Solar Heat for Industrial Processes
Worldwide Potential, Sectors, Processes and Overview on Installed Systems

Werner Weiss
AEE - Institute for Sustainable Technologies
A-8200 Gleisdorf, Feldgasse 2
AUSTRIA
Heat accounts for more than half of world’s total final energy consumption today

World total final energy consumption, 2011 (322 EJ)

- **Electricity**: 25.9%
- **Transport**: 26.7%
- **Industry**: 24.4%
- **Buildings**: 20.2%
- **Other sectors**: 2.8%

Source: IEA Statistics

Source: Paolo Frankl, IEA, Paris
Heat plays important role worldwide

Note: Figure based on 2009 data
Source: Energy Technology Perspectives 2012

Source: IEA Technology Roadmap – Solar Heating & Cooling

www.aee-intec.at  AEE - Institut für Nachhaltige Technologien
Global Solar Heating and Cooling Markets
Total installed capacity of unglazed and glazed water collectors in operation in the 10 leading countries by the end of 2011.

- **China**: 15,784 MWth
- **United States**: 10,710 MWth
- **Turkey**: 10,164 MWth
- **Brazil**: 4,999 MWth
- **Australia**: 4,612 MWth
- **India**: 3,347 MWth
- **Austria**: 3,334 MWth
- **Japan**: 3,275 MWth
- **Israel**: 2,986 MWth

Legend:
- Green: Evacuated tube collectors
- Blue: Unglazed water collectors
- Orange: Flat plate collectors
Total capacity of glazed flat plate and evacuated tube collectors in operation in $kW_{th}$ per 1,000 inhabitants by the end of 2011

Capacity $[kW_{th}/1,000$ inh.]
Annual installed capacity of flat plate and evacuated tube collectors from 2000 to 2011
Total installed capacity in operation by economic regions at the end of 2011

- China: 64.9%
- Europe: 16.7%
- United States / Canada: 7.1%
- Asia excl. China: 4.1%
- Latin America: 2.7%
- Australia / New Zealand: 2.1%
- MENA Region: 2.0%
- Sub-Saharan Africa: 0.4%
Distribution of solar thermal systems by application for the newly installed glazed water collector capacity of by economic region in 2011.
Potential of solar heating and cooling by sector (EJ/yr)

Solar heating and cooling capacity could produce annually by 2050:
- 16.5 EJ solar heat (16% of TFE low temp. heat)
- 1.5 EJ solar cooling (17% of TFE cooling)

Source: IEA Technology Roadmap – Solar Heating & Cooling
Regional solar heating and cooling generation in buildings and industry

Source: IEA Technology Roadmap – Solar Heating & Cooling
Temperature Levels

Three different temperature levels are used for describing the quality of the demand for heat in industries:

Low temperature level is defined as up to 95°C, corresponding to the typical heat demands for space heating or industrial processes like washing, rinsing and food preparation.

Temperatures between 95°C and 250°C are defined “medium”. This heat is normally supplied through steam.

Temperatures over 250°C are “high” and needed to manufacture metals, ceramics, glass etc.
Industrial heat demand by temperature level and industrial sector

Source: ECOHEATCOOL
Industrial Heat Demand

Source: IEA ETP 2012
Industrial heat demand by temperature level and industrial sector

Industrial heat demand by temperature level in the EU in 2010 (left) and industrial heat demand in the EU in 2010 and expected demand in 2050 (right). Source: OECD / IEA (2012).
Temperature levels of processes

- Parabolic trough collector
- CPC collector
- Vacuum tube collector
- Flat plate collector

- Food industry:
  - Cooking
  - Cleaning and washing
  - Evaporation and distillation
  - Pasteurization

- Textile industry:
  - Washing
  - Dyeing
  - Drying
  - Bleaching

- Surface treatment:
  - Cleaning
  - Finishing
  - Surface treatment

- Chemical industry:
  - Distillation
  - Extraction
  - Cooking

- All sectors:
  - Preheating of processes
  - Heating of industry halls

<table>
<thead>
<tr>
<th>Process Temperature</th>
<th>100°C</th>
<th>200°C</th>
<th>300°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Efficiency first

1st step

2nd step: Solar Thermal Energy
Integration on supply level – hot water

Feed-in solar energy in heating circuit
High set temperature
Simple system integration
Small number of system layouts
Integration on process level

Solar energy is directly used for the process
Different system layouts possible
Often complex system integration
Parabolic Trough Baking Device developed in Lesotho

Source: Ivan Yaholnitsky, BBCDC
Mzuri Sana Farm - Zimbabwe
First Results – IEA SHC Task 49 Data base

