PVT systems
SHC Task 60

Highlights of a 3 years collaboration

JUNE 15TH, 2021

Jean-Christophe Hadorn, former Operating Agent, Switzerland
Task Duration: 2018 - 2020

PVT strengths

Delivery of:

- **Heat up to 170 C !**
- **Cold**
- **Electricity for all kind of usage**

Shared roof for PV & T

Task 60 Organisation to better assess PVT solutions

Operating Agent
JC Hadorn, Switzerland

A
PVT systems in operation

T. Ramschak,
AEE, Austria

In situ monitoring

B
PVT Performance Characterization

K. Kramer, Fraunhofer ISE,
Germany

Performance Characteristics

C
PVT Modeling

As. Sanz
Tecnalia, Spain

System Simulation

D Systems Design Examples
best practice of solutions from B and C with A constraints – KPIs – Basic recommended control strategies

Dissemination and market support

D. Zenhäusern, A. Haeberle, SPF, Switzerland

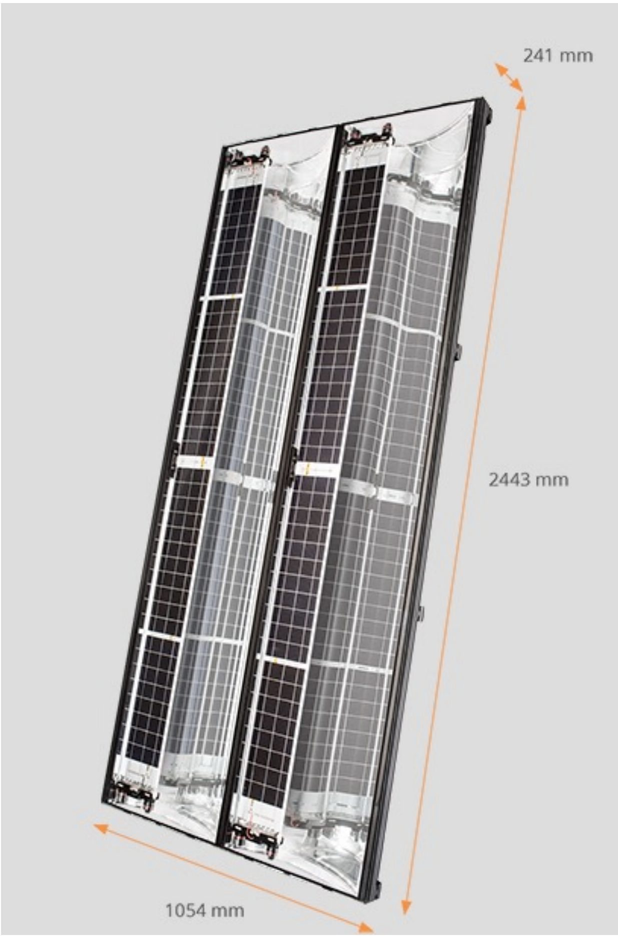
System Design examples

Participation from labs & companies

- **Australia** **Sunovate**
- **Austria** **FH Wels, AEE Intec, *3-F***
- ***Canada*** ***Trigo energies***
- **China** **Dalian Univ of technology**
- **Denmark** **DTU BYG**
- **France** **Univ Perpignan CESP*, *Dualsun**
- **Germany** **Fraunhofer ISE, Berlin HTW, ISFH, Univ Saarland, Stuttgartt HFT, easy-tnt, Consolar , Sunoyster, PA-ID (2Power)**
- **Italy** **Politecno Milano , Uni Catania, Uni Bologna (with Solink)**
- ***RSA***
- **Spain** **Tecnalia, Endef, Abora**
- **Sweden** **Univ. Gävle, BDR Thermea bv, Solarus AB**
- **Switzerland** **SPF, ZHAW, ETHZ LKE, *CSEM*, *HEIG-VD Lesbat*, Vela Solaris, ESSA, Hadorn**
- **NL** **SEAC-TNO, Eindhoven Univ Tech, Solarus BV**
- **UK** **Naked energy, Solar Speedflex**
- *Observers from: USA (Univ Charlotte EPIC, Tyll solar), Macedonia (Camel Solar), Czech (Tech. Univ. Prag),*

