Latest developments of Solar Thermal Technology

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  – solar collectors
  – heat stores
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The 2030 solar thermal vision of the ESTTP

The heat and cold demand is covered by solar thermal energy to 100 % for new built houses and to at least 50 % for the existing building stock. For industry and agricultural applications a significant share of heat below 250 °C is delivered by solar thermal energy.

→ Overall goal: To cover 50% of the low temperature needs up to 250°C with solar thermal energy

What does this mean for solar thermal technology?
Ongoing research and development is required!
Examples of latest R&D developments related to solar collectors
Polysol - Development of an all polymeric collector

Key features:

- Significant weight and cost reduction
- Use of recycled polymeric materials
- Made by extrusion
- Overheating protection by temperature dependent emissivity
- Pressure resistant up to 4 bar

a consortium of 10 partners from 5 different European countries
Gas filled flat plate solar collector

Key features:
• Filling gas e.g. Xenon, Argon, Krypton
• Higher thermal performance
• Thinner collector design and reduced weight

Chalmers University of Technology
Gothenburg, Sweden

Chalmers
Facade collector based on vacuum tubes

- Combination of glass façade and evacuated tubular collector
- CPC mirror is perforated to allow light to enter the building

Source: Ritter Energie- und Umwelttechnik, University of Stuttgart
Industrial Solar Fresnel Collector Field

Key features:

- 4 collector strings with 16 modules each
- Gross area approx. 2100 m²
- Total aperture area 1408 m²
- Pressurised water circuit at 16 bar
- provided temperatures: 200 °C
- used to drive an absorption chiller

Source: INDUSTRIAL SOLAR thermal solutions Freiburg, Germany
Examples of latest R&D developments related to heat stores
Water stores

- Achievement of large volumes by cascading

Disadvantages:
- Large space requirement
- Great effort for installation and control
- High thermal losses due to large surface
Large water stores

Key features:
• Large stainless steel store (pressurised)
• New buildings: installation during construction phase
• Existing buildings: Welding at the place of installation

17.5 m³ store; source: http://www.jenni.ch/
Cylindrical polymeric stores

Key features:

• cylindrical polymeric store made from fibreglass-reinforced plastic
• prefabricated components, laminating at place of installation
• volume: 1 – 100 m³
• with this flexibility only available as unpressurised store
Cubical polymeric water store

Key features:
• Optimal use of space due to cubical shape
• Steel frame with polymeric panels
• Construction and sealing on-site
• Individual sizing to fit the room
• Unpressurised
Pressurised polymeric water stores

Arbeitsgemeinschaft Druckspeicher:

**Key features:**
- First pressurised cylindrical polymeric store made from fibreglass-reinforced plastic
- Low thermal conductivity
- Corrosion-free
- Low weight
- Stratified charge and discharge device

source: http://www.energie-depot.com/bildergalerie.10.html
ModSto – Modular hot water store

Key features:
- Reduced space requirements compared to typical cylindrical hot water stores (PP)
- Pressure resistant up to 2,5 bar
- Module volume 1.3 m³
- Total volume up to 10 m³
- Very low heat losses
- Quick and easy installation

Source: Consolar
ITW, University of Stuttgart
Underground stores

Key features:

- Large volume achievable independent of building size
- Installation also possible in building stock
- Unpressurised stores up to 7 m³
- Pressurised stores up to 11 m³
- Significant costs for ground works

In development:

- Diffusion resistant foil bag instead of a steel store

source: Mall Umweltsysteme
Heat losses of water stores

Major disadvantage of storage of sensible heat is heat loss. **Counter action:**

- Thermal insulation with low thermal conductivity
- Good fit of thermal insulation
- Avoiding thermal bridges
- Prevention of convection inside the storage connections

<table>
<thead>
<tr>
<th>Volume (l)</th>
<th>Heat loss rate (W/K)</th>
<th>Annual heat loss of the store</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 l</td>
<td>2 – 2.7</td>
<td>ca. 500 kWh/a, hot water system</td>
</tr>
<tr>
<td>1000 l</td>
<td>3 – 4</td>
<td>ca. 1000 kWh/a, combisystem</td>
</tr>
<tr>
<td>10000 l</td>
<td>9 – 10</td>
<td>---</td>
</tr>
</tbody>
</table>
Vacuum super insulated water store

Key features:
- Extremely low heat losses
  Heat loss rate for a 16 m³ store: 1.98 W/K
  (typical value for a “standard” 250 l store)
- Perlite powder used as filling material
  - low costs 50 €/m³
  - low density 30-100 kg/m³
  - small pores 10-100 µm
  - high porosity 75-97 %

Source: ZAE Bayern, Germany
Mechanisms of heat storage

- **Storage of sensible heat**
  - **Sensible heat**
    - liquid
    - solid
  - **Water store**
    - space heating
    - climatisation
  - **Solid store material**
    - underground storage
    - ceramic material for high temperature processes

- **Latent heat**
  - solid-liquid
  - melting

- **Reaction heat**
  - liquid-gaseous
  - steam

**Thermal**

**Chemical**
Underground heat storage

Investigation of University of Innsbruck and Passive House Institute Darmstadt on a new concept to use solar and heat pump to supply heat to passive houses.

