Market potential and system designs for industrial solar heat applications

W. Weiss[1], H. Schweiger[2], R. Battisti[3]

[1] AEE INTEC, Institute for Sustainable Technologies
A-8200 Gleisdorf, Feldgasse 19, Austria
Phone: +43 31125886; Fax: +43 31125818; e-mail: w.weiss@aee.at

[2] AIGUASOL Engineering, C/Palau 4, 2n-2a, E-08002 Barcelona, Spain
Phone: +34 933424255; Fax: +34 933424756; e-mail: hans@aiguasol.com

[3] Department of Mechanical and Aeronautical Engineering
University of Rome "La Sapienza", Via Eudossiana 18, 00184 Rome, Italy
Phone:+39 06 44585271, Fax:+39 06 4881759, e-mail: riccardo.battisti@uniroma1.it

1. Introduction

Task 33/IV is a collaborative project of the Solar Heating and Cooling Program and the SolarPACES program of the International Energy Agency (IEA) in which 16 institutes and 11 companies from eight countries are involved. The aim of the project is the development of solar thermal plants for industrial process heat. To reach this goal, studies of the potential are being carried out for the countries involved, medium-temperature collectors developed for the production of process heat up to a temperature of 250°C, and solutions sought to the problems of integrating the solar heat system into industrial processes. In addition, demonstration projects are being realised in cooperation with the solar industry.
Knowledge is transferred to industry via an annual industry newsletter and by holding relevant conferences.

2. Potential of solar process heat

The industrial sector shows the highest energy use in OECD countries with about 30%, closely followed by the transport sector. Due to the fact that energy from fossil fuels is cheap and seemingly infinitely available, manufacturing companies have only taken modest steps towards replacing energy from fossil fuels with energy from renewable sources.
The use of solar energy in manufacturing and industrial processes and to heat production halls has been limited to just a few applications. The 150 million square meters of collectors installed world-wide, with a total thermal power of around 105 GW_{th}, are used almost exclusively for domestic hot water or for swimming pools and space heating in the residential and tourism sectors /1/.
One of the first duties of Task 33/IV was therefore to investigate the potential of solar process heat, to document existing plants and uses, and to analyse the experiences made with these plants.
The potential studies for the three countries: Spain, Portugal and Austria have shown that the need for industrial heat at low temperatures, which could be met using solar heat, is around 26 PJ (technically achievable potential) /2/. Even if only 5% of this potential were to be achieved in the coming years, equal to only 0.6 % of the low-temperature heat requirement of these three countries, this would require the installation of one million square meters of collectors with a capacity of 700 MW_{th} .

3. Industrial sectors involved and existing solar plants

More than 60 existing plants in the industrial sector, with a total installed capacity of 42 MW_{th} and a collector area of 60.000 m², have been documented as part of Task 33/IV.

