Solar Industrial Process Heat
– State of the Art –

Intelligent Energy Europe

Executive Summary

The major share of energy which is needed in industrial production processes is below 250°C – a temperature level, which could be well supplied by solar thermal technologies. The lower temperature level (< 80°C) can already be provided today with commercially available solar thermal collectors.

Most solar applications for industrial processes are on a relatively small scale and are mostly experimental in nature. There are currently about 85 solar thermal systems supplying heat for industrial processes. These plants have a total installed capacity of 27 MW_{th} (38,500 m²)[4].

Solar Heat for Industrial Processes (SHIP) is still in its infancy and yet, as discussed in the market potential section of this report, there is potentially an enormous range of Solar Thermal applications within this sector which can supply a large portion of our total energy demand.

Current SHIP applications are based on presently available technologies. RD&D is performed both on developing new components with a quality suitable for specific industrial applications, e.g. higher temperatures, and on refining configurations of products which are already available. As new developments become available, more SHIP applications will become viable.

Because solar industrial process heat is not yet widely available, it is important to understand its specific barriers to growth and consequently the best strategies to help overcome these barriers. The following short list will help policy-makers develop and implement suitable support policies for SHIP. A more detailed list can be found at the end of this document.

Barriers to growth

- Awareness: The number of solar thermal installations for industrial processes is very small, and most decision makers in relevant industries have never heard of, or even seen, a SHIP system. This is a key barrier to the broad adoption of SHIP.
- Confidence only in long-term proven technology: Most managers are very conservative when it comes to basic infrastructure needs. Especially when mission-critical heating processes are concerned, they will almost always choose conventional, long-term proven technology. Any potential day of delay or interruption seems more dangerous to them than reliance on unpredictable future prices of conventional fuels.
- System cost: Like most renewable energy technology, SHIP systems have typically higher investment costs, but save conventional energies throughout operation. With current technology, financial payback times are often beyond commercial requirements.

- Lack of technology: Many industrial processes require higher temperatures than the typical solar thermal applications (domestic hot water, space heating, swimming pool heating). New designs, sometimes new materials, are needed to cater for these higher temperature demands.
- Lack of suitable planning guidelines and tools: So far, only few engineering offices and research institutes have experience with SHIP installations. Planning guidelines and tools for typical industrial use cases are still missing.
- Lack of education and training: Only few professionals have attended courses on SHIP. Without that knowledge, very few will offer SHIP solutions to their (potential) customers.

Recommendations

- Specific awareness raising campaigns targeted at decision makers in the industries most suitable for solar thermal process heat, e.g. food and textile industry.
- Large number of demonstration projects – to gain more experience, develop planning guidelines and to increase confidence in this emerging technology.
- Financial incentives to companies, which install solar thermal systems to drive their industrial processes.
- Funding of R&D into new technologies, which can improve the viability of SHIP installations, e.g. medium temperature collectors, improved heat transfer fluids.
- Training courses for professionals – to raise awareness and to overcome the current lack of expertise amongst professionals (planners, installers).

Introduction

The present document was produced within the framework of the Intelligent Energy-Europe project *Key Issues for Renewable Heat in Europe (K4RES-H)*[1]. The project looks at providing guidelines for best practice policies to support renewable heating and cooling (RES-H) technologies. Because most of the current support policies for RES-H focus on commercially available products, this document aims at highlighting one of the promising, upcoming applications for solar thermal: Solar Industrial Process Heat (SHIP)
If one compares the energy consumption of the industrial, transportation, household and service sectors, then one can see that the industrial sector has the biggest energy consumption in the OECD countries at approximately 30%. The major share of energy, which is needed in commercial and industrial companies for production, processes and for heating production halls, is below 250°C.

Components of solar thermal systems for industrial processes

The low temperature level (< 80°C) complies with the temperature level which can easily be reached with solar thermal collectors already on the market. However, for many industrial applications higher temperatures are needed. While pipes and pumps from conventional heating systems designed for this temperature range can be used, the solar thermal collectors must be specifically made to provide heat at temperatures above 80-100°C.

Solar thermal collectors for SHIP

Today, the most common collectors used are water-based flat plate collectors and evacuated tube collectors. They have undergone a great deal of development in the last few decades and are typically very efficient, using selective coated absorbers, and highly transmissive glass, sometimes in connection with anti-reflective coating. These collectors work very effectively up to 80°C and are frequently used in SHIP applications.

