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BIPV PRODUCTS FOR FAÇADES AND ROOFS: A MARKET ANALYSIS

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ABSTRACT: In this paper, the authors report on a jointly conducted analysis of the current status of the BIPV market starting from a comprehensive overview on the available product, discussing the application ranges and finally by giving the price levels. For this purpose a market survey was conducted among the various stakeholders in the BIPV sector, including architects, installers and BIPV product suppliers. The product survey was conducted for the general European Market and the price survey concerned only Benelux and Swiss markets. The most frequent products analysed were PV tiles and in-roof mounting systems (for residential roofs). Although crystalline silicon technology was most commonly used, thin film technologies gained considerable share in façade products. The data from the price survey showed that new buildings using BIPV products can be executed at very similar costs than projects involving conventional and/or building applied PV products.

Keywords: BIPV, building integration, architecture, benchmark, roof, façade

1 INTRODUCTION

An interesting European photovoltaic market is constantly growing: Building Integrated Photovoltaics Market (BIPV). Its key market driver is the European Directive 2010/31/EU [1]. By this directive, all residential and utility buildings built after 2018 should be 'nearly zero energy'. In order to meet the directive architects will generally look for cost-effective technological solutions that allow sufficient freedom of design. Building Integrated Photovoltaics (BIPV) has the promise to be a highly suitable solution.

In BIPV applications, photovoltaic modules, available as flat or flexible surfaces, realized with cells or laminates, are integrated into any surface of the building envelope and due to their features (size, flexibility, shape and appearance), are particularly suitable for being "designed". In fact, these photovoltaic elements can be used together with materials that are common in architecture, such as glass or metal, in opaque as well as in semi-transparent surfaces. This is particularly true for roof systems where solar cells are incorporated in conventional building components such as shingles or tiles. In order to create structure among all different BIPV applications, we came up with multiple categories. In Figure 1, we distinguish 2 types of BIPV applications: Façade and Roofing.

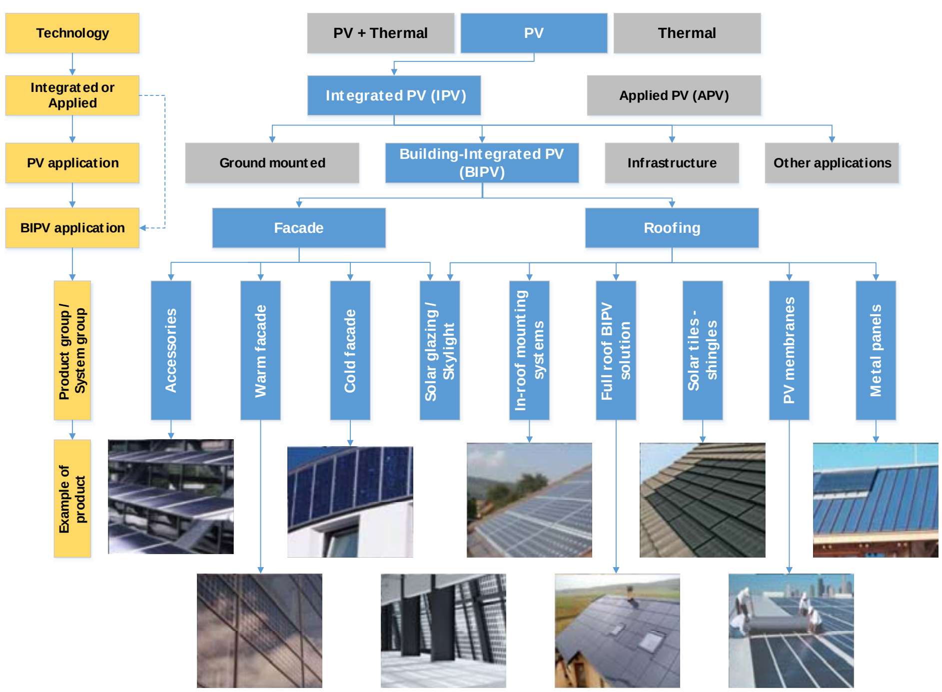

Figure 1. Product categorization used throughout the product benchmark analysis.