Key features:

- Single family home (2 Persons)
- Energetic reference area 152 m²
- Heat demand 15 kWh/(m² a)
- Solar system: 10 m², 750 l
- Brine/water-HP 4.8 kW

Source: Passivhaus Institut
Underground heat storage

Ground-coupled heat exchanger: 4 x 75 m PE (20 x 2 mm) = 3 m/m² below base plate inside the clean layer

Application in single family homes:
• High technical effort for ground activation
• Low energy efficiency
• High thermal losses

source: Passivhaus Institut
Mechanisms of heat storage

- Latent heat store
- Refrigeration and climatisation (restricted)
- Additional heat store suitable for different renewable energy sources
Mechanisms of latent heat storage

Advantages:
- High energy density at the phase change temperature

Disadvantages:
- Relatively high material costs
- Low thermal conductivity
- Large effort for heat transfer

Field of operation:
- Single PCM store
- Combined with water store
- Very few suppliers in the market
Latent heat storage in ice stores

Key features:
• Very large heat of fusion
• Low material costs

Field of operation:
• In combination with heat pump systems
• For „cold storage“ in solar thermal cooling systems

Source: ITW, Germany
Mechanisms of heat storage

Thermo-chemical heat store
- first developments in the field of adsorptions-processes
- first approaches in the field of chemical reactions
Development of thermo-chemical heat stores

Chemical heat store for low temperature applications:
- Open adsorption/hydration system using ambient air or exhaust air
- Salt in combination with an active / passive porous matrix
- Most promising composite material:
  - CaCl2 on passive matrix
  - MgSO4 on active matrix
- External cross-flow reactor with structural integrated heat-exchangers
- High regeneration temperatures (120-180 °C) required
- Experimentally reached storage density: 230 kWh/m³
- Loss less heat storage
Comparison of heat store mechanisms

<table>
<thead>
<tr>
<th></th>
<th>Energy density</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground soil*</td>
<td>ca. 35 kWh/m³</td>
<td>0,5</td>
</tr>
<tr>
<td>Water*</td>
<td>60 kWh/m³</td>
<td>1</td>
</tr>
<tr>
<td>Latent</td>
<td>50 - 120 kWh/m³</td>
<td>1 – 2</td>
</tr>
<tr>
<td>Adsorption</td>
<td>120 - 180 kWh/m³</td>
<td>2 – 3</td>
</tr>
<tr>
<td>Reaction</td>
<td>200 - 600 kWh/m³</td>
<td>4 – 10</td>
</tr>
</tbody>
</table>

* at $\Delta T = 50$ K
Examples of latest R&D developments related to system technology
Combined solar thermal and heat pump systems
Solar district heating with seasonal heat store

2,500 m² solar collectors on buildings
- multi-family houses
- residential area

2,500 m² solar collectors on buildings
- district heating net
- school building

5,000 m² solar collectors on noise barrier

Source: ITW, Germany
SmartHeat – intelligent modular SH & DHW

Key features:

• modular system topology
• effective integration and use of renewable energy sources
• Very applicable for retro-fitting
• Extendible by adding heat sources
• Reduced space requirements due to use of cubical PCM stores

Source: SmartHeat
Ongoing research and development is required to achieve the goals of ESTTP.

Besides improvements in collector design and new system topologies efficient heat storage is most sufficient.

In the present market almost exclusively water stores are the mature technology but still have further potential for optimisation:
- Modular concepts to achieve larger volumes
- Easy installation into building stock
- Underground storage
- Improved thermal insulation (vacuum-insulation)

Thermal activation of the soil or building components has low potential for single family homes.

Conclusion
Conclusion

• Beginning activity in the field of latent heat storage (PCM)
• Ice stores are used in combination with heat pumps and the field of refrigeration and climatisation
• Thermo-chemical energy storage is promising but technically extensive
  - Loss-less long-term heat storage
  - High energy density of the store
  - Increasing national and international research activity
• Very large systems for district heating and seasonal storage as well as small systems with a high grade of flexibility due to modular system topology are being investigated.
• More intelligent controllers are being developed to guarantee an optimised use of several renewable energy sources.
Thank you for your attention!