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ESTABLISHING STANDRAD CHARACTERISTICS FOR PVT HEATING SYSTEMS EVALUATION

Summary

The paper argues for fact-based information to support energy refurbishment policies and highlights PVT heating systems as a growing option in buildings. In a field study of a 32-unit apartment building, a CHP plant (100 kW) and a brine/water heat pump (44 kW) operate with 56 PVT collectors (109 m²) and a 23.8 kWp PV array to provide space heating and domestic hot water. Core KPIs are SPF3 (seasonal performance factor for the heat pump), GTY and GEY (gross thermal and electrical yields of the collector field), a characteristic temperature, and the electricity self-consumption ratio. The analysis compares CHP and HP contributions under varying outdoor conditions, evaluates collector-field performance, and quantifies PV-PVT interactions to determine self-consumption. SPF3 emerges as a robust energy-performance indicator; GTY/GEY support product-level comparisons and inform market diffusion and storage planning.

Field of application for the findings: PVT Heating systems in Buildings

Addressed audience: Energy System Planers, Installers, Architects, Providers of heating systems

1. Introduction

In the context of pressuring legislation on energetical refurbishment and future safe building codes it is of outmost importance to provide factful information for the buyers’ decision on possibilities, limitations pros and cons and characteristics like performance and price for the different competing heating technologies. PVT heating systems therein are a rather new, nevertheless fast-growing option. To develop a healthy, compatible and sustainably scalable market share, the technology must be accessible for the markets. One element is performance expectation. Based on over 7 years of continuous monitoring and cross checked with experience from other technologies characterization the paper presents a small set of key performance indicators to be established through about the market to provide information. The paper shows how this can be applied also for multifamily homes and complex heating systems, focusing on the PVT heating system part.

Monitoring object

The building is an apartment building with 32 units and a heated floor area of 2,300 m², built in 1985. As part of a partial renovation, the building's heating system was renewed. The thermal insulation remained unchanged. Only individual radiators were replaced so that the building can be heated at lower supply temperatures. The new heating system, installed to replace a gas boiler, supplies the building with space heating and domestic hot water. The heat sources are a cogeneration plant (CHP) with a heating capacity of 100 kW and a brine/water heat pump with a heating capacity of 44 kW (B0/W35). The heat source for the heat pump is represented by 56 PVT collectors. The collectors consist of a TOPCon PV module on the front side and an aluminum heat exchanger with fins on the back side. The total PVT collector area is 109 m². The thermal capacity installed is 50.2 kW. The electrical capacity is at 23.8 kW_p. Additionally, another 56 PV modules with a total capacity of 23.8 kW_p are installed. The collectors are installed on both sides of a gable roof, with half on each side. The roof ridge is oriented 6° east. The collectors have an almost perfect east-west orientation. The roof pitch is 30°.

Metrology

The system is equipped with extensive measurement technology. Heat meters record all relevant temperatures, volumetric, and energy flows at both the combined heat and power burner CHP and heat sources, as well as on the load side of the heat pump. In addition, another heat meter is installed on the building roof. This measures five collectors of the collector field individually. In addition, there are heat meters on the consumption side of the system for space heating and domestic water heating. On the electrical side, the PVT and PV fields as well as the heat pump are each measured with corresponding meters. Solar irradiance on the horizontal plane, as well as wind speed on the horizontal plane and in the collector plane, are recorded. In addition to the outdoor temperature, the air temperature in the gap between the roof tiles and the underside of the PVT collector is measured. The measurement interval for the heat meters and electricity meters is 5 minutes; the additional heat meters for the collector string and the ambient sensors are polled at 10-second intervals.

KPIs

The essential indicator for evaluating the performance of a heat pump heating system is the Seasonal Performance Factor SPF3 (Daniel Zenhäusern et al. 2020). It considers the heat energy provided by the heat pump prior to the storage tanks and relates this to the electrical energy of the heat pump (compressor and control system) as well as the brine pump. Any heating rod that might be present would also be considered on the electrical side. However, this is not present in the system under investigation.

The thermal and electrical yields of the collector field are quantified using gross thermal yield GTY and gross electrical yield GEY (K.Kramer et al. 2025), respectively. GTY denotes the thermal energy generated by the collector field during the measurement period, and GEY denotes the electrical energy generated by the collector field. As GTY does not per se indicate the temperature level of the delivered energy which in the application is most meaningful and interesting in the context of exergy the additional concept of the characteristic temperature (M.Lämmle et al. 2017) is proposed.

In addition to the two previously mentioned KPIs, the self-consumption ratio is being determined. This value describes the portion of the heating system's electrical energy that is supplied by locally produced PV power (Daniel Zenhäusern et al. 2020).

