Integrating Solar Heat into Industrial Processes (SHIP)

Booklet on results of Task49/IV Subtask B

Deliverable B6

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Contact:

Bettina Muster-Slawitsch
AEE INTEC
b.muster@aee.at
http://task49.iea-shc.org/

Information sources:

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P. Krummenacher and B. Muster-Slawitsch, Methodologies and software tools for integrating solar heat into industrial processes *13th International Conference on Sustainable Energy technologies* SET2014- E10049 (2014).

B. Muster-Slawitsch, T. Prosinecki, Q. Ahmad, C. Sattler, J. Buchmaier, S. Lux, W. Van Helden Helden, Anh Phan, and Christoph Brunner, Potential Enhancement of Solar Process Heat by Emerging Technologies, IEA Task 49/IV, (2016).

Integrating Solar Heat into Industrial Processes

When integrating solar heat into industrial or commercial processes, the aim is to identify the most technically and economically suitable integration point and the most suitable integration concept. Due to the complexity of heat supply and distribution in industry, where a large number of processes might require thermal energy, this task is usually not trivial.

Within Task 49/IV Subtask B several documents have been developed to assist with the necessary steps when planning the integration of a solar process heat plant.

Integration Guideline

Integrating solar heat is possible at several points in the heat supply and distribution network of an industrial production site (see Figure 1). Generally, we distinguish between Integration on "Supply Level" and Integration on "Process Level". While supply level integration means integrating solar heat within the central heat distribution lines or central heat storages, we understand by process level integration the coupling of solar heat to one specific process step or process heat storages.

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To assist with the necessary steps for the identification of suitable integration points for solar heat and their planning, a specific Guideline for Integrating Solar Heat in Industrial Processes (Integration Guideline) has been developed within IEA Task 49/IV.

This Guideline shows the overall necessary steps of an assessment methodology for solar process heat projects and leads the planner in detail through the following steps: consideration of **process integration for solar process heat**; specification of **integration concepts**; planning of **solar process heat systems concepts** and **criteria for selecting most promising integration points**.

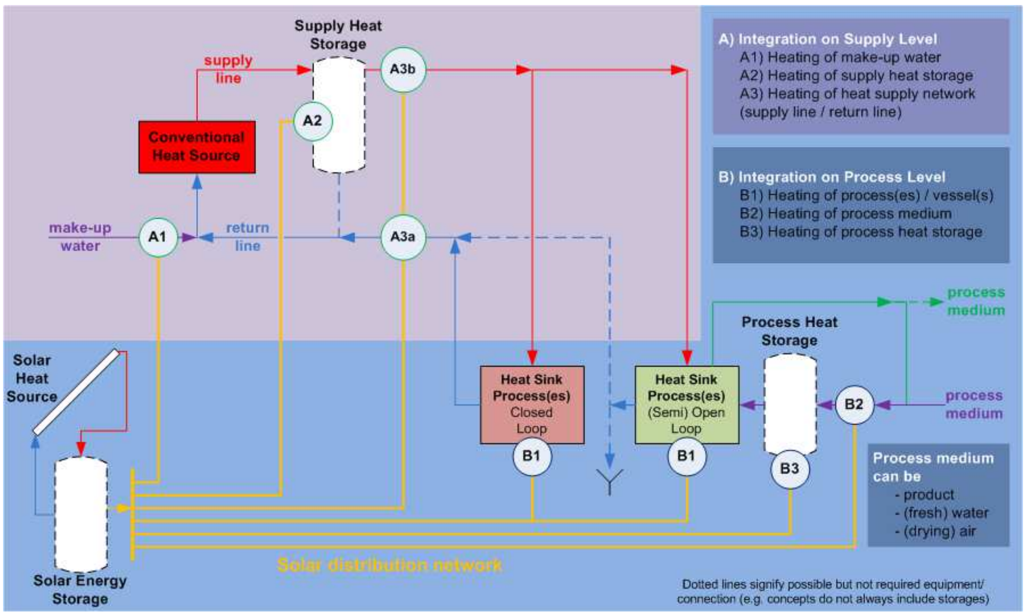

Figure 1: Possible integration points for solar process heat (MusterSlawitsch et al., 2015)

