Building Integrated Photovoltaics:

A practical handbook for solar buildings' stakeholders

Status Report

2024

Developed by

SUPSI

In collaboration with

BECQUEREL INSTITUTE
Strategy Consulting in Solar PV

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The Innovative Envelope team specializes in energy-efficient building envelopes and Building Integrated Photovoltaics (BIPV), serving as Switzerland's competence center for BIPV (see www.solarchitecture.ch for more). The team focuses on applied research, developing and testing multifunctional photovoltaic products that generate renewable energy while fulfilling architectural roles such as solar control, thermal protection, and waterproofing.

Key activities include:

→ Development and demonstration of innovative, market-ready BIPV solutions. Product validation and performance analysis through testing and monitoring in mock-ups and real buildings.
→ Economic analysis and market studies to facilitate the integration of solar systems in building processes.
→ Creation of training and stakeholder engagement formats, and support for digital modeling in the BIM field. The team collaborates with SUPSI's PVLab for performance and safety tests, and continues work with the iWin start-up, founded in 2019, to develop photovoltaic-integrated windows. Team members also contribute to education and play active roles in international technical committees.

The Becquerel Institute is a privately-owned Belgian company founded in 2014, providing a hybrid service of high-quality consultancy and not-for-profit research focused on the role of solar PV and its ecosystem in the energy revolution.
This spans through neighbouring fields such as the building and transportation sectors, as well as electricity storage, “green” hydrogen production and more. The Becquerel Institute provides research, strategic advisory services and due diligence to private companies as well as to public and institutional organizations. Its internal team of researchers and consultants provides advisory excellence thanks to its extensive experience in the PV and energy sectors, completed by partners and external consultants from around the globe. Together, they empower companies and organisations to embrace the energy revolution.

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Preface

"When I am working on a problem, I never think about beauty...
but when I have finished, if the solution is not beautiful, I know it is wrong." R. Buckminster Fuller

Legislative frameworks like the Renovation Wave Strategy and the EU Solar Strategy highlight Europe's commitment to accelerating the deployment of solar energy in the built environment. These initiatives aim to create millions of jobs, increase renovation rates, and support industrial-scale manufacturing of solar technologies, all while promoting photovoltaics (PV) as an integral part of building designs. By 2030, Europe envisions the renovation of 35 million buildings, with Building-Integrated Photovoltaics (BIPV) playing a central role in achieving these ambitious targets. BIPV technologies, with their dual role as both construction products and energy generators, are poised to become a flagship for European industry. The construction sector, deeply rooted in local traditions, is at a pivotal moment of transformation. While historically grounded in regional practices, the evolving demands of sustainability and refurbishment are driving the need for innovation. For Europe's construction industry, BIPV offers the potential to enhance the sector's competitiveness while aligning with Europe's climate and renovation goals.

Realizing this potential across Europe requires scaling up production, building capacity, and fostering the development of an integrated BIPV value chain. Establishing uniform certification standards, alongside enhanced professional training, will ensure also that BIPV can be deployed widely and effectively.

To achieve this, Europe must focus on three key priorities: scaling up BIPV capacity, establishing a resilient EU value chain, and training a new generation of skilled professionals to drive this transition. With the right support, BIPV has the potential to become the mainstream construction material of the future, contributing to a sustainable and competitive market.

However, to succeed, the integration must maintain strong links to established construction methods and ensure product customization that meets both local and European standards.

For decades, the European market has faced increasing competition from global players. In response, BIPV provides a path to reinforce Europe's industry by fostering demand for innovative solutions, creating new highly specialized professions and industry, and introducing novel skills across the sector. With the recent legislative shift, including the adoption of the EU Solar Standard and ambitious strategies such as REPowerEU, the stage is set for BIPV to evolve from a niche technology to a cornerstone of modern construction.

The 'BIPV Status Report 2024' explores these developments through three chapters:

- → Chapter 1 offers an analysis of the BIPV market dynamics across Europe and Switzerland, supported by real case studies.
- → Chapter 2 assesses how BIPV solutions are perceived by the construction industry, drawing insights from stakeholders across regions.
- → Chapter 3 focuses on mapping the roles of key players, emphasizing the interdisciplinary collaboration needed to integrate BIPV into existing construction workflows.

The 'BIPV Status Report 2024' aims to provide actionable insights and guidance for stakeholders across the industry, from architects and engineers to policymakers and end-users. Through real-world data and case studies, it seeks to facilitate the integration of PV into Europe's construction sector, fostering innovation and ensuring Europe remains at the forefront of the global green transition.

Solar installations are becoming mandatory for new and renovated buildings, but this alone is insufficient. The transition must be primarily cultural, shifting the perception of PV from merely an add-on energy solution to a fundamental, aesthetic element of building architecture. Sustainability must be a project, not a destiny!

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BIPV MARKET STATUS AND DYNAMICS

Despite the promising potential of various market studies, questions persist as to why photovoltaics in architecture remains largely confined to annex systems. Integrated photovoltaic solutions have yet to achieve the volumes that were quantified, hoped for, and at times, overstated in past years (REF 1). Today Europe, in particular, is home to over 90 BIPV manufacturers and products, benefiting from more than 20 years of experience and industrial competitiveness that rivals other regions of the world. This strong foundation positions the BIPV sector for continued growth, even if current market performance is below predictions, ranging 22%-48% under the projections made in the 2020 BIPV Status Report (REF 2). Nonetheless, the sector's potential is vast, and the lessons learned thus far will undoubtedly fuel further innovation and adoption in the coming years.

On the one hand, there is limited awareness among decision-makers in the building process. On the other hand, although the market offer has expanded in recent years, in terms of technology and product variety, it has not yet achieved a social acceptance. This reluctance is partly due to the perceived high costs, which are often not yet seen as justifying the associated risks.

To understand how the BIPV market has evolved, which markets are the most virtuous, to quantify the current end-user price of active cladding and technological systems, as well as to identify stakeholders in the European landscape, a multi-sectoral market analysis is provided in the following sections with a focus on the Swiss BIPV market.

This analysis is continuing the work conducted in past research publications such as BIPVBOOST, a Horizon Europe project focusing on BIPV (REF 3), and is based in part on data collected through the Task 1 of IEA-PVPS, gathered in the Trends in PV applications report (REF 4).

European market

Quantified estimations of past and future BIPV market deployment in Europe are presented in this section. First, a historical review of the market evolution between 2015 and 2023 is provided. A breakdown of the major market countries for the year 2023 is added to provide insight into the dynamics of the European BIPV market. Then, short-term forecasts for the evolution of the European BIPV market are outlined using three development scenarios until 2028. This is completed by an analysis of the possible main market countries in 2028.

Market History

The data presented here is based on an analysis of national PV market databases, whose level of availability and precision widely varies. In addition, countries use different capacity thresholds for the categories of distributed PV installation, as well as different criteria for the definition of BIPV. This complexifies the analysis, and in some cases no distinction of segments or integration level is made at all. Therefore, this quantitative analysis is completed by a qualitative analysis. The latter consists in inventorying BIPV projects and conducting discussions with PV associations, experts, regulators or other market and industry stakeholders to gather insights on their local markets. By cross-checking these data sources, applying a critical analysis and making sound assumptions when necessary, we can provide numbers with an acceptable degree of uncertainty. Still, we advise using these estimations with caution and consider them for what they are: a tool to describe and understand the meta-trends ongoing on the European BIPV market.

The year 2015 marked the end of a blossoming period for BIPV in Europe that started around 2010. This boom was mainly the result of a privileged political support through advantageous incentives in several countries, most notably France and Italy. By 2017, most of these targeted support schemes had been discontinued or merged into larger incentives, including regular rooftop PV, also known as BAPV (building attached PV). As a result, the European BIPV market declined until 2018, when the annual installed capacity is estimated to have fallen under 150 MWp. However, the market picked up from 2019, helped by Switzerland, Netherlands and Germany, where a combination of incentives and a general positive perception of BIPV ensured a solid growth. Other countries such as France, which remained the biggest market despite the change in support schemes, have

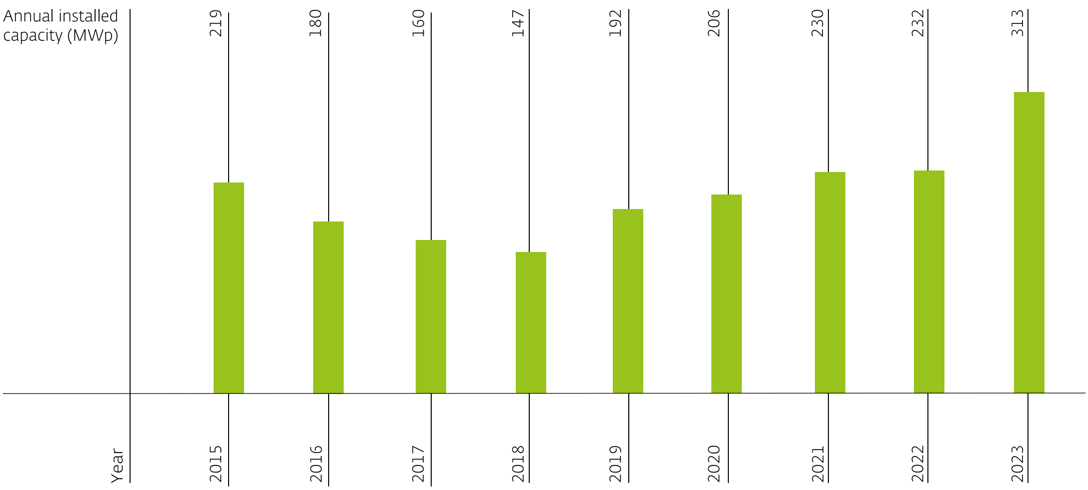

Fig. 1: BIPV market history in Europe (covering EU27+CH+NO+UK). Source: Becquerel Institute.

also showed steady growth in the years 2020 and onwards.
This is also due to the general drop in prices of PV cells and modules (sharply accentuated in 2023), explained by the rapid growth of the PV industry in recent years. The war in Ukraine, the resulting energy crisis and the ensuing political willingness to push for renewables has also contributed to an exceptional year for PV in Europe in 2023. The annual installed capacity in 2023 for BIPV culminated at more than 300 MWp, which represented around 0.5% of the total PV market in Europe in 2023.

France's distributed PV market growth in 2023 has been notable, driven by the residential and commercial sectors. BIPV has been historically omnipresent in the French residential sector, being targeted by advantageous support schemes springing a huge uptake of BIPV solutions. It is worth noting that the French definition for BIPV in the support schemes has included BAPV solutions during a certain period, increasing the number of installations benefiting from the support schemes. (REF 3) (REF 5). These schemes have been slowed down and then discontinued by 2018. However, the French BIPV market has still thrived despite the change in support schemes. Currently, BIPV makes up more than 3% of the French distributed market. As a result, France is the biggest market for BIPV in Europe at present with around 86 MWp installed in 2023.

Austria's PV market has experienced an exceptional growth in 2023, more than doubling its annual installations from 1 GWp in 2022 to around 2,6 GWp. This growth has been largely driven by the distributed market, which accounts for almost 90% of annual installations. Support schemes have played a significant role, with BIPV projects benefiting from greater support. As a result, around 65 MWp of BIPV is estimated to have been installed in 2023, representing just under 3% of the Austrian annual distributed PV market.
Switzerland has had an impressive development of BIPV over the years considering its relative size to countries such as France. Since 2018, both BIPV and attached PV systems have experienced consistent annual growth. Current incentives for BIPV and the increase of electricity tariffs explain the significance of the Swiss market, which has reached more than 60 MWp of installed capacity in 2023.
Germany has also traditionally been one of the main markets for BIPV in Europe, helped by a solid distributed PV market, which has seen a tremendous rise in 2023, reaching 10 GWp. Although the BIPV market itself is not expected to follow the same exponential growth as the whole PV market, it is expected to have grown steadily over the years, reaching between 30 and 40 MWp in 2023.

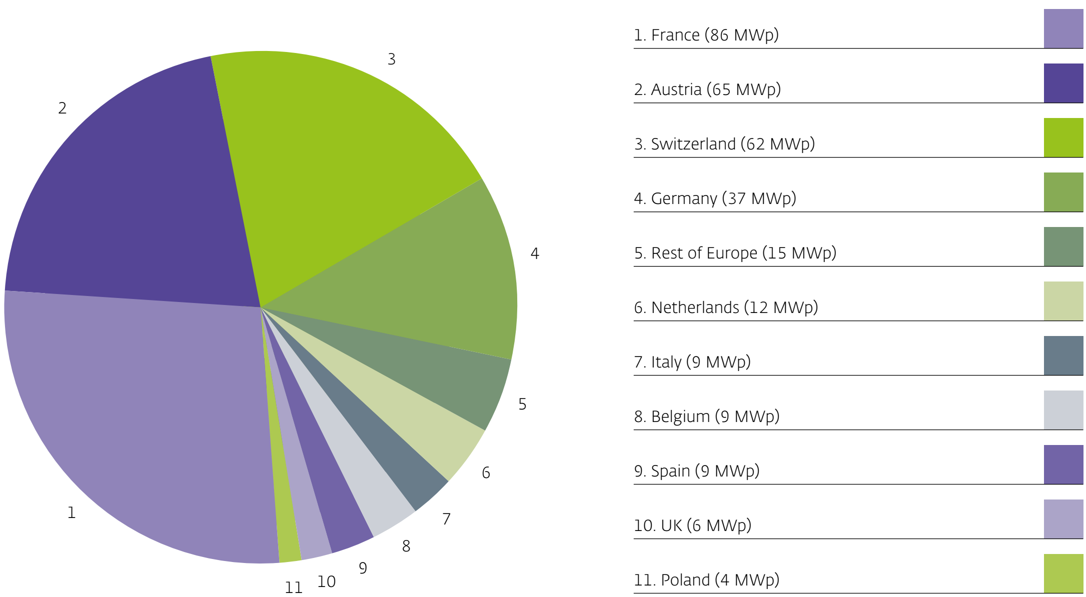

Fig. 2: Breakdown of the main BIPV markets in Europe in 2023. Source: Becquerel Institute.

Netherlands has seen a rapid growth of the BIPV market around 2019, boasting one of the biggest markets for BIPV in Europe at the time. However, in the following years the Dutch market has slowed down, partly due to the public reputation of BIPV being affected by safety incidents. Now, the trust of the public opinion is being rebuilt and the market is expected to start growing again, at a slower but healthier pace, not relying solely on incentives. Between 10 and 20 MWp are estimated to have been installed in 2023.

Italy's total PV market has caught up with France and Netherlands, having installed over 5,2 GWp in 2023, with more than 4 GWp attributed to distributed PV. Similarly as France, it is the residential sector that accounts for a big part of this growth. The share of BIPV is expected to be less than 1% of the distributed market. Whereas it historically has been higher due to specific support schemes, the market is now expected to grow steadily, but at a slower pace compared to the total PV market, which had an exceptional growth in 2023.

Spain's PV market has historically been driven by centralized installations, although more than 1 GWp of distributed PV is installed annually since 2021, a big part of it attributable to the industrial sector, with installations of more than 250 kWp. While it is likely that only a very small part of the industrial sector uses BIPV systems, around 1% of residential and commercial PV systems is estimated to be BIPV. This accounts for an annual market estimated at around 10 MWp.

Belgium's BIPV market has been fuelled by incentives targeted at BIPV in the past, although varying amongst regions (now being mostly discontinued). Today, around 1% of the distributed market is attributable to BIPV. 2023 has seen the annual Belgian PV market double, mainly due to the closure of a regional PV support scheme, resulting in a significant growth in the distributed PV segment. While that peak is expected to be exceptional, the BIPV market is nonetheless estimated to have grown as well in 2023, although to a lesser extent.

The United Kingdom's PV market has been disrupted by the cessation of support schemes, leading to a drop off in installations from 2015 onwards, going from over 4 GWp of annual PV market in 2015 to a mere 0,3 GWp in 2020. It has since been slowly growing again, most probably due to the drop in price of PV modules. Amidst this changing market, BIPV is estimated to have followed the same general trend, accounting for under 1% of distributed installations.

Poland has had a tremendous growth in recent years in terms of PV installations, going from a cumulative installed capacity of just over 1 GWp in 2019, to 17 GWp in 2023, with an annual market of around 5 GWp. Most of this growth has come from the distributed segment. While BIPV is not known to have been a big part of this growth, around 0,1% of the distributed market is estimated to be attributable to BIPV. Recently, however, grid congestion issues have hindered the growth of PV in general.

Market Forecast

Having analysed past trends, it is also valuable to explore future pathways. Forecasting the evolution of the BIPV market is no easy task. Indeed, it is dependent on constraints and forces at play within both the PV sector and the construction sector. Moreover, these constraints can be of multiple natures. One can mention the regulatory environments and their likely evolution. But other factors can be highly influential as well, such as the characteristics of the building stock, the maturity of the BIPV sector or the availability of skilled workforce.

The year 2023 has seen outstanding installed PV capacity in many countries. However, it is expected that not all markets will continue growing at this exceptional pace. For example, as already mentioned, recent grid congestion issues have hindered PV growth in few countries (such as Poland and the Netherlands). To account for this uncertainty, the forecasted annual BIPV market values are presented with a high and low scenario, represented by an error bar in the graph. Short term forecasts are presented for the next five years, up to 2028. The estimated market breakdown between countries is shown in Fig. 4.