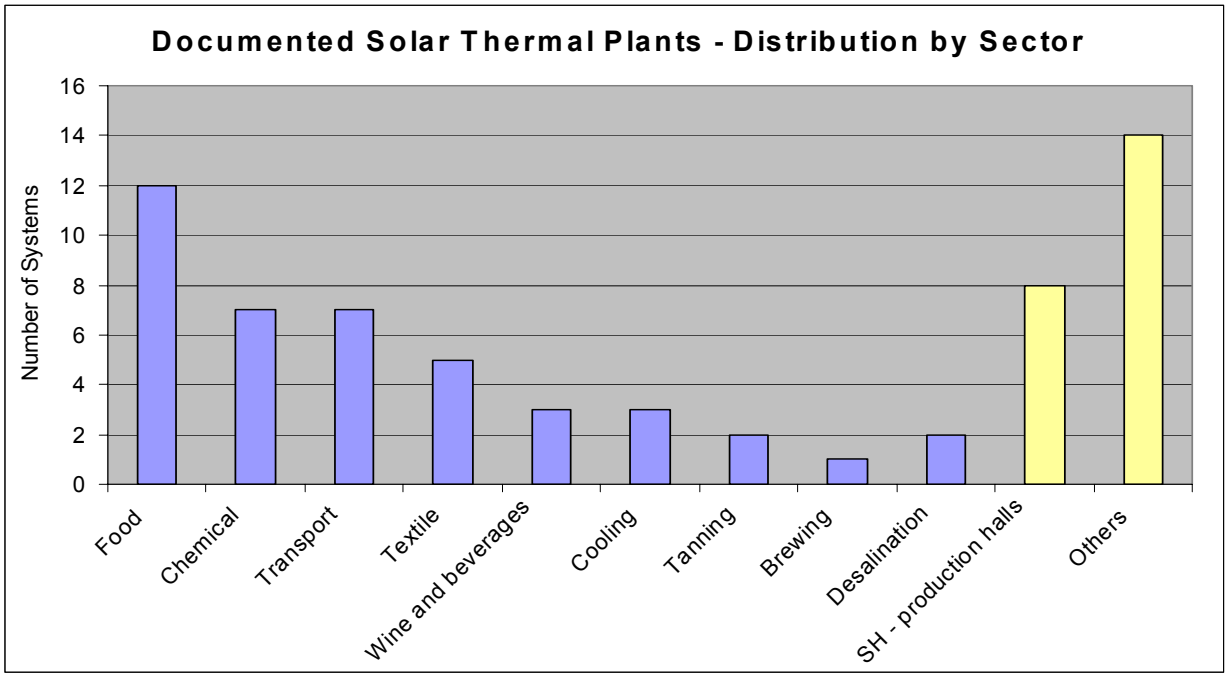

Fig. 1: Distribution of the documented solar plants for process heat uses.

Table 1: Industrial sectors and processes with the greatest potential for solar thermal uses

Industrial sector	Process	Temperature level [°C]
Food and beverages	drying washing pasteurising boiling sterilising heat treatment	30 - 90 40 – 80 80 – 110 95 – 105 140 – 150 40 – 60
Textile industry	washing bleaching dyeing	40 –80 60 – 100 100 – 160
Chemical industry	boiling distilling various chemical processes	95 – 105 110 – 300 120 - 180
All sectors	pre-heating of boiler feed water heating of production halls	30 – 100 30 – 80

As can be seen in Table 1, the most significant areas of use for solar heat plants are in the food and beverage industries, in the textile and chemical industries and for simple cleaning processes, e.g. car washes. This is, above all, due to the low temperatures required for the processes in these sectors. 30°C to 90°C, allowing the use of flat-plate collectors, since they are very efficient in this temperature range. Solar heat is used not only to provide process heat but also to heat production halls.

Table 1 also shows that, alongside the low temperature processes up to 80°C, there is also significant potential for processes in the medium temperature range up to around 250°C.

4. Development of medium-temperature collectors

To be able to provide heat for the whole medium-temperature range from 80° to 250°C for industrial processes at a reasonable price, it is necessary to optimize and further develop medium temperature collectors.
Therefore three categories of medium-temperature collectors are being developed and tested as part of Task 33/IV:

- flat-plate collectors with multiple glazing and anti-reflection coatings,
- stationary CPC collectors and
- small parabolic trough collectors.

5. Integration of solar heat into industrial processes

The fact that solar plants used to produce process heat can easily achieve a collector area of 500 to 1000 m² represents a new challenge which the system technology must meet - in particular the stand-still behaviour of the plant, since it is likely that the produced heat may not be used at weekends or during company holidays.
A further challenge is the integration of solar heat into the industrial process itself. In using solar thermal energy, the temperature of the available heat and the variability of solar energy must be considered, as well as the heat profile required by the industrial process.
To rise to these challenges, more than 20 system technology concepts were developed according to the requirements of the different energy carriers (air, water-glycol, pressurised water or steam), the temperature levels and the process to be supplied with heat. These concepts are currently being realised and trialled in demonstration plants.

6. Pilot- and demonstration plants

Three system concepts (generic systems) out of 23, which have been identified in the framework of Task 33/IV are herein described. They show different characteristics concerning collector types, heat carrier, temperature level and application.

6.1 Air based drying systems

Removing moisture from a dissolved solids/liquid mixture, paper, spools of dyed thread, hanks of yarn, fresh cut lumber, and countless other industrial products can be achieved in number of ways ranging from simple air drying, to mechanical methods (presses, centrifugation, and vacuum), and thermal methods (cans, ovens, rotary, flash, dehumidification, and spray dryers).
Dryers can be batch or continuous designs. Batch operation is normally only chosen for small production runs, or where each product will have unique identification (such as pharmaceutical products or high quality dyestuffs). Continuous dryers are commonly drum, air suspension, belt, or convection oven designs.
One typical drying process is crop drying, which takes place usually at temperatures between 30 and 80°C.
In the following a typical air-based drying system is described. Systems like this have been realized in several projects in the recent years /3/.

Main features

Air based system. The air heated in the solar collector array is the intake air for the biomass boiler. The collectors used in these applications are glazed or unglazed air collectors or the Solar Wall ® system. Since the system concept is quite simple and there is no storage needed the system cost (including installation) for already realized systems is € 100 per square metre.

