Combining gas absorption heat pumps and borehole energy storage in semi closed greenhouses

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Green Growing Workshop 22 October 2013, Lokeren
1. Concept

2. Research
   1. Energy use
   2. Heat pumps
   3. Drill hole energy storage

3. Future research
1. Concept

SUMMER SITUATION (and warm periods)

COLD STORAGE

CO2

condensor

Gas absorption heat pump

evaporator

HEAT STORAGE

Drillhole energy storage

SITUATION IN WINTER (and cold periods)

COLD STORAGE

CO2

condensor

Gas absorption heat pump

evaporator

Drillhole energy storage
1. Aluminium gutter
   ✓ Better isolation
2. Anti reflection glass
   ✓ 6% more transmission
   ✓ Less reflection
3. Climate screen
   ✓ 63% energy saving
   ✓ 65% light screening
4. Energy screen
   ✓ 45% energy saving
   ✓ 14% light screening
5. Air treatment equipment
   ✓ Thanks to dehumidification more closed culture
   ✓ Better use of CO2 and heat
6. White coating
   ✓ More light reflection on the infrastructure
7. Polycarbonaat in the outdoor walls (two chambers 16 mm)
   ✓ Better isolation
   ✓ $U = 2.3\, \text{W/m}^2\cdot\text{K}$
8. Low temperature network, growpipes Ø 51 mm
   ✓ Better use of low temperature
9. CO₂ coming from the GAHP

**U-value = 2.75\, \text{W/m}^2\cdot\text{K}**
2. Research – energy use

Research on energy use organic tomato 2012
- Greenhouse of 400 m²
- Full soil growing media
- Energy and transparent screen
- Broad irrigation

- Heating
  - Railtube Ø 51 mm (max 55 °C)
  - Growpipe Ø 51 mm (max 45 °C)
  - Use of minimum tube 30 °C
  - Heat pumps

- Climate
  - Day 19 °C (150 – 500 W/m²: + 3° C) / Night 17 °C
  - RH: 80 % - 85 % day / 85 % - 90 % night
  - Close ventilation Februari – March
  - Semi-closed growing: open windows when RH ↑or heat ↑
  - Minimum CO2 level 700 ppm
2. Research – energy use

Energy use tomato 2012

- Buisrail cumul
- Groeibuis cumul
- LBU cumul
- Totaal Cumul

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## 2. Research – energy use

### Energy use tomato 2012

<table>
<thead>
<tr>
<th>Greenhouse surface: 400 m²</th>
<th>Tomaat – 312 d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Railtube</td>
</tr>
<tr>
<td><strong>Heat demand (kWh/m²)</strong></td>
<td></td>
</tr>
<tr>
<td>253,43</td>
<td>97,50</td>
</tr>
<tr>
<td><strong>Gas (kWh/m²)</strong></td>
<td></td>
</tr>
<tr>
<td>189,56</td>
<td>72,93</td>
</tr>
<tr>
<td><strong>Gas (m³/m²)</strong></td>
<td></td>
</tr>
<tr>
<td>16,43</td>
<td>6,32</td>
</tr>
</tbody>
</table>

COP 140 %

Standard energy use 40 m³/m² → 35 % saving

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2. Research – energy use

Research on energy use organic tomatoes 2013

- Greenhouse of 400 m²
- Full soil growing media
- Energy and transparent screen
- Drip irrigation

- Heating
  - Railtube Ø 51 mm (max 55°C)
  - Growpipe Ø 51 mm (max 45 °C)
  - Minimum tube 30 °C until end of March
  - Heat pumps

- Climate
  - Day 19 °C (+ 3° 150 – 500 W/m²) / Night 17 °C
  - RH: 80 % - 85 % day and night
  - Railtube Ø 51 mm (max 55°C)
  - Minimum CO2 level 700 ppm
  - More screening and less ventilation
2. Research – energy use

