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Almería (Spain)

Lecture:

Research & Development lines for medium temperature SHIP applications

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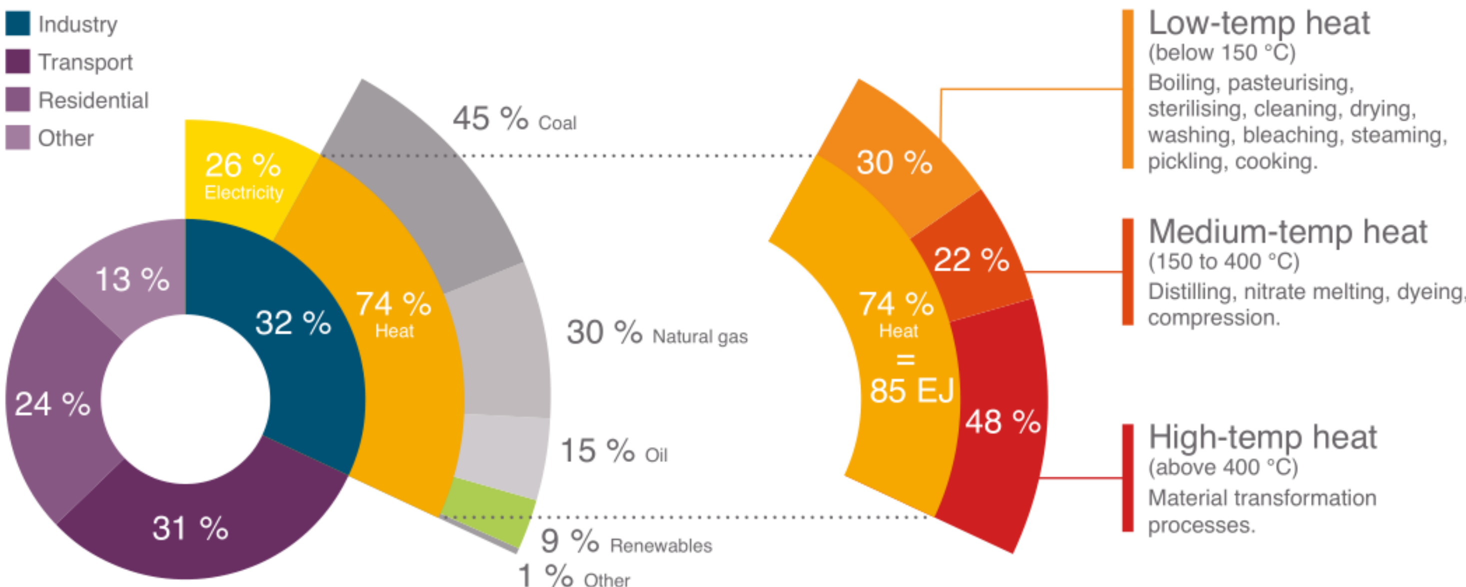
- Introduction
- Collector designs
- Working fluids
- Soiling & corrosion
- Integration tools
- References

Introduction

What is the potential for medium temperature SHIP?

