

BUILDING INTEGRATED PHOTOVOLTAICS IN GERMANY NEW DEVELOPMENTS AND TRENDS

Ingo HAGEMANN, Architect

Architekturbüro Hagemann, Annuntiatenbach 43, D-52062 Aachen, Germany

Fax/Phone: +49/(0)241/30547

E-mail: Ingo.Hagemann@RWTH-Aachen.de

Abstract – Photovoltaic technology (PV) is becoming a popular part of the building vocabulary in Germany. It can be used today on both existing and new buildings. Its use in the building envelope is very varied and open opportunities for creative designers. In particular, semitransparent photovoltaic glass modules can be changed into a truly multifunctional building component which is able to serve in addition to an electricity production other functions of the building envelope as well. Such synergy effects of a photovoltaic module only turn out to be successful if its integration in the building fabric is carefully understood and the photovoltaic component is fully integrated into the overall design and energy concept of a building. Presently, in particular, non-technical barriers still need to be resolved to allow an intelligent and wide spread application of photovoltaics in the built environment.

1. INTRODUCTION

There is an increasing awareness about the destruction of the natural environment and a growing concern about the quality of the built environment in Germany. As a result goals, specifications and requirements for the construction and design of buildings do change. In the centre of interest of necessary changes is the building envelope. The rise of new technological developments allow today completely different visions of a conventional façade or roof. With respect to the multifunctionalism of the building envelope it is more and more necessary to make use of different active and passive solar techniques. One solar technique, which is becoming, increasingly, an important part of the building vocabulary, is the photovoltaic (=PV) system.

A photovoltaic module is basically a covering material which has the added value that given the right conditions it can produce electricity during certain periods of the day. The production of electricity may be considered, thus, a bonus to this unique exterior building material. On the other hand there is also a clear vision, that photovoltaics will be able to contribute substantially to the main stream power production, even though it is still five times more expensive than grid power (1). Building integrated photovoltaics (BIPV) offers cost advantages and is attractive for urbanised regions in countries, like Germany, with limited unoccupied land availability.

2. BUILDING INTEGRATED PHOTOVOLTAIC (BIPV)

Photovoltaics can be used today in different ways on both existing and new buildings. Its use on façade and roof areas are very varied and open new opportunities for creative designers.

2.1 Building façade panels

Façades occupy the majority of the surface area of the structural shell of the building. A façade gives each visitor an initial visual impression of the building and architects are keen in using a façade to express their concepts and translate their client's wishes into an appropriate language of shape and colour. As such, standard photovoltaic modules can be added on the existing wall to provide an aesthetically successful

façade. The photovoltaic modules are just added on to the structure and there is no need to provide a weather tight barrier, this being performed by the structure underneath the modules.

Photovoltaic systems can also be an integral part of the building element of the façade. The main features of a photovoltaic laminate used as a cladding material are basically the same as tinted glass. Photovoltaic laminates provide long lasting weather protection, they can be tailor-made at any size, shape, pattern and colour and they can give partial lighting inside the building. They can be configured as a simple façade plate or as a multifunctional element for cold or warm façades, sunshading devices or as windows within the outer skin of the building. In Germany these multifunctional photovoltaic façade elements are available from different companies and can be assembled with standard mounting systems which are adapted to this particular purpose.

The Ökotech 3 building in Berlin (Photo1) is an interesting example of the added value of a photovoltaic façade. The building's façades consist of granite and glass panels using a star-shaped mounting device (SJ-Façade-System) to fix the panels. The parapet area of the 2nd to the 5th floor are covered with photovoltaic panels which are partially reflective, having the same appearance as other glass panels. The use of expensive cladding material gives the building a certain class. Using photovoltaic material shows that the environmentally conscious owner is also producing part of his energy.

