Task 33: SOLAR HEAT FOR INDUSTRIAL PROCESSES

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TASK DESCRIPTION

Around 100 million square meters of solar thermal collectors, corresponding to an installed capacity of 70 GW_{th}, were installed by the year 2001 in the OECD countries. 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 solar character of the 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: Spain)
- 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 2004

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

During the year 2004 the potential study for Austria was completed and the final report is available. The results of the Austrian study and the preliminary results of studies for Spain, Portugal and Italy show that the potential for solar low temperature heat ranges between 3% and 4 % of the total heat demand of the industry.

Besides the potential studies information has been collected on industrial-process solar heat plants operating world wide. From the 49 plants that have been reported, the majority of the projects are in the food and beverage, textile, transport and chemistry sectors with a large majority in food processes. Indeed there are 12 plants in the food industry in fish, meat and olive processing. In the transport sector, most plants are washing installations; in the textile industry, at laundry companies.

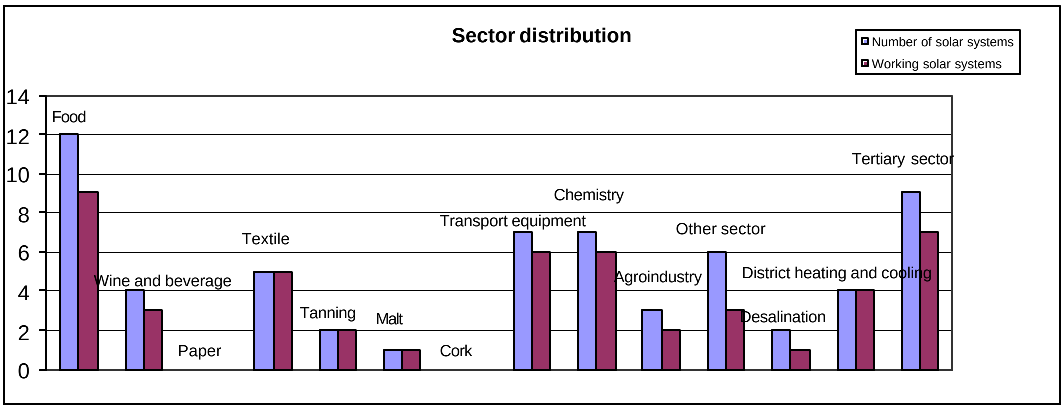

Figure 1.: Distribution of solar plants reported to Task 33/IV. Number of projects: (a) total and (b) plants still in operation. State: April 2004.

The majority of the operating plants are in the countries which have now the most important solar industrial development. Indeed, in Austria, Greece, Spain and the USA, where there have been several plants built during the 90ies, there are more than 67 % of the reported plants.

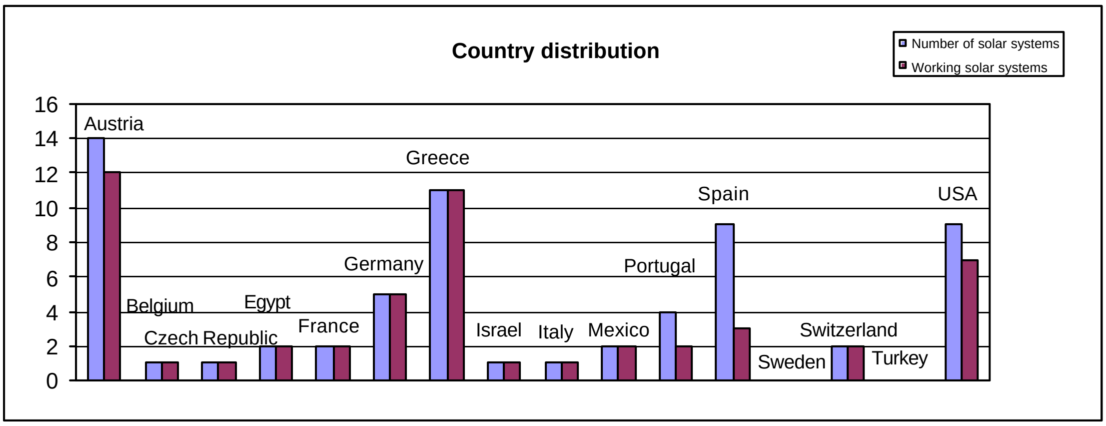

Figure 2: Solar plants documented by Task 33/IV: Distribution by countries. State: April 2004.

Most of the reported plants supply heat at temperature levels between 60 °C and 100°C. Some plants are working at temperatures above 160 °C and there is only one project operating in the intermediate range from 100 to 160 ºC. Out of the five plants working at more than 160 °C there are two prototype plants and three plants for space heating and cooling with double effect absorption machines (steam production).

