Panels that produce both electricity and heat could make better use of sunlight – but heat from the thermal absorber can damage the sensitive photovoltaic cells. The strengths and weaknesses of solar hybrid systems.

Roofs are filling up. By 2020, the German government hopes to increase the share of solar electricity from 3% to 10%. At the same time, thermal collectors are to replace the ageing oil and gas boilers in German basements as quickly as possible. But is there enough room for all these systems? The solution could be simple. Photovoltaic (PV) cells only convert about 15% of the sun's rays into electricity; the rest becomes waste heat and is lost. If this lost energy is used instead, system efficiency could be significantly increased, and less space would be needed. So what are we waiting for? Let us throw some cells and collectors into a glass box and start seriously harvesting the sun's power. But it is not as easy as it sounds. Although research has been conducted on photovoltaic-thermal (PVT) panels for some time now, the technology has not had a strong showing on the market so far. The problem is that PV and thermal cause each other problems when they are put together under a single pane of glass. "A thermal collector is operated at the highest possible temperatures, while photovoltaic cells work better the cooler they are," explains physicist Michael Powalla of Stuttgart's Centre for Solar Energy and Hydrogen Research (ZSW). In other words, neither electricity nor heat can be optimally produced.

An odd couple

By Sascha Rentzing

The PV aspect is especially causing developers some grief. As the temperature increases, solar power production decreases by half a per cent for each degree Celsius. With a cell temperature of 25 °C and insolation of 1,000 watts (typical in Germany), a standard panel can produce 200 watts. At 90°C, it only produces 135 watts—about a third less. A simple PV panel deals with such temperatures only rarely, in the dog days of summer, but a thermal collector sees them quite often. High temperatures are necessary to heat up water in the solar thermal system's storage tank for showers or heating.

Sometimes the collector can get even hotter. In summer, the storage tank is often already full by the afternoon. In this case, a regulator stops the pump between the collector and the tank to prevent too much heat from the roof from bringing the stored water to a boil. "In these times of stagnation, the collector can reach up to 200 °C," says project engineer Alban Heßberger of German hybrid panel manufacturer PA-ID. At such temperatures, cells would only reach 12.5% of their nominal capacity—at a time that would otherwise be optimal for solar power production.

Excess heat

Besides the heat, size can also be a problem. Because of the attractive feed-in tariffs set down in Germany's Renewable Energy Act (EEG), most solar arrays are designed to produce more electricity than each individual household needs. A typical PV system on a single family home in Germany produces five kilowatts (kW) and measures a good 50 square metres. Thermal collectors only need a third of that area, since their size is related to heat demand. The rule of thumb for a supporting solar thermal system is that four square metres of collector area is needed per person—16 square metres for a four-person family. It would be counterproductive to cover the entire roof with PVT panels. "The temperature in the collectors would rise because so little of the heat would be used, thereby decreasing power production," explains Matthias Rommel, head of the Institute of Solar Technology at the Rapperswil University of Applied Sciences in Switzerland.

Does all this mean that the hybrid idea is doomed to failure? Despite the difficulties, Rommel believes there is a future for the solar duo. "The technology could be interesting for hospitals and apartment buildings," he suggests. Hybrid modules would be operated at low temperatures on the roofs of such building, because hot water would constantly be taken from the storage tanks while cooled-down heat-conducting liquid is pumped back into the insolation collectors. The cells would thus stay cool and keep their efficiency high.

Swedish firm Absolicon already offers a hybrid system specially designed for large-scale heat consumers. The Double Solar Technology system uses a semicircular parabolic trough that tracks the sun to collect light at a concentration of 10 times onto an absorber tube in the middle of the collector. The solar fluid circulating there transfers the heat to tap water or heating water before cooling down the cells on the side of the receiver facing the sun. "Our target customers are municipalities that want to produce district heating and power and buildings, like hotels, that

use a lot of hot water," says CEO Joakim Byström. Absolicon has already installed 25 PVT systems around the world, he says; the most recent—and the biggest at 200 square metres—support the biomass-fired district heating system in the Swedish city of Härnösand. In the summer, the system's thermal capacity of 100 kW contributes 5% of the city's heating and 20 kWof electricity, which is exported to the public grid.

