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Switzerland's first plus-energy building has 220 m² of PV modules and 150 m² of solar thermal collectors to cover more than its energy demand. Photo: Kälin

"A synthesis of arts"

Solar architecture can appear in a wide variety of forms, depending on whether architects with an integrated approach or solar manufacturers are at the helm.

The inhabitants of Rottenburg-Oberndorf, a village of 1,500 people, have stopped being surprised when yet another group of Japanese, Indians or South Africans walks past their houses. They know it is not the late Gothic altar in St. Ursula's Church that has attracted the visitors to their small community in the south-west of Germany, but the "Sonnenzentrum" (Solar Centre). The Solar Centre, a building that is heated exclusively from regenerative sources, is the company building of the solar specialist Hartmann Energietechnik. Its owner Thomas Hartmann has been planning and installing solar systems for 15 years. His catchment area has a radius of about 100 km around his place of residence. But with the new building, which he opened in the autumn of 2006, Hartmann and his architect Klaus Osterried wanted to popularize their idea of solar architecture well beyond the country's borders.

It has worked: the guests come in droves – architects, timber construction professors, scientists, politicians, teachers, and members of many other professions and other sections of the population want to see how a building can be supplied with energy in a reliable and climate-friendly way in times of declining fossil fuel reserves. The solar building concept that Thomas Hartmann has put into practice is but one among many that can come under the heading "solar architecture". If one takes a closer look at the various concepts, it becomes obvious very quickly that the ideas are enormously diverse, depending on the field the protagonists come from.

A matter of perspective

The participants at the Energy Forum, a conference about solar buildings and solar architecture that has been held in Brixen, South Tyrol, every year since

2006, could easily get the impression that any large photovoltaic installation on a prestigious building can be described as a prime example of solar architecture. Little wonder, because this is the impression given when the manufacturers of modules for building-integrated PV (BIPV) use glamorous examples to describe the considerable possibilities of PV in architecture, as is done at the conference, for example, by Scheuten Solar, Ertex Solar or United Solar Ovonic (Uni-Solar). But every year, the Energy Forum ends with a panel discussion, which puts the ideas straight again. Architects such as Meinhard von Gerkan, who is active worldwide, discuss the topic with representatives of solar companies and associations. In these debates, worlds collide. The architects plead for an integrated approach that pays special attention to the local building culture and the climatic conditions. On the other hand, the representatives of the manufacturers – most of them from the PV sector – defend the advantages of PV roofs and praise the appearance of glass façades that generate electricity.

The former still frequently lack knowledge of the possibilities of solar technology. The latter are often not interested in the building planners' ways of thinking and working. But the number of those who are seeking information exchange and cooperation is increasing, as the architects and the solar industry report.

One attempt at building a bridge is being made by Helmut Hohenstein, owner of the agency Hohenstein Consultancy in the South German town of Prien, who advises governments, associations, institutes and other organizations worldwide about sustainable building. Hohenstein emphasizes that it is the task of architects to meet "a whole bundle of requirements". The priority, says Hohenstein, is the greatest possible reduction in energy consumption. The subsequent issue is to cover the remaining energy need using solar or other renewable energy sources. "The solar industry cannot contribute in any way to reducing the energy requirement", says Hohenstein. "It is the solar industry's turn in the second stage, when it comes to covering the remaining demand using renewable energies. It is up to the architect to decide which instruments are appropriate, depending on the individual building and the climate zone."

Low-energy house in Jordan

He would probably take pleasure in a project in Jordan. In Aqaba, the Dutch architect Florentine Visser has designed a prime example of integrated solar architecture that has considered the country-specific conditions right from the beginning. The Aqaba Residence Energy Efficiency (AREE) Project is a result of the project MED-ENEC. The EU-funded project aims at boosting energy efficiency and the use of renewable energies in buildings in countries south and east of the Mediterranean. During the first project phase from January 2006 to June 2009, ten example buildings were erected under the direction of the German Gesellschaft für Technische Zusammenarbeit (Organization for Technical Cooperation, GTZ), one in each of the ten participating countries, from Morocco to Turkey – including Israel and Palestine.

