State of the art for solar thermal or PV cooling and refrigeration

Daniel MUGNIER – 15/10/2014

SHC 2014 Conference

Beijing (China)
To Introduce the importance of...

SOLAR COOLING for China...

...one picture taken this morning in Datun Road close to CNCC
Solar Cooling nearly 17% of total energy use for cooling!

Big potential of growth especially in China

1.5 x 10^{18} \text{ J/a} = 416.7 \text{ TWh/a} Solar Cooling by 2050

Systems could enter the market between 2015 and 2020
### Solar thermal collector technologies versus Application for solar cooling

<table>
<thead>
<tr>
<th>Solar thermal collector</th>
<th>Heat transfer medium</th>
<th>Collector temperature</th>
<th>Application for cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air collector</td>
<td>Air</td>
<td>40-60°C</td>
<td>Air-conditioning</td>
</tr>
<tr>
<td>Flat plate collector</td>
<td>Water, Water-Glycol</td>
<td>70-90°C</td>
<td>Air-conditioning, slab cooling</td>
</tr>
<tr>
<td>Evacuated tube collector</td>
<td>Water, Water-Glycol</td>
<td>90-120°C</td>
<td>Air-conditioning, slab cooling</td>
</tr>
<tr>
<td>Parabolic trough / Fresnel collector</td>
<td>Thermal oil, Water</td>
<td>120-250°C</td>
<td>Refrigeration, air-conditioning, slab cooling</td>
</tr>
</tbody>
</table>

Source: JER
Small-scale capacity adsorption chillers

- **SorTech**
  - eCoo10
  - Water / Silica gel

- **InvenSor**
  - LTC10 & HTC18
  - Water / Zeolithe

- **Cooling capacity range:** 10 kW to 18 kW
- **Heating temperatures:** 60 – 95°C
- **Cold water temperatures:** 15°C
- **COP:** 0.6 – 0.65 (0.7*)

*High Efficiency Modus

Source: SorTech

Source: InvenSor

[Image of small-scale capacity adsorption chillers]
Small-scale capacity absorption chillers

- **Cooling capacity range:** 15 kW to 19 kW
- **Heating temperatures:** 65 – 95°C
- **Cold water temperatures:** 6 – 7°C (NH₃ -5°C)
- **COP:** 0.65 – 0.75 (0.5)
Latest progresses: Integrated hydraulic unit for comfortable system integration

Source: InvenSor

Source: SorTech
High-temperature applications

**Example**: Football Stadium in Qatar
Market development of solar thermal cooling

About > 1,200 systems installed worldwide (2013)

Source: Solem Consulting / TECSOL
Market share of solar driven sorption chillers (2009)

- Absorption: 71%
- Adsorption: 13%
- DEC Solid: 14%
- DEC Liquid: 2%

Sources: EURAC, Tecsol
Technical status

- **Mature components available** (both solar and refrigeration, A/C)

- **Main progress made in last decade**
  - *Small scale heat driven chillers*
  - *Increasing number of high efficient double and – recently – triple effect absorption chillers*
  - *Development of systems using single-axis tracking solar collectors*

- **Main technical shortcomings are still on system level**
  - *Energy efficient heat rejection system*
  - *Energy management*

- **Bottleneck: good trained technical staff almost not available**
Energy performance

- Many systems lead to measurable energy savings when compared to a best practice conventional reference solution.

- Best values of overall electric COP range up to 6-8, which means that 6-8 kWh of useful cooling are produced with 1 kWh of invested electricity.

- Target value for electric COP > 10.

- However: also many systems do not achieve these values in practice due to:
  - Non-optimal design
  - Non-optimal operation (e.g. control, part load)
Campus area: 76,000m² / 820,000ft²

Students: approx. 2700

Solar Panels: 3900 m² / 2.73 MW_therm

Chiller size: 1500kW / 420 tons

Storage: For Cooling 60 m³ For Hot Water 7 m³

Electrical efficiency of 6.3 in 2013
Desert Mountain High School, USA

Solar Panels: 5,000 m² → 3.5 MW

Cooling load: 500 tons / 1750 kW

In operation since 2014
**SERM Montpellier SAC/DHW system**

Montpellier Heating and System net utilities
=> System owner

TECSOL : engineering company

AXIMA GDF SUEZ : company in charge of the works

**Picture of the collector field**

240 m² DG FP collectors + 35 kW Yazaki abs. chiller
+ solar circuit in drainback mode
## Full year balance (March 2013/ March 2014)