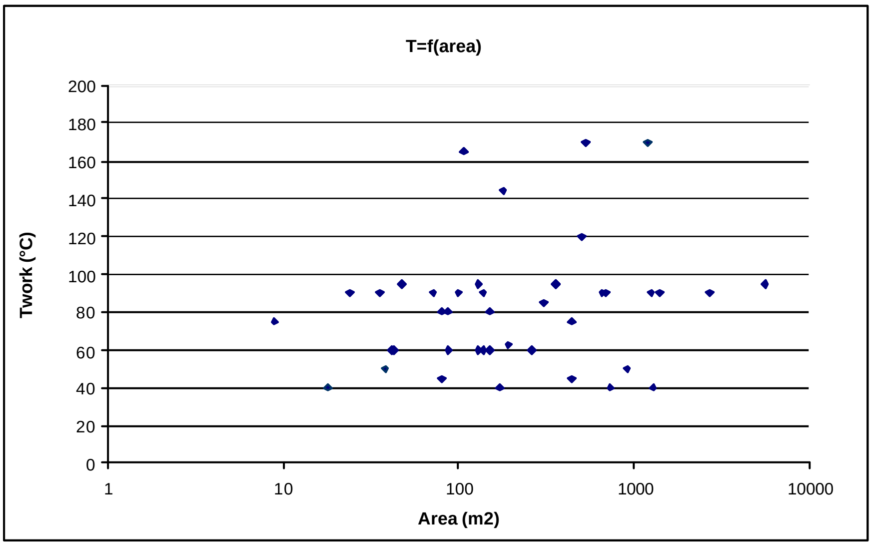

Figure 3: Solar plants documented by Task 33/IV: Correlation of working temperature vs. solar field size. State: April 2004.

In the following some plants for solar process heat in industry are described:

EL NASR, Pharmaceutical Chemicals (Egypt)

Application: production of process steam for a pharmaceutical company

Location:	Cairo, Egypt
Installed capacity:	1330 kW
Collector area:	1900 m^2
Collector type:	parabolic trough collectors
Heat transfer medium:	steam (8 bar)
Operating temperature:	173 °C
Start of operation:	2004 (January)

100 percent renewable energy for a production hall and an office building

Application:	heating of a production hall
Location:	Bludesch, Austria
Installed capacity:	56 kW
Collector area:	80 m²
Collector type:	flat-plate collector
Heat transfer medium:	water-glycol
Operating temperature:	20 – 80°C
Storage:	950 litres
Start of operation:	1994

Solar-powered air conditioning system for a road traffic control centre in Carcavelos, Portugal

Application: space heating and cooling with a single effect lithium-bromide 79 kW absorption cooling machine.

Location:	Carcavelos (BRISA), Portugal
Installed capacity:	464 kW
Collector area:	663.3 m^2
Collector type:	CPC solar collectors
Heat transfer medium:	water-glycol
Operating temperature:	80 - 90 °C
Storage:	20 m^3
Start of operation:	2004 (January)

Industry workshops

In conjunction with the Task 33/IV meeting in Brussels an industry workshop was organized on March 31. Besides the task participants 11 representatives from the solar industry, the European Solar Thermal Industry Federation ESTIF, the European Commission and EUREC Agency participated.

Another industry workshop was organised on November 11 in conjunction with the ISES Latin America Regional Conference in Guanajuato, Mexico.

Subtask B: INVESTIGATION OF INDUSTRIAL ENERGY SYSTEMS

The integration of solar heat into industrial production processes is a challenge to both the process engineer and the solar expert. In applying solar heat, attention must be paid to the temperature levels used in the heat supply system. Another challenge is the time-dependency of the solar energy supply and the heat demand of the processes.

Favourable conditions for solar thermal energy are mean temperatures which are as low as possible, processes that need a constant amount of energy during sunlight hours and high energy prices in the existing system. Besides these parameters, the characteristics of load curves of industrial production processes with the potential to use solar heat have been documented and analyzed with regard to peak hours and stop times and compared with the supply loads of solar thermal systems.

Based on the analyses described above, the most promising processes, applications and industrial sectors for solar heat were identified.

