Solar Heat for Industrial Processes

Available Technologies, Design Procedures, Upcoming Innovations

IEA SHC Solar Academy: Solar Heating for Industrial Processes

Pedro Horta

Fraunhofer Institute for Solar Energy Systems ISE

6th July 2017

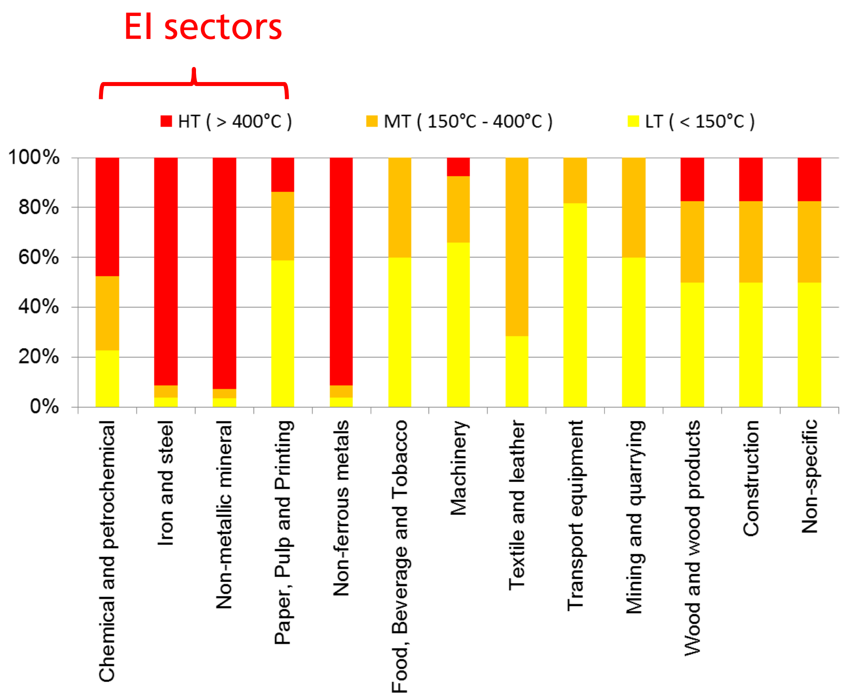
www.ise.fraunhofer.de

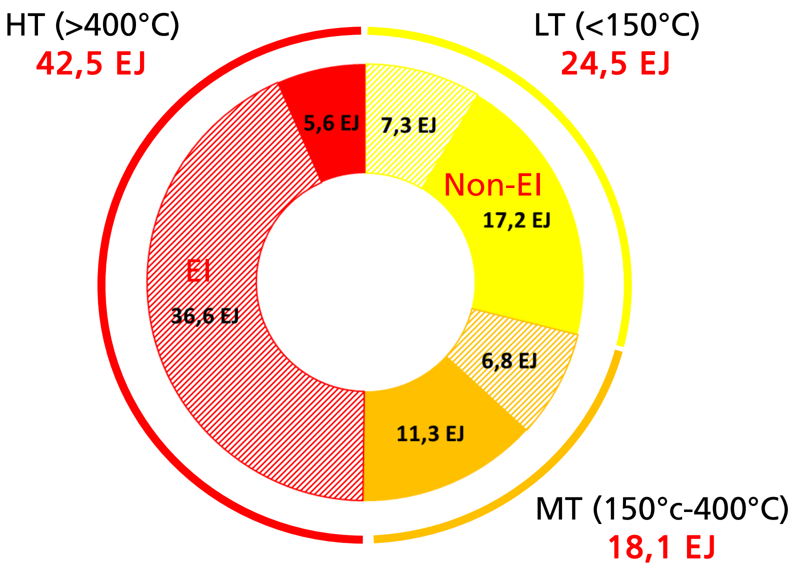
Fraunhofer ISE

Temperature levels

- Heat requirements in Industry occur at different temperature levels in different sectors [1]:

