PVT Systems: Heat or Electricity From Solar – Why Only One When You Can Have Both?

A solar PV/Thermal (PVT) collector produces both heat and electricity thanks to a combination of a PV panel and a solar thermal collector or absorber. IEA SHC Task 60: PVT Systems investigated the possible concepts for the last three years with a group of experts from research laboratories and solar industries. The end results, good examples of different types of installations around the world, simulation models, key performance indicators, and a comparison of concepts. This article summarizes the work and findings of the Task and confirms that PVT technologies can play a vibrant role in the transition towards more solar energy for both heating and electricity production.

PVT concepts are not a new idea for the hybridization of solar energy collectors. For more than 20 years, there have been developments on possible solutions, and IEA SHC conducted preliminary work in SHC Task 35: PV/Thermal Systems from 2005–2010 followed up on by Task 60: PVT Systems from 2018–2020. A new PVT push came in 2016 when the PV industry reached relatively low costs for their technologies, and the solar thermal industrial market was mature. These developments in the solar community opened the door for more and new PVT applications building on:

- Strong and increasing interest in Building Integrated PV (BIPV) and Façade Integrated PV (FIPV) not only in office and industrial buildings but also in residential buildings where both electricity and heating and sometimes cooling are required
- Developments in heat pump technology creating more possibilities to use the low exergy heat source of uncovered PVT collectors and reduce the energy cost for the user and the need for borehole storage
- Decreasing costs of PV modules, making it more attractive to combine PV with thermal to produce more solar energy while using the same roof area

But there is still work to be done to show the HVAC industry the possibilities and benefits of PVT solutions. SHC Task 60 experts contributed to this effort by helping to make the technology more visible and working on international standards devoted to PVT collectors to create more confidence in the use of a new technology by solar energy planners and final customers.

Three clear conclusions came out of this Task work:

1. PVT maximizes the use of a rooftop or any area by delivering electricity and heat without compromising the efficiencies of either technology.
2. Reliable solutions are on the market.
3. PVT can play a valuable role in the energy transition of any country with its attractive cost of electricity and heat from the sun.

Participating Countries

Australia
Austria
Canada
China
Denmark
France
Germany
Italy
Netherlands
South Africa
Spain
Sweden
Switzerland
United Kingdom

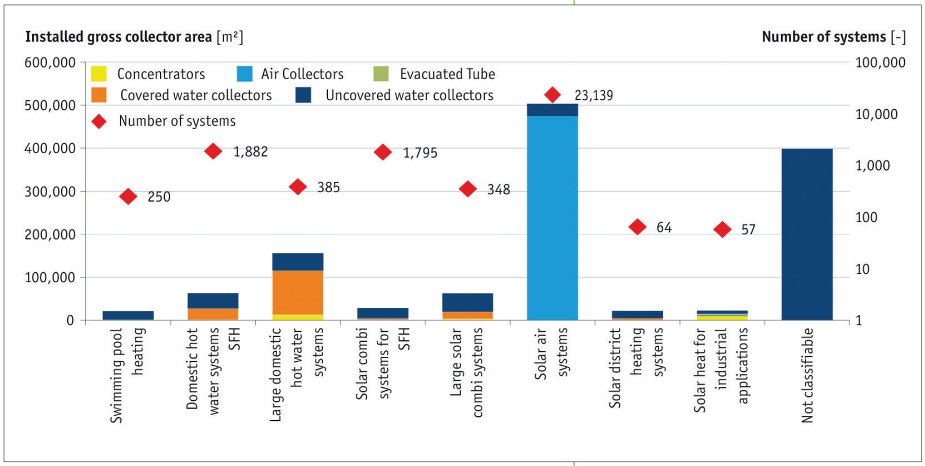

Figure 1. PVT systems in operation worldwide by the end of 2020. (Source: IEA SHC Task 60 survey, AEE INTEC. IEA SHC Solar Heat Worldwide 2020)

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PVT Systems Around the World

By the end of 2020, a cumulated PVT collector area of 1,275,431 m^2 was installed with 27,920 systems in operation. What this latest data confirms is that the global PVT market is experiencing steady growth, 9% on average from 2018 to 2020, and the market momentum is strong.

