregular surfaces, chimneys or other elements. Special parts such as dummies, customizable parts are typically not provided. The panels are often inserted in a geometrically defined portion of the roof next to the conventional roofing material. The PV panels do not always have a role in the water-tightness functionality. In some systems a watertight layer is added underneath the modules. The same concept is also applicable in case of a vertical integration where photovoltaic conventional modules are to be installed as a façade cladding through a mounting system not specifically developed for the building skin technological units. Since the PV panels replace conventional roof tiles or cladding materials, mounting systems fall under the *functional* definition of BIPV.

Full Roof solution (totally integrated)



The *full roof solution* includes cases where PV doesn't represent an "insertion" within an already defined roof surface but it is a characterizing factor of building skin technology and architectural design involving both an aesthetical and functional/constructive integration. A full solar roof concept is often involved so that the roof surface is exclusively conceived as a solar collector for energy production. This whole concept concerns also the special development of the PV element as a building component which has to satisfy the main requirements of the building skin (e.g. water tightness). Accordingly, these solutions typically include 'dummies', flashings, metal works, sub-structures, roof components, etc. to ensure a proper functional and constructive integration of the whole roof system. Special PV elements are developed (e.g. modules with special frames, borders, joints and connections), along with installation procedures, to comply with the main construction requirements (such as water tightness, mechanical resistance and safety, etc.) and mounting procedures. Since the full roof system replaces conventional roof tiles and is designed to maintain *aesthetics*, it falls under both the *functional* and the *aesthetic* definition of BIPV.

Prefab systems



A prefabricated BIPV system (the fastening system and/or other building functions are already integrated with the PV module) is mainly a building skin element that can be described as a unitized pre-assembled element to be directly used as roof or façade. Such a product has to comply with the multifunctionality characteristics required to BIPV modules, along with additional construction and installation concepts such as an easy mounting approach as well as a hassle-free replacement on the basis of a plug & play concept (both electrical and technical). Since a prefab system is, in all respects, an integral part of the building envelope (with the special feature to be energy active), it has to comply with all the applicable electrical and building code and standards. It is not necessarily designed with only aesthetics in mind since in the prefab system the functional definition of BIPV involves all the building skin engineering.

Solar tiles



Solar tiles are usually designed to resemble the conventional roof tile as much as possible. The solar tiles are often inserted in a geometrically defined portion of the roof next to the conventional roof tiles. The visible panel height is chosen to be equal to the roof tile's row height (e.g. of the order of 40cm in typical roof tiling). This ensures a perfect optical blending in of the solar tiles with the conventional roof tiles. The width of the solar tiles varies from small (0.30m) to large (1.60m). Smaller tiles have the advantage of greater roof filling and best aesthetics. Larger tiles have potentially a lower cost level, although this has not yet been demonstrated in any of our price surveys. Solar tiles can be glazed (glass sub/superstrate) or foil-based on i.e. polymer membranes. Solar tiles traditionally have a small market share due to the high cost levels, but recently gained significant marketing exposure due to their ability to replace the traditional tiling in a roof. Since the solar tiles replace conventional roof tiles and are designed to maintain aesthetics, they fall under both the functional and the aesthetic definition of BIPV.

Lightweight systems



With lightweight PV systems we generally refer to all those product whose weight per square meter is significantly lower than conventional products which are usually based on glass. It is hard to define a specific threshold but we can assume as a reference a value < 12-15 kg/m² for the cladding part, excluding substructures. The reduced weight of these kinds of systems makes them suitable for some applications such as the refurbishment of the building envelope. Typically the ultra-thin or innovative nature of some laminates make them also suitable for its integration on most substrates. The lightweight products on the market can be divided in three main sub-categories:

- Light-weight PV modules (rigid or flexible). Such panels are able to meet some demanding requirements, even in some unusual installations. E.g. plastic-based flexible/bendable PV modules that can be mounted and removed with ease, thanks to several accessories, and adapt to various surfaces.
- Roofing membranes where flexible PV panels are laminated onto roofing membranes such as TPO (Thermoplastic Polyolefin), PVC (PolyVinyl Chloride) or EPDM (ethylene propylene diene terpolymer).
- Metal panels where flexible lightweight PV panels are laminated onto metal panels. The metal panels are used in metal seamed roofing or façades. The market offers plenty of types with different materials (steel, copper, zinc, aluminum, etc.).

The technological families of the flexible lightweight PV panels traditionally are: thin film silicon, thin film CIGS and thin film organic-PV (OPV). In the last few years, some products of these families have appeared and disappeared from the market. Recently are emerging also crystalline silicon based ultra-lightweight PV panels. Modules with thin layers of glass (<2 mm thickness) or rigid transparent plastics would theoretically also fall within this category. This is an example of a category where the products currently available on the market usually do not fall in the *functional* definition of BIPV. Especially the flexible PV panels do not replace existing building materials, but instead are glued on top of them. We did choose to include this category in our report because these lightweight systems have the potential to be integrated in the building skin both as functional building component and as a part of the visual design and if so will fall within the *aesthetic* definition of BIPV.

Skylight/Solar glazing



These glazed PV laminates for roofs are often made by crystalline silicon cells with adjusted spacing or by laser grooved thin film which provides filtered vision, encapsulated within glazed panes. In buildings they are often found in envelope systems together with extruded aluminum frames (but also steel, woods, etc.) in-filled with glass, similarly to a curtain wall. They can be used as part of a semi-transparent roof, so-called 'skylight'. 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. These structures usually combine glass-glass PV laminates with adjustable light transmission, stimulating the architectural design of light and shadow and performing a fundamental role for the energy balance of the building. Skylights can be used in flat roofs, pitched roofs, and sometimes also in curved surfaces.

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Curtain wall (warm façade)



A curtain wall is typically a continuous building envelope system in which the outer walls are non-structural. A curtain wall fulfills all building envelope requirements such as load bearing, thermal insulation, weatherproofing and noise insulation. Since PV is fully integrated in a complex building skin system, when using highly-glazed curtain walls, the energy parameters related to solar gain control such as thermal and visual comfort are strictly related to the PV design (e.g. cell's arrangement, distance, etc.). Similarly to skylights, the transparent functional layer (glass) is replaced with an active glazed pane including PV (e.g. a laminated glass), whilst the load-bearing part, represented by the frame, is equipped for the electric wirings passages. Different technological solutions are included in this category (stick system with mullions/transoms, structural-sealant glazing, suspended façade, point-fixed façade, etc.).

Rain-screen façade (cold façade)



This façade 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 air cavity that is naturally ventilated (stack effect) through bottom and top openings. This is the reason why it is also called "cold façade", seeing that it brings a cooling effect for the wall and improves the efficiency of the modules. Many constructive models and technological solutions are available. The solar modules can be integrated as the outer building cladding like a conventional cladding element.

17

Accessories

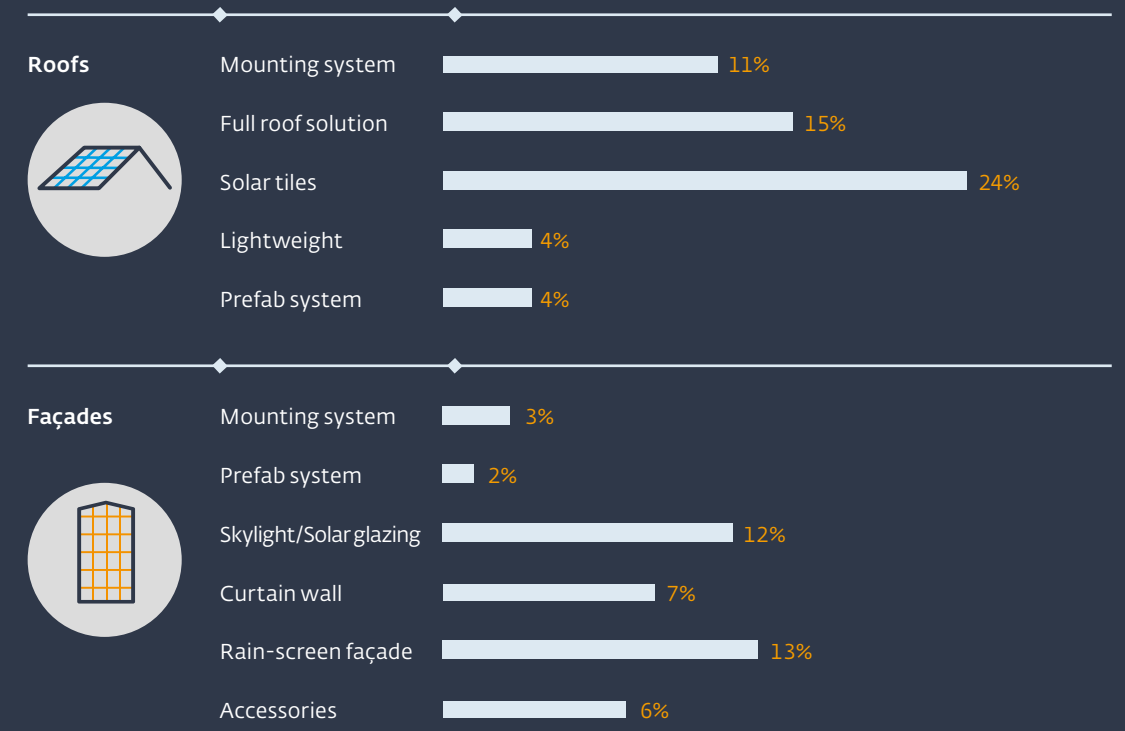


Buildings may have 'solar accessories' integrated in the design. These components may include balconies, parapets, outdoor partitions, shading systems and several other elements. Shading systems are the most commonly used accessory. The control of the indoor microclimate, especially in glazed façade systems, usually requires the use of shading devices aimed to select the solar radiation for ensuring the thermo-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 these accessories offering a perfect way to utilize the shadow function with electricity production.

2 BIPV Products database

This chapter presents a list of BIPV products classified in the different categories as defined earlier in this report. The chapter focuses mainly on the manufacturers and installers based in Europe, and emphasizes on systems commercially available in the Swiss and Dutch/Benelux markets. The SUPSI website www.bipv.ch [6] and the SUPSI-SEAC BIPV status report of 2015 [7] served as basis for the products list. We carefully removed products that were withdrawn from the market since 2015 and added new products that entered the market since 2015. This was executed through a punctual search on the internet, interviews with the industry and trade fair visits.

Figure 2 shows the overview of the products grouped for BIPV product categories. The most common product group is that of solar tiles (any size) followed by the full roof solution (totally integrated system) and mounting systems which generally are used to install conventional PV modules in sloped roofs with a standardized kit of components (partially integrated). In 2015 this trend was already visible even though full roof system 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 significantly bigger than the façade market. To notice than products described as skylight and/or solar glazing for roofs are generally marketed also with a curtain wall variant.

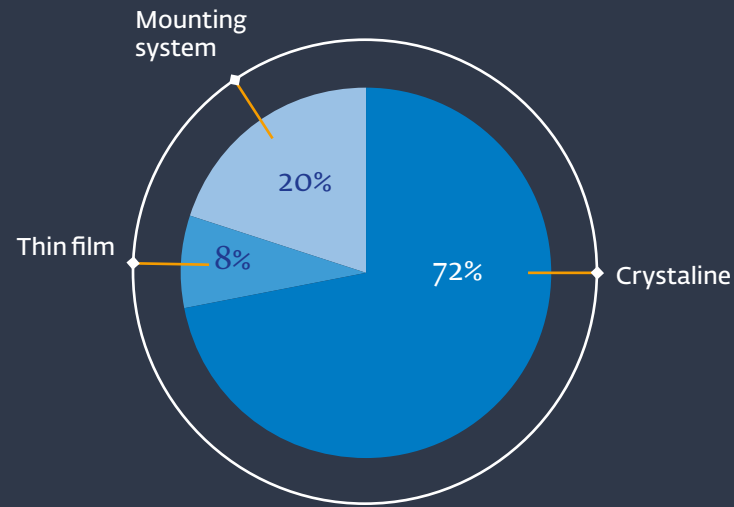


Distribution of listed products according to the different categories. Results of the market survey presented in terms of the occurrence of product groups.

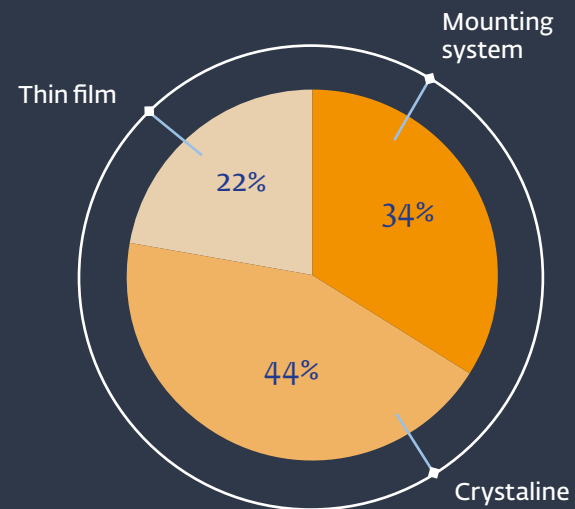
Next, in Figure 3 is presented an overview of the PV technology used within the listed products, with a focus on the technology share of 'crystalline silicon' versus the 'thin film'. We found that 8% of the BIPV products for roofs and 44% of the BIPV products for façades were using thin film technology. 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 thin film technology [8]. We propose the possible explanation for the success of thin film PV technology in BIPV, especially on façades, to be due to two key reasons: first of all the aesthetic appearance and secondly the low price/m², and associated high relative substitutional costs when saving out conventional building materials.

TECHNOLOGIES USED FOR ROOF PRODUCTS



TECHNOLOGIES USED FOR FAÇADE PRODUCTS



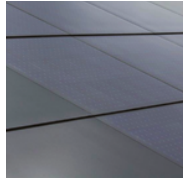
Pie charts of the technology used in the roof and façade application areas.

The following table shows a non-exhaustive list of BIPV products currently available on the market. During the data collection phase it was noticeable how products appear and disappear on the market in a consistent manner. Comparing the lists of our previous report and the current edition we can make the following observations. About 35% of the companies listed in the current edition did not offer their product 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, two years ago, stopped their activities or no longer offer BIPV products. We strive for continuous actualization of our database. Please feel free to contact us on www.bipv.ch in case you have a new product offering that could be included as well.

