UTES Experiences from Sweden

Göran Hellström
Lund University, Sweden
NeoEnergy Sweden Ltd
Closed Loop - Sweden

400,000 Ground-Source Heat Pumps (GSHP) installed
Ground source supplies 15 % of national heating demand
30-35 % of all single-family houses has a heat pump
UNDERGROUND THERMAL ENERGY STORAGE
Underground Thermal Energy Storage

**ATES** – Aquifer Thermal Energy Storage
Sweden: ca 40 systems

**BTES** – Borehole Thermal Energy Storage
Sweden: ca 50 systems larger than 5000 m drilling

**CTES** – Cavern Thermal Energy Storage
Sweden: 3 systems
World’s largest open loop system – savings 3-4 Gwh electricity, 10-15 Gwh heat
Payback time 6-7 years
ATES/Open loop - Arlanda Airport
BTES - Project Lulevärme, Luleå

Seasonal storage of waste heat

- Summer: Storage of waste heat from steel plant
- Stored heat: ca 2000 MWh (maximum temp 82 °C)
- Winter: University building heated with/without heat pump
- Extracted heat: 1000-1200 MWh
- In operation 1983-1989
Borehole heat store: 120 boreholes  depth 65 m
Connection pipes and manifold
Measured temperature in center of store
测得和模拟的能量平衡 1983-1988

BTES - Luleå

能量（MWh）

-1500 -1000 -500 0 500 1000 1500 2000 2500 3000 3500 4000 4500

模拟的热输入
测得的热输入
模拟的热输出
测得的热输出


测得和模拟的能量平衡 1983-1988
Estimated ground temperature after charging
Simulation results in good agreement with measurements
BTES - Project Emmaboda
Seasonal storage of waste heat

- Summer: Storage of waste heat from foundry
- Stored heat: ca 3600 MWh
- Winter: Factory building heated
- Extracted heat: 2000 MWh
- In operation 2010-

<table>
<thead>
<tr>
<th>Heat source</th>
<th>Supply temp. ($^\circ$C)</th>
<th>Direct use</th>
<th>To BTES storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directly from ovens</td>
<td>55-70</td>
<td>1 500</td>
<td>1 300</td>
</tr>
<tr>
<td>Heat pump produced</td>
<td>60</td>
<td>2 500</td>
<td>2 300</td>
</tr>
<tr>
<td>Minor sources</td>
<td>65-70</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td><strong>Totally</strong></td>
<td><strong>-</strong></td>
<td><strong>4 200</strong></td>
<td><strong>3 800</strong></td>
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</tbody>
</table>
BTES - Emmaboda

Borehole heat store: 141 boreholes depth 148.5 m
BTES Emmaboda System layout
BTES Emmaboda
Borehole heat exchanger

Open coaxial pipe of polypropylene
BTES Emmaboda
Borehole heat exchanger
BTES Emmaboda
Connecting pipes
BTES Emmaboda
Connecting pipes

3000 m DN40 polypropylene pipes

14 manifolds

Foam glass insulation
BTES Emmaboda
Boreholes

Measurements of borehole deviation
BTES Emmaboda
Operation strategy

Heat carrier fluid temperature
BTES Emmaboda
First operating experience

Charged energy: 900 MWh (2010), 3000 MWh (2011)
CTES
Lyckebo

- Volume of cavern: 104,300 m³
- Storage capacity: 5,5 GWh
- Store temperature 60-90 ºC
- Used for seasonal storage
- Cost: 17,5 MSEK (1982)
CTES
Lyckebo

System design
CTES Lyckebo

Solar collector field
CTES
Lyckebo

Rock cavern schematic
CTES
Lyckebo

Rock cavern during construction
CTES

Avesta

Temperature field
CLOSED LOOP BOREHOLE HEAT EXCHANGERS
Astronomy Department, Lund

BTES heating and free cooling combined with district heating
Office space 4,900 m²
Energy load

- Heating need: ca 100 kWh/m²/year
- Cooling need: ca 30 kWh/m²/year

Outdoor temperature in Lund:

- Temperature range: -10°C to +20°C
- Hours/year range: 0 to 8760
Energy supply

- Auxiliary heat: 8 kWh/m² BTU/year
- Heat pump: 89 kWh/m² BTU/year
- Evaporator cooling: 3 kWh/m² BTU/year
- Direct cooling: 25 kWh/m² BTU/year
- Evaporator cooling: 2 kWh/m² BTU/year
- E1 to heat pump: 19.6 kWh/m² BTU/year
## Energy balance

<table>
<thead>
<tr>
<th>Energy balance</th>
<th>Normal year (adjusted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat from heat pump</td>
<td>475 MWh</td>
</tr>
<tr>
<td>Cold from ground source (free cooling)</td>
<td>155 MWh</td>
</tr>
<tr>
<td>Electricity to heat pump compressor</td>
<td>104 MWh</td>
</tr>
<tr>
<td>District heating (hot water + peak load)</td>
<td>40 MWh</td>
</tr>
<tr>
<td>Electricity to circulationspumps (ground and condensor side)</td>
<td>7 MWh</td>
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</table>