With those figures, Absolicon's parabolic trough is still far from the ideal hybrid system, in which the two parts would work as well as two separate systems. In the Swedish company's concept, PV only plays a supporting role, producing just 100 watts per square metre of panel area—less than a normal standard PV panel, which would achieve 125 watts. In addition, the parabolic trough is not really designed for inclined roofs, and therefore does not save much space.

No real hybrids yet

Solarhybrid of Saxony, however, has designed a combination panel especially for use on roofs. It is built like a conventional thermal collector; to produce hot water, it makes use of the natural greenhouse effect in the air chamber between the front pane of glass and the absorber's surface. However, the high temperatures in the glass container can be a bit of a problem for the cells laminated onto the inside of the glass every so often in rows of three or four. Overheating can occur especially when too little heat is taken away to be used.

"For this reason, we determine the storage tank's size exactly according to a household's daily heat demand," explains Solarhybrid CTO Peter Tyrra. If the storage tank is still full in the evening, energy has to be dissipated to unburden the system. At night, a heat exchanger transfers some of the stored heat to the solar fluid, which is then pumped to the roof and cooled down by the outdoor air. "That is how we make room for the next day."

However, this type of PV cooling has some disadvantages. The additional pumping uses more electricity, while unused energy is sent out into the night. And that is just for a relatively small PV component. Solarhybrid's most powerful combination panel, at 2.51 square metres, only produces about 193 watts, or 77 watts per square metre—a good third less than a normal PV panel. Interested parties must do their research to decide whether the new technology would really pay off, especially since, unlike simple collector systems, hybrid panels do not receive any funding from the German government's market incentive programme despite their thermal component. The feed-in tariff for solar power must, therefore, be enough to compensate for system costs and the lack of additional government support.

Other companies offering hybrid collectors—such as PA-ID, Anafsolar of Pavia, Italy, and Solarzentrum Allgäu—are, therefore, focusing on optimizing power production. "It is all about increasing electricity yield," says PA-ID engineer Heßberger. The front of his company's 2Power hybrid module is completely covered with crystalline silicon cells. The back functions as a heat exchanger, with a cooling medium flowing through it that takes heat from the cells and carries it to the tap water in a storage tank. PAID has also done away with the air chamber typically found in thermal collectors to allow less heat to build up. "The panel temperature therefore rarely exceeds 60 °C," Heßberger explains. The cooling system, he says, keeps the cells' efficiency stable, while the use of heat for tap water increases power production by at least 3%.

But PA-ID, too, faces the hybrid dilemma. When one side is optimized, the other loses some power. At 330 watts per square metre, the combination panel only achieves about two-thirds of a conventional thermal collector's thermal capacity. Cooling the solar cells also means that only low temperatures of 40 to 50 °C are produced for heating water.

For higher temperatures from the roof, you have to connect the PVT panel to an extra heat pump with a downhole heat exchanger. This system works like a refrigerator in reverse. A cooling medium is vapourized under pressure before being turned back into liquid. The heat that has been set loose in the process enters a separate water cycle. "Just a few degrees in the hybrid cycle here can generate 60 °C in the heat cycle," says Heßberger. Theoretically, a heat pump could be used to improve electricity yield, too. A conventional heat pump system with a downhole heat exchanger generally works at temperatures just above zero. The hybrid panel's solar fluid is, therefore, also quite cold and can cool down the PV component well. "Electricity yield is thus increased by 15%," Heßberger explains.

But even besides the need for more space and the extensive construction work needed for three-part hybrid solutions—heat exchangers and storage tanks must be installed underground—the heat pump complicates the already quite complex hybrid technology even more. It also drives up the price – the heat pumps and the electricity and regulators they need are not free. ■

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