Solar Thermal Combined with District Heating and Seasonal Heat Storage

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Content

- Introduction
- Seasonal Thermal Energy Stores
- Central Solar Heating Plants with Seasonal Storage (CSHPSS)
- Summary
Solar Thermal Combined with District Heating and Seasonal Heat Storage

- Introduction -

German end energy consumption in 2008: 9098 PJ

Use of **solar energy** for
+ space heating
+ tap water
+ process heat and cold

Energy research programm
+ promotion initiative „energy stores“
Solar Thermal Combined with District Heating and Seasonal Heat Storage

- Introduction -

**Diagram Description:**

- **Heat Demand:** The diagram shows the monthly heat demand throughout a year. It peaks in winter months and is lowest in summer months.

- **Solar Irradiation:** The solar irradiation (qualitatively) is depicted as a curve that peaks in summer and is lower in winter.

- **Solar Energy:** The solar energy production is shown as a bar graph, with significant contributions in the summer months.

**Key Notes:**

- **Solar Assisted District Heating with Seasonal Storage**
- **Solar District Heating with Short Term Storage**
Design characteristics for CSHPSS

- Minimum system size: > 100 flats
- Collector area: $0.14 - 0.2 \text{ m}^2/\text{m}^2_{\text{living area}}$
- Storage volume (seasonal heat store): $1.4 - 2.1 \text{ m}^3/\text{m}^2_{\text{Acoll}}$
- Solar fraction: ~50%
Solar Thermal Combined with District Heating and Seasonal Heat Storage

- Introduction -
Solar Thermal Combined with District Heating and Seasonal Heat Storage

- Seasonal Thermal Energy Stores -

- Hot Water Thermal Energy Store
- Gravel / Water Thermal Energy Store
- Borehole Thermal Energy Store
- Aquifer Thermal Energy Store
Solar Thermal Combined with District Heating and Seasonal Heat Storage

- Seasonal Thermal Energy Stores -

### Hot Water Thermal Energy Store

- high thermal capacity (water)
- good operation characteristics (high (dis-) charging power, usable as buffer store)
- freedom of design (geometry)
- thermal stratification
  (+) maintenance/repair
  (-) limited size (< 100 000 m³)
  - high construction costs

### Gravel / Water Thermal Energy Store

- reasonable construction costs
- medium (gravel-water) to high (water) thermal capacity
- nearly unlimited store dimensions
  (-) sophisticated cover (water)
  - limited freedom of design (slope angle)
  - maintenance repair difficult/not possible

### Requirements:

- stable ground conditions, preferably no groundwater, 5 -15 m deep

1) $\theta_{\text{max}} = 90 \, ^\circ\text{C}$, $\theta_{\text{min}} = 30 \, ^\circ\text{C}$ without heat pump
2) $\theta_{\text{max}} = 80 \, ^\circ\text{C}$, $\theta_{\text{min}} = 10 \, ^\circ\text{C}$ gravel-water TES with heat pump
## Solar Thermal Combined with District Heating and Seasonal Heat Storage

### - Seasonal Thermal Energy Stores -

#### Borehole Thermal Energy Store

- low construction costs
- easily extendable
- low thermal capacity
- operation (low (dis-)charging power, buffer required, heat pump recommended)
- limited choice of locations
- no thermal insulation at side and bottom
- maintenance repair difficult/not possible

#### Aquifer Thermal Energy Store

- very low construction costs
- (+) medium thermal capacity
- (-) operation (low/medium (dis-) charging power, heat pump recommended)
- very limited choice of locations
- no thermal insulation

### Requirements:

<table>
<thead>
<tr>
<th><strong>Borehole</strong></th>
<th><strong>Aquifer</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>drillable ground, high heat capacity, high thermal conductivity, low hydraulic conductivity (k_f&lt;10^{-10}) m/s, natural ground-water flow &lt; 1 m/a, 30 -100 m deep</td>
<td>natural aquifer layer (20 - 50 m) with high hydraulic conductivity (k_f&gt;10^{-4}) m/s), confining layers on top and below, no or low natural ground-water flow, suitable water chemistry</td>
</tr>
</tbody>
</table>
CSHPSS with BTES => Neckarsulm

