Concentrating solar collectors for process heat and electricity generation

Fraunhofer ISE
Anna Heimsath
anna.heimsath@ise.fraunhofer.de
Werner Platzer
werner.platzer@ise.fraunhofer.de
Stefan Heß
stefan.hess@ise.fraunhofer.de

DLR
Dirk Krüger
dirk.Krueger@dlr.de
Markus Eck
markus.Eck@dlr.de

Concentrating solar thermal collectors for global markets

Concentrating collectors are particularly suitable for generating process heat and electricity in climatic regions with high direct solar irradiation potential around the world. The earth's so-called sun belt extends to the left and right of the equator, incorporating Southern Europe, North Africa, and the great deserts of our planet.

Collectors in the temperature range from approx. 250 °– 450 ° are suitable for use in solar thermal power plants, such as those planned for the Desertec project. To date, thermal oil has primarily been used as the heat transfer medium in parabolic trough power plants. A future alternative is direct evaporation of water for parabolic troughs and linear Fresnel collectors, a cost-effective and environmentally friendly heat transfer medium. Smaller concentrating collectors, which generate process heat at temperatures between 150 °C and 300 °C, are suitable for solar cooling and for combined heat and power generation. This allows direct supply of industrial companies with heat/cooling and electricity. That is particularly interesting for regions with unstable electricity grids or grid-remote regions. In India alone, the off-grid electricity generation in the power range below 1 MW_{el} accounts for 12% of the overall electricity consumption.

In Europe, approx. 27% of the overall final energy requirement is accounted for by industrial process heat. Approx. 30% of this requirement occurs at temperatures below 100 °C and a further 27% occurs in a range between 100 and 400°C [1].

Figure 1
Overview of concentrating collectors, applications and corresponding operating temperatures

Figure 2
Second test sample of the RefleC collector for measuring the efficiency curve at Fraunhofer ISE (rotated 90 ° counter-clockwise).

A majority of process heat can be generated via solar energy. Processes with great potential for integration of low-temperature process heat up to 150 °C and medium-temperature process heat up to 400 °C are used in the foodstuffs and textile industries, for example, as well as in laundries, the metal and paper industries.

Stationary collectors for generating low-temperature process heat

One approach to utilising the great potential in the area of low-temperature process heat is the development of low-concentration stationary (i.e. do not track the sun) collectors. Compared with focusing collectors, they have the advantage that much of the diffuse solar irradiation can also be used for energy conversion. Compared with standard flat-plate collectors, they generally have significantly lower thermal losses. Therefore, these collectors are suitable for the temperature range between 80 °C and 150 °C [2]. An example for this kind of collector concept is shown in *Figure 2* – the RefleC collector, developed by Wagner & Co. Solartechnik in cooperation with Fraunhofer ISE as part of a project funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Based on the technology of standard flat-plate collectors the following goals are pursued:

- Reduction of thermal losses by using a second transparent collector cover and concentrating reflectors
- Lower costs and better draining in the event of stagnation than evacuated tube collectors
- Adaptation of the maximum collector output to the load profile of the application to be supported (via the shape of the reflectors)

Simulation results in Würzburg for the version shown in *Figure 2* indicate that at a constant input temperature of 120 °C, the annual energy yield is 40% higher than for a double covered flat-plate collector due to the use of reflectors.

Direct evaporation for power plants

In generating electricity in solar thermal power plants, the system efficiency is primarily determined by the upper process temperature. Currently, a synthetic heat transfer oil stable up to approx. 400 °C is used in parabolic trough fields. A further increase of the process temperature, and thus the system efficiency, is not possible with this approach.

However, if water is evaporated directly in the collector arrays and overheated, the upper process temperature can be increased significantly. Direct evaporation of the water in the collector array is far more complex than the current technology from a process technology point of view, due to the two phase flow and the great difference in density between water and steam. The fundamental controllability of the direct solar evaporation was demonstrated successfully in the DISS test system at the Plataforma Solar de Almería (PSA) during over 10,000 operating hours.

Current development targets consist in improving key components of the collector array so that they can be used at temperatures of up to 500 °C and pressures of up to approx. 130 bar.