Figure 1 shows the dominance of solar air systems in the PVT market, mainly driven by France, where PVT air systems were successfully introduced quite early by two manufacturers. The advantages of PVT solar air systems are that the low-temperature systems with air as the distribution medium exhibit high efficiencies and low stress on the PV cells. Plus, they are very well suited to low-energy houses, easily achieving a solar fraction of up to 50%. But there are numerous other PVT applications for all different heating and cooling market segments, some of which were analyzed and documented in SHC Task 60's report, Existing PVT Systems and Solutions.

▲ **Figure 2. In France, six PVT uncovered panels, 9.6 m2 and 1.5 kWp, for domestic hot water preparation, heat for a heat pump, and electricity for self-consumption and the grid.** (Credit: Dualsun)

Systems with Heat Pumps

Uncovered PVT collectors are very well suited to operate as a heat source of a heat pump. This solution provides several advantages 1) unlike an air heat pump, the noise of a water/water heat pump is much lower, and inside a cellar, the cost of a borehole is avoided, 2) the temperature of the evaporator source is on the average higher than for other sources like ambient air, 3) the PV part produces part of the electricity to drive the heat pump, and 4) the area taken up by the PVT field is not larger than what would have been installed if only PV was selected.

Several manufacturers provide turnkey solutions of hybrid PVT collectors with heat pumps mainly for single-family houses, but not exclusively. Many of these installations have high COPs (3 to 5 annually) and a reasonable payback time of 7–12 years. Moreover, in houses, this solution maximizes the use of the rooftop area for collecting solar energy.

Collectors can be made of aluminum or polymer and, because they are uncovered, show high durability due to the maximum temperature reached under stagnation stays well below 100°C. This means less stress on the PV cells than in covered or concentrating technologies.

▲ **Figure 3. In Switzerland, this PVT system uses 178 uncovered PVT panels + 699 PV modules to generate 237 kWp. The heat pre-heats the groundwater storage, which is then transferred directly to the heat pump and the overflow basins of the pools. The heat pump generates heat for pools, space heating, and domestic hot water. A gas boiler supports the heat pump for peak loads. Electricity is for self-consumption and the grid. (**Credit: Meyer Burger)

Systems without Heat Pumps

Unglazed collectors can deliver heat to low-energy houses at 30°C–40°C in sunny climates during winter, such as in the south of France, thus avoiding the need for a heat pump. Air PVT systems are an excellent example of such installations.

In more harsh climates or to deliver 60°C heat for DHW preparation, PVT collectors must be glazed or operated under vacuum, such as in evacuated tube collectors. Several PVT manufacturers produce very good collectors that can achieve 60°–80°C fluid delivery temperatures and are well suited for when DHW is needed year-round, as for hotels, sports centers, and community dwellings. The electricity produced can be self-consumed during the day for any of the building's electrical equipment.

▲ **Figure 4. In Spain, 28 PVT glazed panels covering 46 m2 generates 6.7 kWp for DHW in a firehouse. Electricity is for self-consumption and the grid. (**Credit: Endef Engineering)

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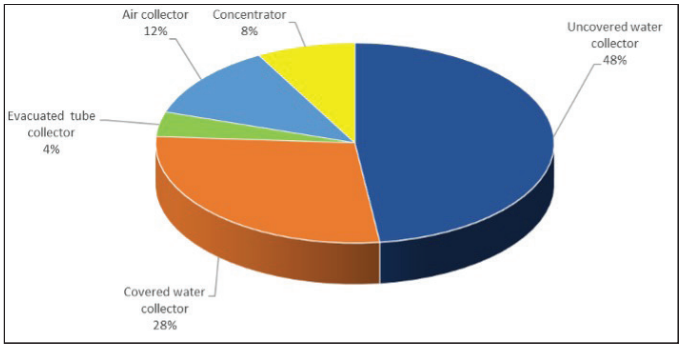
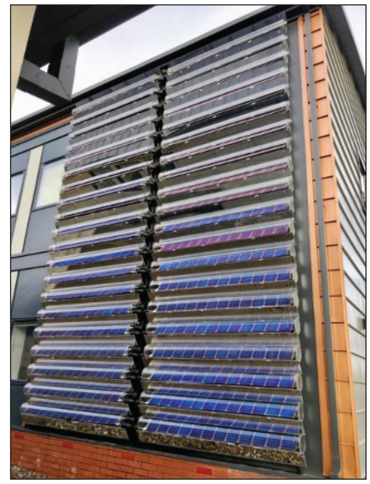
PVT Collector Technologies

Depending on their use, PVT collectors vary in design. The most common PVT collectors are uncovered collectors, also referred to as unglazed or WISC (wind and/or infrared sensitive) collectors.

