Advancing BIPV in Europe

BIPV | The EU-funded PVSITES project is working on a number of initiatives aimed at accelerating the roll-out of building-integrated PV across the continent. Members involved in the initiative outline some of the efforts being made to unleash BIPV's as-yet untapped potential

Credit: ONYX Solar

Figure 1. Internal view of ONYX Solar's photovoltaic glass-glass curtain wall at Balenciaga storefront (Miami, USA). The BIPV laminates include crystalline silicon technology and blue tinted glass, one of the products developed and tested within PVSITES project

Over the past decade, the expansion of the building-integrated photovoltaic (BIPV) market predicted by analysts bumped into a context that combined a lack of regulatory and standardisation framework, political support and cost-competitiveness. As a consequence, market forecasts were overestimated, and BIPV installations were mainly limited to niche flagship construction projects. Despite that adverse scenario, the BIPV sector has managed to evolve and has steadily consolidated its presence, proving that the bright future depicted by market experts is about to blossom. BCC Research estimated the worldwide installed BIPV capacity during 2016 to nearly 2GW, confirming the growing trend, increasing by 12.6% compared to 2015, when 1.78GW of capacity was installed [1].

The BIPV sector has also faced the difficulties derived from merging two different sectors: the photovoltaic sector, thoroughly focused on the manufacturing of standard PV modules and the implementation of economies of scale; and the construction sector, demanding aesthetics, customisation, freedom in terms of design, and in general terms reluctant to the introduction of novel active solutions.

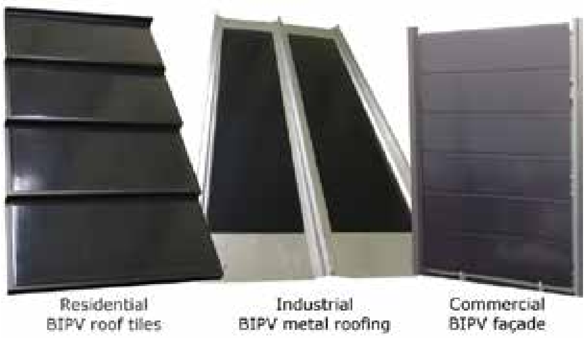
During the past few years, the understanding of both sectors has significantly progressed, especially due to the irruption of new BIPV companies providing solutions that met the features demanded by architects and building owners: customised solutions, adequate aesthetics and, in certain cases, even cost-competitiveness when tailored business models were applicable.

In Europe, the so-called Winter Package evidenced the clear bet made by the European Union towards the decarbonisation of the economy and the building sector. Although no clear binding measures are specifically defined for BIPV technology, the framework drawn up by the latest recast of the Energy Performance of Building Directive (EPBD) expects a prominent role for BIPV, implicit in the low primary energy consumption allowed for nearly-Zero Energy Buildings (nZEBs) by most Member States' transposition of the Directive, requiring renewable on-site generation to comply with the regulation.

The global context seems finally appropriate for the mass deployment of BIPV technology. This will require further progress in overcoming the traditional barriers of the technology, such as the lack of awareness or confidence in BIPV technologies among key stakeholders, the difficulties in the technical and aesthetical integration of BIPV systems in the building skin and, most importantly, the final cost of BIPV. Mastering these key market drivers will help unleash the great and still untapped potential of BIPV.

Towards cost reduction

The European PVSITES project [2] has been conceived as an industrial joint approach to provide robust BIPV technology solutions to comply with market needs. The ultimate goal is to significantly enhance BIPV market deployment in the short and medium term. Clearly one of the main challenges faced by the BIPV sector is to demonstrate significant cost reductions that can lead to large market uptake, moving from exclusive projects