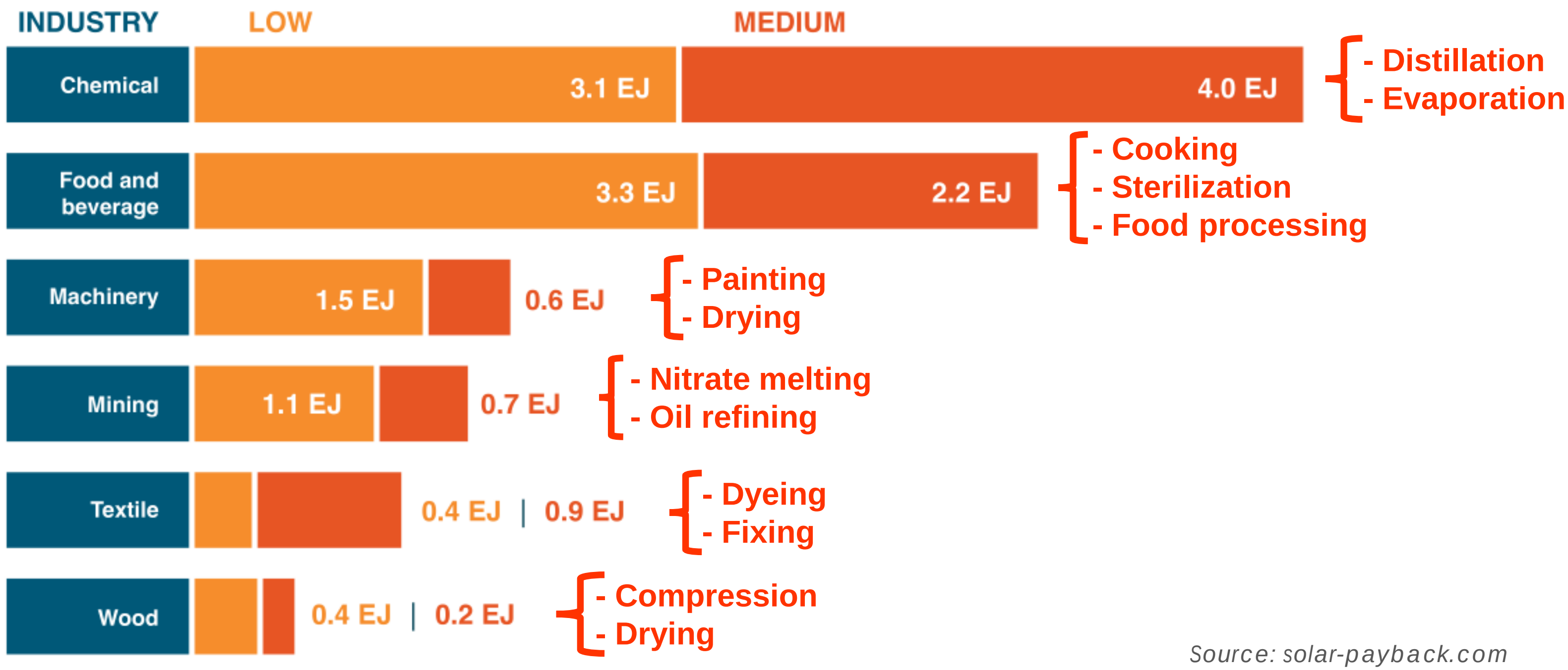


Source: solar-payback.com

- Final heat consumption in industrial sector is higher than electricity consumption worldwide. However, more attention is paid to electricity.
- The proportion of industrial heat supplied by renewable sources is still very low (9%). There is huge potential for SHIP.

Introduction

What industrial sectors & processes require medium temperature heat?



Source: solar-payback.com

- Approx. 40-60% of total required energy in steam, 10-30% in hot air.
- Conditions compatible with solar thermal technologies, with or w/o concentration.

Introduction

What are the most suitable technologies?

- Lots of technologies to produce heat from solar radiation.
- For medium temperature (150 °C – 400 °C), solar technologies with low or medium concentration (C<100) are the most suitable.
- If T < 200 °C, non-concentrating solutions (flat plates, evacuated tubes) may also be considered.
- Several design options and configurations, depending on process temperature, storage and integration requirements.

Parabolic-Trough Collectors (PTC)

Linear Fresnel Collectors (LFC)

Compound Parabolic Concentrators (CPC)

Fixed-Mirror Collectors

Introduction

What are the main challenges for medium temperature SHIP?

Technological

- Provide technological solutions suitable for industrial applications: space availability for large scale systems, flexibility.
- Focus on specific industrial needs: steam generation, air heating.
- Gain experience with thermal storage systems.

Costs & Reliability

- Increase reliability & durability of materials & devices.
- Long-term degradation of solar components in industrial environments.
- Reduction of investment costs, LCoH, O&M costs, payback periods.

Industrial Awareness

- Low awareness & visibility of SHIP.
- Integration of solar technology in existing & new industrial capacity.
- Facilitate installation, O&M.
- Provide technical resources & tools for SHIP integration.

