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Building integrated Photovoltaics (BIPV): Solar electric power systems conquer large roofs and façades

by Rolf Hug
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Since the beginning of 2007 photovoltaic records are going from strength to strength: in Brandis near Leipzig (Germany) the world's largest solar power plant with an output of 40 Megawatt is being built and will be commissioned by 2009, in the Spanish town of Beneixama City Solar AG is working on a 20 MW photovoltaic system that is to be completed in October 2007. These are both ground mounted systems, such as the power plants of "Solarpark Gut Erlasee" (Germany, 12 MW), "Serpa PV Power Plant" in Portugal (11 MW) and the German Solar Park "Pocking" (10MW). International demand for German photovoltaics is on the rise and export figures of manufacturers are continuously increasing. Executive German companies are becoming active abroad and are building large-scale open-space systems in Spain, Greece and even as far afield as Africa.

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5,1 MW solar roof of Sharp production site in Kameyama (Japan); solar power system integrated into a roof in Muggensturm near Rastatt (Germany). Sources: Sharp, Tauber Solar

Megawatt solar roofs implemented mainly in Germany



But also photovoltaics integrated into buildings (BIPV) is aiming for new superlatives: just behind the solar roof complex of Sharp in the Japanese town of Kameyama with an impressive output of 5.1 MW, the list of the largest solar roofs boasts two German photovoltaic roofs in Birstadt (5 MW on one roof) and Muggensturm (3.9 MW on one roof) in second and third place. Other solar roofs of the Megawatt category can be seen on four factory stores of the private company Franz Fischer in Dingolfing (Bavaria; 3.7 MW) or in the Michelin Solar Park Homburg (Saarland; 3.5 MW). On the roof of the new Trade Fair in Munich an impressive 2.1 MW have been installed, the roofs of the Solar Park Pfersdorf e.G. achieve 2 MW, a logistics centre in Relzow (Mecklenburg-West Pommern) has 1.5 MW. The discount store LIDL is operating a solar roof with 1.2 MW near Freiburg in Breisgau.

Vertical photovoltaics are also showing a tendency towards larger systems. The Solar Report 6 / 2007 presents some examples of high-output photovoltaic solar roofs, innovative solar power façades and a brief outlook on the future integration of photovoltaics into buildings.

The second largest solar power plant worldwide on a single building in Baden-Württemberg

On the flat roofs of the logistics company Hartmann AG in the town of Muggensturm the company TAUBER-SOLAR from Tauberbischofsheim installed 80 000 square metres of solar power modules. The photovoltaic system is located in the district of Rastatt, directly next to the A5 Autobahn. The annual solar power output covers the consumption of 900 four-person households. This photovoltaic power plant is currently the third largest system worldwide installed on a building. The almost 30 000 Conergy solar power modules were installed on stands on a flat saddle roof (double-layer steel trapezium profile) with integrated insulation layer and cover a surface corresponding to 16 soccer fields. At a peak performance of 3.84 Megawatt (MWp) the operator expects an annual output of 3.5 million kilowatt hours.



In particular roofs of large companies are suitable large-scale locations for PV modules. Photos: Property of the logistics company Hartmann in Muggensturm, some of the approx. 30 000 solar power modules that were installed. Source: Tauber Solar

Inverter station weighing 50 tonnes, total investment of 17 million euro

Eight large inverters of the company SMA Technologie AG from Niestetal/district of Kassel (4 x SMA Sunny Central SC500HE, 4 x SMA Sunny Central SC350HE) are located in a double-storey concrete station with a height of 6.8 metres and a weight of over 50 tonnes. These are located next to the buildings and convert the solar direct current into indirect current so that it is compatible with the network. Feed-in is done directly into the medium-voltage network of the municipality of Muggensturm (network operator: eneregio Muggensturm).

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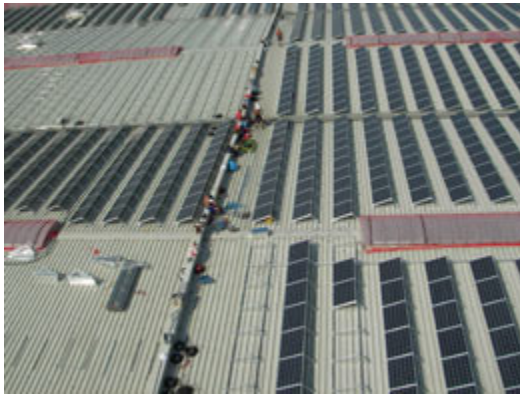
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Row by row solar modules are installed on the roof. Assembly of one of the large inverters.