Credit: Flisom

Figure 2. Several CIGS on metal designs for BIPV integration by FLISOM

		Single House	Educational building	Carports	Industrial building	Apartment building	Office building
Responsible partner		FormatD2	Flisom	Flisom	Cricursa	Vilogia	Tecnalia
Location		Stambruges Belgium	Geneva Switzerland	Zürich Switzerland	Barcelona Spain	Wattignies France	San Sebastián Spain
BIPV	Product(s)	Roofing shingles (CIGS on steel)	Large tiles on façade (CIGS on metal substrate)	Roof tiles (CIGS on metal sheets)	Large roofing shingles (CIGS on metal substrate)	Ventilated façade (c-Si modules with hidden bus bars)	Ventilated façade (Glass-glass back contact c-Si cells)
	Manufacturer	Flisom	Flisom	Flisom	Flisom	Onyx Solar	Onyx Solar
	Orientation	SSW	E + W	Horizontal	Horizontal	SSE	SSE
	Surface	75 m²	136 m²	145 m²	225 m²	130 m²	170 m²
	Installed power	8 kWp	4 + 8 kWp	7 + 7 kWp	19 kWp	20 kWp	10 + 10 kWp
	Use for electricity	Self-consumption + Grid	Self-consumption + Grid	EV chargers + Grid	Grid	Self-consumption + Grid	Self-consumption + Grid

Figure 3. Overview of the main PVSITES products and demonstration sites. The market-ready products developed in the project are being implemented in a variety of existing buildings throughout Europe

towards a mass market including the ordinary built stock. European policies are aligned with this objective, as clearly stated in the "SET Plan – Declaration on Strategic Targets in the context of an Initiative for Global Leadership in Photovoltaics"[3]. The ambitious targets in the Declaration point to a 50% reduction of additional costs for BIPV modules in 2020 and to a 75% reduction in 2030, with respect to the reference costs in 2015.

PVSITES partner ONYX Solar, manufacturer of BIPV glass laminated products, is deeply invested in the achievement of this cost reduction roadmap. Glass-based BIPV products must compete directly with the traditional architectural glass industry, in which high aesthetic standards are imposed. ONYX Solar has worked in recent years in a large portfolio of crystalline and amorphous silicon glass-based solutions with high aesthetic levels and attractive ROI values for the final user. The company's strategy towards 2020 and beyond includes a further automation of its manufacturing lines and quality control processes, materials-related innovation and further economies of scale (Figure 1).

Flisom, manufacturer of CIGS solar modules in the PVSITES project, has also defined a clear roadmap for cost reduction with a focus on two main factors:

- An overall module efficiency improvement from 10 to 14%, at the same time decreasing the cost per Watt.
- An increased annual production capacity from 15 MW to 100 MW, bringing significant economies of scale.

Combining these two aspects, production costs below €0.5/Wp are realistically achievable.

Cost reductions are also achievable for balance-of-system components and grid interface electronics as evidenced in the PVSITES project. On the one hand, low-cost conversion technologies removing unnecessary power stages are proposed, with target prices of €0.12/W for a 5kW Silicon Carbide (SiC) based inverter and €0.16/W for a 10kW PV storage inverter, developed by CEA INES and TECNALIA respectively.

All the BIPV modules and inverter solutions developed within PVSITES are being demonstrated through integration in seven installations in Europe, as detailed in Figure 3.

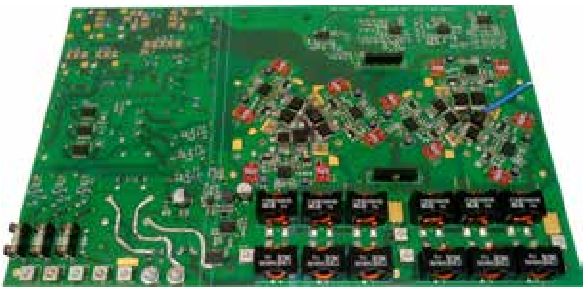
Aesthetics and multifunctionality

Another main driver to enhance the fast adoption of BIPV by the construction sector lies in the aesthetic value of the integration and the ability of BIPV products to provide additional functionalities to the building, at the same or superior level than traditional construction materials. BIPV systems are construction products, and as such provide weather protection, thermal control and aesthetics in addition to on-site electricity generation, among other features. Novel multifunctional BIPV products are giving place to large product portfolios based on different PV technologies, material substrates, transparency degrees, colours, etc.