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 or by sending an email to info@bipv.ch.

The listed products are registered in alphabetical order in consideration of the name of the manufacturer. Roof products are highlighted by the color **blue**, while façade products with the color **orange**.

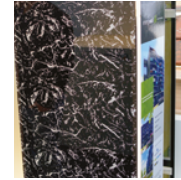




Aerspire (NL)
AER
Crystalline
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Full roof solution
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Full roof solution
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EnergyWall
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Rain-screen façade
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VSG-glass module
Crystalline
130-155 W
Accessories
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Evalon Solar cSi
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130-155 W
Full roof solution
www.brandonisolare.com



EMERGO (NL)
Energiedak 1.0
Crystalline
Prefab system
www.emergohout.nl



Ertex Solar (AT)
VSG-EVO-Module
Crystalline
90 - 166 W
Skylight / Solar glazing
www.ertex-solar.at



Asola Technologies GmbH (DE)
VITRUM Balcony
Crystalline
40-350 W
Accessories
www.asola-tech.de



Büro Dach & Wand (CH)
Kalzip AluPlus Solar
Thin Film
68-144 W
Lightweight
www.kalzip.com/kalzip



EnergyGlass (IT)
EnergyGlass ceramica fotovoltaica
Crystalline
50-100-190
Full roof solution
www.energyglass.eu



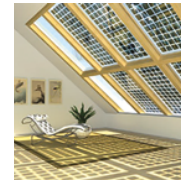
Ertex Solar (AT)
VSG-ISO-Module
Crystalline
330-350 W
Skylight / Solar glazing
www.ertex-solar.at



Asola Technologies GmbH (DE)
VITRUM SunSecret
Crystalline
80-160 W
Skylight / Solar glazing
www.asola-tech.de



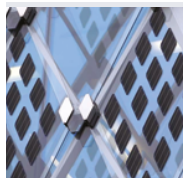
ClickCon GmbH & Co.KG (DE)
ClickPlain Indach Montagesystem
Mounting system
In roof mounting system
www.aerspire.com



EnergyGlass (IT)
EnergyGlass vetri fotovoltaici
Crystalline/Thin film
Custom made
Skylight / Solar glazing
www.energyglass.eu



Eternit (Schweiz) SA (CH)
Integral 2
Crystalline
180 W
Full roof solution
www.eternit.ch



Asola Technologies GmbH (DE)
VITRUM Super
Crystalline
250 W
Rain-screen façade
www.asola-tech.de



Colt International (CH)
Shadovoltaic
Crystalline
Accessories
www.colt-info.de



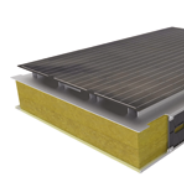
Ernst Schweizer AG (CH)
Photovoltaik-Fassaden
Crystalline
Rain-screen façade
www.schweizer-metallbau.ch



Exasun (NL)
Black Mystiek
Crystalline
Solar tiles
www.exasun.com



Batineg SA (CH)
Faceactive
Thin Film
Prefab solution
www.batineg.ch



Designenergy SA (CH)
TCR
Crystalline
160 - 260 W
Prefab system
www.designergy.ch



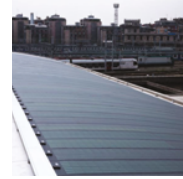
Ernst Schweizer Metallbau (CH)
Solrif
Mounting system
In roof mounting system
www.schweizer-metallbau.ch



Fent Solare Architektur / Lucido Solar AG (CH)
LucidoPlus
Crystalline
Prefab system
www.fent-solar.com



Flisom AG (CH)
SF Gen1
Thin film
33-40 W
Rain-screen façade
www.flisom.ch



Hanergy Holding Group (CN)
GlobalSolar PowerFLEX
Thin film
Max 300 W
Lightweight
www.globalsolar.com



Industrie Cotto Possagno Spa (IT)
Coppo in cotto fotovoltaico
Crystalline
4 W
Solar tiles
www.cottopossagno.com



Länge Glas (AT)
Al-Wall Solar
Mounting system
Rain-screen façade
www.langleglas.com



Fornace Fonti srl (IT)
Tegole DF2-DF3 in cotto
Crystalline
8 / 12 W
Solar tiles
www.fornacefonti.it/it



Hanergy Holding Group (CN)
Hanergy BIPV Hollow Panel
Thin film
Max 45 W
Curtain wall
www.hanergy.com/en



Industrie Cotto Possagno Spa (IT)
Tegola in cotto fotovoltaico
Crystalline
8 W
Solar tiles
www.cottopossagno.com



LOF Solar (TW)
6x6 BiPV Module
Crystalline
120-135W
Skylight / Solar glazing
www.lofsolar.com



Galaxy Energy GmbH (DE)
Galaxy Energy Indachsystem
Crystalline
185-270 W
Skylight / Solar glazing
www.galaxy-energy.com



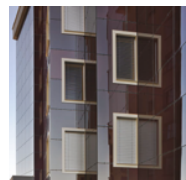
Hanergy Holding Group (CN)
Hanergy BIPV Modules
Thin film
Max 65 W
Curtain wall
www.hanergy.com/en



IRFTS (FR)
EASY ROOF EVOLUTION
Mounting System
In roof mounting system
www.irfts.com



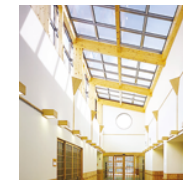
Marcegaglia Building (IT)
Brollo Solar
Thin film
68-144 W
Lightweight
www.marcegaglia.com



Gasser Fassadentechnik SA (CH)
////
Thin Film
Rain-screen façade
www.gasserfassadentechnik.ch



Hanergy Holding Group (CN)
Solibro CIGS
Thin film
120 – 125 W
Rain-screen façade
www.solibro-solar.com



Kaneka (BE)
See-Trough PV module
Thin film
44-55 W
Skylight / Solar glazing
www.kaneka-solar.com



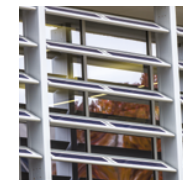
Mecosun (FR)
MV3R
Mounting system
In roof mounting system
www.mecosun.fr/fr/



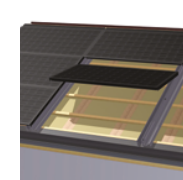
Gielleplast (IT)
Gielleplast-Tile
Crystalline
8 W
Solar tiles
www.gielleplast-tile.eu



Hermans Techniek (NL)
Techniglaz
Crystalline
Solar tiles
hermanstechniglaz.nl



Kawneer North America (USA)
1600 PowerShade
Crystalline
75 W
Accessories
www.kawneer.com



Megasol Energie (CH)
Megasol NICER
Crystalline
200-270 W
Full roof solution
www.megasol.ch



glass 2 energy (CH)
////
Thin film (DSSC)
Skylight / Solar Glazing
www.g2e.ch



Imerys (FR)
Tuile photovoltaïque Imerys
Crystalline
66 W
Solar tiles
www.panneau-solaire-tuile-photovoltaïque.fr



Kawneer North America (USA)
1600 PowerWall™
Mounting system
Curtain wall
www.kawneer.com



Megasol Energie (CH)
Megasol Swiss Premium Mono
Crystalline
255-280 W
Rain-screen façade
www.megasol.ch



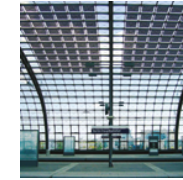
Megasol Energie (CH)
Megasol Swiss Premium Transluzid
Crystalline
255-280 W
Skylight / Solar glazing
www.megasol.ch



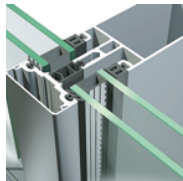
NaturHaus Solar GmbH (DE)
nD-System
Mounting system
In roof mounting system
www.nd-system.de



Sanko Solar (NL)
////
Thin Film
Full Roof solution
www.sanko-solar.nl



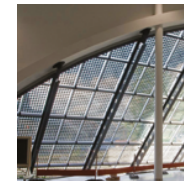
Scheuten Glas (NL)
Optisol Sky
Crystalline
152-380 W
Skylight / Solar glazing
www.scheuten.com



Metra SpA (IT)
Metra Polyedra Sky 50
Mounting system
Skylight / Solar glazing
www.metra.it



Panotron (CH)
Panotron Solar-F (ZR)
Crystalline
28 W
Solar tiles
www.gasserceramic.ch



Sapa Building System (BE)
Sapa Solar
Mounting system
Curtain wall
www.sapa-solar.com



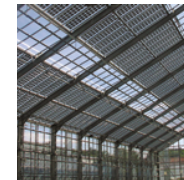
Schletter GmbH (DE)
BiPV 2-11
Mounting system
In roof mounting system
www.schletter.de



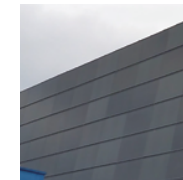
Meyer Burger (CH)
Megaslate
Crystalline
190 W
Full roof solution
www.meyerburger.com



Rebor BV (NL)
LOCI
Thin Film
80-120 W
Prefab system
www.loci-zonnepanelendak.nl



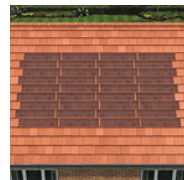
Sapa Building System (BE)
Sapa Solar
Crystalline / Thin film
Custom made
Skylight / Solar glazing
www.sapa-solar.com



SCX Solar (NL)
Solowall
Thin film
Rain-screen façade
www.scx-solar.eu



Mijn energiefabriek (NL)
In-dak Easy-in
Mounting system
In roof mounting system
www.mijnenergiefabriek.nl



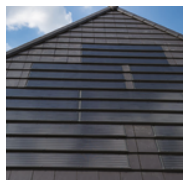
Romag Ltd (UK)
Intecto
Crystalline
N/A
Solar tiles
www.romag.co.uk



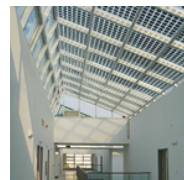
Scheuten Glas (NL)
Optisol Screen
Crystalline
186-497 W
Curtain wall
www.scheuten.com



SCX solar B.V. (NL)
Integral 2
Crystalline / Thin film
(Variable)
Prefab system
www.scx-solar.eu



Monier (NL)
Monier VI90
Crystalline
95 W
Solar tiles
www.monier.nl



Romag Ltd (UK)
PowerGlaz
Crystalline
Custom made
Skylight / Solar glazing
www.romag.co.uk



Scheuten Glas (NL)
Optisol Shade
Crystalline
93-350 W
Accessories
www.scheuten.com



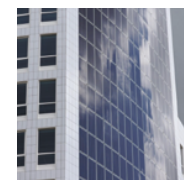
SED Trading GesmbH (AT)
Solardachstein
Crystalline
45-48 W
Solar tiles
www.solardachstein.com



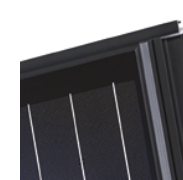
Naps Systems (FI)
Naps Solar Glazing System
Custom made
Skylight / Solar glazing
www.napssystem.com



Romag Ltd (UK)
Romag RI Roof Integrated Solar Tiles
Crystalline
120-66-45W
Solar tiles
www.romag.co.uk



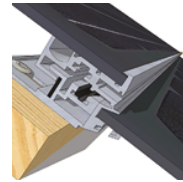
Scheuten Glas (NL)
Optisol Skin
Crystalline
72-288 W
Rain-screen façade
www.scheuten.com



Si Module GmbH (DE)
SI-Power Indach
Crystalline
260-280 W
Full roof solution
www.si-module.com



Smartroof NV (BE)
Neosolpan
Crystalline
125 W/m²
Solar tiles
www.smartroof.be



SolarMarkt GmbH (CH)
Arres Solar
Mounting system
In roof mounting system
www.solarmarkt.ch



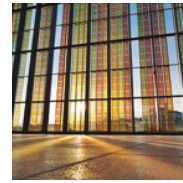
SolarWorld (DE)
Sundeck
Mounting system
In roof mounting system
www.solarworld.de



SOLTERRA SA (CH)
SOLTI
Crystalline
270-295
Full roof solution
www.solterra.ch



Smartroof NV (BE)
RenoSolPan
Crystalline
75 W/m²
Solar tiles
www.smartroof.be



Solaronix (CH)
Thin Film (DSSC)
Curtain wall
www.solaronix.com



Solaxess SA (CH)
White Solar Technology
Crystalline
90 - 130 W/m²
Rain-screen façade
www.solaxess.ch



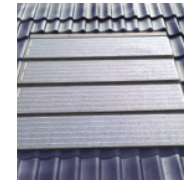
Solus engineering (BE)
Solus Zonnedakpan SE_F.B.S.
Crystalline
18 W
Solar tiles
solusengineering.com



Société d'Énergie Solaire SES (CH)
Sunstyle
Crystalline
155 W
Solar tiles
www.solairesuisse.ch



Solarstone Std (EE)
SolarStone
Crystalline
109 W
Solar tiles
www.solarstone.ee



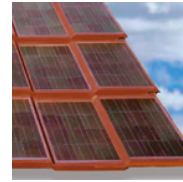
Solinso (NL)
Mystiek
Crystalline
Solar tiles
www.solinso.nl



Stafier Solar Systems (NL)
Stafier premium
Crystalline
93 W
Solar tiles
www.stafiersolar.com



Solar Retrofit (CH)
Solar Retrofit
-
Mounting system
www.solar-retrofit.ch



SOLARTEG srl (IT)
GTFV100
Crystalline
100 W
Solar tiles
www.solarteg.it



Solstis (CH)
Oryon
Crystalline
150-245 W
Full roof solution
www.solstis.ch/en/



Stafier Solar Systems (NL)
Stafier Full Roof
Mounting system
In roof mounting system
www.stafiersolar.com



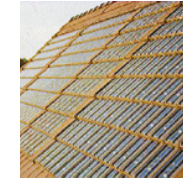
Solarcentury (UK)
C21e
Crystalline
50 W
Solar tiles
www.solarcentury.com/nl



Solarwatt (DE)
Glass-Glass Modules
Crystalline
275-305 W
Rain-screen façade
www.solarwatt.de/de/startseite



Soltech (DE)
Indachsysteme
Mounting system
In roof mounting system
www.solartechniken.de/