India (1 from Solar Thermal Federation of India), Israel

Example of 3 types on the market



Courtesy of Dualsun , Solarus, Naked energy, Meyer Burger

Report A1: 30 Existing PVT systems and solutions

3.20 Single-family house in WETTSWIL AM ALBIS

3.20.1 Introduction and description

The object concerned is a single-family house with a heated outdoor swimming pool, where an existing heat supply system based on a heat pump coupled with a ground source was expanded in 2012 by adding a PVT system. The reason for the integration of the PVT system was an observed cooling of the boreholes.

Figure 40: View of the PVT system on the roof of the single-family house in Wettswil.

3.20.2 Solar installations

28 PVT collectors (Meyer Burger Hybrid 240/900) were installed on the flat roof of the building (total collector area, 45.9 m^2; 6.7 kWp electrical output). The modules are oriented to the southeast (30°) with an inclination angle of 10°. In addition, a PV system with the same orientation comprising 10 modules of the same type, though without heat absorbers, was installed (16.4 m^2; 2.4 kWp).

3.20.3 Heat supply concept and integration of PVT collectors

The heat supply system is depicted in simplified form in Figure 41. It is based on a heat pump coupled with three geothermal boreholes, each with a length of 150 metres. In the summer, the building is cooled through free cooling via the geothermal probes, which are thus partially regenerated. The building also has a wine cellar cooling system, some of the waste heat from which is used for heating up water, while the remainder is fed into the boreholes.

For the integration of the solar system the boreholes were hydraulically separated. Only two of them are regenerated via the PVT collectors, and the third is used for free cooling. This means that both functions can be used simultaneously. When heat is drawn by the heat pump, all three boreholes are used in parallel. The solar heat can be used for heating the swimming pool in addition to the regeneration of the ground source. The installed hydraulics would also allow for use of the solar heat as a direct source for the heat pump. This operation mode, however, is not planned.

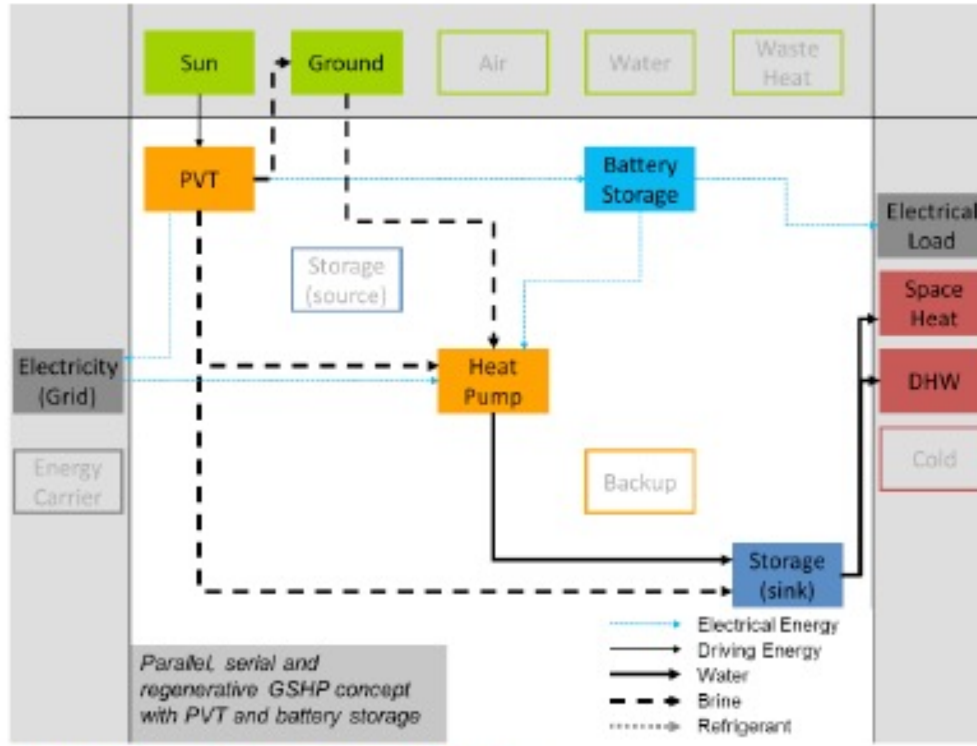
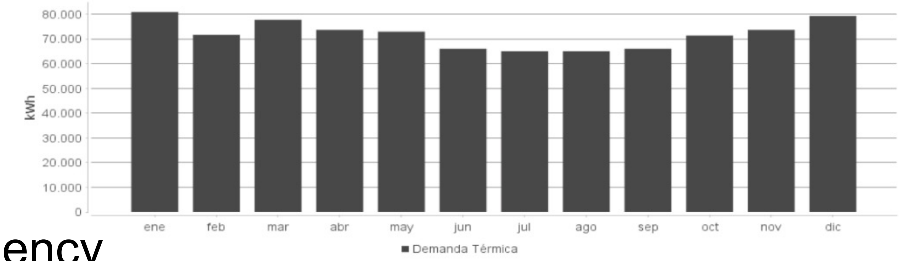