A relevant challenge for the development of the BIPV market is the possible overheating of PV modules after building integration. A performance loss of nearly 0.4%/°C is observed for crystalline silicon PV modules, decreasing their electrical performance as well as their lifetime compared to traditional rack-mounted PV modules. This effect could be reduced using PV technologies less sensitive to temperature (CIGS, amorphous silicon, bifacial cells…), or through thermal management based on passive solutions such as natural convection through the air gap between the roof and the PV modules (e.g., the CIGS shingles designed by FLISOM for industrial buildings in the PVSITES project), phase change materials or active cooling methods (e.g., forced

Credit: ONYX Solar

Figure 4. San Antón market (Madrid, Spain) amorphous silicon transparent skylight by ONYX Solar.



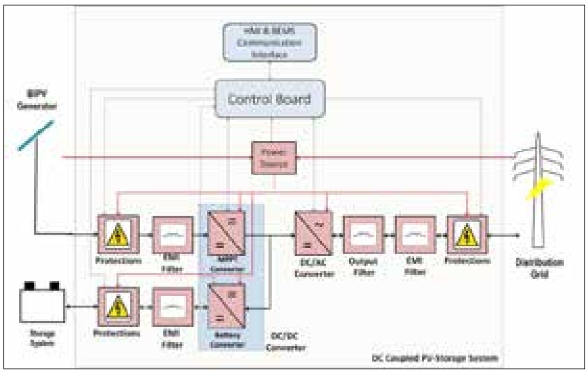


Figure 5. (Above) Power Board of the SiC current source inverter designed (soft and hard) by CEA-LITEN-INES (width 390mm x depth 245mm). (Below) Block diagram of the 10 kW three-phase DC-coupled PV storage system developed by TECNALIA

convection in hybrid BIPV/thermal solar collectors), with an opportunity for heat recovery and valorisation.

Enhanced grid integration

Progressing towards a more manageable, grid-friendly and profitable generation in terms of energy savings in buildings remains a challenge. As part of the PVSITES project, TECNALIA and CEA INES are aiming at improving the integration of the electricity generated by the PV panels in the grid.

The CEA INES Photovoltaic Systems Laboratory is working on a new inverter technology that simplifies the chain of conversion of electrical energy: the three-phase current switch. This type of inverter allows the direct injection of electrical energy from a PV array to the network in a single conversion stage. This new inverter topology is simpler and does not require any capacitance hence will be cheaper and more robust. This evolution is made possible by the emergence of silicon carbide semiconductors offering compact and high efficiency conversion solutions. The CEA INES team has fully designed the hardware and software of this three-phase current source inverter and has manufactured a first 5kW inverter prototype (Figure 5) for full validation prior to launching the industrialization of a pilot series of eight 5kW inverters. These will be installed on two demonstration sites in Spain: the ventilated façade of an office building and an industrial roof (Figure 3).

A high-efficiency, low-cost and flexible 10kW three-phase DC-coupled PV storage inverter has furthermore been developed by the Solar Energy Group at TECNALIA Research & Innovation. This system is proposed in order to cope with different storage requirements and operating modes. The 10kW inverter can be easily parallelized to make larger systems up to hundreds of kW, being suitable for the residential, commercial and industrial markets. DC coupling is achieved by means of multilevel DC-DC converters for the PV generator and batteries, and a high-voltage DC link, increasing the conversion efficiency of the whole system. These inverters will be demonstrated at a residential roof in Belgium and at the ventilated façade of a multifamily building in France (Figure 3).