Process Integration for Solar Process Heat

The detailed consideration of available waste heat and necessary energy demand on different temperature levels can help the solar planner to design an efficient industrial process and to ensure that solar heat will go beyond the heat recovery potential. To assist with an integrated planning of heat integration and solar process heat, several methods and tools are availble. Details have been documented in the *Integration Guideline* or in the more specific report *Methodologies and software tools for integrating solar heat into industrial processes*.

Figure 2 shows an exemplary scheme of a heat integration concept including solar heat as utility. Simulations may allow designing of heat exchangers and storages to achieve best performances.

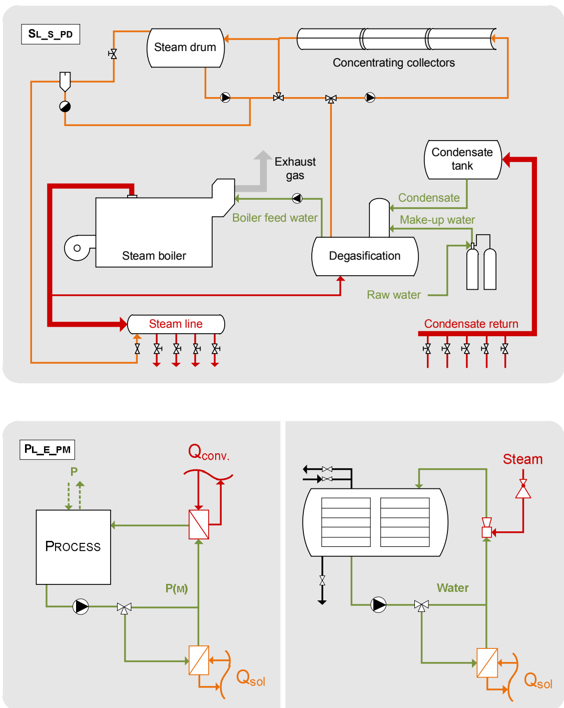

Figure 3: Integration concepts for direct solar steam generation (above) and solar heating of a product or process media with external heat exchanger (below) (Schmitt, in Muster-Slawitsch et al., 2015)

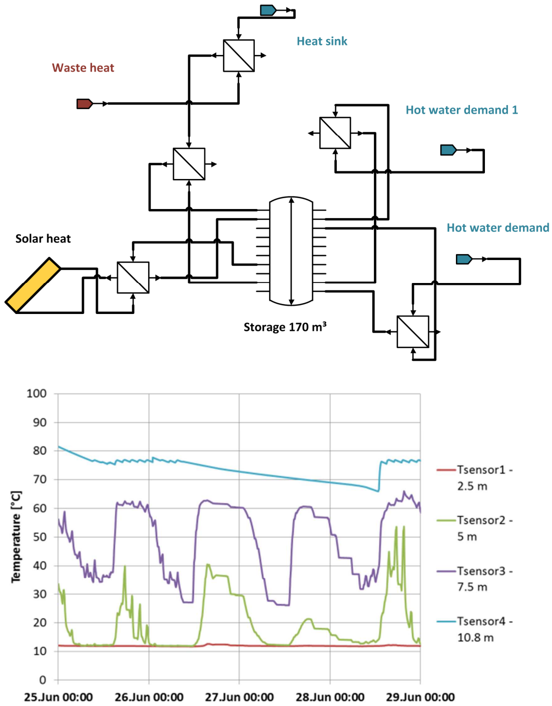

Figure 2: Heat integration concept with solar heat and simulation result of a combined storage (Krummenacher and Muster-Slawitsch, 2014)

Integration concepts for solar thermal energy

To ensure a fast identification of a suitable integration concept for solar thermal energy, industrial heat consumers can be classified. On process level, for instance, thermal driven processes can be assigned to one of three main categories: “(pre)heating of fluid streams,” “heating and maintaining temperature of baths, machineries or tanks” and “thermal separation processes.”