Figure 41: Visualisation of the PVT system "Wettswil".

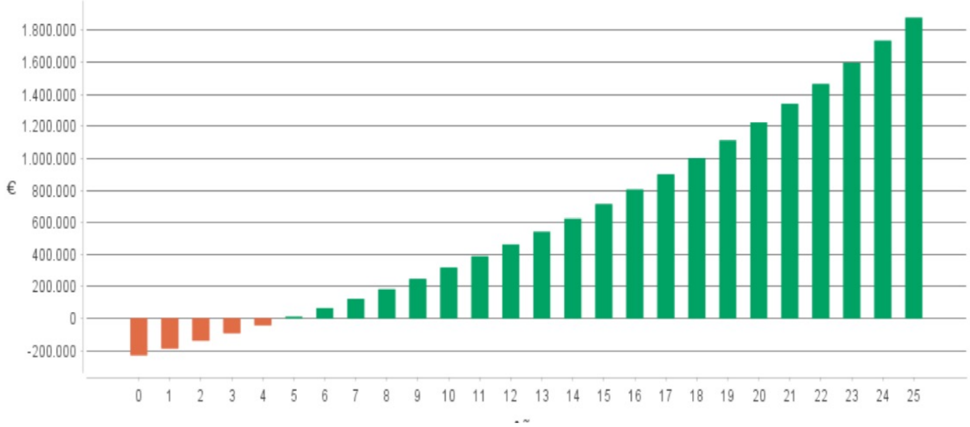
Hotel case in Barcelona – 200 rooms
200 PVT modules - 314 m2 - 56 kWp

Annual demand: 833’000 kWh
Solar fraction: 34%



T: 295’000 kWh = 940 kWh/m2, 50% efficiency
PV: 70’000 kWh = 1’250 kWh/kWp, 80 % self

Investment: 730 €/m2
Payback time: 4 years !



Report B1: Status Quo of PVT Characterization

2.1.2 Operating Below Ambient Temperature

(Based on contribution of Christian Schmidt, Manuel Lämmle, Korbinian Kramer)

2.1.2.1 Model including condensation and freezing

The model is based on ISO 9806 QDT approach with additional considerat
Following changes were included:

1. In the long wave radiation term T_a is replaced by T_m in order to have the radiation as a correction term by equating the average temperature T_m c collector and not the ambient temperature T_a.
2. The term $+a_{10}(2.8+3.0u)(\mu_a-\mu_{sat}(\vartheta_m))$ is added to compensate evaporation/condensation effects (Duffie und Beckman 1991).
3. When the collector temperature is lower than the ambient, there is a p supplied by the collector. So, $(\vartheta_m-\vartheta_a)^2$ is replaced by $(\vartheta_m-\vartheta_a)|\vartheta_m-\vartheta_a$
4. For this particular model, the incidence angles are not taken into account to the position of the collectors in relation to the surrounding buildings and optical efficiency terms $\eta_{0,b}K_b(\theta_L,\theta_T)G_b+\eta_{0,b}K_dG_d$ are simplified to $\eta_0 G$.
5. The term $+a_9(\sigma T_b^4-\sigma T_m^4)$ is added to include effects of long wave radiatic the rear of the collector.