Additionally, an advanced Building Energy Management System (BEMS) has

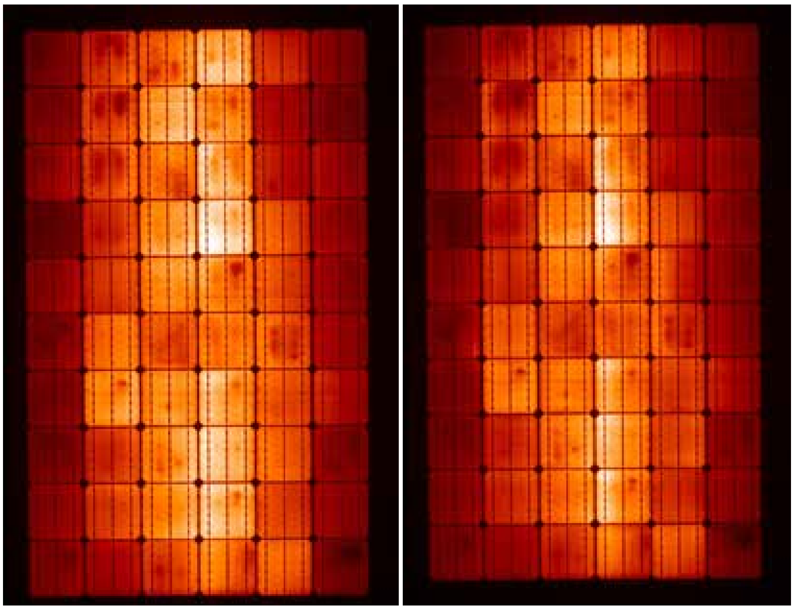


Figure 6. Electroluminescence imaging of ONYX Solar 60 cell glass-glass BIPV modules with a black rear glazing: before (left) and after (right) 100 thermal cycles

been developed by TECNALIA within the PVSITES project for different building typologies. The BEMS optimises energy flows between the building and the grid and increases overall energy performance. Economic benefits come from a better utilization of the produced electricity for peak-shaving and self-consumption maximisation at the most profitable time, taking advantage of known daily evolution of electricity tariffs in each country. The developed BEMS smartens the interface between the prosumer and the rest of the electricity system, exchanging information about anticipated performance.

Progress in standardisation

The still ongoing development of a specific and complete standardization framework for BIPV is a main barrier affecting the market deployment of the technology. In order to be suitable for building integration, a BIPV product has to demonstrate compliance with the Low Voltage Directive as electrical equipment, and the Construction Products Directive as building component. Additionally, as elements contributing to energy performance of buildings, BIPV systems are subjected to the EPBD and the Energy Efficiency Directive. The recent European standard EN50583, "Photovoltaics in buildings", parts 1 and 2, gathers these requirements. National building codes and regional/local regulations also apply on BIPV elements. A complete analysis of the BIPV standardisation framework has been made in the PVSITES and Construct PV [4] projects.

One of the first applications of EN 50583 standard in Europe has taken place within the PVSITES project. For each BIPV c-Si glass-glass and CIGS-on-metal-based product developed within the project, an in-depth analysis of the standard was made and a test sequence was defined and executed by project partners, with the final goal of ensuring long term performance and increased reliability.

Within the complex standardisation framework described above there are still gaps in how the different functionalities of BIPV systems are addressed. In general terms, it is clear that performance in operational BIPV conditions can be significantly different from that of traditional photovoltaics, building-attached systems, or non-photovoltaic construction materials. Another issue is that, given the large variety of module configurations, testing is performed almost on a single project-basis, which increases the final costs. Therefore, significant progress regarding BIPV systems qualification is still key to support cost reduction and market development. Several related initiatives such as the IEA PVPS Task 15, "Enabling framework for BIPV acceleration" [5], or the new IEC Technical Committee 82 PT 63092 [6] are currently under way.

Developing new skills

Even with an increasingly favourable regulatory framework and technical solutions in place, a key factor in the deployment of BIPV systems remains the know-how of designers and installers at the end of the value chain. Specific efforts are needed at different levels to make integrated solar energy a standard practice in the construction sector.

Architects need to be familiar with up-to-date solar architecture concepts and associated benefits in terms of indoor comfort and energy savings, as well as with the possibilities offered by the broad range of BIPV products available on the market. Initiatives are ongoing to make this knowledge and skills part of the main curriculum in the education of building designers. For instance, the European project Dem4BIPV [7] is developing a course to be implemented in a number of leading universities.

