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Developments in Solar Heat from Concentrating Solar Systems

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Abstract. Industrial heat applications are a significant market for concentrating solar technologies. Currently, concentrating collector technologies are offered by a number of suppliers. This publication gives an overview on the installations which have been built recently in terms of capacity, application and country. Several examples show combinations with storage, different heat transfer media and a large collector field for district heating. Facilitating financing is possible by ESCOs (Energy Service Companies) and collector certification according to ISO9806.

GLOBAL INDUSTRIAL HEAT DEMAND

A significant part of the final energy consumption comprises of industrial heat demand (Fig. 1). It is even higher than the global electrical consumption in all sectors. Although the temperature requirements are for some part above the capabilities of solar systems and many sites do not have the required space available, the market for solar process heat is large from a technical point of view.

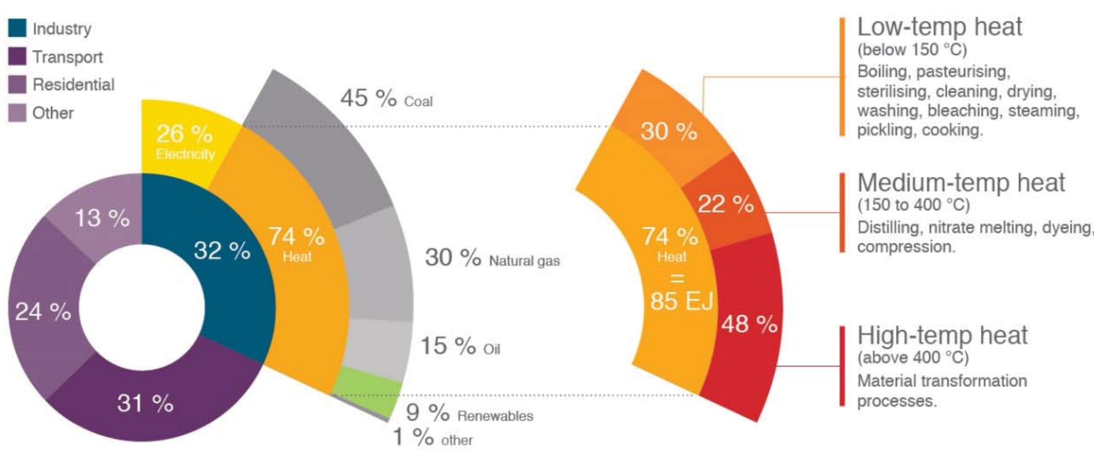

FIGURE 1. Distribution of global energy demand in industry in 2014 [1]

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STATUS OF CONCENTRATING COLLECTORS IN OPERATION AND IN PROGRESS

A total of 792,046 m² of concentrating collectors for heat production are in operation according to annual surveys among SHIP (Solar heat for industrial processes) suppliers worldwide within the Solar Payback project. The highest number of installations has been erected by the company Inventive Power by now about 100 installations of which about 66 are for SHIP [2].

The most popular sort of solar concentrating technology was again parabolic trough collectors, used in 12 projects in 2019 aside from Miraah in Oman, a parabolic trough plant in greenhouses which added 257,143 m² (180 MW) to the new installed collector are in 2019. However, sales in that market sector fell slightly from 11,096 m² in 2018 to 7,542 m2 in 2019. Solar dishes were put up by only two companies, Megawatt Solutions and Quadsun, both based in India. Likewise, linear Fresnel remained a niche technology installed by Belgian-based Rioglass and Spanish-based Solatom during four projects in 2019 (Figure 2). Non-SHIP applications in the table refer to hotels, swimming pools or cooking. The thermal power is related with factor 0.7 to the aperture area.

Xuchen Energy has placed the largest concentrating heat producing plant after Miraah in 2016 with 71,000 m² parabolic trough collectors on the ground and 22,000 m² of parabolic trough collectors on a single roof in Hongqingde Village, Inner Mongolia, China.

	Application	Newly installed collector area 2018 [m² aperture]	Newly installed collector area 2019 [m² aperture]	Newly installed thermal power 2018 [MW]	Newly installed thermal power 2019 [MW]
Parabolic trough	SHIP applications	11,367	7,539	8.0	5.3
	NON-SHIP applications	21,220	4,051	14.9	2.8
	Glasspoint (Miraah)	0	257,143	0	180
	Total	**32,587**	**268,733**	**22.8**	**188.1**
Dish	SHIP applications	1,075	1,962	0.8	1.4
	Commercial cooking	1,576	160	1.1	0.1
	Total	**2,651**	**2,122**	**1.9**	**1.5**
Linear Fresnel	SHIP applications	360	636	0.25	0.45
	Total	**360**	**636**	**0.25**	**0.45**
	Total across all three technologies	**35,598**	**271,491**	**24.9**	**190**

FIGURE 2. New collector installations in the years 2018 and 2019 [2]

SELECTED LATE DEVELOPMENTS AND EXPERIENCES

Within ship-plants.info the costs for 32 SHIP systems of Inventive Power have been published. They are plotted as a function of the aperture area in Fig. 3. The total investment costs (excl. VAT) include: Turnkey costs including solar collectors, piping, support construction, storage, design, commissioning reduced with subsidies.

