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BIPV Position Paper
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Building Integrated Photovoltaics (BIPV) as a core element for Smart Cities –

Integrated Research, Innovation and Competitiveness Strategies within the Energy Union

www.etip-pv.eu

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Disclaimer

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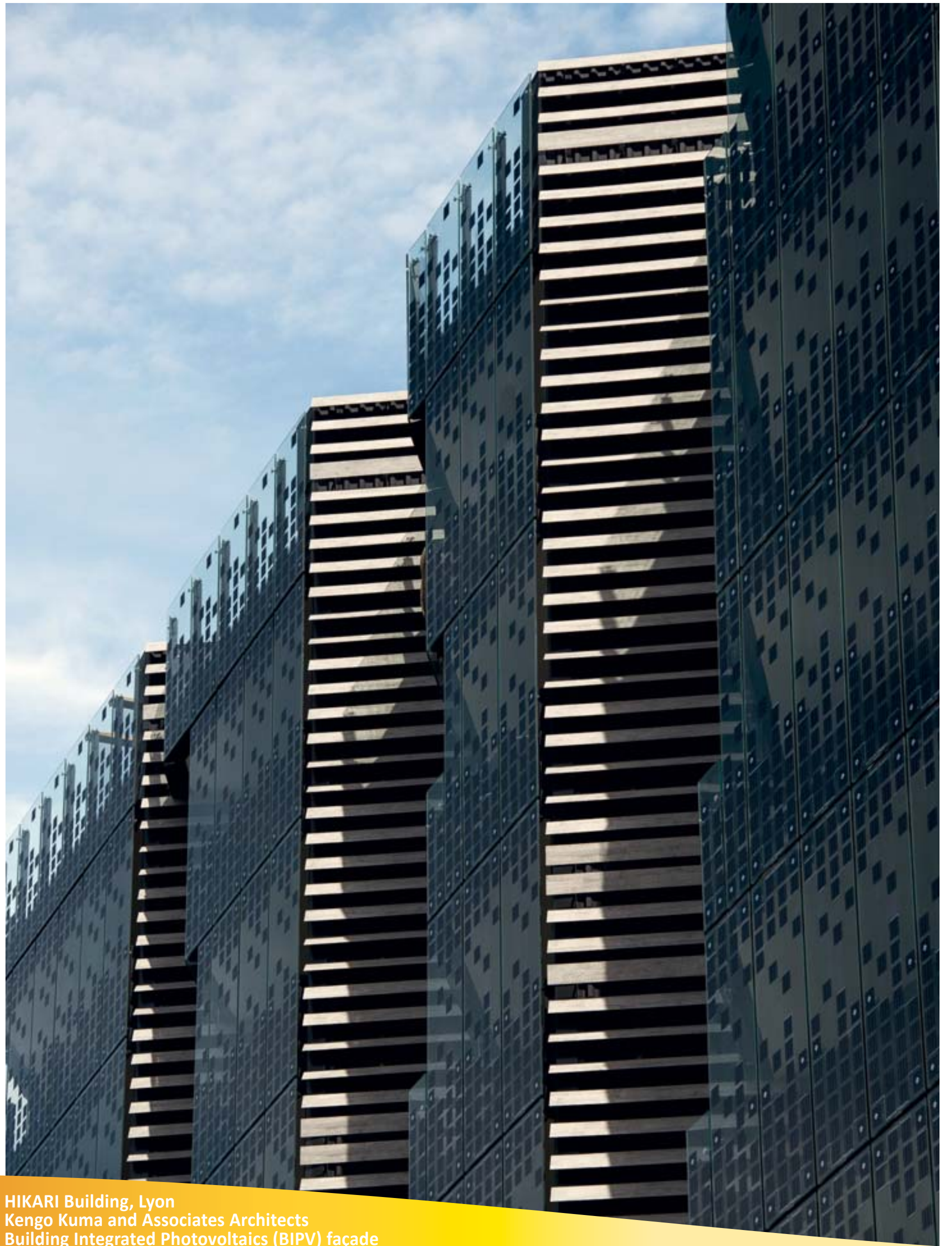