As discussed above, SHIP applications often require temperatures from 80°C to 250°C, which require medium temperature collectors, of which only few are available in the market today and which need optimising and developing further. Therefore, the International Energy Agency's Solar Heating and Cooling Programme (IEA-SHC) develops and tests three categories of medium temperature collectors as part of their Task 33:

- Improved flat plate collectors
- Concentrating flat plate and evacuated tube collectors
- Other – more highly – concentrating collectors

Improved flat plate collectors

To enable flat plate collectors to provide hot water at 80-120°C, various possibilities exist. Most importantly, the thermal losses of the collector must be reduced without losing too much optical efficiency. This can be achieved by, for example:

- multiple glazing with anti-reflective glass
- filling a hermetically sealed flat plate collector with a noble gas
- evacuating a hermetically sealed flat plate collector

Figure 1 shows the efficiency curves for single, double and triple-glazed collectors covered with newly developed anti-reflective glass.

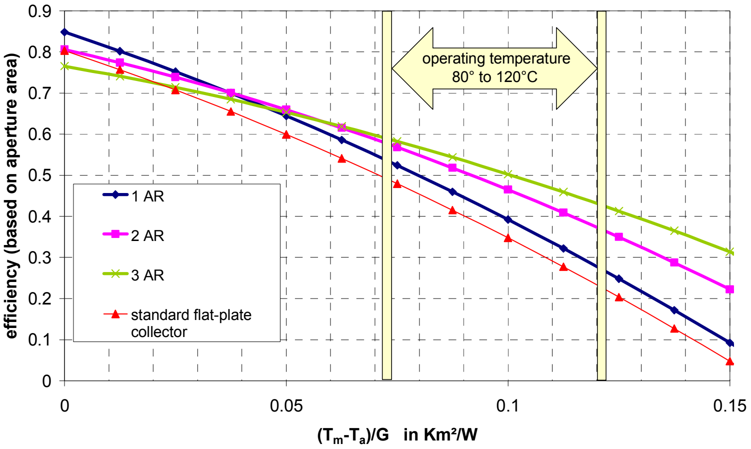

Figure 1: Comparison of the efficiency curves for a standard flat-plate collector (normal solar glass) and the curves for single, double and triple- anti-reflective (AR) glazed collectors (G=800 W/m²). Source: M. Rommel, Fraunhofer ISE.

Concentrating flat plate and evacuated tube collectors

Thermal losses of the collector can also be reduced by using concentrating technologies, which reduce the surface of the heated area. Compound Parabolic Collectors (CPC) are based on this principal. Their concentration factor is around 2 and no sun-tracking devices are required. Figure 2 shows the construction of a CPC, in which the absorber fins, which absorb on both surfaces, are mounted in the reflector troughs perpendicular to the aperture opening.

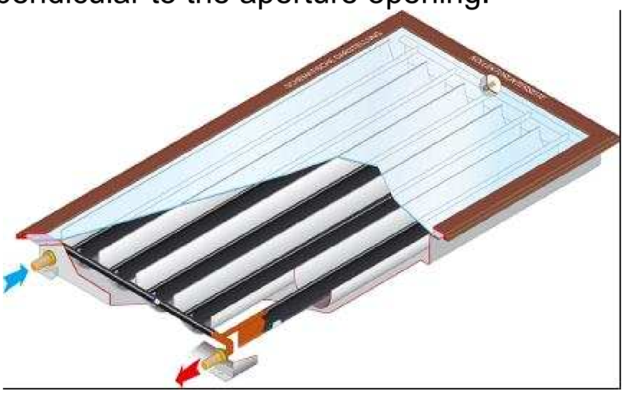

Figure 2: CP collector. Source: Solarfocus

Other – more highly – concentrating collectors

For temperatures of 150°C to 250°C, it is interesting to consider more highly concentrating collectors. These, however, can no longer be mounted in a fixed position but require at least one-axis tracking. Most of the new developments use parabolic mirrors to concentrate the sunlight onto the receiver; others use the Fresnel principle to achieve a similar effect. At present, at least seven concentrating collectors are in development. Success here will make new SHIP applications possible. Further information on these developments can be found in the brochure "Medium Temperature Collectors", available at www.iea-ship.org/3_1.html.

