Solar collectors for 500+°C process heat

SolarPACES

Fabian Gross[1], Axel Schweitzer[1], and Alf Oschatz[1]

[1] sbp sonne gmbh, Germany

*Correspondence: Fabian Gross, f.gross@sbp.de

1. Introduction

Sunshine is thermal radiation and can be collected to provide high temperature heat. Several technologies with different characteristics allow to tailor suitable solutions. The heat consumer may be e.g., refineries, smelters, drying plants.

2. Methodology

This paper compares the means to harvest solar power for high temperature process heat well above 400°C with high capacity factor beyond 80%. As storage for high temperatures (300 - ~1000°C) are commercially available (e.g., molten salt, concrete, ceramics), the proposed solar solutions can address nocturnal process heat needs with or without backup depending on the flexibility and reliability.

The solar options comprise the following collectors: Parabolic trough, heliostats with tower, fixed and tracking photovoltaics, or hybrid combinations of the above. Grid integration can facilitate the sell-off of excess electricity and purchase of backup power, whilst remote places need local backup, they also compete against high-cost fuels.

The available solar resource, the scale of requested power, desired temperature and availability, land as well as fuel and CO_2 cost contribute to the economics of the project. Local content, adaptability during the plant lifetime and speed of construction influence investment decisions.

The scenario for this comparison of the solar collectors is a constant demand of 100 MW_th at 500°C that needs to be filled by backup (100 €/MWh, 50 k€/MW_e/a capacity) if solar is insufficient. Excess electricity can be sold for FIT 20 €/MWh. The electric heater's specific CAPEX is assumed to 0.1 €/W, storage happens in molten salt. The reference sites are Australia -20°, Saudi Arabia 30°, China 40°.

The paper analyses the production characteristics, the system cost and levelized cost of heat for typical assumptions.

3. Results

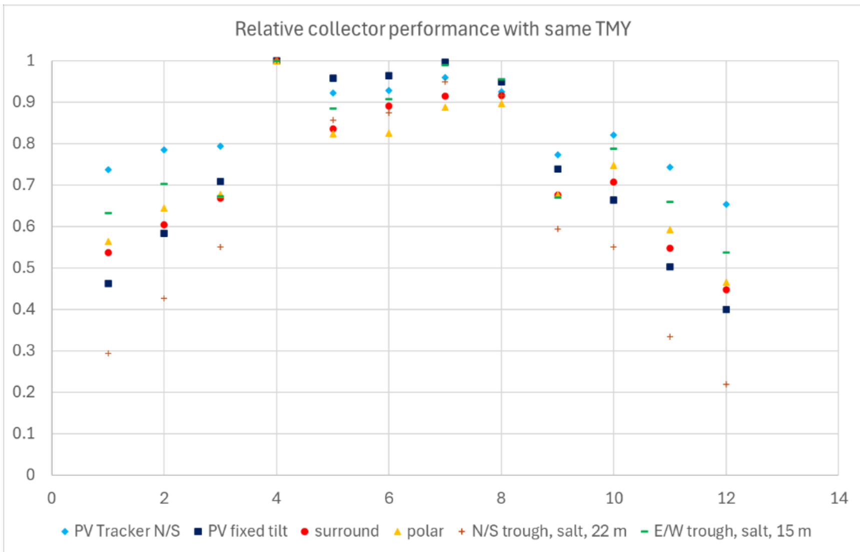
The parabolic trough contains the receiver system and can be built economically from ~1 MW_t. Whilst a N/S-axis with enough pitch (ground coverage ratio GCR ~ 0.3) allows for high annual heat collection with distinct seasonal variation, an E/W axis allows for high density fields (GCR ~ 0.5) with little shading and stable output also in winter. The terrain needs to be quite flat, and the field shape should be rather regular for collectors of 150+ m length. The HTF (here molten salt) can be piped for a few kilometers to the consumer if necessary.

The heliostat field does not require a flat terrain and makes sense at scales above several MW_t. A polar rather than a surrounding field has very high efficiency in winter and is suitable for yearlong baseload. Depending on the heat transfer fluid and (multi)tower configuration, the pipeline system can be costly and a tight integration with the (greenfield) process is advantageous. The tower may be restricted close to special infrastructure like airports.

Photovoltaics have developed so far that their levelized cost of heat is the same order of magnitude as of CSP systems. They profit also from diffuse radiation. PV can be built with low GCR and trackers to maximize the yield per module and relatively stable production during the daylight hours. The tracker at moderate latitudes in an exemplary TMY (aDNI ~2.2 MWh/m²/a) offers more production in winter. As it is possible to completely cover the ground with PV (GCR = 1), the yield per ground area can be comparable to a dense parabolic trough field at the expense of yield per module. Electricity as the backbone of the energy system is versatile and can be sold to the grid or bought for backup. As grid capacity typically has a price, a battery system may be lucrative.

The solar collectors (trough, heliostat, PV) behave differently in terms of the metrics: Daily and seasonal production profile, typical footprint, cost (CAPEX, OPEX), LCoH.

The abstract shows the relative performance distribution across the year, starting in winter.



4. Outlook

The range of solar collectors allows to tailor solutions for the solarization and decarbonization of process heat. As the deployment of renewable energy continues and allows the learning curves to progress, reducing the carbon footprint of industry will become cheaper. The results from this study can be extrapolated to lower target temperatures below 500°C.

References

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