Such classification enables to develop integration concepts (see examples in Figure 3) suitable for each class of heat consumer. In this way, the choice of the most suitable integration concept among the large number of possible concepts can be easily done by the planner. Details on the classes of heat consumers and respective integration concepts are documented within the *Integration Guideline.*

Solar Process Heat System Concepts (SHIP concepts)

The integration concepts specify how solar process heat is connected to the heat consumer on supply or process level. However, they do not give detailed information on the solar side. Therefore, the Integration Guideline guides the user to extend the integration concepts to suitable solar process heat system concepts (SHIP concepts). These concepts detail all 5 possible subsections of a solar process heat plant: the collector loop, the charging point, the storage, the discharching strategy and the integration point.

In low-temperature SHIP systems with storage, usually all five sections can be distinguished. At systems without storage, as for example, at direct solar steam generation, only the subsections "collector loop" and "integration point" are found.

Within the *Integration Guideline* different types and characteristics of each subsection are described and detailed as shown in Figure 4 for different charging concepts. Further various exemplary solar process heat system concepts are explained and their possible combination with integration concepts is shown.

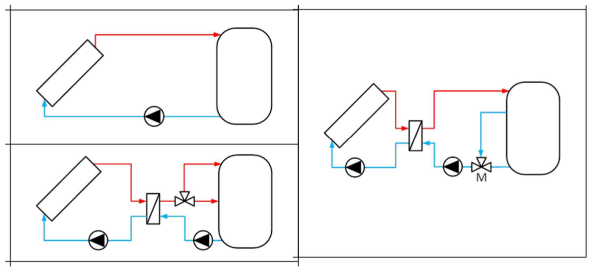

Figure 4: Different charging concepts ((a) direct charging without heat exchanger; (b) external heat exchanger with stratification valve; (c) external heat exchanger with mixed charging return flow) (Helmke and Hess, in Muster-Slawitsch et al., 2015)

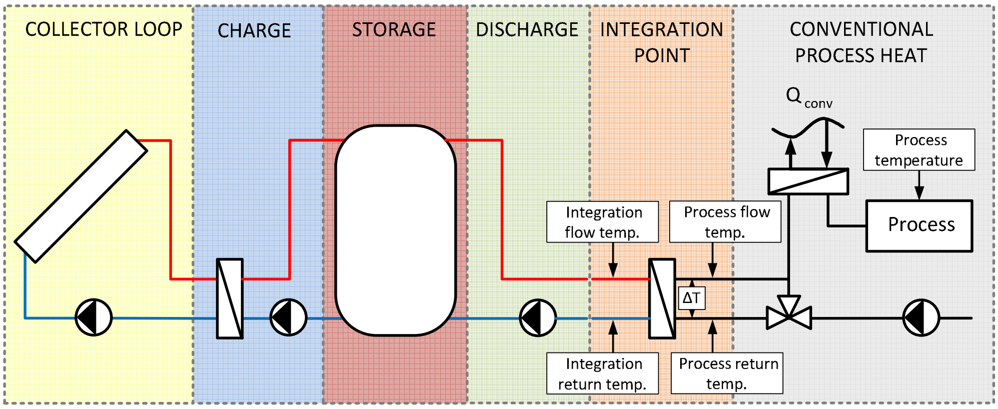

Figure 9: General SHIP system for pre-heating with five subsections supplying an industrial heat consumer (Helmke and Hess, in Muster-Slawitsch et al., 2015)