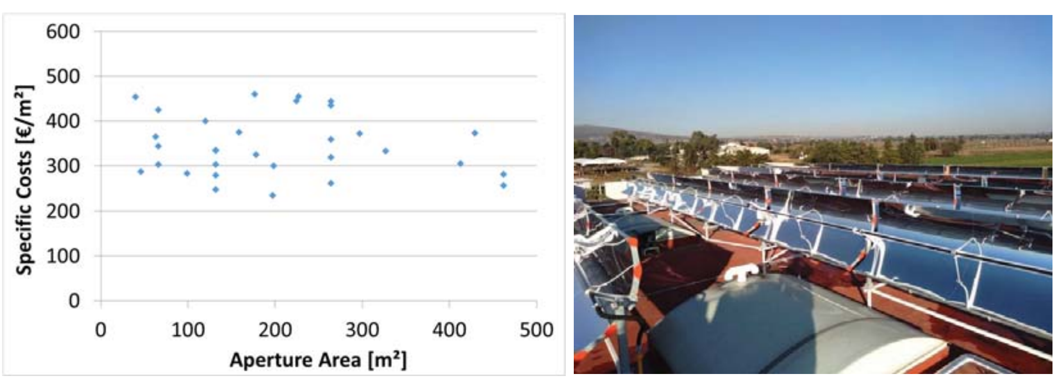

FIGURE 3. Plot of specific collector costs given by Inventive Power (Photo: Inventive Power / AEE Intec http://ship-plants.info)

Recently an increasing number of parabolic trough installations has been erected in Turkey by Soliterm, Germany, as a collector supplier and EPC. In 2017 the largest field of 4,996 m² has been erected to provide steam to the Kaya laundry in Turkey. In 2018 one plant totalling 4,320 m² was installed in Bursa/Turkey for steam supply in a textile process. 5 plants have been erected at butcheries in Herat and Kabul, Afghanistan. In 2019, Soliterm commissioned a 6,000 m2 field for a company in Izmir/Turkey.

According to Soliterm the motivation of their customers is to replace gas and reduce the dependency on volatile fuel prices and to have a more sustainable and manageable heat supply. Also CO2 reduction is of importance and avoidance of CO2 taxes.

Heat supply contracts have come up in recent solar thermal projects with stationary collectors. Project Developer NewHeat, France, closed a EUR 13 million EUR bank loan deal in August 2020 to finance five ESCO (Energy service company) solar heat projects in France with 28 MWth in total.

Azteq, Belgium, has started as an ESCO with two trough plants of 1,100 m² of aperture area at chemical production and storage facilities with Solarlite, Germany, as EPC contractor (Fig. 4). These plants have been erected in Belgium. Other suppliers of concentrating collectors have plans to add solar heat contracts to their portfolio. The collectors are cleaned by turning them into rain.

FIGURE 4. Collector fields at chemical facilities in Belgium (photos Solarlite)

A combination of trough collectors, concrete storage and CPC collectors has been realized by protarget, Germany, for a juice production in Cyprus (Fig. 5). The trough field of 283 m² provides heat of up to 410°C to a storage or to a steam boiler which supplies steam at 11barg and 188°C. The concrete storage with a capacity of 640 kWh is also connected to the steam boiler. For the pre-heating of the boiler feed water a 225 m² field of CPC supplies a hot water tank which delivers up to 95°C feedwater. According to protarget the customer values that on Monday mornings the boiler operators can arrive two hours later, because it already has been pre-heated by the CPC vacuum tube solar field.