Within each of these categories multiple product groups are defined. The segmentation as depicted in Figure 1 is derived from the product categorization used by numerous institutes [2], [3] and [4]. Manufacturers today can provide the building sector with various interesting products, ready to be used by architects and planners. Nevertheless, PV is still looked upon with suspicion in the building sector, because its potential is not well known by architects, and, from the technical point of view, its affordability is not sufficiently demonstrated. It is now the right time to investigate the versatility and potential for this emerging market.

The purpose of this work was to conduct a thorough study on the application range and price levels of BIPV products. By this study we intend to inform architects, stakeholders and engineers on the capabilities, potential, specifications, strengths and weaknesses of PV in building

2 BIPV PROJECT EXAMPLES

To map the progress and innovations in the emerging BIPV market, we describe BIPV roofing and façade project exampless which are currently being constructed or have been finished recently. It concerns two Swiss façade projects and two Dutch roofing projects.

The first project (Figure 2) is the refurbishment of an eight storey building located in Chiasso Switzerland. This building is for the largest part covered by photovoltaic modules. The eight-storey apartment building was built in 1965 and has recently been refurbished. By covering almost the entire façade, the building owner achieves zero energy target. A massive reduction of heat loss through the hi-insulation of the building envelope was required. Moreover, for a high rise building, the roof space is not sufficient for integrating PV when aiming to achieve a zero energy balance. For this reason, the four facades play an important role in the energy production. Thus the cladding elements of the Palazzo Positivo are transformed in an energetic skin integrating glass-glass thin-film modules and monocrystalline modules. In addition, 51.8 kWp was installed on the garage roof and on the main roof.

Figure 2: Palazzo Positivo after the retrofit. The whole façade is covered by BIPV (source: Frontini, SUPSI)

Blind (dummy) components were installed on the corners, the openings and in the shady parts of the facades. This building represents a demonstrative case, unique in its kind, where PV becomes a constructive and architectural building material in a cost-effective way. The use of a thin-film amorphous-Si technology with a low power density of about 50 W/m^2 results in a very-low end-user price for the BIPV system with a price of around 120 €/m^2 (including mounting system, installation, BOS and everything else for the functioning of the PV system). The aesthetical characterization of this recladding is provided by the PV integration in the vertical skin. Also different interesting aspects related to self-consumption emerges thanks to the different orientation of PV modules. It was calculated a surplus of energy production of about 4800 kWh compared to total consumption estimated.

The second project (Figure 3) is a new Minergie residential building. The residential building is located at an altitude of 1050 m above sea level, in the ski center of Laax (Graubunden Canton in Switzerland). The south facade is characterized by the integration of PV modules with high efficiency monocrystalline cells. The cold facade system manufactured by the Austrian producer MGT esys, was installed onto a wooden substructure and allows appropriate ventilations of the panels. The solar facade is equipped with a special mechanical anchoring system that is invisible from the outside. The architectural language is characterized by the grey appearance of the solar cladding obtained by the all-black modules. This creates a uniform striped effect similar to the wooden cladding of the other facades. The PV system which is grid connected produces enough electricity to meet the energy demand of the apartments.

Figure 3: Casa Solara in Laax (Switzerland). The façade is cladded with BIPV and wood (source: MGT)

The third project described entails the renovation of 75 dwellings in Tilburg, The Netherlands. A fairly new concept is used to completely renovate terraced dwellings in a relative short period. In only 25 days, a terraced house is completely demolished and newly built. SCX solar is the company who has developed a BIPV full roof solution called the “SCX Soloroof”. As shown in figure 4, the roof has a homogeneous appearance and covers one side of the roof. Flashings are used as finishing material to cover every possible dimension. In total 138 modules of 200Wp, 726 modules of 250Wp, and 752 modules of 260Wp panels were installed. The construction of each roof envelope had to be initiated and completed in one day. Moreover, exactly the twelfth day in the building process. The customer here is a housing association.