Overall, a steady, lasting growth of the European BIPV market is foreseen, which is promising. The growth of the global PV market is benefiting BIPV, which is expected to follow this growth albeit at a lower scale. More importantly, this growth is expected to be healthier than the strong development that occurred over a decade ago, as BIPV deployment should be primarily led by the intrinsic attractiveness

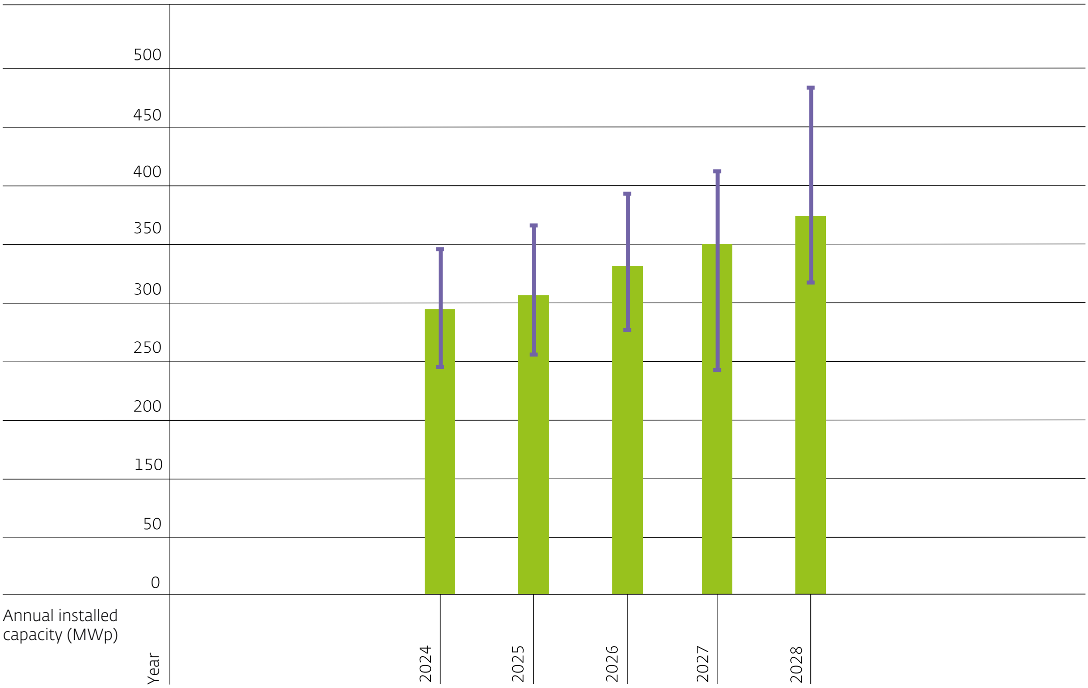

Fig. 3: Short term BIPV market forecast in Europe (covering EU27+CH+NO+UK). Source: Becquerel Institute.

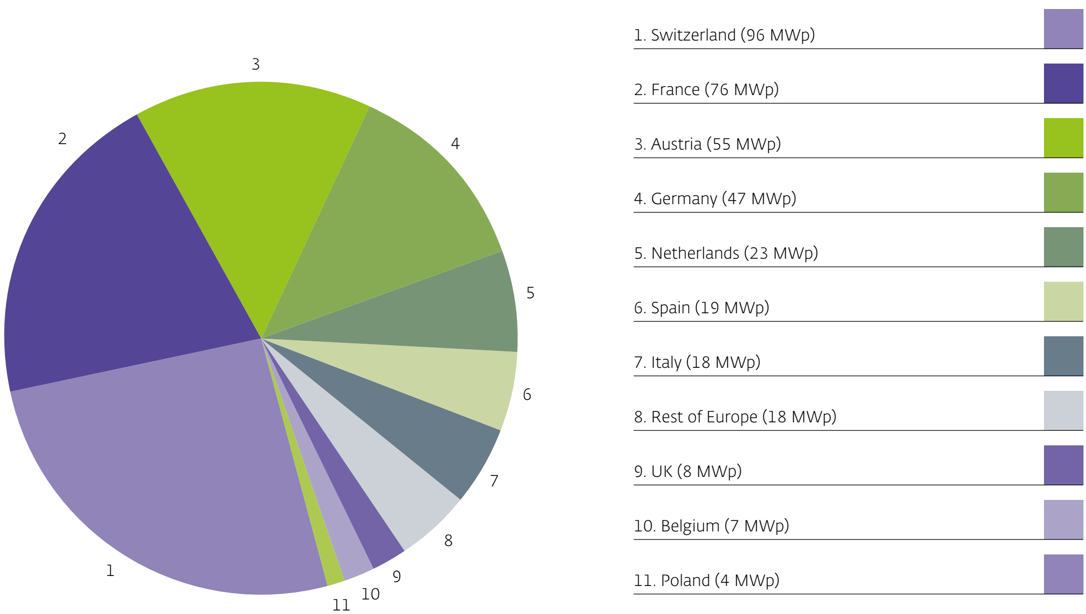

Fig. 4: Breakdown of the forecasted main BIPV markets in Europe in 2028. Source: Becquerel Institute.

of the solutions rather than financial incentives from support schemes. Despite the growth in 2023, not all markets are expected to follow this dynamic in the coming years. To account for this uncertainty, two scenarios ("low" and "high") have been drawn out and are represented with an error bar in the graph, while the main bar chart is the estimated most likely position of the market. The "low" scenarios considers that countries with a historical BIPV market, but which have struggled in recent years, such as the Netherlands and the United Kingdom, will continue to evolve at a slow pace, taking some time to recover their past annual market values. Overall, more countries could start to face grid access and management issues due to the rapid development of renewables, halting the progression of the BIPV and PV market. This could slow down the strides made by some emerging markets such as Poland, which has been subject to those issues. In this scenario, markets with a historically small share of distributed PV (compared to the total PV installations) such as Spain, are not considered to experience a rise in their development pace for BIPV. Finally, although the market is less reliant on incentives, changes in the regulation could still negatively impact it.

On the other hand, although the inertia of the building and construction sector is high, and competing investment strategies still prove to be more cost-efficient in many situations, NZEB regulations could provide a push for BIPV solutions across Europe. In the "high" scenario, countries where BIPV is currently struggling, such as the Netherlands, are expected to recover and grow again to reach their previous levels. Countries with currently low BIPV penetration rates are expected to see growth in this scenario. This may result from the recognition of BIPV's intrinsic advantages and the decreasing cost of PV modules, which could make new business models more viable and sustainable. Furthermore, the development of storage solutions could help limit grid management issues. Finally, the next years might see a political push for PV, with countries taking action to reach their 2030 targets. This could also benefit the BIPV market.

Countries such as France, Switzerland, Germany, Austria, the Netherlands, Spain and Italy are expected to be leading the market penetration of BIPV in Europe in 2028.

20 years of BIPV in Switzerland

According to the European market analysis, Switzerland emerges as one of the most promising markets for the development of solar architectures. As shown in the previous chapter, in 2023, the BIPV installed capacity reached more than 60 MWp, higher than Germany, Netherlands, Italy and Spain for example. The accurate Swiss database of real BIPV installations collected by Pronovo (www.pronovo.ch), provides a reliable overview of the market in the country, which is presented in the following chapter.

More than 200'000 photovoltaic installations, either attached to or integrated into buildings, were sampled between 2005 and 2023. The data refer specifically to PV systems that applied for subsidies from Pronovo. This suggests that even more PV systems may have been installed in Switzerland, both integrated into or attached to the built environment.

It is important to note that the collected data exclusively concern PV systems that are building-integrated or attached, and do not include ground-mounted or off-grid systems. From an initial analysis, the cumulative and annual installed capacity of the two different systems can be deduced, as shown in Fig. 1 and Fig. 2 respectively. The installed capacity of BIPV in Switzerland increased at a compound annual growth rate (CAGR) of approximately 41% between 2006 and 2023, and at an all-time positive CAGR of around 13% between 2018 and 2023. Meanwhile, the installed capacity of attached photovoltaic systems grew at a CAGR of roughly 48% from 2006 to 2023, with a constant positive CAGR of about 40% from 2018 to 2023. Since 2018, both BIPV and attached PV systems have experienced consistent annual growth.

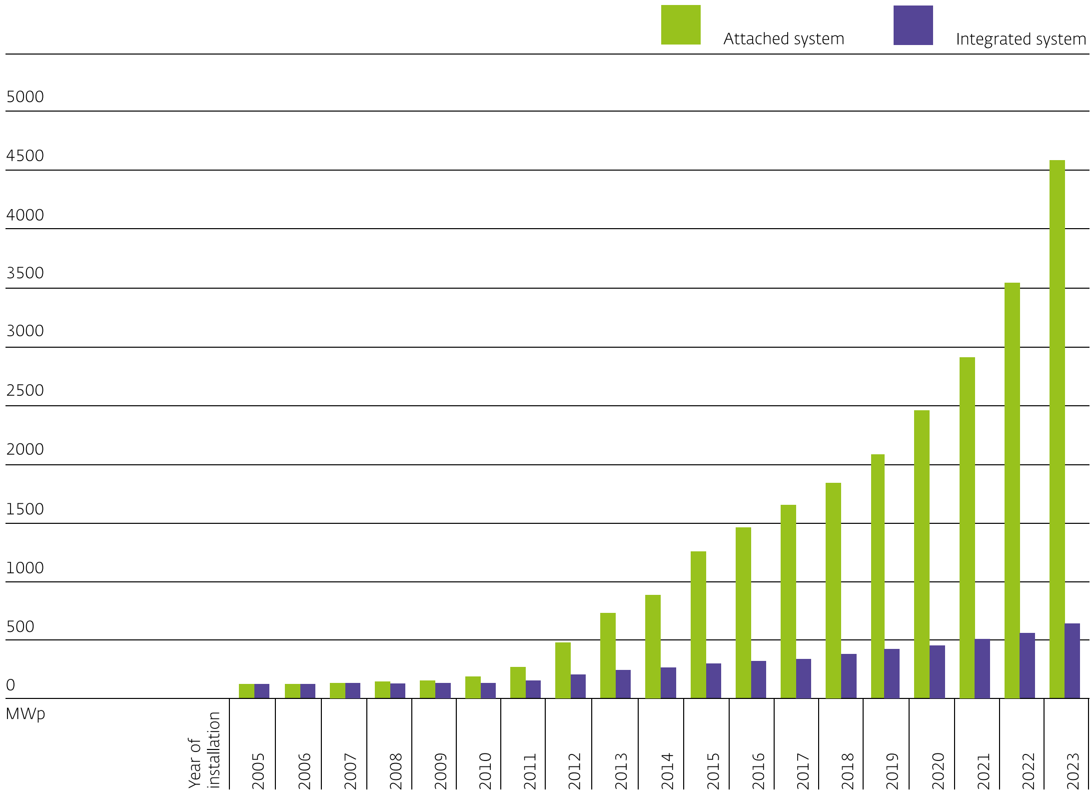

Fig. 1: Annual cumulative installed capacity of attached and integrated systems. Source: SUPSI.

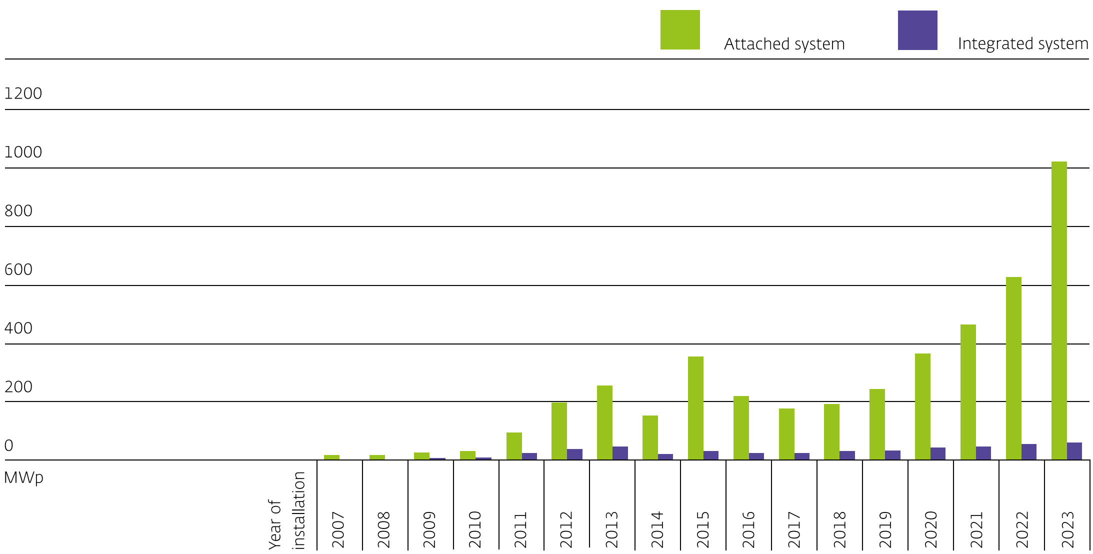

Fig. 2: Annual installed capacity of attached and integrated systems. Source: SUPSI.

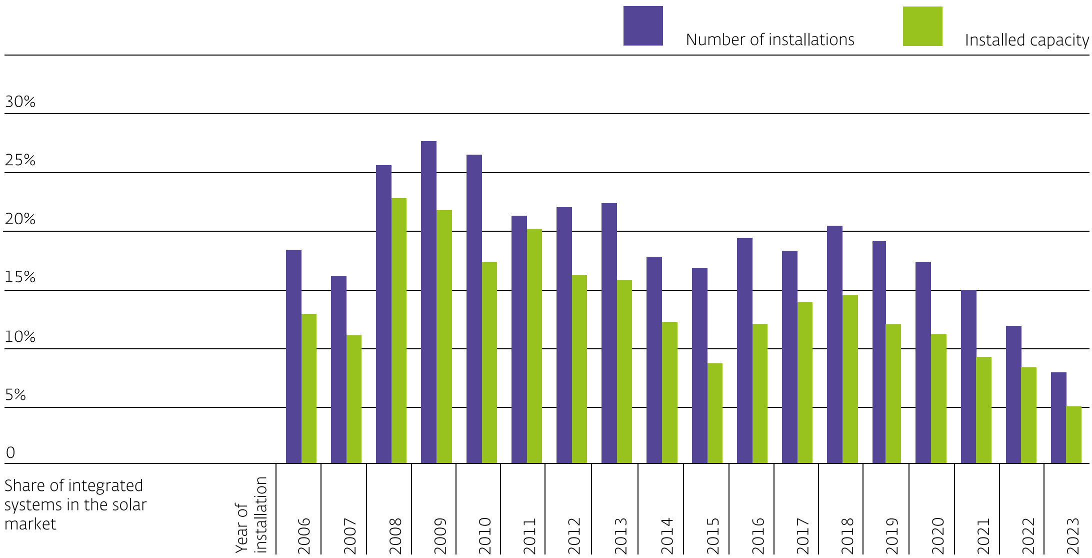

Fig. 3:Annual market share of integrated systems in the building photovoltaic sector (integrated + attached), measured by number of installations and installed capacity. Source: SUPSI

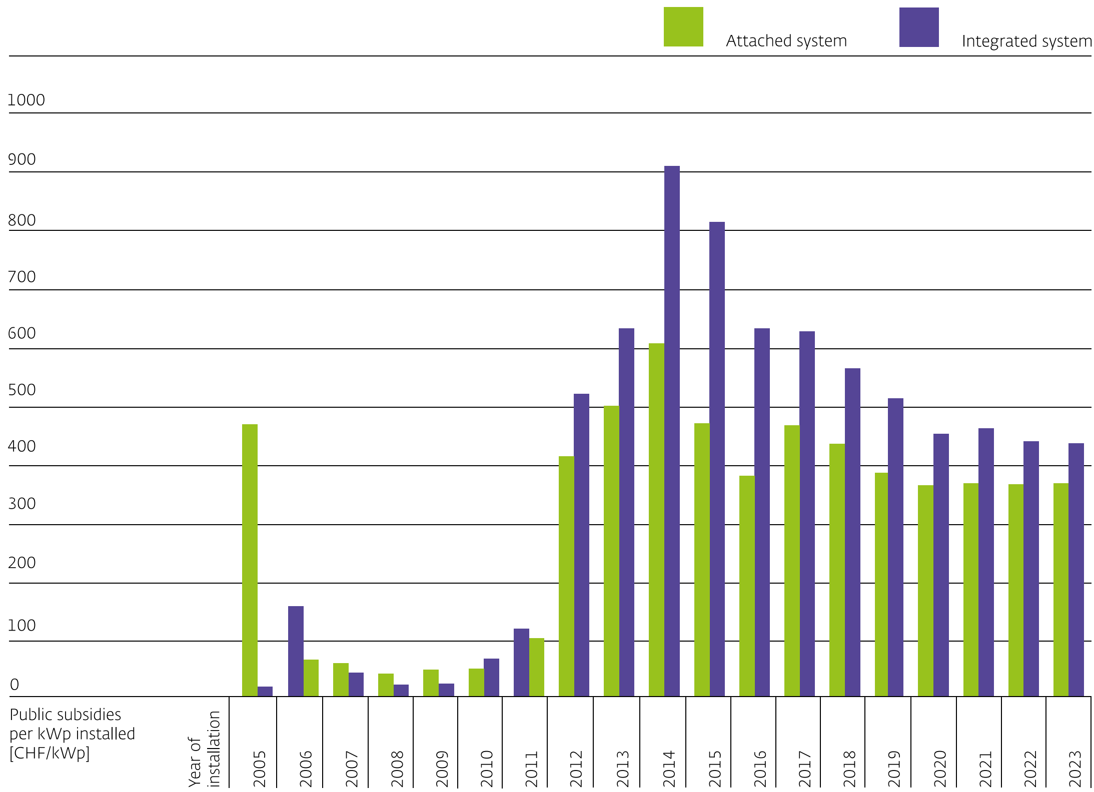

Fig. 4: Public subsidies for annual installed capacity of attached and integrated systems. SUPSI.

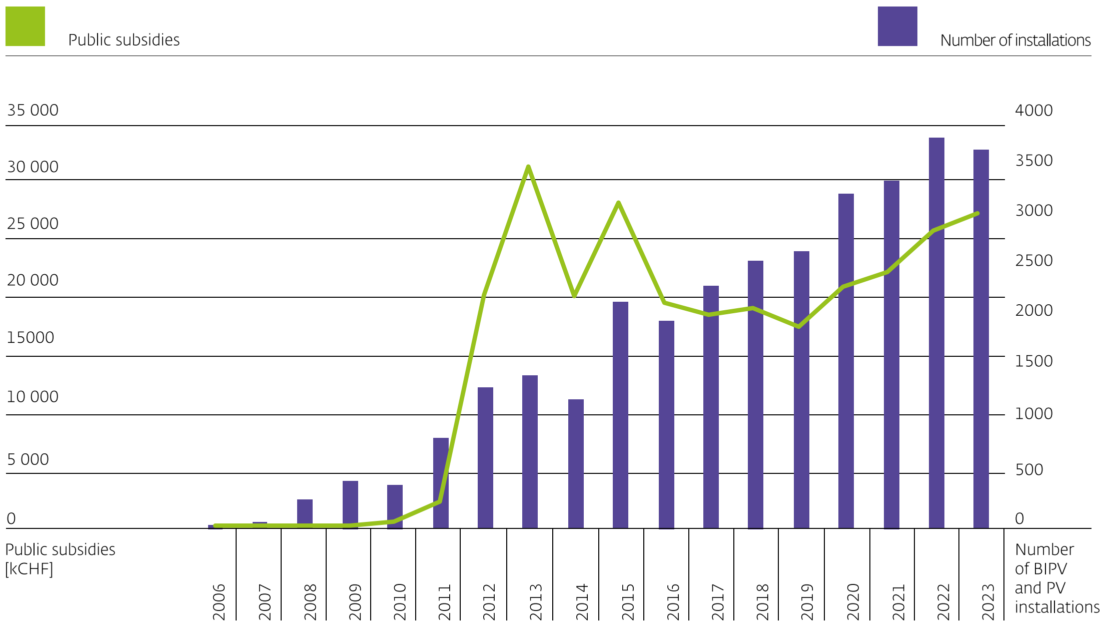

Fig. 5: Combined graph of annual public subsidies and the number of integrated and attached system installations per year. Source: SUPSI.