The design of the Aqaba building combines historic knowledge und practices from the region with modern techniques and solutions. "Construction methods were intended to be applicable and easily adopted", it says in the project description. The building has 420 m^2 of residential space, with a possible alternative use as a study centre, including guest-researcher lodgings. Computer simulations have shown that the annual electricity consumption of this type of building would be around 38 MWh. The AREE design reduces this to 10 MWh, which reduces the electricity bill by around 70 %. "The initial construction costs were 45 % higher than for a comparable conventional house but will be offset by the savings made during the first years of operation", says Klaus Wenzel, Teamleader of MED-ENEC phase I. "We estimate that the additional investment will be paid back after around 12 years".

The additional costs amounted to about € 47,000. However, this also includes considerable extra costs,

The Solar Centre in Rottenburg-Oberndorf attracts guests from all over the world who want to see this building that is heated exclusively from regenerative sources. Photo: Sonnenzentrum

The photovoltaics team of the green building project in Sakhnin, Israel (f.l.t.r.): Carsten Petersdorff (MED-ENEC), Shlomo Kimchie (R&D Manager, TAEQ – Towns Association for Environmental Quality, Sakhnin, Israel), Hussein Tarabeah (Director TAEQ), Riad Dwere, Architect at Towns Association for Environmental Quality Photo: GTZ

for example for custom-built products and for innovative technologies, Wenzel adds. In the context of a larger construction programme, and if only the most efficient technologies were used, the additional costs would be about € 12,000, and the payback period would be reduced to five years.

When she planned the building, the architect first considered the climatic conditions in a place with a hot and arid climate, such as Aqaba. In orientating and designing the building, she aimed at reducing as far as possible the heat absorption in the summer as well as heat losses in the winter. This shows, for example, in small windows and in a natural ventilation system. The latter makes use of a chimney effect that is generated by air inlet ducts underneath the house and outlet flaps under the roof. Insulation played an equally important role. The architect used locally available volcanic bricks to improve the insulation and increase the thermal mass.

For the purpose of cooling the building, a solar cooling system is used. On the flat roof there are 38 m^2 of evacuated tube solar collectors at an operating temperature of 70°C (adsorption technology). The solar collectors are also used for heating. The solar cooling system is complemented by local evaporative cooling. For this purpose, there is a grate in the ground with a water basin below, located at the garden exit in the prevailing wind direction.

If asked whether the building is an example of solar architecture, the GTZ Project Manager Klaus Wenzel answers with a clear "yes". "It is an integrated approach – that is the point", he says. "First of all, the outer shell has to be sealed and the building well insulated. Then, one can look for options to use renewable energies." But the building projects in the ten Mediterranean countries have also taught him that the solution does not always have to be solar thermal energy or photovoltaics. "Sometimes, it can also make sense to use a heat pump", he says and cites the MED-ENEC projects in Turkey and Palestine as examples.

With its projects, the GTZ has not been welcomed with open arms right from the beginning. "In these countries, you cannot come to the people with the issues of protecting the climate and the environment", says Wenzel. "For many people here, this is daydreaming that one might be able to afford in Europe." Here, other arguments go down well, such as "'Thereby, the city and the citizens can save money" or "It pays off". Based on these aspects, sustainable building has turned into a "big market" in those countries where energy is not highly subsidized, such as Turkey.

However, traditional methods of saving energy should not be neglected, Wenzel adds. "Shading plays an incredibly important role." In the AREE house in Jordan, clever shading and an intelligent orientation of the house cut the energy requirement by 20 %.