Figure 4. SCX Soloroof System as a BIPV full roof solution (Tilburg), 75 terraced dwellings

The fourth and last BIPV project described entails the renovation of 29 terraced dwellings in Maarn (See figure 5). The investor here is the "Spoorweg" pension fund. The concept used here is "concept Plan 5", where the complete building envelope is being replaced by a new one within 5 days [5]. Stafier developed a BIPV in-roof solution called "Stafier Standaard", here one side of the roof is partly covered with modules. The remaining roof area on the PV side is finished using conventional roofing tiles. The other roof side is completely filled with conventional tiles. Stafier offers also the possibility for a BIPV full roof solution, and use flashings as finishing material. The modules can be integrated both portrait and landscape. Next, there is a square module to increase the freedom regarding module positioning. Another feature in this concept is the option to include a porthole in the BIPV roof solution.

Figure 5. Stafier Standaard as a in-roof mounting system (Maarn), 29 terraced dwellings

3 METHOD

In order to arrive at a well-established product categorization several earlier attempts to categorize the BIPV markets and products were investigated [1]-[6]. The final categorization we arrived at is depicted in Figure 1. The definitions, as will be reported in a second report (available online by the end of 2014), are briefly described below:

- *In-roof mounting* systems are used to mount mainly conventional PV modules in pitched roofs. Usually only a part of the roof is covered by PV. From a constructive perspective the most common systems does not satisfy primary building requirements through the PV layer (such as water-tightness) that are demanded to the roofing layers underneath. Additional foil is often used to ensure water-tightness.
- *BIPV full roof solution* includes cases where the roof surface is exclusively conceived as a solar collector. This whole concept concerns both building technology and architectural language. Accordingly these solutions often include 'dummies', windows, chimneys, etc. since the solar surface becomes the architectural meaning of the whole roof. Special mounting systems and modules are provided for ensuring the satisfaction of building requirements such as water tightness, mechanical resistance, etc .
- *Solar tiles* (large sized or small, such as shingles, slates, etc) are usually designed to resemble the conventional 'roof tiles' with solar PV tiles. Due to the integration of the solar component into the conventional constructive elements, the mounting system is the same as for conventional roof tiles.
- *Warm façade* is often used as a curtain wall system, designed with extruded aluminium frames (but also steel, woods, etc.) completed with glass. Since it is the envelope building system, parameters related to solar gain control such as thermal and visual comfort have to be controlled when using highly-glazed curtain walls.
- *Cold façade* represents the opaque facade cladding including an air gap between the wall and external elements, accordingly to the building model of ventilated façade.
- *Accessories*, are parapets, balconies, external devices such as solar shadings, etc. that do not directly belong to the building skin.

The results of the product survey will be presented using these categories. Different manufacturers were contacted by the authors (the complete database is available at www.bipv.ch) and BIPV product information from databases and technical sheets worldwide [2] [5] were collected. The gathered product information includes a profile of the companies' background, technical data', description about the PV panel/system or mounting system and photos of the product and its mounting phases, as well as technical drawings if available.

Furthermore, a price survey that followed the same categorization of products was conducted through a four-page questionnaire that was sent to architects, producers, suppliers as well as installers of BIPV products. The survey was conducted by actively involving the producers. This enabled to work with reliable and complete data. The price survey focused on two clear application areas: Residential roofs and utility scale façades. The price survey was conducted for those products available on the Benelux and Swiss market.

To ensure the validity of the price survey results, we used a minimum number of respondents of 5 per category. If the number of responses for the price survey was less than 5, the product category was not included in the analysis.