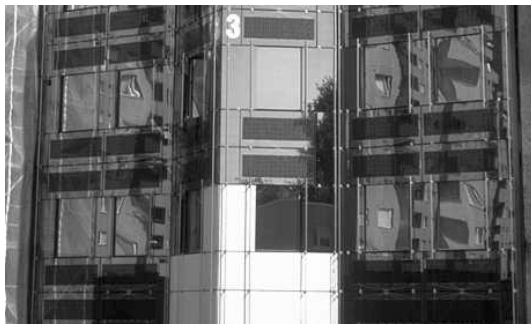


Photo 1: PV-Cladding, 4,2kWp, Ökotech 3, Berlin

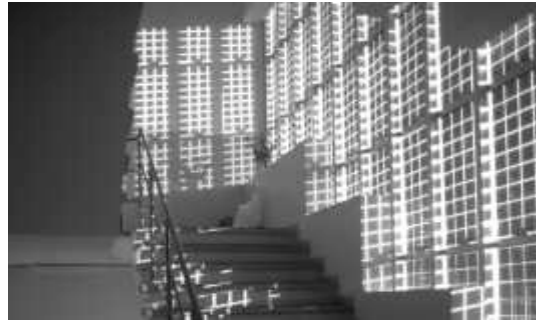


Photo 2: Semitransparent cold façade with PV, 8,5kWp, Greenpeace, Hamburg

2.2 Semi-transparent façades

As windows, photovoltaic laminates can realise its transparency function in two ways. The photovoltaic cell itself can be so thin or laser grooved that it is possible to see through it providing a 20-50% filtered vision to the exterior. Semi-transparent amorphous silicon modules are especially appropriate for this, but, very few building integration examples exist to date in Germany.

Crystalline cell modules on the other hand may have the cells on the laminate spaced in such a way that partial lighting filters through the photovoltaic element and illuminates the room. This is now available from various manufacturers, which are selling standard, or custom made see-through laminates. Light effects from these panels lead to an ever changing pattern of shades in the building itself (Photo 2). The room remains shaded yet not constrained. By adding layers of glass to the base unit of the semi-transparent photovoltaic module thermal and acoustic insulation as well as other special requirements can be designed according to individual requirements of each application (Photo 3). This type of a truly multifunctional building component with photovoltaics is most successful in Germany and is able to serve a large market in the building sector.

2.3 Shading systems

There is a growing need for carefully designed shading systems on the building market due to an increasing use of large window openings and curtain walls in today's architecture. Photovoltaic modules of different shapes can be used as shading elements above windows or as part of a roof structure. Since many buildings already provide some sort of structure to shade windows, the use of photovoltaic shades should not compromise the load bearing capacity of the building structure. The exploitation of this synergy effect helps to reduce the total costs of such a photovoltaic installation and to create added values to the PV as well as to the building and its shading system (Photo 4). New market opportunities for photovoltaics could be developed if a mass production of photovoltaic shading elements could be achieved (2). Photovoltaic shading systems may additionally use one way trackers to tilt the photovoltaic array for maximum power and at the same time provide a variable degree of shading.

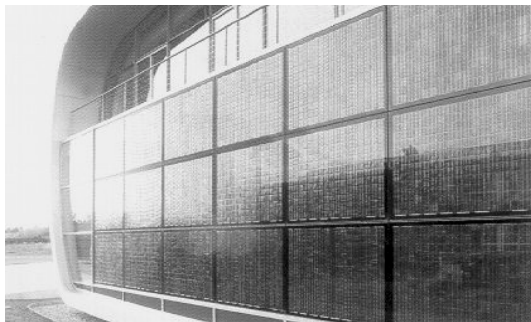


Photo 3: PV-Façade with insulating glass, 4,5kWp, Tobias Grau KG, Hamburg

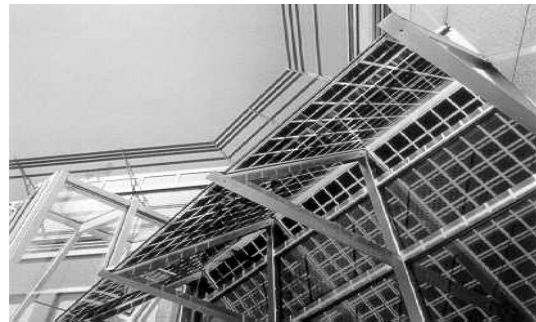


Photo 4: PV-Shading system, 1,5kWp, Metal Company Lehr, Mainz

2.4 Roofing materials

Roofs are ideally suited for photovoltaic integration. There is usually less shadowing effects at roof heights than at ground level and a roof usually provides a large unused surface for integration. For photovoltaic integration purpose, a distinction between pitched and flat roofs is made.