<table>
<thead>
<tr>
<th></th>
<th>DHW Production (kWh)</th>
<th>Cooling Production (kWh)</th>
<th>Parasitic elec. Consumption (kWh)</th>
<th>Useful Solar Yield (kWh/m²·y)</th>
<th>Overall elec efficiency (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>from 18/03/2013</td>
<td>4,654</td>
<td>0</td>
<td>110</td>
<td>19.4</td>
<td>42.3</td>
</tr>
<tr>
<td>April 2013</td>
<td>11,588</td>
<td>0</td>
<td>290</td>
<td>48.3</td>
<td>40.0</td>
</tr>
<tr>
<td>May 2013</td>
<td>16,478</td>
<td>0</td>
<td>380</td>
<td>68.7</td>
<td>43.4</td>
</tr>
<tr>
<td>June 2013</td>
<td>7,497</td>
<td>2,765</td>
<td>902</td>
<td>42.8</td>
<td>13.4</td>
</tr>
<tr>
<td>July 2013</td>
<td>9,482</td>
<td>3,983</td>
<td>1,190</td>
<td>56.1</td>
<td>13.5</td>
</tr>
<tr>
<td>August 2013</td>
<td>8,628</td>
<td>1,970</td>
<td>840</td>
<td>44.2</td>
<td>14.2</td>
</tr>
<tr>
<td>September 2013</td>
<td>9,316</td>
<td>676</td>
<td>554</td>
<td>41.6</td>
<td>18.9</td>
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<tr>
<td>October 2013</td>
<td>7,843</td>
<td>0</td>
<td>240</td>
<td>32.7</td>
<td>32.7</td>
</tr>
<tr>
<td>November 2013</td>
<td>4,789</td>
<td>0</td>
<td>220</td>
<td>20.0</td>
<td>21.8</td>
</tr>
<tr>
<td>December 2013</td>
<td>3,851</td>
<td>0</td>
<td>157</td>
<td>16.0</td>
<td>24.6</td>
</tr>
<tr>
<td>January 2014</td>
<td>3,734</td>
<td>0</td>
<td>190</td>
<td>15.6</td>
<td>19.7</td>
</tr>
<tr>
<td>February 2014</td>
<td>6,435</td>
<td>0</td>
<td>218</td>
<td>26.8</td>
<td>29.5</td>
</tr>
<tr>
<td>March 2014</td>
<td>12,860</td>
<td>0</td>
<td>348</td>
<td>53.6</td>
<td>30.9</td>
</tr>
<tr>
<td>April 2014</td>
<td>14,085</td>
<td>0</td>
<td>360</td>
<td>58.7</td>
<td>39.1</td>
</tr>
<tr>
<td>May 2014</td>
<td>12,633</td>
<td>281</td>
<td>326</td>
<td>54.0</td>
<td>40.2</td>
</tr>
<tr>
<td>June 2014</td>
<td>8,847</td>
<td>944</td>
<td>685</td>
<td>39.7</td>
<td>15.2</td>
</tr>
<tr>
<td>July 2014</td>
<td>5,586</td>
<td>2,959</td>
<td>851</td>
<td>26.8</td>
<td>12.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>148,308</td>
<td>13,578</td>
<td>7,861</td>
<td><strong>674.5</strong></td>
<td><strong>20.6</strong></td>
</tr>
</tbody>
</table>

*Elec consumption linked to the solar useful production (pumps solar, DHW, generator, evaporator, condensor circuits) without measuring back up elec consumption.*

**Global Electrical efficiency of nearly 21 in average for a full year & a solar yield of 674 kWh/m²·y**
Monotoring results for Summer 2014

Average electrical efficiency again of 12
Cost development of solar cooling Kits (2007-2012)

Cost reduction of 45-55% within last 5 years!
Economic viability

- First cost 2-5 times higher than for conventional technology

- Total first cost found in realized installations: 2000 – 5000 € per kW of cold production (for entire system including solar collector field)

- Payback time depends strongly on boundary conditions
  - Annual numbers of use (cooling, heating, hot water, ...)
  - Conventional energy cost
  - Climatic conditions

