# Task 33: SOLAR HEAT FOR INDUSTRIAL PROCESSES

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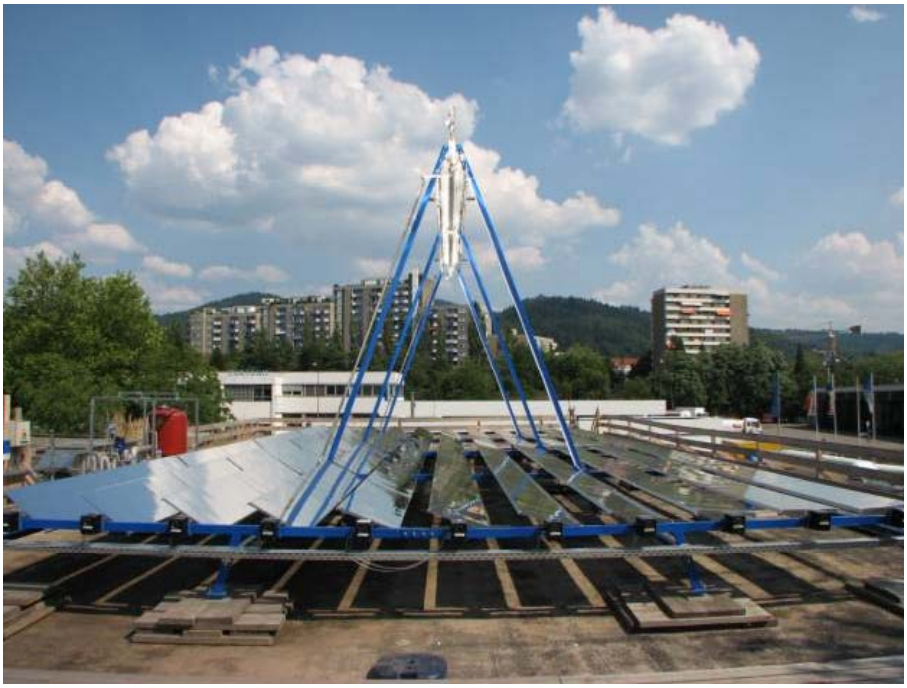

PSE Fresnel Collector, rooftop installation to power a $NH_3/H_2O$ Absorption Chiller
(Source: PSE, Germany)

## TASK DESCRIPTION

Around 150 million square meters of solar thermal collectors, corresponding to an installed capacity of 105 $GW_{th}$, were installed by the year 2004 worldwide. Until now, the widespread use of solar thermal plants has focused almost exclusively on swimming pools, domestic hot water preparation and space heating in the residential sector.

The use of solar energy in commercial and industrial companies is currently insignificant compared to the use in swimming pools and the household sector. Most solar applications for industrial processes have been used on a relatively small scale and are mostly experimental in nature. Only a few large systems are in use worldwide. However, if one compares the energy consumption of the industrial, transportation, household and service sectors in OECD countries, the industrial sector has the highest energy consumption at approximately 30%, followed closely by the transportation and household sectors.

The major share of the energy, which is needed in commercial and industrial companies for production processes and for heating production halls, is below 250°C. The low temperature level (<80°C) complies with the temperature level that can easily be reached using solar thermal collectors already on the market. The principles of operation of the components and systems apply directly to industrial process heat applications. The unique features of these applications lie on the scale on which they are used, system configurations, controls needed to

meet industrial requirements, and the integration of the solar energy supply system with the auxiliary energy source and the industrial process. For applications where temperatures up to 250°C are needed, the experiences are rather limited and suitable components and systems are missing. Therefore, for these applications the development of high performance solar collectors and system components is needed.

To be able to make use of the huge potential for solar heat in industry and to open a new market sector for the solar thermal industry, SHC Task 33 is going to carry out potential studies, it will investigate the most promising applications and industrial sectors for solar heat, and it will optimize, develop and test solar collectors for medium temperature applications (up to approximately 250°C). The development of integral solutions for solar thermal energy applications for given industrial processes (based on the "PINCH-concept") is also one of the main topics of this Task. In additions, the development of design tools (based on TRNSYS simulations) and a software tool for fast feasibility assessment, economic analyses as well as the design and the erection of pilot plants in co-operation with industry are planned.