HIKARI Building, Lyon
Kengo Kuma and Associates Architects
Building Integrated Photovoltaics (BIPV) façade
Photo credit © Baptiste Lobjoy

Scope and Mission of the BIPV Position Paper

The document is based on the main outcomes of the Workshop in London "Where Sustainability meets Aesthetics" in July 2015 - a dialog between architects, engineers, building industry and Building Integrated Photovoltaics (BIPV) industry to usher and to foster innovation in the BIPV sector - and Hamburg at the EU PVSEC, "Reaching out for opportunities in BIPV - technology and industry developments" in September 2015, as well as subsequent discussions. This position paper outlines Strategies for integrated research, innovation and competitiveness within the Energy Union in the field of Energy Efficiency in buildings & cities and BIPV and should be used to distribute the results widely over the PV-community, interested and concerned sectors, such as the building sector and the political and R&D responsibles at the EU-commission and the Member States. This document should reinforce the status of BIPV in relation to energy efficiency in buildings on the way to Nearly Zero Energy Buildings (NZEB), as a crucial component of truly Smart Cities, enlarging the opportunities for the BIPV industry. The document is also based on a close relation to the Energy Union and the SET Plan Implementation plan as well as to the EU priorities in the field of energy efficiency and renewable energies. In this context it is important to underline that Energy efficient buildings including the integration of renewable energy (such as BIPV) will allow to develop breakthrough affordable solutions at building and district scale, connecting them at a larger scale to future smart cities.

Although there has been investment in energy efficiency and use of renewable energy in buildings for some decades, the level of investment has not been sufficient. Investment in this area has become strategically important for the EU as a result of the high level of energy imports (the EU imported 55% of the energy used in 2012, at a cost of 400 bn EUR), volatile energy prices, and for reaching the EU target for 2030 of cutting greenhouse gas emissions by at least 40% compared with 1990 (which includes the target of a 30% reduction of greenhouse gases in non-ETS [1] sectors). A number of the policies and markets that are central to shaping investment in energy efficiency and on-site renewable energy are still relatively new, and it will take time for their full effect to be felt. [2]

Reporting, accounting and procurement procedures must facilitate, and not hinder, appropriate investment in energy efficiency in public buildings while also clarifying the regulatory, fiscal and accounting treatment and standardising Energy Performance Contracts.

[1] ETS – Emission Trading Scheme
[2] https://ec.europa.eu/energy/sites/ener/files/documents/EPBD%20Public%20Consultation.pdf

Section 1: Context and Opportunities

Cities and Energy

Under business-as-usual projections, global energy use in buildings could double or even triple by 2050. BIPV is an important option and business opportunity in this context. Cities cover less than 5 percent of the Earth's land and over half of the world's population lives in cities, while up to 80 percent is projected for 2050. **Cities account for over 70 percent of global energy use and, 40 to 50 percent of greenhouse gas emissions worldwide.** In several cities, heating and cooling can account for up to half of local energy consumption. Any solution for the climate and energy transition must explicitly address sustainable urban heating and cooling, as well as electricity. One of the least-cost and most efficient solutions in reducing emissions and primary energy demand is the development of modern (climate-resilient and low-carbon) district energy in cities. Tackling the energy transition will require the active role of cities. Among the core components of the transition to a sustainable energy future are the integration of energy efficiency and renewable energy technologies, and the need to use "systems thinking" when addressing challenges in the energy, transport, buildings and industry sectors.[3] The integration of renewable energies in cities, in particular building integration of photovoltaics (BIPV), represent huge opportunities in combination with increased energy efficiency.

Economic impact of the building sector

With a yearly turnover around € 1.2 trillion, the European Construction Sector, including its extended value chain (e.g. materials & equipment manufacturers, construction & service companies), is the largest European single activity (10% of GDP) & the biggest industrial employer (14.6 million direct jobs).[4]

Buildings and Cities within Europe's 2030 Energy Strategy and the COP21 goals

EU countries have agreed on a new 2030 Framework for climate and energy, including EU-wide targets and policy objectives for the period between 2020 and 2030. The targets are based on a thorough economic analysis that measures how to cost-effectively achieve decarbonisation by 2050. The climate change mitigation goals that were agreed upon in Paris at the COP21 make achieving these targets even more urgent. The cost of meeting the targets does not substantially differ from the price we need to pay anyway to replace our ageing energy system.[5] The main financial effect of decarbonisation will be to shift our spending away from fuel sources and towards low-carbon technologies especially in cities.