~ 50% HT; ~ 50% MT + LT



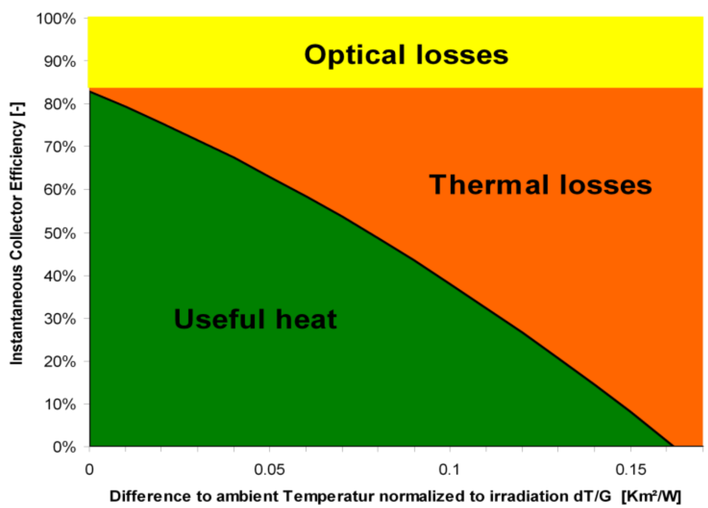


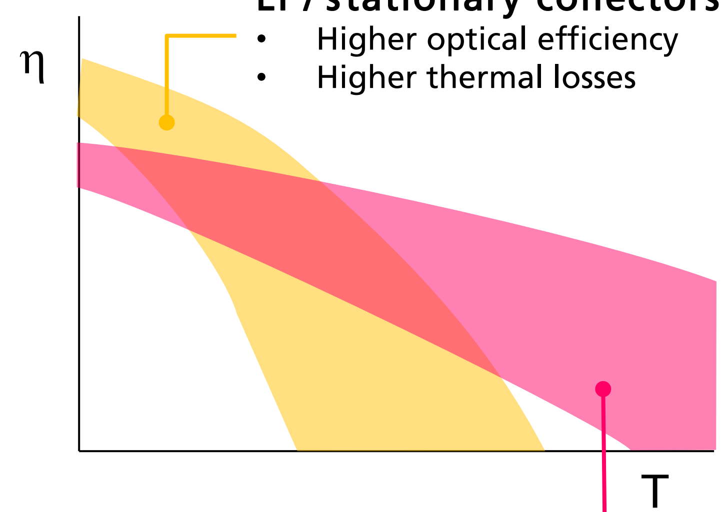
 [1] International Renewable Energy Agency (IRENA), calculations by Deger Saygin based on IEA source [2] (2014)

Fraunhofer ISE

Technology vs. Temperature

- The efficiency of a solar collector depends on incidence dependent optical losses and on operating temperature dependent thermal losses





LT / stationary collectors:
- Higher optical efficiency
- Higher thermal losses

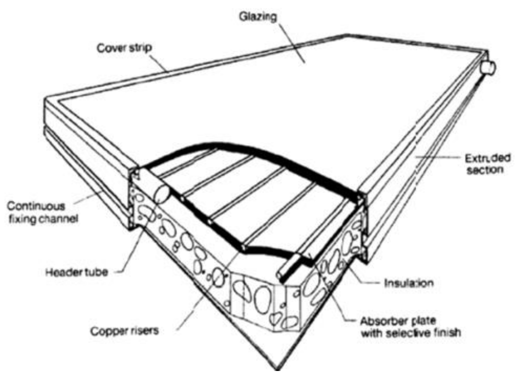
MT / tracking collectors:
- Lower optical efficiency
- Lower thermal losses

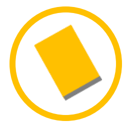
Fraunhofer ISE

Stationary collectors

- Stationary collectors present lower O&M requirements and system costs. Operation temperature limited to LT (T<150°C)

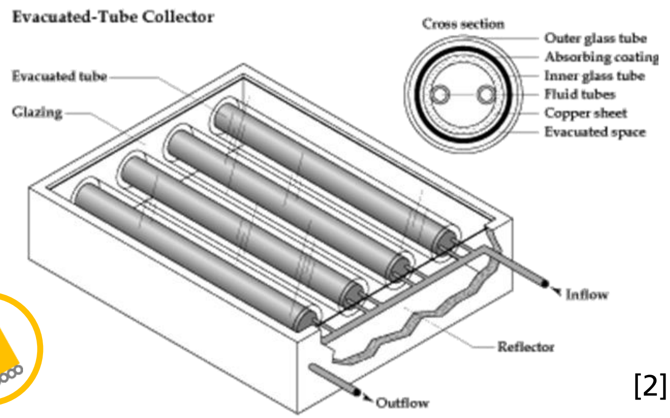
[2]

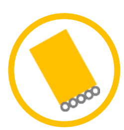




Flat Plate collectors:
- common temperature range of 30°C – 100°C
- absorber tubes through which working fluid flows covered by absorber sheet and a transparent cover.
- absorber coating converts solar irradiation into heat transferred to the working fluid in the tubes
- usual working fluid is water/glycol mixture
- little maintenance and relatively cheap