The construction was not easy, he has been told by the architect. Every day, her team had to be present at the construction site in order to make sure that the works were conducted as planned. "The learning costs were very high", concludes Wenzel. In the second phase of the MED-ENEC project, which will start at the beginning of 2010 and last four years, the GTZ, together with its partners, therefore wants to use the experience gained in the first phase. In the second phase, it is planned to cheaply upgrade existing large, conventional building projects. Apart from design characteristics such as building orientation, the window area fraction of the façade, and shading, the most important and at the same time the cheapest elements of the energy concept have turned out to be a sealed building envelope, roof insulation, solar water heaters and efficient lighting. Depending on the country-specific requirements, additional technologies can be integrated.

"In the past, things were already done very well. There was a lot of knowledge", says Klaus Wenzel, who is going to manage the second phase of MED-ENEC as well. The thermal mass, shading, natural ventilation and the proper orientation, as well as inner courtyards with fountains were the means that were frequently used to make living comfortable even during hot or cold periods.

Green building in Israel

This was also the approach taken for the green building project in Sakhnin, Israel. The building is a result of the MED-ENEC programme, too. Located in a 100,000 m^2 ecological village in Sakhnin, the two-story building with a total floor area of 2,101 m^2 is an education, research and demonstration centre for green building technologies. The building with a stone vernacular style includes lecture halls, classrooms, laboratories, offices and public areas.

Sakhnin, located in Galilee in the north of Israel, has a Mediterranean climate with a mean temperature of 26.2 °C during summer and an average temperature of 10.9 °C in winter. The solar radiation is

1,000 to 1,100 W/m² in summer and 500 to 700 W/m² in January, the coldest month of the year. Therefore, the building requires energy both for heating and cooling purposes.

The target was to save energy. This was achieved on three levels. First, architectural elements such as the building envelope, central courtyard, domed and vaulted roofs, shading, fountain etc. were exploited to enhance the energy efficiency of the building. In this way, 50 to 70 % energy savings compared to a conventional building were achieved.

Secondly, active renewable energy generating systems including PV, a solar heating system and a wind turbine were installed in order to minimize the need for grid electricity. Finally, energy saving appliances and control instruments are being used.

"During 18 months of monitoring, the building, with its annual energy consumption of 68,000 kWh showed an overall energy saving of 72 % in comparison with a conventional building", says Klaus Wenzel. Payback periods for the solar sliding cover of the inter courtyard and the structural solar walls are 12 and four years respectively. The wind turbine and the PV system have payback periods of about 21 to 22 years. "As this is a demonstration and training centre, cost recovery was not the first priority", says Wenzel.

Solar houses in Switzerland

Lowering the energy requirement as far as possible, and covering the remaining demand from renewable energies are also the aims of the Swiss solar house pioneer Josef Jenni. In 1989, the solar storage tank manufacturer caused a sensation when he opened a single-family house heated purely by solar energy at his company headquarters in Oberburg in the Swiss region of Emmental. The installation, which according to Jenni has only had slight modernizations, is still in operation. The house is inhabited by his brother's family. In 2007, Jenni came up with the first multi-family dwelling in Europe that is heated exclusively by solar energy. Eight tenants get all the heating energy they need from 276 m² of collector area. The heat is stored in a tank with a volume of 205 m³.

Be it a single-family or a multi-family house, privately or commercially used, all the solar houses based on the Jenni design have the same building and heating concept. At least half of the energy required for heating a building must be covered by the sun if the building is to be regarded as a "solar house".

In the north, where solar irradiation is not as high as in the countries of the Mediterranean, it is always the primary goal to capture as much of the precious solar energy as possible. Therefore, the first principle of building design is to orientate the building optimally, if possible facing directly to the south. The entire shell, including the roof, the walls and the windows, must be very well insulated in order to minimize heat losses. For the purpose of passive utilization of solar energy, large windows and doors are installed on the south side. In order to generate as much heating energy as possible in the transition seasons and in winter, the south-facing roof should be as steeply inclined as possible. On the roof, a large area of collectors is installed. The solar heat is stored in a correspondingly large, building-integrated water storage tank. The energy from the wood-fired boiler is also stored here, and is used to provide the remaining energy needed for heating and hot water – this completes the "solar house à la Jenni".