As far as the product information is concerned, the technical properties (technology, dimensions, weight, module layout, and energy properties) were requested along with the quality and warranty certifications as far as the photovoltaic and the constructive part is concerned. Furthermore, the cost of the product itself was requested, separately was asked to provide the PV panel cost per square meter, fastening system cost per square meter and the labour cost for the installation per square meter (if available). Finally the end-user price of the PV system per square meter was requested or calculated. This refers to the price which the consumer pays for the complete PV system, divided over the total square meters of the PV part of the roof or façade. The VAT was excluded by the indicated costs. Due to the European verdict case C-219/12, all European PV system owners can reclaim the VAT of the PV systems. However, for BIPV system owners the amount of VAT one can reclaim depends strongly on the national tax legislations. For example in The Netherlands one can reclaim only one third of the VAT when it concerns a BIPV system. In the case of a BAPV system, one can reclaim the complete VAT (Rijksoverheid, 2013). To keep the results comparable between the various European countries we decided to exclude the VAT in our analysis.

This paper focuses on the €/m² of a PV system. Using this measurement unit allows benchmarking between conventional materials and BIPV systems. A disadvantage is that the power density per square meter (Wp/m²) has to be evaluated along with this measurement unit. A PV system with a relatively low cost price per square meter is not necessarily cheaper than one with a high cost per square meter if the system size is leading.

Assume we have two PV systems. System 1 costs 300 €/m² and system 2 costs 200 €/m². If we do not know the power density of each system, we could argue that system 2 is much cheaper. However when system 1 has a power density of 150 Wp/m², and system 2 has a power density of 100 Wp/m², the price per Wp is the same. For the system 1, the price is 2€/Wp (300 €/m² / 150 Wp/m²). For the system 2, the price is 2€/Wp as well (200 €/m² / 100 Wp/m²). We see that both systems are equally priced even though system 2 requires 50% more PV area. Note that these differences are most significant for BIPV tiles since only a part of the tile is covered with a PV cell. For the other product groups the power density is on average significantly higher, and is around 155 Wp/m².

In order to put the results of the BIPV roofing products into perspective, we included BAPV roofing products in the benchmark. Within the Benelux PV roofing market the vast majority are BAPV systems. A BIPV system fulfils the functionality of both roof and that of generation electricity. The only function of a BAPV system is producing electricity. In order to be able to compare BAPV with BIPV we included conventional materials in the calculation. Conventional roofing materials for that area that is covered by the BAPV modules, considering that BAPV modules do not replace the conventional building envelope. So, conventional roofing material is used as the building envelope for the BAPV system and has a fixed cost in the calculation to ensure the validity of the results. For the BIPV roofing systems, conventional roofing materials are not required. Note that the cost per square meter is calculated over the end-user price of the PV system and not the complete roof. At last, the conventional roofing materials (cost per square meter) are compared to the BAPV and BIPV roofing systems.

4 RESULTS

The results of the product and price survey are separately discussed. First the results of the product survey are shortly discussed (a more detailed and exhaustive discussion will be presented in a second report that will be published in the end of 2014). The second parts of the results are based on the price benchmark and show the price differences within and among conventional materials and the different PV product groups.

3.1. Product survey

More than 120 parties contributed in the product survey. Table 1 shows the distribution of the participants.

Table1: Number of participants in the product survey with BIPV products.

BIPV application	*Product group*	**Product survey** *# worldwide*
Facade	Accessories	8
	Solar glazing	4
	Warm façade	8
	Cold façade	9
Roof	In-roof mounting system	34
	Full roof solution	8
	Solar tiles	36
	PV membranes	8
	Metal panels	4
	Skylight	8
	Total	128

The participants were not evenly distributed over the various markets and segments. In the BIPV roofing market, the in-roof mounting systems and BIPV tiles are dominant and represent about 70% of the products within roof market. The BIPV façade market is significantly smaller in the number of available products. Here the warm and cold façade product groups are dominant and represent about 60% of the façade market. Metal panels currently do not seem to be offered frequently for BIPV applications. An explanation for the absence of metal panels could be that PV membranes are also suitable for metal panels but are categorized in a different product group. The significant larger amount of products in the BIPV roofing market indicates that this market is currently significantly bigger than the façade market.

