IEA SHC Task 49 SolarPACES Annex IV

Solar Process Heat for Production and Advanced Applications

General requirements and relevant parameters for process heat collectors and specific collector loop components

Deliverable A 1.1.

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1 Description of IEA SHC Task 49

Note: The content of chapter 1 of this report is very similar to the description of the Work Plan of IEA SHC Task 49 / SolarPaces Annex IV (Version 5, October 2011, download at www.iea-shc.org/task49) but serves as background information for chapter 2.

1.1 Background

Solar Heat for Industrial Processes (SHIP) is currently at the early stages of development. Less than 100 operating solar thermal systems for process heat are reported worldwide (as of 2009), with a total capacity of about 24 MW_{th} (34,000 m^2). Most of these systems are of experimental nature, and are relatively small scale. However, there is great potential for market and technological developments, as 28% of the overall energy demand in the EU27 countries originates in the industrial sector, majority of this is heat of below 250°C.

According to a study (Ecoheatcool 2006), around 30% of the total industrial heat demand is required at temperatures below 100°C and 57% of this demand is required at temperatures below 400°C. The main part of the heat demand below 100°C could theoretically be met with solar thermal systems using current technologies, if suitable integration of the solar thermal system can be identified. With technological development, more and more medium temperature applications up to 400°C will also become market feasible.

In several specific industry sectors, such as food, wine and beverages, transport equipment, machinery, textiles, pulp and paper, the share of heat demand at low and medium temperatures (below 250°C) is around 60% (POSHIP 2001). Tapping into this potential would provide a significant solar contribution to industrial energy requirements.

The methodology which has been developed in order to realize thermal energy supply in industry with minimal greenhouse gas emissions is based on a three step approach:

- Technological Optimization of the processes (e.g. increased heat and mass transfer, lower the process temperature) and solar thermal system (e.g. operation of solar field, integration schemes, control, safety issues etc.)
- System Optimization (enhancing energy efficiency using e.g. Pinch Analysis for heat exchanger network for a total production site)
- Integration of renewable energy/solar thermal energy (based on exergetic considerations)

In the last two years the awareness for solar process heat in the industry increased and some new solar thermal systems were installed. This positive development should be supported now by further research and development in the key research questions of solar process heat.

After completion of the IEA SHC/Solar Paces Task 33, key areas for further technological development, which should be treated in the context of a new Task, were identified:

- Process heat collector development with heat loss control and maximization of energy collection
- Material research with improvement of components on a higher temperature level and better materials for concentrated optics
- Process heat collector testing for working temperatures above 100°C

The content of this new proposed project were defined based on this knowledge out of IEA

SHC 33/Solar Paces Task IV and other position papers like the strategic research agenda of the European Solar Thermal Technology Platform and the experience of several national projects in the field of solar process heat.

1.2 Task Objectives

Subtask A: Process heat collectors

- Improvement of solar process heat collectors and collector loop components
- Comparison of collectors with respect to technical and economic conditions
- Comprehensive recommendations for standardized testing procedures

Subtask B: Process integration and Process Intensification combined with solar process heat

- Development of advanced pinch and storage management tool(s)
- Survey on integration methodologies for solar process heat
- Develop System concepts and integration guideline
- Survey and dedicated Workshop on new process technologies
- Identification of the increasing potentials and compendium of ongoing activities and existing pilot plants/case studies

Subtask C: Design Guidelines, Case Studies and Dissemination

- Design Guidelines
- Simulation Tools
- Performance assessment methodology
- Monitoring of demonstration projects and “Best practice” projects
- Dissemination of task results
- Market deployment
- Potential study

1.3 Task 49 Scope

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

- All industrial processes which are thermal driven and running in a temperature range up to 400°C
- 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 400°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, concentrating collectors with stationary receivers, parabolic trough collectors, Fresnel collectors, etc.
- Technologies for industrial application which can be driven by sunlight or specific spectrums (e.g. UV)

Specific process engineering technologies to which solar heat has to be supplied, such as the technologies for desalination of sea water, industrial cooling applications and electricity generation, are not the main focus of the Task. They may be considered to a certain extent if there is strong interest from industry.

For cooling applications, for instance, the work will be restricted to the adaptation of the

results of IEA SHC Task 38 to industrial applications.
The foreseen activities in the field of heat storage management will not deal with the development of storage technologies and the application of new storage materials. This work will be addressed in the IEA SHC Task 42 and its follow up activities.
There is a link of this IEA SHC Task to the activities in IEA SHC Task 45 “Large scale systems” due to the size of the solar thermal systems and the challenges faced by both applications. The main differences of the planned Task 49/IV from the IEA SHC Task 45 can be seen in:

- Close interlink age between solar thermal system and industrial processes
- Combination of process intensification and solar thermal systems
- Dealing with new applications
- Different temperature levels (SHIP up to 400°C) and more relevance on the development and application of concentrated systems
- Based on the higher temperatures different challenges on material, fluids, collector and components behaviour are considered
- Different stagnation behaviour due to batch processes and different hot storage management
- Detailed focus on industrial processes in combination with solar thermal collectors

1.4 Task 49 Subtask A, activity A1: Improvement of solar process heat collectors and collector loop components

In order to support the development and improvement of cost effective and at the same time well-performing and reliable process heat collectors, the appropriate requirements are investigated. It shall be described and evaluated which parameters have to be taken into account for the development and improvement, which ones are more important than others and which kind of measurements can enhance the development/improvement. Also material topics and the accuracy that is necessary will be discussed and described.