The research efforts in this area focus on

- Absorber tubes, in which the temperature stability of the selective coating must be increased,
- Flexible pipelines, which must remain flexible at significantly higher process pressures, and
- The storage system in which economic solutions are developed for storing the latent evaporation heat.

The development work has now reached a level of maturity which encouraged German and Spanish consortia to produce initial demonstration systems. At the beginning of 2009, Novatec-Biosol commissioned the first solar thermal power plant with direct solar evaporation near Murcia (Spain). The power plant has an electricity output of 1.2 MW and uses linear Fresnel collectors (*Figure 3*).

Industrial process heat and combined heat, cooling and power generation

Steam is often used in industrial companies and hotels to supply heat to various consumers.

Figure 3
Collector array of the first solar thermal power plant with direct solar evaporation near Murcia
(Image: Novatec-Biosol)

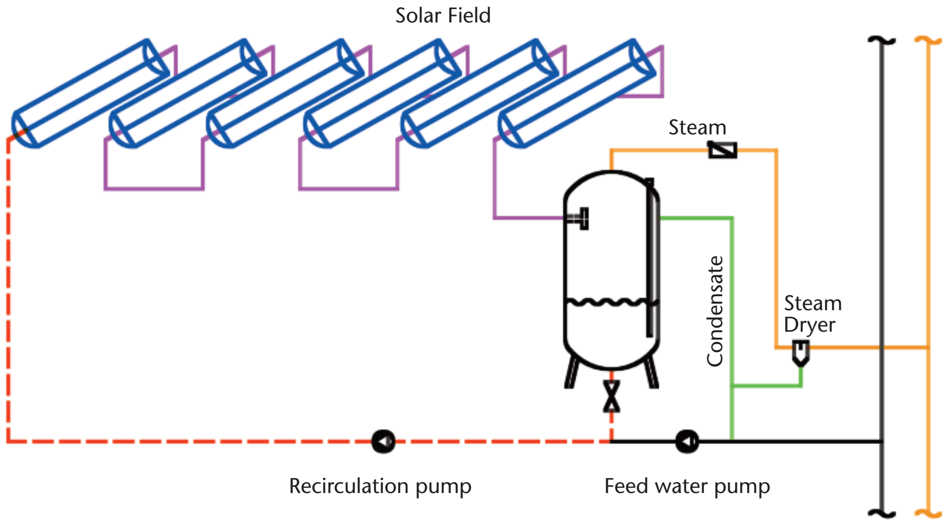

Figure 4
Steam circuit for direct solar process steam generation

Small heat transfer surfaces and rapid heating of the connected processes are key advantages. Solar collectors can provide steam for this purpose; however, so far only a few systems have been built which use this principle. Steam is generated indirectly, oil or pressurised water is heated in the solar array and then routed to a steam generator or a pressure release. However, direct evaporation in the solar array can increase the efficiency and possibly decrease the system costs [3].

The direct evaporation is currently being demonstrated in the "Pilot solar process heat generation system with parabolic trough collectors" project. For this, 100 m² of Solitem PTC1800 collectors were installed on the roof of a production hall of the Alanod company with funding by the BMU [4]. The solar array is operated in recirculation mode, i.e. only part of the water is evaporated. The water/steam mixture is then routed to a steam drum and separated there. The saturated steam is routed to the production steam mains, as soon as a pressure of over 4 bar (abs), equivalent to a temperature of 143 °C, is reached. The water in the steam drum is pumped back into the solar array (recirculated). The evaporated water quantity is routed back to the solar array from the condensate line (Figure 4).

The combined generation of electricity and heat was studied thoroughly at Fraunhofer ISE in the "Medifres" project funded by BMU. Case studies showed that under favourable conditions in high irradiation countries, replacing diesel generators with combined solar heat, cooling and power is already worthwhile. Companies and research institutes can network on the topic of „Medium and Small Scale CSP" via the www.mss-csp.info homepage.

Summary and outlook

Concentrating collectors can make an important contribution to future solar heat and electricity supply. Concentrating collectors support the industry in decreasing their dependency on fossil fuels.

Decentralised combined heat, cooling and power can be an interesting future option. In order to establish these technologies globally, further demonstration projects are required, as well as research and development in the field of small-scale thermal engines, system integration and collector development customised for target markets, to develop concentrating collectors as an important component in future.

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