Building-integrated photovoltaics: guidelines and visions for the future of BIPV

Dr. Arch. Silke Krawietz, SETA Network, Rome, Italy

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ABSTRACT

Renewable energy and, specifically, the integration of photovoltaics in residential development will play an important role in the context of global sustainability and resource conservation. Just like EPIA outlines in its Solar Europe Industry Initiative (SEII) plan (2010-2012), as distributed PV and other renewable energy technologies mature, they can provide a significant share of European electricity demand. However, as their market share grows, concerns about potential impacts on the stability and operation of the electricity grid may create barriers to their future expansion. Additionally, low-cost, high-quality integration of PV in buildings and other objects poses major development challenges. The goal of the SEII is to unlock the potential for making PV a mainstream energy source, with special attention on aspects of system integration.

Introduction

In order to achieve the target of generating up to 12% of the European electricity consumption by 2020, the PV industry, together with the network operators and building sector, needs to develop economical and technical solutions that will allow a large penetration of PV at a competitive level [1].

With respect to system integration, the SEII plan shows the following key performance indicators:

- Demonstration of reliable operation of grids with high levels of PV penetration;
- Demonstration of high-quality, versatile integration of PV in buildings and infrastructural objects;
- Demonstration of large-scale use of new PV technologies;
- Availability of comprehensive PV technology, economy, market.

In the field of building-integrated photovoltaics (BIPV), very large-scale deployment of PV will strongly benefit from (or may even partly depend upon) the availability of multifunctional PV modules for integration solutions for buildings and infrastructural objects (sound barriers and many more). This is because turnkey system costs can be reduced by advanced integration concepts, but also because public support may be fostered or strengthened by the high aesthetic quality achievable with full integration. It is therefore imperative to develop concepts and hardware for the integration of PV [1].

Fig. 1 shows the budget distribution for R&D and demonstration projects under the SEII: 2010-2012. It should be noted that this does not include other types of investments (such as, for instance, capacity expansions or the ongoing national research on the various topics), which are not directly included under the SEII.

BIPV, using first- (wafer-based approach) or second-generation (thin-film) photovoltaics, is already offering enormous possibilities for architects and engineers to integrate this cutting-edge technology into their buildings and to make BIPV a part of their overall architectural concepts. Nevertheless, there are still many unexplored possibilities and challenges, as BIPV is not yet integrated in every new or refurbished building. This will, however, hopefully be the case in the near future, keeping in mind the European Energy Performance of Buildings Directive (EPBD), which was recast in 2009, and other policy movements that promote the use of renewable energies in buildings.

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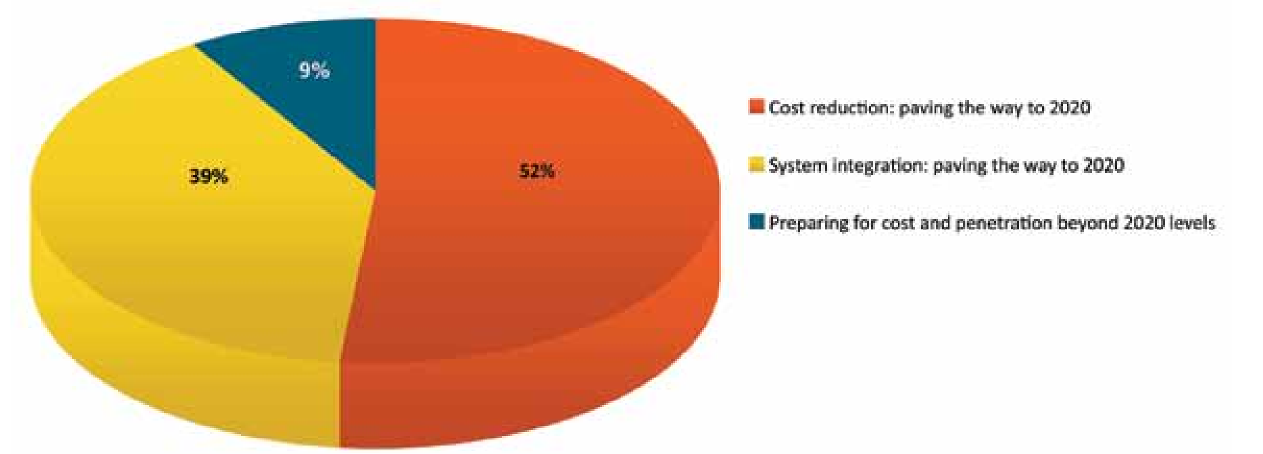
The integration of photovoltaics in buildings is a key to the future of PV technology. A BIPV system will be integrated successfully if it is incorporated into the building fabric with good design and structure and with a sustainable energy concept. The building envelope has become a more complex and multifunctional element, with increasing façade performance expectations. With new technological developments, radical changes to the design of façades and roofs can be realized. While designing