The costs of this large-scale solar power plant are estimated by TAUBER SOLAR to amount to approx. 17 million euro. Per kilowatt of peak performance the system price was 4.415 €. Project management was done by the engineering company IBU from Karlsruhe, the installation was done by the company activ solar (Tauberbischofsheim and Friedelsheim/district of Bad Dürkheim) that is now in charge of maintenance of the entire solar power system.

The world's largest PV system on one single roof in Bürstadt (Hessen)

An overview of all large-scale photovoltaic systems of above 150 kilowatt peak that are installed throughout the world can be found on the Internet under <http://www.pvresources.com>. This overview also includes the world's largest system on a single roof that is run by TAUBER SOLAR. The Solarserver presented the solar power plant "Sonnenfleck" in Bürstadt as "Solar System of the Month" in May 2005 under <http://www.solarserver.de/solarmagazin/anlagemai2005.html>.

Hartmann AG is a logistics company that transports mainly food and frozen products as well as spirits and beverages. The contact with the owner of the roof was established through the Raiffeisenbank Südhardt. The town of Muggensturm with its 6 300 residents and the owner of the roof are proud to have written solar history with this sun roof: some of the trucks of this company are decorated with large sunflowers, and the slogan "Solar power from Muggensturm" is an awareness-raising campaign on their trips through Germany.

Increasing numbers of thin-layer modules on roofs and façades

Cost-effective thin-layer technology is used increasingly in open-space systems, but is also suitable for larger façades. The new PV roof of the Colruyt Group on a factory store in the Belgian town of Halle consists of thin-layer photovoltaic systems and achieves a total output of 330 kilowatt (kWp). This is clearly below the Megawatt line but it is nevertheless the largest system in Belgium. On a wheat silo of the mill "Schapfenmühle" in Ulm the largest CIS photovoltaic system worldwide was integrated into the highest façade and consists of 1 300 modules with a total nominal output of 98 kWp. The new solar façade at the Ferdinand Braun Institute for Hyper-Frequency Engineering in Berlin-Adlershof has a peak output of 39 kilowatt, the modules covering a surface of approx. 640 square metres.

The installation of thin-layer modules directly onto the roofing prevents problems of statics

Currently the largest photovoltaic system of Belgium is located on the roof of a factory store of the discount store Colruyt in Halle in the province of Flemish-Brabant. The Colruyt Group, one of the leading food chains of the country, obtained the thin-layer modules of the "PV Plate" make with a total output of 330 kWp from the Paderborn-based company

BIOHAUS PV Handels GmbH.



PV roof with thin-layer modules of the company Biohaus. Source: Biohaus

The bitumen flatroof has a total surface of 12 000 square metres of which three quarters are covered with modules. The company Colruyt is not only attempting to establish a “green” image through the utilisation of renewable energies – the long-term goal of the discount store is to cover their own energy demand to a large extent with regenerative energies. Besides the photovoltaic system, the property in Halle also boasts a wind power station. A 2MW turbine at another location, the participation in a planned wind park in Ypern, as well as investments in offshore wind projects are further proof of the ecological commitment of the company.

Originally Colruyt engineers had even planned a solar power station of about 900 kWp. Sufficient space would have been available for such a system just below the Megawatt line on the neighbouring roof. "Since it's not yet clear whether this hall will be changed soon, we decided to restrict ourselves to the one roof first," project engineer Dirk Vandercammen explains in an interview with Photon Magazine (2/2007). The new building that is currently being planned is designed for the inclusion of a large-scale solar power station. This was not the case with the surface areas that have been covered with modules thus far – and that is the reason why thin-layer modules were installed directly onto the roofing, without frames, without covers and without assembly frameworks. "Otherwise we could not have installed the system, because the statics of the roof simply would not have carried the weight," Vandercammen explains. These special conditions, that exist quite frequently in factory stores, were decisive in Biohaus winning the tender with its PV-Plate modules.



"Our thin-layer systems are ideal for roofs like these," Ralf Zirkler, Technical Manager of BIOHAUS explains. The solar modules that are each over 5 metres in length weigh only about 50 kg and are stuck directly onto the bitumen roof.

Photo: Biohaus

With the triple-junction technology used, they can achieve excellent outputs even if the pitch of the roof is minimal – in the case of Colruyt the pitch is a mere three degrees – and even if the buildings are facing to the East or the West. The BIOSOL PV Plate system was developed by BIOHAUS at the beginning of 2007. The large module achieves an output of 2 x 136 Wp and is primarily to be used in the agricultural and industrial sectors.