Figure 2 shows a pie chart with the technology used in the roof and façade application areas. The PV technology used for most BIPV roof products is for 75% crystalline silicon. This is mainly due to area restrictions for roof applications making ‘high efficiency’ a strong requirement. In contrast, thin film technologies have a considerable share in the façade application area. Architectural aesthetics and price/m² are more important here, and the solar energy conversion efficiency is a less crucial factor. Some products offer the possibility for multiple technologies.

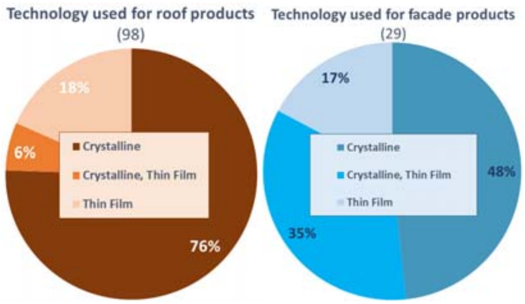

Figure 6. Technology used in the various product categories [2], [6]**.**

3.2. Roof price survey

For the price survey 44 parties participated. Table 2 shows the distribution of the participants. Only roofing product groups were included here. Not enough producers/installers of façade products attended to the survey to conduct an analysis and draw conclusions. so that some point data have been not considered significant for defining a market trend. However some consideration concerning façade costs are reported later.

In the price survey we distinguished conventional roofing, the BAPV roofing and BIPV roofing solutions. The BAPV system installed on top of concrete tiles represents the cheapest and common roofing material in the Netherlands. Eight installers of BAPV systems participated in the price survey. By means of a box-and-whisker plot the price range, 25%, 75% quartiles, and median within each product group was displayed.

The BIPV roofing applications available are divided into in-roof mounting system, BIPV tiles and full roof BIPV solution. The other product categories are not included so far in this product price survey since we were not able to gather enough data for any statistical significance. The number of participants per product group are stated in Table 2. Figure 7 shows the results of the price survey including the conventional roofing materials. The costs (€/m²) in the figure can be separated in conventional roofing materials and PV systems (both BAPV as well as three types of BIPV product groups).

Table 2: Number of participants in the product survey with BIPV solutions for a roof.

BIPV application	*Product group*	Price survey *# NL*	Price survey *# CH*
Roof	In-roof mounting system	12	11
	Full roof solution	2	9
	Solar tiles	10	1
	PV membranes	0	0
	Metal panels	0	0
	Skylight	0	0
	Total	23	21

Looking at the results for conventional roofing, the figure shows a significant price range for the different roofing materials. The price of concrete and ceramic tiles vary between over 30 €/m², for cheap concrete tiles to almost 75 €/m² for expensive ceramic tiles. This can be explained by the type of roof tile used. Furthermore the size of the roof and the installer experience have an impact on the price per square meter. When a construction company does the roofing for a complete block of for example 50 houses, the price per square meter decreases. Investigating the roof slates we see an even wider price range that varies between almost 75 €/m² to o 125 €/m². The prices of different slate materials play an important role here. For metal roofing the price range can be explained mainly by the thickness of metal and how they are finished. Degreased and painted metal sheets are more expensive. The final conventional roofing material is thatch roofing which costs between 85€ and 105€ per square meter.

The products within the BAPV roofing category vary between 225 and almost 300 €/m², this is including the concrete tile underneath. The smaller range indicates the competitive market.

Within the BIPV roofing product groups, we see large price differences. For the in-roof mounting system the price varies between 350€/m² and almost 500 €/m². Although 50% of the prices lie between 300€/m² and 400 €/m². For the BIPV tiles the price varies between 225 and 500 €/m², 50% of the prices lie between 375€/m² and almost 475 €/m². The relative low price of 250 €/m² can be explained by the earlier discussed power density of the BIPV tiles. Furthermore, we see a positive development regarding the emerging BIPV full roof solution. This product group covers the complete price range, from the most cheapest to the most expensive roofing product. The price varies between just over 200 €/m² and almost 650 €/m². Although 25% of the product prices vary between 250 €/m² and just over 300€/m².