New building design practices also require adapted tools. The advent of Building Information Modeling (BIM) as the new paradigm for the conception of construction projects is a significant breakthrough in this direction. BIM platforms allow building designers to integrate BIPV elements from the very early conceptual

Credit: CADCAMation

Figure 7. Visualisation of a BIPV project with the PVSITES software tool (CADCAMation). The user is guided through the different project steps, from the computation of solar irradiance on all model surfaces to the system's economic assessment

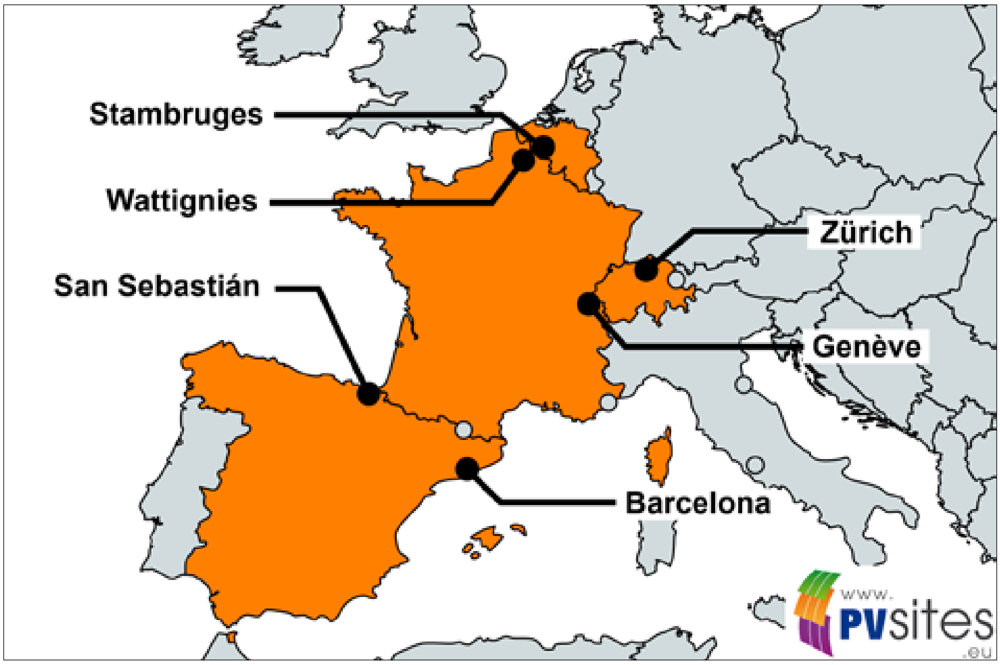


Figure 8. Location of the main PVSITES demonstration sites. Training courses for installers and guided visits will be organised in local languages in late 2018 and early 2019

stage and to simulate their effects in terms of electricity production, light transmission and thermal performance. To this effect, a user-friendly and BIM-compatible tool allowing designers to model and assess BIPV installations is being developed by PVSITES partner CADCAMation, as illustrated in Figure 7. Early versions of the software can be downloaded for free on the project website [2].

Lastly, the large-scale deployment of BIPV is entirely dependent on the availability of a skilled workforce of installers. Installers of traditional PV systems are already qualified regarding electrical aspects of BIPV systems, but typically lack experience regarding constructive aspects (structural assembly, thermal insulation, and air and water tightness). Conversely, roofing, façade and glazing professionals are fully qualified regarding constructive aspects of BIPV but may lack the necessary electrical know-how. There is therefore a need to train expert BIPV installers with knowledge in both trades. As a pilot action, PVSITES partners will organise free half-day practical training sessions at the demonstration sites in Spain, France, Belgium and Switzerland during autumn 2018 (see Figure 8). Information and registration will be made available through the project website [2].

Outlook for BIPV

Building-integrated photovoltaics is reaching commercial maturity, with the availability of a large diversity of reliable products and a steady reduction in costs. But despite being boosted by a favourable regulatory context, the large-scale implementation of BIPV systems in Europe still requires a number of obstacles to be overcome. Besides costs, these are currently mostly related to standardisation issues and to the slow spreading of new practices amongst construction professionals. Overall, the photovoltaic and building sectors need to work closer together to accelerate the deployment of BIPV in the near-future.

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Turn to p.58 to learn more about BIPV system modelling

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