Figure 3: Testing of two PTC 1000 modular parabolic trough collectors at DLR in Germany.

Heat storage

In many cases, solar thermal can be used directly, in other cases a heat storage is required or advantageous. To date, most heat storages are water based and their capacity depends largely on the storage size and operating temperature. In order to expand the solar thermal usage, new storage concepts and technologies must be developed – not only for industrial processes. Where large water tanks are not feasible, either thermo-physical methods (e.g. using phase-changing materials) or thermo-physical processes could store large amounts of energy in the future.

The European Solar Thermal Technology Platform (ESTTP) has therefore identified advanced heat storage as one of the key R&D topics for the solar thermal sector. The aim is to store more thermal energy in smaller volumes and without (significant) losses. An improvement of the storage density by the factor 8 compared with water, would for example allow 100% solar heat supply of buildings without increasing today's storage volumes. The development of such technologies would also benefit other applications, such as SHIP.

Controllers

Due to the variety of industrial processes, standardised controllers for SHIP do not exist. While the hardware (sensors, controllers) is readily available, the configuration is the key challenge: The control strategy must be tailored to the concrete heat demand and system. This is where more experience – more demonstration projects – will help develop best practice guidelines and partially standardised solutions.

Market Potential

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

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

The most significant current SHIP application areas are in: the food and beverage industries, 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 commercially available flat plate or vacuum tube collectors which are very efficient in this temperature range. Solar heat is used not only to provide process heat but also to heat industrial buildings.

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.

Industrial process heat is one of the least developed solar thermal applications so far. The potential is huge, but the variety of industrial applications makes it difficult to standardise solar thermal systems. Without suitable support measures solar thermal will only penetrate the industrial heat market slowly.

On the demand side, industry is a huge consumer of energy. In OECD countries, it accounts for 30% of energy consumption[2]. In the EU, 2/3 of these 30% consists of heat rather than electrical energy[3].

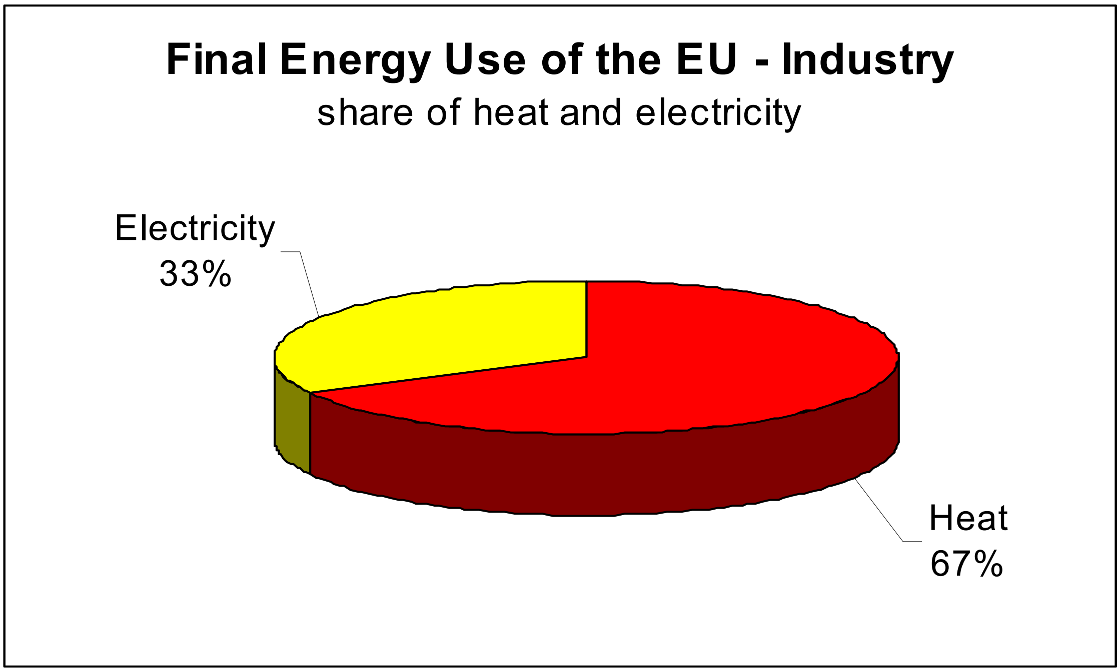

Figure 4: Final Energy Use of EU - Industry[4]

Much of this industrial energy is in the form of heat below 250°C, a large proportion of which can be supplied by current or close-to-market solar thermal technologies. In 2000, the energy demand in the EU-15 for industrial process heat up to 250°C was estimated at about 300 TWh.