Ample roofs available for power from the sun

The fact that solar systems will be installed on the roofs of the new Colruyt food chain “Bioplanet” is non-negotiable for Vandercammen, “Our decision for a solar expansion programme has been taken.” However, much still needs to be done to achieve self-sufficiency from the sun and the wind. In Halle, for example, the cold stores and the cleaning system for transporting containers annually consume 15 million kilowatt hours of electricity. The wind power system generated about 1.8 million kWh in the past years, the PV system is to supply approx. 250 000 kWh of solar power per year. Ample space is available on the Colruyt roofs for new solar power systems – and surely on large-scale commercially used property in Germany. The German discount store LIDL, for example, is operating a solar power station with a peak performance of about 1.2 megawatt (MWp) since September 2006 on the roof of its logistics centre in the town of Hartheim.



The 10 000 square metres of solar modules cover almost the entire roof surface. They produce 1.1 million kilowatt hours of solar power per year and are thus among the largest roof systems in Germany.

Photo: Solar Fabrik AG

Bigger, higher, stronger: photovoltaic façades with new technology and improved output

The highest façade-integrated CIS photovoltaic system worldwide can be seen in Ulm. Besides the world-famous Minster (161 metres) the city now boasts another symbol: from the air or from the ground, the new wheat silo of the Schapfenmühle Ulm with its impressive photovoltaic system integrated into its façade can be seen from afar.



The solar power system that reaches a height of 102 metres is made up of 1 300 CIS modules from Würth Solar and has a total nominal output of 98 kWp. Every year it produces about 70 000 kilowatt hours of solar power and thus avoids approx. 50 000 kg of CO₂ emissions. The prominent position of the building at the entrance to the city led to construction and planning companies paying particular attention to the visual appearance of this extremely long and high silo tower.

Photo: Würth Solar

The CIS modules manufactured by Würth Solar not only functionally but also optically blend into the façade with their uniform matt black surface. With this impressive building, the Schapfenmühle, which is the oldest still manufacturing mill in Ulm, has proven that tradition, craft and latest technologies can be well unified under one roof.

Innovative solar wall with CIS photovoltaic elements in Berlin

On 25 January 2007 the solar façade of the Ferdinand-Braun Institute for Hyper-Frequency Engineering in Berlin-Adlersdorf was commissioned. This is the largest solar power system of the young photovoltaic manufacturer Sulfurcell thus far. Solar cells on the basis of copper-indium-sulphide transform solar radiation into electrical power. The shining black solar wall is about 640 square metres in size (8 by 80 metres) and achieves approx. 39 kilowatt peak performance (kWp). The architecturally striking solar façade is located on the southern side of a laboratory building that forms part of the Ferdinand-Braun Institute for Hyper-Frequency Engineering. The architect Christian Matzke from Dresden designed the elegantly shaped solar wall.



The solar power system consists of a total of 730 active modules with an output of 45 to 60 Watt each and a size of 1.296 by 0.656 metres. The total costs amounted to approx. 250 000 euro. In this case an anthracite-coloured layer of copper, indium and sulphur was used instead of the usual metallic blue silicium.

Photo: Solar wall of 640 square metres at the Berlin FBH. Source: Forschungsverbund Berlin e.V.

CIS layer absorbs as much solar radiation as silicium which is a hundred times thicker

“Our solar modules consist of highly active thin layers in the inside. Their anthracite colour decorates the Ferdinand-Braun-Institute,” Sulfurcell CEO Dr Nikolaus Meyer explains. The core of the module is a thin CIS layer that absorbs just as much solar radiation as silicium used in conventional modules which is a hundred times thicker. “Our technology drastically reduces the material and energy used in manufacturing which will allow solar energy to become economically viable in a few years. The innovative solar system and the FBH show us today what buildings will look like tomorrow,” Meyer continues.

New renewable energy law to become a further incentive for investments into building-integrated solar power systems

The Deutsche Gesellschaft für Sonnenenergie e.V. (DGS) aims at such innovative photovoltaic technology to be installed on a larger scale throughout Germany. This technological and scientific centre emphasises that the German solar industry will only be able to defend and uphold its technologically leading position with premium products that are locally produced. “This will surely not be possible with mass production of a standard module, since the conventional semi-conductor industry has shown that Germany is not a preferred manufacturing site for this,” DGS President Jan Kai Dobelmann emphasises. This goal can only be achieved through innovation in the field of integration of photovoltaics into buildings, because German manufacturers can respond more aptly to technological requirements than low-cost Asian manufacturers. However, this will have to be supported by a sustainable renewable energy law in order to safeguard the future of this manufacturing location.