[3] http://www.unep.org/energy/districtenergyincities
[4] ECTP, Luc Bourdeau, EUPVTP- BIPV conference, July 2015, RIBA, London
[5] International Energy Agency (IEA):
Energy Technology Perspectives 2016 – Towards Sustainable Urban Energy Systems

Targets for 2030 and opportunities for BIPV innovation

- a 40% cut in greenhouse gas emissions compared to 1990 levels
- at least a 27% share of renewable energy consumption
- at least 27% energy savings compared with the business-as-usual scenario [6]

Buildings and construction sector is responsible for 30% of global CO2 emissions. According to the International Energy Agency (IEA), moving to below 2°C path requires reducing the buildings sector's energy consumption by at least 30% through means of mainstreaming highly energy-efficient new buildings and a deep renovation of the existing building stock of buildings by 2050.

In order to reach the EU targets for 2030, buildings are essential in this regard and Building integration of Photovoltaics (BIPV) is an important sector in relation to energy efficiency in buildings and renewable energy integration into the built environment.

The Energy Union, as one of the EU's ten priority areas for action, has five mutually reinforcing and closely interrelated areas of focus, one of which is 'Energy efficiency contributing to a moderation of demand'. **The Energy Union strategy identifies improvements to energy efficiency in the building sector as a change that could make a critical contribution to the Commission's energy and climate strategy[7].** The sector of Building Integration of Photovoltaics is directly related to both areas energy efficiency and renewable energies and constitutes therefore an important topic in the future development and huge potential for innovation and competitiveness in the BIPV sector.

Information and communication technologies (ICT) are also contributing to the improvement of energy efficiency and the reduction of total energy use in buildings (houses, offices, public buildings and spaces) and will be central to creating Smart Cities.

The **European Roadmap for Energy Efficient Buildings** (2014-2020) prepared by the E2BA[8] within the European Construction Technology Platform (ECTP)[9] integrates also the topic of PV and in particular BIPV in various sections and core areas. More details, can be found in this roadmap. This interrelation of the two sectors is very important for the future approach and further development of BIPV and energy efficient buildings. With reference to the European Roadmap for Energy Efficient Buildings and the general objectives, successful research and innovation activities will allow to develop innovative and smart systemic approaches for green buildings and districts, helping to improve the competitiveness of EU building and as well PV industry by providing cost-effective products for smart cities.[10]

[6] A policy framework for climate and energy in the period of 2020 – 2030 [COM(2014) 15]
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0015&from=EN
[7] http://ec.europa.eu/priorities/energy-union/index_en.htm
[8] E2BA- Energy Efficient Buildings Association, an initiative of the European Construction Technology Platform (ECTP)
[9] http://ectp.ectp.org/cws/params/ectp/download_files/36D2981v1_Eeb_cPPP_Roadmap_under.pdf,
In particular see targets 8.2, 9.2 and 10 (10.7, 10.8)
[10] http://ectp.ectp.org/cws/params/ectp/download_files/36D2981v1_Eeb_cPPP_Roadmap_under.pdf

EPBD and the Energy Roadmap

The Energy Performance of Buildings Directive requires Member States to set energy performance standards for buildings, to issue buildings with energy performance certificates and to ensure that, by the end of 2020, all new buildings are 'nearly zero energy' buildings. The Directive introduced a benchmarking system, the aim of which is to create an incentive for making the energy performance requirements set by national or regional building codes more ambitious, and to ensure that these requirements are reviewed regularly. Member States were required to have most of the measures set out under the Directive in force by January 2013. It has been estimated that the Directive will reduce the EU's total energy consumption by 5-6% by 2020.