122 systems, 125,600 m², 87.8 MW

52 systems with 2,250 m² total

17 systems with 98,700 m² total

Source: IEA SHC Task 49
First Results IEA SHC Task 49 - Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>20</td>
</tr>
<tr>
<td>Germany</td>
<td>13</td>
</tr>
<tr>
<td>Greece</td>
<td>13</td>
</tr>
<tr>
<td>Spain</td>
<td>12</td>
</tr>
<tr>
<td>Portugal</td>
<td>4</td>
</tr>
<tr>
<td>Switzerland</td>
<td>4</td>
</tr>
<tr>
<td>France</td>
<td>2</td>
</tr>
<tr>
<td>Romania</td>
<td>2</td>
</tr>
<tr>
<td>Cyprus</td>
<td>1</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>1</td>
</tr>
<tr>
<td>Sweden</td>
<td>1</td>
</tr>
<tr>
<td>Turkey</td>
<td>1</td>
</tr>
<tr>
<td>India</td>
<td>8</td>
</tr>
<tr>
<td>China</td>
<td>5</td>
</tr>
<tr>
<td>Thailand</td>
<td>3</td>
</tr>
<tr>
<td>Vietnam</td>
<td>3</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>1</td>
</tr>
<tr>
<td>Jordan</td>
<td>4</td>
</tr>
<tr>
<td>USA</td>
<td>8</td>
</tr>
<tr>
<td>Panama</td>
<td>1</td>
</tr>
<tr>
<td>Argentinia</td>
<td>1</td>
</tr>
<tr>
<td>Chile</td>
<td>1</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>1</td>
</tr>
<tr>
<td>k.A.</td>
<td>7</td>
</tr>
</tbody>
</table>

Source: IEA SHC Task 49
System price related to system size
Drying Applications
Generic System - 1Nso

Main Applications
- Coffee Drying
- Tea Drying
- Maize Drying
- Tobacco Drying

Temperature range for the processes: 30 - 80°C

Heat carrier: air

Recommended Collector Types:
- glazed or unglazed air collector
- Solar Wall ®
Air based Drying System
Air based Drying Systems in India

Source: C.PALANIAPPAN, PAN
Leather Drier with Solar Hot Air Ducts
M/S M.A. KHIZAR HUSSAIN & SONS, RANIPET

Source: C.PALANIAPPAN, PAN
Sadesa Leather (1)

Sadesa, Thailand
Tanery
Hot water for tanning process

System
Aschoff solar
Start of operation: 2013
1.890 m² Vacuum tube collector
35 m³ heat store
30 - 80 °C
Sadesa Leather (3)
Food Industry
Main Applications

cleaning of:

• bottles
• textile
• cars

Temperature range for the processes: 40 - 90°C

Heat carrier: water

Recommended Collector Types:

• flat-plate collector
Parking service Castellbisbal SA, container washing, Barcelona, Spain. Installed capacity: 357 kWth. Source: Aiguasol Engineering, Spain.
MOGUNTIA Meat Spices, Kirchbichl Tyrol

Installed Capacity: $150 \text{ kW}_{\text{th}}$ (215 m$^2$ FPC)
MOGUNTIA Meat Spices, Kirchbichl Tyrol

Year of Installation: 2007
Installed Capacity: 150 kW_{th} (215 m^{2} collector area)
Storage Volume: 10 m^{3}
Daily Hot Water Demand: 8000 Liter
Solar Fraction: 45%

Processes:
- Cleaning of stainless steel containers for spices
- Cleaning of dispersing machines
- Hot water for processing liquid spices and pastes
- Dehydration of production halls in summer
Closed Systems

Main Applications:

- Textile Industry
- Tanneries
- Dairy
- Breweries
- Beverage Industry

Temperature range for the processes: 30 - 110°C

Heat carrier: Water / Steam

Recommended Collector Types: FK, CPC, VR
Tyras dairy, Trikala, Greece

Dairy, TYRAS S.A., Trikala, Greece

Installed Capacity: $728 \text{ kW}_\text{th}$ (1040 m$^2$ FK)
Prestage Food (1)

North Carolina, USA
Prestage Food (2)

Poultry Company in NC, USA
Energy-Contractor: FLS Energy → Owner of the Solar System

Demand 568 [m³/d] Hot water at (>60 °C) for Cleaning processes

System
Start of operation 2012
7,804 m² Flat plate collectors
852 m³ Heat Storage (10 x 85 [m³])
50% Solar Fraction (Hot water)

Source of pictures: FLS Energy
Prestage Food (3)

A) Integration on Supply Level
   A1) Heating of make-up water
   A2) Heating of distribution network (supply line / return line)
   A3) Heating of supply heat storage