### Energy use tomato 2012 - 2013

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2013</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato 400 m²/ 1m³ gas = 11,52 kWh</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total energy use 252 days</td>
<td>127,75 MWh</td>
<td>94,15 MWh</td>
<td>33,06 MWh</td>
</tr>
<tr>
<td>Average daily energy use</td>
<td>506,37 kWh</td>
<td>369,34 kWh</td>
<td>137,03 kWh</td>
</tr>
<tr>
<td>Gas use per m²</td>
<td>19,78 m³/m²</td>
<td>14,32 m³/m²</td>
<td>5,45 m³/m²</td>
</tr>
</tbody>
</table>

- No more use of minimum tube after March
- More closed growing and screening
2. Research – energy use

Average monthly radiation 2012 -2013

<table>
<thead>
<tr>
<th>Month</th>
<th>W/m² 2012</th>
<th>W/m² 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Januari</td>
<td>614,16</td>
<td>624,16</td>
</tr>
<tr>
<td>Februari</td>
<td>1,163,50</td>
<td>1,386,8</td>
</tr>
<tr>
<td>Maart</td>
<td>2,064,13</td>
<td>2,554,1</td>
</tr>
<tr>
<td>April</td>
<td>3,019,4</td>
<td>3,842,47</td>
</tr>
<tr>
<td>Mei</td>
<td>4,214,3</td>
<td>4,546,9</td>
</tr>
<tr>
<td>Juni</td>
<td>4,335,0</td>
<td>4,446,60</td>
</tr>
<tr>
<td>Juli</td>
<td>4,200,55</td>
<td>5,075,71</td>
</tr>
<tr>
<td>Augustus</td>
<td>4,359,8</td>
<td>3,708,87</td>
</tr>
<tr>
<td>September</td>
<td>2,877,10</td>
<td>3,284,8</td>
</tr>
<tr>
<td>Oktober</td>
<td>1,527,8</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>793,3</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>490,5</td>
<td></td>
</tr>
</tbody>
</table>

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Average monthly temperature 2012 - 2013

Januari: temp 2013 = 1,97, temp 2012 = 1,99
Februari: temp 2013 = 1,23, temp 2012 = 1,99
Maart: temp 2013 = 3,27, temp 2012 = 8,67
April: temp 2013 = 9,18, temp 2012 = 9,36
Mei: temp 2013 = 11,42, temp 2012 = 14,44
Juni: temp 2013 = 16,01, temp 2012 = 16,05
Juli: temp 2013 = 20,21, temp 2012 = 19,00
Augustus: temp 2013 = 19,36, temp 2012 = 19,36
September: temp 2013 = 12,62, temp 2012 = 14,97
Oktober: temp 2013 = 10,76, temp 2012 = 7,31
November: temp 2013 = 5,36, temp 2012 = 5,36
December: temp 2013 = 12,62, temp 2012 = 16,05
2. Research – heat pump

Three gas absorption heat pumps
• Total power 130 kW
• Source: greenhouse or ground (DES)
• CO2 directly used in greenhouse
• Cold used for dehumidification in greenhouse
• Source: 5 °C - 15 °C
• Outlet: 35 °C – 60 °C

COP or Coefficient of performance
• Measured seasonal efficiency 141 %
• Min 135 % - max 155 %
• Primary energy saving 29 %
• Outlet temperature ↑ => COP↓
2. Research – DES

Drillhole energy storage
• 28 drillholes of 100 m
• Winter: heat pump low value heat source (12°C – 7°C)
• Summer: store heat and dose additional CO2 (20 ° - 25 °C)

Heat storage (01/06 – 31/09)
• 52,33 MWh heat stored in 2013
• 2350 kg CO2 additional dosed for 800 m² départements

Use DES as additional cold water source in summer?
2. Research - DES

Geothermal energy storage DES summer 2013

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3. Future research

- Optimize system
  - Better humidity control in greenhouse
  - Lower energy use to 15 m³/m² gas
  - Optimize efficiency heat pumps

- Measure electric energy use
- Use DES as cold source in summer for dehumidification and cooling
Funding

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