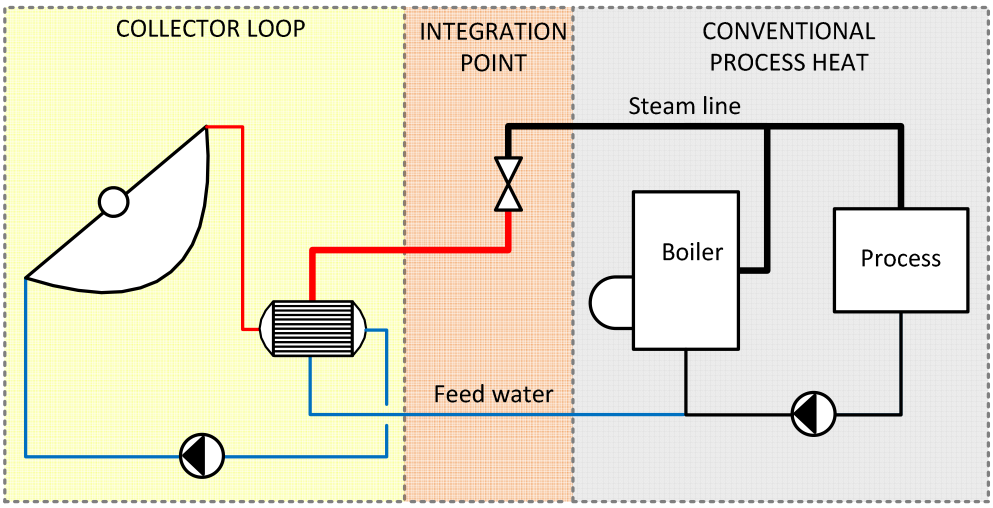

Figure 10: SHIP system for indirect steam generation (Helmke and Hess, in Muster-Slawitsch et al., 2015)

Criteria overview for selecting integration points

There are various criteria which might influence the final decision on where to integrate solar process heat in industry. We can generally distinguish between criteria that can be applied just after the analysis of industrial energy flows and optimization potential, where little is still known about how solar process heat could be integrated (“pre-integration”) and criteria which can only be known once

Figure 14: Criteria overview (Ben-Hassine, in Muster-Slawitsch et al., 2015)

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integration concepts have been specified (“post-integration)”.

“Pre-integration” criteria include information on temperature, , annual heat demand, operation schedule and quality of the technology in place (willingness for changes). “post integration criteria take into account reliability of required regulation, sizing of heat exchangers and storages, required auxiliary energy and estimated solar yield etc. Details on all criteria and their application are given in the *Integration Guideline.*

		Indicator name	Indicator variable	[unit]
pre- integration	Demand	process (return) temperature	T_p	[°C]
		tempearture lift	ΔT	[°C]
		annual heat demand	Q_a	[kWh/year]
		storage capacity	Q_{st}	[kWh]
		storage charging	$\dot{Q}_{st}$	[kW]
		operation time	t_{op}	[h/year]
		mean load	$P_{av} = Q_a / t_{op}$	[kW]
		recirculation	$1/rec$	[-]
	Schedule	daily demand coincidence	$C_d = Q_{mid}/Q_{day}$	[%]
		demand seasonality	$C_a = Q_{sum}/Q_a$	[%]
		demand uniformity	$unif = P_{av,day}/P_{max,day}$	[%]
		rescheduling	t_i	[h]
	Technology	equipment supply quality	$\pm\Delta T_e$	[°C]
		product supply quality	$\pm\Delta T_p$	[°C]

post-integration	Reliability	Process continuity
		Load balancing
		Control Hardware
		Control Software
		Fouling risk
	Cost	HX sizing
		Storage sizing
		Distance to solar
		Auxiliary energy
	Benefit	Estimated solar yield
		Multi-supply
		Modulation
		Dependency on radiation
	Efficiency	Replacement of CHP
		Replacement of WH/HR

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Potential Enhancement of Solar Process Heat by Emerging Technologies

In its strive towards green, safe and efficient production processes, industry is starting to change its traditional practices, by implementing new process technologies or changing engineering strategies.