Characteristic parameters will be determined for both modeling collectors in simulation programs to reflect the realistic performance of medium temperature collectors in process heat systems and comparable measurement data evaluation for different locations, applications etc.

For the integration of solar heat into industrial processes it is compulsive that the systems operate totally reliable in all the operation modes that may occur. In this respect, special emphasis has to be put on the aim that the solar thermal systems can handle stagnation or overheating situations without any danger of failure and without the need for additional maintenance works. Whereas for collectors with stagnation temperatures lower than e.g. 250°C stagnation has to be regarded as a normal operation mode of solar thermal systems, this has to be investigated and analyzed for collector concepts leading to higher temperatures when there is no sink for the solar heat (e.g. times without industrial production because of weekends or vacation times, but also technical faults like the breakdown of a pump etc.). In this context, also the terminology “stagnation” will have to be discussed and adapted with respect to process heat collectors as for collectors aiming at high usual operation conditions overheating will lead to severe material problems. The influences and consequences of stagnation/overheating on the collector loop fluids and components will also be addressed and solutions (avoidance of overheating/stagnation by conceptual approaches, coolers, …) will be developed. The aim is to develop techniques to handle stagnation situations also in large medium temperature collector fields.

Not only stagnation, but also the (dynamic) behavior of the collectors and the collector loop is of interest. Investigating the collector behavior will be done by collector testing at high temperatures and by the evaluation of measurement data from existing plants. Also, material problems for medium temperature collectors up to 400°C operating temperature and system components will be investigated, such as heat carriers, insulation etc. If possible, these measurements will be carried out in existing systems and in laboratory measurements in order to be able to realistically model medium temperature systems and to give recommendations for testing procedures.

With all the knowledge gained, even some of the collectors already available on the market for up to around 100°C could be modified to be used for higher temperatures. Furthermore, there is a considerable potential for the improvement of existing process heat collectors in many aspects. New collector developments and improvements will lead to a better cost/performance ratio as is presently achieved for medium temperature systems. The collectors to be investigated are for example, double glazed flat plate collectors with anti-reflection and low-emissivity coated glazing, hermetically sealed collectors with inert gas fillings or vacuum (with and without reflectors), CPC collectors, evacuated tubular collectors with and without reflectors, parabolic trough collectors, Fresnel collectors etc...). In these activities, investigations on materials suitable for medium temperature collectors will play an important role.

Beside developing and/or improving collectors, also other components and whole collector loops for process heat applications will be analysed and further developed in co-operation with the involved industry. The main aspects are performance, reliability and cost effectiveness. Both new or improved collector concepts and design details will be addressed and improved peripheral devices are aimed at (e.g. tracking with high accuracy, collector connections, …).

In order to achieve an improved cost/performance ratio for collectors for industrial processes, the reliability of collectors and their service life time is important. Moreover, in the development of medium temperature collectors, new materials and components will be used. This concerns the full width of collector technologies from flat-plate collectors to vacuum tubular collectors and parabolic trough collectors, e.g. reflectors (including their mechanical support), tracking devices, glazing and absorbers addressed.

Representative and realistic test samples will be identified and prepared. Relevant performance parameters will be defined and characterisation procedures will be established. Existing durability test procedures will be investigated and adapted where required. Adequate accelerated ageing tests will be developed as a basis for longevity assessments.

Summarizing, the overall aim of this activity is to achieve improvements optimizing the combination of thermal performance, collector durability and costs for process heat collectors.

For activity A1 in Subtask A, three deliverables are foreseen and will be available for download at www.iea-shc.org/task49:

A 1.1 General requirements and relevant parameters for process heat collectors and specific collector loop components (this document)

A 1.2 Report on overheating/stagnation issues including the high temperature behaviour of the investigated components

A 1.3 Brochure on State of the Art of process heat collectors

2 General requirements and relevant parameters for process heat collectors and specific collector loop components

As described above, part A1 of Subtask A aims to improve (and develop) all types of collectors, collector loops and collector loop components (e.g. thermal insulation, hydraulic parts, heat carriers etc.) for process heat applications. All devices will be investigated with respect to performance, reliability and cost effectiveness. A first step is to increase the knowledge about general requirements and relevant parameters of process heat collectors and their improvement, and to agree on these criteria among the Task 49 participants. These requirements comprise the thermal and optical performance of collectors and components, but also the reliability/durability and costs.

The target groups which have been identified by the Task 49 participants (and which should be aware/informed regarding the general requirements and relevant parameters for process heat collectors and specific collector loop components) are

- manufacturers
- installers
- planners
- legislative & certification bodies
- R&D groups
- industrial clients and operators of Solar Process Heat systems

2.1 What is a process heat collector?

Basically, there is no clear distinction between a “conventional” solar thermal collector and a process heat collector as the heat delivered by any solar thermal collector may be used for industrial heat applications with suitable temperatures/efficiencies etc. Therefore, indicative ranges of temperature levels are defined (see Table 1) so that it can be addressed more clearly in which range of operating conditions some of the general requirements are already known and in which range at least some of them have to be described in more detail.