→ Adapt solar-thermal technologies to fit the needs of specific industrial processes

Introduction

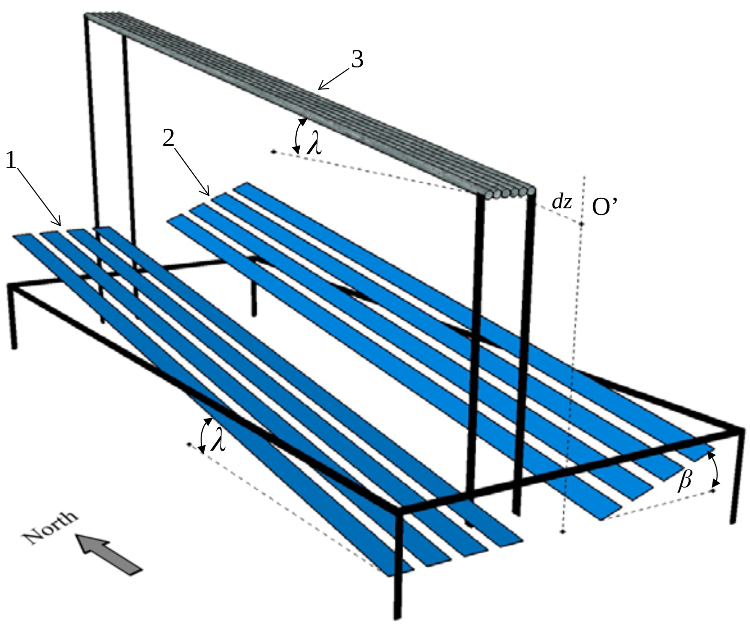
What are the main R&D lines to face those challenges?

- New collector designs suitable for industry
  (compact, lightweight, low cost & space requirements, easy installation & maintenance)
- New working fluids & devices
  (for easier steam generation, air heating & thermal storage)
- Analysis of soiling & corrosion in industrial environments
  (enhancement of maintenance methods)
- Development of improved integration methods, software tools, etc.

Content

Collector designs

Innovative compact linear Fresnel collector for industrial applications



Source: Pulido (2019)

Features & Benefits

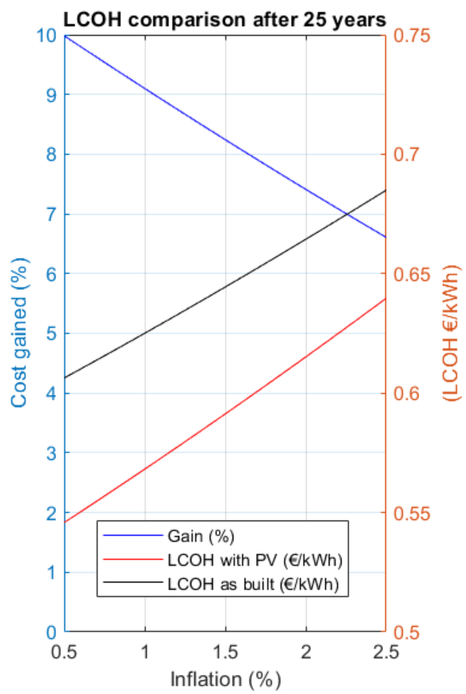
- Tilted design for both reflector & receiver: optical optimization to increase annual efficiency.
- Reflector arranged in two wings: for low sun elevations, one of them rotates to reduce optical losses at sunrise/sunset.
- Compact design, lightweight & low-cost materials, low space requirements.

R&D status

- ✓ Final design completed, patent presented.
- ✓ Prototype is being built at PSA.
- ✓ Test campaign, evaluation & experimental characterization planned.

Collector designs

Hybrid linear Fresnel collector (thermal + PV) for industrial uses



Source: Montenon (2018)

Features & Benefits

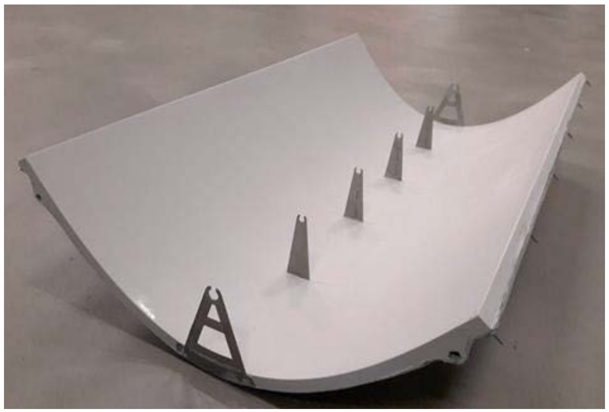
- PV modules attached to the side of linear Fresnel collector, with the same tracking axis as reflectors.
- Reduction of electrical consumptions (~50%) in industrial applications.
- Reduction of LCoH & financial risks.