Fig. 3 shows the share of BIPV capacity and installations relative to the total PV market, which includes both attached PV and BIPV systems, over the years. The peak was observed in 2008, when BIPV capacity reached approximately 23%, and in 2009, when BIPV installations accounted for around 29%. By 2023, with a more solid PV market in the country, BIPV's relative share has declined, contributing roughly 6% of total PV capacity and 8% of installations, with input from the residential, commercial, and industrial sectors.

Fig. 4 illustrates the amount of public subsidies per kWp of BIPV and PV installed capacity. Generally, public subsidies for BIPV systems are higher than those for attached PV systems. Over the past five years, this trend has been stable, with subsidies averaging around 430 CHF/kWp for BIPV and 350 CHF/kWp for attached PV systems.

Fig. 5 depicts the relationship between the total amount of public subsidies and the number of BIPV installations over the years, revealing a clear correlation. When subsidies increase, the number of BIPV installations rises, and when subsidies decrease, the number of installations declines. This underscores the crucial role of subsidies in driving market penetration for distributed solar technology.

Technological systems

1. Discontinuous roof

The cold roof (or shingled roof) typically consists in a pitched/sloped opaque envelope which is known as “discontinuous” due to the presence of small overlapping elements (tiles, slates, shingles, etc.) with the main function of water tightness. It is the part of the building envelope where the PV transfer has had its first successes due to the advantages of optimal orientation of pitches and the easiness of installation.

2. Rainscreen

Well known also as cold or ventilated facade, it consists in a load-bearing substructure, an air gap and a cladding. Usually, PV elements are integrated similarly to non-active building claddings. In summer, heat from the sun is dissipated thanks to the cavity that is naturally ventilated through bottom and top openings. The cold facade is ideal for enhancing rear ventilation. Many constructive models and technological solutions are available on the market, also with various joints and fixing options.

3. External integrated devices

Transparent or opaque multi-functional and photovoltaic solar shading devices (louvers or inter-pane Venetian blinds) for facades or balustrades with the role of “fall protection” that are necessary for the safety of the building (e.g. in balconies, loggias, parapets). Transparent or opaque shading devices for roofs aimed to select the solar radiation. Integrated canopies, greenhouses and verandas.

4. Skylight

It is a light-transmitting building element that covers all or a part of the roof. They are typically semi-transparent for daylight purposes with additional thermal, acoustic, waterproof functions when protecting an indoor environment.

Alternatively, it serves mainly as a shelter if protecting outdoor (non heated) areas (atriums). They can be fixed or openable and retractable.

5. Curtain wall

They are external, not ventilated and constitute continuous building skin fenestration systems, totally or partially glazed, composed of panels supported by a substructure in which the outer walls are non-structural. A curtain wall is designed to resist air and water infiltration, dividing outdoor and indoor environments, and is typically designed with extruded aluminium frames (but also steel, woods, etc.) filled with glass panes. The facade should satisfy multiple requirements, such as load-bearing function, acoustic and thermal insulation, light transmission, waterproofing, etc. and can be realized according to different construction systems such as Stick-system, United curtain wall, Structural Sealant Glazing (SSG), Pointfixed or suspended facade. In their most basic form, they are windows, while in more complicated forms they can be used to realize complex double skin facades.

6. Prefab system

It is typically a unitized and pre-assembled multi- functional element installed on the facade or on the roof, composed of the PV cladding, protective layers and the substructure. Polyvalent components are able to satisfy more than a single technological requirement in a unitized way. Off-site manufacturing of building envelope can result in advantages in terms of process efficiency, installation time, cost, quality and safety management. These systems can also be integrated in massive walls/roof (e.g. masonry walls).

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End-user price

The price associated with using photovoltaics in architecture are frequently discussed, as they are still perceived as a highly innovative solution by many stakeholders, including architects, building owners, and decision-makers. However, when viewed as a building material, photovoltaics stands out as possibly the only one that can offset its own price over its lifespan through energy generation (REF 6).
Unfortunately, the promotion of photovoltaics in architecture often reduces it to a mere solar panel whose sole purpose is electricity production. This narrow perspective overlooks the additional value of photovoltaics as a multifunctional architectural component.

It is crucial to recognize photovoltaics not just as an energy producer but as an integrated building material that offers a range of benefits beyond power generation.
To clarify market price, the following sections will provide a comprehensive overview of the end-user price associated with both active cladding systems and entire building systems. A clear distinction will be made between the price of cladding materials, sourced directly from manufacturers, and the price of final technological systems installed on the building envelope, which are based exclusively on data from existing case studies.

End-user price of photovoltaic cladding

A photovoltaic cladding system refers to the outermost photovoltaic layer of a building's envelope, encompassing both facade and roof systems, as well as external elements like parapets, balustrades and canopies. The Fig. 1 illustrates the end-user price for various photovoltaic cladding. These values were derived from a survey conducted among European BIPV manufacturers, aimed at cataloguing the range of products available on the market that are manufactured, assembled, or laminated in Europe, while also analysing current pricing trends in the BIPV sector. The survey collected data for 35 BIPV products, based on a minimum order size of 100 m^2. Additionally, the degree of customization for each building skin technology was assessed, considering variations in colour,size, and shape. This allowed for a comparison of similar components (e.g. Discontinuous roof customized is colour and size versus not customized solutions).

The results reflect the average, minimum, and maximum end-user price for individual photovoltaic cladding:

→ Rainscreens, discontinuous roofs, and roof tiles: The end-user price covers only the cladding, excluding back rails and substructure.
→ Prefabricated systems: the end-user price includes both the insulating element and the substructure.
→ Curtain walls and skylights: The end-user price includes photovoltaic laminated glass.

External devices such as canopies, balustrades, and parapets are excluded from this analysis due to insufficient data. Special claddings, such as shading devices, are excluded from this analysis because it is impractical to identify their cladding components as standalone elements. For all claddings, end-user price does not include transportation, from the BIPV factory to the end-user, or taxes, which may differ by country.

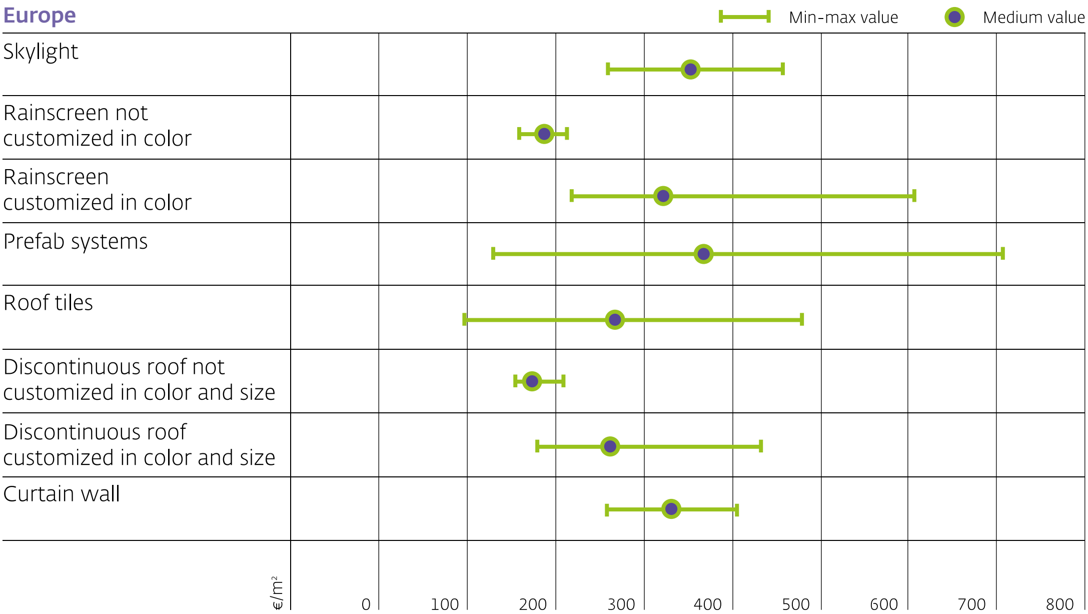


Fig. 1: Photovoltaic cladding end-user price. Source: SUPSI.

End-user price of photovoltaic technological systems

This section presents the end-user price associated with a complete technological system installed as building envelope. The BIPV system's end-user price represents the price for the entire BIPV-based building envelope solution. This includes not only the BIPV modules themselves (which serve as the building's outer skin and cladding) but also all other components necessary for anchoring and mounting the building skin system, ensuring its full functionality, safety, and compliance with regulations (primary and secondary structure). For example, in the case of a rain screen facade, this would involve cladding, frames, fixing clamps, and load-bearing anchors. The system end-user price also covers electrical components such as cabling and inverters (BOS), as well as soft end-user price like labour for construction and electrical installation (installation), design/engineering, and all the other end-user price.

The end-user price data were carefully collected from 54 European case studies and projects, both completed and ongoing. In particular, 16 case studies are from Switzerland, 15 from Benelux, 9 from Scandinavia, 5 from France, 5 from Italy/Spain and 4 from Germany/Austria. This includes information from stakeholders on projects completed after 2019. For statistical analysis, a minimum of three case studies was required, with most items analysed using data with more than three case studies. Consequently, end-user price data are provided only for technological systems in Europe and Switzerland (see Fig. 2 and Fig. 3). The cost breakdown is presented at the European level (see Fig. 4-8). Note that the end-user prices do not include transportation expenses, which can vary by country.

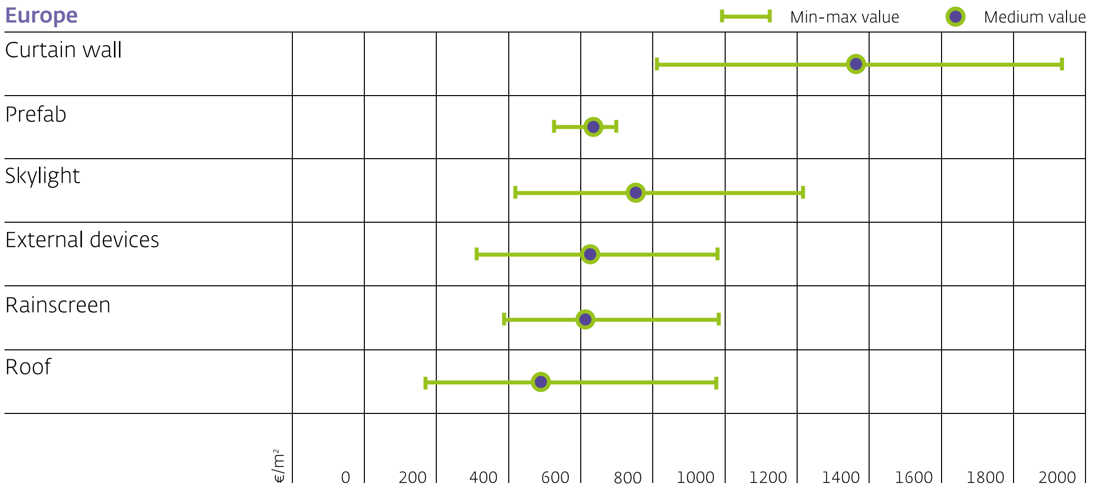


Fig. 2: Technological system end-user price in Europe.

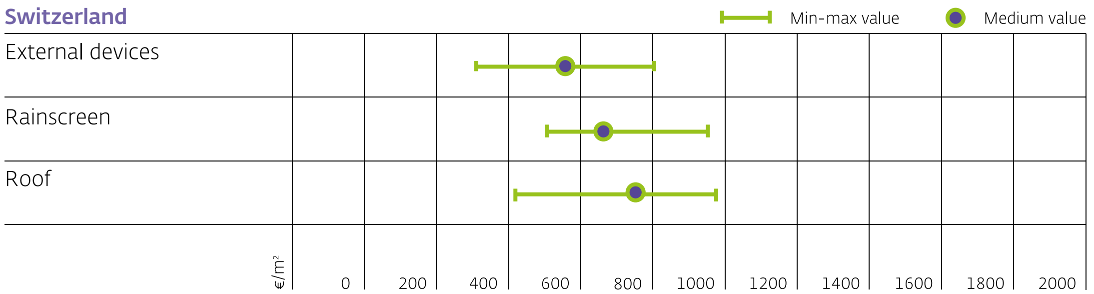


Fig. 3: Technological system end-user price in Switzerland.

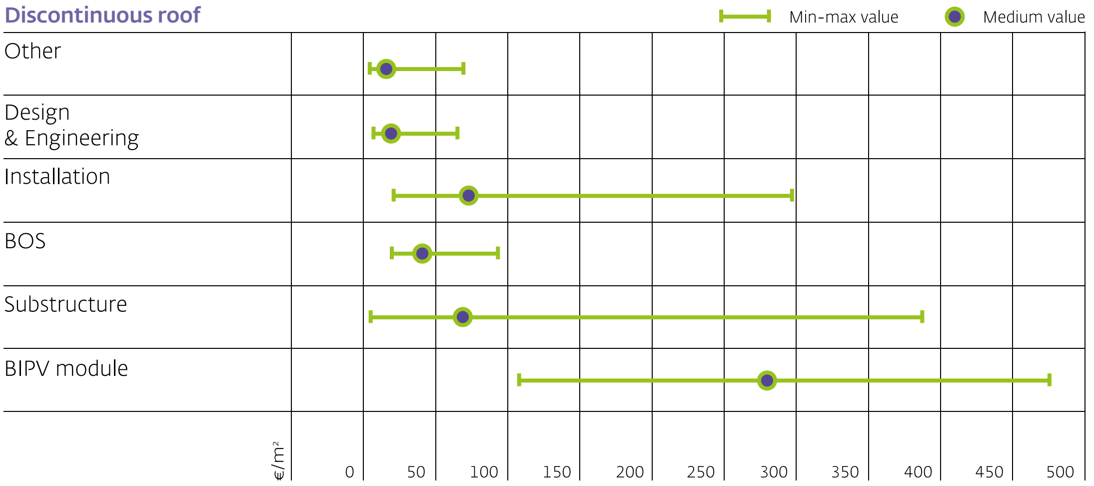


Fig. 4: Discontinuous roof end-user price breakdown in Europe.

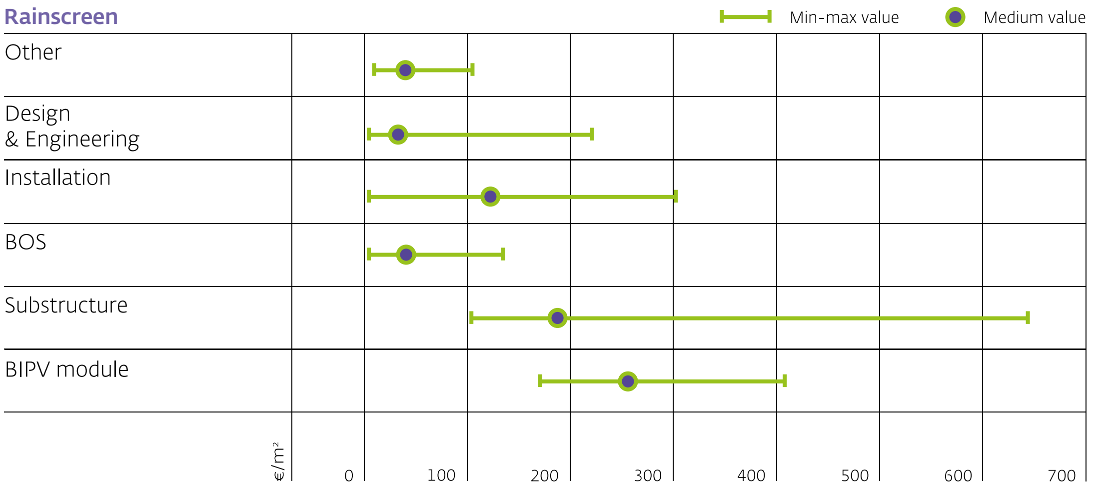


Fig. 5: Rainscreen facades end-user price breakdown in Europe.

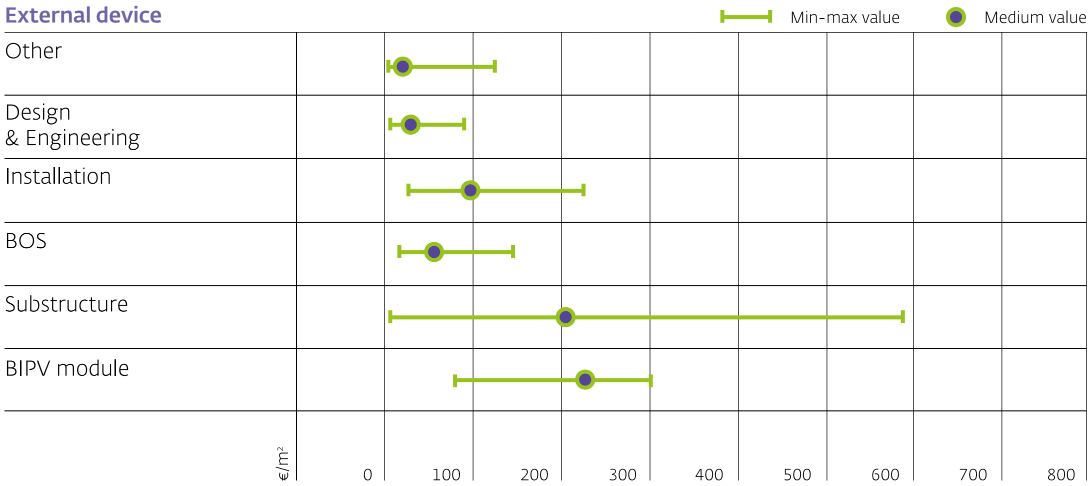


Fig. 6: External devices end-user price breakdown in Europe.