Table 1: Indicative temperature ranges for solar process heat collectors and applications

below 100°C	100 °C .. 250 °C	above 250 °C
“low” temperature collector or application	“mid” temperature collector or application	“high” temperature collector or application

Despite a necessary cost effectiveness of the technical solutions, all collectors should have a “reasonable” collector output. For “mid” and “high” temperature collectors, “reasonable” means that the collector output exceeds 300 W/m^2 gross collector area for the following conditions: 1000 W/m² hemispherical irradiance, 15 % diffuse fraction and 20 °C ambient temperature at an operating temperature above 100 °C (“mid” temperature collector) and above 250 °C (“high” temperature collector), respectively.

2.2 General requirements and relevant Parameters

With respect to the temperature level, the general requirements for collectors and loop components used so far for “low” temperature collectors and applications are described (cf. e.g. DGS 2010; Peuser 2001; Remmers 2002; VDI 2004; Scheuren 2008) and may not need to be described differently if the collectors are used to supply heat for industrial process, either on the supply or on the process level. Yet, some of the requirements mentioned below are still valid for “low” temperature applications, if they are meant to supply heat for industrial processes. For higher operating or design temperatures the requirements are not so well described and defined. E.g. it should be considered which standards have to be taken into account for steam installations, which restrictions have to be met regarding the choice of specific heat transfer fluids, mechanical loads, etc. Some aspects have already been described in existing documents. Thus, the review of existing documents, e.g. the QAiST project report on concentrating / tracking collector component characterization (cf. QAiST R2.4 Topic Report, 2012) will help to extend this report in the further course of the Task.

In the following, requirements and relevant parameters for process heat collectors are listed that have been addressed by the Task participants during the first year and that should be considered during the course of the Task and the related projects. For a better overview, they have been divided into technical aspects, costs / general information and application aspects.

2.2.1 Technical aspects:

- Comprehensive description of collector performance: Design Temperature and Efficiency Curve, Power output curve, IAM for direct and diffuse irradiance, thermal capacity of the collector etc. (just as for existing collectors, but with regard to the design temperature). Further aspects: “design power range”, pressure loss
- Comprehensive description of reliability/durability aspects (just as for existing collectors, but with regards to the design temperature). Further aspects: Wind resistance, ground usage, maintenance needs of collector field (e.g. for cleaning or evacuation), expected (and guaranteed) operating life
- Description of stagnation behavior of the collector (e.g. intrinsic safety also in case of power loss (passive) or active overheating protection)

  Note: This topic will be treated in a separate Deliverable A 1.2. The corresponding action plan will have to be defined at the 3rd Task Meeting in Rapperswil (March 2013).
- Existing standards: Which do apply for which collector/loop/application (e.g. in case of steam production) and to which extend?
- Which new topics come up with concentrating collectors regarding testing? E.g. validation of tracking systems, …
- A review of IAM definition

  Note: The IAM topic will be further discussed at the 3rd Task Meeting in Rapperswil (March 2013) and then a working group will be formed. It will also have to be discussed and defined at the coming meeting in which Deliverable the outcome on the IAM discussions should be placed (e.g. Deliverable A3).
- Thermal capacity of collector fields and sections of the collector field, dynamic behavior, field losses (especially for mid and high temperature applications), control aspects (e.g. feed forward)
- Which HTF (=Heat Transfer Fluid) can be used when / where
- …

2.2.2 Costs and general information

- Information about collector and component costs, maintenance, safety, installation
- Distinguish between stationary and tracked as well as non-concentrating and concentrating collectors and provide information regarding the use of diffuse

irradiance, e.g. a common way to display performance curves and figures

- (Further) Develop tools for a quick assessment of the energy performance of different collectors, such as gross energy calculation tools

  Note: This will specifically be addressed by Task Deliverable A.2.
- Which are industrial requirements that need to be met? In other words: What does the collector have to fulfill in order to work in industrial environments? (e.g. temperature control, power range, safety). For this, it shall be evaluated and discussed which kind of information the planners of industrial heat installations usually use and deal with so that solar manufacturers, planners and installers can adapt to this.
- Which are the requirements for manufacturers and suppliers to provide a product (a process heat collector)
- Information for customers: what do they want / need to know

2.2.3 Applications

Note: Here, the general requirements of the collectors / the collector loop are described, not the general requirement of the integration which is part of the other Subtasks

- Direct Steam Generation: Available hydraulic components and costs, advantages/disadvantages/challenges, control, …
- Drain Back Concepts for Process Heat: Available hydraulic components and costs, advantages/disadvantages/challenges, control, …

This listing is not meant to be complete but to be a starting point for further investigations on the relevant parameters which are listed in this document. Thus, it will be a “living document” that can be further extended and changed during the course of the Task.

3 Literature References

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