R&D status

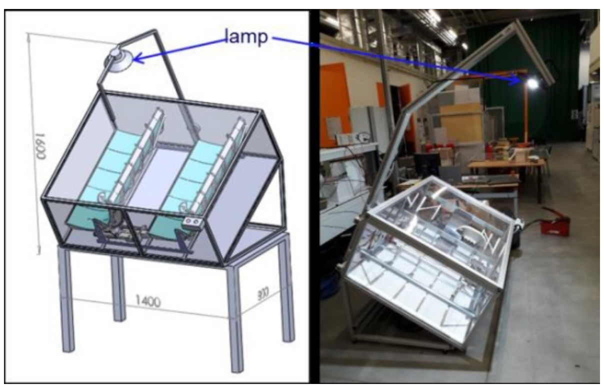
- ✓ Already installed at Cyprus Institute, supplying electricity/air conditioning to NTL (34%). Techno-economical assessment.
- ✓ Optimization for industrial environments planned.

Collector designs

"Solar Box": encapsulated parabolic-trough collector



Module



Prototype

Source: Vidal (2017)

Features & Benefits

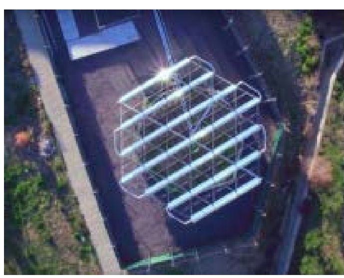
- ➢ Small-size parabolic troughs enclosed in a glasshouse.
- ➢ Reduction of wind loads, avoids heavy & costly structures (similar to flat plates).
- ➢ Protection of receiver tubes (not evacuated).
- ➢ Easy integration in buildings & reduced spaces.
- ➢ Low cost & easy maintenance

R&D status

- ✓ Prototype built at CEA (France).
- ✓ Overall assessment performed to evaluate theoretical & experimental results.
- ✓ Planned: Integration in "district heating" micro-grid.

Collector designs

Parabolic troughs with dual-axis tracking for industrial process heat



Source: lucidasolar.com

Features & Benefits

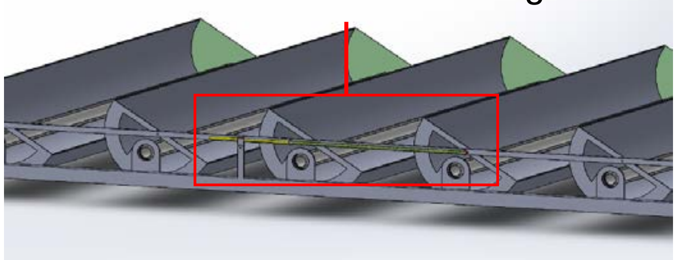
- Dual-axis solar tracking: elevation (conventional) and azimuthal (carousel system).
- 30 small modules (glass cover) in a moving carousel: reduces mobile parts & foundations.
- Increase of annual efficiency.
- Modular structure, easy integration & installation

R&D status

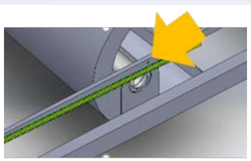
- ✓ Currently in commercial development (Lucida Solar: https://lucidasolar.com).
- ✓ Pilot unit giving solar heat & cooling to an industrial building at Izmir (Turkey) since 2017.
- ✓ Annual assessment performed by PSA.