By managing energy demand, the EU can influence the global energy market and hence the security of energy supply. The **Energy Roadmap 2050** (COM (2011) 885 final) shows that improved energy efficiency in new and existing buildings will be critical to managing energy demand over the period 2020-2050. Nearly zero energy buildings should become the norm. **Buildings could even produce more energy than they use.** Smart technologies such as home automation will give consumers greater influence over their own consumption patterns, and individual buildings and districts will play an active role in local distribution and storage grids.

The expected role of RES in energy-efficient buildings is important for future developments and in order to reach the EU targets about NZEB and future energy plus buildings. Buildings could satisfy their own energy needs or even contribute excess power to the community (zero/positive energy buildings). The estimated share of onsite renewable energies involved in nearly zero energy buildings, is 30% in North Europe and up to 90% in South Europe (see Figure 1).

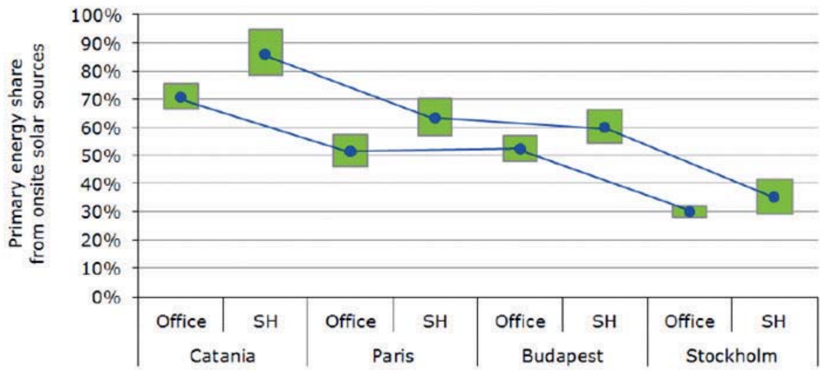

Figure 1. Estimated share of onsite solar renewable involved in nearly zero-energy buildings (source: ECOFYS)

Section 2: The present BIPV-field

Comparable prices between BIPV systems and conventional building materials

Building Integrated Photovoltaics (BIPV) is about multifunctional building elements that generate electricity. BIPV therefore brings the worlds of construction and photovoltaics together with all the challenges and chances inherent to such a change of paradigm. After more than 20 years of R&D[11], the market for building-integrated photovoltaics has kicked off with very interesting products and elegant showcase projects. The birth of this market has been based on an enormous progress in PV technology development (cost-wise and performance-wise), together with the vision of some leading architects and industries.[6]

Figure 2 displays the results of the price survey (€/m2.) which compares conventional façade systems with some BIPV solutions. This leads to the following important conclusion: for façades a very interesting price point has been obtained, as BIPV systems are very comparable in price with conventional façade materials. Low cost BIPV façade strengthen the promise of BIPV because these applications are cost-wise suitable as a substitute for the conventional façade solutions.[12]

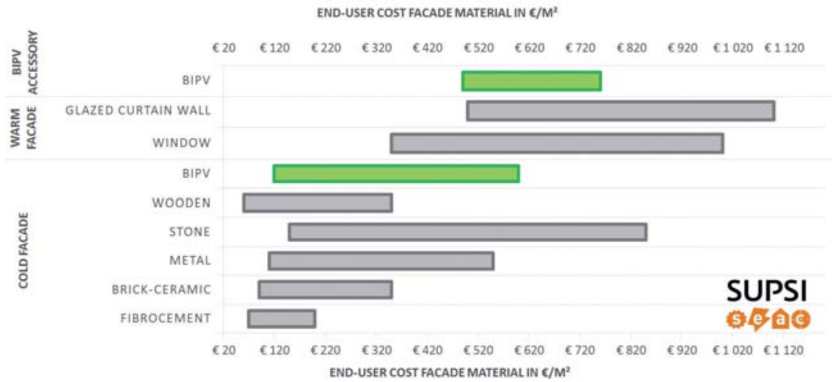

Figure 2. A benchmark of the conducted price survey, comparing conventional facade materials with BIPV Facade solutions. The price is defined as the end-user price and measured in €/m2. (Source: BIPV STATUS REPORT 2015, SUPSI – SEAC, BIPV product overview for solar façades and roofs, pg. 19.) ©: www.seac.cc

BIPV roof products are priced about 200 €/m2 above conventional roof products. Several products in the BIPV full roof solution category were found to be lower priced than the alternative of roof tiles topped with conventional BAPV systems, making these products the most cost-effective PV solution for newly built or renovated houses.