Star Unity (CH)
Sunny Tile
Crystalline / Thin film
6.5 W / 2 W
Solar tiles
www.starunity.ch



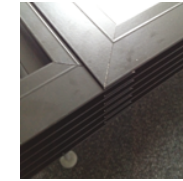
Solarcentury (UK)
Sunstation
Crystalline
270 Wp
Full roof solution
www.solarcentury.com/nl



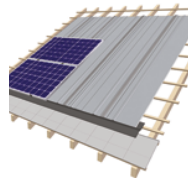
Solarwatt (DE)
EasyIn 60M Style
Crystalline
280-285 W
Full roof solution
www.solarwatt.de/de/startseite



SolteQ Group (DE)
SolteQ Quad38
Crystalline
38,5 - 40,5 W
Solar tiles
www.solteq.eu



SUNAGE (CH)
SUNAGE Capillary Comb 60/6
Crystalline
260-300 W
Full roof solution
www.sunage.ch



SUN-Integration SA (F)
Integ PV
Mounting system
In roof mounting system
www.sun-integration.com



SVH Energie (FR)
GSE In Roof System
Mounting system
In roof mounting system
www.gseintegration.com



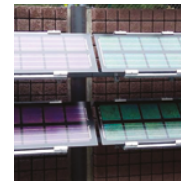
ÜserHuus AG (CH)
NexPower Terra Cotta BIPV
Thin Film
Full Roof solution
www.userhuus.ch



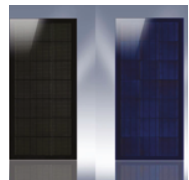
SUNOVATION GmbH (DE)
eFORM Arc
Crystalline
50-650 W
Accessories
www.sunovation.de



SwissInso Holding Inc (CH)
Kromatix
Crystalline
Rain-screen façade
www.swissinso.com



ViaSolis UAB (LT)
ViaSolis BIPV module
Crystalline
Custom made
Curtain wall
www.viasolis.eu



SUNOVATION GmbH (DE)
eFORM Color
Crystalline
Custom made
Rain-screen façade
www.sunovation.de



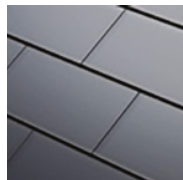
Tegolar Canadese SPA (IT)
Tegolar
Thin film
Solar Tiles
www.tegolacanadese.com



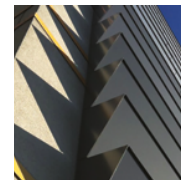
Vindo Solar (NL)
Sunstyle
Crystalline
Full Roof solution
www.vindsolar.com



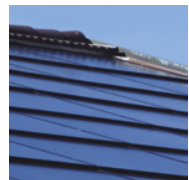
SUNOVATION GmbH (DE)
eFORM Crystal
Crystalline
Custom made
Curtain wall
www.sunovation.de



Tesla (USA)
Solar Roof
Crystalline
Solar Tiles
www.tesla.com/en_EU/solarroof



Wallvision (NL)
Zigzag solar
Crystalline
Variable 38,5 – 40,5 W
Accessories
www.zigzagsolar.nl



Sunwatt Bio Energie SA (CH)
Megatuiles
Crystalline
Solar tiles
www.sunwatt.ch



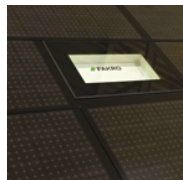
Tritec (CH)
Tri-roof
Mounting system
In roof mounting system
www.tritec-energy.com/en



Wys Aluhit AG (CH)
Aluhit
Mounting system
Rain-screen façade
www.wysaluhit.ch



SVH Energie (FR)
GSE Air' System
Mounting system
In roof mounting system
www.gseintegration.com



TULIPPS (NL)
COSMOS
Crystalline
Full Roof solution
www.tulipps.com



Zep BV (NL)
Ceramic Solar Rooftile
Crystalline
9 W
Solar tiles
www.zepbv.nl

3 BIPV Technology trends



The origin of BIPV is a pioneering experimentation conducted in architecture in 1978-82: a glazed surface of a residential unit in Munich designed by Thomas Herzog in collaboration with Fraunhofer that is still today an undiscussed reference on both PV technology and integrated design approach. Since 1990s, the trends of BIPV has increased worldwide both in terms of research and industrial projects for improving BIPV products/processes and applications in buildings. The process of photovoltaic transfer in building ranges between new and tradition. The replacement of an existing material with a new one in architecture, is usually accompanied by the permanence of old traditions looking both at architectural languages and building systems. But this slow process of innovation is also linked to new conceptual models which can be related to building morphology, architectural image, technological behavior and so on. Regarding the building envelope, for example, flexibility and lightness of thin film solar strips permit to incorporate PV in ultra-thin and multi-performance membranes. The inkjet printing "roll to roll" promises supplying flexible, thin, lightweight and eco-friendly solar devices.

Many experiments show different innovative trends in the wide field of BiPV such as Luminescent Solar Concentrators (LSC), new technologies (e.g. DSSC) or some prototypes that are opening the scenario of an hidden (colored and white PV), "invisible" PV and indoor PV.

The technological transfer of PV in the architecture field is changing 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 of the technology. But, beyond functional and construction aspects, definitely BIPV is today one of the new fundamentals for the contemporary innovation in architecture.

In this chapter we describe some main BIPV technology trends that we believe will have the chance to emerge within the next 5 years and to be transferred in the construction market for new buildings and for renovations.

Prefab mounted BIPV

The first trend we discuss is that of the prefabricated BIPV. This trend has emerged in recent years in Dutch social housing renovation programs. In these programs, poorly insulated houses are stripped and given a new building skin using well-insulated and prefabricated facade and roof elements. The use of large prefabricated elements is preferred as it allows a very fast building speed and allows people to stay inside their homes for most of the renovation period. Several product developers saw this as a chance for PV application: If a prefabricated roof is constructed for the house renovation anyway, why not immediately equip it with a PV mounting system?

A key challenge here is what level of mechanical stress a PV panel can handle, and who will be responsible for PV panel (micro)cracking during transport of the prefabricated PV elements. Due to these challenges, a first step in the prefabricated integration of PV and building element is the application of 'only' the mounting system. As an example the Emergo Energy Roof is shown in the picture above. It consists of prefabricated roof elements of 3 x 5 m, that are prefabricated covered with (ventilated) EPDM roof membrane and PV mounting profiles. After the roof elements have been installed, the PV panel mounting takes place. The difference with 'traditional' BAPV mounting might seem small, but is essential:

35



Figure 3 – Examples of prefabricated building methods used in The Netherlands for industry halls. Clockwise from the top image: residential facades, temporary offices and housing, high-rise office buildings and residential roofs.

The PV is integrated in the building process from the start; significant costs are saved by reducing the PV mounting time; Aesthetic improvement by designing the roof and PV panels as a whole. As the BIPV price study of chapter 5 will show, the associated cost savings are of the order of 0.10-0.20 €/Wp. Other suppliers in the Dutch market of prefab BIPV products besides EMERGO are SCX Solar-Unidek, ReBor-Unilin and Rebor-Rockwool.

So where do we think this trend will go? First of all, the products will continue to be developed in the direction of BIPV: Integrating PV panels as a whole instead of only the mounting system, using the PV panel itself as waterproof layer, improving aesthetics and lowering costs. Secondly, due to the impending nearly Zero Energy Buildings (nZEB) regulations in European countries all new built houses need some form of PV on their roof. We expect the market for roof integrated solutions to experience a strong surge. New concepts to further lower costs and increase building speeds are essential to accommodate this surge. So residential new built housing projects in several EU countries will want to use the prefab building method as well, further increasing the market potential.

Finally, we expect the trend to continue to other elements than roof elements. The picture below gives some impression of the various prefab elements that are being used in the construction industry. In the

distant future, all of these elements will also have a version equipped with prefab PV, to reduce costs and enhance design possibilities.

On the database are listed other prefab mounted products which are already established on the market.

In some available prefab systems the whole process of design, manufacturing and implementation is performed industrially. These products are also customizable and it is possible to select: colour, stratigraphy (e.g. insulation thickness), dimensions, ratio transparency/opacity, types of interior and exterior coating, 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. E.g. façade elements are prefabricated in the factory and the PV modules are pre-wired according to the specific wiring diagram so that the implementation of these elements is very fast and it is executed from the exterior as the modules are fixed from slab to slab without scaffolding. If we consider the complexity and the typical relevant cost of such a building skin systems, this solution is arguable most interesting as it brings a very low extra-cost due to the BIPV, in comparison to a conventional cladding so that in some cases we could really speak about a "PV for free".

Colored or Patterned Façades

The second trend we discuss are "coloured façades". The market demand for PV façades is strongly increasing, on the short term due to the fact that real estate owners have found out their building value and rental fees increase if it is a green building, better if proven by BREEAM and LEED certificates. In the time-frame 2018-2021 the nearly zero energy buildings directives will come into place, in 2018 for governmental buildings and in 2021 for all other buildings. A significant amount of solar is required on the façade to meet the demands for this legislation. So far the coloring of PV, namely its ability to be camouflaged or "designed", has been considered an essential requirement for market acceptance of PV façades. In many recent flagship projects, as shown in the next chapter, the active part of the building skin is not recognizable. In BIPV glass façade, the conventional PV material language can be camouflaged behind colored patterns that completely dissimulate the original materiality of the PV cells. However, 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 of the BIPV modules. 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. Different customization techniques can be identified in the current developments [9].

Coloring of PV panels may occur by several different methods, of which examples are shown in the figure below. The methods will be discussed one by one.



Figure 4 – Examples of different coloring methods: (top) front glass coloring by ceramic paste printing prior to glass annealing [Manz]; (center) laminated color foil with diffuse reflector [Solaxess]; (bottom) conventional colored façade panels in combination with conventional hidden solar panels in a zig-zag pattern [ZigZag Solar].

- **Coloring the cells and backsheet.**

Every solar cell contains an anti-reflection coating, normally tuned for zero reflection around 700nm, ensuring optimal light in-coupling in the cell over the 400-1100 nm wavelength range. The reflection coating can be made thicker leading to a shift in the reflection minimum to near infrared ranges, and boosting the reflection in the visible spectrum. For increasing thickness the colors blue, green, yellow, orange, and pink can be made. The main problem with this method is the difficult logistics. Cell manufacturers are not used to product diversification and are incapable of producing small batches for specific customers at acceptable price levels.

- **Coloring the front glass.**

A strong new trend is the coloring of the front glass. Five main methods exist:

- 1) Applying a ceramic paste to the glass prior to tempering of the glass. The additives bake out and the ceramic paste strongly bonds to the glass. By printing in a dot-pattern sufficient light can pass the paste and reach the cells;
- 2) Digital in glass printing: process that allows to print special ink on the glass surfaces in order to obtain a drawing. In the framework of the EU project Smart-Flex [10], a novel digital ceramic-based printing has been developed, enabling to print high definition pictures (up to 720 dpi) on the glass;
- 3) Sandblasting: technique that consists in spraying sand at high velocities on the front glass surface, creating milky white patterns and sketch. Within the EU project ConstructPV [11], different BIPV glass modules have been designed and realized with this technique, paying attention to the balance between costs, energy output and visual effects;
- 4) Satin finish and glass printing: a satin finishing on the outer glass surface is sometimes combined with the silk-printing on the inner side. Therefore, there is a reduction of the glass transparency and a resulting colored matte surface;
- 5) Applying a multi-layer reflective coating on the glass, as it happens in the so-called Kromatix™ technology. This technology was developed in the Swiss INSO start-up company in Switzerland and commercialized in the Dubai joint-venture Emirates Insolaire. The glass manufacturer has to produce the size and color in small batches per color and supply it to the module manufacturer. The coloured coating is deposited on the front surface by chemical etching and it allows to realize different colors such as grey, terracotta, blue, bluish-green, green and yellow.

- **Coloring an intermediate foil**

In the intermediate foil concept, a foil with a certain color appearance is laminated inside the module. The disadvantage of this technology is the adding of materials: the carrier foil for the color coating as well as an extra sheet of encapsulant is needed. The key advantage of using an intermediate foil is that the logistic challenge is greatly reduced. The color foil can be cut in size and shape at the module manufacturer, who does not need to order any 'specials' from his cell or glass supplier. A second advantage is that the coloring technique is potentially a lot cheaper when applied to foils than to glass plates, and strong synergy with conventional foil printing techniques from the graphical industry can be realized. Lastly, semi-transparent inks can be used that allow the infrared light to pass through. Due to these key advantages it is our expectation that in the long run the intermediate foil will reach the largest large market share. Some innovative products with scattering and reflection filters have been developed by CSEM, the Centre Suisse d'Electronique et de Microtechnique, such as the "white module" or the Kaleo-Solar, a unique technological solution for integrating high-definition images in solar panels [12].

Moreover it is also possible to design conventional façade panels in a complex design and using conventional PV panels to obtain a 'hidden' appearance, at the façade system level. In this case PV is used with a special saw-tooth pattern and in combination with other materials. The Dutch company Wallvision, as well as the Swiss company Solar Retrofit, are adopting this solution. The concept allows architects and project developers to use of conventional façade cladding materials that gives to the building a certain design, appearance or image, combining it with 'hidden' conventional PV panels. This concept is the benchmark for any PV coloring technology, and it sets and limits the added price that the market will be prepared to pay for colored PV panels.

So where does this trend go? We expect to see many users of such a technologies in the short term, supplying panels to façade projects of governmental and office buildings, but also for other public buildings and residential multi-family housing. When the price pressure increases, cheaper intermediate foil-based concepts will start to enter the market and will slowly drive the added costs for colored PV down from 60 €/m² to a value below 20 €/m² which is typical for a specialty foil in other industries.

Solar glazing

A second trend that is linked to the market for PV façades is so-called "solar glazing". In itself, the technology for semi-transparent PV panels is not new at all. There has not been yet a breakthrough in technology that suddenly led to a price drop.

However, the combination of glass and photovoltaics, despite their different appearance and materiality, 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. Moreover, both in architecture and research perspective, there are many products, flagship buildings, research projects and some arising innovation trends that represent drivers for a successful transfer of BIPV glass into the factual built environment. Since a lot of requirements are needed for a high-quality architectural project which is also compliant with challenging energy levels, these "innovation trends" can be interpreted as the "meeting points" between different fields: architecture, construction products, glass façades and energy [13]. It is also remarkable that such a systems often includes a significant qualification level for the building sector (e.g. safety glass, EU marking for construction regulation, fire safety, etc.) since they are directly derived from already well-established building skin systems (e.g. curtain walls) used with conventional glasses.