Collector designs

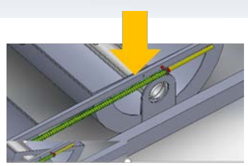
Quasi-stationary CPC with seasonal tracking



SMA actuator for tracking



Winter



Summer

Features & Benefits

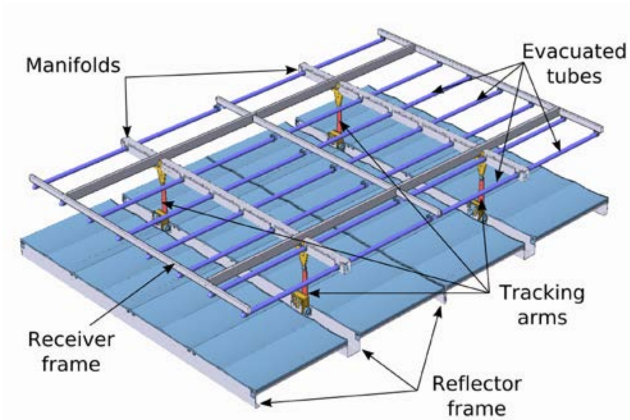
- ➢ Shape Memory Alloys (SMA) actuators: changes shape according to temperature
- ➢ Enables seasonal tracking (low cost, durable, simple): increases annual performance without expensive tracking systems.
- ➢ Tilted & flexible installation: integration in rooftops & industrial environments

R&D status

- ✓ Prototype installed and tested at Evora University (Portugal).
- ✓ Pilot solar field built at IRESEN (Morocco).
- ✓ Planned: complete thermal system (~100 kW) at industrial end user.

Collector designs

Fixed-Mirror concentrator with moving receiver



CCStaR solar concentrator (2015)

Features & Benefits

- Fixed reflectors with a mesh of rotatory receiver tubes following the focus: low cost, simple tracking, easy maintenance.
- Takes advantage of beam & diffuse radiation.
- Tilted & flexible installation: integration in rooftops & industrial environments

R&D status

- ✓ 2 Pilot modules installed and tested at UIB (Mallorca) & Cork Institute (Mérida).
- ✓ Commercial model until 2015 (CCStaR collector from Tecnología Solar Concentradora SL)
- ✓ No longer commercial (company ended activity).

Content

Working fluids

Main fluids considered for medium temperature SHIP

Conventional HTFs

Liquid water

- Clean, cheap.
- Mixed with glycol to avoid freezing.

Pressurization required for T > 100 °C

(T = 250 °C => P~40 bar)

HX required for process integration.

Thermal oils

Suitable for medium T

Toxic, flammable, expensive.

Alternative HTFs

Steam

Air

- Clean, cheap, suitable for medium T.
- Direct integration with industrial processes using steam/air.

Steam:

- Control of two-phase flow.
- Difficult integration with storage.

Air:

- Bad heat transfer
- High pumping consumptions.

Working fluids

Case study: Direct steam generation integrated with steam boilers

Source: industrial-solar.de

Features & Benefits

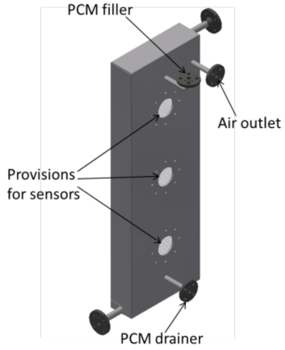
- Direct steam generation in the solar field (400 m^2 linear Fresnel, 166 °C, 6 bar): gained experience in supplying solar process steam.
- Combination with conventional steam boilers: reduce consumption of heavy fuel oil.
- Facilitate integration of solar heat in industry without interfering with existing infrastructure.