In Germany, the concept has been popularized since 2004 by the members of the Sonnenhaus-Institut (Solar House Institute). Especially since the oil price climbed to more than US$ 100 per barrel, and since solar heating has been supported by the German federal government, the Sonnenhaus-Institut has gained more and more members. Founded by five installation companies, it is now supported by a member circle consisting of about 190 architects, planners, solar companies and building contractors. Georg Dasch, a solar architect and the institute's chairman,

On the Aqaba Residence Energy Efficiency (AREE) Building in Jordan 38 m² of vacuum tube collectors provide energy for both solar heating and cooling.

Photos (2): GTZ

This solar pergola in Melbourne, Australia, was designed to provide shade and weather protection to the rooftop area of the landmark building – and to produce electricity. Photo: Going Solar Projects

Solar building with a high proportion of solar thermal in Switzerland: in the summer of 2007 a house for 8 families was erected in Emmental. On its south facing roof it has 276 m² of collectors, while a storage tank of 205 m³ is inside.
Photo: Jenni Energietechnik

estimates that about 100 houses heated largely by the sun are being built in Germany this year on the initiative of members of the institute. Meanwhile, the members have become active in South Tyrol and in Austria as well.

Solar centre in Germany

Thomas Hartmann, who was mentioned at the beginning of this article, is one of the founding members of the Sonnenhaus-Institut. His Solar Centre houses a restaurant with a wood-fired baking oven, offices, the collector production facilities of the company Hartmann Energietechnik, the warehouse and a private apartment. The building has a total area of about 2,000 m². "We wanted to create a solution for solar technology integration into architecture that has an outstanding design," says Hartmann, describing the targets of the planning phase. Architectural attractiveness and energy efficiency were the criteria.

The elongated timber structure faces directly south. The walls are insulated with cellulose and hemp. The windows have triple glazing and a U value of 0.5 W/m²K. A large glass façade on the south side ensures passive utilization of the sun. For active solar energy harvesting, Hartmann installed a solar thermal façade system on the south side of the building with 150 m² of collector area and an inclination of 70°. For supplementary heating he uses a firewood gasification boiler and a pellet boiler in the exhibition area. A heat exchanger in the wood-fired baking oven and the heat recovery system of the refrigeration equipment provide additional heat.

Whoever enters the Solar Centre cannot help wondering what the big round object in the entrance area might be. It is the solar storage tank, containing 20,000 litres of water. With a height of 9.1 m and a diameter of 1.7 m, it is designed to immediately direct the visitors' attention to the unusual heating concept. Now that the solar building has been in operation for almost three years, Hartmann confirms that he can cover about 80 % of the building's heating energy demand from solar energy. For supplementary heating, he needs an average of eight cubic metres of wood per heating period. In addition, PV modules with a capacity of 60 kW are installed on the roof. "It is very comfortable to live and work in the Solar Centre. The temperatures are surprisingly pleasant", Thomas Hartmann says with satisfaction. The shading for the summer is the remaining issue he still needs to take care of.

Some prefer solar thermal energy, others photovoltaics. Upon closer inspection, the link between the field of activity of the involved parties and the solar technology they prefer is very obvious. Josef Jenni produces large solar storage tanks and Thomas Hartmann collectors. Logically, both used their own products for their buildings. In exactly the same way, a module manufacturer was involved in the construction of the first plus-energy multi-family dwelling in Switzerland. But this is just the nature of things, and all the projects contribute to the "synthesis of arts" of solar architecture.

Plus-energy house in Switzerland

The most striking feature of the seven-family house dubbed "Power station B" in Bennau is a 35 kW on-roof solar installation from the Swiss module manufacturer 3S Suisse Solar. The modules, with black, monocrystalline cells from Ersol, have been mounted all over the south-western roof of the main building and on the roof of the bike shelter. With an annual yield of 33,000 kWh, the 220 m² installation on the roof, which has an inclination of 40°, fully covers the total electricity used, spread over the year.