Another key aspect that drives this development is the need for energy neutral office buildings. Windows occupy the largest area fraction of modern office buildings by far. Entrance of daylight is crucial in maintaining high productivity among employees and this is not something companies will be willing to give up in exchange for more solar on their façade. The nZEB/BENG (nearly Zero Energy Building / Dutch National Plan Nearly Zero-Energy Buildings) requirements for governmental buildings in 2018 and office buildings in 2021 will lead to a stronger demand for these products in the years to come.

Likewise with colored PV, there are several key technological methods by which solar glazing can be manufactured. The various options are shown in the figure below.

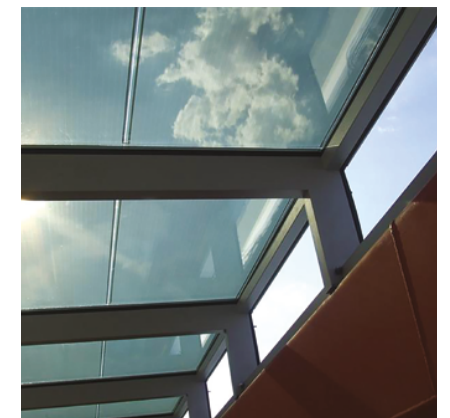


Figure 5 – Various technological routes to manufacture solar glazing: (top) Crystalline silicon glass-glass modules [Schott]; (center) Crystalline silicon cell strips [Solaria]; (bottom) thin film solar cell strips [Onyx].

The various technological routes will be discussed one by one.

- **Crystalline silicon glass-glass modules**

Advantages of this conventional technology is that there are many suppliers. These products have now an higher efficiency and lower production costs compared to the past. The square block pattern is not something that architects or end-users always like. However, this concept could still obtain a position in the low end market segment. It also finds its way in application of elevated roofs such as railway stations. Manufacturers include Scheuten, Kameleon, Romag, Soltech, Issol, Sunovation, Onyx, Ertex, Gaia and Viasolis.

- **Crystalline silicon cell strips**

Solaria in collaboration with Pilkington/NSG has started a new development to improve the aesthetics of the crystalline silicon glass-glass panel. The solar cell is cut in small strips making the square cell pattern much less apparent. The current phase of this development is that market entry has started and up-scaling is underway. The price development of this technology is still a question mark.

- **Thin film solar cell strips**

Thin film solar PV can be elegantly turned into semi-transparent solar glazing by laser scribing part of the absorber away. This process was already adopted by Schott Solar more than ten years ago. It gained recent interest again due to sharply dropped costs of laser processing, increased demand for solar glazing and stronger diversification of thin film PV manufacturers as a result of the sharp competition on price with crystalline silicon technology. Typically, 20-40% of the absorber is blasted away, leading to a consequent drop in output power. Suppliers include Sanko Solar, Onyx Solar, Advanced Solar Power, Manz and Antec Solar.

- **Thin film solar strips hidden by a lens system**

In an attempt to further enhance the aesthetics of the thin film PV strips, Sunpartner Technologies has developed a special foil with linear lenses that blend the cell strips making them nigh to invisible when looked from certain angles. Sunpartner recently signed a joint development agreement with Avancis, to up-scale their technology to full size thin film PV panels. It remains a question in which markets end users are willing to pay the additional associated costs with this technology for the improvement of aesthetics. It is clear that Sunpartner develops a high end product for a high end market.

- **Luminescent solar concentrators**

Luminescent solar concentrators were developed in the 80s as a new concept to reduce costs. Several universities and institutes kept working on LSCs even though the industrialization never happened. Recently, the strong price drop of crystalline silicon cells forced the researchers to focus on new applications such as solar glazing. In LSCs, a luminescent material is embedded in the glazing that absorbs and re-emits a certain fraction of the light in a random direction. Cells embedded in the window frame collect the fraction of light that is re-emitted in the right direction. Peer+ and Physee are two Dutch startups that try to develop the LSC concept into an affordable window pane. Peer+ was recently bought by Merck and continues their development in Merck Labs. Physee recently realized their first demonstrator in the Rabobank building of Eindhoven, The Netherlands. In 2016 the university of Milano-Bicocca set up a spin-off called Glass to Power with the objective to industrialize an innovative product based on the LSC technology.

- **Thin absorber layers**

A last method to realize semi-transparency is to use thin absorber layers that do not fully absorb all of the light, but still have a certain transparency. The problem with this approach is that the absorption is highly spectrally sensitive. Typically, blue and green light is immediately absorbed in the absorber layer whilst only deep red and infrared light manages to pass through. Polysolar and Brite Solar are companies actively promoting the use of this kind of semitransparent panels in applications where the red color is no big disadvantage. Another option is the use of Dye Sensitized Solar Cell (DSSC), in which a specific Dye is chosen that only absorbs a limited section of the light spectrum. Companies glass2energy and Solaronix are determined to bring this technology to the market.

So where does this trend go? No clear technology winner is visible yet even though a very high potential is expected since this is one of the most diffused system for the building skin where PV implementation is relatively easy and affordable due to an extra-cost that is not very relevant if compared with the total cost of investment of a conventional façade. Moreover several new developments on improved aesthetics are on their way to further push BIPV but no strong cost price decrease is foreseen. There will definitely be more commercial projects with solar glazing in the next 5 years. Due to further upscaling of production equipment (for example the laser scribing equipment) the costs should incrementally decrease also for special treated glasses and the market subsequently increase.

Lightweight systems

The topic of flexible, light-weight PV is in itself not very new. In the 2000-2010 timeframe the US based producer UNI-SOLAR manufactured and sold many flexible photovoltaic modules that ended up in integrated products such as metal roofs (RheinZink, Corus "Kalzip") or polymer roof membranes (Alwitra, Solar integrated technologies). After the bankruptcy of UNI-SOLAR in 2012 the 'dark ages' of flexible PV started in which it was very difficult to find a good replacement product for UNI-SOLAR. There are some signs that these dark ages of flexible PV might soon be over. In this section we give a short overview of lightweight modules and systems on the market today.

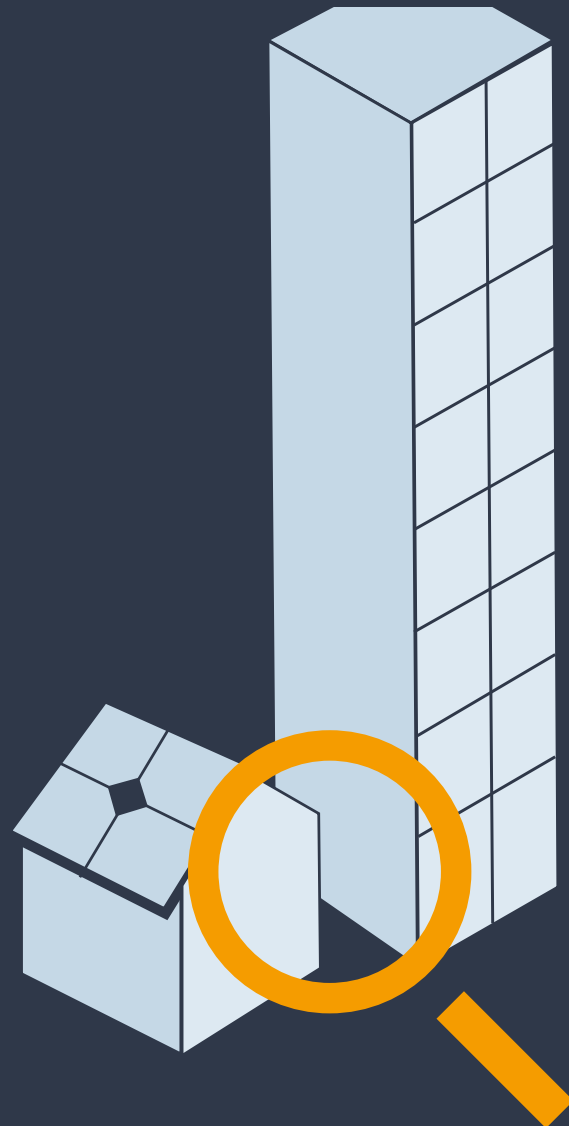


Figure 6 – Various examples of light-weight, flexible PV modules from various manufacturers, from left to right: MiaSolé, HyET Solar, DAS energy, Kameleon Solar.

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 boats, tents, geomembranes, corrugated sheets and the like. Crystalline silicon flexible light-weight panels are cheaper and higher efficient than their thin film counterparts, but less flexible and less good looking. They would therefore be a good choice for 'invisible' applications with a permanent fixture, such as flat roofs.

So where does the trend go from here? Flexible light-weight panels from the new entrants are still expensive (~1 €/Wp) and have a high risk perception. Reliability for the building skin and integration with building technological units (e.g. compatibility with mounting systems for roof/façade) is still under investigation in lightweight/flexible products. It is important to get a few 'Lighthouse' projects where large areas are covered and where performance is carefully monitored and published. This way the risk perception can significantly lowered and more roofers and façade builders will dare to use the products. We have to critically follow the speed of this trend and give a new update in a future edition of the BIPV status report. However some promising researches are emerging in this field on the development of robust and reliable ultra-lightweight solutions (e.g. using a composite sandwich as a backsheet) [14].

4 BIPV Project Case-Stories



In the growing field of “sustainable architecture”, solar energy represents one of the main challenges that is progressively changing the building concept.

The use of a material in architecture, in the course of building history, has always been enriched with something other than simple technological innovation, including a symbolic spirit, expressing its own linguistic value, the change and the design power. In the common imaginary, for example, glass is the material that can express a sense of constructive and perceptual lightness, whose peculiarities result in the physical dematerialization of the architectural object and in obtaining a perceptual and psychological transparency.

When people hear about photovoltaics, however, the image that is invoked in their mind is a blue or black element that usually seems to “overload” the aesthetical image of a building. Even though a PV element has the basic role to produce renewable energy, this is not the main aspect concerning the “innovation in architecture”. However, as described before, both in the architecture and research perspective, there are many products, flagship buildings, research projects and some arising innovation trends that represent drivers for a successful transfer of BIPV into the factual built environment.

International researches have already shown plenty of interesting examples of nice looking, conceptual, typological, constructive and aesthetical integration of PV in contemporary architecture as well as in existing built heritage (www.bipv.ch; task41.iea-shc.org). Undoubtedly PV is progressively becoming one of the “tools” of contemporary architecture, similarly to any other building material (such as wood, stone, brick, glass, etc.) or component (window, cladding, etc.). More than 120 example projects are collected in the database of the SUPSI website. Moreover further Swiss examples currently under investigation regards the Swiss Solar Awards and other recent best-cases at federal level (Flagship projects). Some of these examples are also presented in the framework of the Task 15 of International Energy Agency.

In the following chapter we will describe three Swiss and three Dutch BIPV projects. The goal of these examples is to show through some realized projects a selection of the possible architectural and expressive potentials of PV, both at component and building level. It should be used as reference point by architects, engineers, and developers as an input of an attitude in using solar as a building material that, of course, need to be case by case adapted and re-interpreted in each context and in the today complexity of architecture.

KohleSilo Basel (CH)

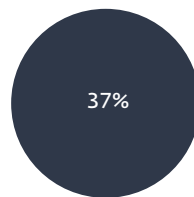


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Key-facts



Innovative BIPV modules for a building refurbishment in a sensitive area



BIPV covers around 37% of the total energy demand



R&D project to optimize the self-consumption using a 2nd life battery energy storage system

Project overview

Location	Dornacherstrasse 192, 4053 Basel
Completion year	2015
Architect	Baubüro In Situ AG
Typology	Administrative
Category	Refurbishment
Surrounding	Urban
Installed pv power	23 kWp
Orientation	North, South
Dimension	159m ²

Why BIPV?

The Solar Silo is the result of the refurbishment of an old coal silo tower, where coal was stored to produce heat for an ex-industrial field "Gundeldinger Field", established in 1844. In the last 15 years, the foundation Kantensprung AG has bought the industrial area to return this site to the local population. The main criteria for site transformation are: neighborhood, ecology and integration. Therefore, this transformation has been carried out adopting a holistic sustainable approach: re-use of existing material, rainwater collection, green roofs, photovoltaic systems and space reconversion for social/work/commercial activities.

With regard to the photovoltaics, it has been integrated into the building envelope to provide a visible sign of the shift from the use of fossil fuels for an old manufacturing site to the use of renewable energies for a new cultural and commercial site. Moreover, BIPV gives an important contribution in order to pursue the objectives of the 2000 Watt Society, that involves also this area in the city of Basel.

The architectural language

BIPV modules have been installed as cladding elements of the ventilated roof and ventilated façades – both southern and northern. This would highlight the fact that the BIPV facing north can produce an amount of electricity but it is also part of the building skin as a traditional constructive product, forming a homogeneous architectural language.

The aesthetical appearance of the BIPV façades and the BIPV roof arises from the use of innovative coloured PV modules that have been combined with attention to the geometrical aspects and existing constraints of the roof and the façades. The modules technology is characterised by a colour coating on the outer surface of the module's glass that makes the modules a matte panels and the PV cells are hardly recognisable.

Besides the technological specific features of the modules, the roof modules have standard dimensions and they have been used as mosaic tiles whereas the façade modules have been customised for keeping the modularity of the existing surface with the less number of custom-sized panels.

The energy concept

Considering the sensitive context, the BIPV modules are designed in order to respect the general aspect and the morphology of the pre-existing area, improving at the same time the sustainability and the energy efficiency of the whole area. Therefore, the BIPV modules are installed to produce electrical energy to be used directly for reducing the electricity demand from the grid.

As an R&D project, each BIPV module is monitored and the whole PV system is combined with a 2nd life battery energy storage system for studying how to better optimise the self-consumption of electricity in the area.

Acknowledgements

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Service intercommunal de l'électricité Crissier (CH)



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Key-facts



Competition for an extension of the existing building with sustainable energy criteria



Use of prefabricated BIPV façade elements

The SIE SA, the Intercommunal Electricity Service of four [15] municipalities in the West of Lausanne, wanted to move all its services in its operative center in Crissier, abandoning maladjusted administrative buildings located in the center of Renens.