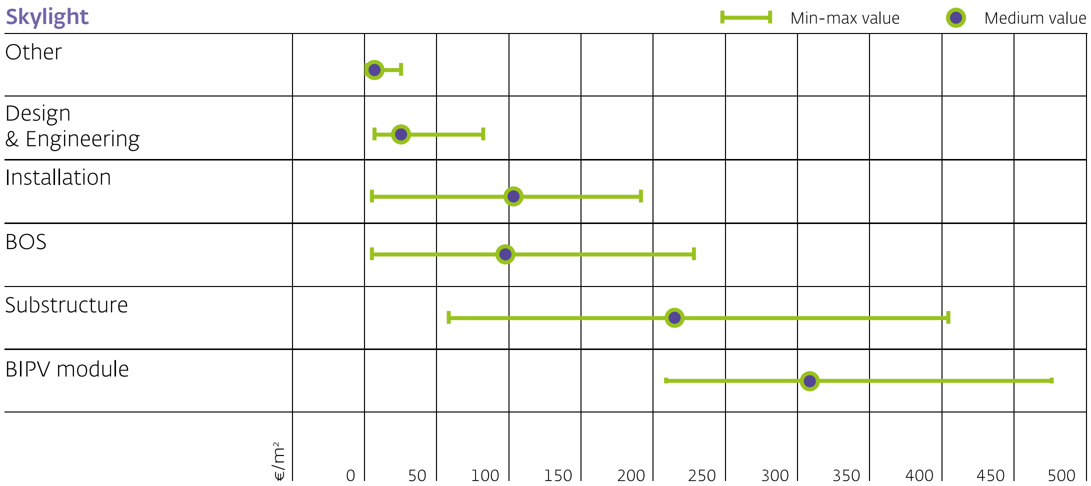


Fig. 7: Skylight end-user price breakdown in Europe.

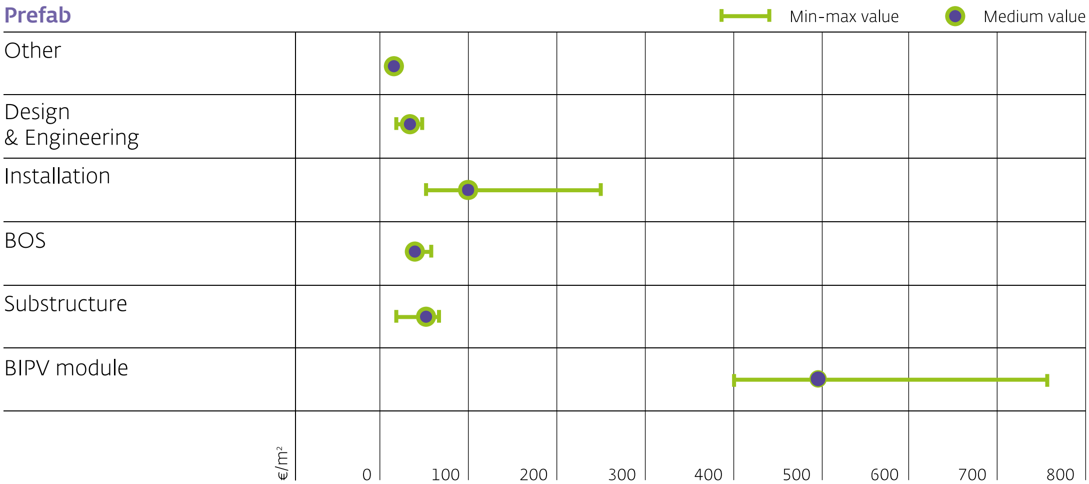


Fig. 8: Prefab systems end-user price breakdown in Europe.

Industry and products

Manufacturers are key drivers in the development of BIPV technology and can play various roles in the decision-making process for BIPV project applications. Their main focus is on producing high-quality, attractive products for clients and investors, while also ensuring compliance with regulatory standards for BIPV adoption. The following sections offer an overview of the European BIPV market, segmented by country and technological system, highlighting available products and key industry players. The section concludes with a list of European BIPV manufacturers and their contact information.

To obtain an overview of the situation of the BIPV market in Europe, in-depth research was conducted to identify the main BIPV manufacturers on the continent, exploiting web resources and contacts with sector partners. A total of 98 manufacturers operating on the European market (covering EU-27, United Kingdom, Switzerland and Norway) in the upstream part of the BIPV value chain were listed between March and August 2024. The companies analysed are those involved in the production of cladding and, therefore, the customized photovoltaic semi-finished products.

The selection criterion was to identify all manufacturing companies that had their headquarters in a European country with some or all production activities carried out within the continent.

However, we recommend using these estimates with caution and considering them for what they are for this report's scope: a tool to describe and understand the meta-trends ongoing on the European BIPV market.

The 98 BIPV manufacturers were identified and categorised by country (location of headquarters), year of foundation and type of cladding for a specific technological system. These manufacturers were analysed to produce graphs in an aggregated and completely anonymous manner. In particular, Fig. 1 shows the distribution of BIPV manufacturers across Europe, with reference to the location of their headquarters. It is immediately evident that Italy hosts the largest number of manufacturers, followed by Switzerland, Netherlands and Germany. The remaining countries have fewer and fewer manufacturers.

BIPV EU Manufacturers

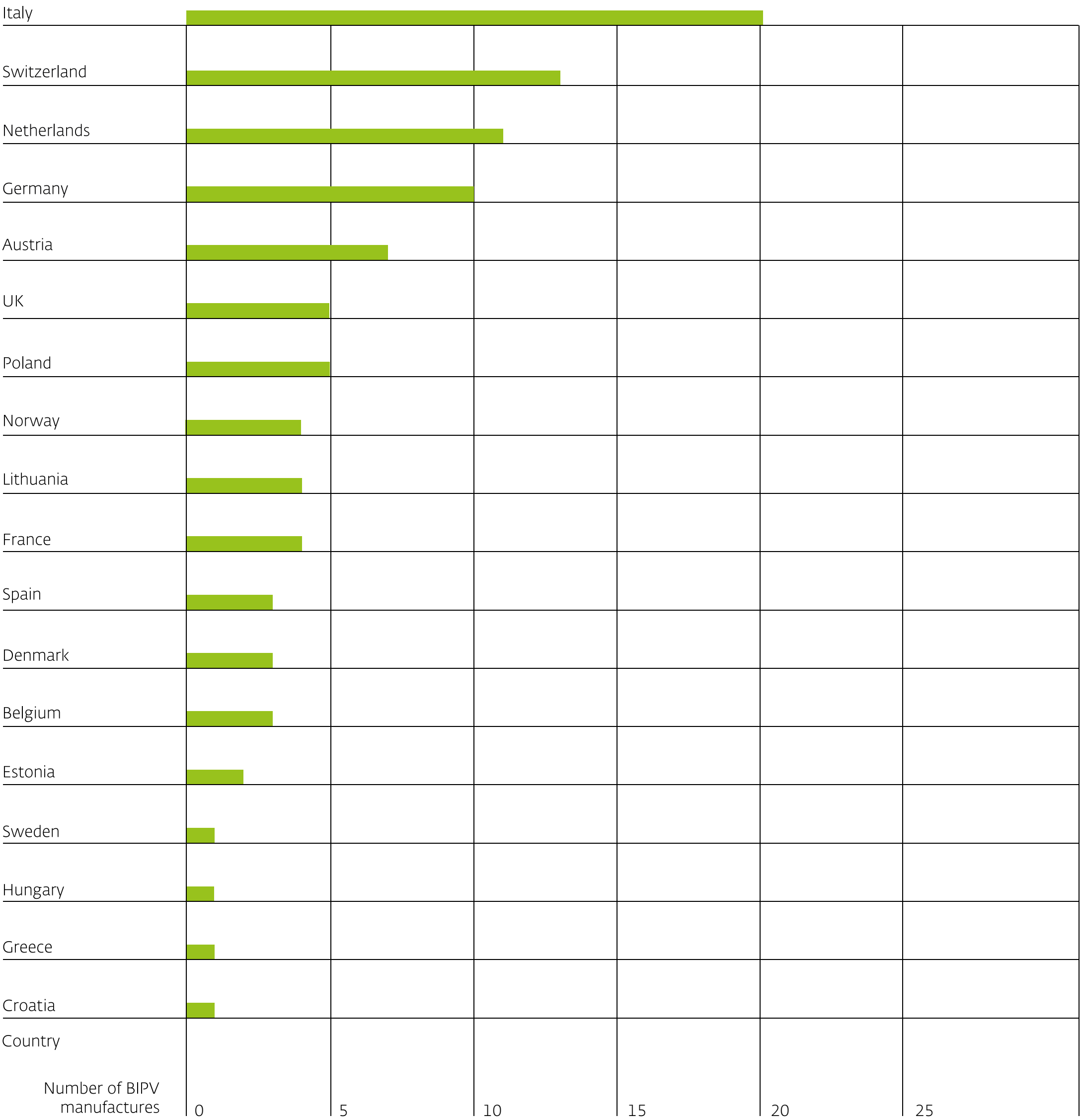


Fig. 1: Distribution of BIPV manufacturers across Europe. Source: SUPSI.

The identified BIPV manufacturers concentrate their activity in roof-integrated technology systems, specifically 46% of the total, almost half of the listed BIPV manufacturers. Instead, a smaller number of manufacturers are focused almost equally on integrated facade systems and other integrated systems (e.g. parapets, sunshades, canopies, etc.), relatively 29% and 25% of the analysed manufacturers, as shown in Fig. 2.

Fig. 3 displays the exact number of BIPV manufacturers analysed across individual European countries, grouped by macro-category. Notably, slightly more than half of the manufacturers—55 in total—do not specialize exclusively in a single macro-category ("Roof," "Facade," or "Other") but operate across multiple categories. Only 43 of the 98 BIPV manufacturers analysed are specialised in a single macro-category of integration. This means that for the realisation of the Fig. 2 and Fig. 3, the same manufacturer may have been taken as a reference for more than one macro-category and this inevitably affects the values shown in the graphs.

Indeed, it is possible that in some countries, the BIPV manufacturers on the market offer a wider range of technological solutions, covering more than a single macro-category of integration, and this leads to a clear numerical difference between these countries and the others in Fig. 3.

On the other hand, Fig. 4 shows the percentage incidence of the individual micro-categories within the macro-categories of BIPV integration which are shown and described in previous chapters. As before, it should be specified that a single BIPV manufacturer may be present several times within the same macro-category. Therefore, by way of example, in the manufacturers belonging to the macro-category of roof-integrated systems ("Roof"), a single manufacturer may be present more than once since it is possible that it covers both "Discontinuous roof" and "Skylight" and/or "Prefabricated roof" etc. Likewise, it is possible that the same manufacturer also deals with integrated facade systems and/or integrated external systems, in which case it will also be present in more than one macro-category.

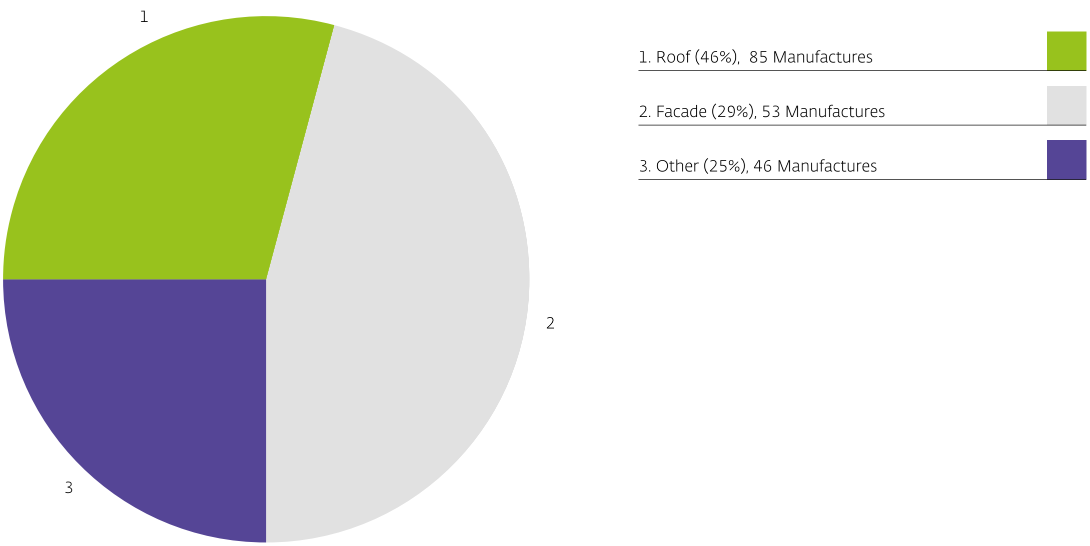


Fig. 2: Distribution of BIPV manufacturers' products across Europe: Source: SUPSI.

BIPV EU Manufacturers sector

Fig. 3: Macro-category of integration per EU country. Source: SUPSI.

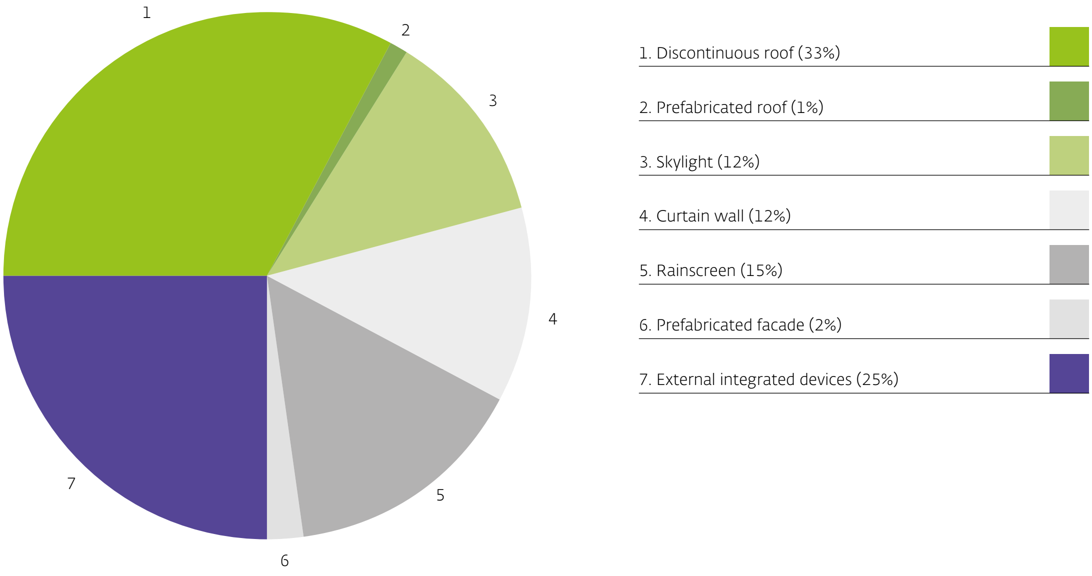


Fig. 4: Percentage incidence of the individual micro-categories within the macro-categories of BIPV integration. Source: SUPSI.

To gain a deeper understanding of the European BIPV industry's evolution, it is helpful to analyse Fig. 5. The figure presents two key metrics: the number of new European BIPV companies established each year (in blue) and the total number of active European BIPV companies per year (in green), accounting for both ongoing operations and closures. It was not possible to find out with sufficient reliability the year of foundation and/or the year of start of activity in the field of BIPV for all 98 companies, so a sample of 81 companies from which this information could be obtained was taken as reference.

Additionally, 11 companies that are no longer in business (bankrupt, acquired by other companies, etc.) were added to the analysis, bringing the total number of sample companies to 92. What is striking at first glance is certainly the higher concentration of companies founded in 2007 and 2012, with a higher number of companies born in the middle years between 1998 and 2023.

BIPV EU Manufacturers per year

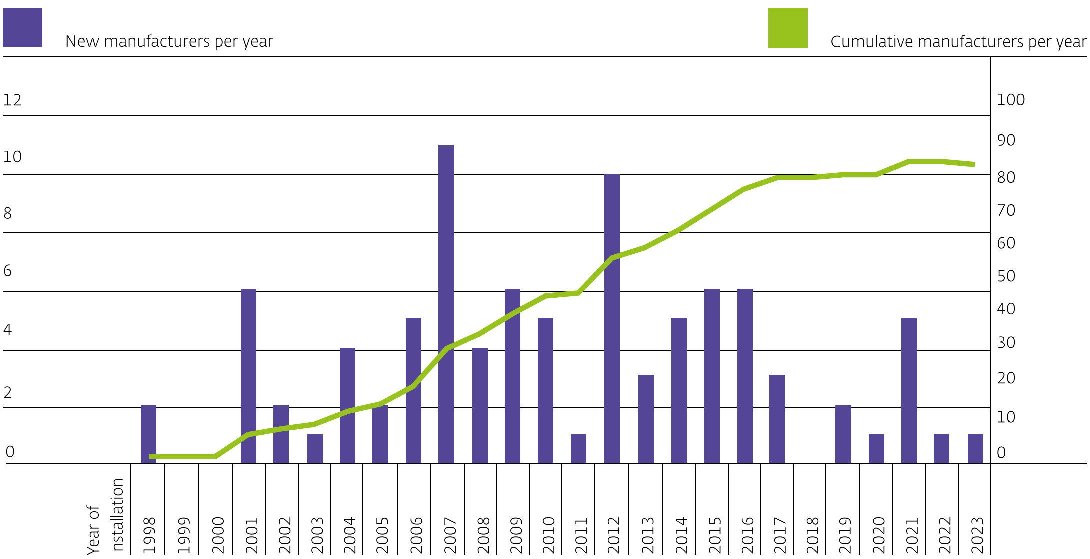


Fig. 6: Number of new and cumulative BIPV EU manufacturers per year. Source: SUPSI.