In the 1980s and 1990s several studies were carried out on the industrial heat demand at different temperature levels for various industrial countries[5]. Theses studies give a representative overview of the typical process heat demand up to 250°C. In spite of particular differences among these countries, some general conclusions were drawn out of the analysis:

- The studies confirm a general tendency: About 50% of the industrial heat demand is located at temperatures up to 250°C.
- The biggest heat demand is located in the paper and food industries. A considerable heat demand is also found in the textile and chemical industries.
- A very high percentage of heat demand in the medium and medium-high range is found in food, paper, textile and chemical industries.
- In the range from 100 to 200°C most of the process heat is used in food, textile and chemical industry for such diverse applications as drying, cooking, cleaning, extraction and many others.

Overview of selected demonstration projects

More than 85 existing plants in the industrial sector, with a total installed capacity of $27MW_{th}$ and a collector area of 38.500 m^2 have been documented as part of Task 33/IV of the IEA-SHC Programme[6]. The food industry had the largest number of solar thermal demonstration plants, followed by the chemical industry and transport companies.

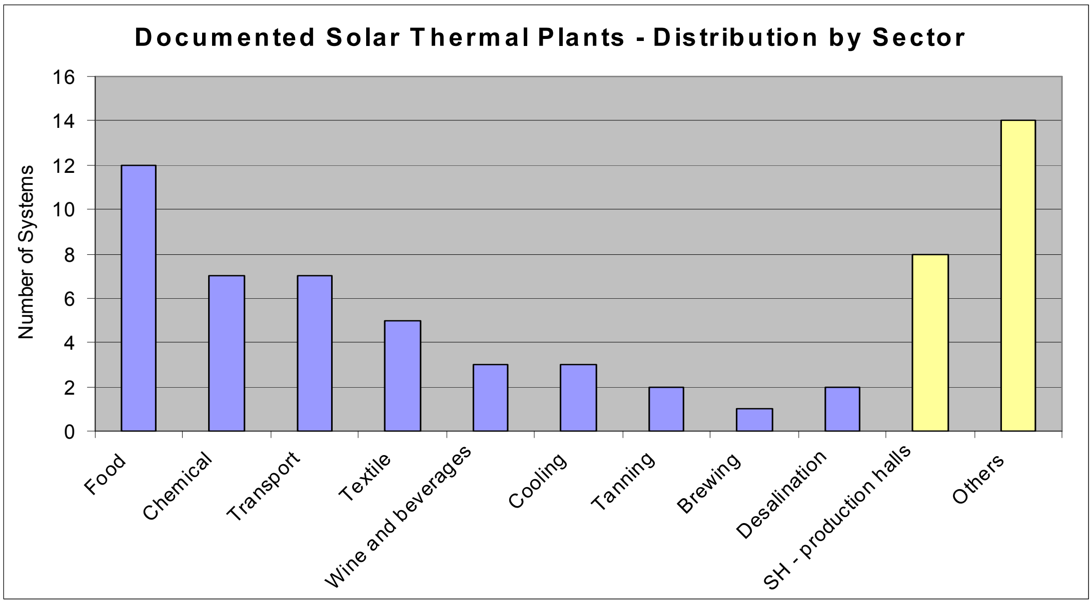

Figure 5: Distribution of the documented solar plants for process heat applications[7]

Washing processes

Cleaning processes are a typical application in many industries, and for most of them hot water is needed at a temperature level between 40 to 90°C, which can be easily provided by today's flatplate or vacuum tube collectors. Because the two systems operate in a similar temperature range, the system design is quite similar to large-scale hot water systems for residential properties. Typical applications for solar thermal washing systems are feed water for bottle washing and washing processes in the textile industry and transport sector.

Example:
In Austria, a transport sector system was created for the Hammerer transport company. A 126 kW capacity system (180 m² collector array) was installed to produce hot water to clean transport containers for trucks as well as for space heating of the offices[8].

Figure 6: Demonstration plant "Hammerer", Austria.