The building of the operative center in Crissier had some few administrative office and a storage hall and it needed extension and renovation. Therefore, the owner decided to carry out the project in the form of a competition with some "constrains":

- The elaboration of a project to give the idea of an open approach to new and sustainable technologies;

Project overview

Location	Chemin de la Gottrause 11, 1023 Crissier
Completion year	2011
Architect	Batineg AG
Typology	Administrative
Category	Refurbishment
Surrounding	Urban
Installed pv power	-- kWp
Orientation	South East and South West
Dimension	380m ²

This choice has ensured the integration of photovoltaic panels in the building envelope and it has led to realize a BIPV façade of about 380 m², capable to produce an amount of about 30'000 kWh yearly. In detail, the PV modules that have been used for the prefabricated façade elements are thin film modules (upper layer of amorphous silicon and another microcrystalline lower layer) that have 20 years of warranty and they are already electrically wired in order to be installed easily. What it is interesting to note is that the non-active façade surfaces – about 420 m² – are not easily recognizable from the BIPV surfaces. Hence, the building façades take on their homogeneous and dark aspect without any interruption or use of evident dummy elements.

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- the achievement of a Minergie standard;
- the connection to the CRICAD district heating plant, which generates heat by burning wood waste and electricity by ORC turbine.

Moreover, the competitors had to present innovative energy and energy management concepts for the building extension and renovation.

Batineg SA – who won the competition in 2010 – presented an original project compliant with all these requests and fast to be realized.

As a result, the renovated building has a further storey and it has been enlarged in the rear part. The additional building envelope surfaces have been renovated: the roof has been transformed into a green roof and the façades have been entirely "dressed" with prefabricated insulated elements to improve the thermal characteristics of the structures and contribute at aiming the Minergie standard.

The façades have been designed according to the Face-Active® concept, which advantage is represented by the possibility to install glazed windows, opaque panels or pre-wired PV modules as cladding materials on the prefabricated wooden frame façade elements in the factory. Moreover, the prefabricated panels are insulated with rock wool and have an internal lining ready for the on-site application.

Renovation of a residential building Zurich (CH)



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Key-facts



BFE Lighthouse Project



Use of mimetic BIPV glass



Holistic sustainable renovation concepts

Project overview

Location	Hofwiesenstrasse 22, 8057 Zürich
Completion year	2016
Architect	Viridén + Partner AG
Typology	Residential
Category	Refurbishment
Surrounding	Urban
Installed pv power	Abt. 180 kWp
Orientation	All
Dimension	1'535 m ² (façade) + 165 m ² (roof)

Zürich Lighthouse project

Since the sustainable renewal of the building sector [16] represents one of the major challenges for Switzerland, the Swiss Confederation and the canton of Zurich, together with a consortium of private and public investors and companies, have developed a multi-year pilot project to show a possible strategy for the renovation of existing building and the maximization of the consumption of the photovoltaic production. Such a strategy considers both the energy concepts, as well as the importance of the urban context for the aesthetical integration of PV systems.

Energy-active glass skin

With regard to the use of BIPV, there were several requirements to take into account in the façade design. For instance, the use of anti-reflective modules to be placed as cladding on the rear-ventilated façades, the uniform appearance of all the building surfaces, the invisibility of the fittings, simplicity in the façade construction, solutions with standard details, etc. It is important to note that not only the aesthetics was a high priority, but also a "good" performance was requested.

As a result, a camouflaged photovoltaic façade has been developed. Indeed, the cladding façade panels are glass-glass monocrystalline photovoltaic modules, where the outer glass layer is satined with a matte grey-green colour. This hiding technique involves an energy performance of the coloured modules of about 60% in comparison with an uncovered version. Moreover, the use of 18 different formats for the frameless modules and the installation by means of back rails

(SSG-bonding on glass module) allow the homogeneous aspect of the façades and an easy access to each PV module that can be interchangeable and individually fixed.

This achievement would therefore represents a photovoltaic system that can be imitated for other façades in urban context, since also other colours can be chosen for the modules in order to best fit the settlement environment.

Positive Energy Balance

The successful integration of the BIPV modules is combined also with a the refurbishment of the whole building that reduces the heating energy requirement up to the 88%, allowing the building to be classified as Minergie-P despite an increase of apartments (from 20 apartments and 2 office units to 28 apartments and 2 office units) and an increase in area needing heating. Moreover, the BIPV façade and roof generate produce so much energy that contribute in reaching a positive annual energy balance for room climate, lighting and other applications and only a small amount of the electricity represents a surplus. However, as a pilot-project a measurement campaign is envisioned: without electricity storage systems in 2017 and with a storage system in 2018.

Acknowledgements

The project is supported by the Swiss Federal Office of Energy (SFOE) and the Canton of Zurich (AWEL), while the consortium is composed by several participants: the private building owner, EcoRenova AG (owner façade), Viridén + Partner AG (architect and project management), Diethelm Fassadenbau AG (façade planning), the electricity network of the city of Zurich (ewz), E4plus AG, Gasser Fassadentechnik AG (façade sub-structures) and Zurfluh Lottenbach GmbH.

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Administrative building “The Edge” Amsterdam (NL)



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Key-facts



Customized BIPV modules for a high end office building



(BI)PV covers the total energy demand

Why BIPV?

In 2010, the architect (PLP architects), project developer (OVG) and renters (Deloitte and AKD) together started the preliminary design of the building. In collaboration with the municipality of Amsterdam it was decided to use BREEAM-NL as sustainability methodology. Innovative practices and smart solutions in the design made the team win more and more credits. This resulted in receiving the Outstanding BREEAM design certificate and being the most sustainable office building in the world.

Project overview

Location	Gustav Mahlerlaan 2930-2970, 1081 Amsterdam
Completion Year	2014
Architect	PLP Architects
Typology	Office building
Category	New building
Surrounding	Urban
Installed pv power	
Façade	100 kWp
Rooftop	190 kWp
Rooftop nearby buildings	640 kWp
Orientation	
Façade	South
Dimension	
Façade	720m ²
Rooftop	1200m ²
Rooftop nearby buildings	4100m ²

solar panels exist of 62 different sizes in order to optimally fit to the design of the building. Even though these specials were a relatively expensive operation, the panels were deliberately custom sized to make them part of the total architectural concept. More to the North (both westward and eastward) the transparency of the façade increases to a 100% transparent façade in the North.

The energy concept

In the Building, photovoltaic panels have been applied at three levels: at the façade, at the rooftop and at the rooftop of two buildings in the near vicinity (within 10 km). The total installed capacity is enough to fulfil the total electrical demand of the building. The electrical energy that is generated by the Solar cells on the rooftop is directly used for the installation of the heat and cold storage. The remaining generated electricity is mainly used for the low-energy LEDs, all laptops and smartphones in the building and all electric powered vehicles, used by employees. The current energy consumption is now estimated to be -0.3 kWh/m²/yr.

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The building is entirely energy-neutral. To achieve this, the entire southern façade is equipped with photovoltaics. In addition the rooftop was filled with photovoltaics, such as the rooftops of two buildings in the close vicinity. Furthermore thermal energy is generated by a heat cold storage. To save energy, a smart LED lighting system was installed that offers users of the building the possibility to change climate and light at their individual working spot.

Next to saving energy attention was paid to the environment by collecting and reusing rainwater, certifying the materials and products used in the building to secure that parties organize their business with regard to man and the environment and an ecological corridor for bats and breeding birds was realized.

The architectural language

The Edge is orientated and shaped in such a way that the power of the sun is optimally utilised. This led to a design solution for the south façade where was sought for the optimization of daylighting while minimizing heat entry that influences the temperature inside. This resulted in a south façade that is transparent for 50 percent. At the closed parts, solar panels were installed as cladding elements of the ventilated façade. The 450

It remains a tricky matter to map (financial) costs and benefits of 'sustainability'. A significant amount of money was needed to realize the most sustainable office in the world. However, a number of measures (and thus costs) will be recouped within 10 years. Whether the buyer of The Edge would have paid less when the building was less sustainable remains unknown. However banks are merely willing to finance a project when it has a sustainable character, and municipalities impose minimum sustainability ambitions, users/tenants draw more and more requirement with respect to durability and job-applications have been proven to drastically increase for the companies housing 'the most sustainable office'. This all is promising for the sustainable development of buildings and the application of BIPV.

Acknowledgements

Authors thank Nena Rood (OVG real estate) for her willingness to be interviewed. OVG real estate (2014) Case study The Edge. Retrieved at February 2nd, 2017 from <https://www.breeam.nl/projecten/edge-amsterdam-0>. OVG real estate (n.d) Combination of technology and sustainability. Retrieved at February 2nd from <http://ovgrealestate.com/project-development/the-edge>

Energy neutral residential buildings

Best (NL)

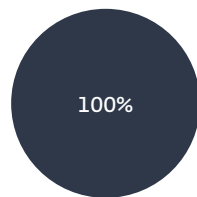


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Key-facts



Social housing of 48 apartments in two buildings



Zero energy building, PV covers 100% of the total energy demand



BIPV on all façades, east-west-south-north.

Project overview

Location	Willem de Zwijgerweg, Best, The Netherlands
Completion year	2017
Architect	NBA
Typology	Social housing apartment building
Category	Demolish & re-build
Surrounding	Urban
Installed pv power	250 kWp
Orientation	North, South, East, West
Dimension	2500 m ²

Why BIPV?

The most important objective for social housing corporations is to realize affordable housing for low-income tenants. Historically, their efforts are mainly focused on 'low rent' housing. In recent years the focus has started to shift towards 'low cost of living' housing, including the energy bill. By building zero-energy apartments the housing corporation ensures long lasting real estate with low cost of living for their tenants. The business model behind the zero energy apartment building is complex and involved various subsidies, incentives and legal frameworks. Part of the investment could not yet be earned back by the housing corporation. This is seen as investing in the future, in learning how to build zero energy buildings, as communication money and as contribution to the society.

The architectural language

The name of the buildings are the 'Willem' and the 'Zwijger'. William of Orange, also known as "Willem de Zwijger" (William the Silent), was one of the founding fathers of the Netherlands. Years of silent diplomacy brought together the northern provinces of The Netherlands, and led to a revolution against the Spanish usurpers. This brought great prosperity to the residents of what would later be called The Netherlands.

A parallel to the buildings the 'Willem' and the 'Zwijger' exists. As landmark the buildings will be silent witnesses of an energy revolution in the years to come. They will see more and more buildings rebel against the fossil fuel economy, and become energy independent. The energy neutral buildings will bring a new period of great prosperity to the residents.

The total of 48 apartments are a mix of single and double rent apartments intended for people who are eligible for rent subsidies. With the realization of these apartments it's made possible for tenants to live in affordable housing in a sustainable way. Thus it meets the demand for small, affordable accommodation in Best.

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The energy concept

The partners 'thuis, NBArchitecten, EigenEnergie.net and BAM Woningbouw realized the first Zero Energy 5-storey building in the Netherlands. Zero Energy truly means zero energy here. The residents have no energy bill. The building is equipped with water-water heat pumps and a heat recovery system. This installation is able to provide the hot water needed throughout the year and space heating needed in winter. The electrical energy is generated with matte all-black, thin film PV panels. To provide all households with the electricity for lighting, appliances and the heat pumps, just solar panels on the roof is not enough. The special feature of this project is that the façades are covered with solar panels.

Placing PV panels on south façades already was common practice. In this building the choice was made to place the panels also on east and west façades. The advantage of the east and west placement is that the panels peak their electricity production exactly in the early mornings when the residents get up and late afternoons when they return from their work. The panels are nicely integrated in the building design with some color accents near the balconies.

Acknowledgements

Authors thank Harold van der Ven (NBArchitecten) and Henrico van den Boomen (EigenEnergie.net) for their help in writing this section and supply of data and photos.

Energy neutral terraced houses Eindhoven (NL)



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Key-facts



Social housing of 14 residential terraced houses



Zero energy buildings, PV covers 100% of the total energy demand



Full roof BIPV system, PV covers entire roof

Project overview

Location	Karel de Grotelaan, Eindhoven, The Netherlands
Completion year	2015
Architect	Van Helmond-Zuidam
Typology	Social housing terraced homes
Category	Demolish & re-build
Surrounding	Urban
Installed pv power	70 kWp
Orientation	South
Dimension	500 m ²

Why BIPV?

The social housing corporation Woonbedrijf in Eindhoven had the ambition to convert the Eindhoven Airey neighborhood into the most sustainable neighborhood of Eindhoven. The first step in this process is the project at the Karel de Grotelaan. A row of 14 houses was demolished and fully rebuilt. A PV system on the row of houses plays an essential part in the plan to make them sustainable. Rather than installing conventional roof tiles and a PV system on top, the choice was made for Building Integrated PV. On the longer term, this allows for saving costs due to omitting of the roof tiles. On the shorter term, the BIPV roof improves the aesthetic appearance of the houses, with clear impact on the value of the real estate and on the social safety and general liveability of the neighborhood.

The architectural language

The houses are situated in the Airey neighborhood. Airey was a British concept of mass manufactured houses used in many cities in the rebuilding period after the 2nd world war. Now Europe is seeing a similar challenge. This time the energy concept of the houses needs to be rebuilt. The general consensus was to maintain as much as possible the general idea and appearance of the neighborhood, to keep reminding ourselves of this period of rebuilding after the war. The row of houses were designed in close cooperation with social housing corporation Woonbedrijf, contractor Heijmans, aesthetic energy roof supplier Aerspire. But also the 'green tenants' were selected as early as possible and involved in the design phase. How can they be

encouraged to live sustainably together? The tenants actively think about all sorts of topics, including the demolition and new construction in the district Airey. In September 2015, the roof was elected the 'most beautiful PV project in The Netherlands' in an on-line election campaign by the website Ensoc.nl.