Obviously changes of the industrial processes will effect the energy supply strategies of companies. Besides using new emerging technologies, there is currently a strong trend towards hybrid energy supply where industry is seen as one player within large supply grids of heat and electricity. This changing energy supply will have an influence on the choice of process technologies, as PI and emerging technologies will have to be able to react on the variable offers. In such grids also exergy efficiency will be decisive to effectively re-use low grade waste heat or solar heat.

New process technologies aim to enhance heat and mass transfer to "intensify" reactions, mixing or heating/cooling of process media. These intensification strategies can be active, by actively introducing a new force, such as pulsation or radiation, or passive, by solely enhancing the transfer environment, such as extended surfaces for heat exchange. Strategies used in new technologies with impacts on solar heat supply are:

- Heat transfer enhancment
- Batch to continuous
- Increasing selectivity in separation processes
- Intensification of electrohydrodynamics

Within Subtask B of IEA Task 49 some exemplary processes have been collected that enhance the potential or techno-economic feasibility of solar process heat by new process technologies. These range over new heat exchanger concepts, over membrane reactors to solar furnaces and solar particle receiver technology, as shown in Figure 15.

Further details can be found in the report *Potential Enhancement of Solar Process Heat by Emerging Technologies.*

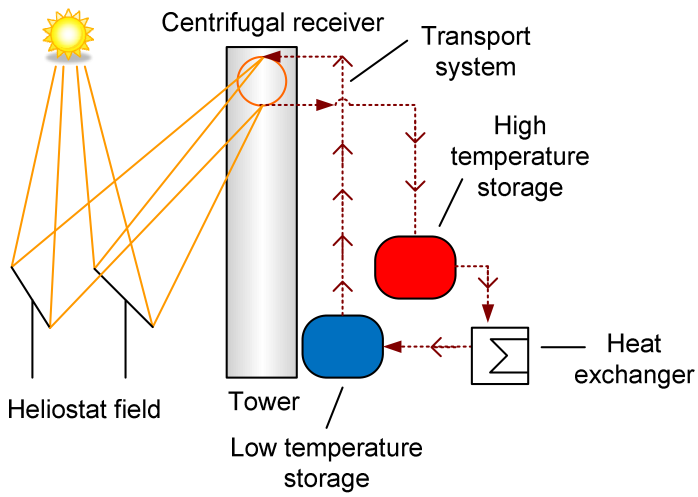

Figure 15: Solar particle receiver – new high temperature concept (Prosinecki, in Muster-Slawitsch et al., 2016)

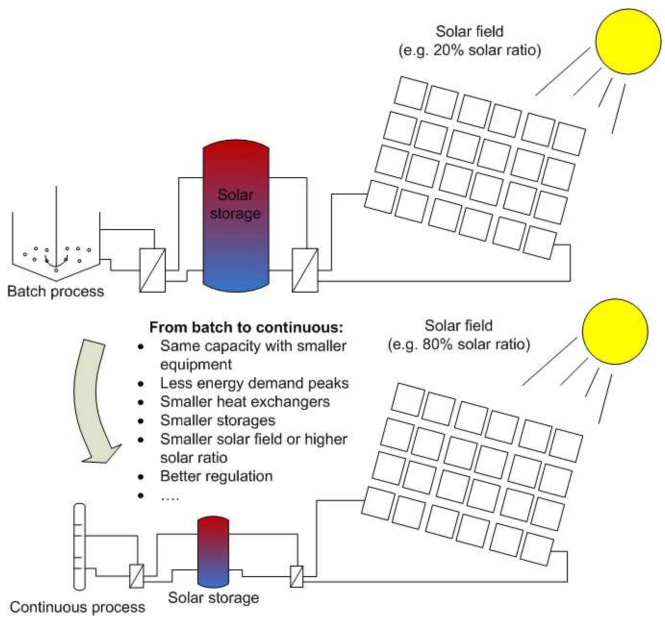

Figure 16: effects on solar process heat by changing from batch to continuous processes (example for intensification strategies)