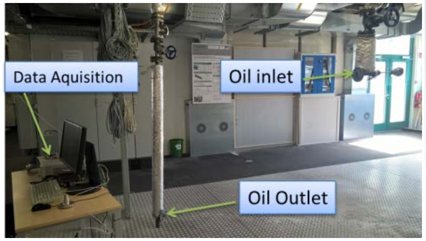
Status

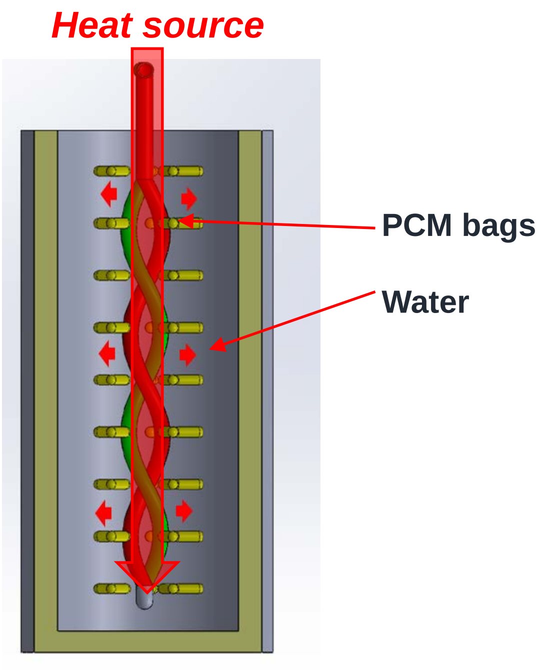
- ✓ Supplying steam since 2015 to RAM Pharma industry in Amman (Jordan)
- ✓ Tests of two concepts (steam drum / separator) in industrial environment.
- ✓ Assessment of two-phase flow pattern

Working fluids

PCM evaporator for indirect steam generation







Features & Benefits

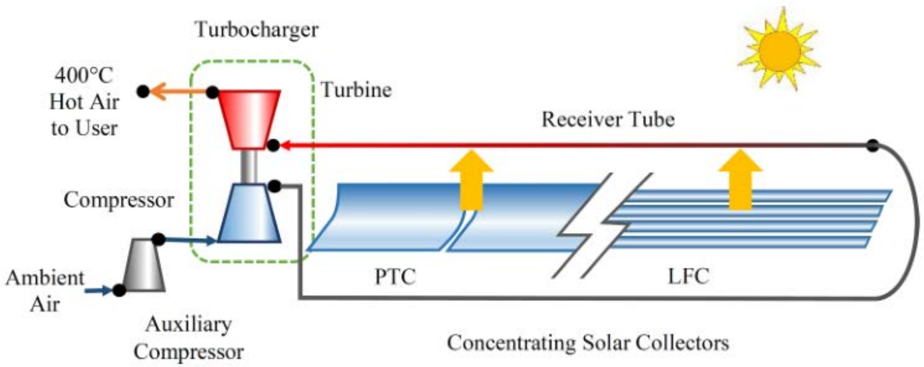
- Thermal storage device in latent heat.
- Efficient steam generation at medium temperature (T > 100 °C), enabling control of steam parameters.
- Reduces integration costs, improves dispatchability of steam production.

R&D status

- ✓ Prototype built and tested at Fraunhofer-ISE.
- ✓ Thermal models of alternative HX with encapsulated PCM.
- ✓ Planned integration in real industry.

Working fluids

Direct solar air heating assisted by turbocharger



Linear Fresnel Collector

Turbocharger

Source: Famiglietti (2021)

Features & Benefits

- Produces hot air for industrial applications (drying) at 300-400 °C.
- Direct air heating inside line-focus concentrating collectors (LFC/PTC).
- Avoids pumping consumptions with turbocharger (turbocompressor + turbine), using an open Brayton cycle.

R&D status

- ✓ Viability assessment performed.
- ✓ Prototype installed and tested at UC3M, connected to a small linear Fresnel collector.

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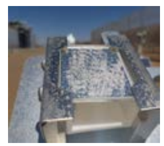
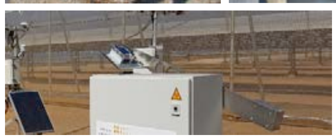
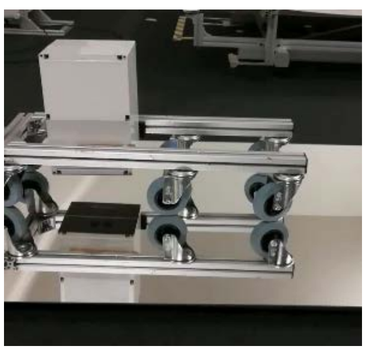
Soiling & Corrosion

Analysis of soiling in industrial environments




Objective

- Determine and reduce the impact of soiling on solar reflectors in industrial environments

Advantages & Benefits

- Development of anti-soiling coatings.
- Selection of locations, performance prediction.
- Improve cleaning devices & maintenance methods.

