DHW/Cooling hybrid strategy for solar cooling:

Practical successful monitoring results in South of France

D. Mugnier (TECSOL)
Introduction

* Long history in France for solar cooling (1980-2013)

However, special national conditions for solar cooling:

- **Mild** climate (cooling season especially in South of France)
- **Low energy price** (one of the lowest in the World for electricity)
- **Mitigated feedback** until now on performance levels (technical dysfunctionning, low economical interest, lack of providers)

⇒ **Important need to structure the sector & get Full Best practice**

Big challenge: which system/project to follow up the story in 2013?
GICB: a 20 year Solar cooling system

Reminder:

SOLAR COOLING = VERY RELIABLE TECHNOLOGY
Introduction

Solution to create a dynamics for the sector:

- Emergence Program (high incentive against guarantee of results)

- Extend the solar resource use as much as possible
  \[ \Rightarrow \text{Idea to go to a mix DHW (instead of heating) + cooling system} \]

- Find sites where the system integration is possible including a simple scheme and simple working conditions

- Find motivated customers for such an application

One example: « Amiral block » Solar DHW/Cooling project in Montpellier!
Targeted building description

Montpellier Heating and System net utilities
=> System owner

TECSOL : engineering company

AXIMA GDF SUEZ : Company in charge of the works

Existing Building block in ZAC Jacques Coeur in Port Marianne area (Montpellier, France, built in 2010)

2 parts : building A & B (mini district)

Building A : 11 000 m² for offices and shops
Building B : 10 600 m² with 167 dwellings
Load

**Load**: real monitored data from 2010 to 2011

DHW + cooling = 46 kWh/m².y  => 1 GWh/y

Heating + cooling equipments: compression chillers + gas burners

(900 kW)  (700 kW)

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**DHW load on a yearly basis**

**Cooling load on a yearly basis**
Load & system strategy

Sizing strategy:
- available place on the roof
- simplicity & maximum yield

⇒ nearly 500 m² available on different locations on the Block A roof => 240 m² solar collector

- DHW only in Winter + cooling (if possible +DHW) in Summer
System description

- 240 m² double glazed flat plate collectors
- one 35 kW absorption chiller
- solar circuit in drainback mode (with water glycol + HX)
- one 1500 liter hot buffer storage tank
- DHW preheating
(+ 10 m³ DHW additional storage capacity in Building B for dwellings)
Hydraulic principle
Hydraulic scheme

DHW distribution

Solar production

Drainback system

Cold production

Anti legionella adiabatique cooling tower
Lessons learnt from installation & running

• **Architectural issues**:
  Existing building with a lot of caution in the architectural integration process.

• **Installer skills**:
  Very few installers skilled for both absorption / solar / control => learning process and high importance of engineering coordination.

• **Building in use**:
  Preventing any disturbance to companies/organizations working in the lower floors of the building.

• **Real cooling load**:
  In office buildings in August, the cooling load can become very very low (some tens of kW against some hundreds).
First monitoring results in 2012

* Nominal working conditions for domestic hot water production since May 2012

* Excess of available heat in sunny days: perfect safety functionality of the Drainback system against overheating

* Short test sequences:
  - checked capacity to run properly the chiller
  - power balance around the chiller:
    - Generator: 28 kW – 80/77°C
    - Evaporator: 18 kW – 7,5/10,5 °C
    - Heat rejection: 46 kW – 31,5/34°C
DHW monitoring results for a Winter day

<table>
<thead>
<tr>
<th>Date</th>
<th>18 March 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energies</strong></td>
<td></td>
</tr>
<tr>
<td>Available solar energy</td>
<td>1491.28 kWh</td>
</tr>
<tr>
<td>Collected solar energy (secondary circuit)</td>
<td>563.48 kWh</td>
</tr>
<tr>
<td>Solar DHW distributed (after the buffer tank)</td>
<td>494.17 kWh</td>
</tr>
<tr>
<td>Electrical energy consumed</td>
<td>12.29 kWh</td>
</tr>
<tr>
<td><strong>Ratios et calculations</strong></td>
<td></td>
</tr>
<tr>
<td>Collector &amp; Heat exchanger yield</td>
<td>37.78 %</td>
</tr>
<tr>
<td>Buffer tank yield</td>
<td>87.70 %</td>
</tr>
<tr>
<td>Installation yield (from solar to DHW)</td>
<td>33.14 %</td>
</tr>
<tr>
<td>Electrical COP</td>
<td>40.22 -</td>
</tr>
</tbody>
</table>