### Key factors

<table>
<thead>
<tr>
<th>Key factors</th>
<th>Normal year (adjusted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal performance factor - heat pump (incl. circulation)</td>
<td>4,5</td>
</tr>
<tr>
<td>Seasonal performance factor - free cooling</td>
<td>47</td>
</tr>
<tr>
<td>Heating and cooling demand</td>
<td>126 kWh/m², yr</td>
</tr>
<tr>
<td>Bought energy</td>
<td>28 kWh/m², yr</td>
</tr>
<tr>
<td>Seasonal performance factor - ground source (heat pump + free cooling)</td>
<td>5,7</td>
</tr>
<tr>
<td>Seasonal performance factor - total (ground source + district heating)</td>
<td>4,4</td>
</tr>
<tr>
<td>Project</td>
<td>Boreholes</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
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<tr>
<td>BRF. Ljuskärssberget, Stockholm Saltsjöbaden</td>
<td>156</td>
</tr>
<tr>
<td>Kemicentrum (IKDC), Lund</td>
<td>153</td>
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<tr>
<td>Lustgården, Stockholm</td>
<td>144</td>
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<tr>
<td>Vällingby Centrum, Stockholm</td>
<td>133</td>
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<tr>
<td>BRF. Igelbodaplatsan, Stockholm Saltsjöbaden</td>
<td>120</td>
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<tr>
<td>Kv. Bergen, Stockholm Husby</td>
<td>98</td>
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<td>ITT Flygt, Emmaboda</td>
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<tr>
<td>Kv. Galgvreten, Enköping</td>
<td>86</td>
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<tr>
<td>Copperhill Mountain Lodge, Åre</td>
<td>92</td>
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<td>Centrala Gribbylund, Täby</td>
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<tr>
<td>Thulehem, Lund</td>
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<tr>
<td>IKEA, Uppsala</td>
<td>100</td>
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<tr>
<td>NIBE, Markaryd</td>
<td>110</td>
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<tr>
<td>Centralsjukhuset, Karlstad</td>
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<tr>
<td>Backavallen, Katrineholm</td>
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<tr>
<td>IKEA, Karlstad</td>
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<tr>
<td>Musikhögskolan, Örebro</td>
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<tr>
<td>Sjukhuset, Kristinehamn</td>
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<tr>
<td>Vattenfalls Huvudkontor, Solna</td>
<td>53</td>
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<tr>
<td>IKEA, Helsingborg Väla</td>
<td>67</td>
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<tr>
<td>Stenungsbaden Yacht Club, Stenungsund</td>
<td>50</td>
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<tr>
<td>Näsby Parks Slott, Stockholm</td>
<td>48</td>
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<tr>
<td>Projekt Lulevärme, Luleå</td>
<td>120</td>
</tr>
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</table>
Hybrid GSHP

- Ground source
- Exhaust air source
- Outdoor air source
- Water source (lake, river)
- Solar source
- Waste heat
GSHP/Solar hybrid

- Hot water
- Space heating
- Increasing HP evaporator temperature
- Recharging of ground loop
Seasonal storage of solar heat

Examples: Neckarsulm, Germany, and Anneberg, Sweden
Sea Water

Hybrid system - Boreholes with summer recharge from lake
Combining ground-source for buildings with different load

Community clusters

Common ground source

RESIDENTIAL

OFFICE
Combining ground-source for buildings with different load
Avantor-Nydalen, Oslo, Norway

Area: 180,000 m²
Energy store: 90 boreholes, depth 200 m
+ 70 borehole, depth 260 m
Energy balance by combining buildings with different load profiles
Heating load

Total heat demand: 8.5 MW
Heat pump capacity: 1.8 MW
- From ground loop: 1.2 MW
Cooling load

Total cooling demand 3,0 MW
Katrineholm Sport Centre

Community clusters

Common ground source

ICE RINK
Cooled sep-may

OFFICE
Heated sep-may

GYMNASIUM
Heated sep-may

Outdoor SOCCER
Heated when air above 0 C

Outdoor ICE RINK
Cooled when air below 0 C

SWIMMING POOL
Heated all year
At present two office/service buildings and six stores are using borehole storage (BTES) or aquifer storage (ATES) for combined heating and cooling

- Distribution Centre, Torsvik, installed 1999 (BTES + horizontal GSHP)
- IKEA Meeting Point in Helsingborg, installed 2003 (BTES)
- IKEA Store in Karlstad, installed 2007 (BTES)
- IKEA Store in Uppsala, installed 2008 (BTES)
- IKEA Store in Malmö, installed 2009 (ATES)
- IKEA Store in Väla, installed 2010 (BTES)
- IKEA Store in Uddevalla, under construction 2012 (BTES)
- IKEA Store in Borlänge, under construction 2012 (BTES)
IKEA – Applications in Sweden