PV façades in Tübingen (left) and Freiburg. Sources: SunTechnics; Solarfabrik AG

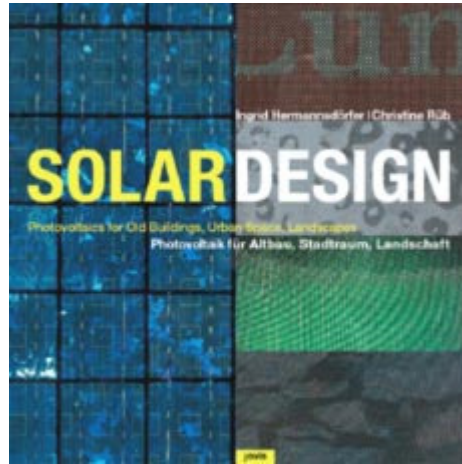
Innovation bonus for PV and construction

The DGS already indicated in its position paper for the hearing of associations in the Federal Ministry of Environmental Affairs that it was open for an optimisation and amendment of future compensation for solar power in terms of the renewable energy law. The association considered it important that future perspectives of photovoltaics be expanded and that no disadvantages would result for local leaders in technology. Building shells were to be discovered and utilised as a “climatically neutral power plant”, the DGS pointed out. To this end the renewable energy law would have to include an innovation bonus for solar technology that forms part of a building shell. In this way the continued growth of the solar sector in Germany as well as the construction industry would be ensured and strengthened. This will still require some time but would be an investment in our future. “If this protection is offered now, it will have an immediate effect on the national medium-sized businesses and the craft,” the DGS explains.

Exemplary solutions of PV integration

In comparison to optimally positioned modules installed on a roof, solar façades are exposed to less global radiation over the period of a year which results in lower yields. However, specifically designed photovoltaic façades are increasingly being used as architectural element. Solar façades multiply the design options of architects. They are a well visible “promotion” of the utilisation of solar energy and reflect ecological awareness of the construction company. Transparent PV facades also establish contact with the outside world and allow impressive lighting effects in the inside of buildings. Even from an economical point of view, the replacement of conventional façade elements may be of interest, because solar systems not only supply solar energy but also fulfil the tasks of building shells. Thus a photovoltaic façade can replace expensive natural stone tiles or stainless steel elements and can also represent a high prestige value such as these.

The building shell as a decentralised and emission-free electricity supplier in the immediate proximity of the consumer becomes a feasible option if the immense interest in the generation of solar power is combined with well-founded specialised information on architecturally meaningful integration of photovoltaics. This task was assumed by Dr Ing. Ingo B. Hagemann – and glamorously accomplished. His book “Gebäudeintegrierte Photovoltaik” (Solar Book of the Year 2002) documents an interdisciplinary approach and shows international developments of the integration of solar power systems. Architects, engineers and the construction industry are presented with multiple uses and concepts of photovoltaics in the building industry.



Sources: Verlagsges. Müller; Jovis Verlag.

With over a 1000 graphic presentations, tables and photos Hagemann shows integration techniques and documents exemplary building practices that include photovoltaics throughout the world. The 180-page section with photos of PV systems as well as detailed drawings is a reflection of global solar architectural performance. The book shows the different shapes and sizes of solar cells, the fact that modules are available for virtually every roof shape, what façade solutions are feasible and how convincing and aesthetically attractive the integration of solar power systems can be.

The "Solar Book of the Year 2005" also shows new possibilities of an aesthetically sensitive integration of solar power plants; in addition "Solar Design" presents different concepts and modules. Ample examples and illustrations are provided for the retrospective installation of solar power plants in existing constructions, such as old buildings, monuments and existing city spheres. Furthermore, it is shown how possible conflicts between the protection of historical monuments and solar technology can be avoided. Solar Design reports on the results of the German-Italian research projects "PVACCEPT" and proves by way of short descriptions of projects and many photos how solar power plants can be utilised differently and deliberately as design elements in construction.

Solar thermal applications are also ideally suited for integration into buildings. Solar heating façades and roofs covered with thermal solar collectors provide heating for utilisable water and for support of heating when required and thus contribute to an increased autonomy in energy supply.

Further information on photovoltaics integrated into buildings (in german only):

[Tübinger Solarstromfassade zeigt Möglichkeiten der Photovoltaikintegration.](#)

[Denkmalintegrierte Solaranlagen: Kompromisse statt Kontroversen.](#)
[Solarfassaden: Sonnenenergienutzung in der Senkrechten.](#)

[Solarstrom-Weltrekord auf einem Dach: Der "Sonnenfleck".](#)
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