Courtesy of EPIA, p. 18.

Figure 1. Budget distribution for R&D and demonstration projects by categories under the SEII: 2010-2012.

the building exterior we need to be aware that the use of PV as part of the envelope is important.

This presents only one aspect of various building envelope performance characteristics which need to be considered in the planning stage. To accomplish all these building performance expectations, PV building products should not only produce electricity, but also be able to fulfill other functions. Photovoltaic integration is becoming a design element for buildings. PV modules in a building can have several functions such as providing weather protection, heat insulation, sun and noise protection, as well as assisting with the modulation of daylight [2].

Instead of conventional façades and roof elements, the use of photovoltaic modules could be described as constructive integration. The modules thus replace components of the building envelope and roof. In the broadest sense an integrated PV into the façade is and can be an architectural visual enhancement, in accordance with the eligible BIPV solutions for the FiT in various countries.

> "In planning a BIPV system, the orientation of the selected building surfaces for PV must be taken into account."

How is it possible to achieve a successful integration of photovoltaics into buildings? Which criteria and critical factors should be taken into consideration early on in the planning stages and then in the overall architectural concept itself?

By following some critical principles and various aspects of BIPV that must be considered by architects and planners in order to achieve a maximum yearly energy output of the system, a successful BIPV will be capable of achieving the maximum possible energy output for the installed PV system as well as a pleasant aesthetic result.

The factors to be considered are:

- Inclination and orientation of the BIPV system;
- Rear ventilation; and
- Shadowing and different orientations.

Inclination and orientation of BIPV systems

Both the inclination and orientation of a solar cell surface influences the yield. The ideally positioned PV system corresponds in its inclination approximately to the degree of latitude of the location, and is orientated to the south.

A south-orientated vertical BIPV system can still achieve 70% of the best possible yield. It achieves good performance even when the sun is low in the sky (for example in the morning, the evening and mostly in winter). In the summer, the conditions are not as favourable for a high energy yield result.

A vertical system, which is orientated towards the east or west, can reach up to 50 to 60% of the maximum energy yield and has good performance in the morning and evening respectively.

A vertical façade, which is oriented towards the north in Europe, rarely receives any direct sunlight, with the exception of indirect sunlight for brief periods in the summer, early in the morning or late in the evening. Nevertheless, it achieves 20 to 30% of the best possible yield due to diffuse light scattered across the sky, especially in cloudy weather.

To achieve acceptable yields, it is advisable but not essential that the system is oriented towards to the south. Electricity is often required most on summer afternoons due the air conditioning load in the building. A system oriented more to the west than the east could be the best choice in this case.

In planning a BIPV system, the orientation of the selected building surfaces for PV must be taken into account to a certain extent. Although the planning criteria should not be purely yield-oriented, it is nevertheless important to include the requirements of these electrotechnical components in the design considerations.