R&D status

- ✓ Characterization of soiling conditions in different environments, evaluation of impact on mirrors' reflectance.
- ✓ Determination of pollen deposition rate by satellite imagery, monitoring of organic soiling in industrial areas (Freiburg).
- ✓ Prototype of cleaning device with integrated measurement of soiling (reflectometer).

Soiling & Corrosion

Analysis of reflectors' corrosion in industrial environments

Pollutant	Industrial source
SO_2	Use of coal and oil, industrial plants (cement, coke, incinerators)
NO_2	Traffic, cement plants, incinerators
H_2S	Pulp and paper industry, farming, coal-preparation plants, coke plants
Cl_2	Pulp and paper industry

Source: García-Segura (2019)

Objective

- Characterize and mitigate the degradation of solar reflectors due to corrosion sources in industrial environments

Advantages & Benefits

- Improvement of reflectors' durability in industrial applications, selection of suitable materials for specific environments.
- Prediction of expected degradation.
- Definition of maintenance requirements.

R&D status

- ✓ Classification of corrosive gases & conditions in industrial environments
- ✓ Accelerated ageing tests of reflectors with different materials in representative industrial locations.

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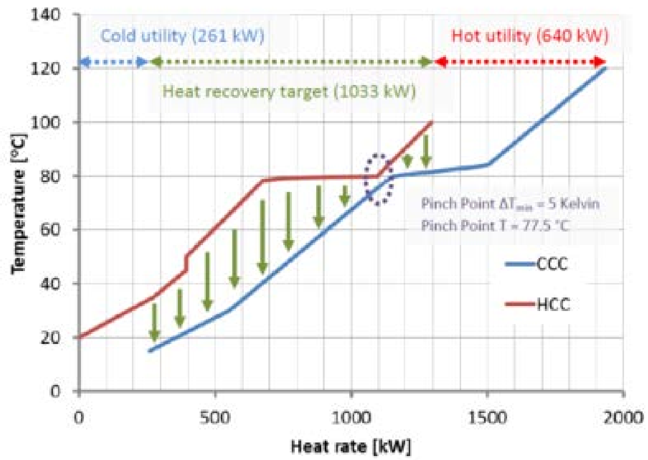
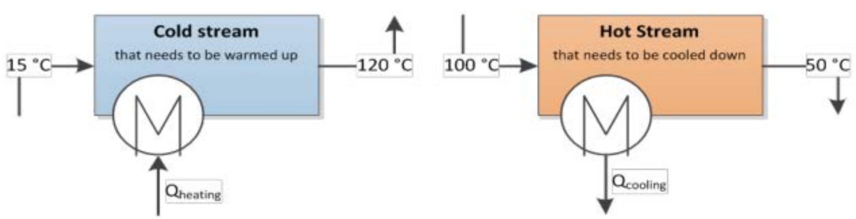
Integration tools

"Pinch analysis": methodology for optimized integration of heat flows





Features & Benefits

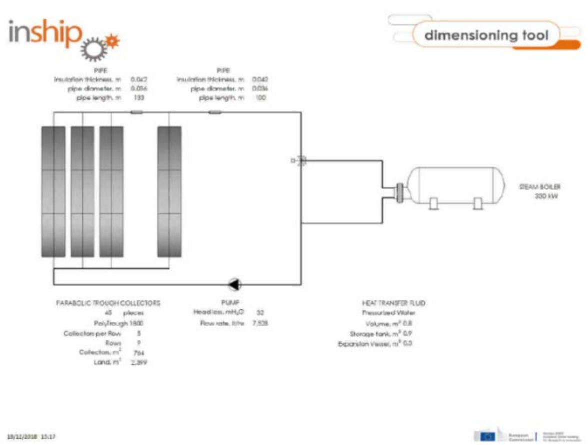
- Systematic method for reducing energy consumption of industrial processes by calculating thermodynamically feasible energy targets.
- Enables an overview of cross-process heat exchange possibilities, visualized via hot and cold composite curves (CCs).
- Efficient energy supply: quantification of maximum heat recovery and effective heating and cooling requirements.

