Solar Energy System of the Month:

Zero-energy house with photovoltaics and heat pump

2008/02/06

With the house of the Purper's in Eltville-Rauenthal/Rhine (Germany), the solar architect Clemens Dahl demonstrates how zero-energy houses can be included at difficult locations in high-density residential areas in the centre of a town. With solar panel positioning, good heat insulation and energy-efficient heating technology, energy consumption is reduced significantly – to such an extent that the solar power generated on the roof with a photovoltaic system (7.5 kWp) equals energy consumption. After the Solarserver, in December 2008, presented the head offices of the juwi Group as the most energy-efficient office building in the world with complex efficiency and photovoltaics technology, we now present, in February 2009, a solar construction concept and its components that demonstrates on a small scale, how architectural structures, energy efficiency and solar power generation can create an energy equilibrium.

Solar Energy System of the Month as PDF-Dokument

Photovoltaic system on the roof: 61 m² of modules; Nominal output 7,59 kWp.
Source: Clemens Dahl, Architect.

The house was erected in the place of a small building that needed restoration on a farm yard in the second row. For this difficult location the architect Clemens Dahl from Geisenheim designed a solar house with a foundation storey of solid brick work and a wooden construction for the roof and the attic storey. The large open-plan kitchen was positioned in

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the upper storey in order to better utilise the sunny location, whilst the bedrooms and other rooms were placed on the ground floor. The building was designed and built as a low-energy house, however, not explicitly as a zero-energy house. During construction, however, many decisions were taken that favoured better thermal insulation. Amongst others, a blower door test was requested to be done, in order to test the air exchange rate and to point out weak points so that these could still be rectified before completion of the construction phase. Initial assessments positively surprised the developer: the competition between the electricity consumption counter and the feed-in counter for the solar power system, clearly favoured the photovoltaically produced energy.

Left: View from the farm yard onto the building. Right: The blower door test checks whether a house is air-tight, so that energy losses can be identified and avoided in the construction phase already. Images: C. Dahl; Gerold Weber Solartechnik GmbH (right)

Optimum insulation, efficient heating and controlled airing

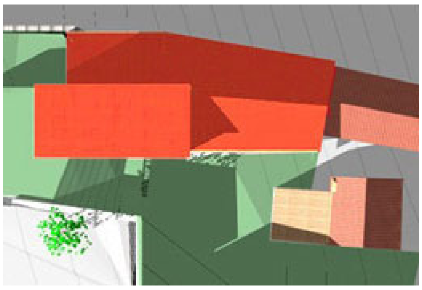
In designing the building, Clemens Dahl considered one of the basic rules of solar construction, which was already well known in ancient Greece, but that has until today not always been consistently implemented in practice: in positioning the large window surfaces on the southern side of the house, i.e. in accordance with the movement of the sun, the rooms will become light and friendly and passive solar heat can be won. Optimum orientation and pitch of the photovoltaic modules located on the roof allows for maximum solar power output. In addition, the heating concept provides for a large heated mass that was realised through a floor plate insulated at the bottom, solid interior walls and stairs. The floor plates are not separated from the air in the room through stone floor and insulation, but are directly utilised as heat storage. Thus a maximum share of solar energy can be utilised “passively“.

View from the living area into the garden. Even on dull autumn days this room is light – and in winter the sun can assist in heating...

The under-floor heating is integrated into the concrete ceiling and the floor plate.
For the massive external walls, porous bricks of burnt clay with a

thickness of 30 centimetres were used, as well as plastered external insulation of 12 cm thickness. The fine air pores in the bricks increase thermal insulation. A balanced capillary and pore volume, as well as differentiated hole positioning in the cross-section of the brick, allow co-ordination between thermal insulation and storage. The wooden roof as well as the attic storey are insulated with wood fibres (24 cm).

The under-floor heating selected by the architect is located in the floor plate and the concrete ceiling. Operation has shown that this heating system can be run at very low temperatures (pre-run under 24°). This creates excellent conditions for the air-air heat pump used that works particularly efficiently at low temperature requirements. Also to minimise the allergies of the owner, a ventilation system was installed that retrieves a part of the waste heat. The room air is further optimised by a central vacuum cleaner.