Evacuated Tube collectors:
- common temperature range of 50°C – 130°C
- row of parallel vacuum glass tubes
- absence of air highly reduces convection losses
- 2 categories of ETC:
- Direct flow principle
- Heat pipes principle (as in figure)





[2]

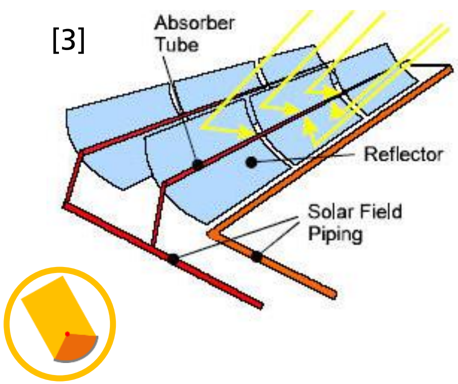
[2] gef, UNEP, ome; Technical Study report on SHIP, State of the art in the Mediterranean region

Fraunhofer ISE

Tracking collectors

- <u>Tracking collectors</u> are more demanding in terms of O&M and costs. Yet operation temperatures cover the <u>whole range of MT (T<400°C)</u>

[3]

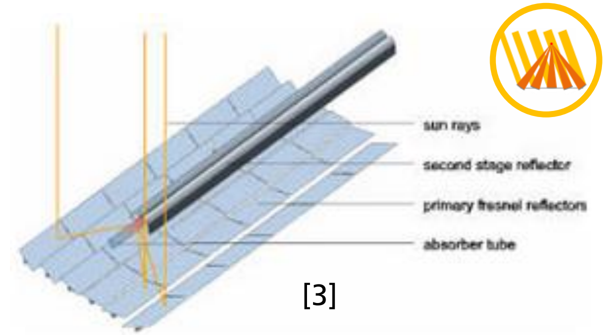


Parabolic Trough:

- <u>temperature range of 150°C – 400°C</u>
- Line-focusing system (one-axis tracking)
- Reflector: curved glass mirror or aluminium sheet
- Usual HTF: Water/Steam or thermal oil

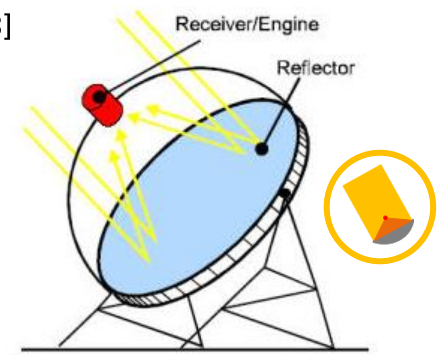
Linear Fresnel:

- <u>temperature range of 150°C – 400°C</u>
- Line-focusing system (one-axis tracking)
- approx. parabolic trough by segmented mirrors: principle of Fresnel
- Easier installation in flat rooftops (weight distrib., lower aerodyn. loads)
- Reflector: curved glass mirror or aluminium sheet
- Usual HTF: Water/Steam or thermal oil



[3]

[3]