European BIPV manufacturers database

3S Swiss Solar Solutions (CH)	www.3s-solar.swiss
AGC - Active glass (BE)	www.agc-activeglass.com
ACTIV'GLASS Issol Schweiz (CH)	www.activ-glass.com
Aleo Solar (DE)	www.aleo-solar.com
Antec Solar (DE)	www.antec-solar.de
Apollotech (NO)	www.apollotech.no
Asca (DE)	www.asca.com
Autarq (DE)	www.autarq.com
Avancis (DE)	www.avancis.de
AxSun Solar (DE)	www.axsun.de
AZETA 23 (New Roof) (IT)	www.tegola-solare.com
BIPV Production of Norvegia (NO)	www.bipv.no
BIPVco (UK)	www.bipvco.com
BMI Group (UK)	www.bmigroup.com
Brandoni Solare (IT)	www.brandonisolare.com
Colt (UK)	www.coltinfo.co.uk
D.A.Glass (PL)	www.daglass.pl
DAS Energy (AT)	www.dasenergy.com
Dyaqua (IT)	www.dyaqua.it
Eclipse Italia (IT)	www.eclipseitalia.com
Edilians (FR)	www.edilians.com
EigenEnergie.net (myenergyskin) (NL)	www.myenergyskin.nl
ElectroTile (PL)	www.electrotile.com
Ennogie (DK)	www.ennogie.com
Ernst Schweizer (CH)	www.ernstschweizer.ch
Ertex Solartechnik (AT)	www.ertex-solar.at
Fly Solartech Solutions (CH)	www.flysolartechsolutions.com
Freesuns (CH)	www.freesuns.com
Gasser Ceramic (CH)	www.gasserceramic.ch

Gielle Plast (Giellenergy-tile) (IT)	www.giellenergy-tile.eu
Glass to Power (IT)	www.glasstopower.com
Heliatek (DE)	www.heliatek.com
Hermans Techniek (Hermans Technisolar) (NL)	www.hermanstechnisolar.com
Industrie Cotto Possagno (IT)	www.cottopossagno.com
INHAUS Group (SST Energy) (AT)	www.sst-energy.com
Innos (NO)	www.innos.no
Intelligent Solar (LT)	www.intelligentsolar.eu
Invent (IT)	www.inventsrl.it
IWIS Group (Tegola Canadese) (IT)	www.tegolacanadese.com
Izpitek Solar (ES)	www.izpiteksolar.com
Kalzip (DE)	www.kalzip.com
Kameleon Solar (NL)	www.kameleonsolar.com
Kromatix (CH)	www.kromatix.com
Lenzing Plastics (AT)	www.lenzing-plastics.com
Marley (Viridian Solar) (UK)	www.viridiansolar.co.uk
Megasol Energie (CH)	www.megasol.ch
MetSolar (LT)	www.metsolar.eu
MGT-esys (AT)	www.mgt-esys.at
Midsummer (SE)	www.midsummer.se
ML System (PL)	www.mlsystem.pl
OET - Organic Electronic Technologies (EL)	www.oe-technologies.com
Onyx Solar Energy (ES)	www.onyxsolar.com
Peimar Industries (IT)	www.peimar.com
Pixasolar (NL)	www.pixasolar.com
Polysolar (UK)	www.polysolar.co.uk

PREFA Aluminiumprodukte (AT)	www.prefa.at
Roofit Solar Energy (EE)	www.roofit.solar
Saule Technologies (PL)	www.sauletech.com
Smartroof (BE)	www.smartroof.be
Sol R&D (NL)	www.sol-rnd.com
Solar Cloth System (FR)	www.solar-cloth.com
Solar Innova (ES)	www.solarinnova.net
Solarix (NL)	www.solarix-solar.com
SolarLab (DK)	www.solarlab.global
Solaronix (CH)	www.solaronix.com
Solarstone (EE)	www.solarstone.com
Solartag (DK)	www.solartag.eu
Solaxess (CH)	www.solaxess.ch
Solbian Energie Alternative (IT)	www.solbian.eu
Solinso (NL)	www.solinso.nl
SoliTek (LT)	www.solitek.eu
Solskifer (NO)	www.solskifer.no
Soltech (BE)	www.soltech.be
Soluxa (NL)	www.soluxa.solar
Solvis (HR)	www.solvis.hr
Sonnenkraft (KIOTO Solar) (AT)	www.sonnenkraft.com
Sottile Solar (IT)	www.sottile.solar
SOYPV - Soleil sur Yvette Photovoltaïque (FR)	www.soypv.com
SPS istem (IT)	www.spsistem.com
Stafier (NL)	www.stafier.com
STG Group (Energyglass) (IT)	www.energyglass.gruppostg.com
S'Tile (FR)	www.silicontile.fr
Sunage (CH)	www.sunage.ch
Sunerg Solar Energy (IT)	www.sunergsolar.com
Sunovation (DE)	www.sunovation.de
Sunspeker (IT)	www.sunspeker.com
SunStyle (CH)	www.sunstyle.com
Swisspearl Group (CH)	www.swisspearl.com
Terran Rooftile Manufacturer (HU)	www.terranteto.hu
Trienergia (IT)	www.trienergia.com
TULiPPS Solar (NL)	www.tulipps.com
Union Glass (IT)	www.unionglass.it
ViaSolis (LT)	www.viasolis.eu
XDISC (Activesol) (PL)	www.activesol.energy
Zecca Group (Piz) (IT)	www.piz.it
Zentrale Solarterrassen & Carportwerk (DE)	www.solarcarporte.de
Zigzagsolar (NL)	www.zigzagsolar.nl
Zurich Soft Robotics (Solskin) (CH)	www.solskin.swiss

Case study analysis: Veterinary Hospital La Trinità, Cadempino, Switzerland

Project: deltaZERO | Image: L. Carugo

Building and system description

The architecture office deltaZERO in Lugano, Switzerland designed a veterinary hospital building that is 80% covered with BIPV modules. This innovative envelope and the building technologies has the ability to power basic heating, cooling, ventilation and lighting systems. Inside its structure are: an external air filtration system, water-water reversible chillers with a high-performance water well, solar collectors, solar panels that cover the entire building and produce electricity. A generator which, in the event of an electrical fault, can keep the structure running for 7 days without the need for external energy.

These technologies, combined with the structure's optimal insulation and triple-glazed windows, enable sustainability and energy efficiency to be achieved, ensuring a harmonious balance between innovative architecture and responsible care of our planet. The building energy certification is Minergie-P (code: TI-278-P) The BIPV technology systems are colored glass/glass rainscreen facade modules, flat walkable roof, terrace roof, canopy and balustrade BIPV modules that are covering a 643 m2 area and results in nominal installed power of 86 kWp. This installation should produce around 80 MWh of solar electricity per year with annual yield of 935 kWh/kWp.

System features

Building typology	-	Veterinary hospital building
Technological system	-	Rainscreen facade, Flat walkable roof, Terrace roof, Canopy, Balustrade
Active cladding surface	m^2	615
Non active surface	m^2	181
Orientation	°	West; East; South, North
Tilt	°	90 (facade and balustrade) 5 (canopy) 0 (roof)
Nominal power	kWp	86
System power density	Wp/m^2	140

Product features

BIPV typology	-	Glass-glass with coloured front glass (facade and roof)
PV technology	-	Glass-glass FullBlack (balustrade)
Cladding specification		Mono c-Si PERC
Manufacturer of BIPV modules		Glass/Glass, 46.2, 66.2, 1010.2, 1212.2 laminated safety glazing types
Model of BIPV module		Activ'Glass Issol Switzerland ltd.
Customization in size	-	Yes
Customization in colour	-	Yes

Energy features

Energy production (Simulated)	kWh/yr	80691
Final yield	kWh/kWp	938
Energy demand	kWh/yr	N.A.
Self-consumption	%	N.A.
Self-sufficiency	%	N.A.

Cost competitiveness

Business model	-	Swiss Mini-Energy building scheme, reduced energy bill to occupant, client image, government incentives
Value self-consumed electricity	cts€/kWh	28
Value injected electricity	cts€/kWh	11

Project: deltaZERO | Images: L. Carugo

REQUIREMENTS FROM CONSTRUCTION SECTOR

Our primary goal is to promote active collaboration between the photovoltaic sector and the building industry by highlighting essential requirements for BIPV products and providers, along with key factors that will enable the smooth integration of PV technology into buildings. The primary objective of this undertaking is to focusing on illustrating to BIPV manufacturers the market appeal of BIPV solutions from a perspective of the construction sector.

The analysis is based on a survey conducted as part of the "Mass Customization 2.0 for Integrated PV" (MC2.0) European project (ID 101096139). It involved 34 interviews and 45 stakeholders across 13 different regions or markets. Further details about the methodology and the breakdown of the stakeholders interviewed can be found in the referenced research (REF 1). The Fig. 1 delineates the correlation between the requirements from the construction sector (BIPV product, BIPV provider and key driver) and the stakeholder who referenced them in the interview.

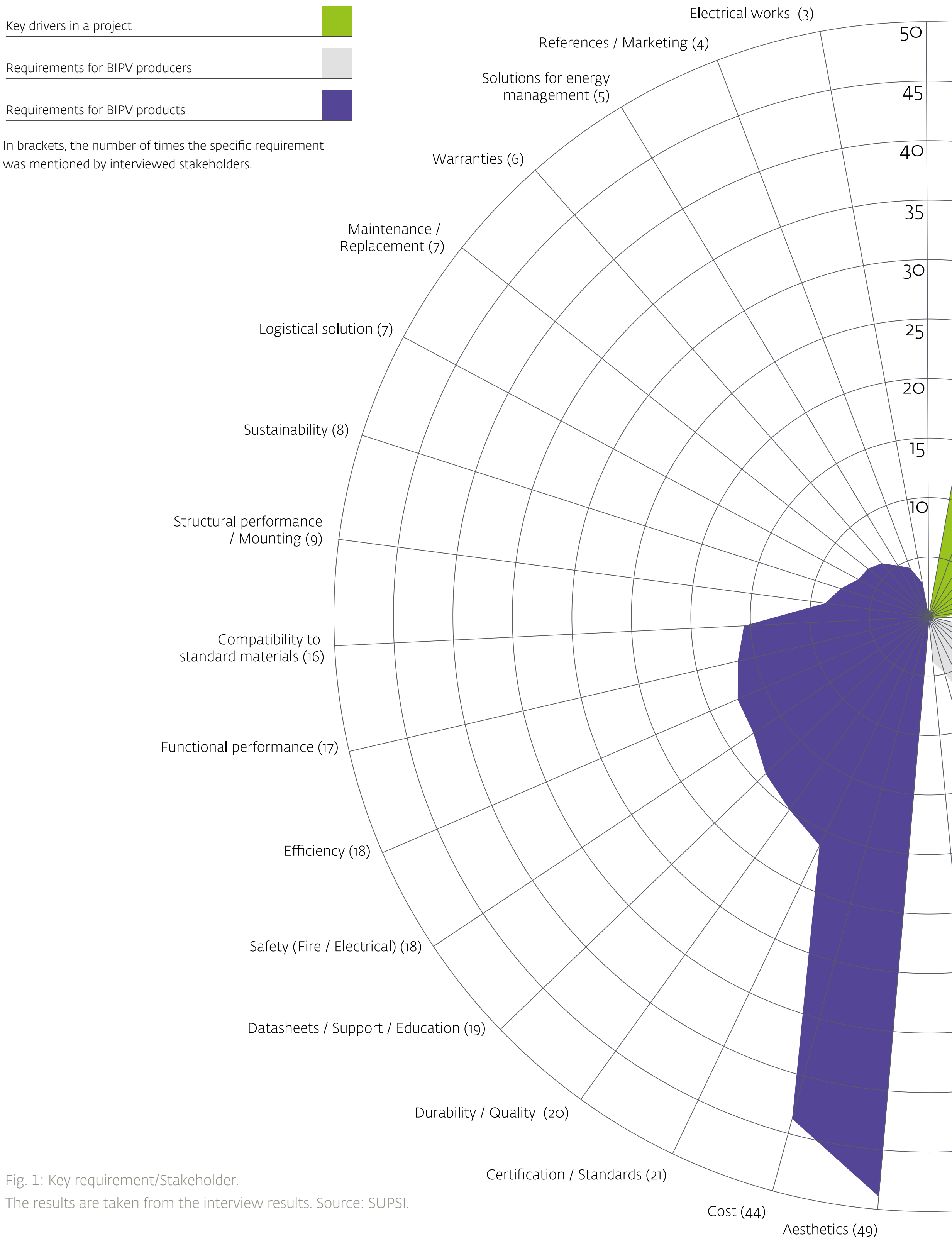


Fig. 1: Key requirement/Stakeholder.
The results are taken from the interview results. Source: SUPSI.

Sustainability (20)
Energy targets (17)
Corporate / Client Image (14)
Economical motivation (14)
Incentives / subsidies (8)
Building standards (8)
Innovation (4)
Design objective (4)
Technical superiority
of BIPV to standard materials (1)
Give trust to the market (22)
Adequate business
model / visibility (18)
High level expertice (16)
Clear product offering (15)
Support (14)
Commitment to education (9)
Delivery terms (5)
Commitment
to susainability (4)

Requirements for BIPV products

Among the 34 interviewees, a thorough analysis identified 17 distinct product requirement categories. The most frequently mentioned requirements included aesthetic considerations for BIPV products, cost, certification, regulatory standards, durability, and quality. Additional factors such as data sheets, support and education, as well as electrical and fire safety, efficiency, functional performance, and compatibility with standard construction materials were also emphasized. Furthermore, interviewees highlighted varying levels of importance on structural performance, sustainability, logistical solutions, maintenance and replacement needs, warranties, energy management solutions, references, marketing strategies, and cabling solutions.

A key product requirement circle was identified and shown in Fig. 2, which involves an iterative optimization process to achieve acceptable cost, functional performance and design compromises. The process of BIPV design and integration into a building involves a set of compromises, that every stakeholder has to make, which can look as for example – increased cost, due to increased aesthetic performance, but reduced energy output, due to not optimal shapes and coloured front glass, thus longer ROI, etc. The goal of a BIPV designer is to find the optimal point and/or stop the iteration process at some point where the global compromise is acceptable to all stakeholders involved in the design and decision-making process. And in the design of a BIPV product case, the weighting factors for BIPV product requirements are based on the number of times a certain requirement was mentioned in an interview process.

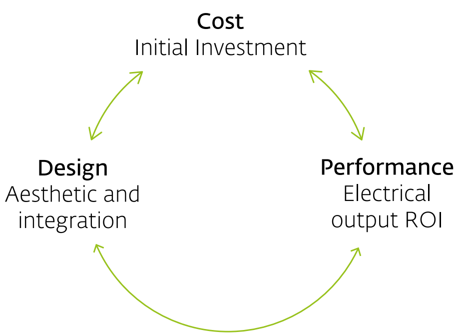
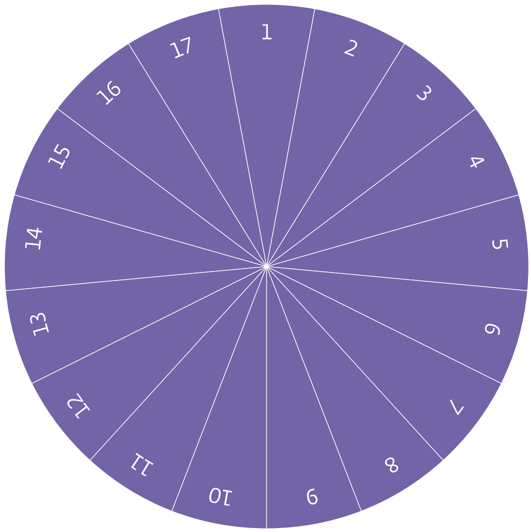


Fig. 2: A “requirement circle” for BIPV product as identified by the interviewees. Source: SUPSI.



Product requirement 1: Aesthetics

Aesthetics of BIPV product is the key requirement as highlighted by interviewees. The parameters that define the aesthetics are: colour and visual perceptions; shapes; size flexibility; formats; solutions for dummies; texture of material; customization ability; design flexibility; fit in with the global design of the envelope.

Product requirement 2: Cost

The interviewees highlighted the cost as the second most frequently mentioned parameter. However, it is crucial to recognize that the expectations regarding cost vary significantly depending on the type of stakeholder, geographical location, and the specific technology involved. It's important to note that the data gathered primarily reflects the expectations of the stakeholders. It is noteworthy that a significant portion of the interviewees referenced cost without providing explicit details on the acceptable Return on Investment (ROI) or the perceived value. The determination of an acceptable cost by end customers is influenced by complex, interconnected factors and requirements. Consequently, the decision-making process regarding what constitutes an acceptable cost is intricate and multifaceted. Some precise statements in no particular order were as follows:

→ Cost at 200 €/m² only for BIPV glass (Facade designers, USA market, Facade cladding);
→ Cost of <0.4 €/Wp (Architect, Benelux and France markets, general BIPV products, glass/back sheet modules);
→ Key parameters are €/m² and €/Wp (PV/BIPV engineer/installer, market CH, BIPV products);
→ ROI around 7-8 years for cladding (Developer, BIPV system owner, Norway, Facade cladding);
→ ROI within the time line of the product (25-30 years) (Structural/Facade engineer, German market, BIPV facade products);
→ ROI <50 years (Sustainability/PV/BIPV engineer, Canada, General BIPV products);
→ Energy and cost paybacks within 10 years (Developers, Canada, General BIPV products);
→ For Facade – cost increase two times to standard PV is acceptable (PV/BIPV installers/engineers, Norway, general BIPV products);
→ ROI <12 is acceptable (PV/BIPV installers/engineers, Norway, glass/glass BIPV facade);
→ Cost – max double to a standard glass facade (General contractor/ Facade installer, Scandinavia, Glass/glass BIPV facade);
→ ROI of standard PV materials (Architect, Canada, General BIPV products).

Product requirement 3: Certification, Code requirements and Standards

The third most common requirement according to the survey is the compliance of the PV products to adequate IEC standards and certifications. The requirement to comply with regulations related to building norms, like safety glass and other is mandatory. The outcome of the survey is a count of various requirement mentions by stakeholders. The product compliance to adequate norms and standards is mandatory. However, for innovative BIPV products to enter the market or be accepted by construction value chain, as is observed from the survey results, it is not a key requirement. Basically, if the product does not satisfy aesthetic and cost requirements of the stakeholders in a project, the conformity to codes is not going to have the adequate impact to product appeal.

Product requirement 4: Durability and Quality

This requirement is essentially a conclusion of the functional and structural compliance to norms, which is an expectation of the BIPV product to have adequate durability, mechanical stability, UV resistance, adhesion quality and comparable to standard construction materials lifetimes or at least >15 years. The key observation is that, for example, if a product that satisfies IEC norms for photovoltaic modules, potentially might not achieve a necessary durability and quality requirements expected for a premium building envelope material. This is indeed a psychological parameter, since the motivation to use a BIPV material on a building envelope is not always rational, but rather emotional. If a client is ready to pay for a premium material, the expectation is to receive a premium product, not simply a solution that "complies to norms".

Product requirement 5: Data sheets, Support and Education

This requirement group includes product technical data, like data sheets, mounting instructions, good brochures, to be cross-confirmed in the construction value chain, to be inserted in standard collaborative design platforms, ability to obtain samples quickly, and high level of technical support.