**Energies and energies ratio for March 18th 2013**

The installation performances on a sunny day in March are quite good with an electrical COP reaching 40
Monitoring results for Summer 2013

Average Solar collector + HX efficiency on 2 month $\approx 30\%$
Monitoring results for Summer 2013

Average Thermal COP of 0.6
Monitoring results for Summer 2013

Average Electrical COP / Efficiency of 12.3
Summary for the 2013 cooling season

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar irradiation</td>
<td>kWh</td>
<td>104 000</td>
</tr>
<tr>
<td>Collected solar energy</td>
<td>kWh</td>
<td>30 000</td>
</tr>
<tr>
<td>Generator input</td>
<td>kWh</td>
<td>9 800</td>
</tr>
<tr>
<td>Evaporator output</td>
<td>kWh</td>
<td>6 000</td>
</tr>
<tr>
<td>Domestic hot water</td>
<td>kWh</td>
<td>18 000</td>
</tr>
<tr>
<td>Electricity consumption</td>
<td>kWh</td>
<td>2 000</td>
</tr>
<tr>
<td><strong>Thermal COP</strong></td>
<td>(-)</td>
<td>0.60</td>
</tr>
<tr>
<td><strong>Electrical Efficiency /COP</strong></td>
<td>(-)</td>
<td>12.2</td>
</tr>
<tr>
<td>Water consumption (m3)</td>
<td>m3</td>
<td>60</td>
</tr>
</tbody>
</table>

Big advantage of this system: complementarity between cooling & DHW function

Simplicity of functioning: no issue on the control (Cooling -> DHW)
Conclusions

- Project running since May 2012
- Very learnful feedbacks
- **Complete monitoring system** permitting full feedback on energy performance level
- Very interesting 2013 cooling season with high electrical COP
- **Interesting new concept** for DHW/solar cooling:
  - Maximal usability of solar ressource & simplicity of the system
  - Economical optimum (gains for DHW + Cooling production)
  - No risk of regular oversizing
  - Drainback strategy in case of dysfunctionning
  - First application of the French Incentive Emergence Program
- One case of mini **Solar District Heating/Cooling system**
Thanks for your attention!

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

* Nominal functioning from August (fully sunny day / average sunny day)

- 7 hours operation
- Generator temperature range: 80-88°C
- Recooling stable conditions
First monitoring results

* Monitoring campaign ongoing (after cooling season, heating season now)
First monitoring results

* DHW monitoring results for a Winter period

<table>
<thead>
<tr>
<th>Date</th>
<th>9 days period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energies</strong></td>
<td></td>
</tr>
<tr>
<td>Available solar energy</td>
<td>9922,98 kWh</td>
</tr>
<tr>
<td>Collected solar energy (secondary circuit)</td>
<td>3569,40 kWh</td>
</tr>
<tr>
<td>Solar DHW energy distributed (after the buffer tank)</td>
<td>3345,92 kWh</td>
</tr>
<tr>
<td>Electrical energy consumed</td>
<td>78,16 kWh</td>
</tr>
<tr>
<td><strong>Ratios et calculations</strong></td>
<td></td>
</tr>
<tr>
<td>Collectors &amp; Heat exchanger yield</td>
<td>35,97 %</td>
</tr>
<tr>
<td>Buffer tank yield</td>
<td>93,74 %</td>
</tr>
<tr>
<td>Installation yield (from solar to DHW)</td>
<td>33,72 %</td>
</tr>
<tr>
<td>Electrical COP</td>
<td>42,81 -</td>
</tr>
</tbody>
</table>

*Energies and energies ratio for a 9 days period in March 2013*
First monitoring results