- Best conditions: payback < 10 years very difficult to reach
Conclusion for solar thermal cooling

- About 1,200 solar cooling systems installed worldwide (2013)
- Several new small and medium-scale Absorption and Adsorption chillers were developed worldwide in the last few years, especially in Europe
- Standardized Solar Cooling Kits available to bring down the costs
- Solar heat is particularly of interest if a solar thermal system is used for other heat needs, too (e.g. heating, DHW)
Need of a new Generation solar cooling systems

Solar thermal « traditionnal » cooling has **difficulty to emerge as a economically competitive solution**

Main reasons :
- **Technical** : Limit on adaptability due to hydraulics, complexity
- **Economical** : Investment cost, especially for small systems

⇒ Still need **intensive R&D** for quality improvement and best solution selection (ongoing IEA SHC Task 48)

⇒ Very innovative concepts such
How to find a solution for small/medium size?

* A very important priority: solar for cooling, especially for small to medium size

Example: 10% of the entire Saudi Arabia oil production for national cooling

* New context on economics for PV and trend towards selfconsumption

* A real growing market...

... but strong need of:

IEA SHC Task 53

* standards
* thermal management optimum
* monitoring & best practice
Example of Basic concept for the PV approach

- PV
- Controller / Inverter
- Air conditioner / Heat Pump / Food conservation
- Water storage (chilled water / hot water / DHW)

Optional: GRID

Task 53
New Generation Solar Cooling & Heating Systems (PV or solar thermally driven systems)

Overview

The main objective of this Task is to assist a strong and sustainable market development of solar PV or new innovative thermal cooling systems. It is focusing on solar driven systems for both cooling (ambient and food conservation) and heating (ambient and domestic hot water).

The scope of the Task are the technologies for production of cold/hot water or conditioned air by means of solar heat or solar electricity, i.e., the subject which is covered by the Task starts with the solar radiation reaching the collector or the PV modules and ends with the chilled/hot water and/or conditioned air transferred to the application. However, although the distribution system, the building and the interaction of both with the technical equipment are not the main topics of the Task this interaction will be considered where necessary.

http://task53.iea-shc.org/
IEA SHC Task 53 Subtask A

Which systems do we have?

**NG systems close to market**  
- PV CH (Cooling/ Heating) on the Market
  - STDCH
    - SolabCOOL (NL)
    - SUNCOOL/Climatewell (SE)

**R&D Systems close to Market**  
- PV CH (Cooling/ Heating)
  - BIG HEATING company (GER)
  - Helioherm
- STDCH
  - FREESCOO (IT)
  - Climatewell (SE)
State of the art of this new **Market**

(no claim for completeness)
Main categories

Solar air conditioners : Splits

PV+ HP coupling for Office/Commercial
Solar Air Conditioner
SEER 35 • Solar Hybrid Heat Pump
Model ACDC12
Connect Up To Three Panels (Max 840W)
Runs On Solar Power & AC Power
11,000 BTU Cooling/12,000 BTU Heat
Plug-And-Play Solar Connection
No Batteries Required

Home
Keep the inside cool all day for next to nothing in energy costs. Preventing daytime heat build-up also cuts evening cooling costs.

Office
Keep the work area comfortable during business hours for pennies per day. Cool or heat up to 700 Sq. Ft. (65m²).

International
Compatible with 50Hz and 60Hz power, use it anywhere in the world.

Ultra-High SEER Solar Air Conditioner

Connects Directly To Solar Panels

ACDC12-Hybrid
Retail/List-$1695ea FOB Factory
Dealer Price: 4-49 units $1290ea FOB Factory
Distributor Price: 50+ units $891ea FOB China
**Unit includes 3m lineset
Typical ALREADY EU market available solution

Efficient Geothermal Heat Pump: COP of 5.3
Field test since 2011 in Switzerland

PV booster => overall yearly COP of 6.9
State of the art of the future new **Market**

**Active R&D participants in Task 53**

Testing principle for a Chinese PV split unit  
(Source: Universidad Miguel Hernández de Elche)

Concept for compact solar thermal air conditioner based on fixed & cooled adsorption beds  
(Source: Solarinvent)

Task 53
http://task48.iea-shc.org/

http://task53.iea-shc.org/

Thanks for your attention!

Contact: Daniel Mugnier, TECSOL
daniel.mugnier@tecsol.fr