**Scope of the Task**

The scope of the Task is on solar thermal technologies for converting the solar radiation into heat, (i.e., starting with the solar radiation reaching the collector and ending with the hot air, water or steam transferred to the application). The distribution system, the production process and/or the optimization of the production process are not the main topics of the Task. However, influences on the production process and the distribution system arising from the character of the solar heat source will be studied in the framework of the Task.

Applications, systems and technologies, which are included in the scope of this task, are:

- All industrial processes where heat up to a temperature level of approx. 250°C is needed.
- Space heating of production or other industry halls is addressed, but not space heating of dwellings.
- Solar thermal systems using air, water, low pressure steam or oil as a heat carrier, i.e. not limited to a certain heat transfer medium in the solar loop.
- All types of solar thermal collectors for an operating temperature level up to 250°C are addressed: uncovered collectors, flat-plate collectors, improved flat-plate collectors - for example hermetically sealed collectors with inert gas fillings, evacuated tube collectors with and without reflectors, CPC collectors, MaReCos (Maximum Reflector Collectors), parabolic trough collectors.

To accomplish the objectives of the Task, the participants are carrying out research and development in the framework of the following four subtasks:

- Subtask A: Solar Process Heat Survey and Dissemination of Task Results
  (Lead Country: Italy)
- Subtask B: Investigation of Industrial Energy Systems
  (Lead Country: Austria)
- Subtask C: Collectors and Components
  (Lead Country: Germany)
- Subtask D: System Integration and Demonstration
  (Lead Country: Germany)

**Collaboration with other IEA Programmes**

Due to the complementary background and know-how of the participants of the SHC and the SolarPACES Programmes, significant synergies were expected from collaboration. Therefore, it was agreed to co-operate with the SolarPACES Program on a "moderate level" according to the SHC "Guidelines for Co-ordination with other Programs."

**Duration**
The Task was initiated on November 1, 2003 and will be completed on October 31, 2007.

## ACTIVITIES DURING 2006

### Subtask A: Solar Process Heat Survey and Dissemination of Task Results

#### Existing plants and Potential studies

Currently about 84 solar thermal plants for process heat are reported worldwide, with a total installed capacity of about 23.8 $MW_{th}$ (33,991 $m^2$). These plants are located in 19 countries and cover 11 different industrial sectors, showing that solar thermal can be fruitfully used for several applications in industry. In 2006, several new plants have been reported from India, Italy, Spain Switzerland and Austria.

The results of the performed potential studies in the participant countries have been updated, including the potential study for the Australian state of Victoria.

According to the last assessment, extrapolating the outcomes of the studies carried out (Austria, Germany, Italy, Portugal, Spain, Netherlands), the overall potential for solar thermal in industry in the EU25 is between 90 and 112 $GW_{th}$ (128 - 160 million $m^2$). This would cover 2.5% of the total heat demand of the industrial sector.

This figure represents a relevant contribution to fulfill the EU target for solar thermal. For instance, solar process heat plants could deliver to industry up to 64 TWh/year, a remarkable contribution. This would be about 25% of the Renewable Energy Target for Europe defined by EREC (European Renewable Energy Council), which equals to 279 TWh/year by 2020.

Also the potential market volume sounds astonishing: 112 $GW_{th}$ (160,000,000 m²) of new capacity installed for the European solar industry, while at the end of 2005 the total installed capacity of solar thermal collectors in Europe was about 11 $GW_{th.}$

Therefore, also considering a conservative scenario, e.g. a penetration rate of 10% of the above described potential, it would lead to a total market volume of 11.2 $GW_{th}$ (16,000,000 m²). If this global figure is split in a 10 years installation program, an annual market of 1,600,000 m² will be reached (European market in 2005 was: 2,000,000 m²). Also the impact on new jobs would not be negligible: 160,000 new jobs in ten years.

#### Industry Workshops

In 2006, two industry workshops were carried out. The first industry workshop, "Solar Thermal for Heat Production in Industries", was held on March 31$^{st}$ at the University of Rome "La Sapienza". The seminar, promoted by the Province of Rome, the Region Lazio and the Italian Ministry of Industry, was attended by about 150 participants. The speakers panel included policy makers, Task 33/IV experts and also representatives from solar thermal industry and small and medium enterprises.

The second industry workshop was held on October 13$^{th}$ at INETI in Lisboa (Portugal) and it was attended by about 70 participants. The speakers panel included Task 33/IV experts,

experts on eco-design and sustainable efficiency measures for industry from INETI and also a solar thermal industry representative of a Portuguese manufacturer of CPC collectors.

The presentations of both workshops are available for download at www.iea-ship.org/3_1.html.