[11] Building Integrated Photovoltaics: An emerging market, http://www.solarserver.com/solar-magazine/solarreport/solar-report/building-integrated-photovoltaics-an-emerging-market.html

[12] BIPV STATUS REPORT 2015, SUPSI – SEAC, BIPV product overview for solar façades and roofs, pg. 19

Section 3: Challenges and R&D priorities in BIPV

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A number of issues will be critical for BIPV to become a new and important growth sector within the PV-branch. These critical factors were identified in the activities of the BIPV Working Group of the European Technology & Innovation Platform Photovoltaics (ETIP PV)[13] but these findings are also supported by many parallel Roadmap exercises going on in European-wide organizations like ETCP[14], National Groupings like KTN, UK or within the context of individual companies.

From all these documents a number of general issues comes forward. It turns out that the present offering of BIPV-products by the PV-industry imposes too many restrictions relative to the wishes of the architects and building developers. This results in a market situation where only prestigious and large projects can be executed as only these projects allow mobilizing sufficient financial means to adapt the PV-product to these wishes. As a result, the typical size of such projects exceeds several 100 m2. This is a missed opportunity as the potential market size for BIPV is much larger given the renovation needs for existing building stock (at least 1-2%/year) and the opportunities in the construction of new buildings.

In order to better grasp these opportunities it will be required that both the PV-industry and the construction industry would leave their “comfort zone” For the construction industry it will be crucial to fully understand the potential improvement of energy efficiency in buildings and aesthetic design in using BIPV elements. The PV-industry has to develop a broader perspective than limiting itself to the traditionally used parameters like efficiency under standard conditions and minimal cost/Wp. The focus on these parameters leads to a maximum degree of standardization, which is incompatible with the wishes from building construction side. Instead of using cost/Wp as the main metric to evaluate technologies and projects, more BIPV-relevant parameters are to be taken into account (cost/m2, energy yield/m2, ...) and addressing less easily quantifiable parameters such as the value of building aesthetics is of essence. Findings of field tests also indicate that there is a very erratic link between the performance of a PV-system integrated in the building and the expected performance based on standard measurements.

Drilling down on these issues and parameters, the keywords for improving the present situation are achieving flexibility and consistency. The flexibility is of importance on different levels. Flexibility has to be present in terms of color, shape and outlook of the PV-modules as well as on the electrical level. The latter is required for the BIPV-system and will often impose a certain reconfigurability (intermodule, but possibly even intra-module) to cope efficiently with issues like partial shading, non-rectangular shapes, different colors resulting in current mismatch, ...). The electrical reconfigurability might comprise both the module making as well as its operation. In addition, there is a need for much better understanding and bottom-up design tools to obtain estimations with improved accuracy of energy yield when integrated in the building skin. These improved energy yield predictions are not only needed for long term predictions intended for ROI-calculations, but are also a must for short term predictions as the BIPV-system will be controlled by a local energy management system.

Achieving these goals will comprise a broad number of actions on the level of research, development and demonstration:

- Design tools allowing to :
  - Integrate PV into the building skin from the early architectural design phases
  - To make the link between the building design and the detailed module lay-out
  - Extract accurate energy yield predictions for short and long term

- These design tools are to be calibrated by means of data provided by specific BIPV-oriented test centers or coming from existing and finished projects. Actually, there is quite some room here for data mining to optimize design, operation and maintenance.

