Exergy and cost analysis of heating systems with energy storage

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Outline

- Electricity and district heating in Sweden
- Heating method in service and household
- Heat price with district heat, electric boiler, and heat pump
- Thermal energy storages
- Summary
The energy and exergy efficiencies in Sweden

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Energy efficiency</th>
<th>Exergy efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP</td>
<td>97%</td>
<td>32%</td>
</tr>
<tr>
<td>Fuel boiler</td>
<td>93%</td>
<td>15%</td>
</tr>
<tr>
<td>Electric boiler</td>
<td>80%</td>
<td>13%</td>
</tr>
<tr>
<td>Heat pump</td>
<td>4 (COP)</td>
<td>69%</td>
</tr>
</tbody>
</table>
Heat for houses
Heating source for service and household

![Graph showing heating source for service and household from 2002 to 2015. The graph indicates a significant decrease in oil usage and an increase in biomass and DH (district heating).]
Heating source for service and household use in Exergy content

![Graph showing TWh of heating sources from 2002 to 2015. The graph indicates the contribution of various sources such as Other, Gas, Biomass, Electricity, DH, and Oil over the years.]
Methods for heating in service and household in Sweden

- District heating: about 54%
- Electric boiler/heater and heat pump: about 24%
- Biomass boiler: about 15%
- Other boiler and methods: about 7%
Heat cost including tax using district heat, electric boiler and heat pump

Price [SEK/MWh]

- District Heat (energy price)
- Heat from HP (energy price)
- Heat from EB (energy price)
- District Heat (exergy price)
- Heat from HP (exergy price)
- Heat from EB (exergy price)
Thermal energy storage
Heat distributed to net during one year in a solar district heating system
Evaluation of thermal Storage

- \( \eta = \frac{\text{Total energy recovered} + \text{Accumulated energy in storage}}{\text{Total energy delivered}} \)
  \[= \frac{Q_r + Q_{acc}}{Q_c} = 1 - \frac{Q_{loss}}{Q_c} \]

- \( \eta_{ex} = \frac{\text{Total exergy recovered} + \text{Accumulated exergy in storage}}{\text{Total exergy delivered}} \)
  \[= \frac{E_r + E_{acc}}{E_c} = 1 - \frac{E_{loss} + E_{destruction}}{E_c} \]
Energy Storage efficiency

• Overall energy efficiency of thermal storage : about 60%

• Overall exergy efficiency of thermal storage : about 19%
Investment cost of energy storage

<table>
<thead>
<tr>
<th>Energy Storage Type</th>
<th>Euro/MWh</th>
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</thead>
<tbody>
<tr>
<td>Pumped Hydro</td>
<td>100,000</td>
</tr>
<tr>
<td>Sodium-sulphur battery</td>
<td>600,000</td>
</tr>
<tr>
<td>Compressed air</td>
<td>200,000</td>
</tr>
<tr>
<td>Tesla power wall</td>
<td>600,000</td>
</tr>
<tr>
<td>Solar DH</td>
<td>10,000</td>
</tr>
<tr>
<td>Large tank for CHP plant</td>
<td>5,000</td>
</tr>
<tr>
<td>4000 l tank for building</td>
<td>10,000</td>
</tr>
<tr>
<td>160 l dwelling heat tank</td>
<td>900,000</td>
</tr>
</tbody>
</table>
Summary

• Avoid to convert high quality energy sources to low quality energy sources, use low quality renewable energy resources

• Heat pump is good example combined low and high quality energy input, and price could complete with district heating at present

• Electricity storage is about 100 times more expensive than storage, in energy, and 20 times more in exergy
Thank for your attention!