### Industry Newsletter

The third issue of the industry newsletter was prepared and it will be published by the end of January 2007 in English and in the languages of all participating countries. It will be also available for download at www.iea-ship.org.

## Subtask B: INVESTIGATION OF INDUSTRIAL ENERGY SYSTEMS

### Matrix of Indicators

A "Matrix of indicators" (MATRIX), which is a comprehensive database, was developed in Subtask B as a decision support tool for solar experts. With this matrix the work with industry and the identification of suitable solar applications will be facilitated. With the MATRIX it should be possible to investigate and calculate the installation of solar heat in production processes without detailed knowledge of the relevant unit operations.
Some industry sectors such as food, chemistry, plastic processing, textile industry and surface treatment industry can be identified as very promising sectors for solar thermal applications. For these industries detailed information like general benchmark data, temperature levels of the processes, flow sheets of production lines and generic hydraulic schemes for solar integration can be found in the MATRIX.
The investigation of these relevant industries has to focus on an integrated analysis of cooling and heating demands taking into account competitive technologies, when assessing the (economic) feasibility of solar thermal energy. Among those competing technologies are heat integration, co-generation, new technologies and heat pumps, which also have been described in the relevant parts of the MATRIX.

### Expansion of the Existing Heat Integration Models

Most industries have a heat demand in the production and at the same time a lot of waste heat. The use of this waste heat has the advantage of being in competition with the heat demand of other processes. The reuse of this waste heat has to be done at as a high temperature as possible. The most promising methodology to identify the maximum heat recovery in a defined system is the pinch analysis. With this tool the minimum heating demand and the minimum cooling demand can also be identified. Within the work of Subtask B a computer program (Pinch Energy Efficiency – PE²), which calculates the recovery potential and designs the technically and economically feasible heat exchanger network for given processes has been developed. The new software PE² fulfills the needs of heat integration calculations in the promising industries.

Front page of the PE² software, which was developed within Task 33/IV by JOINTS

**Subtask C: Collectors and Components**

**Medium Temperature Collector Developments**

The reports and discussions during the two experts meetings in the year 2006 in Rome and Lisbon showed that many development projects are in progress now. And still even more projects are started and new concepts for concentrating collectors in the temperature range from 150 to 250°C are investigated. This is a very positive situation, which is considered to be also a result of the successful work of Task 33/IV.

For example, AEE INTEC reported on the further development of the Parasol One collector from the company Button Energy in Austria. This is a parabolic trough collector, which is designed for the temperature range up to 200°C. Successful experiments on the direct steam generation were carried out during summer 2006. Suitable heat transfer media for a first application of the collector in a solar cooling system were investigated.

The company PSE GmbH from Germany develops a Fresnel process heat collector for the temperature range of 150 to 250°C. The first experimental collector was erected in December 2005 in Freiburg, Germany. The total reflector area of this collector is 88 m². It is operated in a testing loop for experimental investigations. And already during summer 2006 the second Fresnel process heat collector with a reflector area of 132 m² was setup in Bergamo, Italy. This collector is installed in a system for solar cooling. The heat of the collector is used to operate an absorption chiller of the Italian company Robur. First operating experience was gathered during summer 2006 with respect to the collector, the absorption chiller and their common interaction. The measured monitoring data of the collectors and the cooling system are now evaluated and the development work will be continued.

A new collector development was also started in Spain: The CCStaR collector is following the concept of fixed Fresnel reflectors and a moving receiver. The work was started at the Universitat de les Illes Balears in Mallorca. In June 2006 the company Tecnologia Solar Concentradora S.L. has been constituted with the purpose of developing the CCStaR concept to an industrial stage.

The CCStaR collector developed by the Universitat de les Illes Balears, Spain

Finally it has to be mentioned here that a new parabolic trough collector is developed in Australia. The NEP SOLAR Polymer Carrier PTC has an aperture width of about 1m and a new reflector design. It was set up for testing during the summer 2006 and it is planed that in 2007 it may come to the market.