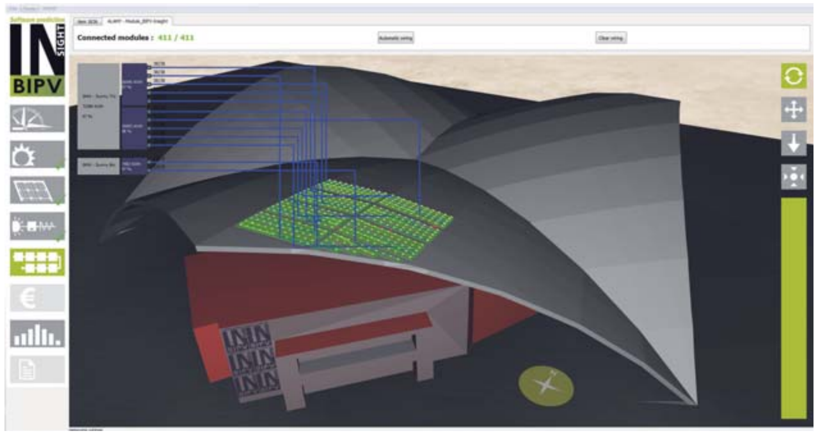

Figure 3. Example of early design incorporation of PV-elements (Source: BIPV-Insight Platform)

[13] European Photovoltaic Technology Platform (EU PVTP) has been merged with Solar Europe Industry Initiative (SEII) to European Technology & Innovation Platform Photovoltaics (ETIP PV)

[14] http://ectp.ectp.org/cws/params/ectp/download_files/36D2981v1_Eeb_cPPP_Roadmap_under.pdf

- Development of freeform module technology which is compatible with the required flexibility. This might result in process flows where the coating processes of the active layers (front-end technology) is separated from the details of the intra- and inter-module interconnection (back-end technology).

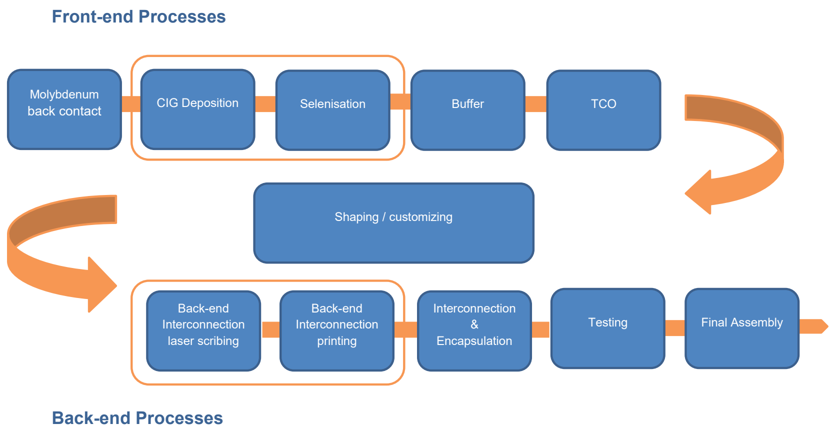

Figure 4. Freeform module technology flow (Source: Solliance)

- Performance is to be evaluated in relation to the local properties when used in the BIPV-skin, taking into account aspects like thermal conductivity, local ventilation, ... This will require the development of flexible test centers which go beyond the capabilities of the existing certification labs.

- Development of home and district energy management systems optimizing the energy flows within the building and between buildings. This also comprises the integration of electrical and thermal networks. In view of its similarity to the "Internet of Things" paradigm, one could describe this as the Internet of Power/Energy.

A first prioritization exercise to deal with these issues was done in the frame of the EU PV Technology Platform. The prioritization was done using a building-oriented value chain as a framework. The results are presented in table 1. The prioritization was built on the results of two workshops organized by the EU-PV Technology Platform and a number of conference call discussions amongst players in different parts of the BIPV value chain (see below in Table 1).

All these issues are to be dealt with in a frame where a new equilibrium between flexibility and costs in comparison to PV-systems to be deployed in large-scale PV power plants is to be found.

