PERFORMANCES OF PVT FIELDS FOR LOW TEMPERATURE DISTRICT HEATING

Summary

An online software tool for calculating the thermal and electrical output of large PVT fields in connection with district heating systems has been developed. The PVT field produces electricity and heat at low temperatures. The heat is generated by an increase of the temperature of the heat transfer fluid circulating through the PVT field.

The software, which uses thermal and electrical efficiency equations for PVT panels, has been used to calculate the yearly thermal and electrical performances of PVT fields for four locations in Europe. The results of the calculations are presented in the paper.

Keywords: PVT fields, low temperature district heating, calculations, yearly performances

Field of application for the findings: Preliminary evaluation of suitability of PVT fields connected to low temperature district heating systems

Addressed audience: Researchers, consultants, energy planners, decision makers, district heating companies

1. Introduction

Calculations of the yearly performances of PVT fields installed on the ground with several rows with PVT panels are carried out with the simulation model described in (Dannemand et al., 2025). The simulation model is available on https://pvtfield.streamlit.app/. The PVT fields are assumed to be connected to district heating systems. The PVT fields produce electricity and heat at low temperatures. The heat is generated by an increase of the temperature of the heat transfer fluid circulating through the PVT fields.

The heat produced by PVT fields can be transferred to the water of district heating networks by means of heat exchangers. The water can be distributed to the consumers via a thermonet or a 5th generation district heating network and used as a source for individual heat pumps which will deliver the temperature level required by the consumers. Another way for district heating companies to utilize the heat produced by the PVT fields is by means of large, centralized heat pumps to increase the temperature in the district heating network to the required level at the district heating plant.

2. Assumptions for the calculations

The PVT field consists of 25 rows with 20 south facing PVT panels installed in each row, and the row distance is 5 m. Both the PV area and the absorber area of each PVT panel is 2 m² resulting in a total panel area of the PVT field of 1000 m². The calculations are based on the following equations for the PVT panel:

Thermal performance:

$$\dot{Q} = \begin{bmatrix} \eta_{0,b} \cdot K_b(\theta) \cdot G_b + \eta_{0,b} \cdot K_d \cdot G_d - a_1 \cdot (T_m - T_a) - a_2 \cdot (T_m - T_a) \cdot abs(T_m - T_a) \\ -a_3 \cdot u \cdot (T_m - T_a) + a_4(E_L - \sigma T_m^4) - a_6 \cdot u \cdot (G_b + G_d) - a_7 u(E_L - \sigma T_m^4) \end{bmatrix} \quad \text{(eq. 1)}$$

where the incidence angle modifier is determined by:

$$K_b(\theta) = 1 - tan^p(\theta/2) \quad \text{(eq. 2)}$$

Electrical performance:

$$P/A_G = G(b_D - b_1 \cdot \Theta_m - b_2 \cdot \Theta_a - b_3 \cdot G) \quad \text{(eq. 3)}$$

The symbols used are shown in table 2.

The height of the PVT panel above the ground is assumed to be 2 m and the mean solar collector fluid temperature of the panels is maintained constant during the year. Calculations are carried out for four locations: Stockholm - latitude 59.4°, Gothenburg - latitude 58.0°, Copenhagen - latitude 55.7° and Lisbon - latitude 38.7°. The hourly weather data used for the four locations are taken from ERA5 for 2023, (https://cds.climate.copernicus.eu/datasets/reanalysis-era5-single-levels?tab=overview). For each time step of the year with a duration of 1 h, the heat and electricity production by the PVT panels are calculated by means of equations 1, 2 and 3.

The parameters for the efficiency expressions for the unglazed PVT panels are given in Table 1.

Tab. 1: Efficiencies for PVT panel

Thermal efficiency/parameter	**Quantity**	**Electrical efficiency/parameter**	**Quantity**
Peak collector efficiency based on G_b, $\eta_{0,b}$	0.60	Coefficient for the electric power output, b_D	0.20
Constant in IAM coefficient, p	4.50	Coefficient for the electric power output, b_1	0.0005 1/K
IAM for diffuse solar radiation, K_d	0.92	Coefficient for the electric power output, b_2	0.0005 1/K
Heat loss coefficient, a_1	15.0 W/(m²K)	Coefficient for the electric power output, b_3	0.000001 m²/W
Temperature dependence of heat loss coefficient, a_2	0 W/(m²K²)		
Wind speed dependence of heat loss coefficient, a_3	5.0 J/(m³K)		
Sky temperature dependence of heat loss coefficient, a_4	0.85		
Wind speed dependence of zero loss efficiency, a_6	0.05 m/s		
Wind speed dependence of infrared radiation exchange, a_7	0 W/m²K⁴		

3. Yearly performances of PVT fields

Yearly thermal performances and yearly electrical performances are calculated for the four European locations mentioned in chapter 2. As an example, the performances for the PVT field with a panel tilt of 45° located in Copenhagen are shown in figure 1 and 2 as functions of the mean collector fluid temperature.