Left: With a CAD model the shading study was carried out in order to optimally utilise solar energy passively (direction of windows) as well as actively (orientation of solar modules); right: partial view of the solar generator.

Solar power harvest on roofs facing south

The 46 installed, multi-crystalline photovoltaic modules of the make ASE165 (SCHOTT Solar) with 165 Watt peak each, achieve a total output of 7.59 kWp. A multiple-string inverter of the make Kaco 4500 xi as well as a solar inverter Kaco 1501 xi transform the direct current from the modules into alternating current that can then be fed into the alternating current of the grid. All modules could be directed exactly to the south. 36 modules have a pitch of 19° and are absolutely free of shade, 10 modules have a pitch of 40° and are slightly in the shade during the winter months.

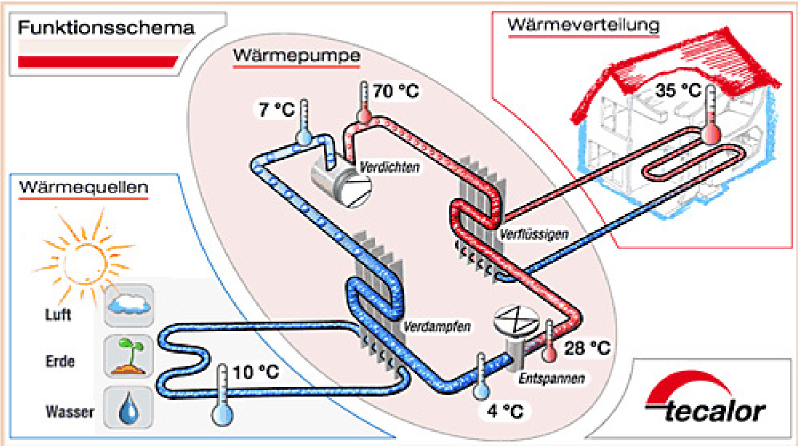

View from the garden onto the building: on the main roof with a pitch of 19°, 36 solar modules from SCHOTT Solar have been mounted. Sources: C. Dahl; SCHOTT Solar AG.

In 2008 the developer fed 7 516 kWh of solar power into the grid according to the counter. This is an above-average solar power harvest of 990 kW per installed kW of photovoltaic performance (kWp).

The heat pump: a “reverse“ refrigerator

For heating the building the architect selected an air-air heat pump of

the make Tecalor TTL 13 with a thermal output of 7.4 kW which is externally fitted and has an internally located storage tank. The heat pump allows environmental heat (stored solar energy) to be utilised. Approximately three to four parts of environmental energy and one part electrical energy (ideally, ecologically friendly electricity) are used for heating. In the case of low temperatures persisting, electricity is required to "pump" the environmental energy of -20℃ to +35℃ (air) to a temperature level that can be utilised for heating (hot water).
A heat pump works in a similar way as a refrigerator. While the refrigerator extracts heat from the foodstuffs through the evaporator, in order to cool these, a condenser at the back of the refrigerator will emit heat. In the case of the heat pump, however, the evaporator extracts heat from the environment (water, earth, outside air or waste air) and adds this to the heating system through the condenser. In addition to the heat pump, a central ventilation system with cross-flow counter-current heat exchanger was installed in the attic storey that controls the incoming and outgoing air through the roof.



This is how a heat pump works... Graphic: tecalor GmbH
[Wording of image: Functional diagram; Sources of heat: air, earth, water; Heat pump: compressing, liquifying, removing tension, evaporating; Heat distribution]

Solar power system allows for positive energy balance

According to statements by the owner, the air heat pumps used a total of 4 024 kWh of electricity for the preparation of hot water as well as for controlled living area ventilation in the past year. This corresponds with average monthly heating costs of about 52 Euro. In 2008 the photovoltaic system produced a proud 7 516 kWh of solar power. This results in a solar power surplus that, in terms of figures, corresponds with the consumption of an average household and provides a balanced energy equation: the building that was designed as a low-energy house became a self-sufficient zero-energy house.

Material and images: Clemens Dahl, Architect; Am Sonnenhang 20;65366 Geisenheim; www.architekt-dahl.de, tecaclor GmbH; SCHOTT Solar AG. Solarserver editor: Rolf Hug

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