Manufacturers try to reduce collector costs through three actions 1) choice of material, 2) automation of production, and 3) simplicity of concepts. The absorber plays a big role in the efficiency of a PVT collector, and several new designs have been developed over the last three years. Total current system costs range between 500 and 1500 €/m². The PVT collector cost is between 100 and 300 €/m².



▶ **Figure 6. Distribution of PVT collector types in 2018.** (Source: IEA SHC Task 60 report, Existing PVT Systems and Solutions)



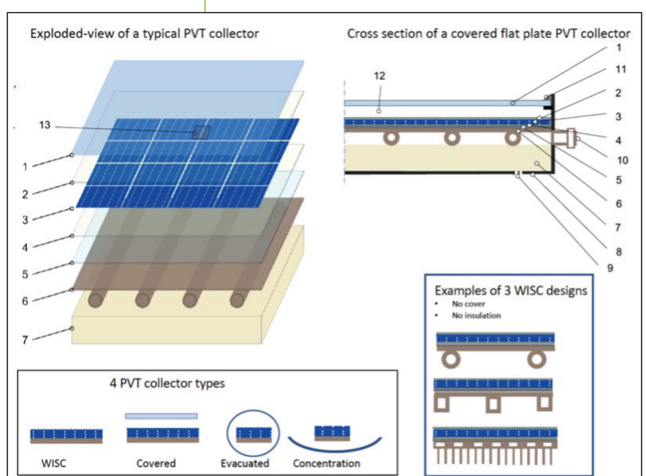
▲ **Figure 5. In the UK, an example of an evacuated tube PVT collector system on a vertical facade.** (Credit: Naked Energy)

How to Define PVT Efficiency

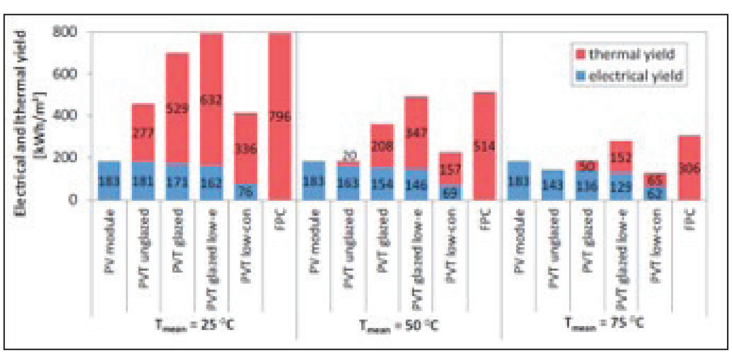
Global efficiency can be defined as the sum of the outputs (electricity + heat) defined by the incident solar radiation. This is with no exergy consideration for the electrical output to keep it simple.

PV efficiency can depend on the temperature of the collector, so this also has to be taken into account for PVT collectors operated at various variable temperatures. The average yearly and weighted operating temperature of a PVT collector is thus an important value to assess system efficiency.

Other factors to consider are ISO standards and Solar Keymark certification, which can provide the basic characteristics curve of a PVT module by testing according to PV or T protocols. A PVT protocol is a work in progress. One reason for testing is to provide input for the economic and technical key performance indicators (KPIs). For PVT, the challenge is, to some extent, that the KPIs are not yet mature and settled in the market. SHC Task 60 has issued a list of relevant KPIs for PVT that can be regarded as a standard.