The energy concept

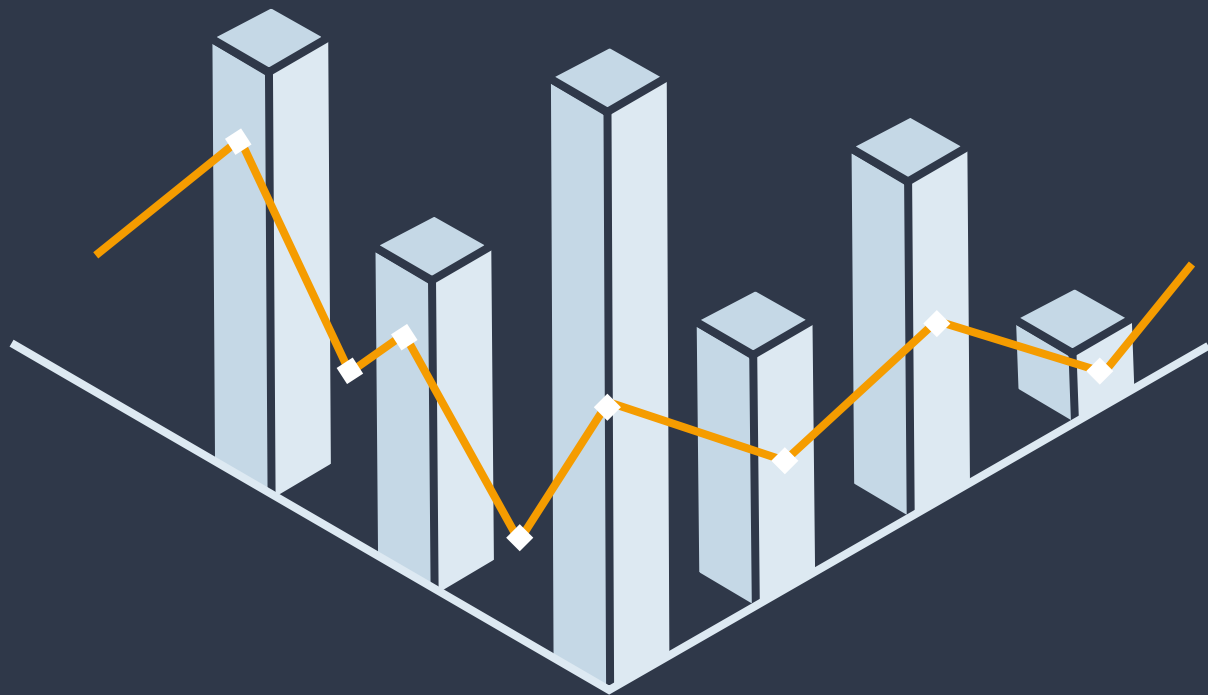
The AER (Aesthetic Energy Roof) concept is developed by the Dutch start-up company AERSpire. It provides a complete roof solution, and replaces the function of the roof tile. The AER roof is constructed entirely of glass plate products. Cost savings are reached by omitting the frames, junction boxes, and back sheets that are normally used in PV modules, and instead rely fully on a glass-glass watertight interlocking of the PV panels. Furthermore, an innovation in this product is the clever ventilation to the back side of the panels. This keeps the solar panels cool and allows them to have a high yield of 900-1000 kWh/kWp/a, which is even higher than the Dutch average for conventional on-roof mounted PV systems.

Acknowledgements

The authors thank Esther Philipse and Alfred van Hese from AERSpire BV for the information and photos.

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5 BIPV Price Survey



The economic sustainability of BIPV technology is a crucial aspect of its feasibility and market success. So far the main efforts towards cost-effectiveness have been focused, similarly to conventional PV, on minimizing the final installation price per kWp that usually is the price of the installed and functioning system, including design, materials, mounting, tests and labor (building and electrical). Nevertheless, in recent years the real experience of installed PV plants has shown the growing relevance of other "cost items" which are not always properly considered from the initial stages of design and business plan and typically include the quality of modules in terms of reliability, the correctness of installation procedures (electrical and mechanical degradation, damages, etc., affecting energy production), adequate maintenance and energy management/ optimization during the operating lifetime.

When using PV, the economic analysis and the affordability assessment is generally focused on the energy payback time and in the return of investment. The actors involved in the decision making process tend thus to simplify the reference price levels not taking into account all the added value of an integrated application. Contrary to standard costs of conventional PV installations, the value (meaning the relative worth in consideration of the perceived quality) of a BiPV installation is objectively characterized by added values, which other building components do not have, such as multifunctionality and production of renewable energy. Including this extra value in a cost analysis is quite difficult as it is related to the specific case and also to qualitative aspects such as aesthetics, long term sustainability, etc. Mostly, since integrated PV is not an isolated device but rather an integral part of a building-envelope solution (e.g. roof and façade), every evaluation (including the economic) should refer to the entire building skin in order to enlarge the perspective, from a balance which merely refers at the return of investment (ROI) of PV as happens in the state-of-art, to the broader energy/technological quality of the building envelope affecting the cost-effectiveness.

The cost of a BiPV installation is not so straightforward to assess. The BIPV cost is strongly affected by variable factors such as the part of building skin under consideration, the construction site installation needed to carrying out the work, characteristics of the local market, legal and contextual conditions, design, etc. that cannot be easily generalized. Especially when the BiPV is carried out simultaneously with other building interventions (e.g. energy retrofit of a façade), it is possible to maximize the economic feasibility of the installation by reducing the extra-costs caused by safety and practical requirements (scaffolding or safety railings, lifting by crane or mobile crane, etc.) and administrative procedures over the entire building and not just on the PV system.

As premised, it emerges that a BIPV system, as part of the building envelope, satisfies a wide range of requirements so that its value, and its price, should be referred to the whole system rather than a single component. Moreover since any site, location or place includes a number of features that characterize it and create the context of the architectural design and design process, it is not easy to generalize the final reference costs for BIPV since it includes several variable factors.

In a ground-mounted or in an 'on-roof' plant (BAPV), PV is conceived as a technical device and its components (modules, structures, etc.) are standardized elements with conventional costs which can easily be established through a price list of PV panels and supporting structures. In a BIPV system, however, PV is a part of a complex building skin solution whose functions and requirements range from energy to aesthetic, constructive and technological, including safety, health and well-being, energy efficiency, and sustainability. Even in cases when a building skin technical solution is established (e.g. a rain-screen façade or a stick-system curtain wall) it is not easy to generalize a reference cost estimation of the product in €/m² (nor to compare them with other conventional PV systems), since the performance can be quite different (e.g. fire or static safety required depending on the context) and final costs depend on some further aspects (e.g. the size of a panel or the modularity of the façade can strongly influence the final price since it would require special parts and higher costs of production/installation).

Again, from an energy perspective, a BIPV envelope as a whole is always part of a more complex system which combines the passive behavior of the building skin (e.g. thermal insulation) with an active capacity, producing both costs and benefits in financial terms that should be considered together.

For the reasons previously described, ideally, the economic analysis of BIPV should be based on the following considerations:

- Multi-functionality. BIPV is considered as a building material which replaces a conventional layer of the building skin and performs its functions (weather protection, mechanical resistance, thermal protection, etc.), thus potentially providing a cost saving as compared with the cost of the replaced building cladding.
- Unitary concept of BIPV and building envelope. The economic assessment is conducted considering the BIPV system together with the whole building skin, as a unique element. For example this is the case of a photovoltaic façade where the PV modules are part of a unitized construction system.
- Energy target of the building envelope. The cost-effectiveness of PV should be assessed considering the energy efficiency of the entire building, since PV synergistically adds to the whole energy balance of the built organism. Because of that PV is better enhanced in those buildings where the energy consumption is optimized through a comprehensive energy concept, a performant building envelope and efficient technical installations.
- Life-cycle costing. The balance of costs and benefits is extended to the entire life cycle of both PV and the building envelope.
- Local-based or case-specific cost approach. In the building sector it is difficult to generalize the final costs of the building skin systems due to several contextual and specific factors. Price levels thus are often affected by uncertainties and the real cost-effectiveness should be assessed in each specific case or, at least on representative building skin categories, rather than at a general component level as happen in PV field.

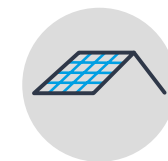
A complete life-cycle costs analysis could, however, be performed solely at the building level, meaning that it can only be applied to a specific project of which are known characteristics and peculiarities. The cost of a BIPV component thus, despite is clearly a central part in the definition of the economic feasibility and cost effectiveness, should be included in a more extensive evaluation. Moreover, during the early design phase, a multi-criteria approach could better reveal the added value and cost-effectiveness of BIPV[17].

In the following chapter are presented the price levels of some BiPV product/system categories currently available on the market; the manufacturers provided the cost of only the BiPV system (supply and deliver) or the final cost (including planning, supply, delivering, installation and electrical system).

Results of the on-line survey 2017

A market survey was conducted through an on-line web form that was sent to producers, suppliers as well as installers of BIPV products. Instead of conducting the survey by accessing the technical data through the producers' websites, it was preferred to actively involve the producers to the data collection procedure. This enables to work with reliable and complete data. The market survey was conducted mainly for the Dutch/Benelux and Swiss markets. Firstly it was requested the cost of the product itself and separately it was also asked to provide the material and labor cost for a turnkey installation (if available) in order to assess the final overall price and to separately take into account the variable costs (installation, local market conditions, etc.).

The survey was sent out to about 120 contacts from which we collected 35 respondents. Roof solutions collected more feedback than façade products probably because these kind of systems have been on the market for a while and they are characterized by a lower cost level due to the simpler implementation similar to standard roofing tiling. If BIPV roof solutions are seeking to be as similar as possible to standard roofing applications, façade products are instead focusing more on aesthetics as well as on building engineering solutions (rain-screen façade, curtain wall), so that in most cases the price levels are still uncertain and less definable or, as mentioned before, cannot be really generalized.



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.

The number of respondents per product group are stated in Table 1. To note that the cost information collected for BIPV Façade products is limited and doesn't allow a generalization of the collected data.

On the other hand in-roof systems 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 a specialized and customized niche products for which it is difficult to find participants in a price survey.

Only a very limited part of the interviewed manufacturers and/or retailers have provided cost information of their products. There can be various reasons for this, that we consider not related to the method of investigation since the proposed online web form allows to easily reach multiple users and "depersonalizes" the request of information. Nevertheless, in the case of a market survey focusing on costs, we realized that there is a certain reticence and maybe a sense of hazard in providing cost data which will be used in a generic context since many variable factors affects the final costs of a real case, as discussed before.

Regarding the BIPV façade systems, only 7 parties participated in the 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 because of that there is a large cost variety depending on the building type, building skin application and on the specific context of intervention. A frequently used argument is the demanded discretion by the customer/owner regarding the project costs. This may be explained considering that very often BIPV façades have been experimented in pilot-demonstrative projects and their cost was specifically linked to the context and influenced by building size, technology adopted, owners policy and special supporting measures (e.g. funding for Pilot and Demonstration Project in Switzerland). Thus the absence of a well-established market influenced this phase of research.

Moreover the goal to obtain clearly comparable prices based on the information emerged from the survey, especially of turn-key installations, has been difficult since it is not always clear for some parts of the building envelope (e.g. fastening system, waterproof layer) which components should be considered as a part of the BIPV final cost.

The only cost that is verifiable and comparable, taking into account the specific regional market conditions, is the supply and delivery of the material. The costs caused by the installation are again influenced by different aspects in each project and which are also determined by regional factors such as the location, specific

regulations, expenses due to administrative procedures or design requirements (e.g. safety, labor cost, special installation requirements, etc.), etc. The installation phase of the BIPV system thus is another additional cost that is difficult to generalized, since not only it is highly dependent on the type of installation, but also on the project characteristics (size, complexity, height, site/urban context, etc.) of the regional building market.

Following these premises, 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 €/m², 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 €/m² it is possible to directly compare various PV technologies to conventional building materials.

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 in special points, 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.

Cost (€/m² of available building skin area)

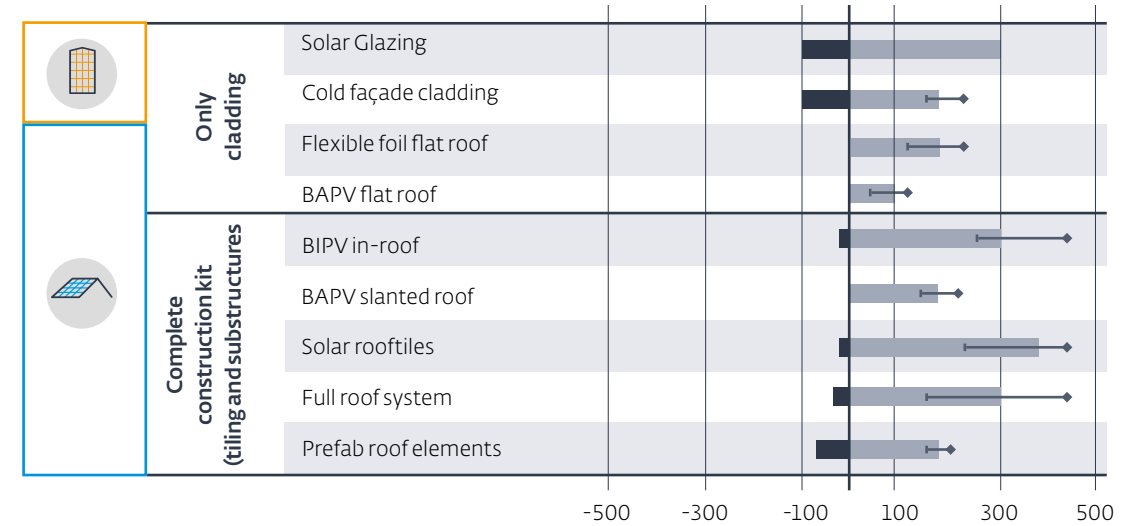


Figure 1: The cost of BIPV as resulted from our survey. The black bars represent the share of the costs that is avoided because no conventional building material (passive element) has to be used. The grey bars represent the true additional costs that contractors need to spend in order to apply a PV functionality 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 we received.