* DHW monitoring results for a Winter period

Energies and electrical COP for a 9 days period in March 2013
Economics

Total cost of the project (cooling + DHW) : **330 000 € (w/o eng.)**

Public funding available for the project : **50%**

Final investment cost for the customer : **≈ 165 000€**

Savings :
- For cooling:  * electric central heat pumps with average electrical SEER = 2
  * electricity price = 0,04664 €/kWh
- For DHW production :  * gas boiler (average η = 80%)
  * gas price = 0,04182 €/kWh

Annual gross saving of **≈ 8 000 €/year**

Annual actualized saving during 20 years : **11 100€/year**

(average 6% /year increase for energy price)
Economics & Environment

ROI of the project not very performing (≈ 15 years) ... **BUT**

- Guarantee for the customer of performances (Emergence system)
- Considered as a Demo project (experiment + no profitable project (cover total coast on system life)

CO2 savings from this solar cooling/DHW installation.

Hypothesis:
- For electricity: 120 g of CO2/kWh
- For gas: 273 g of CO2/kWh

=> 40 tons CO2 / y

Equivalent to **25 cars travelling 11 500 km/y**
Expected results

<table>
<thead>
<tr>
<th>Month</th>
<th>DHW production (kWh)</th>
<th>Cooling production (kWh)</th>
<th>Electric consumption (kWh)</th>
<th>Solar productivity* (kWh/m²)</th>
<th>Electrical COP (-)</th>
<th>Solar fraction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>2 476</td>
<td>0</td>
<td>256</td>
<td>10,3</td>
<td>9,7</td>
<td>7,7 %</td>
</tr>
<tr>
<td>February</td>
<td>4 694</td>
<td>0</td>
<td>371</td>
<td>19,6</td>
<td>12,7</td>
<td>19,1 %</td>
</tr>
<tr>
<td>March</td>
<td>11 073</td>
<td>0</td>
<td>566</td>
<td>46,1</td>
<td>19,6</td>
<td>22,2 %</td>
</tr>
<tr>
<td>April</td>
<td>16 252</td>
<td>228</td>
<td>723</td>
<td>68,7</td>
<td>22,8</td>
<td>17,3 %</td>
</tr>
<tr>
<td>May</td>
<td>18 556</td>
<td>1 843</td>
<td>892</td>
<td>85,0</td>
<td>22,9</td>
<td>18,7 %</td>
</tr>
<tr>
<td>June</td>
<td>14 002</td>
<td>3 033</td>
<td>938</td>
<td>71,0</td>
<td>18,2</td>
<td>16,8 %</td>
</tr>
<tr>
<td>July</td>
<td>12 083</td>
<td>7 348</td>
<td>1329</td>
<td>81,0</td>
<td>14,6</td>
<td>9,8 %</td>
</tr>
<tr>
<td>August</td>
<td>11 583</td>
<td>6 281</td>
<td>1207</td>
<td>74,4</td>
<td>14,8</td>
<td>11,6 %</td>
</tr>
<tr>
<td>September</td>
<td>7 939</td>
<td>1 340</td>
<td>661</td>
<td>38,7</td>
<td>14,0</td>
<td>9,2 %</td>
</tr>
<tr>
<td>October</td>
<td>8 896</td>
<td>0</td>
<td>547</td>
<td>37,1</td>
<td>16,3</td>
<td>25,6 %</td>
</tr>
<tr>
<td>November</td>
<td>3 450</td>
<td>0</td>
<td>293</td>
<td>14,4</td>
<td>11,8</td>
<td>12,7 %</td>
</tr>
<tr>
<td>December</td>
<td>2 077</td>
<td>0</td>
<td>234</td>
<td>8,7</td>
<td>8,9</td>
<td>6,6 %</td>
</tr>
<tr>
<td>TOTAL</td>
<td>113 080</td>
<td>20 073</td>
<td>8 017</td>
<td>554,8</td>
<td>16,6</td>
<td>13,9 %</td>
</tr>
</tbody>
</table>

* Solar productivity: Calculated in winter as the distributed hot energy divided by the collector surface, and in summer the distributed cold energy is divided by the collector surface but also by the thermal COP of the chiller.

Emergence program: mini annual thermal performance levels to reach
- Solar yield is estimated to 554,8 kWh/m².year >> 350 kWh/m².year
- Electrical COP is estimated to 16,6 >> 5
⇒ Project eligible to the Emergence funds