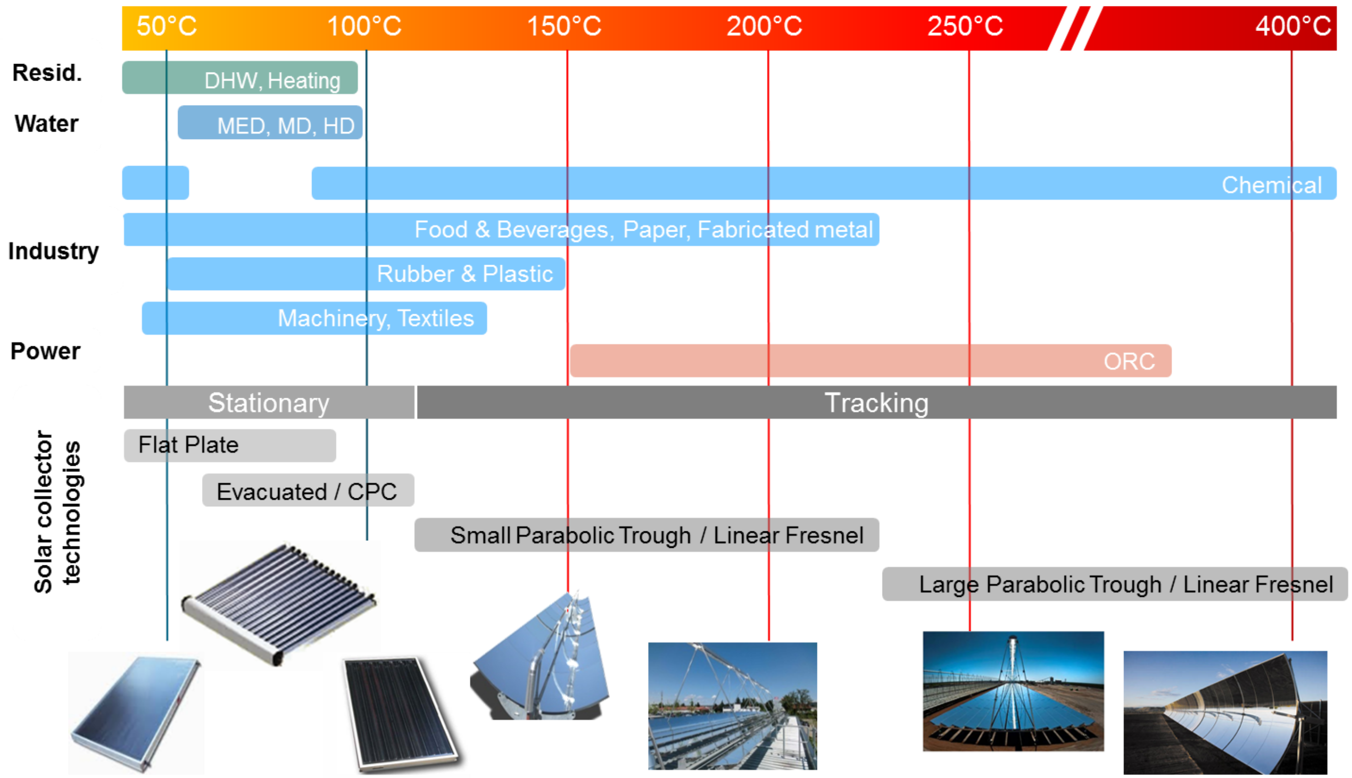
Parabolic Dish:

- <u>common temperature range of 250°C – >400°C</u>
- Point-focusing system (2-axis tracking)
- Moving (modular) receiver
- Potential for higher temperatures

 [3] Adapted from SolarPaces.org, 2016), http://www.solarpaces.org/csp-technology/csp-technology-general-information

Technology vs. Temperature

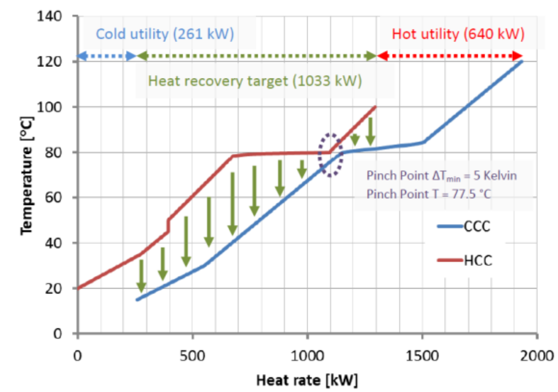
- Solar collector technology vs. required process temperature

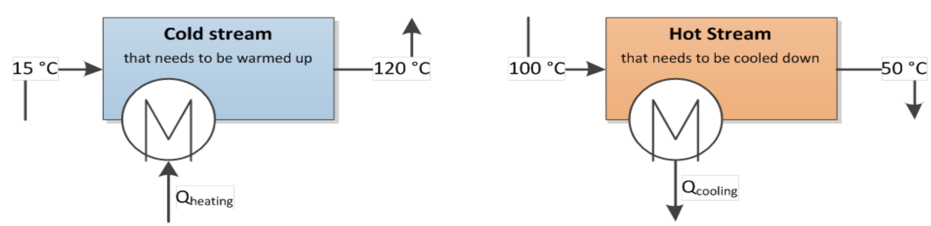


Design procedures

EE potential

- EE regarded as the first step towards a reduction of energy intensity in Industry
  - improving industrial energy efficiency by implementing best practice technologies (BPT) could reduce total final industrial energy demand more than 25% [4]
- Pinch analysis enables an overview of cross-process heat exchange possibilities [5]
  - Quantification of maximum heat recovery and effective heating and cooling requirements (efficient energy supply)
  - visualized via hot and cold composite curves (CCs)
  - Requires a detailed knowledge of the heating and cooling requirements
  - Each stream is defined by mass flow, specific heat and inlet and target temperatures