	Design of the building	**Choice of BIPV building components**	**Manufacturing of PV building components**	**Integration in the building skin**	**Operation and maintenance**	**Deconstruction and recycling**
High	Education Early inclusion Design tools Benefits quantification Stable and clear regulation Effect of orientation, slope	Color tunability Dimensional tunability Cost versus standardization	Performance Freeform module technology Standards for testing and certifying BIPV building components	Education and training of construction workers on PV modules Defining integration structures	High durability for standard PV and building code conditions Clarity& safety Clarity O&M instructions Self cleaning BIPV systems Risk ownership	Avoidance of toxic materials in BIPV modules Optimize recycling process for BIPV elements Ease of substitution and replacement
Medium	Removal of administrative barriers	Performance for low illumination conditions and high temperature Adapted convertors	Short lead times to deliver BIPV-elements More insurance options of BIPV products	Not yet discussed		Definition of local recycling centers close to end-users

Table 1. Prioritisation of R&D&D subjects in BIPV

Section 4: Strategies for Innovation and Competitiveness in the Energy Efficiency and BIPV Sectors

Measures relating to energy efficiency and the use of renewable energy are part of broader initiatives designed to ensure that the EU meets the objectives of its energy and climate change policy. Enhanced BIPV market uptake and innovation in the BIPV sector could be reached through interdisciplinary collaboration among the building sector and PV industry.

In the context of the SET Plan and the target of NZEB (Nearly Zero Energy Buildings) and future PEB (Plus Energy Buildings) the design and new structural concepts of BIPV are essential for reaching the climate goals in Europe and world wide. The need for innovation with new BIPV materials and the combination of energy efficient building materials with BIPV, as well as new ways of BIPV design are important in this process. The need for energy strategies at district and city level in this regard is in line with this concept.

The **European Roadmap for Energy Efficient Buildings** (2014-2020) underlines as well some challenges and drivers related to PV, such as:

- Interaction with other research areas especially the integration of supply systems for renewable energy including storage systems would be mandatory.
- The energy equipment must adapt to the new smart grids and to lower unit energy demands from more energy efficient buildings, which requires sizing down the current portfolio while keeping energy efficiency at the highest level possible as well as unit investment cost down. Beyond existing technologies, breakthrough solutions can be expected from heating/cooling systems combined with renewable energy sources, storage (heat and electricity) and building or district integrated solutions in combination with smart grid technologies.
- Growing interaction between buildings or districts and grids/networks: building design would more and more benefit from evolving electricity, heating and cooling distribution networks which integrate more decentralised and renewable energy sources, as well as emerging flexibility in the consumers' demand (demand response schemes).
- Future buildings would be able to communicate with each other and their environment. They would manage the energy use taking into consideration the availability of local renewable resources and the more profitable periods for network connections.[15]

[15] ECTP, Luc Bourdeau, EUPVTP - BIPV conference, July 2015, RIBA, London

BIPV and Energy Efficiency business and technology opportunities in Europe

The business and technology opportunities for BIPV in Europe for increased innovation and competiveness in the PV sector are huge and represent unique opportunities for the building integration of photovoltaics further developments. The creation of jobs and reaching the EU and world-wide climate targets is closely related to this. Energy efficiency and BIPV are strongly interrelated and industry opportunities based on cross-sector collaboration among the building and photovoltaic industry and with architects, developers and research institutes. Hand in hand with these opportunities in the R&D&I for BIPV, challenges for the future investment and applications are as well inter-connected.

For the integration of PV into the building skin it is important, to consider BIPV technical options from the early design phases. The close collaboration with architects and designers is essential for enhanced future energy efficiency in buildings with innovative BIPV. Education of professionals and architects is as well interlinked with this need. For the improvement of the present BIPV situation and an enhanced market share of BIPV, flexibility, colour and consistency are important topics. The flexibility is of importance on different levels. Flexibility has to be present in terms of colour, shape and outlook of the PV-modules as well as on the electrical level.

Collaboration among stakeholders and the collaboration with the building industry, developers, architects and engineers, as well as with the Smart Grid and Smart City industries. The close collaboration with the ECTP (European Construction Technology Platform) and the European Technology & Innovation Platform (ETIP) Smart Grids underline the future way of interdisciplinary exchange and collaboration in the field of energy efficiency in buildings and the integration of renewable energies, in particular integration of photovoltaics into buildings, cities and the smart grid in order to ensure energy security and sustainability in the building and construction sector.