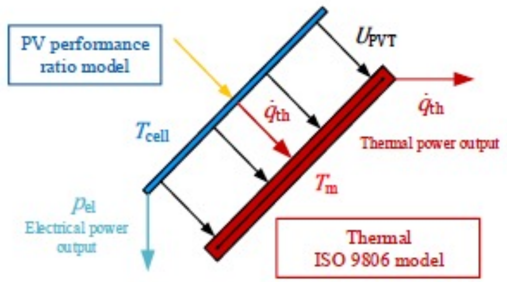


Figure 11: Coupled PVT Model

The PVT cell temperature T_{cell} is calculated via an equivalent thermal network with an internal heat transfer coefficient U_{PVT}, which connects the PVT cell temperature with the mean fluid temperature T_m of the PVT collector (see 12). The mean fluid temperature is calculated as mean temperature between the thermal model input and output temperature. The PVT cell temperature is then given by:

(57)

Tl

collector. Therein, the
eter identification during
according to ISO 9806.
ctor efficiency factor F',
ts, or via FEM methods.

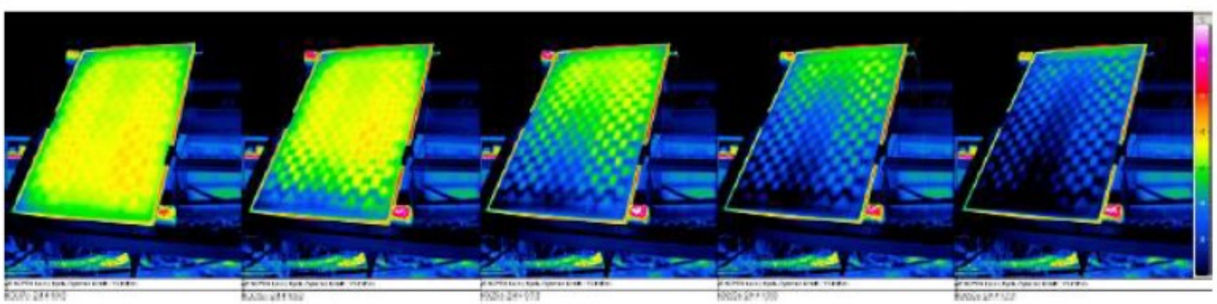


Figure 4: Picture series of a thermal internal shock test according ISO 9806 filing an overheated PVT collector with cold fluid.

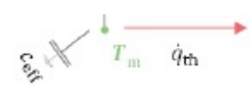
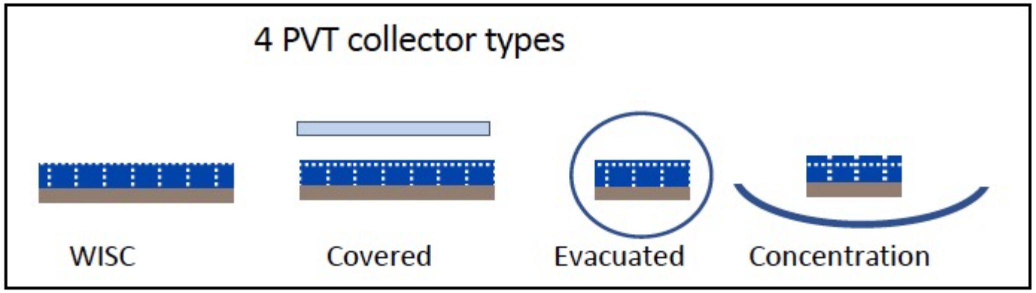
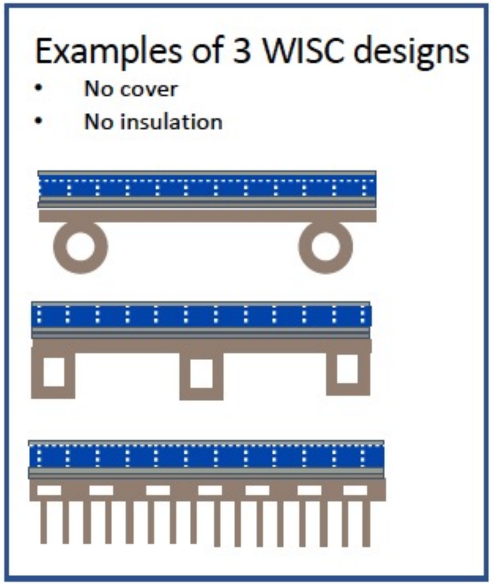