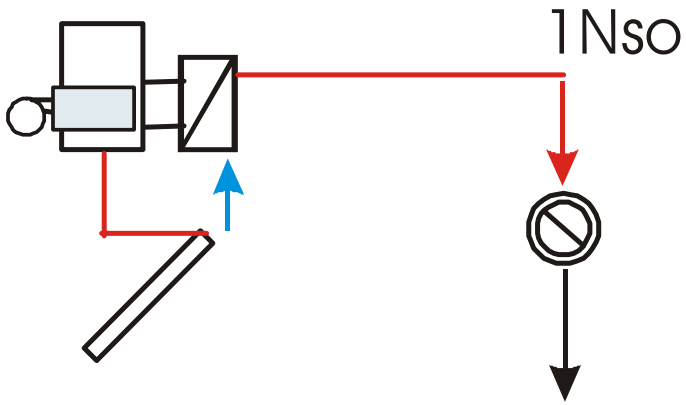

Fig. 2: Air based drying process - generic system concept

Systems of this type have been realized for drying of coffee, tea, maize and tobacco.

Fig. 3: Coffee drying, Coopeldos, Costa Rica, Installed capacity: 595 kW_{th} (850 m² Solar Wall collector)

6.2 Washing processes

Cleaning processes are mainly applied in the food industry, the textile industry and in the transport sector. For cleaning purposes hot water is needed at a temperature level between 40 and 90°C. Due to this temperature range flat-plate collectors are recommended for this application. The system design is quite similar to large-scale hot water systems for residential houses, since they work in the same temperature range and the water is drained after usage. Concerning the hot water loop, it is an open system. Usually heat recovery is not feasible.

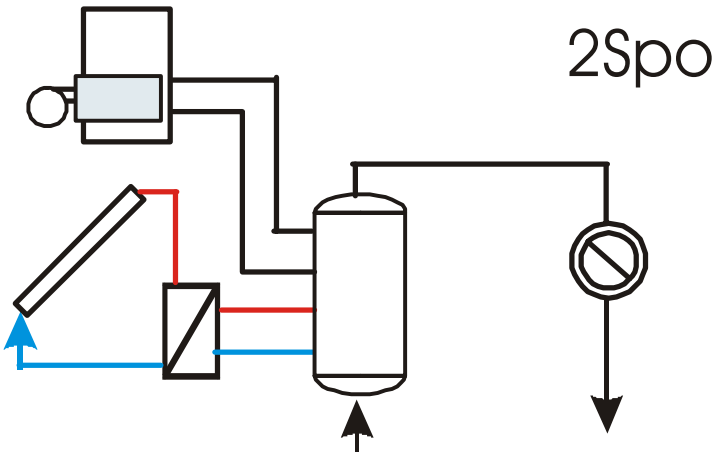

Fig. 4: Washing processes with open hot water loop - generic system concept

Typical applications are washing processes in the food industry like feed water for bottle washing machines, washing processes in the textile industry and washing processes in the transport sector.
One system in the transport sector was realized for the transport company Hammerer in Austria. In total a capacity of 126 kW (180 m² collector array) were installed to produce hot water for cleaning purposes (transport containers of trucks) as well as for space heating of the office.

Fig. 5: Demonstration plant “Hammerer”, Austria.

6.3 Distilling and chemical processes

For industrial processes where temperatures between 120°C and 250 °C are needed, concentrating solar collectors, such as parabolic trough collectors have to be used. The heat carrier in these systems is either pressurized hot water or steam.

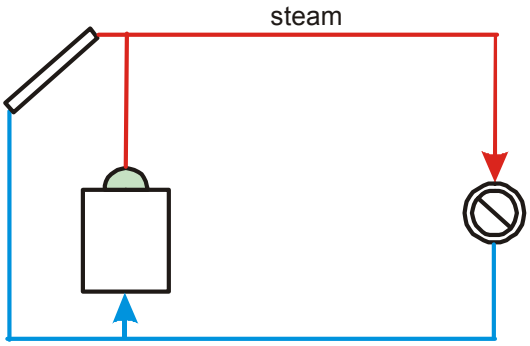

Fig. 6: Steam production via a flashing process - generic system concept

The Egyptian New & Renewable Energy Authority (NREA) issued an international tender to build a 1.3 t/hr pilot solar steam plant using parabolic trough collectors at a site just outside Cairo. The project was financed by the African Development Bank.
The plant's 144 parabolic concentrators are arranged in four parallel loops and provide a net reflective area of 1.900 m². The steam is produced by the reduction of the pressure of the water in the collector loop, via a flashing valve and is delivered to an existing saturated steam network operating at 7.5 bar.

Fig. 7: El NASR Pharmaceutical Chemicals, Egypt. Installed capacity: 1,33 MW_{th}
Source: Fichtner Solar GmbH. Germany.

References:

/1/ Weiss, W. et.al: Solar Heating Worldwide, Markets and contribution to the energy supply, IEA Solar Heating and Cooling Programme, Internal paper 2005.

/2/ Müller, T. et. al.: PROMISE – Produzieren mit Sonnenenergie, Projekt im Rahmen der Programmlinien „Fabrik der Zukunft" des Bundesministeriums für Verkehr, Innovation und Technologie, Endbericht, Gleisdorf, 2004

/3/ www.iea-shc.org/task29
Further information: www.iea-shc.org