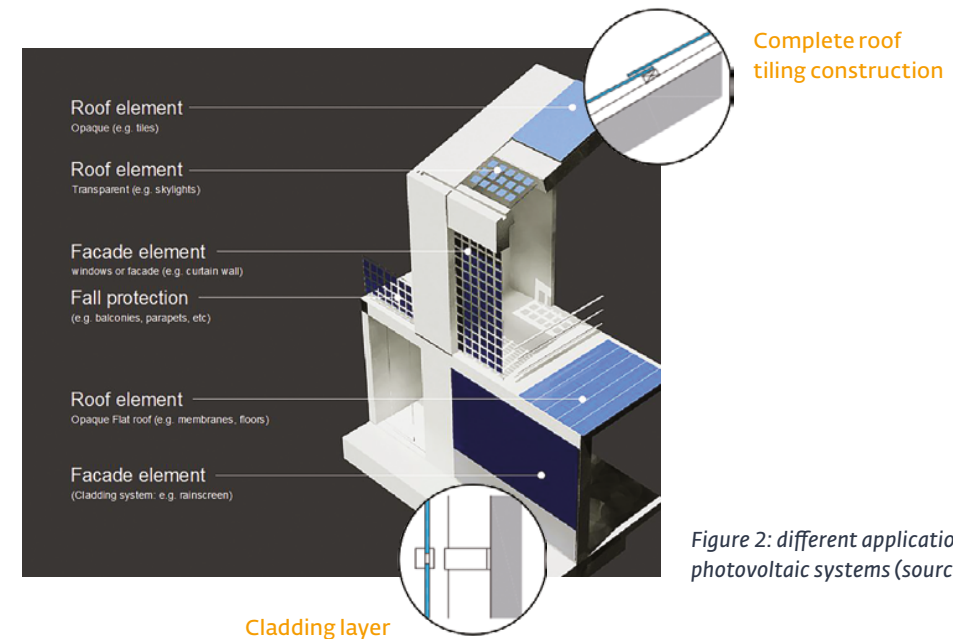


Figure 2: different applications of integrated photovoltaic systems (source: SUPSI)

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. In conventional roof tiling the price of concrete and ceramic small tiles usually varies between 25 €/m² for cheap concrete tiles to almost 60 €/m² for more 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 cost have an impact on the price per square meter. Investigating the roof slates we observe a wider price range varying between almost 60 €/m² to 90 €/m². The different materials play an important role. 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 prices for conventional roofing applications were resumed from the 2015 report where a Dutch database on building price information was used. In the previous graph the costs are considered excluding VAT. BIPV roof products are averagely priced about 200 €/m² above conventional roof products (extra-cost). These added costs should be paid back by the electricity sales.

Cost of façade cladding

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

The graph specifically refers to the cost of the cladding, namely the outer material layer that represent the exterior wall. The costs of the substructures, fixings and insulation are excluded for the conventional building material.

In the case of curtain walls is included the cost of the whole system (including mounting and shading elements). Not to consider these variables could lead to confusing evaluations on costs.

Figure 4 displays the results of the price analysis (€/m²) which compares conventional façade systems materials with some BIPV claddings. The price is defined as the end-user price and measured in €/m². Conventional façade technologies include brick-stones, wood, high standard stone cladding and curtain walls. Prices range all the way from 60-110 €/m² for a brick stone façade to 1.100 €/m² for a special curtain wall (e.g. self-lighted, interactive façade, etc.). The price of the BIPV cladding panel varied from 100-150 €/m² for a thin film PV rain-screen façade (with a really simple sub-structures and a low-efficiency solar technology, typically provided as a standard panel) to 500 €/m² for a high end PV crystalline module. The wide range of prices is mainly linked to different products available including custom made components).

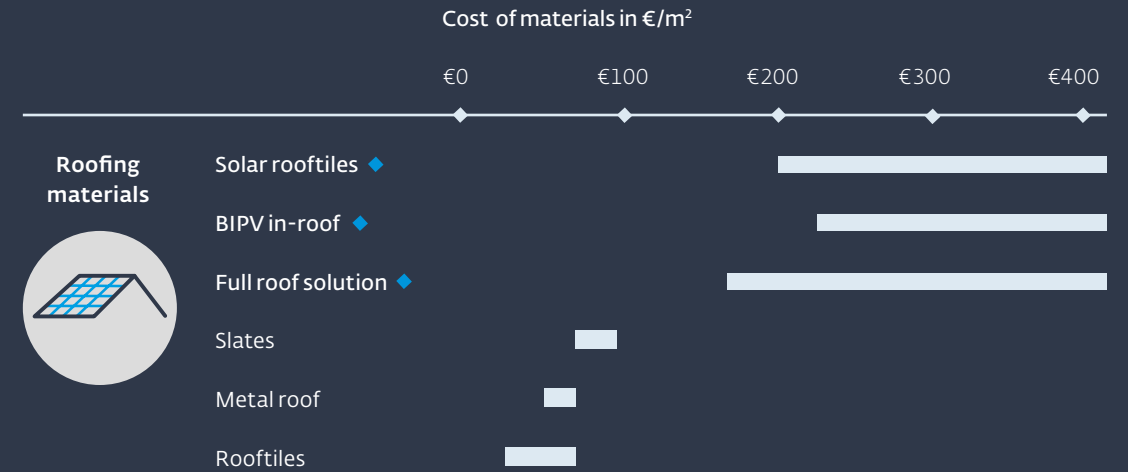


Figure 3: Cost of BIPV roof tiling compared to other roofing materials used in conventional pitched roof.

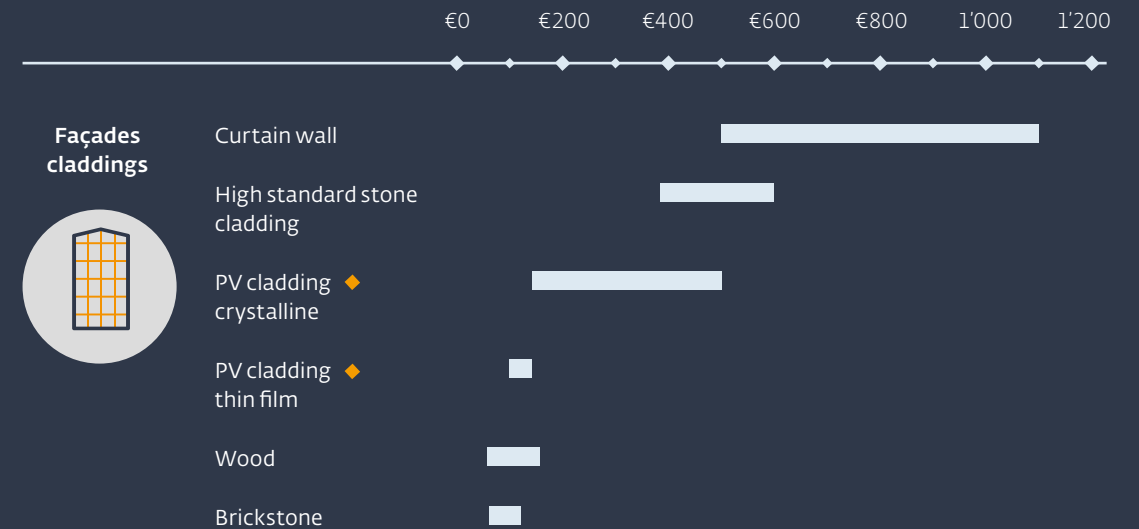
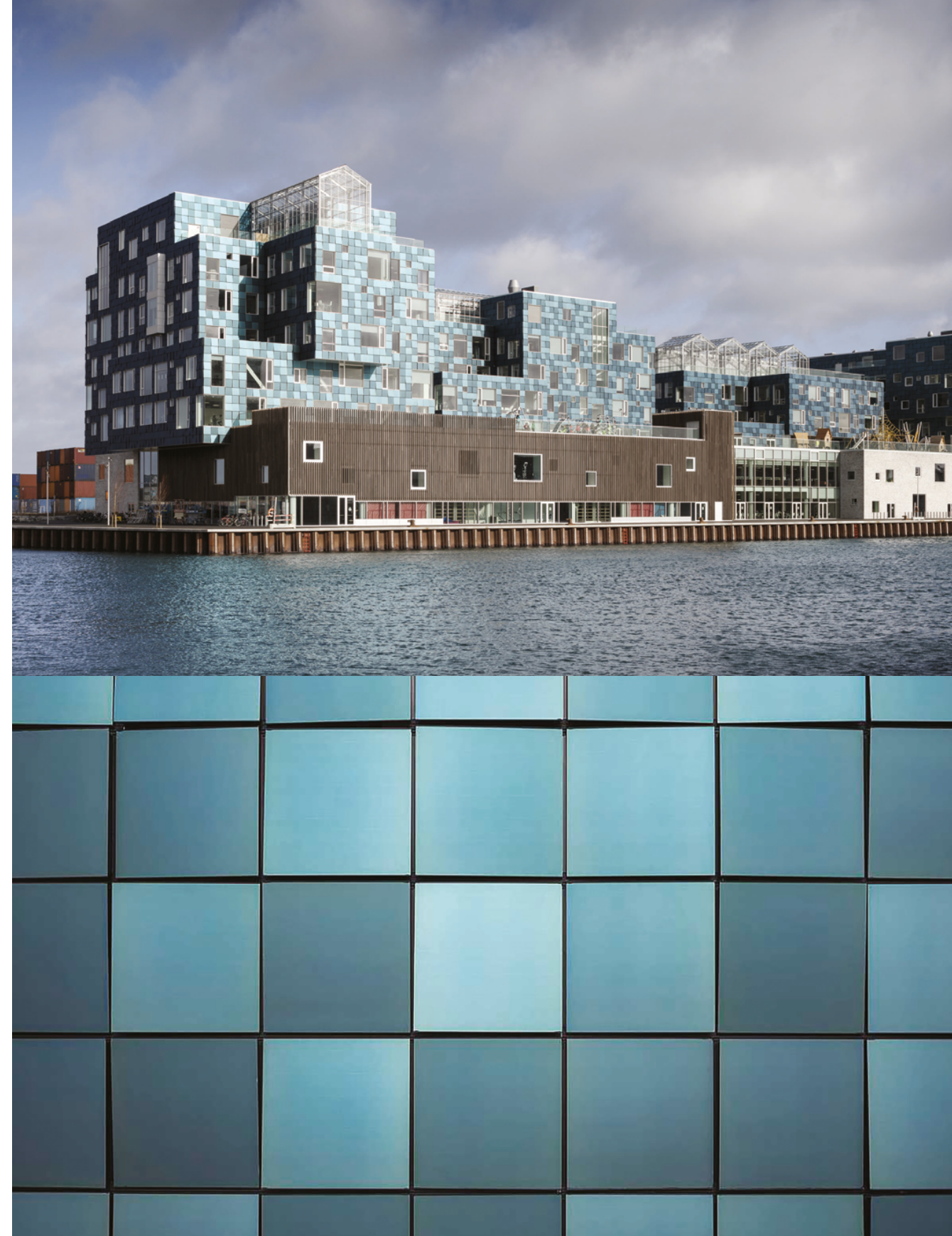


Figure 4: PV costs compared to other cladding materials used in the built environment as façade cladding materials.

Figure 4 provides some reference costs, which will have to be verified with an ad-hoc request of quotation once the specific building project is accurately determined. The cost per square meters 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. 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. Because of that BIPV façades are a highly promising emerging field, as the products are priced very similar to conventional façade materials with lower extra-costs than a roof. This holds the promise of 'PV for free' in some building contexts where façades are quite expensive (unitized façade, curtain wall, rain-screen façade, etc.), e.g. a building with BIPV built without any added costs compared to a conventional building.



Cost analysis

In the following tables the real costs of two potential installations are presented and analyzed, a PV rain-screen façade on a refurbished residential building and a new photovoltaic roof made of PV tiles.

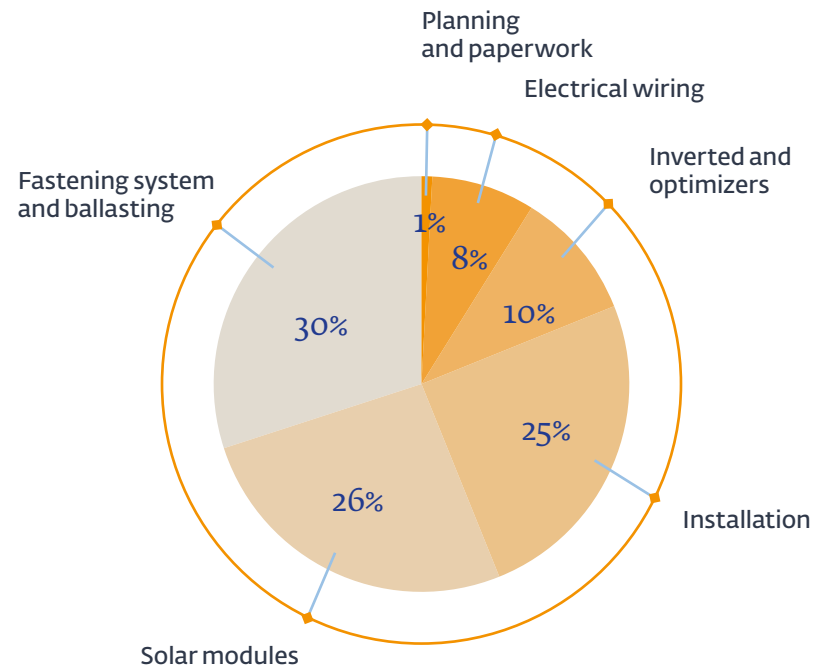
The role of the façade, despite the east orientation and the vertical surface which are not optimal to maximize energy production, is still convenient for increasing the share of self-consumption and therefore a scenario that considers the PV installation on both the roof and on the east façade is a worthy combination in terms of energy, as well as in regard of the architectural and technological re-qualifying of the building envelope. Economy-wise, it should be noted that the cost of the

solar façade is to be compared with the typology of the built-in system (ventilated façade) and its building performance. Unlike on-roof installations (photovoltaic modules mounted on easy-to-lay structures), a PV façade is an actual building envelope which contributes to its technological and architectural upgrading, which explains the extra cost and makes its value non comparable to that of a conventional solar installation.

In the planning and paperwork costs are not included the expenses for an eventual façade engineering (e.g. static calculations) which could be requested in non-conventional installations.

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RESIDENTIAL BUILDING FAÇADE PRODUCTS



Residential building



TYPE OF INSTALLATION:

Rain-screen façade

OBJECT:

Multistory residential building

AGE OF THE BUILDING:

1960

STATUS:

Refurbishment

LOCATION:

Ticino - Switzerland

NOMINAL POWER:

38 kWp

SURFACE OF THE INSTALLATION:

390 m², 2 vertical bands on the east façade

FINAL YIELD:

500 kWh/kWp

ESTIMATED USED PV ENERGY:

100%

CHF/kWp:

4'350 (reference cost, excl. VAT)

CHF/m²:

410 (reference cost, excl. VAT)

The considered costs don't include scaffolding and other security devices as these expenses are covered by the refurbishment and insulation of the façade since these interventions are carried out at the same time of the photovoltaic installation.