Figure 12: U_{PVT} approach

Report B2:





Legend:
Nomenclature
Function
Guidelines
Materials

6a Absorber

Absorbs solar radiation and heat from the PV, transfers heat to the heat transfer medium

Low IR emission, good contact with upper layer, high heat transfer with ambient for WISC PVT, light-weight, thin, easy to weld or moulded or extruded,
high thermal conductivity, thin for lamination, low pressure drop, low inertia, low temperature coefficient, high heat transfer to fluid properties, eventually transparent

Copper, Aluminium, Steel, Polymer

Very high exchange surface with ambient for non-insulated WISC PVT when operated with a heat pump

Wikipedia page

Photovoltaic thermal hybrid solar collector

From Wikipedia, the free encyclopedia

Photovoltaic thermal collectors, typically abbreviated as PVT collectors and also known as hybrid solar collectors, p
cogeneration systems, are power generation technologies that convert solar radiation into usable thermal and electrica
sunlight into electricity, with a solar thermal collector, which transfers the otherwise unusued waste heat from the PV m
generation within the same component, these technologies can reach a higher overall efficiency than solar photovoltai

Significant research has gone into developing a diverse range of PVT technologies since the 1970s.[2] The different P\
heat transfer fluid and address different applications ranging from low temperature heat below ambient up to high temp

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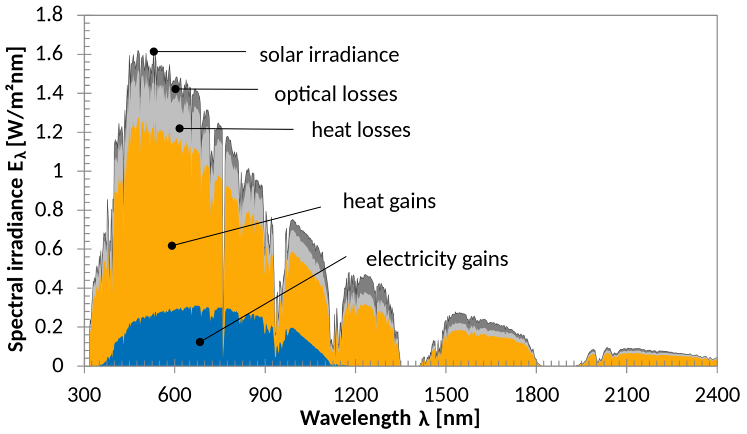

PVT markets [edit]

PVT collectors generate solar heat and electricity basically free of direct CO2 emissions and are therefore regarded[by
and heat to buildings and industrial processes.[citation needed]

Heat is the largest energy end-use. In 2015, the provision of heating for use in buildings, industrial purposes and other
and around 46 % in the building sector. While 72 % of the heat was provided by the direct combustion of fossil fuels, o
to 150 °C is estimated to be 26.8 % of the worldwide final energy demand, which is currently serviced by fossil fuels (g
19.7 % (49.0 EJ residential and 13.6 EJ commercial)[6]

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Report C1: Numerical simulation tools for PVT collectors and systems