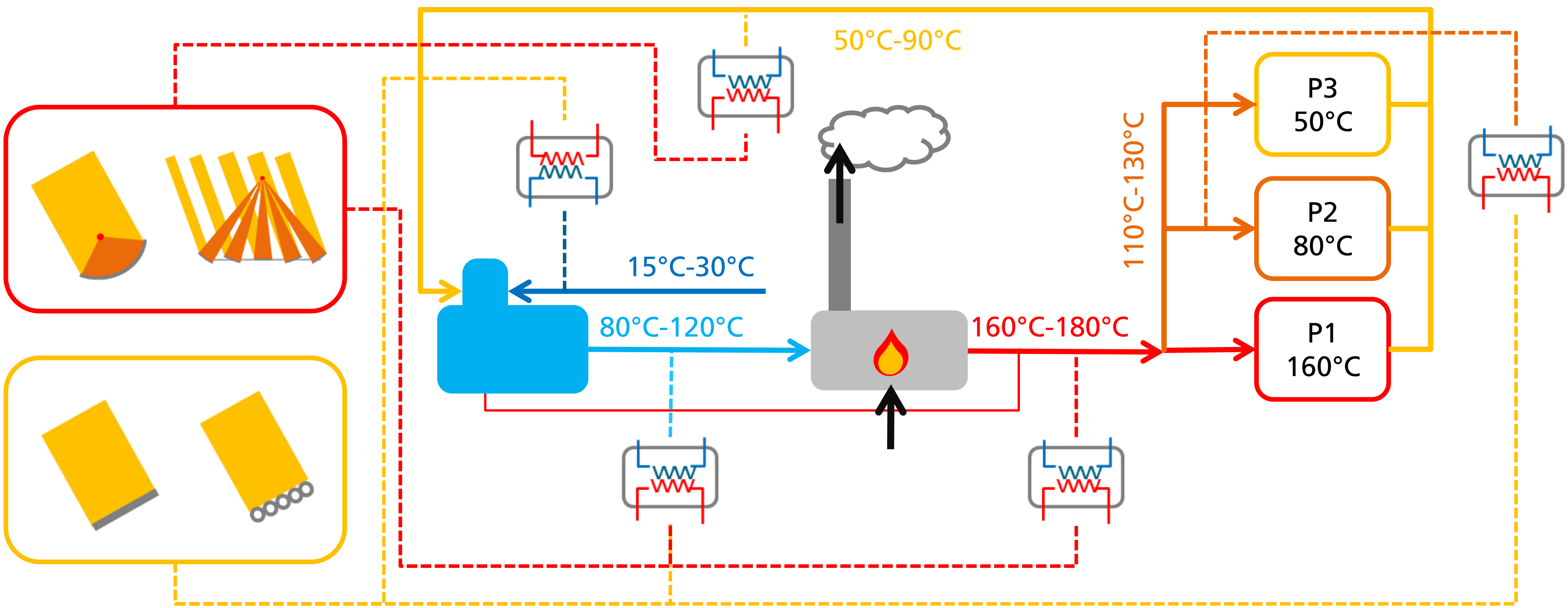


[4] Saygin, D., Patel, M.K. and Gielen, D.J. (2010). Global Industrial Energy Efficiency Benchmarking: An Energy Policy Tool, Working Paper, November 2010. United Nations Industrial Development Organization (UNIDO), Vienna.
[5] Muster, Bettina et al., 2015. Guideline for solar planners, energy consultants and process engineers giving a general procedure to integrate solar heat into industrial processes by identifying and ranking suitable integration points and solar thermal system concepts. IEA/SHC Task 49/IV, Subtask B, Deliverable B2

Fraunhofer ISE

Design procedures

- Less resistance to integration at supply level. Lower temperatures in integration at process level