Table 1: The most promising processes, applications and industrial sectors for solar heat

Operations and processes in some important industrial sectors (· : important, X: very important)												
process	food	textiles	building materials	galvanising, electroplating	fine chemicals	pharmaceutical and biochemical	service industry	paper industry	automotive supply	tanning	painting	wood and wood products
cleaning	X	X	·	X	·	X	X		·	·	X	
drying	X	X	·		·	X	X	·	·	X	X	X
evaporation and distillation	X				·	X						
pasteurisation	X					X						
sterilization	X					X						
cooking	X											
general process heating	·	·	·	X	·	·	X		·			·
boiler feed-water preheating	X	X	·		·	·		·		·		
heating of production halls	X	X		·	·	·	·		X	X	X	X
solar absorption cooling	X			·		X	X					

The expansion of existing heat integration models (PINCH technology) to solar energy and the expansion of design tools for solar heating systems to industrial processes were further main topics in 2004. The minimum energy demand of a production system and the maximum potential for heat recovery were analyzed for several industrial processes based on the PINCH theory.

In general, heat integration means the linking of hot and cold streams in a process in a thermodynamically optimal way. The pinch analysis is the most important concept in the field of process integration methodologies. Linnhoff et al developed this concept into an industrial technology and the technology was later expanded into new areas such as water pinch and hydrogen pinch.

The fundamental principal behind the pinch concept is the ability to match the individual demand for a commodity with a suitable supply. The suitability of the match depends on the quality required and the quality offered. In the case of energy the commodity is heat/energy and its quality is measured as temperature.

The pinch analysis is a structured approach to identify energy inefficiencies in industrial processes. The minimum theoretical utility requirement in the processes is calculated for overall energy use as well for specific utilities.

Subtask C: Collectors and Components

An overview of the different medium-temperature collector developments that are being investigated in connection with Task 33/IV was prepared. Concise papers which describe the collectors were written. A report based on these papers, which summarizes the information on the current state-of-the-art, will be published.

The new term 'medium-temperature collectors' is used to denote collectors with operating temperatures between 80°C and 250°C. The aim is to develop collectors that are suitable for applications in this temperature range within which there has been very limited experience to date. In order to give a short overview, three categories may be introduced (the involved partners are given in brackets):

- improved flat-plate collectors: double-glazed flat-plate collectors with anti-reflection glazing (ISE, Germany).
- stationary, low-concentration collectors: stationary CPC type collectors (INETI, Portugal and Solarfocus, Austria),
- tracked concentrating collectors: small parabolic trough collectors (AEE INTEC and BUTTON ENERGY, Austria; SOLEL, Israel; DLR and SOLITEM, Germany; CIEMAT, Spain)

All collector developments are on-going and will be continued in 2005.

Figure 3: Parabolic trough collector under development at AEE INTEC in Austria

Double glazed collector with AR-glasses on outdoor testsite of Fraunhofer ISE, Germany

Two examples of installations which were put into operation in the year 2004 and which use medium-temperature collectors should be mentioned here:
In spring 2004, a system with a SOLITEM parabolic trough collector was put into operation. The system is installed in Dalaman, Turkey. The medium-temperature collectors supply heat for an absorption cooling machine for a dryer and for the air-conditioning system of a hotel with 700 beds.

In December 2004, a compact sea-water desalination system was installed by Fraunhofer ISE in Spain (Gran Canaria) in which double-glazed anti-reflective flat plate collectors are used.

Collector Testing

Until the planned round-robin test starts, it makes sense to describe the medium-temperature collector testing and the activities associated with the test and qualification standards for medium-temperature collectors up to 250°C together.

In the course of the work on this topic, the general approach is to base the considerations on the existing European collector testing standard EN12975. The aim is to investigate which changes or additional requirements are necessary in order to include the broad spectrum of medium-temperature collectors (improved flat-plate collectors, stationary concentrating collectors, tracked parabolic trough collectors) into the existing EN12975 standard. Most of the necessary points of discussions refer to tracked parabolic trough collectors. Due to discussion within Task 33/IV and the discussion with the experts from SolarPACES it became clear that the following topics need further clarification:

- definition of the reference area;
- conditions for valid measurement points;
- wind requirements;
- IAM definition as in EN12975; and
- how to deal with end losses.

The present status of the work in Task 33/IV has been published in a working document by M. Rommel which summarizes the topic from the point of view of the low-temperature collector testing experience. The approach from the high-temperature technology point of view is described in a paper by Lüpfert, Hermann, Price, Zarza and Kistner, "Towards standard performance analysis for parabolic trough collector fields", which was presented at the SolarPACES conference in Oaxaca in October 2004.

Realistic Medium-Temperature Component Parameters for Simulation Models

In the course of the work carried out so far, the decision was made to restrict the work to components of the solar loop and to concentrate especially on piping losses. First results of investigations on measured piping losses in testing systems installed at the testing facilities at Fraunhofer ISE and at PSA (Plataforma Solar Almeria) revealed that the measured losses are distinctively higher than those estimated from plain well-insulated pipes. This work will be continued in 2005.