**Medium Temperature Collector Testing**

New medium temperature collectors require new testing facilities for collector performance measurements in the temperature range up to about 200 °C. An important step was taken during summer 2006 concerning testing of process heat collectors. A "Round Robin" or intercomparison test among test labs was initiated. The testing institutions Fraunhofer ISE in Freiburg, Germany, ITW in Stuttgart, Germany and INETI in Lisbon, Portugal will carry out thermal performance tests on a vacuum tube collector with CPC reflector. Three collectors were acquired for the Round Robin test and the thermal performance of all three of them was measured at Fraunhofer ISE with a newly designed Medium Temperature Test Stand (MTTS) using the indoor test facility with solar simulator. The highest collector inlet temperature in these tests was 185°C. The laboratories at ITW and INETI will now perform their tests so that the results can be compared in the meetings in 2007. Conclusions with regard to testing recommendations for medium temperature collectors will be drawn from the experience gained in these tests.

The stagnation behavior of large (medium temperature) collector fields is still a very crucial point which needs much more attention and further investigation in order to avoid stagnation problems in industrial applications of solar collectors.
For example, Aiguasol Engineering, Spain, reported on the operation experience and the stagnation behavior of the CONTANK system. Stagnation problems occurred there because the load of the system is considerably less than it was assumed in the planning phase of the system. The safety valve was activated several times already due to excessive steam volume produced in the collector. Nighttime cooling trough the collector field is applied and reduces the problems a little bit but not sufficiently. Calculations were carried out for a more appropriate dimensioning of the membrane expansion vessel. The investigations will be continued.
The results from the ongoing German stagnation proof projects indicate that the degradation of the water-glycol fluid is mainly caused by high temperatures. A danger of blocking by degraded glycol residue is caused especially when small absorber tubes are used in collectors

with absorbers that have an unfavorable emptying behavior and low heat losses. The discussions showed that still a lot of experience is missing and no standard procedures to solve stagnation problems in existing plants are known. Especially for large systems with collector areas of hundreds to thousands of m² (which are aimed at in process heat systems) more experience is needed and solid experimental experience and knowledge has to be elaborated.

**Subtask D: System Integration and Demonstration**

Up to now 9 pilot systems were installed. In the year 2006 four new pilot systems were erected in the field of seawater desalination (Fraunhofer ISE), breweries (AEE INTEC) and cooling (PSE). A special focus in 2006 was on breweries and seawater desalination.
Results of investigations at one Austrian and three German breweries were presented and discussed at the expert meeting in Rome. The investigated breweries cover a wide range of company sizes and different applications within the processes. In Austria one brewery was equipped with a solar thermal system and also first monitoring results are available now. The solar heat, which is produced with a newly developed anti-reflective double glazed flat plate collector, is used also for the brewing process.
The following table gives an overview of the pilot systems.

| **Plant, Country** | **Application** | **Installed capacity Collector type** | **Monitoring data available** |
|---|---|---|---|
| Contank Spain | Container washing | 357 $kW_{th}$ flat plate collector | YES |
| Carcavelos (BRISA) Portugal | Space heating and cooling | 466 $kW_{th}$ CPC | NO |
| ROBUR Italy | cooling | 65.5 $kW_{th}$ (132 m²) 132 m² fresnel collector | YES |
| Sea water desalination Gran Canaria, Spain | Sea water desalination | 70 $kW_{th}$ anti-reflective double glazed flat plate collector | YES |
| Sea Water desalination plant, Aqaba, Jordan | Sea water desalination | 50.4 $kW_{th}$ flat plate collector | YES |
| Fruit juices Gangl, Austria | Pasteurising bottle washing | 42 $kW_{th}$ flat plate collector | YES |
| Sunwash, Köflach, Austria | Car wash | 30 $kW_{th}$ flat plate collector | NO |
| Sunwash, Gratkorn, Austria | Car wash | 30 $kW_{th}$ flat plate collector | YES |
| Brewery Neuwirth Austria | Brewing process | 14 $kW_{th}$ anti-reflective double glazed flat plate collector | YES |

Sea water desalination Gran Canaria, Spain (Fraunhofer ISE, Germany)

Ongoing work in the laundry and metal surface treatment sectors, respectively, will be discussed in more detail at the next expert meeting scheduled for March 28 - 30, 2007 in Cologne, Germany.

Another promising application is **space heating of factory buildings**. A review of 10 systems in Austria with solar fractions between 10 and 100% was prepared by AEE INTEC.
Design guidelines for space heating of factory buildings based on TRNSYS simulations are currently under preparation and will be available in a printed version by spring 2007.

## WORK PLANNED FOR 2007

### Subtask A: Solar Process Heat Survey and Dissemination of Task Results

Two booklets will be prepared, summarizing the main outcomes of the survey of existing plants for solar process heat and of the performed potential studies.