HIKARI Building, Lyon
Kengo Kuma and Associates Architects
Photo credit © Baptiste Lobjoy

Section 5: Future outlook

Active City House, Frankfurt am Main
HHS Planer + Architekten AG
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Section 5: Future outlook

Manufacturing of PV modules as building materials can develop to a world-wide market with huge opportunities for the European industry. Driven by policies towards Zero-Energy Buildings and subsequently PEB (Plus Energy Buildings), design and innovation with new BIPV materials and concepts and combinations of energy efficient building materials with BIPV become essential parts of the development strategies of both the PV sector and the building sector. This calls for a multidisciplinary research and development programme involving, among others, the PV manufacturing industry and the building materials industry as well as certification bodies. Breakthroughs in technology, applications and business models are required to transform today's BIPV niche market into a future mass market.[16]

Strategic Targets

Building on the Integrated Roadmap (IR) of the SET Plan, public (EC and Member States/Regions) and private investment must focus on targeted R&I actions to achieve the following goals in terms of PV system performance, cost reduction, sustainability and innovations in Building Integrated PV (BIPV) products by joint efforts between the PV and the building sectors.

- Enabling mass realisation of "(nearly) Zero Energy Buildings" by Building-Integrated PV (BIPV) through the establishment of structural collaborative innovation efforts between the PV sector and key sectors from the building industry. [8]

The building industry is making huge progress with the implementation of energy efficiency measures, new technologies and innovations in building and construction; the PV and BIPV industries should now consider using the enormous possibilities outlined above, in supporting the achievement of European and international climate goals, to spur closer collaboration with the building industry in the field of innovation, new materials and the development of highly energy-efficient building components through the integration of renewable energies, in particular BIPV. The building industry, which is rapidly developing, and the BIPV industry, which is following a slower path, have common issues: energy efficiency in buildings and production of renewable energies in the buildings, in order to reach the EU and international goals. This scenario presents an important opportunity and challenge and strengthens the market opportunities for energy efficiency business and BIPV towards to NZEB and energy-plus buildings.

Active City House, Frankfurt am Main
© Solarnova Deutschland GmbH, Wedel, Germany

[16] SET Plan- Declaration on Strategic Targets in the context of an Initiative for Global Leadership in Photovoltaics (PV)

Unlocking the potential of BIPV

Unlocking the immense energy saving potential of buildings requires not only ambitious legislative frameworks and policy programmes, but also the continued research and development of innovative building techniques and technologies, and the dissemination of learning from real-world best-practice projects. To address the challenges of transforming the energy use in buildings and to allow for their better integration into the future energy systems, a long-term and multi-dimensional perspective is required.

From the previous it is clear that for the development of a thriving BIPV-sector it will be crucial to see the PV-module as a building component technology than rather than a pure PV-module, delivering electricity. In order to exploit the huge economic potential of BIPV and its required close link with local building markets, it will be necessary to (re)organize the value chain, e.g. by enabling flexible ´production on demand´ by the BIPV element producer, in the amount, size, colour etc specified in a specific building project). A key question will be whether the traditional PV-companies will be able to exploit this paradigm shift since many of the items touched upon are orthogonal to their present thinking, but at the same time this offers broad opportunities for the creation of new industrial tissue in Europe which are unlikely to be displaced easily. The close collaboration among architects, engineers, research institutes and BIPV manufacturers and the final "clients" like developers, construction companies is essential for further innovation and competitiveness in the BIPV sector.

For the development of NZEB and positive-energy buildings, new approaches to improving energy performance in buildings are essential, meaning there is a huge potential for the development of innovative building technologies, together with innovative concepts for buildings and urban districts, to promote the integration of renewables such as PV in buildings. BIPV offers huge opportunities in this regard, in particular in façade applications.

The consideration of the availability of local renewable energy resources in buildings / cities (among others BIPV) in connection with demand side management and newest storage technologies will become an important part of the energy system of the future, in combination with the smart grid. The outlined strategies and priorities are in line with the objectives of the Energy Union and the priorities of the SET Plan.

Tanjong Pagar Centre, Singapore
Architect: Skidmore, Owings & Merrill (SOM)
View of the glass canopy with embedded thin-film solar modules
Image courtesy SOM / © Digital Mirage Pte Ltd.

Tanjong Pagar Centre, Singapore
Architect: Skidmore, Owings & Merrill (SOM)
Image courtesy SOM / © Digital Mirage Pte Ltd.

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