▲ **Figure 7. PVT collector design concepts.** (Source: IEA SHC Task 60 report, Design Guidelines for PVT Collectors)



◀ **Figure 8. PVT collectors maximize the solar energy collected at all temperatures. The temperature influence in thermal and electrical gains per square meter of collector aperture area calculated using the software "ScenoCalc" for the city of Würzburg, Germany (Central Europe).** (Source: IEA SHC Task 60 report, Status Quo of PVT Characterization)

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Energy	Thermal and electrical solar yields per m^2
	Thermal and electrical utilization rations (yield/irradiation)
	Output-weighted operating temperature
	Solar thermal fraction
	Seasonal performance factor (for heat pump systems)
Economics	Specific investment cost per m^2
	Levelized cost of heat and electricity (LCOH, LCOE)
	Saved fuel and grid electricity cost
Environment	Avoided primary energy depletion [kWh oil-eq/(a* m^2)]
	Avoided global warming impact [kg CO_2-eq/(a* m^2)]

▲ **KPIs for PVT systems considered by SHC Task 60**

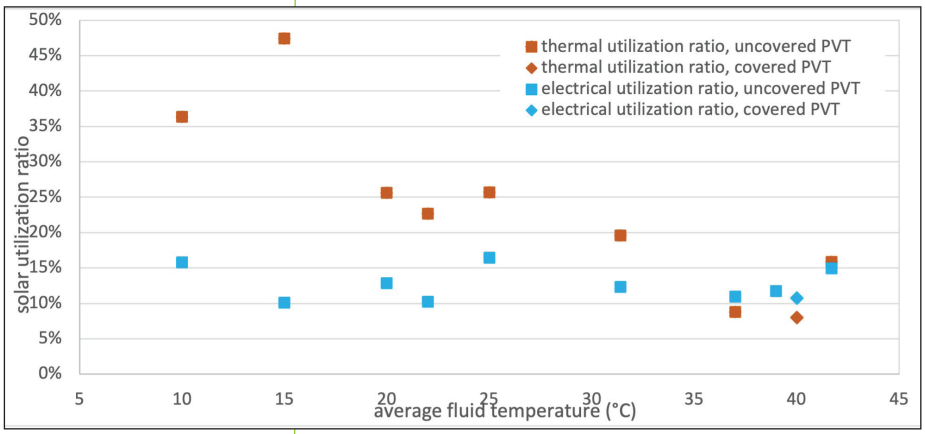
Low Payback Time in Sunny Conditions

In good conditions, such as a sunny climate, electricity demand during the day and heat demand year-round can be met using PVT with a payback time as low as 4–5 years compared to an electrical or gas solution. This is the case for hotels in the Mediterranean, particularly where fossil fuel costs are high. PVT also can deliver electricity for e-mobility, heat for DHW, and act as a cooler for cooling machines.

PVT Deserves Increased Visibility

The results of SHC Task 60's work on assessing existing PVT solutions and developing new system solution principles will no doubt help with the uptake of PVT applications.

As part of the Task's work, participants assessed the many parameters of a PVT installation, including heat production, electricity yield, global efficiency, qualitative indicators, user benefits, investment, energy and maintenance costs, and safety and reliability of operation. All these Key Performance Indicators were defined and evaluated for several typical PVT applications. Participants also collected best practices to accelerate the market acceptance of PVT technologies and highlight the advantages over the classic "side by side installations" of solar thermal collectors and PV modules.



▲ **Figure 9. Temperature dependency of the solar thermal annual utilization ratio (in red, thermal energy output divided by total incident solar) for the example systems studied in SHC Task 60 divided into covered (diamond) and uncovered PVT (square). In blue, the solar electrical utilization ratio for covered and uncovered PVT collectors.** (Source: IEA SHC Task 60 report, Performance Assessment of Example PVT Systems)

The main outcomes of the Task are:

- A state-of-the-art of PVT technology worldwide
- A collection of PVT operating experiences
- Improved testing, modeling, and adequate technical characterization of PVT collectors
- Examples of standard and best practice PVT solutions
- Exploration of potential cost reductions in PVT systems
- Increased awareness of PVT solutions by all stakeholders through webinars and journal articles

But perhaps the most important result was the confirmation that the PVT industry can actively participate in the decarbonization of the heat energy sector and that PVT solutions deserve more consideration.

Article contributed by Jean-Christophe Hadorn, Operating Agent of IEA SHC Task 60: PVT Collectors and Systems. For more information and to download reports, visit https://task60.iea-shc.org

◄ **In Spain, the conditions are suitable for a low payback time. 102 PVT glazed panels covering 200 m² generate 30 kWp to provide hot water and electricity for self-consumption and the grid at this hotel.** (Credit: Abora Solar)