Tools & resources

- PinCH (ETH Lausanne): https://pinch-analyse.ch/en
- SOCO (AEE INTEC): https://www.aee-intec.at/soco-p138
- HeatIt (free & simple Excel tool, Pinchco): http://www.pinchco.com/images/site/heatit_v5.2.4_2014_12_07-basic.xlsm
- Integration (CanmetENERGY, Canadian Gov.): https://www.nrcan.gc.ca/energy/efficiency/industry/processes/systems-optimization/process-integration/products-services/integration-software/5529

Integration tools

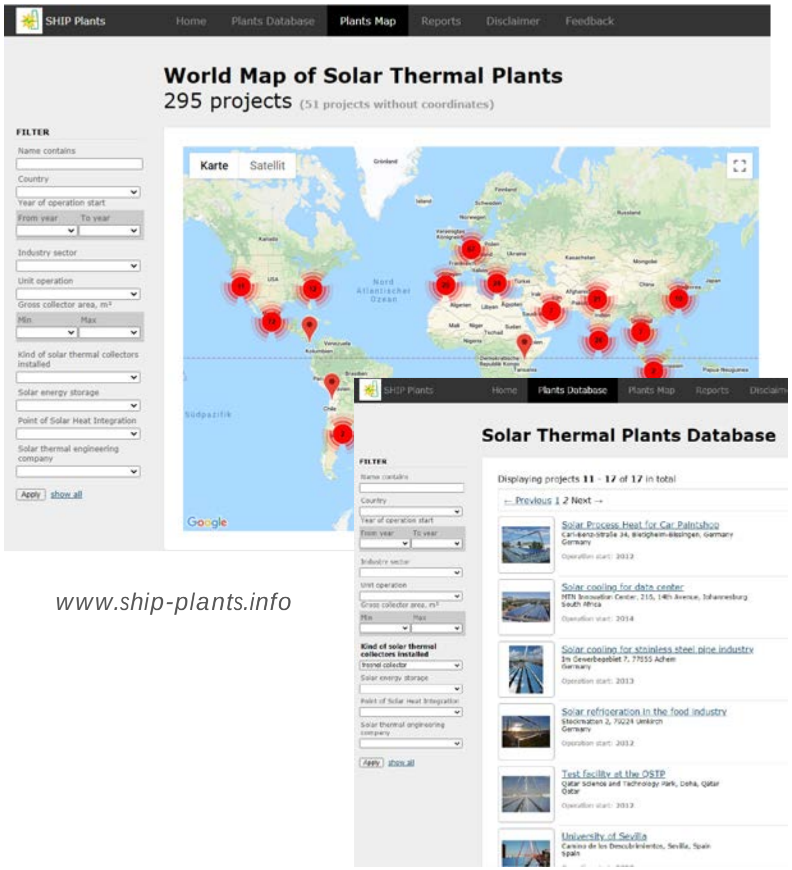
Software tools for design & simulation of SHIP applications



- RESSSPI, solar simulator for industrial processes (free web tool from SOLATOM): www.ressspi.com
- INSHIP dimensioning tool (Excel file)
- Greenius (DLR), free analysis tool including solar process heat: https://www.dlr.de/sf/en/desktopdefault.aspx/tabid-11688/20442_read-44865/
- SAM (NREL), free techno-economic software tool (includes process heat & LCoH calculation): https://sam.nrel.gov/
- TRNSYS, flexible & component-based simulation software: www.trnsys.com
- T*SOL, commercial software for simulation & design of solar thermal systems: https://valentin-software.com/en/products/tsol/
- Polysun (commercial, energy systems simulator): https://www.velasolaris.com/?lang=en

Integration tools

Web resources & databases of SHIP projects



www.ship-plants.info

- SHIP plants database (AEE INTEC): www.ship-plants.info
- Reports, suppliers database & dissemination materials: www.solar-payback.com
- News, webinars, data from largest installations: www.solarthermalworld.org
- IEA SHC Task 49 Website. Integration guidelines & resources for planners & installers: https://task49.iea-shc.org/
- Practical information about industrial processes & integration concepts: http://wiki.zero-emissions.at

Content

References

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Solar Facilities for the European Research Area

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End of Presentation

- Thank you for your attention
- Questions ?

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