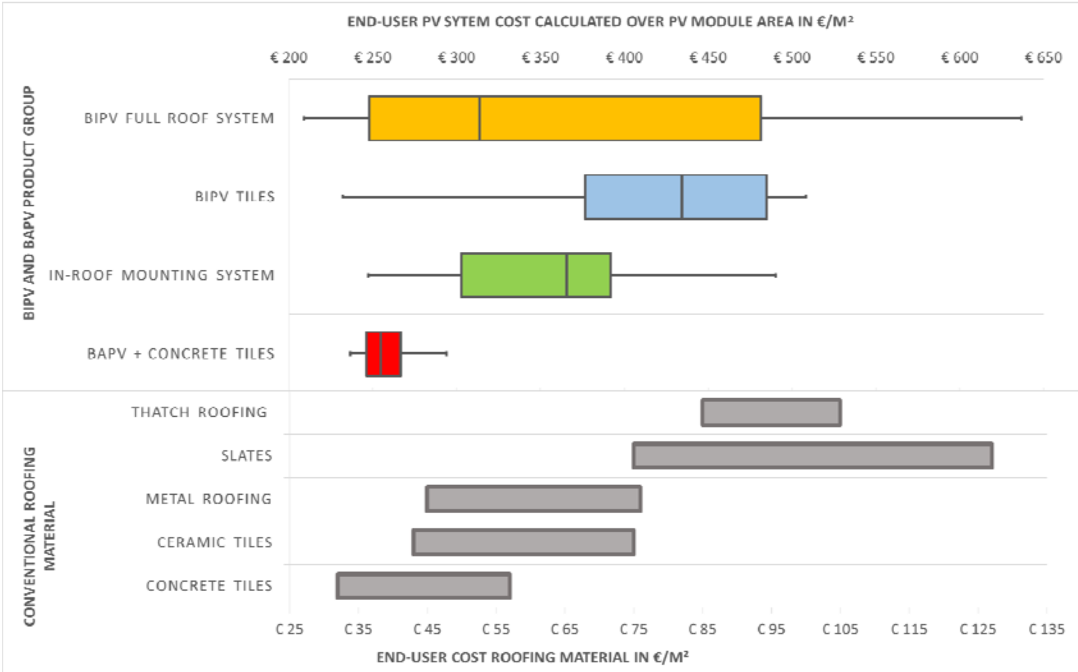

Figure 7. A benchmark of the conducted price survey, comparing conventional roofing materials with BAPV and BIPV roofing solutions. The price is defined as the end-user price and measured in €/m².

3.3. Façade price survey

The BIPV façade applications can be divided into cold façade, warm façade and accessories (such as balconies, parapets, shading devices, etc.). The number of participants per product group was not enough for defining a cost trend for the market, anyway, some point cost indicators have been collected. The market of BIPV façade systems in Switzerland and Europe is relatively small and there is still a large cost variety depending on the building type and application. A lot of producers and installers have not replied to the submitted price survey. A frequently used argument is the demanded discretion by the customer regarding the project costs. This may be explained considering that very often BIPV facades have been experimented in pilot-demonstrative projects so that the cost was specifically linked to the specific context and influenced by building size, technology adopted, owners policy, etc. Thus the absence of a well-established market influenced this phase of research. Only some smaller producers or installers provided some cost data: the main reason was to promote and advertise BIPV demonstrative buildings showing their cost-effectiveness also at a small-medium scale (residential multi-storey building e.g.). In this perspective figure 8 displays the results of the price survey (€/m²) which compare conventional façade systems with some BIPV façade solutions. Within the BIPV facade product groups, we see large price differences and a trend is not yet clear. In some cases such as BIPV accessories (balconies or sun-shadings) some data shows that price varies between 500 €/m² and almost 750 €/m². Obviously, also for façade the considerations concerning the power density (W_p/m^2) are recognized. For example in the case of semi-transparent glazing where nog the complete glazing is integrated with PV cells. Low cost BIPV façade strengthen the promise of BIPV because these applications are cost wise suitable as a substitute for the conventional façade solutions.