Subtask D: System Integration and Demonstration

TRNSYS was agreed upon as the standard simulation tool within Task 33/IV, since most partners are already using it and many solar thermal components are already available. A list of available TRNSYS models applicable for solar process heat systems and their components will be compiled, to form a basis for the identification of further development needs.

A numeric tool to assist inexperienced users in the assessment of potential applications for solar process heat can help to identify promising applications at an early stage without undue engineering analysis effort which presently creates a significant barrier for the market entry of solar process heat technologies. In 2004, a number of programs were screened, but no suitable existing program could be identified. GREENIUS, developed by DLR for the assessment of different renewable electricity generation technologies, was found to provide a good basis to be adapted for the purposes of Task 33/IV.

Besides the work on simulation and design tools, seven case studies have been carried out in different industry sectors and countries:

- A textile company and a dairy in Austria. Carried out by AEE INTEC and JOINTS

- Food industry (jam pasteurising), paper industry (cardboard drying), hotel (laundry and hot water preparation), food industry (slaughterhouse), all in Nicaragua. Carried out by AEE INTEC
- Parking service (hot water preheating) in Spain. Carried out by Aiguasol.

These studies indicated interesting potential in the lower temperature range, and provided good experience for the use of interim results and further development of the design guidelines.

WORK PLANNED FOR 2005

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

Two reports are planned for 2005:
A report on the potential of solar heat for industrial processes and the most promising industrial sectors in the participating countries will be prepared in 2005.
The second report will focus on state-of-the-art solar collector technology, system concepts and system costs in the participating countries and will review existing and projected solar process heat systems.

Another main topic of Subtask A will be the organization of two workshops targeted at industries not directly involved in Task 33/IV and at other potential users of the Task results. These "Industry Workshops" will be organized in conjunction with the Task meetings. One will be organized in Madrid in February 2005 in conjunction with the biennial Spanish industrial trade fair for cogeneration and for HVAC technologies (GENERA 2005).
The second industry workshop will take place in October 2005 in Kassel, Germany.

The publication of the second Industry Newsletter is planned for autumn 2005.

Subtask B: Investigation of Industrial Energy Systems

Since the work of Subtask B must be finalized in 2005, the focus of Subtask B will be on the integration of existing heat integration models (PINCH technology) into the design procedure of solar thermal systems. The other two main topics for 2005 will be the evaluation of solar energy in comparison with other ways to save fossil fuels such as energy efficiency, heat pumps and heat integration, and the development of a short-cut “Total Cost Analysis” for solar plants for industrial applications.

Subtask C: Collectors and Components

The work on the development of the different medium-temperature collectors will be continued in 2005 and a first cost analysis will be carried out for the different collector technologies involved. It is also planned to include LCA (life cycle analysis) considerations, mainly to compare different medium-temperature collector technologies with each other (flat-plate, vacuum tube, parabolic trough).

A first draft of the recommendations for the performance tests of medium-temperature collectors is planned for 2005. The work on testing methods suitable for medium-temperature collectors will be continued and a round robin test for a medium-temperature collector will be started at the end of 2005.

Concerning the reliability of collectors for industrial processes, a first definition of the performance parameters for new materials in medium-temperature collectors is planned for the end of 2005. This mainly concerns the performance parameters of reflectors, absorbers and insulation materials. Accelerated exposure tests on existing and new materials for medium-temperature collectors will be started.

Other work topics will focus on simulation models and on the investigation of the stagnation behavior of large medium-temperature systems. An interim report on the stagnation behavior of large systems for industrial applications will be prepared.

Subtask D: System Integration and Demonstration

According to the work plan, work on the "Design Guidelines" and the adaptation of the GREENIUS program is scheduled to start at a workshop in October 2005.

A main focus in Subtask D will be on a number of case studies in order to initiate first pilot projects. Further activities will be the definition of common monitoring guidelines and the acquisition of funds for the implementation of appropriate equipment in selected installations.

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 2004

- Austrian potential study for solar heat for industrial applications
- First Industry Newsletter
- Six papers on solar heat for industrial applications and the development of medium temperature collectors were presented at international conferences in 2004.

REPORTS PLANNED FOR 2005

- Report on the potential of solar heat for industrial processes and the most promising industrial sectors
- Report on the state-of-the-art of the solar collector technology, system concepts and system costs in the participating countries
- Report and design guidelines for space heating of production halls
- State of the art report on medium temperature collectors
- Second Industry Newsletter
- Subtask B 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

PLANNED MEETINGS FOR 2005

Fourth Experts Meeting
February 23 – 25
Madrid, Spain

Fifth Experts Meeting
October 3 – 8
Kassel, Germany

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