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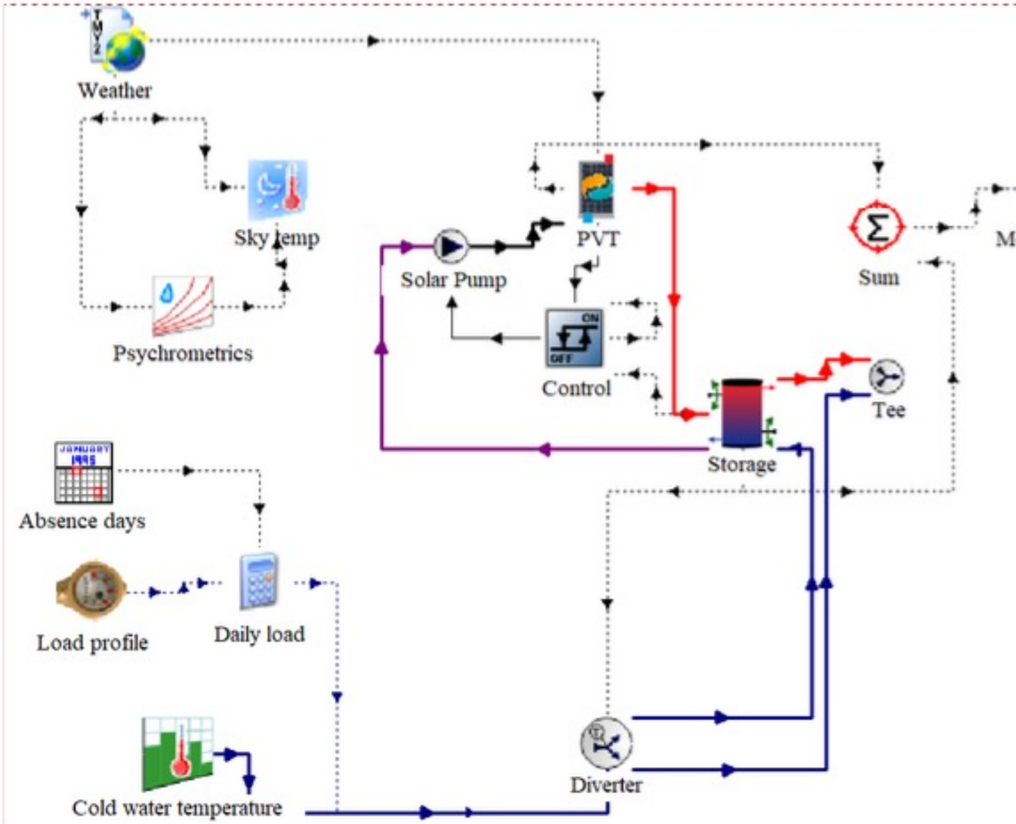

Figure 1: Typical PVT system representation on TRNSYS® deck (Source: Abora Solar).