The orientation of the module surface, when located in a southerly orientation with an inclination of approximately 35 degrees towards the horizontal in Central Europe, enables maximum solar yields to be achieved over the entire year. However, the architect or planner retains substantial flexibility. Deviations from southeast to southwest involve only small losses of yield. Even in the case of vertical installation, with a southerly orientation, it is possible to achieve almost 3/4ths of the solar irradiance compared to an optimal orientation.

Rear ventilation

In addition to the alignment and possible shadowing of the PV surface, the electrical efficiency of the photovoltaic modules significantly influences the yearly energy yield. This decreases as the modules become warmer. The architect/planner can exert influence on their structural integration. Sufficient rear ventilation should therefore be guaranteed, weighing it against other construction and design decision-making criteria. The module cooling may also be combined with controlled waste heat recovery.

Shadowing and different orientations

Solar cells are combined into a module and connected in a series to obtain higher module voltages. Within the particular string of cells, like in series-connected batteries, it is known that the 'weakest' cell determines the total electricity output in the module. This kind of weakening of the cell can be caused, for example, by (partial) shadowing. In this case, the electricity reduction does not occur linearly to the shadowed module surface, but acts disproportionately towards it.

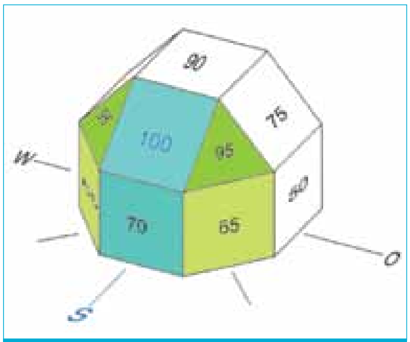


Figure 2. Influence of alignment (orientation and inclination) on the annual insolation quantity in Central Europe [3].

This also applies to the interconnection of the modules in the generator array, because in order to achieve the normal system voltages, multiple modules are connected in series to form a so-called generator string. The generator array can then – according to the desired system voltage – be expanded with several parallel connected strings. The electrical power output of such a string is determined by the weakest module. To minimize the progression due to unavoidable partial shadowing, a weakened module can be 'circumvented' by using so-called bypass diodes between the cell connections. The above-described effect also occurs if the modules in a string have different orientations. Here the amount of electricity is determined by the least favourably-orientated module. However, this problem can be counteracted by the appropriate interconnection of the generator array in strings that are as short as possible.

The decisive factor for the maximum energy yield of a photovoltaic system, in addition to the orientation, is the absence of shadowing on the generator surface because even minor shadowing of individual modules may result in substantial reductions in the energy yield.

Therefore, the module surface should be planned in such a way that it remains shadow-free as much as possible, at least during the summer season. The initial indications can be obtained, for example, with the aid of solar altitude diagrams. More detailed information can be obtained from alternate or other simulation programs.

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Particular attention should be given to the surrounding buildings. Even plants around the building may eventually cause shading and thus have an adverse effect

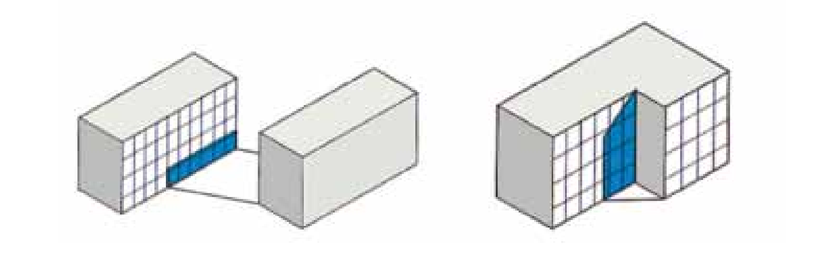

Figure 3. Shadows cast by surrounding buildings (left) and the geometry of the building in question (right) need to be taken into account during the design phase [3].

on the performance of the modules. This applies in particular to newly-planted green spaces, which are often designed by external planners. It is advisable to establish guidelines that can guarantee a shadow-free module surface.