Fraunhofer ISE

Design procedures

- Criteria for process or supply level integration

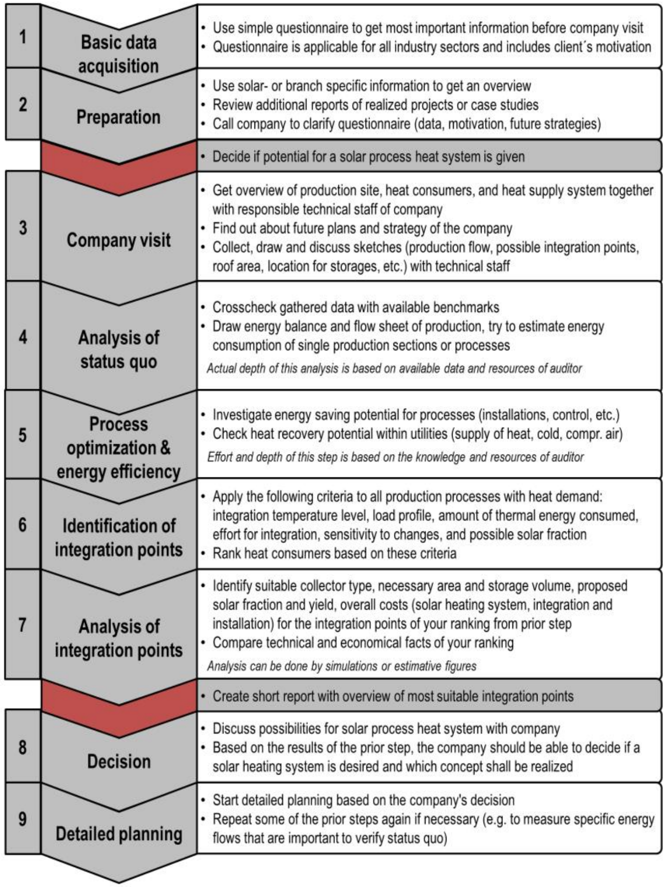
Criteria	Process level	Supply level
Detailed process data	Required	Not needed
Preliminary process integration analysis	Essential	Generally recommended
Flexibility to adapt to later changes in processes	Low	High
Collector efficiency	Potentially higher	Usually lower
Solar heat contribution potential	Restricted	Usually higher
Heat storage necessity	Depends on the profile of the selected process stream(s)	Not necessary if not exceeding the base load of the utility

Design procedures

Pre- and feasibility studies

- Holistic planning approach
  - Pre-analysis: boundary conditions
    - Checklists, phone calls [6]
    - motivation of the company?
  - Analysis of process characteristics and heat distribution network
    - Site visit with technician, sketch of the building
    - Temperature levels, condition of heat distribution network
    - Open / closed processes, heat integration at process level or supply level (heat network)
    - Process-schemes, load profiles, installation of measuring equipment
  - Process optimization and EE measures [7]
    - Processes state-of-the-art? Future plans?
    - Heat exchanger optimization (pinch analysis)

[5]



[6] www.solar-process-heat.eu/checklist

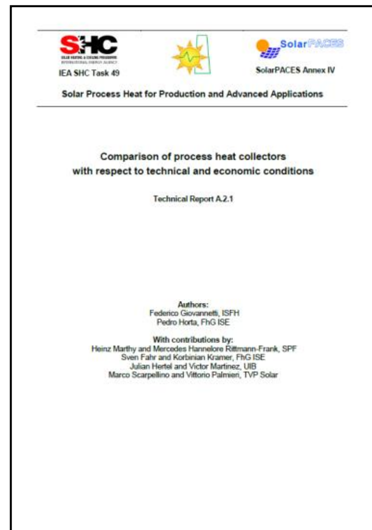
[7] C. Brunner et al. 2010: IEE-Project Einstein: www.iee-einstein.org

Fraunhofer ISE

Design procedures

Simulation tools

- Different simulation tools are available enabling both a simplified or detailed approach
  - Nomograms
  - ScenoCalc (Solar Keymark)
  - TRNSYS
  - T * SOL
  - Polysun
- Summary and comparison of available tools in IEA SHC task49



IEA SHC Task 49

SolarPACES Annex IV

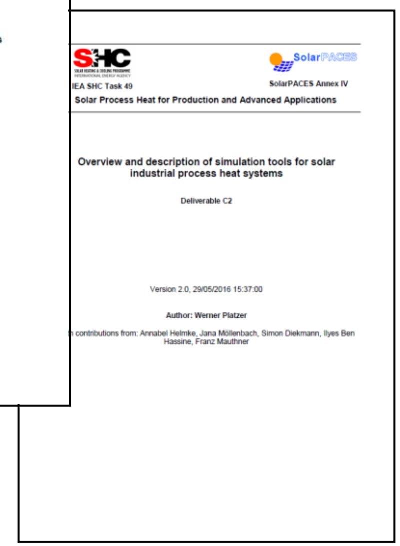
Solar Process Heat for Production and Advanced Applications

Comparison of process heat collectors
with respect to technical and economic conditions