An ideal pitched roof for photovoltaic integration must be tilted towards the south (northern hemisphere) at an angle of $\pm 15^\circ$ latitude for best power production. Roofs which are looking towards the south east or south west are also acceptable and may even be of advantage depending on the power requirement of the building. Photovoltaic modules can simply be fixed on top of pitched roofs providing that special care is given so that the integrity of the roof's protection is not broken. This by itself is not a true architectural integration of the photovoltaic element but permits the installation of photovoltaic modules easily on existing buildings. This type of low-cost application is still used most to mount smaller photovoltaic systems (approx. 5 kW_p) on private homes as well as on existing roofs in Germany. A more elegant way to integrate photovoltaic is to use PV-Shingles or PV-Tiles which permits the mounting of the photovoltaic module, like any shingle or tile, by a roofing contractor. Successful developments from Germany are the "Braas Solar Roof Tile" (Photo 5) or the "Laumans Solar Roof Tile". Both are available on the market.

Flat roofs have the advantage of good accessibility and ease of installation. The classical way of integration has been to mount the array on a substructure that is then fixed to the roof. As with pitched roof, special care must be given to fix the array without breaking the integrity of the roof. Additional care must also be given to the added weight of the array on the roof and against the uplifting force of the wind which could blow the modules away. Experiments and developments in this field have led to lighter, easier and quicker to handle standard array structures, such as SOFREL[®], SOLBAC[®] or the PV-ConSole[®]. In addition to such standard mounting systems

still a number of custom made flat roof structures are carried out in Germany (Photo 7).

2.5 Skylights

Skylights structures are usually the best, from a solar point of view, since they can combine the advantage of light diffusion in the building while providing an unobstructed surface for the installation of photovoltaic modules or laminates. The photovoltaic elements thus provide both electricity and light to the building. The photovoltaic modules and support structures used for this type of application are similar to those of semi-transparent glass façades. These structures, which may appear rather innocuous from the outside, produces fascinating light hallway walks and floors and allow a stimulating architectural design of light and shadow (Photo 6).

Photo 5: Example of "Braas Solar Roof Tile", 1,4kWp, Alzenau



Photo 6: PV-Rooflight, 4,0kWp, Local Utility, Halle

3. PHOTOVOLTAIC BUILDING INTEGRATION IN THE CONTEXT OF ENERGY PRODUCTION

The integration aspects of Photovoltaic elements need to be fully understood and researched. It cannot suffice to simply replace existing building elements by those which additionally incorporate photovoltaic elements. Its integration must always be planned in the context of the building as a whole. An overall energy scheme must be developed for the building right at the beginning of the construction project, when the building size, shape and orientation are being made. The chance of having any influence on the future energy demands of the building decrease with every step of the planning. Additionally, efforts to make any structural changes to the building, increase as the project takes form. The higher the degree of synergy that can be achieved between the photovoltaic material and its electricity production, the more cost-effective will be its integration (3).

4. TRENDS ON THE BUILDING AND PHOTOVOLTAIC MARKET IN GERMANY

Most buildings which have been carried out so far do not provide massive cost savings or show cheap approaches of utilising photovoltaics. As an energy source, photovoltaics is still expensive compared to other grid energy sources. At the same time the various PV applications are in a rapid process of development and cost reduction. In Germany a number of efforts are undertaken to foster the acceptance and demand of building integrated photovoltaics. The goal is to reach a mass production of photovoltaics. Steps in this direction are:

Building Integrated Photovoltaic for the New Government Buildings

The new government buildings in Berlin serve as shining examples for building integrated photovoltaics. Federal building projects, such as the "Federal Ministry of Economics" (100kW_p, 1998), the "Reichstags Building" (39 kW_p, 1998), the "Office of the Federal President" (44kW_p, 1998) or the "German Chancellery" (300kW_p, under construction) all received a photovoltaic installation.

Housing Estates with Photovoltaic

Demonstration projects like the "Solarstrom Siedlung, Essen" (25 x 2 kW_p), "Auf dem Krüge, Bremen" (80 x 2kW_p), the "Sonnensiedlung, Hettstadt" (22 x 3,12kW_p) or the solar initiative of the state government of Nordrhein-Westfalen for 50 solar housing estates help to introduce photovoltaics to home owners and to the general public. These projects were either initiated on a government level or by local utility companies, who also provide the funding or other subsidies for these photovoltaic projects. The already existing projects helped to deal with the responsibility and ownership of a photovoltaic installations and its maintenance, as well as to learn about legal problems that still exist in the German law.



