# SOLAR HEAT PUMP SYSTEM WITH HYBRID PVT COLLECTORS FOR A FAMILY HOUSE

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## Summary

Benefits of solar PVT collector application in combined solar heat pump systems have been analysed and presented in the paper. Energy savings and long-term cost effectiveness have been evaluated. Thermal performance of state-of-art PVT collectors is significantly worse than for reference solar glazed collectors and it cannot be compensated by the direct use of PV electricity produced. Only if new design of PV collectors with low emissive PV absorber is introduced, the electricity demand of the system could be reduced at the competitive costs.

**Keywords:** heat pump, PVT, hybrid collector

## 1 Introduction

Use of the electrically driven heat pumps is considered as a measure for energy use reduction in buildings with a significant advantage of easy integration into smart grids of future. On the other side, today electricity production is primary energy intensive and efficient use of the heat pump technology assumes the high seasonal performance factors (*SPF*). Although the EU Directive on renewables has set out a minimum *SPF* value 2.9, values more than 4.0 have to be met to achieve notably lower emission production and primary energy use level when compared with direct combustion of the fossil fuels.

While heat pumps for the low temperature space heating achieve *SPF* above 4.0, *SPF* for domestic hot water (DHW) preparation above 3.0 is possible only with reduced hot water temperature bellow 45 °C. Combination of solar thermal systems with heat pumps is an approach to eliminate the DHW preparation by heat pump especially in summer season. State of art systems use the parallel approach, i.e. both solar collectors and heat pump deliver the heat into one store for the heat load. Practicaly, the heat pump is an auxilliary energy source for the combined solar thermal system. Second approach is to combine the heat pump system with a PV system. The actual electricity need for heat pump system from external network is reduced by the direct use of electricity produced by PV within such combined PV and heat pump system.

Hybrid photovoltaic-thermal (PVT) collectors represent another step further. Combination of photovoltaic and thermal collector in one single device has the potential to increase energy (heat & electricity) production from building envelope and provide higher self-sufficiency in local networks. Potential use of PVT collector in advanced solar heat pump systems has been analysed from the point of energetic and economic savings and the results are presented in paper.

## 2 State-of-art system and analysed variants

The system simulations have been done for a building defined in frame of T44A38 [1] as the single family house SFH45. Building has space heating demand 60 kWh/m$^2$.a in Zurich climate and hot water load of 73 m$^3$/a at 45 °C. Low temperature system 35/30 °C has been used for space heating. Evaluated electricity consumption of the system comprises of electricity for the heat pump, back-up heater, circulation pumps and controls, including the penalty function if the thermal comfort for space heating or DHW is not achieved.

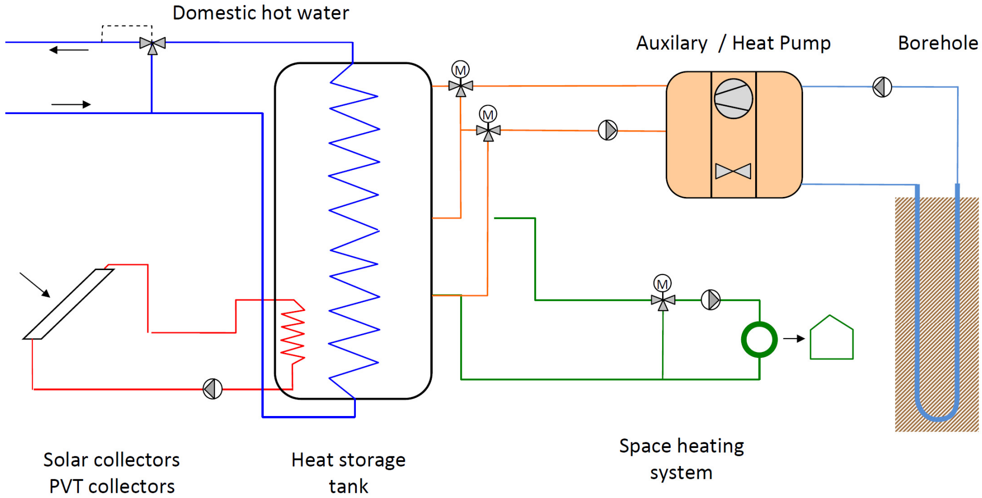


***Fig. 1*** *Reference system scheme*

To analyse the benefits of the hybrid PVT collectors application for the solar heat pump systems, the state of art solar heat pump system (SHP) has been defined as a reference variant (REF). The state of art system comprises of the main store (800 l), single glazed flat-plate collectors (10 m$^2$) and ground source heat pump with a 75m borehole (see **Fig. 1**). The main store has an integrated internal heat exchanger for DHW preparation. Solar loop heat exchanger is placed in the lower part of the store. Heat pump has been designed as monovalent heat source with 5 kW nominal heat output. *SPF* of the reference system is 4.12 in the Zurich climate.