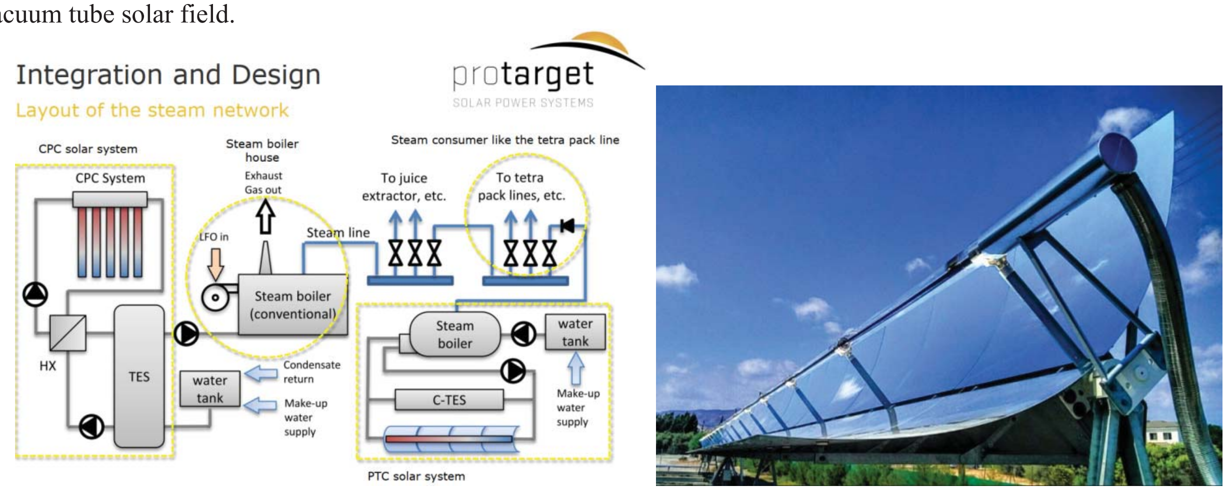

FIGURE 5. Collector field and layout of the steam network for a plant in Cyprus (photo and layout protarget)

An example for direct steam generation combined with a Ruth storage has been installed on a rooftop by Industrial Solar, Germany, in Jordan at JTI for tobacco processing (Fig. 6). The Fresnel collector field of 1,254 m² delivers steam of up to 220°C to the factories steam supply via a 15 m³ steam drum which has been oversized to enable one full load hour of steam supply after sunset. The solar steam is also used to fire a double stage absorption chiller.

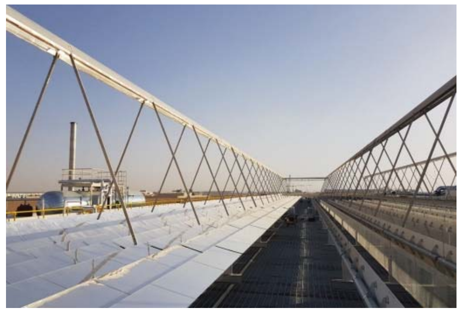

FIGURE 6. Fresnel collector field at JTI in Jordan on rooftop (photo Industrial Solar)

The T160 of Absolicon, other than most parabolic collectors, has a glass cover instead of a receiver glass pipe (Fig. 7). It is one of the first collectors which has been certified according to ISO 9806. The SolarKeymark certificate displays the coefficients of the efficiency function and the incidence angle modifier function and also an annual yield for selected sites in Europe. This allows a comparison of different collector types and is a valuable means to improve the confidence of customers.

FIGURE 7. Parabolic trough collectors with glass cover on rooftop (photo Absolicon)

An impressive installation which is not related to process heat, but to district heating, has been erected by Xuchen in Baotou, Inner Mongolia, China and is in operation since 2016 [3]. A large field of 71,000 m² has been placed on the ground and another field of 22.000 m² is placed on a roof (Fig. 8 left and right). The plant provides space heating for 500,000 m² floor space for buildings in the surrounding industrial zone, a shopping mall and residential buildings in the neighbouring villages. Surplus heat generated in summer, when none of the buildings connected to the SDH system require space heating, is transported by truck to nearby consumers, including hotels, swimming pools and spas as China's green heat policy requires the phase-out of coal boilers in the northern provinces.

The system includes a large water storage of 66,000 m³ with a maximum operation temperature of 95°C. But the solar field temperatures reach up to 220°C as reported by Xuchen.

The installation has been fully subsidised by the central government within its green heating policy.

FIGURE 8. Left: Ground solar field of 71,000 m², right: Rooftop solar field of 22,000 m²

TECHNOLOGIES

The construction principles of the various collectors which have been developed in the last years differ significantly. Collectors can contain components as aluminum mirrors, receivers without vacuum and antireflex coating. For larger collectors glass silver mirrors and vacuum receivers with antireflex coating are more established.

Thick glass mirrors with silver reflector have a specular solar reflectance of 94 % and less degradation and therefore are used in power plant collectors and in some process heat collectors. Aluminium mirrors have an initial specular solar reflectance of about 83 % [4].

Especially in small parabolic trough collectors often aluminium mirrors are applied, because they can be bended into any parabola, thus adapting to the desired construction. Another reason is the availability. The suppliers can deliver high quantities in reasonable time.

The mirror suppliers may offer a customer design, but may ask for an initial payment (e.g. 50.000 €), which could be a reason for collector manufacturers to choose aluminium reflectors. RioGlass offers mirrors for a trough with 2.6 m aperture width.

In 2018 costs for thick glass mirrors were about 17€/m² for orders of 1,000 m² without transport. Presumably aluminium mirrors cost in the same range and thus the costs might not be the foremost reason for a choice.