The next industry workshop will be organized in the framework of the 8$^{th}$ Task 33/IV experts meeting in Cologne (Germany) on 30 March 2007.

The third issue of the industry newsletter will be available by the end of January 2007 in English and in the languages of all participating countries.

### Subtask B: Investigation of Industrial Energy Systems

In 2007 the focus of the work in Subtask B will be on the development of a tool for a cost analysis suitable for detection of all parameters that influence the economic performance of energy efficiency measures and the installation of a solar plant in an industrial process. Total Cost Assessment (TCA) was chosen as a method, because particular emphasis is here on costs related to environmental and health issues, which especially for solar energy use can result in a very different appraisement of costs and investment projects than conventional methods. Additional to the TCA tool a road map will be developed, which will provide companies with a decision making tool to find a tailor-made procedure for investments and/or operating options for consecutive projects protracting over a longer period with several investment phases or changes in operation. This road map will be an instrument to visualize the

differences, advantages and disadvantages of viable investment or operating options and the expected results in terms of either costs or energy use for the different approaches.
Further the matrix of indicators will be completed with detailed data of the textile, electro plating and chemical industry.

**Subtask C: Collectors and Components**

The work on the development of medium temperature collectors will be continued in the different projects involved in the task.

Concerning testing of medium temperature collectors, the activities on the round robin test will be intensified. The experiences from the testing investigations will be used to elaborate recommendations for testing of medium temperature collectors in general.

The investigations on material tests will concentrate on reflectors for concentrating medium temperature collectors.

Regarding system aspects, more field test results will be discussed in the experts meetings in 2007. Data from monitoring of pilot plants will be analyzed. This work will also contribute to the development of adequate collector testing and intercomparison.

The brochure "Medium Temperature Collectors" will be revised and supplemented with additional general information on the different categories of process heat collectors.

**Subtask D: System Integration and Demonstration**

The main focus in 2007 will be the finalization of contributions to the final deliverables, particularly the design guidelines on the task website and the pilot plant booklet. A numerical tool to evaluate the annual performance of potential applications at an early design stage including economic analyses will be developed to complement the process analysis and design support tools provided from Subtask B.

In Germany, the design of a pilot installation of a solar process steam generator with parabolic trough collectors at the site of a metal surface treatment plant will be developed. However the installation of the system will be beyond the time frame of this task. It is endeavored to identify additional potential applications for concentrating and non-concentrating collectors and bring together consortia for the realization of further pilot installations in the most promising sectors as a follow-up activity, for which funding support will be sought.

**LINKS WITH INDUSTRY**
The Task defines two levels of participation for the solar industry:

- **Level 1.** An industrial participant at this level should expect to participate in an annual workshop organized by SHC Task 33 and to receive at least once during the task duration a visit from a task participant, and to answer technical and marketing questions on solar heat for industrial applications (this activity is part of the system survey and the dissemination activity of Subtask A).

- **Level 2**. An industrial participant at this level should expect Level 1 commitment and to participate in all task meetings and to bring information and feedback from the market. Level 2 participation should be seen in close connection with the main participant of the country of origin of the industry.

A total of 15 companies from Austria, Italy, Spain, Portugal, Germany, Belgium, France and Brazil participate in the Task.

## REPORTS PUBLISHED IN 2006

- State-of-the-art report on medium temperature collectors
- Subtask B report

## REPORTS PLANNED FOR 2007

Report on medium temperature collector designs
Report on pilot projects
Report on potential Studies
Report on design Guidelines – Space Heating of Factory Buildings

Furthermore a CD will be published with the following content:

- Demo version of the Pinch program PE²
- Matrix of Indicators

Final task report
Final management report

## MEETINGS IN 2003

First Experts Meeting
December 4 – 6
Gleisdorf, Austria

## MEETINGS IN 2004

Second Experts Meeting
March 29 – 30
Brussels, Belgium

Third Experts Meeting
October 3 – 5
Oaxaca, Mexico

## MEETINGS IN 2005

Fourth Experts Meeting
February 23 – 25
Madrid, Spain

Fifth Experts Meeting
October 3 – 8
Kassel, Germany

## MEETINGS IN 2006

Sixth Experts Meeting
March 29 – 31
Rome, Italy

Seventh Experts Meeting
October 11 – 13
Lisbon, Portugal

## PLANNED MEETINGS FOR 2007

Eighth Meeting
March 28 – 30, 2007
Cologne, Germany

Ninth Meeting
September 12 – 14, 2007
Graz, Austria

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