Product requirement 6: Fire and Electrical safety

Safety, a critical parameter within the Code Compliance (Product requirement 3), has been intentionally singled out due to the significant emphasis on fire and electrical safety in BIPV products by the interviewees. The intricacies of fire safety standards (local regulations) pose a multitude of inquiries from both project developers and clients, necessitating dedicated attention as a separate requirement. Fire and Electrical safety requirements must be addressed for any BIPV product. Indeed, the module safety is covered by IEC norms. However, building designers, facade engineers and other stakeholder that deal with risk management in a construction project, tend to put extra caution on materials they have no experience with. A BIPV product is still a niche solution, and education, clarity and high-level support is important, when dealing with inexperienced stakeholders in a construction project to be able to provide the necessary support to eliminate the real and "imagined" risks that are caused by BIPV product nature.

Product requirement 7: Efficiency

The survey indicates that electrical efficiency is not a top priority for BIPV products. Indeed, a short payback period depends on the product's cost-effectiveness and energy output.

Product requirement 8: Functional performance

The key functional requirements are adequate thermal performance, water tightness, handling of loads, ventilation anti-glare, and transparency.

Product requirement 9: Compatibility to standard materials

BIPV products require simplicity, compatibility with standard construction materials, ease of installation, functionality as genuine building materials, the ability to be installed by standard qualified labour, and clearly defined responsibilities during the installation process.

Product requirement 10: Structural performance and Mounting

This requirement group is specifically highlighted by interviewees, underscoring the importance of the product's ability to be easily mounted without imposing additional responsibilities or supplementary tasks. The emphasis is on leveraging common knowledge within the construction industry.

Product requirement 11: Sustainability

Sustainability includes a good carbon paybacks, at least within 2-3 years and recyclability.

Product requirement 12: Logistical solution

Logistical solution, which covers the necessity to manage the quality of logistics and prevent damage during the delivery process and mainly good delivery terms that are acceptable in construction industry.

Product requirement 13: Maintenance and Replacement

The need to get replacement or spares of the BIPV product and ability to adequately maintain the installed BIPV system on a building is mentioned during the interview process.

Product requirement 14: Warranties

The acceptable warranties depend on the market and normally approved depending on the local construction material standard warranty conditions. For example, in Norway a 5-year warranty is accepted, since this is a standard construction industry warranty period. In other places, minimum 12 years is needed.

Product requirement 15: Solutions for energy management

This requirement pertains to the management of on-site renewable electricity production, which is also applicable to standard PV installations. It primarily involves the need for effective monitoring and the ability to implement electricity management solutions, such as energy storage, maximizing self-consumption, peak shaving, and integrating energy-generating building materials into the overall building operation strategy.

Product requirement 16: References and Marketing

Cultural acceptance in the target market is important, with a mention that the project origin plays a role in that.

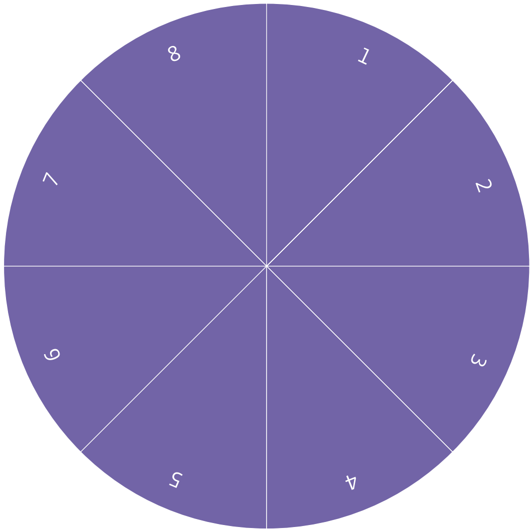
Product requirement 17: Electrical works

This requirement is a part of a global integration strategy. The electrical works can become problematic, if the stakeholders in the project do not have the right team to execute the project or the provider of the product is not able to adequately support to construction consortium within the project.

Requirements for providers

Unlike standard photovoltaic systems, the value chain for construction projects involving active building materials is significantly broader and more diverse. It includes many of the same stakeholders involved in traditional building envelope execution, but with an important distinction: each participant must acquire additional knowledge about photovoltaic technology and its implications.

The BIPV product supplier, in particular, must have a deep understanding of both the PV and construction industries to provide value. This includes specialized knowledge of photovoltaic systems and a solid grasp of construction project processes. According to the survey, the most frequently cited factors for success include "building market trust," "having an appropriate business model," and "possessing high-level expertise."



Provider requirements 1: Give trust to the market

The survey results indicate that the primary requirement from the construction value chain is the ability to establish trust in the market. The key factors for achieving this are as follows:

→ Brand reputation in the market
→ Financial stability
→ Ability to demonstrate the value of their product
→ Demonstrate the ability to give warranty, support and replace products in case of failure
→ Be part of a reliable consortium with a digital strategy
→ Enter the market either with a known reliable partner or an excellent value proposition

Provider requirements 2: Adequate business model and Visibility

A BIPV company should incorporate the following key parameters:

→ Operate like a standard construction company and engage the appropriate stakeholders during marketing and commercial phases
→ Implement effective marketing and communication strategies
→ Consider integration with a larger construction product company
→ Adopt a suitable approach to product applicability, leading to a strong value proposition

Provider requirements 3: High level expertise

This group includes the following key requirements according to the survey:

→ Targeted high-level expertise, like in facade, project management, energy or photovoltaic fields
→ Ability to propose high range of services related to BIPV, construction or project management fields
→ Ability to consult on high range of technical problems, due to the nature of the BIPV produces (power, building physics, safety, lighting, thermal, energy, etc)
→ High level of understanding of their product performance, testing, certification, innovation.
→ Ability to manage solutions, cost, risks and give trust to stakeholders

Provider requirements 4: Clear product offering

The requirement to have a clear product offering is related to ability to demonstrate high level and clear technical information about their products, like data sheets, technical specs, exist in databases, catalogues and be referred in the industry.

Provider requirements 5: Support

This requirement, as emerged from the interview, is in principle an emphasis on the expertise of the BIPV product supplier. The main requirements are basically to participate in the project as a key interface between BIPV industry and standard construction companies, bridging the gaps between technical understanding limitations of non-expert stakeholders. Also, support can be delivered in digital tool development, interfaces or plug-ins in standard tools used in construction industry, ability to give on-site support, installation manuals.

Provider requirements 6: Commitment to education

According to the interviewees input, the main means of the "commitment to education" is:

- → Education of the construction value chain
- → Production of reports on best cases with long term performance data
- → Exposure of the state-of-the-art BIPV knowledge to central organization in the construction value chain and other
- → Exist in central databases accessible to companies and used by architects and specifiers.

Provider requirements 7: Delivery terms

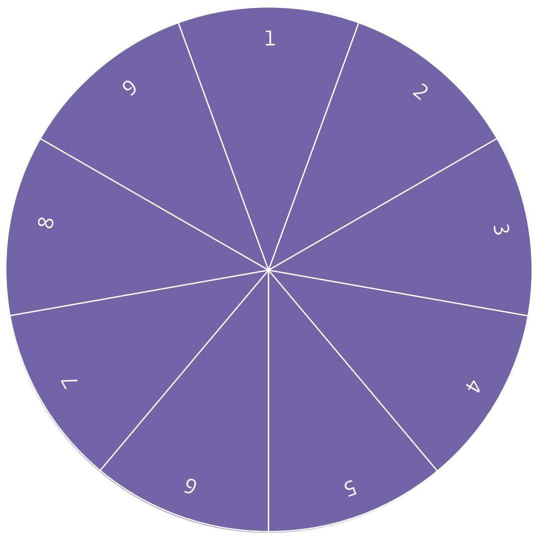
A separate requirement for the companies is the ability to guarantee stable, precise and reliable delivery terms for products, samples and replacement. Different markets, projects and technological solutions require different lead times. It is important to be able to guarantee these delivery terms, which in turn is hinting towards the size of the producer requirement.

Provider requirements 8: Commitment to sustainability

The last requirement group based on the amount of mentions in the survey is the producers Commitment to sustainability. This is presented in a form of ability to provide Environmental Product Declaration (EPD) statements, Life cycle analysis and give reliable environmental data of the product. It is requested that a local producer would be prioritized in these kinds of projects.

Key drivers in a project

The interviewees provided insights based on their prior experiences with BIPV or other construction project developments, as well as their theoretical and practical knowledge. The key driver groups, are categorized by the frequency with which they were mentioned during the interviews. A key driver in a project is defined as the primary motivation for stakeholders to consider or adopt a BIPV product. This includes all product and producer requirements, ranging from technical specifications to support quality.



Key driver 1: Sustainability

According to the survey results, interviewees identified sustainability, CO2 emission reduction, green certifications, low-carbon construction, climate change, and corporate responsibility as key drivers for BIPV projects. Although these factors are among the least cited requirements for products and producers, they represent a promising trend, indicating that the construction industry is increasingly recognizing the importance of low-carbon materials in their operations. The challenge now lies with producers and designers to align their offerings with this driving force and effectively demonstrate that current BIPV solutions truly deliver low carbon footprints.

Key driver 2: Energy targets

The energy target group covers the on-site electricity production parameter, which results in electricity savings, fossil fuel consumption offsets and contributes to Net-Zero targets. High on-site renewable energy production is basically a key tool for the decarbonisation of the construction sector.

Key driver 3: Corporate and Client Image

The main requirement mentions are corporate image, brand image, green washing. This is also a marketing statement for a facade company or a facade installer, to be able to demonstrate that they have the necessary competences to work with advanced envelope technologies as a sign of high-level qualification and problem-solving capabilities for potential future or current demand.

Key driver 4: Economical motivation

The economical motivation stands basically for ROI's. Other drivers in this category are:

→ Marketing means – which is free electricity to potential renters
→ Increased value of the building or assets in the real estate portfolio
→ Increased profitability due to lower operating costs
→ Reduction of rent to potential renter due to lower operating cost. The market drivers of the solar panel market and the BIPV market are quite different. The motivations of the customers are different as well as the profitability horizon of investors. While investors in solar panels will look for a return on investment in the order of 8 to 12 years, real estate investors using active building materials will base their decision on increased profitability due to lower operating costs and a higher value of their assets on the real estate market.

Other market drivers are listed below:

→ In some cases, higher energy standard buildings worth more, which encourages real estate developers to opt for solar-powered building
→ Financial markets turn green as a result of societal changes and the integration of environmental costs into financial models
→ Corporate social responsibilities foster demand for green and local energy generation
→ Active building materials offers superior aesthetics and creates brand image
→ Energy positive buildings generate revenue and attractive cost/effectiveness

Key driver 5: Incentives and subsidies

Incentives and subsidies are an important support that allows to influence decision makers and investors.

Key driver 6: Building standards

The "building standard" covers the following drivers:

→ Laws and regulations promoting sustainability and energy efficiency;
→ Investment in higher quality building to counter the increasing regulations in the future
→ BREEAM ratings (Building Research Establishment Environmental Assessment Method)
→ Higher standards and codes for building construction
→ The main motivation of project developers is not always to produce electricity with BIPV. Their need is more about compliance with standards on the energy efficiency of buildings. A building that complies with current standards or already complies with future standards is a building that has a better value on the real estate market. The increase in value of an active building is greater than the cost of the investment to make it active.

Key driver 7: Innovation

The driver in this case is the objective to have a modern building, to use an innovative product and in some cases the architects are curious to apply an innovative material.

Key driver 8: Design objective

The key drivers in the "design objective" category include:

→ The use of glass envelopes in building concepts
→ The pursuit of net-zero buildings or specific design statements that inform project objectives
→ Client requests for architects to incorporate glass or BIPV, with some architects specializing in BIPV as a value-added proposition

Key driver 9: Technical superiority of BIPV to standard materials

An honourable single mention of the aesthetic superiority of an active building material is the least mentioned driver in a BIPV project.

Case study analysis:
Portalen, Dammen, Norway

Image: Lund+Slaatto Arkitekter

Building and system description

An office building called Portalen was designed by architect Lund + Slaatto and built by a developer Union Eiendomsutvikling AS in Drammen, Norway in 2021. The BIPV facade consists of brown coloured modules: 857m² are active and 503m² dummy modules. The active part results in 88 kWp nominal power that should produce around 60 MWh per year of solar electricity from facades. The building also has a roof installation of standard PV modules witch results in total annual yield of around 100 MWh per year. The facade surfaces are kept in a reddish colour palette in various gradations. This is continued in the treatment of the front glass for the crystalline PV modules, which excellently complements the metallic and glass surfaces of the building through various reflections. A fine texture also appears on the surface when lit by the sun. The result impresses through the integration of the photovoltaics as part of an elegant facade concept. The project received an award by the jury of the "Architecture Award Building-Integrated Solar Technology 2022".

System features

Building typology	-	Commercial
Technological system	-	Rainscreen facade
Active cladding surface	m^2	857
Non active surface	m^2	503
Orientation	°	East & South (active) West & North (dummies)
Tilt	°	90
Nominal power	kWp	88
System power density	Wp/m^2	102

Product features

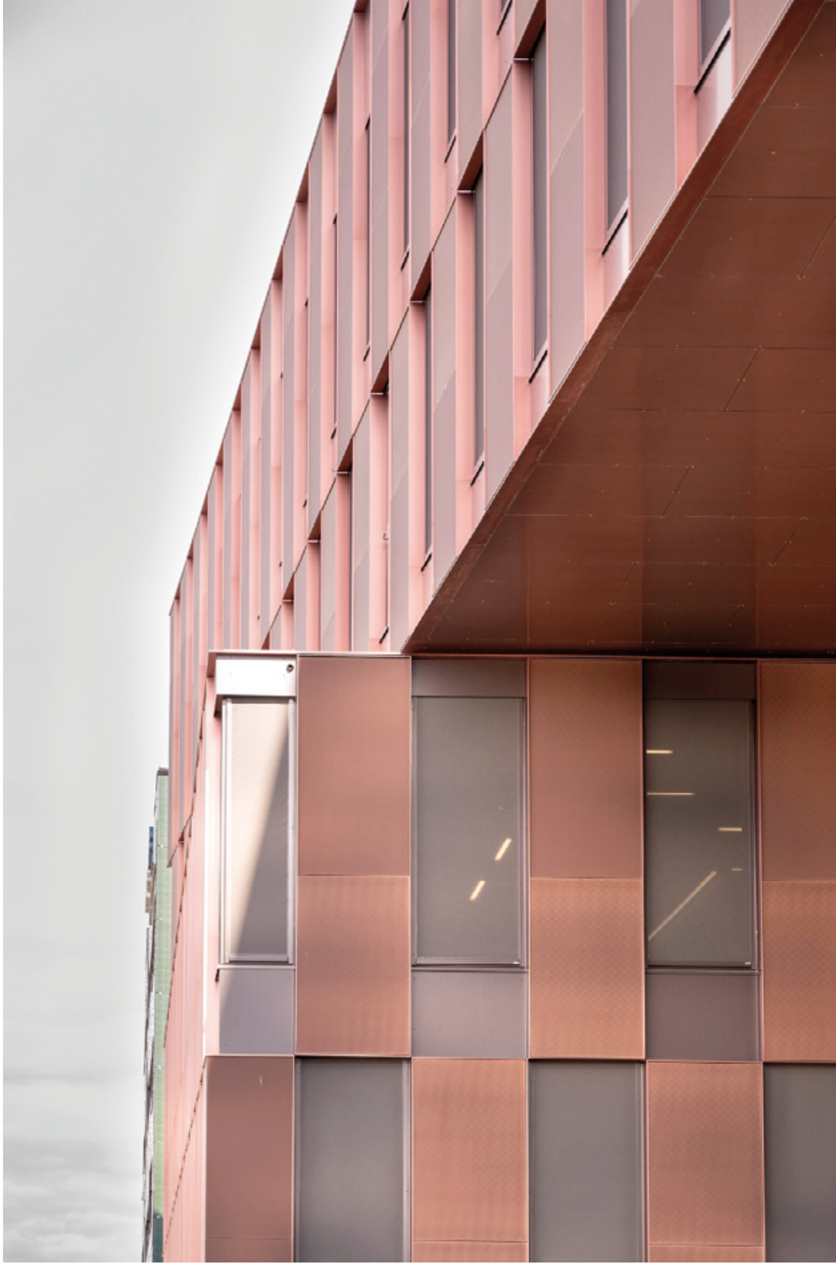
BIPV typology	-	Glass/Glass with coloured front glass and structurally bonded back rails
PV technology	-	Mono PERC
Cladding specification		44.2 safety glazing
Manufacturer of BIPV modules		Activ'Glass Issol Switzerland ltd.
Model of BIPV module		EPOG-44.2-AIT-BR
Customization in size	-	Yes
Customization in colour	-	Yes

Energy features

Energy production (Simulated)	kWh/yr	60300
Final yield	kWh/kWp	688
Energy demand	kWh/yr	N.A.
Self-consumption	%	N.A.
Self-sufficiency	%	N.A.

Cost-competitiveness

Business model		Reduction in rent for clients, tax credit, government incentive
Value self-consumed electricity	cts€/kWh	18.26
Value injected electricity	cts€/kWh	0
Subsidies	€	N.A.



All images: Lund+Slaatto Arkitekter

PLAYERS AND VALUE CHAIN

The chapter outlines the roles and responsibilities of stakeholders across the value chain, offering a detailed overview of the construction process while highlighting the distinctive aspects of BIPV installations. The analysis draws on real case studies, focusing on specific construction phases and working categories, showing how photovoltaic integration can work alongside traditional building methods. Compared to standard construction, social architectures introduce additional elements that brings its own complexities and requirements, including specialized design considerations, the involvement of new professionals, and specific technical demands. However, despite these added complexities and the inclusion of new stakeholders, the overall BIPV construction process remains largely similar to conventional practices.

BIPV construction process

To enhance the precision in defining construction stages, a detailed sub categorization of the process has been proposed in Fig. 1.

Specifically, the construction process is divided into four macro groups and ten stages.