Another option is a thin glass silver mirror. It can only be bended up to a certain extent, so that a minimum of roughly 1.3 m focal length is required, depending on the mirror supplier specifications. It has slightly better reflection than thick glass, but needs backing in contrast to thick glass. The costs are slightly higher than for thick glass mirrors.

Thin flexible glass needs to be chemically treated and is currently not a cost efficient alternative.

A polymer foil with aluminium reflector of 3M has been used in the collector of IST from the US (now Abengoa) but the 3M foil has not been produced anymore since several years.

Although most suppliers offer their product internationally the choice of technologies relates very much with the producers technology in the same country. In Spain, 3 of 4 installations have been realised with Fresnel systems and the three Spanish concentrating collector suppliers Solatom, Rioglass Solar and Covalersa all produce Fresnel collectors. In Mexico all installations are built with parabolic trough technology from Inventive Power as the only supplier so far. All commercial projects with dishes other than the Scheffler construction are situated in India, where Megawatt Solutions and Quadsun are based.

Storages are seldom applied for concentrating solar fields up to now. This limits the share of solar heat which can be supplied to industries with 24/7 operation. Therefore storage solutions need to be found unless water storages can be applied. These are getting expensive with rising temperature and pressure. Collector suppliers are searching for cost effective storage solutions for temperatures higher than about 150°C when low temperature or pressurized water tanks are not adequate.

HIGH TEMPERATURE SOLAR HEAT

For medium to large scale process heat applications at temperatures above 400 °C, solar towers are a viable option. The potential here is large because almost fifty percent of the industrial heat requirement is for high temperature heat, meaning above 400 °C [1]. Processes here include e.g. material transformation processes in metallurgical processes, cement production and a vast range of chemical processes in the chemical industry. The heat demand is largely met by burning of fossil fuels, hence, large amounts of worldwide CO_2 emissions result from these industries.

Even though the potential is high, these applications typically come with a set of requirements that need to be satisfied in a successful transformation of their energy system, i.e. when replacing fossil fuels with renewable energy carriers. In most cases a 24/7 operation of those industrial processes is required, a certain temperature range has to be met and the controllability of these processes need to be taken into account when designing a new system of energy supply.

Concentrated solar technologies, especially solar towers can come here into play, because temperatures up to 1000 °C and higher can be met. Integration of a thermal storage can assure reliable supply of process heat independent from the availability of the solar resource.

An innovative concept uses solid particles as heat transfer and storage medium for solar tower receivers. The particles are stable to temperatures up to 1100 °C, thus enabling a large temperature range. Furthermore they can be used directly as a storage medium, leading to high storage densities and low storage costs.

Within the European project HiFlex [5] the installation of a solar tower using solar particles as heat transfer and storage medium supplying heat to a pasta factory is envisaged. The demonstration plant is going to be developed, built and operated nearby the city of Foggia in Apulia, Italy. The work is a joint project of a consortium of 11 European partners. The system utilizes a particle receiver system, the so called CentRec® technology [6] that has been developed and tested over the last ten years. A 6000 m² heliostat field will provide high solar flux to a 2.5 MW_{th} receiver. A 20 MWh thermal energy storage will be integrated, furthermore a particle transport system for temperatures up to 300 °C and a 0.8 MW_{th} steam generator, providing steam at 620°C. This serves to demonstrate the capability of supplying high temperature heat to advanced Rankine cycles for electricity production. In the demonstration plant, further pressure and temperature reduction allows the supply of process heat to a pasta plant as end user in the project.

IEA TASK 64/IV SOLAR PROCESS HEAT

The market introduction of concentrating solar collectors is assisted by the new IEA Task SHC Task 64/SolarPACES Task IV on "Solar Process Heat" which has started beginning of the year 2020 [7]. It includes the subtasks Integrated energy systems, Modularisation, Simulation and design tools, Standardisation/ Certification and Guideline to market. The goal of the proposed task is to help solar technologies be and also be recognized as a reliable part of the heat supply of industry.

SUMMARY

An increased number of concentrating collector manufacturers discovers the huge potential of industrial solar heat. For further spread carbon taxes and mandatory renewable energy quotes are needed to raise awareness of industrial clients for green heat supply. The hurdle of high investment costs can be overcome by ESCOs (Energy service companies). First companies have erected installations with this model in the process heat sector. A means to improve customer confidence in a collector is a certificate according to ISO 9806.

Customers start to ask for near 100% renewable heat supply solutions. Thus storage will be an integral part of the renewable heat system. Finding cost efficient solutions other than low temperature or pressurized water tanks are a key to future solar supply.

District heating is being addressed by several collector suppliers as a potential market. Such an installation has been realized by Xuchen Energy in Baotou, Inner Mongolia, China with 93,000 m² of parabolic trough collectors.

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