- 5760 m² collector area
- 63360 m³ Borehole Thermal Energy Store
- 2 x 100 m³ Buffer stores
- 3 pipe district heating / solar network
- about 350 flats, school, gymnasium, kindergarten, …
- 512 kWₜʰ heat pump
- \( f_{sol} 50.3\% \) (measured in 2010)
Solar Thermal Combined with District Heating and Seasonal Heat Storage - Central Solar Heating Plants with Seasonal Storage -

CSHPSS with BTES => Neckarsulm

1252 m²
808 m²
454 m²
1109 m²
Solar Thermal Combined with District Heating and Seasonal Heat Storage
- Central Solar Heating Plants with Seasonal Storage -

**CSHPSS with BTES => Neckarsulm**

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<tr>
<td>Solar irradiation</td>
<td>1311</td>
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<td>1243</td>
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<td>Collector area (31.12.)</td>
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<td>5670</td>
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<td>1833</td>
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<td>per m² collector area</td>
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<td>Heat consumption (with heat losses)</td>
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<td>Heat delivery by gas boiler</td>
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<td>1485</td>
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<td>Heat losses (network)</td>
<td>540</td>
<td>709</td>
<td>706</td>
<td>943</td>
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<td>Store performance ratio</td>
<td>%</td>
<td>25</td>
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<td>annual coefficient of performance (heat pump)</td>
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<td>-</td>
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<tr>
<td>Solar fraction</td>
<td>%</td>
<td>39.6</td>
<td>44.8</td>
<td>45.5</td>
<td>41.1</td>
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<tr>
<td></td>
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<td>50.3</td>
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</tbody>
</table>
CSHPSS with ATES => Rostock

- 980 m² collector area
- 20000 m³ Aquifer Thermal Energy Store
- 30 m³ Buffer store
- 1 building (11 sections)
- 110 kW\textsubscript{th} heat pump
- $f_{\text{sol}}$ 49.6% (measured in 2010)
Solar Thermal Combined with District Heating and Seasonal Heat Storage
- Central Solar Heating Plants with Seasonal Storage -

CSHPSS with Aquifer Thermal Energy Store => Rostock

Architekten Partner, Rostock
Solar Thermal Combined with District Heating and Seasonal Heat Storage
- Central Solar Heating Plants with Seasonal Storage -

CSHPSS with Aquifer Thermal Energy Store => Rostock

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<th>2009</th>
<th>2010</th>
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<tbody>
<tr>
<td>Solar irradiation</td>
<td>kWh/m²</td>
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<td>Aquifer discharging</td>
<td>MWh</td>
<td>84</td>
<td>51</td>
<td>154</td>
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<tr>
<td>Solar useful heat</td>
<td>MWh</td>
<td>238</td>
<td>204</td>
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<tr>
<td>per m² collector area</td>
<td>kWh/m²</td>
<td>242</td>
<td>208</td>
<td>301</td>
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<tr>
<td>Heat consumption (with heat losses)</td>
<td>MWh</td>
<td>596</td>
<td>571</td>
<td>590</td>
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<td>Heat delivery by gas boiler</td>
<td>MWh</td>
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<td>351</td>
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<td>Electricity consumption (heat pump)</td>
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<td>26</td>
<td>16</td>
<td>43</td>
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<td>annual coefficient of performance (heat pump)</td>
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<td>4.0</td>
<td>4.1</td>
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<tr>
<td>Solar fraction</td>
<td>%</td>
<td>39.8</td>
<td>35.7</td>
<td>49.7</td>
<td>44.5</td>
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</tbody>
</table>
Solar Thermal Combined with District Heating and Seasonal Heat Storage

- Summary -

- CSHPSS are feasible and work
- Solar fractions of ~50% were measured

Experiences
- Network return temperatures critically (systems without heat pump)
- Integration of heat pump advisable
- Realisation of control strategy needs to be checked carefully
- Components (valves, pumps, heat exchanger...) should be checked regularly

Further improvements
- Reducing of heat losses & improving energy efficiency
- Reduction of construction costs
Thank you!

For more information:
www.itw.uni-stuttgart.de/abteilungen/rationelleEnergie/index.php
www.itw.uni-stuttgart.de/abteilungen/rationelleEnergie/index.en.php