B) Integration on Process Level
   B1) Heating of process(es) / vessel(s)
   B2) Heating of process medium
   B3) Heating of process heat storage

Solar Heat Source

Solar Energy Storage

Supply Heat Storage

Heat Sink Process(es)
Closed Loop

Heat Sink Process(es)
(Semi) Open Loop

Process Heat Storage

Process medium can be
- product
- (fresh) water
- (drying) air

Cleaning of equipment

IEA SHC Task 49

www.aee-intec.at  AEE - Institut für Nachhaltige Technologien
Beverage Industry
Nestle Waters (1)

Al Manhal, Riad, Saudi Arabia

System

Millennium Energy Industries
Start of operation: January 2012
515 m² Flat plate collectors
15 m³ Heat Storage
Replacement of electricity for bottle washing (~ 70 °C)
Nestle Waters (2)
Nestle Waters (3)

Al Manhal, Riad, Saudi Arabia

A) Integration on Supply Level
   A1) Heating of make-up water
   A2) Heating of distribution network (supply line / return line)
   A3) Heating of supply heat storage

B) Integration on Process Level
   B1) Heating of process(es) / vessel(s)
   B2) Heating of process medium
   B3) Heating of process heat storage

Solar Heat Source

Solar Energy Storage

Process Heat Storage

Heat Sink Process(es) (Semi) Open Loop

Heat Sink Process(es) Closed Loop

Supply Heat Storage

Solar distribution network

IEA SHC Task 49
Pre-Heating of Process Water

Gatorade (PepsiCo)
Phoenix, AZ, USA

892 m² solar collectors
38 m³ buffer tank

Pre-Heating fresh water for the soft-drink production at 35° C / 95° F

Annual Energy gains = more than 1 Mio. kWh !!! (= more than 1200 kWh/(m²*y) !)

Source: SOLID GmbH. Graz Austria
Pre-Heating of Process Water

Source: SOLID GmbH. Graz Austria
Textile Industry
Textile Industry Hangzhou China 13000 m²
(9 MW<sub>th</sub>)
Metal Industry
Necessity of a Storage Tank

Main Applications
- Galvanic industry
- Food industry

Temperature range for the processes: 30 - 90°C

Heat carrier: Water

Recommended Collector Types: FP, ETC, CPC
Demonstration Plants

70 kW evacuated tube collectors

Galvanic Industry, Germany
Electroplating Bath in Ludhiana, India
500 m² collector area (350 kW_{th})

The temperature of the electroplating bath is to be maintained at 55 to 60 °C for 12 hours a day.

158,000 m² of the total installed collector area in India was used for industrial applications (2009)

Sources: Greentech Knowledge Solution and Intersolar Systems, India
Mining
Solar Heat for Copper Mining in Cyprus - 0.5MWth

Source: Millennium Energy Industries
Copper Mine in Chile - 26MWth
Copper Mine “Gabriela Mistral”, Chile 26MWth (39,300 m²)

Process

- Electro winning of copper
- Electrolyte is kept on a constant Temp. of 50 °C
- Cleaning Processes

System

- 39.300 m² Flat plate collector
- 4.300 m³ Storage
- 85-100% Solar fraction

Source: SUNMARK and IEA SHC Task 49
Copper Mine “Gabriela Mistral”, Chile
26MWth (39,300 m²)

Source: SUNMARK
Copper Mine “Gabriela Mistral”, Chile
Facts and Challenges

Contracting System performed by Pampa Elvira Solar
Codelco has signed an agreement with the Chilean company Pampa Elvira Solar to deliver solar heat to the mining factory over a 10-year period. Pampa Elvira Solar owns the solar field and is responsible for its operation.

Flow and return temperatures:
primary side: 85 / 55 °C
secondary side – supplying the mine - at 80 / 60 °C

Expected output: specific yield of 1,272 kWh/m²

Challenge:
A special machine for dry-cleaning the collectors was developed by Sunmark. The Gaby mine is in one of the driest areas on earth, with rain only pouring down every 50 years.
Distilling and chemical processes

Steam production via a flashing process - generic system concept

El NASR Pharmaceutical Chemicals, Egypt. Installed capacity: 1,33 MWth

Source: Fichtner Solar GmbH. Germany
Thank your attention
Biggest System Worldwide, Saudi Arabia
36,000 m² / 25 MWₜₗ
Biggest System Worldwide, Saudi Arabia
36,000 m² / 25 MW$_{th}$
Biggest System Worldwide, Saudi Arabia
36.000 m² / 25 MW<sub>th</sub>
Biggest System Worldwide, Saudi Arabia
36,000 m² / 25 MWth
Pipes and Heat Exchangers