Technical Report A.2.1

Authors:
Federico Giovannetti, ISFH
Pedro Horta, FhG ISE

With contributions by:
Heinz Marthy and Mercedes Hannelore Rittmann-Frank, SPF
Sven Fahr and Korbinian Kramer, FhG ISE
Julian Hertel and Victor Martinez, UIB
Marco Scarpellino and Vittorio Palmieri, TVP Solar



IEA SHC Task 49

SolarPACES Annex IV

Solar Process Heat for Production and Advanced Applications

Overview and description of simulation tools for solar industrial process heat systems

Deliverable C2

Version 2.0, 29/05/2016 15:37:00

Author: Werner Platzer

n contributions from: Annabel Helmke, Jana Möllenbach, Simon Diekmann, Ilyes Ben Hassine, Franz Mauthner

[8]

[8] http://task49.iea-shc.org/publications

Fraunhofer ISE

Challenges

Technology and competitiveness

- Technology
  - Central receiver → HT processes (EI sectors)
  - Process level integrations → process intensification
  - Supply level integration → Balance of Plant
  - Available area → building integration, compact optical designs
  - Hybridization → combination with EE, heat pumps, biomass/biogas, power-to-heat
  - Durability → industrial environment conditions / requirements

- Competitiveness
  - Technology cost reductions
  - Optimized integration with waste heat and alternative technologies
  - Switch from Payback to NPV on investment appraisal
  - Hedging against volatile energy prices
  - Contracting models → PPA duration, residual value
  - COP21 emmission goals

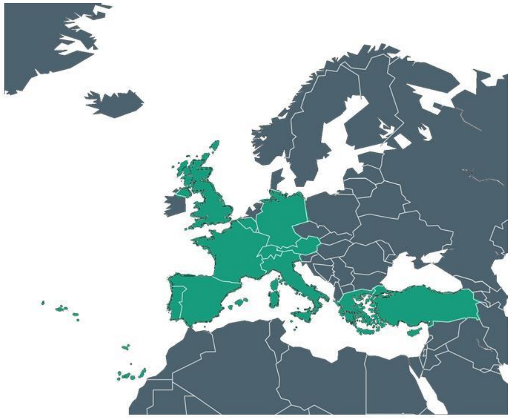
[9] [10] [11] [12] [13] [14]

[9] SolarPACES IEA, http://www.solarpaces.org/
[10] SHC/IEA Task 49, http://task49.iea-shc.org/
[11] INSHIP ECRIA, H2020 GA 731287, http://inship.eu/index.php
[12] FROnT, H2020, http://www.front-rhc.eu/
[13] SHC/IEA Task 54, http://task54.iea-shc.org/
[14] TrustEE, H2020 GA 696140, http://www.trust-ee.eu/

Fraunhofer ISE

Upcoming innovations

- **INSHIP** – Integrating National Research Agendas on Solar Heat for Industrial Processes
  - H2020 LCE-33-2016 (RIA)
    GA: 731287
  - 01.01.2017 – 31.12.2020
    http://inship.eu/
- establishes the European Common Research and Innovation Agenda **(ECRIA) on Solar Heat to Industrial Processes**
  - coordination objectives
  - coordinated R&D activities (TRLs 2 to 5)
    - solutions for solar integration (TRL 2-5)
    - solar technologies for high temperature processes (TRL 2-5)
    - integration of SHIP in the overall energy system



Fraunhofer ISE

Upcoming innovations

- WP2: Technology and applications to low temperature SHIP (80°C to 150°C)
  - Task 2.1 - Solar technology for low temperature SHIP
  - Task 2.2 - SHIP applications in drying processes
  - Task 2.3 - Durability and modularity
  - Task 2.4 - Dynamic solar field and system control
- WP3: Technology and applications to medium temperature SHIP (150°C to 400°C)
  - Task 3.1 - Solar driven steam generation
  - Task 3.2 - Balance of Plant concepts
  - Task 3.3 - Durability and reliability
  - Task 3.4 - Compact and building envelope integrated solar field concepts