Photo 7: PV-Flat roof integration, 44kW_p, Office of the Federal President, Berlin



Photo 8: PV-Roof integration, 72,6kW_p, "Sonnensiedlung", Hettstadt

Large Building Integrated Photovoltaic Projects

Large building projects attract the attention of the mass media. They serve ideally, therefore, as an image carrier and information base for photovoltaics. Project examples are the "Mercedes Benz Factory Bldg., Bad Cannstadt" (435kW_p, 1996), the "New Trade Fair Munich" (1.16MW_p, 1997), the "Education Centre, Herne Sodingen" (1 MW_p, 1999) or the new "Central Railwaystation, Berlin" (300kW_p) which is presently under construction. Those who initiated such projects not only take the profit of the electricity production into account but also the benefits from the green image of photovoltaics.

Prefabrication of Building Components with Photovoltaic

In Germany, major cost savings are expected by an increasing use of prefabricated and integrated building elements with photovoltaics. They will help to cut down the labour as well as construction costs. Cost reductions of this kind allow the sourcing of additional funding for the extra costs of a photovoltaic system on a building. The vision is to have completely prefabricated building elements with integrated photovoltaics (modules, inverter, cables, etc.), which will be simply carried to the construction site and assembled. The market for such prefabricated building components will increase for both the renovation of existing buildings as well as for the erection of new buildings.

Legal Base and Financial Support for Photovoltaic

The so-called federal law "Stromeinspeisegesetz (StrEG)", which recently was renewed, provides the legal base for selling and feeding photovoltaic electricity into the public grid. It guarantees today a price of 0.51 EURO/kWh (=0.78 AU\$/kWh) to each person who feeds PV into the grid. In addition a number of other subsidy programs help as well to get even closer to a cost effective photovoltaic electricity production. In 1999, the German government started the "100-000 Roof Top Program", which provides additional subsidies for the investment costs of a photovoltaic system. Other financing schemes are independent from public money, such as the "Full Cost Rates (FCR) for Solar Energy - The Aachen Model"(4). Legal agreements, which allow a number of shareholders to jointly own a photovoltaic system, also help to make photovoltaic systems financially more attractive to a larger group of people.

Increasing importance of Renovation of Buildings

Further photovoltaic product developments should primarily focus on suitable applications for existing buildings as most of the buildings of the year 2050 are already built in Germany and maintenance, repair and renovation of these buildings will become much more important in building construction than the erection of new buildings.



Photo 9: PV-Overhead glazing, 1MWp, Education Centre, Herne Sodingen



Photo 10: PV-Roof integration, 1.16MWp, New Trade Fair, Munich

5. CONCLUSIONS

It can be seen from the given examples that an integrated approach which takes into account the synergy of power production and weather protection by the photovoltaic material, results in a new concept which can make photovoltaics attractive to builders and their clients. But it must be made clear that a true solar architecture needs to be developed with specific elements developed for this purpose and engineers and architects collaborating fully to develop them. In Germany quite a number of different building integrated photovoltaic products are available on the market now. At the same time, we can fall back on the experiences of quite a large number of buildings with integrated photovoltaic systems. Today we are in the position to say: "*photovoltaic technology is ready for the building market.*"

REFERENCES

- (1) Prasad D., Schoen T., Hagemann I. and Thomas PC (1997) PV in the Built Environment - An International Review. In Proceedings of ISES 1997 Solar World Congress, August 24-30, Expo Science Park, Taejon, Korea
- (2) Hagemann, I. (1998) Shading Systems with PV - A New Market for Prefabricated Building Elements? In Proceedings of PLEA 1998, Lisbon, Portugal
- (3) Hagemann, I. (1996) PV in Buildings -The influence of Photovoltaics on the design and planning process of a building. In Proceedings of World Renewable Energy Congress (WREN), Denver, USA
- (4) Solarenergieförderverein e.V. (1999) Full Cost Rates (FCR) for Solar Energy (The Aachen Model). In <http://www.sfv./infos/soinf171.htm>, Aachen, Germany

Photo 1, 2, 8: Ingo Hagemann, Aachen, Germany

Photo 3: Tobias Grau KG, Hamburg

Photo 4: Saint Gobain Glass Solar (SGG), Aachen, Germany

Photo 5: Braas Dachsysteme GmbH &Co, Oberursel, Germany

Photo 6, 9: Pilkington Solar International GmbH, Cologne, Germany

Photo 7: Solon AG für Solartechnik, Berlin, Germany

Photo 10: Siemens Solar GmbH, München, Germany