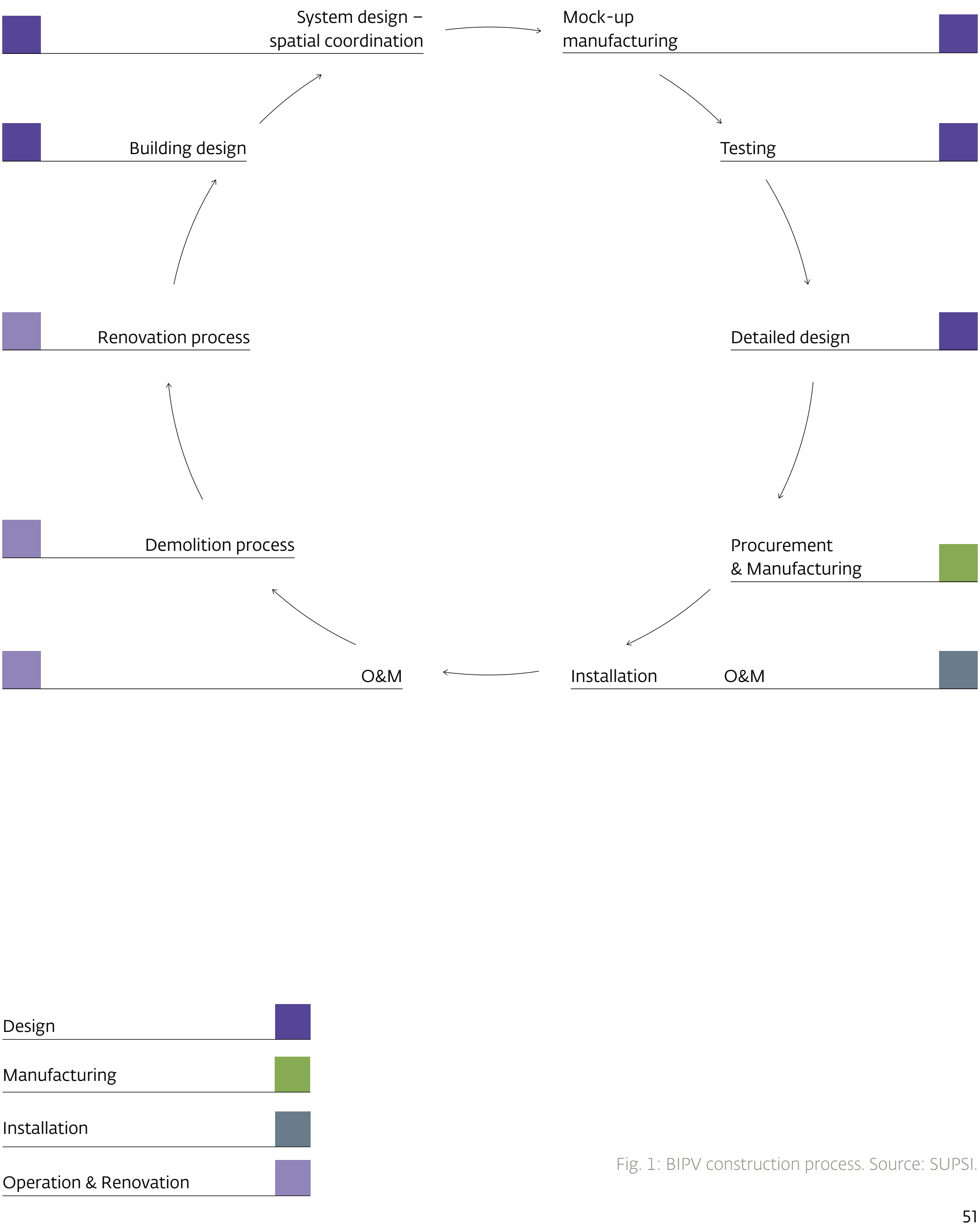


Fig. 1: BIPV construction process. Source: SUPSI.

Stakeholders classification

The proposed stakeholder classification is based on the logic of a general construction project development process. It aims to identify the key stakeholders involved at each stage of a BIPV project. The goal of this stakeholder map is to expand existing frameworks by incorporating a more comprehensive overview of the stakeholders involved in BIPV projects, using a "cradle-to-grave" approach.
Table 1 presents a general stakeholder map, with key groups outlined as follows:

- → Clients and End users
- → Government and Regulation
- → Finance and Investors
- → Manufacturers
- → Designers and Engineers
- → Contractors and Installers
- → Operation and maintenance
- → Demolition process
- → Renovation process

Client & End user	Government & Regulation body	Finance & Investor
Building owner	Politician	Insurer
BIPV system owner	Lobby group	Banks
Purchaser in construction	Government	Third party investor
Energy industry	Local authority	Real estate investor
	Licensing body	Project sponsor
	Regulator (local, national)	
	Certification company	
	Regulatory organization (structural safety)	
	Regulatory organization (sustainability)	
	Regulatory authority (electrical permits)	
	Regulatory authority (subsidies)	
	Regulatory body (safety, permits)	

Design

Manufacturing

Installation

Operation & Renovation

Designer & Engineer	Manufacturer	Contractor & Installer	Responsible for O&M	Responsible for demolition	Responsible for renovation
Sustainability engineer	PV cell producer	Structural contractor	Maintenance company	Demolition company	Renovation companies
Electrical engineer	Glass producer	Facade contractor	Occupant (building manager)	PV plant decommissioning & demolition	Permits
Embodied energy & carbon footprint evaluator	Aluminium producer	Roof contractor	Occupant (resident)	Recycling company	
Architect (execution supervisor)	Cabling manufacturer	Electricity contractor	Occupant (office personnel)	Container & dumping ground	
Engineer (site supervisor)	Glue company	Control & Operation contractor		Storage of USD PV panels & other construction material	
Structural engineer	Polymer company	Safety (site supervision)			
Facade engineer	Isolation solution	BIPV contractor			
PV & BIPV engineer	Raw material supplier (steel, cement, etc.)	Logistic expert			
Expert in fire safety	Aluminium transformer & processor	General project manager			
Sustainability consultant	Glass transformer processor	Facade project manager			
Architect	IGU producer	Electrical project manager			
BIPV consultant	BIPV manufacturer				
	Mounting system manufacturer				
	Monitoring manufacturer				

Table. 1: Stakeholders map. Source: SUPSI.

Clients and End users

The key stakeholder in a construction project is a client. The client/end user makes the final decisions for their project based on their requirements and project vision, financial and other capacities. Depending on the type of client, different requirements are placed on the product. Residential clients normally try to see a short ROI and a reasonable upfront investment, depending on their financing capabilities. In a residential project the architect is not playing a key role, but more the local installer / product provider ecosphere influencing the residential client decisions. The industrial building owners are also usually driven by the same motives as residential clients, but the aesthetic part plays a lesser role. Commercial clients, purchasers in construction and energy industry are usually working behind a bigger organisation that can have different driving motivations to apply PV or BIPV in their project.

Government and Regulation bodies

Regulatory bodies, authorities, and politicians are key stakeholders who can stimulate market growth through incentives or national-level energy and sustainability strategies. However, they are unlikely to directly drive the adoption of BIPV products unless a specific solution is strongly incentivized. A regulation related to safety, for example, could delay a project adoption, until the necessary technical parameters are met, but it would not necessarily drive or break a BIPV project, if the market offering is so attractive and the client already has made a decision to apply a specific product in his project.

Nevertheless, the regulatory and government bodies have a huge influence on the public perception of a certain technology or strategy related to sustainable development and products used with certain environmental targets in mind. Since BIPV is becoming more and more widely spread, more and more its adoption is being regulated, from integration and safety points of view. This is important point to address in the BIPV community to not delay the projects. The high-level expertise and understanding of their product performance under various conditions is crucial, to be able to defend the high-quality requirements to both clients and regulators.

Finance and investors

Finance and investor group in the BIPV stakeholder map includes stakeholders like Insurers, Financing organizations, like banks or third party investors, investors in real estate and project sponsors. It is a crucial group, since one of key product parameters is cost and ROI and in a BIPV adoption decision making process in certain cases, a BIPV product can demonstrate the ability to be strictly a financial investment or a business case tool.

Manufacturers

Raw material producers and product manufacturers include all the ecosystem of the construction production process value chain, from glass, wafer, polymer, aluminium and other raw material producers to IGU, Roof tile, BIPV, Curtain wall and other construction products producers that are ready to be applied in a construction project.

This stakeholder group is not so much involved in a BIPV project application decision making process, but more in the ability to create an attractive high-quality offering for the clients and investors and comply with regulator needs for adoption of the BIPV solutions in projects. Which in fact then become a key stakeholder group and the developer of the BIPV market and industry. This is possible when a visionary developer or producer is manipulating the stakeholder in this group adequately to create the optimal offering for the momentary global techno/eco/socio climate satisfaction.

Designers and Engineers

The appliers of the technologies that participate in the construction industry have to deal with a number of technical challenges related to architectural, structural, facade, electrical, PV and BIPV, engineering related topics, safety and sustainability expertise. This group is responsible for the project technical compliance to regulator demands and client/investor goals. As a solution, BIPV offering has to be able to satisfy the needs of the Design and Engineering group both related to output requirements and ability to obtain the necessary design parameters to facilitate the design process. In turn, the acceptance of the BIPV product in the construction value chain is quite dependant on the designing and engineering group's ability to integrate the product in their design process in a minimally disruptive manner and with manageable risks related to overall quality of the final product. The BIPV industry must not forget, that a standard construction project is already overloaded with compromises, design and engineering optimisation tasks and a high level of risks that are already prevalent in projects, before even considering the application of a BIPV.

Contractors and Installers

The construction group is a bit like the design and engineering group. The focus of the stakeholders in this group is the execution of the project according to the planned design, budget and planning. Again, the same point has to be mentioned as for the design and engineering group, the more disruptive the BIPV solution is for the construction process stakeholders, the less likely this solution will have any acceptance in the circle of potential adopters. So, the necessity to have a minimally disruptive solution with a clearly explained or understandable manipulation or installation with adequate support, minimal potential risks is imperative for the success of a BIPV solution in the construction industry. The stakeholders in this group are architects, engineers, project managers or contractors in general, facade, electricity, roof, facade or PV fields, site supervisors and logistics experts.

Operation and maintenance stakeholders

The stakeholders in this group are maintenance companies of building facade/envelope, building operation or operators, occupants. The BIPV as a solution, after project execution, like any other product can have operation particularities, like power output issues, like quality of the product, like breakage on site after installation, like structural failures, etc. The operation part for the BIPV industry is one of the most important and overlooked parts of the overall life cycle performance of BIPV products. If the BIPV installation is installed on the facade, but not operating well, not maintained, not repaired, not understood and the operation is not supported by the producer or after sales expert, this can form a make-or-break scenario for the BIPV industry as a whole. The project driving factors like Green washing or company image, sometimes do not focus on the actual BIPV output and the proper ROI's as per design. This can undermine the BIPV image in a negative light and the notion, that a BIPV can be a solution to the building energy or sustainability goals, can be misunderstood or negated by anybody, who actually enters the building operation data or carries out the building refurbishment or other. It is absolutely important to put pressure on clients and building operators to make sure, that the BIPV systems are functioning, working and producing towards the planned energy and economical goals. The next step is the documentation and demonstration of good cases and success stories, which is key information to the market to limit the "green washing" or "not reliable" image of the technology.

Demolition process stakeholders

The demolition and recycling group can present solutions for BIPV and standard PV systems that improve the sustainability and reduce the lifecycle CO_2 emissions or contribute to an opportunity to recycle the products Adequate solutions could present a huge opportunity to the overall BIPV/PV industry. The potential to recycle or reuse the BIPV products, could lead to a different cost calculation for the end client and create both a financial and sustainability opportunity. The key stakeholders here are regulatory bodies that issue necessary requirements for safety, acceptable processes and permits, facade and general demolition companies, PV decommissioning and demolition companies, recycling industry, dumping grounds with their rules, companies dealing with recycling, etc. that are working in the PV / BIPV product refurbish, reuse, recycle value chain.

Renovation process stakeholders

Renovation process is similar to demolition process in terms of stakeholder types in the group, which are facade, roof or general renovation companies, authorities granting permits, electricians, BIPV or PV suppliers. The objective of this process is the extension of the operation duration of a BIPV power plant, which can in turn result in better overall income for the client or investor. Durability and long lifecycle of operation of BIPV installations is also a contribution to the notion, that BIPV and PV systems can operate like standard construction materials for extended period of times. In certain cases, an intervention to renovate the BIPV system is quite beneficial if the extension of the life cycle is an objective and from innovative BIPV product development point of view, it is important to take this option of accessibility for replacement and maintenance into consideration, when designing a good BIPV product with claims of long -term performances.

BIPV value chain

In the following paragraphs, the BIPV process is analysed step by step, with key challenges, tasks, main stakeholders, and the duration of each activity discussed for each stage. This analysis is based on data gathered from a case study survey involving various stakeholders in the BIPV industry. The findings are generalized by BIPV typology, reflecting the current state of the art within the case studies examined. However, it should be noted that this does not necessarily represent the optimal process for constructing solar-integrated architectures. The tables below focus specifically on the design, manufacturing, and installation stages and on three technological systems: i) discontinuous roof, ii) rainscreen facades and iii) external integrated devices (parapets, canopies, etc.).

Discontinuous roof

The construction process of discontinuous roof project is based on four case studies. The studies were two heritage building roof renovations, a new residential building and a large industrial purpose building roof renovation project. The steps in the construction process were following similar procedures and in the table generalized summary of each step is discussed addressing mainly key challenges and tasks.

Stage 1 – Building design	Key challenges and tasks	→ BIPV producer / supplier business model description (standard procedures and solutions) → Responsibility repartition of design (electrical, mechanical, architectural), installation and other → Detailed vs. Preliminary budget differentiation at early stage of a project is important. Sometimes a small roof project is compatible with construction process, thus the budget is easy. Sometimes the development is long term and the BIPV cost fluctuations are more than standard roof materials, thus preliminary budgets are varying significantly and the clients / installers are not fond of it → For heritage and protected buildings - approval of products by local authorities and regulatory bodies is mandatory
	Key stakeholders involved	Client and End user; Architect; BIPV producer; BIPV engineer; Regional regulator; Local Authority
	Timing required for each activity	Delay due to client / architect decision making process - approx 5 weeks
Stage 2 – System design	Key challenges and tasks	→ Availability of design tools, dummy materials, precise building roof data if renovation → Necessary technical knowledge of the architect and installer to be able to execute the preliminary designs at needed precision
	Key stakeholders involved	BIPV producer; BIPV engineer; Installer; Architect; Electrician
	Timing required for each activity	Communications and other delays - 3-4 weeks
Stage 3 – Mock-up manufacturing	Key challenges and tasks	Since BIPV roofs are standard products, mock-ups usually are simple tasks. Sample supply is part of building design process
	Key stakeholders involved	BIPV producer; Architect; Client
	Timing required for each activity	2-4 weeks

Stage 4 - Testing	Key challenges and tasks	→ Generally no special testing is needed for a standard and well developed BIPV roof solution → If the client or regulation bodies need to make additional testing within the scope of a project, it can be a standard procedure
	Key stakeholders involved	→ BIPV producer; Testing laboratories; Certification company; Local authorities → Licensing bodies; Regulatory organizations for structural safety; → Regulatory organizations for electrical safety; Regulatory authority (municipality / permits)
	Timing required for each activity	Either not part of a project or it can be up to 2 months, depending on tests and laboratory scheduling
Stage 5 - Detailed design	Key challenges and tasks	→ Availability of good and efficient tools for designing → Making sure the design corresponds to the actual situation on-site. Specially the case for renovation projects, when dimensions are not precise, since there is a risk during installation → The scope of responsibilities have to be clearly defined and understood by all parties during the execution phase. What is the responsibility of the BIPV supplier, BIPV designer, the architect and the installer
	Key stakeholders involved	Installer; Architect; BIPV designer; BIPV producer; Electrician; Contractors roof
	Timing required for each activity	Delay due to client / architect decision making process - approx. 2 weeks
Stage 6 – Procurement & Manufacturing	Key challenges and tasks	→ Agreement of good delivery terms for all parties → Clear definition of mandatory design and order confirmation steps before clear launch of production
	Key stakeholders involved	BIPV producer; Architect; Client; Installer; Other material suppliers; Contractors roof
	Timing required for each activity	Delivery terms 12 weeks
Stage 7 - Installation	Key challenges and tasks	→ Qualified installers that are either familiar with the BIPV system or a support mechanism for the installers to deal with the installation in an efficient way → An efficient and cost-effective way to deal with on-site breakage, dimensioning or design issues, dummies → Qualified personnel to do commissioning → Important to clarify the replacement of BIPV module strategy, issues and procedures
	Key stakeholders involved	BIPV supplier; Installer; Architect; Roof material supplier; Client; BIPV consultant / engineer; Contractors roof
	Timing required for each activity	Can be 1 week if a small project. Up to 3 weeks depending on the project size and installer qualification

Rainscreen

Four commercial building projects were used as case studies for the rainscreen technological BIPV system construction process analysis table below. In all cases the projects were new construction buildings with between 200 – 1000 m² size BIPV facades.