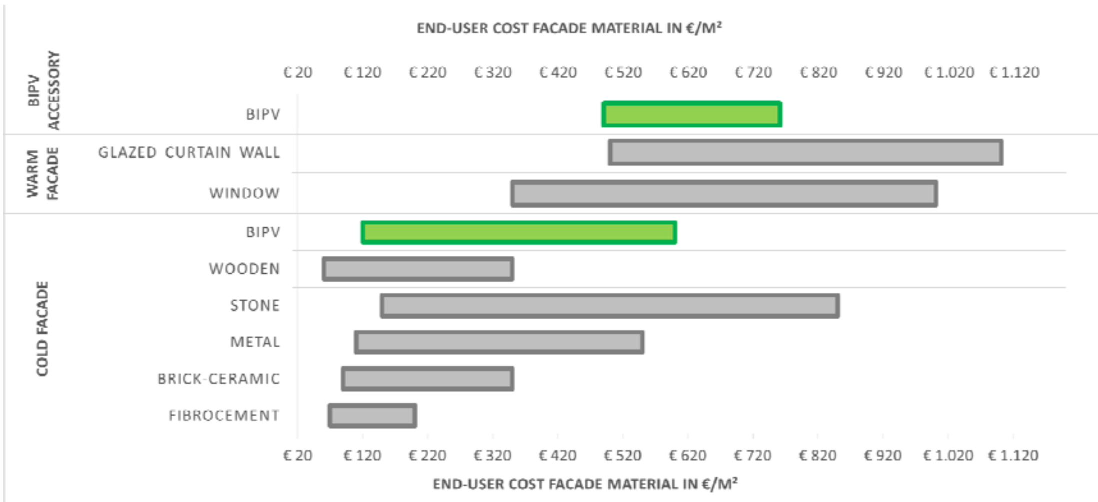

Figure 8. A benchmark of the conducted price survey, comparing conventional façade materials with BIPV façade solutions. The price is defined as the end-user price and measured in €/m².

5 CONCLUSION AND DISCUSSION

BIPV holds the promise to be highly suitable for the built environment. The variation in products and integration possibilities could result in aesthetic appealing buildings. From a technical perspective, the production process decreases in comparison to building applied PV solutions. The savings in construction time, material together with the improved aesthetics could contribute to the success of BIPV. In this paper we have attempted to elaborate on these promises.

The results from the product survey demonstrated the wide variety of products available in the BIPV market. Especially for roofing applications there is wide variety of products in different product groups. The most common products are PV tiles and in-roof mounting systems, for façade applications these are warm and cold facades. Mainly crystalline silicon technologies are used for the manufacturing of roof application products whereas for the façade applications, thin film technologies have a significant market share. New developments within the BIPV roofing market show a new trend with the emergence of the BIPV full roof systems. Developers, producers and installers looking for complete roof solutions. Using well designed modules with sophisticated mounting systems to increase the ease of installation, enhance the physical building properties and aesthetics of the BIPV system.

The price survey showed that the promise of BIPV from an economic perspective has been partly met. The lower priced BIPV full roof solutions are price competitive with BAPV roofing solutions. Moreover, the lowest priced full roof solutions are cheaper per square meter. Not that this is probably the case for larger projects, multiple houses so it can benefit from the economies of scale. Furthermore, the low priced products are suitable for roofs that are simple to construct. Terraced dwellings with gable roofs without chimneys, windows, etc. In the Netherlands, terraced dwellings represent a large share of the dwellings which can contribute to the success of BIPV full roof solutions.

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