Even the possibility of shadows cast by the building itself should be considered. This can be caused both by the building geometry itself and also by details of the constructions' deep cover strips, suspended elements or moving parts – all of which risk casting unfavourable shadows (see Fig. 4).

All of these elements must be considered in the early planning stages of a building, in order to achieve the maximum energy output of the PV system [3].

Outlook into the future

In the future there will be overlapping areas between architecture and the field of photovoltaics and therefore it is important for the sake of future collaboration that architects develop a knowledge of BIPV. This will be increasingly important for future collaboration between architects, PV specialists/experts and PV companies.

Consequently new integration possibilities can be found in an interdisciplinary collaboration among the various branches, as there are still many unexplored possibilities in the field of BIPV. This is a continuing challenge for the architects of today and tomorrow.

Innovation and R&D is necessary for a more widespread use of BIPV and for the development of new products. A strong interdisciplinary collaboration between PV and building component manufactures, architects and engineers is essential. The collaboration between these areas might lead the way new designs of BIPV modules, with more flexibility in shape, colour and dimension. Better performance and higher PV efficiency, together with more variability of BIPV products, is expected.

The future of BIPV can only be designed and developed with common efforts in the direction of a BIPV future and the multiple use of façades, roofs and building components.

PV technology has seen a huge increase in the last decade and more is expected to come, especially in Europe. BIPV will play an even more important role in the future.

As the EPIA report SEII suggests in "System Integration Paving the Way 2020", the development of new multifunctional PV-based products, research infrastructure, test facilities, and test procedures for building-integrated PV products in order to make innovations faster and easier are becoming ever more important.

As well as optimization of the energy output and value in a complex environment, shadowing, and demand-side management options must be considered in order to get the best value in PV production [1].

Every building in 2030 that is designed, constructed and monitored will have cutting-edge BIPV technology. Architects of today and tomorrow have to keep pace with the development of building technologies and stronger policy regulations in the framework of climate change and sustainable development. Amelioration and application of PV is a key to the future.

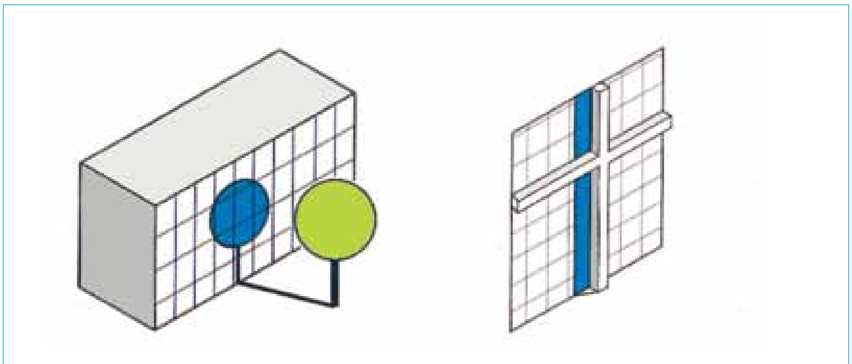

Figure 4. Plants (left) and deep cover strips (right) are among the elements that can cause shadowing on a building and reduce the BIPV system's efficiency [3].

References

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About the Author

Prof. Dr. Silke Krawietz is CEO and Scientific Director of the SETA Network, an organization that is active in the field of Sustainability, Energy, Technology and Architecture and offers services for BIPV projects, information, and consultancy. She is collaborating with EURAC, Bolzano, in the Institute for Renewable Energy, as well as UNEP, Paris in the Sustainable Building and Construction Initiative (SBCI) as a member of the European PV Technology Platform. Dr. Krawietz has been Interim Professor at the Faculty of Architecture at the University of Catania, Italy for the past five years and she has worked on many BIPV projects with international bodies and European universities. An expert in Jeremy Rifkin's team, she holds a Ph.D. in BIPV from the Faculty of Architecture, University of Darmstadt/Germany.

Enquiries

Tel: +39 06 35491557
Email: seta@gmx.net
silke.krawietz@eurac.edu
Web: www. seta-network.com