Report D2: Performance assessment of example systems

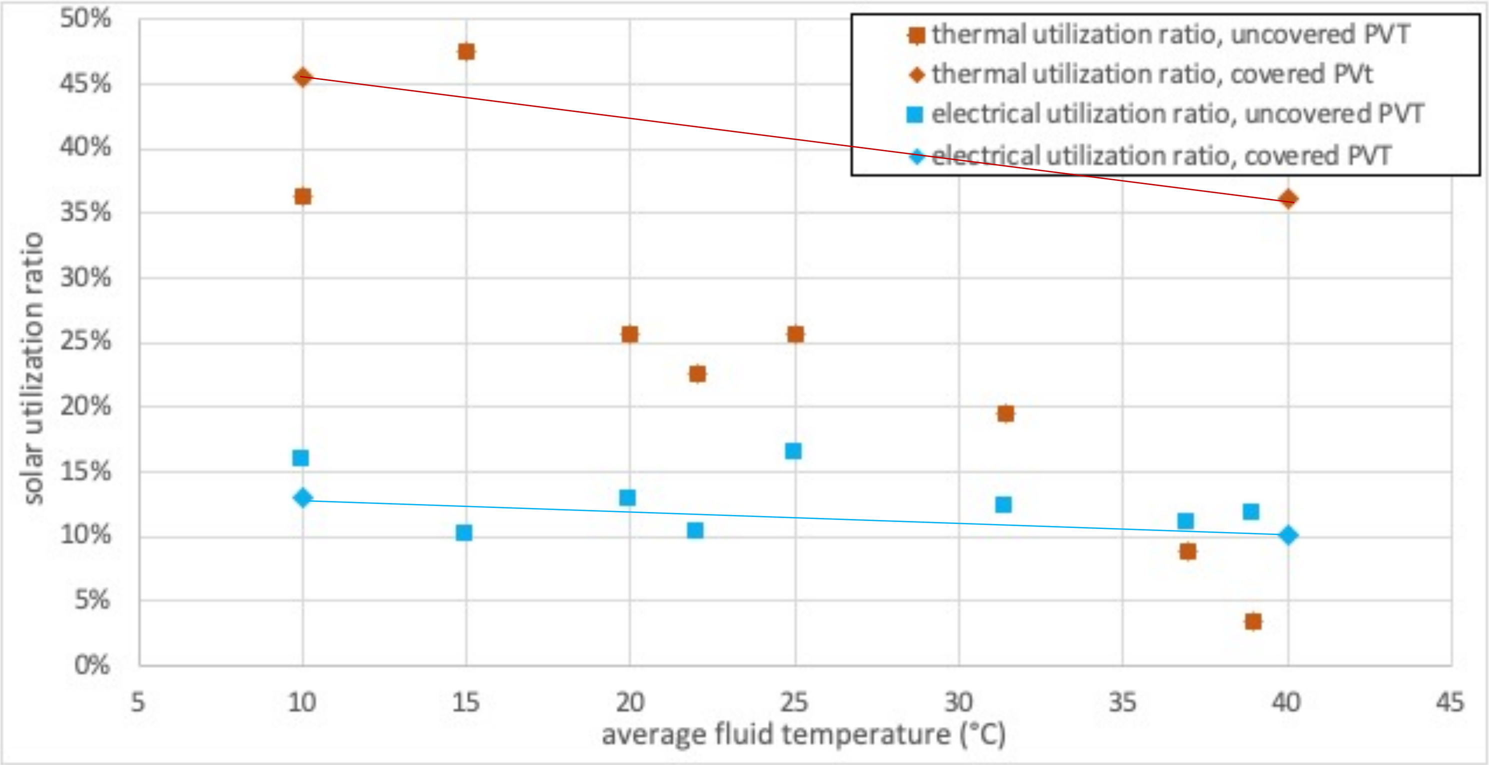

Figure 3: Temperature dependency of the solar thermal utilization ratio (red) for the example systems divided into covered (diamond) and uncovered PVT (square). Additionally the solar electrical utilization ratio is shown in blue for both, covered and uncovered PVT collectors.

PVT and heat pumps

A very good combination

1. WISC collectors best suited
2. Heat source for the HP (no noise, no boreholes) - Cities !
3. Electricity is self consumed (high ROI)
4. Entire roof aestethics
5. Water or air collector
6. Numerous examples (see our report A1)
7. Where PV can be… PVT can be even more efficient !

https://task60.iea-shc.org

+ Webinars

2018 ISES
https://www.youtube.com/watch?v=n1JA-xcclN8&t=3049s

2019 ISES
https://www.youtube.com/watch?v=N8YlgODkbpA

2020 ISES
https://www.youtube.com/watch?v=CdVFqzbSNP8

https://task60.iea-shc.org

See also Research Gate: Task 32, 44, 60 …

Thanks

From Task 60 position paper:

How can solar help reach building renovation targets?

- **PVT can provide PV and hot water and not only PV**
- **PVT can be combined with heat pumps at no noise and no boreholes**

Which technology for which building?

- **PVT WISC or glazed when roof top is available or a flat area somewhere nearby**

How can we stimulate building retrofits using solar?

- **Show that solutions with PVT exist when PV can be installed and will provide much more than electricity**