Drying processes

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 through various thermal methods (cans, ovens, rotary, flash, dehumidification & spray dryers), for which solar thermal energy can be used. One typical drying process is crop drying, which usually occurs between 30 and 80°C.

A typical air-based drying system using solar thermal energy – often combined with bioheat – is described below. Systems like this have been devised in several projects in the recent years[9]. The intake air for the biomass boiler is heated in the solar collector array, made up of glazed or unglazed air collectors. Since the system concept is quite simple and there is no storage needed, the system cost for installed systems is around €100/m^2.

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

Figure 7: Coffee drying, Coopeldos, Costa Rica. Installed capacity: 595 kW$_{th}$ (850 m² Solar Wall® collector)

Distilling and chemical processes

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

Example:
In Egypt, just outside of Cairo, a solar thermal plant based on 1.900 m^2 of parabolic trough collectors provide 1,3 t/h of saturated steam for a pharmaceutical plant. The steam is produced by the reduction of the pressure of water in the collector loop via a flashing valve and is delivered to an existing saturated steam network operating at 7.5 bar.

Figure 8: El NASR Pharmaceutical Chemicals, Egypt. Installed capacity: 1,33 MW_{th}
Source: Fichtner Solar GmbH. Germany

Barriers to Growth of the SHIP Market

So far, the main markets for solar thermal technology have been domestic hot water, space heating and swimming pool heating. However, by comparison to these markets, solar thermal technology has hardly even begun to penetrate the potentially huge industrial heat energy market.

The main barriers to further market penetration of SHIP technologies are:

- Awareness: The number of solar thermal installations for industrial processes is very small, and most decision makers in relevant industries have never heard of or even seen a SHIP system. This is a key barrier to the broad adoption of SHIP.
- Confidence only in long-term proven technology: Most managers are very conservative when it comes to basic infrastructure needs. Especially when mission-critical heating processes are concerned, they will almost always choose conventional, long-term proven technology. Any potential day of delay or interruption seems more dangerous to them than reliance on unpredictable future prices of conventional fuels.
- System cost: As most renewable energy technology, SHIP systems have typically higher investment costs but save conventional energies throughout operation. With current technology, financial payback times are often beyond commercial requirements.
- Lack of technology: Many industrial processes require higher temperatures than the typical solar thermal applications (domestic hot water, space heating, swimming pool heating). New designs, sometimes new materials, are needed to cater for these higher temperature demands.
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Recommendations

Solar heat for industrial processes has a great potential to curb demand for conventional energies and thus to lessen our dependence on imported fuels and to reduce CO_2 emissions.

Because of these strong benefits, the market penetration of solar industrial process heat should be supported by governments. The following recommendations will help governments focus on overcoming those barriers, which are currently most problematic.

- Specific awareness raising campaigns targeted at decision makers in the industries most suitable for solar thermal process heat, e.g. food and textile industry.
- Large number of demonstration projects – to gain more experience, develop planning guidelines and to increase confidence in this emerging technology.
- Financial incentives to companies which install solar thermal systems to drive their industrial processes.
- Funding of R&D into new technologies, which can improve the viability of SHIP installations, e.g. medium temperature collectors, improved heat transfer fluids.
- Training courses for professionals – to raise awareness and to overcome the current lack of expertise amongst professionals (planners, installers).

[1] The K4RES-H homepage can be found at: http://www.erec-renewables.org/projects/proj_K4_RES-H_homepage.htm

[2] Müller, Thomas et al:" PROMISE – Produzieren mit Sonne. Endbericht", Gleisdorf, Austria 2004.

[3] Weiss, Werner: Presentation held in the plenary session ESTTP launch on 30th May 06 (see www.esttp.org)

[4] European Commission:"Green Paper – Towards a European Strategy for the Security of Energy Supply", Brussels, 2001.

[5] Schweiger, Hans et al:" The Potential of solar heat in industrial processes. A state of the art review for Spain and Portugal", Copenhagen, Denmark, 2000.

[6] http://www.iea-shc.org/task33/

[7] Weiss, Werner et al: Overview on technology and market potential for industrial process heat and other medium temperature applications. In: estec2005 Proceedings. Freiburg, Germany, 2005.

[8] Jähnig, Dagmar and Werner Weiss:" Solar beheizte Industriehallen in Österreich". In: erneuerbare energie, 2005-03, Gleisdorf, Austria, 2005.

[9] www.iea-shc.org/task29/