FONDAZIONE BRUNO KESSLER

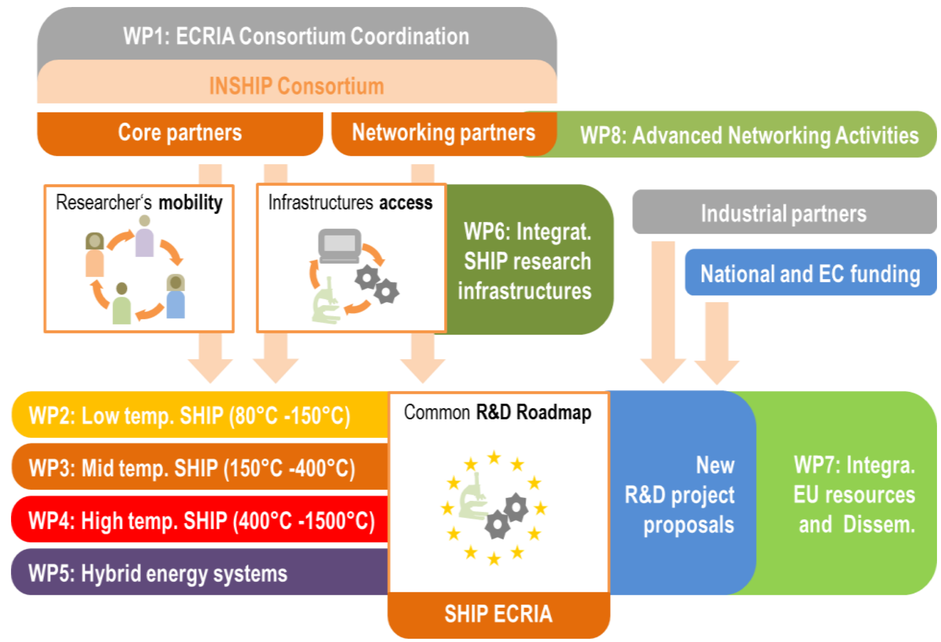
Fraunhofer ISE

Upcoming innovations

- WP4: Technology and applications to high temperature SHIP (400°C to 1500°C)
  - Task 4.1 - Solar metals production for the metallurgical industry
  - Task 4.2 - Solar lime production for the cement industry
  - Task 4.3 - Solar fuel production for the transportation sector
  - Task 4.4 - High-concentration optics for high-temperature solar reactors
- WP5: Hybrid energy systems and emerging process technologies
  - Task 5.1 - Process integration and storage management
  - Task 5.2 - Emerging process technologies (process intensification)
  - Task 5.3 - Hybrid energy supply systems
  - Task 5.4 - Industry parks and heat distribution networks
  - Task 5.5 - 100% RES branch concepts

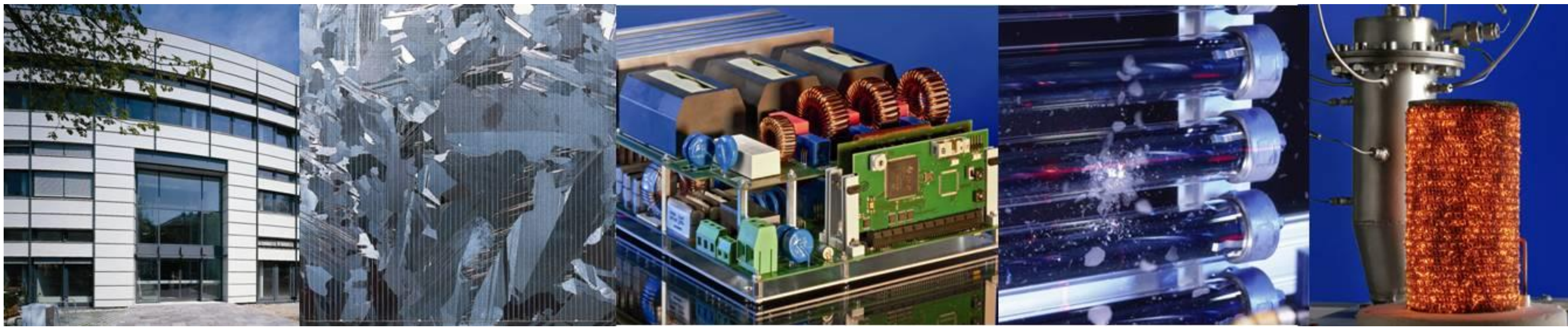
Upcoming innovations

- Coordination objectives
  - cooperation between EU R&D institutions
  - alignment of SHIP related national research and funding programs
  - acceleration of knowledge transfer to the European industry
  - Offer researchers and industry comprehensive portfolio of research capabilities



- Infrastructure Access Scheme
  - Development of R&D activities aligned with INSHIP ECRIA topics
  - Consortia engaging INSHIP and **invited Industrial partners**

Thank you for your attention!



Fraunhofer Institute for Solar Energy Systems ISE

Pedro Horta

www.ise.fraunhofer.de
Pedro.horta@ise.fraunhofer.de

Fraunhofer ISE