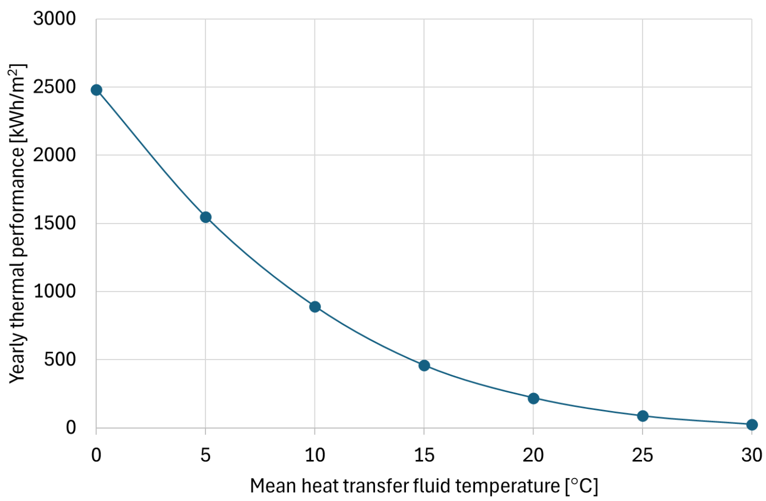

Fig. 1: Yearly thermal performance of PVT field in Copenhagen as function of the mean collector fluid temperature

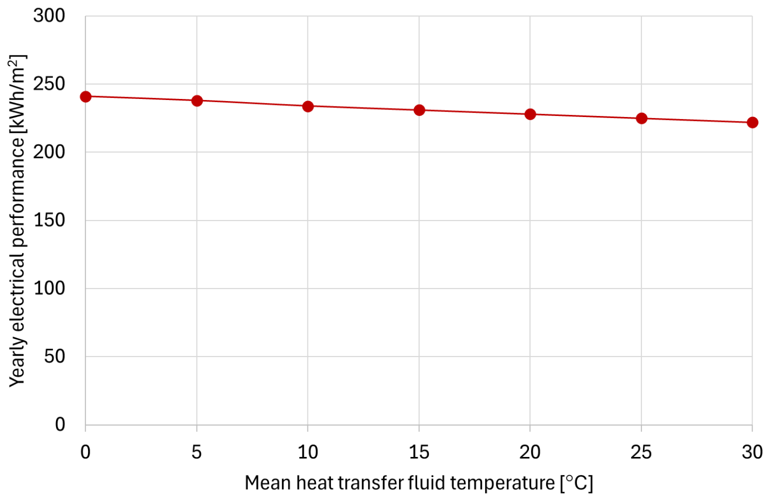

Fig. 2: Yearly electrical performance of PVT field in Copenhagen as function of the mean collector fluid temperature

For increasing fluid temperature, the performances are decreasing.

Tab. 2: Symbols used

Quantity	Symbol	Unit
Heat production	$\dot{Q}$	W/m²
Peak collector efficiency based on Gb	$\eta_{0,b}$	-
IAM for direct solar irradiance	$K_b(\theta)$	-
Incidence angle	Θ	°
Beam irradiance on PVT panel	G_b	W/m²
IAM for diffuse solar radiation	K_d	-
Diffuse irradiance on PVT panel	G_d	W/m²
Heat loss coefficient	a_1	W/(m²K)
Mean temperature of the heat transfer fluid	T_m	K
Ambient air temperature	T_a	K
Temperature dependence of heat loss coefficient	a_2	W/(m²K²)
Wind speed dependence of heat loss coefficient	a_3	J/(m³K)
Wind speed	u	m/s
Sky temperature dependence of the heat loss coefficient	a_4	-
Longwave irradiance	E_L	W/m²
Stefan-Boltzmann constant	σ	5.6704×10^{-8} W / (m²K⁴)
Wind speed dependence of zero loss efficiency	a_6	s/m
Wind speed dependence of infrared radiation exchange	a_7	s/m
Constant in IAM coefficient	p	-
Electricity production	P	W
Gross area of PVT panel	A_G	m²
Total solar irradiance on PVT panel (G=Gb+Gd)	G	W/m²
Coefficient for the electric power output	b_D	-
Coefficient for the electric power output	b_1	1/K
Mean temperature of the heat transfer fluid	Θ_m	°C
Coefficient for the electric power output	b_2	1/K
Ambient air temperature	Θ_a	°C
Coefficient for the electric power output	b_3	m²/W

References:

Dannemand, M., Furbo, S., Kong, W., Cardoso, J.P., Facão, J., Vilke, G., 2025. PVT4EU, Photovoltaic and Thermal for Europe. D5.1 Report on selected application scenarios and simulation models.

https://pvtfield.streamlit.app/

https://cds.climate.copernicus.eu/datasets/reanalysis-era5-single-levels?tab=overview.