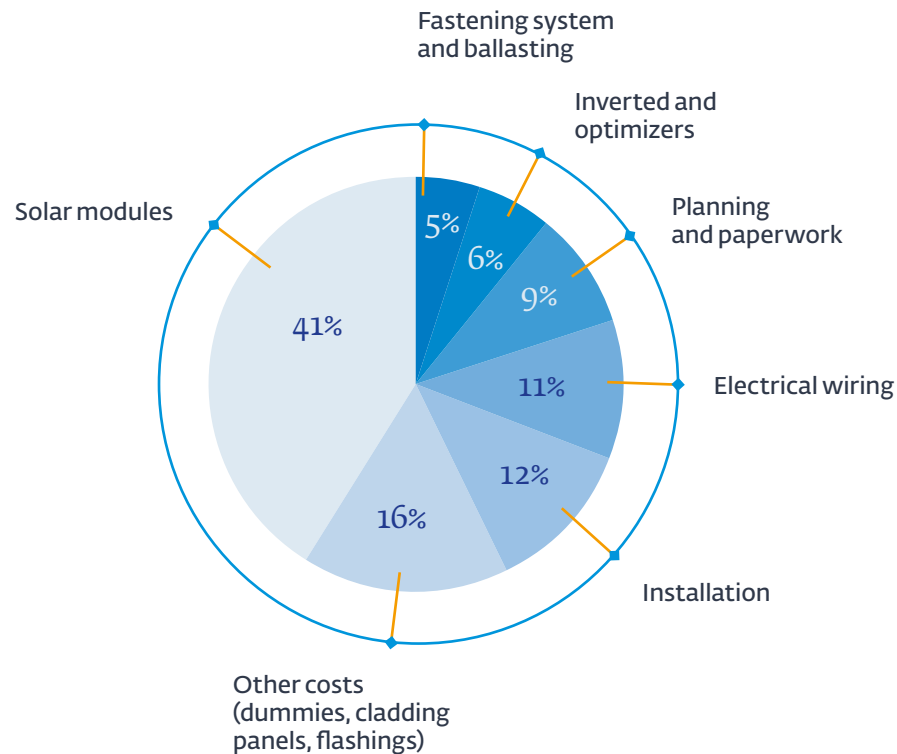
Cost analysis

On buildings with a medium to low architectural quality, installing a photovoltaic plant in concurrence with the indispensable (energy) refurbishment interventions, can significantly reduce the economic impact. In fact, basic costs such as on-site installation, scaffolding/movable safety parapets, administrative procedures, works coordination, etc. are divided on several interventions and therefore have a lower impact on the cost of the photovoltaic installation.

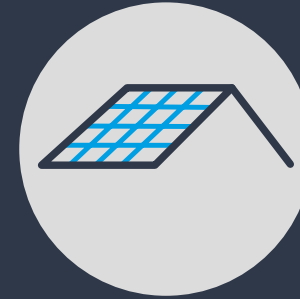
We see that PV technology today is mostly economic driven and therefore its profitability is a crucial factor for its success. If the first goal is surely to minimize the initial investment, also other factors are more and more showing an economic relevance during the life-cycle such as an adequate maintenance, 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 [18-20] for further reading on this topic.

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SINGLE-FAMILY HOUSE ROOF PRODUCTS



Single-family house



TYPE OF INSTALLATION:

Roof tiling

OBJECT:

Two-story residential house

AGE OF THE BUILDING:

2016

STATUS:

New

LOCATION:

Ticino - Switzerland

NOMINAL POWER:

7.8 kWp

SURFACE OF THE INSTALLATION:

55 m², south and west slope.

Cladding in composite aluminum plates included.

FINAL YIELD:

1150 kWh/kWp

ESTIMATED USED PV ENERGY:

25%

CHF/kWp:

3'915 (reference cost, excl. VAT)

CHF/m²:

360 (reference cost, excl. VAT)

The considered costs don't include scaffolding and other security devices as these expenses are covered by the construction of the house itself. Other costs that are not taken into account are the special lathing (size and axle spacing) and the welded undercover. These two cost items are not very different compared to a standard cladding.

The compensation layer was included since it was an explicit design solution. In fact, especially in case of irregular shaped roofs, it is possible to use cladding panels with a more or less similar finishing to that of photovoltaic tiles in order to obtain a more homogenous cladding surface. In the specific case, were used composite aluminum panels which, compared to customized PV tiles or dummies, are more cost effective.

Conclusions

"I have them on my house, JB has them on his house", Musk said, referring to Tesla's Chief Technology Officer J.B. Straubel". Smooth black and textured-glass roof tiles that are indistinguishable from high-end roofing from most viewing angles, looking like standard materials, have brought BIPV at the international attention thanks to the basic premise to make solar ownership more attractive and affordable by eliminating the need to install both a roof and solar panels[1].

Recent news concerning Tesla Solar Roof, also run some numbers and the basic question: How Much Will It Cost You? Generally it's not easy to answer this question for a building product, as we discussed in this report, perhaps impossible without considering local factors and the context, especially in cases when the system represents a functional part of the building skin that cannot be completely standardized, that interacts with other parts of the construction, that needs to comply with different functional solutions, performance and normative requirements depending on the single case, etc. Thus the fact that a Tesla solar roof will cost "less than a normal roof" raised a discussion, also considering that the noticed costs ultimately depends also on the percentage of active solar tiles on the roof itself, on over a 30 years period and considering the tax credits. At the TED 2017 conference in April, Elon Musk estimated that it would be unusual to see non-solar roofs as soon as 15 years from now.

The above mentioned debates, hidden some of the main hints that the report argued in the previous chapter. The integration of aesthetics, technological innovation, reliability, efficiency and cost effectiveness is the key-concept around which innovation in BIPV is evolving and BIPV research has been focusing in recent years with various research projects, efforts and activities at international level.

In this BIPV Status Report 2017 we presented an overview on the capabilities, potentials, specifications and strengths of PV in buildings (Building Integrated Photo-voltaics, BIPV) in order to inform architects, stakeholders and technicians about trend of this growing field. In chapter 1 we described the different product categories that can be distinguished in the field of BIPV. Compared to the previous report, the proposed definition set was expanded with one further category: pre-fabricated system where the fastening system and/or the other building functions are integrated with the PV modules). The other adopted definitions are: mounting

system (partially integrated); full roof solution (totally integrated); solar tiles; lightweight system (which include both PV membranes and metal panels); sky-light/solar glazing; curtain wall (warm façade); rain-screen façade (cold façade) and accessories. Regardless of the category they fall into, the BIPV component is not solely an electrical device but it is finally conceived as a comprehensive part of the building concept.

Chapter 2 consists mainly on a database of more than 100 available products on the market today. The number of products on this list is slightly higher compared to 2014 (from 108 to 114), but about 35% of the companies listed in the current edition were not manufacturing their products two years ago. This means that about 40 products have been taken out of the market and have been replaced by new items. Compared to the previous 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 as a result of innovation projects supported at a national or European level. In chapter 3 we described new trends for BIPV in the years to come. 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. It is our expectation that in the next few years more prefabricated PV products, coloured PV products, semi-transparent PV products and lightweight PV products will have entered the market.

In chapter 4 six examples of BIPV projects are described. Most of these constructions are buildings which were more or less extensively refurbished. This means that with proper design and technical strategies, BIPV technology can be successfully implemented on new constructions designed with a specific "energy focus", but also in the existing built environment which at first glance would not seem particularly suitable for energy exploitation because of pre-existing conditions such as morphological, urban and technological constraints.

Even though BIPV is not a mainstream technology yet, good examples of commercially executed projects with positive business cases can be found. Moreover the more stringent energy performance demanded in the European buildings directives means that more and more buildings and builders will have to follow this path.

Chapter 5 summarized the considerations obtained through an online price survey. Standardized prices per square meter do not exist in BIPV, and suppliers are generally unwilling to share their confidential pricing information. Nonetheless, we managed to get a participation of approx. 35 companies spread over different product categories. We can conclude that BIPV is affordable and that the extra cost compared to normal 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. It's interesting to remark as the numbers are not often well aligned with the general perception. E.g. in BIPV roofs

the extra-cost to make it active, compared to a conventional tiling system, is typically higher than in a BIPV façade where the cost to integrate PV is less significant for the final price of the system.

Overall, the BIPV sector is in a healthy shape. Many attractive products are available, reliable and offered at a competitive price. Examples of aesthetically pleasing and affordable BIPV buildings can be found and are more and more entering the ordinary building stock. 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.

Have a nice solar design!

[1] www.bloomberg.com/news/articles/2017-08-02/tesla-completes-its-first-solar-roof-installs



Picture sources

PREFACE

Picture 1: these glass solar tiles are composed of high-efficiency photovoltaic cells manufactured by Panasonic and covered with a “color louver film”, which allows the cells to blend into the roof while exposing them to the sun. A tempered glass is placed on top for durability. The rendering presentation of the Solar Roof includes two successful Tesla products such as the electric car Model X and the home storage battery PowerWall.

Source: www.tesla.com

Picture 2: 2000–2008 California Academy of Sciences, San Francisco, USA. Client: California Academy of Sciences. Renzo Piano Building Workshop, architects in collaboration with Stantec Architecture (San Francisco). Consultants: Ove Arup & Partners (engineering and sustainability); Rutherford & Chekene (civil engineering); SWA Group (landscaping); Rana Creek (living roof); PBS&J (aquarium life support systems); Thinc Design, Cinnabar, Visual-Acuity (exhibits). General contractor: Webcor Builders.

A solar canopy around the perimeter of the Living Roof, with pv cells supplies almost 213,000 kWh of clean energy year (at least 15% of the Academy’s standard energy needs). Source: www.rpbw.com, photo: © Griffith Tim

MANAGEMENT SUMMARY

Picture 1: photovoltaics as a building material. Solar elements become part of the architecture, entering in dialog with the context and the urban environment. BIPV is beyond energy, it becomes energy of architecture. Kingsgate House, Chelsea - London, UK. Source: SUPSI, photo: P. Bonomo

CHAPTER 1

Picture 1: autarchic multi-family house in Brütten (ZH-CH). BIPV is integrated in both roof (monocrystalline modules) and façades (thin film modules). 2nd Place Norman Foster Solar Award 2016.

Source and photo : www.solaragentur.ch

Picture 2: this private residential building, located in a mountainous area in Austria, is characterized by its wooden construction and by the integration of the PV system in the glazed railing system. The design of the railing, completely configured by semi-transparent PV laminates, includes a frame of galvanized steel. The electrical cabling system passes through the lateral edges resulting completely hidden.

Source: www.bipv.ch, photo: MGT esys

CHAPTER 2

Picture 1: photovoltaic prefabricated façade FaceActive™ developed and manufactured by Batineg SA.

Source and photo: Batineg SA and BFE – SUPSI.

CHAPTER 3

Picture 1: Kaleo-Solar is a unique technological solution for integrating high-definition images in solar. Thanks to the support of the Banque Cantonale Neuchâteloise (BCN), CSEM has developed the KALEO technology, which enables the production of illustrated solar panels. KALEO is still in a technological development process and the expo (June 2017) photos are the first prototypes/proof of concept modules. Source: www.kaleo-solar.ch,

photo: ©briefcom/ bcn/csem

Picture 3: a mobile façade mock-up demonstrating in real-scale different BIPV façade systems and innovative BIPV technologies, variants and possibilities in terms of architectural and technological design/manufacturing of BIPV systems for the façade building skin. Picture of the exhibition at the 10th Energy Forum on Advanced Building Skins in Bern, Switzerland. Source: www.contructpv.eu, photo: SUPSI

CHAPTER 4

KohleSilo - Photo: BFE – SUPSI

Service intercommunal de l’électricité - Photo: BFE – SUPSI

Renovation of a residential building - Photo: BFE – SUPSI

Administrative building “The Edge” - Photo: OVG Real Estate

Energy neutral residential buildings - Photo: NBArchitecten and EigenEnergie.net

Energy neutral terraced houses – Photo: AERSpire BV

CHAPTER 5

Picture 1a and 1b: 2013 - 2017 Copenhagen International School - Nordhavn, DK. Client: Property Foundation Copenhagen International School (ECIS). The school building’s unique façade is covered in 12’000 photovoltaic modules, each individually angled to create a sequin-like effect, which will supply more than half of the school’s annual electricity consumption. The solar cells cover a total area of 6’048 m² (apice) making it one of the largest building-integrated solar power plants in Denmark. The modules are produced by Emirates Insoleire using the Kromatix technology, developed in collaboration with the Swiss Federal Institute of Technology.

Source: . F Møller, photo: Adam Mørk

CHAPTER 6

Picture 1: SwissTech Convention Center (EPFL) - Lausanne. The anodized aluminum roof, shaped like a catamaran, contrasts with the lightness of glassed façade below. This project is the first application of multicolored dye photovoltaic cells. The panels, installed as horizontal shading system in the western façade, are arranged in 65 colored columns, with 5 different shades of red, green and orange, providing a unique color tone to the light transmitted into the interior hall.

Source and photo: BFE - SUPSI

The images illustrated in this report are used for only educational and scientific purposes without any discrimination, commercial use or other scopes. The sources and links are listed here (accessed July 2017).

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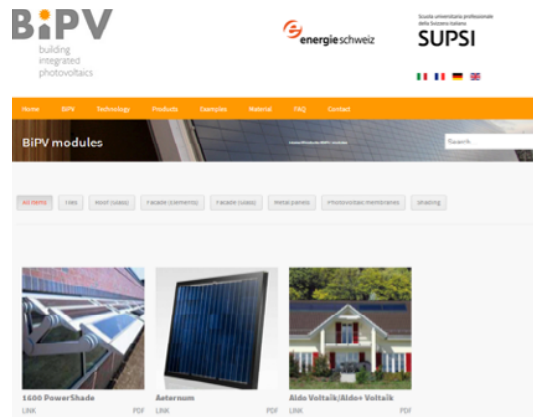
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