General for a 25 000 m$^2$ store in Swedish climate (European system design)

- 50-60% of the heat load covered by the HP, represents 85-90% of the annual heat demand
- Peak load covered by electric boiler, bio fuel burner or DH
- 60% of the cooling load covered by free cooling from the storage, represents 70-80% of the annual cold demand
- Peak load covered by running the HP as a chiller. Dry cooler used for disposal of condenser heat
IKEA – Meeting point 5,000 m², Helsingborg

Facts:
• 36 boreholes, 140 m deep, single U-pipe
• Heat pump, 90 kW piston compressors
• System heat capacity, 270 kW
• System cooling capacity, 350 kW
• SPF (measured) 6.3

Pay-back time
Expected, 5.5 years (2003)
Actual, 4.5 years (2007)
Heat demand
• Max load, 1200 kW
• Energy, 1200 MWh/year

Cold demand
• Max load, 800 kW
• Energy, 500 MWh/year

Expectations
• SPF heating, 3.8 (boiler included)
• SPF cooling, 7.3
• Payback time, 6 years

BTES system installed 2007
• 100 boreholes, 120 m deep, spaced 4.5 m
• Drilled on excavated rock (granite)
• Water filled holes, with single U-pipe
• Construction time 10 weeks (2 rigs)
• High water yields caused problem
• Linked to a 620 kW heat pump/chiller
IKEA – Store 36,000 m², Uppsala

Heat demand
• Max load, 1 300 kW
• Energy, 2 200 MWh/year

Cold demand
• Max load, 1 300 kW
• Energy, 1 500 MWh/year

Expectations
• SPF heating, 4.3 (boiler included)
• SPF cooling, 6.5 (Americ. design)
• Payback time, 5.5 years

BTES system installed 2008
• 100 boreholes, 168m deep, spaced 5 m
• 20 m casing through soil into granite
• Water filled holes, with double U-pipes
• Construction time 10 weeks (3 rigs)
• Highly fractured rock caused problem
• Linked to 2 x 660 kW heat pumps/chillers
ATES system installed 2009
- 5 warm and 6 cold wells,
- 90 m deep into a fractured limestone
- Average well capacity, approx. 10 l/s
- Construction time 6 weeks (1 rig)
- Linked to 2 x 410 kW heat pumps/chillers

Heat demand
- Max load, 1 300 kW
- Energy, 2 350 MWh/year

Cold demand
- Max load, 1 300 kW
- Energy, 1 450 MWh/annually

Expectations
- SPF heating, 4.3 (boiler included)
- SPF cooling, 45 (100 %)
- Payback time, 4.5 years
Karlstad’s Hospital, Sweden

Heating and cooling with combined ground and river source
Karlstad’s Hospital, Sweden

Energy demand (=bought energy)

- District heating: 26,4 GWh/year
- Electricity: 23,6 GWh/year
- Total: 50,0 GWh/year

**Step 1. Energy efficiency measures**
- Changing windows, improving thermal insulation

**Step 2. Change of energy production**
- Installation of ground-source heat pump/energy storage with free cooling during summer and preheating of outdoor air during winter

**AFTER (2011)**
- District heating: 2,5 Gwh/year
- HVAC/GSHP electricity: 22,2 GWh/year
- Total: 24,7 MWh/year

**Savings**
- 24,1 GWh heat (91 %)
- 1,4 Gwh electricity

**Payback time** 5 years
Energy supply - before

District heating

Heat

Free cooling / river

Cooling machine
Energy supply - after

District heating
Heat pump electricity
River
Ground
Hc fluid

Hc fluid
Free cooling / ground
River
Cooling machine
### Kristinehamn’s Hospital, Sweden

Energy demand (=bought energy)

<table>
<thead>
<tr>
<th></th>
<th>BEFORE</th>
<th>AFTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>District heating</td>
<td>2135 MWh/year</td>
<td>155 MWh/year</td>
</tr>
<tr>
<td>HVAC electricity</td>
<td>605 MWh/year</td>
<td>465 MWh/year</td>
</tr>
<tr>
<td>Total</td>
<td>2740 MWh/year</td>
<td>620 MWh/year</td>
</tr>
</tbody>
</table>

**Step 1.** Energy efficiency measures  
- Changing windows, improving thermal insulation

**Step 2.** Change of energy production  
- Installation of ground-source heat pump/energy storage with free cooling during summer and preheating of outdoor air during winter

**Savings** 2120 MWh (78 %)

**Payback time** 5 years
Kristinehamn’s Hospital, Sweden

Before energy efficiency measures

- HVAC electricity
- District heating

After installation of GSHP

- Bought energy (MWh)
  - Before: 2500 MWh
  - After energy efficiency measures: 1500 MWh
  - After installation of GSHP: 500 MWh

Bought energy (MWh)
Installation costs

- Drilling* 20-35 EUR per m

- Complete system (borehole heat exchanger, installation, heat pump)
  1500 EUR per kW heating capacity

* Depending on local geological conditions