As the second component of active solar energy utilization, 150 m² of solar collectors have been integrated into the south-west façade. Another part of the façade is generously glazed, so that solar irradiation is used passively as well. In its project report, the architect's office Grab Architekten AG with its headquarters in Altendorf, Switzerland, writes about the collector façade: "The vertical orientation theoretically reduces the annual yield by 20 %, but in return the yield is more constant, which makes an expensive, large (75 m^3 or more!) seasonal storage tank (and its losses) dispensable. Instead, only a 25 m^3 tank is utilized, and excess heat is used to supply hot water to the neighbouring building." This energy export, which takes place primarily in the summer, compensates for the wood used in the small thermal storage heating stoves (in winter) and thus allows a positive heat energy balance to be achieved, the report continues.

For the plus-energy house, attention was also first paid to good heat insulation. The thickness specifications for the insulating layers of the solid construction type building are as follows: 40 cm for the façade, 50 cm for the roof and 20 cm towards the unheated basement. The windows have triple heat insulation glazing (U = 0.5 W/m^2K).

The plus-energy house in Switzerland is one of the more recent prime examples of building-integrated photovoltaics (BIPV). The architects can be pleased about the Swiss Solar Award, which was presented to them in August for their "Power station B".

Scheuten Solar is a producer of BIPV products who prefers overhead glazing with semi-transparent modules like this 100 kW installation in the school of agriculture in the region of Bourges, France.

Photo: Scheuten Solar

BIPV showcase project in France

Recently, the BIPV sector, which is still a niche market, has had a new impetus from the high bonus for building integration that is paid in France and Switzerland. More and more module and glass manufacturers are launching products for roofs and façades, which they advertise using reference projects.

One of the companies that likes to attract public attention through remarkable projects is the Dutch module manufacturer Scheuten Solar. For example, Scheuten supplied the modules for the new main railway station in Berlin, the showcase project of BIPV in Germany. In October of this year, the company informed the public about a new project in France. By August 2009, 334 PVB modules (the modules have a PVB film as an intermediate layer) and 50 insulated glass-glass-modules with a total power output of approximately 100 kW had been fitted to the roof of the school of agriculture in the region of Bourges.

Overhead glazing with semi-transparent modules is a specialty of Scheuten Solar. The modules are custom-made as individual solutions. This makes the technology expensive, which is criticized by architects such as Georg Reinberg from Vienna. In principle, the solar architect is open to photovoltaics, but he thinks it should be very carefully considered whether the PV installation makes more sense in economic terms than an investment in another regenerative energy source, such as a wind turbine. Reinberg is not a fan of integrated PV modules. The insufficient rear ventilation, he says, reduces the solar yield and jeopardizes even further the profitability of a technology that is already expensive anyway. In the case of "flying photovoltaics", there is no such shortcoming, Reinberg points out. Therefore, he prefers working with free-standing PV arrays (see interview on page 43).

These can be, for instance, modules on roof overhangs. As an example of this, the module manufacturer Schott Solar can boast a model project in Australia. In South Melbourne, Going Solar, a partner company of Schott, installed a solar pergola on the landmark building 40 Albert Road in 2005. It is the first installation using ASI THRU laminates from Schott Solar in Australia. The system has been installed on the roof of a building. Its functions are to provide shade and weather protection. It is definitely a good example of an on-roof BIPV installation. The experts may argue about whether it can also be regarded as solar architecture.

Ina Röpcke

Further information:
Sonnenzentrum: www.sonnen-zentrum.de
Energy Forum: www.energy-forum.com
Dr. Hohenstein Consultancy: www.hohenstein.biz
MED-ENEC (Projects Jordan and Israel): www.med-enec.com
Jenni Energietechnik: www.jenni.ch
Sonnenhaus-Institut: www.sonnenhaus-institut.de
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