2. Evaluations

First, the contributions of the two heat generators (CHP and HP) to meet the building’s heating demand are compared, and the SPF3 for the heat pump is calculated. The contributions and SPF3 are analyzed and evaluated with respect to the prevailing operating conditions, with regard to outdoor temperature and the resulting thermal load of the building. The thermal output of the collector field is analyzed with respect to outdoor temperature, solar irradiance, and wind conditions. Due to its design, the PVT system used here is particularly well-suited to use outdoor air as a heat source, delivering source energy even at night. A focus of the evaluation is on operating situations where no solar radiation was present. In this installation, the PV and PVT collector fields are equal in size. Both fields consist of 56 modules with a nominal electrical power of 23.8 kWp each. Both fields are each connected to their own inverter. This arrangement enables comparing the electrical yields of PV and PVT fields against each other, thereby quantifying the cooling effect of PVT collectors on the electrical yield. Surplus the electrical energy which is used by the heat pump can be determined thereby allowing to give the ration of grid electricity to PV electricity locally converted, called self-consumption ratio for the heating system. The following figure 1 shows a portion of the metrics and KPIs studied for the first two months of this year. In the conference contribution, the data are broken down by month.

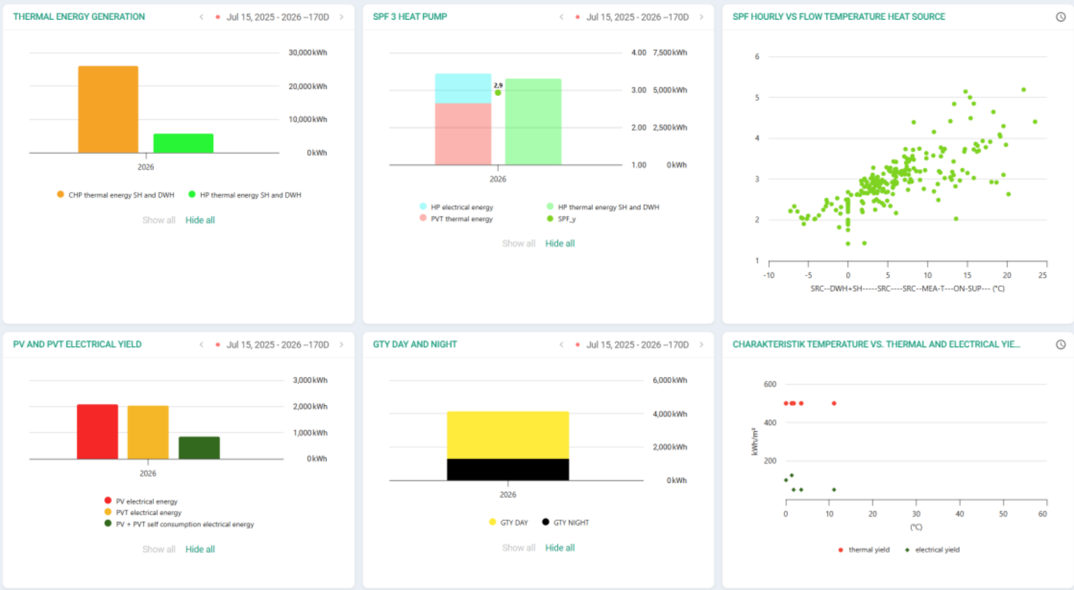

Fig. 1: Dashboard overview of the energy characteristics proposed

3. Conclusions

The field measurement provides essential insights in the complexity of operating hybrid heating systems. With having the opportunity of gathering energy data in the highly innovative installation of the project, following findings could be made. Firstly, the SPF 3 is a very suitable characteristic to describe the energy performance of PVT heating systems. The authors recommend to balance energy fluxes in monitoring projects always as defined, so intercomparison of different installations is doable and meaningful. Secondly, the gross energy yield in thermal (GTY) and gross electrical energy yield (GEY), is a collector specific characteristic which is very adequate to describe (energy output forecast simulations), compare and rank (energy label) PVT collectors on the product level, even though the grading of the heat is a challenge still for the concept. Important basis for those characteristics is the recent methodology development, which was implemented in the revision of ISO 9806 and could be cross-checked in the project with field measurement. More details will be published in a separate abstract. Thirdly, the self-consumption, timely coincidence of solar yields and heat load is documented. This provides orientational knowledge of the energy fluxes and the specific invest to make those accessible. This information is meaningful for the market diffusion of those systems and design questions like adding battery or heat storage at respective costs. Lastly, the effect of having a PVT operating at different temperatures compared to the identical PV field next to it was quantified. The data base is limited because of the duration of measurement and more details will be published elsewhere at a later point, nevertheless the method is developed, and valid results can be provided to be recognized and discussed.

4. References

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International Organization for Standardization (ISO)