Stage 1 – Building design	Key challenges and tasks	→ This stage includes feasibility study and concept design task → From BIPV system feasibility study point of view, the key tasks are energy simulations, ROI, technical feasibility to support customer decisions and architects design among others → The feasibility study results identify the BIPV technology application in the project details. If the client decision is go further with this solution, a BIPV producer needs to address a call for tender during a concept design stage → In design phase, the results have to be quite precise, to be able to make a correct BIPV solution selection and budget estimation. Additional changes at later stages can be costly → Important to be clear of the BIPV supplier business model, delivery terms, processes, etc. → Correct product selection is the key at this stage - glass thickness, mounting system, aesthetics, facade layout, etc... → Clear scope of delivery needs to be defined → Depending on the project, if a heritage building or a building in protected areas, in product selection government and regulation bodies are also involved
	Key stakeholders involved	Architect; Government and regulation bodies; BIPV producer; Building developer; Client; BIPV consultant; Commercial building owner; Purchaser in construction / energy industry; Insurers; Financing organizations (banks); Financing organizations (third party investors); Investors in real estate; Project sponsors, Specialists in structural, facade, fire and other safety and engineering fields
	Timing required for each activity	A feasibility study normally takes around 2 weeks. For conceptual BIPV design around 2-4 weeks need to counted. NOTE - the responce to the tender is within 2/tv4 weeks, but the period for selection and further development can takes around a year
Stage 2 – System design	Key challenges and tasks	→ At this stage several products are selected that are suitable for the project and more detailed proposals (technical, budget) needs to be supplied → Usually, some samples need to be delivered, to evaluate the aesthetical and technical suitability of the product → Generally, at the end of this stage all suppliers, including the BIPV supplier is selected
	Key stakeholders involved	BIPV producer; Architect; BIPV designer; Client; Facade installer; Backrail and bonding solution suppliers; Facade Engineers; Structural engineers; Sustainability engineers
	Timing required for each activity	2-6 weeks
Stage 3 – Mock-up manufacturing	Key challenges and tasks	→ Mock-up is usually supplied by the selected supplier → A mock-up is usually supplied to finalize and confirm the preliminary designs, select the most suitable glass types, colours, finalize technical parameter details that are not clear, etc. → It is important to understand the client / architect expectations to be efficient at this stage and deliver good solutions that are matching with the initial budgets and expected aesthetics
	Key stakeholders involved	Glass producer; Module producer; BIPV producer; Architect; Facade builder; Project developer; Client; BIPV designer
	Timing required for each activity	4 weeks

Stage 4 - Testing	Key challenges and tasks	→ Mock-up testing or testing of glass laminate construction can be needed depending on the project. Usually, the conformity to standards is already confirmed in the initial stages, when selecting the right product or making the preliminary system design → Communication of the scope of deliveries and responsibilities are key in all of the initial steps
	Key stakeholders involved	Manufacturer of BIPV product; Structural engineers; Facade Engineers; Experts in fire safety; Project manager facade; Regulatory organizations for structural safety; Certification company
	Timing required for each activity	Depends on testing type. Approx 3-8 weeks
Stage 5 – Detailed design	Key challenges and tasks	→ This step is related to mechanical, architectural, electrical design finalization for execution. Usually, the final designs need to be confirmed by the client or architect before the module production and procurement start → At this stage, efficiency and clarity is key. Final conceptual choices are done, layouts are finalized, changes after this step are costly and can result in delays
	Key stakeholders involved	Client; Architect; BIPV designer; Facade builder; Developer; Structural engineers; Facade Engineers; Electrical engineers; PV / BIPV engineers
	Timing required for each activity	2-4 weeks
Stage 6 – Procurement & Manufacturing	Key challenges and tasks	→ When execution designs are confirmed, procurement orders are placed and confirmed, the BIPV producer is launching the production → The key is to assure that no design changes are possible, which can result in extra costs and delays in production → Delivery terms must be agreed and is the key for successful project execution
	Key stakeholders involved	Glass supplier; Module producer; BIPV designer; BIPV producer; Facade builder; Developer; Logistics service supplier
	Timing required for each activity	12-16 weeks

External integrated devices

Three case studies were analysed of new construction commercial building projects including an BIPV external shading device in the range of 200 – 500 m^2 size-wise. Generalized results are laid out in the table below.

Stage 1 – Building design	Key challenges and tasks	→ Important to explain the technical differences between standard glass/glass external devices like canopies and balustrades and a BIPV glass/glass canopies and balustrades. The key differences are mechanical performance, due to different encapsulants, since in PV applications usually EVA or POE encapsulants are used, which have slightly different mechanical performance than standard encapsulants used in glass industry, like PVB, Ionoplasts or other. Important to address the j-box positions when prescribing the fixation system and the scope of warranties and responsibilities the BIPV producer gives with respect to as standard glass provider → In the initial stage, important to have a close to finalized design to be able to estimate the budget correctly → Ideally a standard mounting system used in glass/glass devices should be feasibly → At this stage the cable management might be rising questions, thus need to be addressed in feasibility study → In the feasibility study energy production, ROI's and other parameters are studied as well
	Key stakeholders involved	Commercial building owner; Architect; BIPV suppliers; Various consultants for architect assistance; Purchaser in construction / energy industry; Local authorities; Regulatory organizations for structural safety; Regulatory organizations for electrical safety; Regulatory organizations for sustainability; Insurers; Financing organizations (banks); Financing organizations (3rd party investors); Investors in real estate; Project sponsors
	Timing required for each activity	For BIPV details around 4wk. (NOTE - the response to the tender is within 2-4 weeks, but the period for selection and further development can takes around a year
Stage 2 – System design	Key challenges and tasks	→ The key parameters to evaluate are the module layout, glass thickness, fixation system, cell layout, cabling. This will provide sufficient information to estimate correct budgets and finish the architectural designs → At this stage specific safety and certification standard requirements might be addressed, since the application is not common. A budget and planning for supplementary testing might need to be agreed upon → Usually the suppliers are selected at this stage
	Key stakeholders involved	Client; Architect; BIPV supplier; Installer; Structural engineers; Facade Engineers; Energy system designers / sustainability consultants; PV / BIPV engineers
	Timing required for each activity	2-4 weeks
Stage 3 – Mock-up manufacturing	Key challenges and tasks	Mock-up for external devices procedures are similar to standard glass systems. It depends on the project, technical application, project location, etc.
	Key stakeholders involved	Project manager general; Architect; BIPV supplier; Structural engineers; Facade Engineers; PV / BIPV engineers; Project manager facade; Contractors facade
	Timing required for each activity	4-6 weeks

Stage 4 - Testing	Key challenges and tasks	→ Testing procedures are similar to standard glass systems, unless there are special requirements to BIPV products, that were not addressed in the initial design phases. This testing is normally project based → If there are specific requirements that the BIPV producer does not cover with his standard product certificates, a potentially supplementary certification campaign can take place, if accepted by project stakeholders
	Key stakeholders involved	→ BIPV producer; Testing laboratory; Certification company; Regulatory organizations for structural safety; Regulatory authority (municipality / permits) → PV / BIPV engineers; Structural engineers; Project manager general; Project manager facade
	Timing required for each activity	Depends on the tests. Can be around 2 months
Stage 5 – Detailed design	Key challenges and tasks	Detailed design is related to finalizing the glass stability calculations, fixation system selection, finalizing the BIPV glass electrical attributes, cabling of the modules, layout of the cables in the structure, DC/AC system design, project planning, etc.
	Key stakeholders involved	Project engineers; Installers; BIPV engineer; Architect; Electrician; Structural engineer; Project manager facade; Project manager electrical
	Timing required for each activity	3-5 weeks
Stage 6 – Procurement & Manufacturing	Key challenges and tasks	→ When the detailed design is confirmed, a supply order is signed, execution drawings are confirmed. The supply scope is agreed before → The glass production can start, with confirmed module design drawings by the client or architect
	Key stakeholders involved	Client; Architect; BIPV supplier; Glass supplier; BIPV producer; BIPV engineer; Project manager general; Project manager facade; Contractors structural; Contractors facade; Contractors electricity
	Timing required for each activity	12-16 weeks
Stage 7 - Installation	Key challenges and tasks	→ Delivery terms must be agreed upon clearly and the supply plan defined → The installation of the external devices is quite similar to standard glass balustrade and canopy installation, so the installation is quite common for glass mounting companies → Additional tasks include custom cabling of BIPV modules
	Key stakeholders involved	Architect; Installer; Electrician; BIPV supplier; BIPV engineer; Project manager; Contractors structural; Contractors facade; Contractors electricity; Site supervision (safety); Contractors BIPV
	Timing required for each activity	2-6 weeks

Case study analysis:
Residential House, Grono, Switzerland

Image: Greenkey.

Building and system description

In 2022, the owner of a private home in Canton Grisons, Switzerland, decided to retrofit the roof. A new, discontinuous roof was installed, featuring a single type of cladding, which includes glass-glass BIPV panels. The photovoltaic system was integrated across the four slopes of the roof, prioritizing architectural design and color consistency. Dummy modules were also used to maintain uniformity in the roof's visual language. The BIPV cladding spans approximately 390m² of the roof, with an installed peak power of about 64 kWp. The modules have a sleek, black appearance without the need for additional layers or films to alter their color. The monitored energy production is about 64'000 kWh per year with an annual yield of 991 kWh/kWp.

Table system features

Building typology	-	Residential
Technological system	-	Discontinuous roof
Active cladding surface	m^2	390
Non active surface	m^2	
Orientation	°	West; East; South, North
Tilt	°	11
Nominal power	kWp	64
System power density	Wp/m^2	165

Table product features

BIPV typology	-	Opaque glass-backsheet BIPV solution without thermal properties
PV technology	-	Mono c-Si
Cladding specification		5mm ESG
Manufacturer of BIPV modules		3S Solar plus
Model of BIPV module		MegaSlate
Customization in size	-	No
Customization in colour	-	No

Table energy features

Energy production (Simulated)	kWh/yr	63800
Final yield	kWh/kWp	991
Energy demand	kWh/yr	46270
Self-consumption	%	N.A.
Self-sufficiency	%	N.A.

All images: Greenkey.

Case study analysis: UCAV Technology Center, Ávila, Spain

Image: UCAV Technology Center.

Building and system description

The Catholic University of Avila (UCAV) is a benchmark of academic excellence, social commitment and ethical values. Founded in 1996, the UCAV has grown steadily, becoming a reference in higher education in Castilla y León, backed by the high employability rate of its graduates.

The new UCAV Technology Center seeks to be a benchmark for innovation and accessibility, demonstrating the university's firm commitment to academic excellence and environmental sustainability. A project conceived out of the need to reinvent an old building that previously housed areas for professors and some laboratories and that will now house a significant number of laboratories, in a building of more than 2800 m².

The intervention, finished in February 2024, consists of an extension of an existing building intended for classrooms and laboratories for the Catholic University of Avila (UCAV). The architect has designed a new space in front of the existing building to house

new stair cores and create a lobby at various heights to allow vertical visual communication. The curtain wall system uses Onyx Solar's photovoltaic glass with varying degrees of transparency, color and technology to combine natural light and thermal comfort. All photovoltaic glass units incorporate insulating air chamber and low-e glass to the interior (IGU).
The photovoltaic glazing occupies the 856 m^2 of the vision (491 m^2) and opaque (365 m^2) areas of the curtain wall oriented mainly to the South, with a small part oriented East, leading to a total peak power of 66 kWp. The photovoltaic glasses have been manufactured in 4 different configurations and colors, the transparent ones are made of amorphous silicon in different degrees of transparency and blue PVB interlayer (10, 20 and 30%) and the opaque ones are made of crystalline silicon technology using a hidden PV solution based on a front glass with blue digital printing. In total, there are 365 photovoltaic glass units based on the most repeated standard size of 1978x1178mm to adapt to the 2x1.2m axis modulation of the curtain wall profile system, and other size variants (up to 31 different types) have been manufactured to cover starts, corners and expansion joints.

Table system features

Building typology	-	Educational
Technological system	-	Curtain wall
Active cladding surface	m^2	491 (a-Si) and 365 (c-Si)
Non active surface	m^2	0
Orientation	°	South (partially east)
Tilt	°	90
Nominal power	kWp	16 (a-Si) and 50 (c-Si)
System power density	Wp/m^2	77

Table product features

BIPV typology	-	Semitransparent glazed (a-Si) and opaque glazed (c-Si) BIPV solutions with thermal properties
PV technology	-	a-Si and c-Si
Cladding specification		Amorphous silicon (a-Si) and cristalline silicon (c-Si)
Manufacturer of BIPV modules		Onyx Solar
Model of BIPV module		N.A.
Customization in size	-	Yes
Customization in colour	-	Yes

Table energy features

Energy production	kWh/yr	N.A.
Final yield	kWh/kWp	N.A.
Energy demand	kWh/yr	N.A.
Self-consumption	%	17
Self-sufficiency	%	N.A.

All images: UCAV Technology Center.

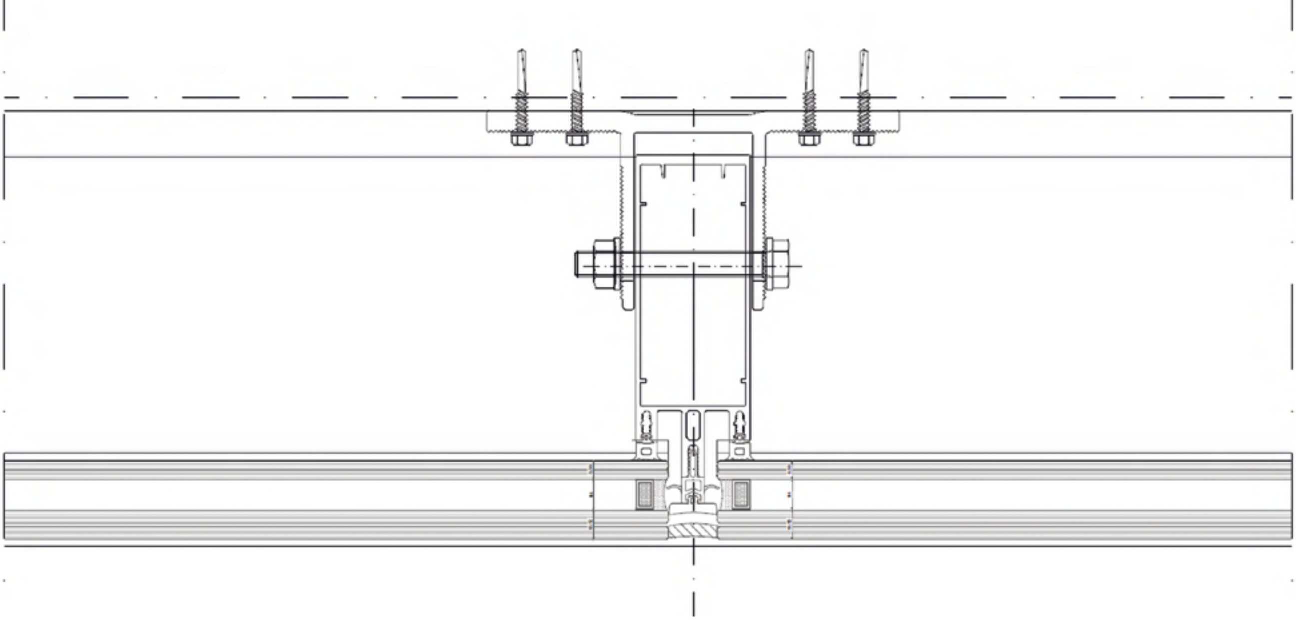


Fig.1: Technical detail of the horizontal section of the curtain wall. Onyx Solar.

Conclusions

To ensure the widespread adoption of BIPV, more than regulatory mandates are needed; a cultural shift is crucial. Photovoltaics must be seen not just as an energy solution but as an aesthetic, multifunctional element integral to building design. Legislative shifts like the EU Solar Standard and REPowerEU are setting the stage for BIPV to become a central feature of modern construction. However, achieving this requires focusing on two key priorities. Firstly, Europe must scale up BIPV production and capacity to enable the multifunctional use of space in the built environment, generating solar energy while enhancing building aesthetics and functionality. Secondly, establishing a robust, integrated EU BIPV value chain is essential. Aligning the construction and solar industries will help build resilience and foster a competitive "made in Europe" BIPV market. The BIPV Status Report 2024 provides practical insights for the construction industry, using real data to engage a broad range of stakeholders, including end-users and decision-makers. Based on over 80 contributors—through case studies, interviews with architects, engineers, and BIPV manufacturers—the report offers in-depth analysis of 54 European solar architecture projects. This data-driven approach delivers a clear, actionable view of the opportunities and challenges in integrating photovoltaics into buildings. Ultimately, the report aims to foster a deeper understanding and encourage the practical adoption of innovative solutions, strengthening the future of the construction sector.

What are the past and future market prospects for BIPV in Europe?

Chapter 1 presents past and future BIPV market estimates in Europe. It first reviews market trends from 2015 to 2023, followed by short-term forecasts based on three scenarios until 2028. By 2028 it is expected that BIPV market in Europe will achieve 371 MWp. Steady, a growth is expected, driven by the appeal of BIPV solutions rather than financial incentives. However, not all markets will follow this trend, and some may face grid management challenges due to rapid renewable energy growth. France, Switzerland, Germany, Austria, the Netherlands, Spain, and Italy are projected to lead BIPV adoption by 2028.
End-user prices for active cladding systems and full building systems are also detailed. Survey data from 35 European BIPV products show end-user prices ranging from €225 to €600/m² for colored cladding and €150 to €205/m² for full-black cladding. Roof tiles range from €90 to €470/m². Survey data from 54 European case studies, both completed after 2019 and ongoing, reveal rainscreen facade end-users prices between €380 and €980/m², roof systems from €170 to €970/m², and curtain walls from €810 to €1930/m², including frames, fixing clamps, and load-bearing anchors or glazing units, BOS and soft prices (labor and electrical installations). A cost-breakdown for each technological system is also shown.

What factors drive the market appeal of BIPV solutions in the construction sector?

In chapter 2, a survey of 45 stakeholders across 13 regions explored the market appeal of BIPV solutions from the construction sector's perspective. Key product parameters identified were aesthetics (1st), cost (2nd), certification and compliance (3rd), quality (4th), and clear technical data (5th). For BIPV producers, the main requirements were building market trust (1st), having a solid business model and visibility (2nd), demonstrating expertise (3rd), and offering clear product solutions (4th).
While interpretation may vary by producer profile, the market clearly demands reliable suppliers who can deliver aesthetically pleasing, cost-effective, high-quality products with transparent offerings and strong support. The weighting of these factors depends on specific markets, stakeholders, and projects, suggesting areas for future research.

How do stakeholders and workflows shape the BIPV installation process?

Chapter 3 details the roles and responsibilities of stakeholders across the BIPV value chain, offering insights into the construction process and the unique aspects of BIPV installations. It identifies 69 stakeholders involved in the BIPV process and analyzes three BIPV workflows based on 11 case studies across various building types—commercial, heritage, residential, and industrial, both new and renovated. The findings are generalized by BIPV typology, reflecting the state of the art within the examined case studies.

By providing actionable insights, data, and real-world case studies, the report serves as a knowledge transfer tool, empowering stakeholders to drive BIPV innovation, overcome market barriers, and scale up adoption across Europe. This shared knowledge is key to building capacity, establishing a resilient value chain, and positioning BIPV as a mainstream solution in sustainable building practices.

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Chapter 1

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Chapter 2

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Disclaimer

This report provides an overview of mega-trends in the EU BIPV (Building-Integrated Photovoltaics) market and is intended for informational purposes only. While we have made every effort to ensure the accuracy of the data and information presented, we do not guarantee that it is exhaustive or without error. The information contained in this report should not be used for business plans, commercial strategies, or other financial or operational decision-making. Any data or information from this report must be properly attributed to the source. We assume no responsibility or liability for the use of the data for commercial or business purposes.

The website www.solarchitecture.ch is one of the communication means of the Swiss BIPV Competence Centre.
Here you find essential information concerning PV technology, integration in buildings and different projects realized both in Switzerland and abroad. Moreover, you can consult a large database of BIPV modules and fastening systems collecting the main product's information in a datasheet. The website is an active interface opened towards different stakeholders thanks to the possibility to upload and store your BIPV examples (architects, installers, owners, etc.) or products (manufacturers, suppliers, installers, etc.) as well as to the technological/client support through the contact info@solarchitecture.ch.

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