There are several variants of the system investigated and compared (see **Tab. 1**). Reference solar collectors are replaced by PVT collectors in different designs: unglazed low cost PVT collectors (PVT-ungl), nonselective glazed PVT collectors with a new gel lamination resistant to temperatures above 200 °C (PVT-nsgl) and a new theoretically proposed design with low emissivity coating on PV absorber to achieve the selective PVT collector (PVT-segl). All hybrid PVT collector variants are in the state-of-art level or under development (increased performance, reduced costs). PVT collectors available on the market show performance/cost ratio usually worse. Efficiency characteristics of the collectors are shown in **Fig. 2**. Thermal characteristics for PVT collectors are presented in maximum power point tracking mode (MPPT). A variant with PV only system has been also investigated for comparison. Total costs for 2.25 $kW_p$ PV system (15 $m^2$, pc modules) has been used 3150 €, BOS cost has been considered as 50 % of total costs.

***Tab. 1*** *Investigated variants of the solar heat pump system*

| Variant | Description |
|---|---|
| REF | reference parallel solar and heat pump system (solar collector price 350 €/$m^2$) |
| PV | reference system combined with PV only system (total PV system costs 3150 €) |
| PVT-ungl | system with reference collectors replaced by 15 $m^2$ low cost unglazed PVT collectors (PVT collector price 250 €/$m^2$) |
| PVT-nsgl | system with reference collectors replaced by 10 $m^2$ glazed nonselective PVT collectors (PVT collector price 450 €/$m^2$) |
| PVT-segl | system with reference collectors replaced by 10 $m^2$ glazed selective PVT collectors (PVT collector price 450 €/$m^2$) |

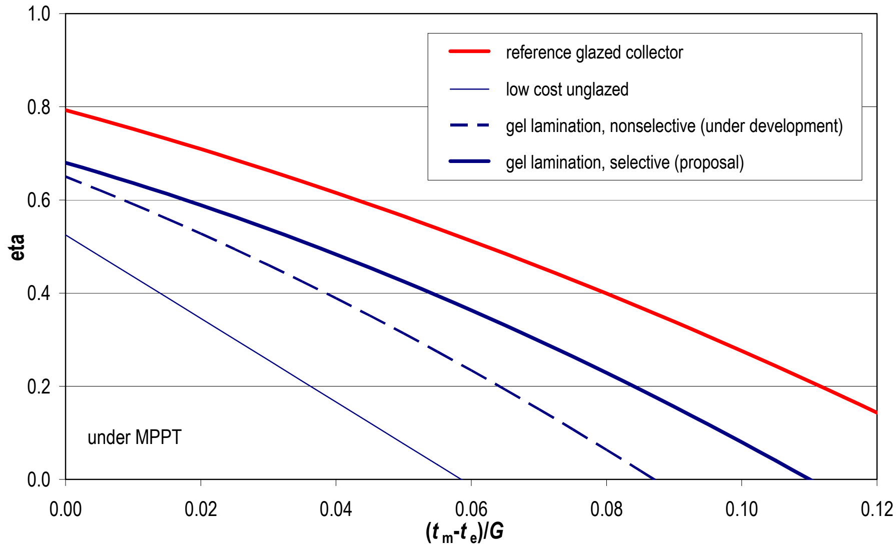


***Fig. 2*** *Efficiency characteristics of solar collectors used in analyses*

## 3 Results and discussion

Use of PVT collectors for both heat and electricity supply for the solar heat pump system has been evaluated from energetic and economic point of view. Simulation analysis of the combined solar heat pump system in described variants has been done in TRNSYS with nonstandard component models, especially for unglazed PVT collector (type 203) [2]. The electricity produced by PV is taken into account to reduce the electricity demand of the solar heat pump system only if there is a match between PV production and system consumption (direct use of PV electricity). Electricity demand of the system has been evaluated in the given variants and cost-benefit analysis has been performed. The total 20years cost difference per year has been evaluated including annuity cost of investment and maintenance (3 % rate of interest and 1 % for maintenance) and the average cost for the electricity over the lifetime (0.16 €/kWh at present and 5% cost-increase per year).

**Tab. 2** shows the results of analysis. Differences in system costs to reference system have been determined from reference collector costs savings and additional cost for new components. Costs for PV part of the PVT collectors and BOS costs have been considered only by the fraction $f_{PV}$ the solar heat pump system uses the PV electricity produced. Change in electricity demand $\Delta W_{el}$ and *SPF* of the system have been evaluated.

***Tab. 2*** *Results of system simulations in given variants*

| **Variant** | **Δcost [€]** | $f_{PV}$ **[%]** | $\Delta W_{el}$ **[%]** | **Total Δcost [€/a]** | ***SPF*** **[-]** |
|---|---|---|---|---|---|
| PV 15m$^2$ | +340 | 10.8 | -11 | -53 | 4.64 |
| PVT-ungl 15 m$^2$ | -912 | 14.6 | +6 | -29 | 3.91 |
| PVT-nsgl 10 m$^2$ | +329 | 19.0 | 0 | +28 | 4.12 |
| PVT-segl 10 m$^2$ | +354 | 19.8 | -4 | -1 | 4.30 |

# 4 Conclusions

Use of PV only system combined with solar heat pump system has shown high energy and cost savings. Unglazed PVT collectors have shown a poor thermal performance which cannot be balanced by the simultaneous electricity use for the SHP system. Also, the glazed nonselective PVT collectors show worse performance than reference glazed collectors used in state-of-art system and high additional costs make this variant economically unfavourable. Only if new design of the selective PVT collectors would be applied, the electricity demand of the system could be reduced at the competitive costs.

# Acknowledgement

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# References

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