UTES Experiences from Sweden

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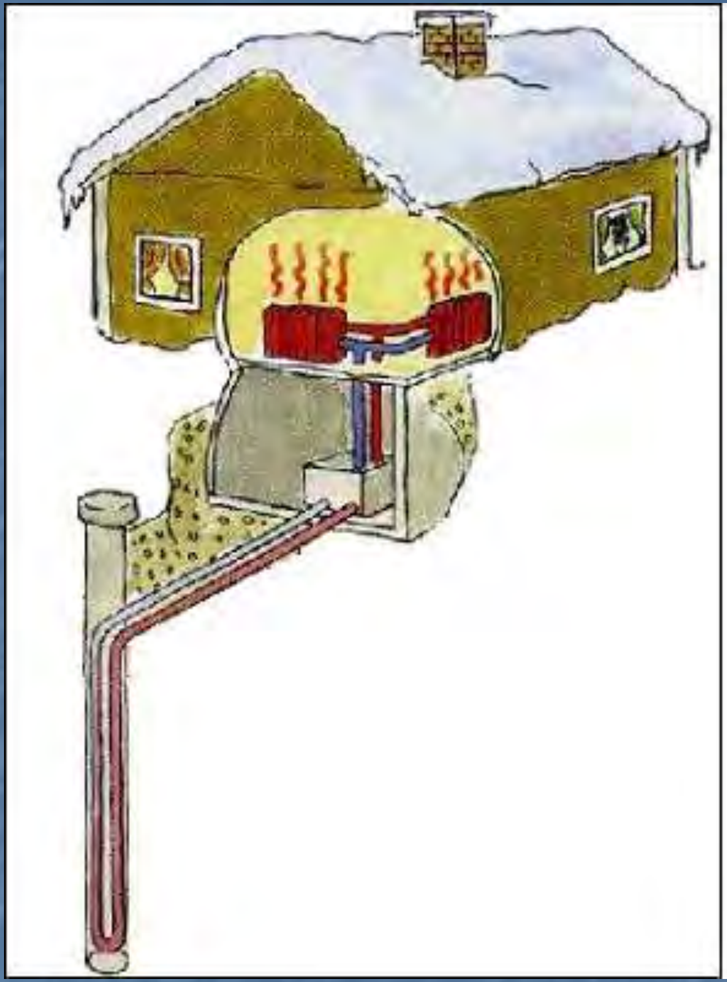
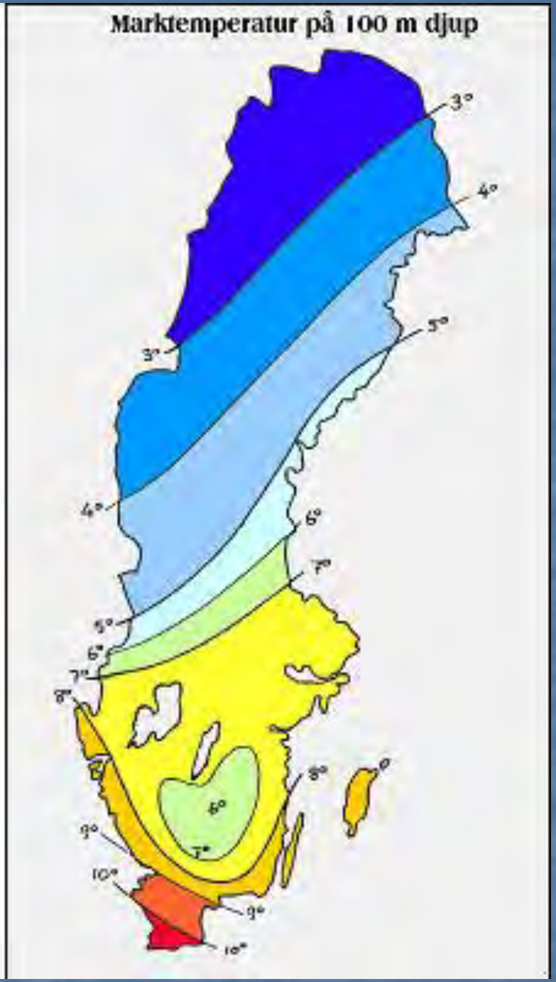
NeoEnergy Sweden Ltd

Closed Loop - Sweden

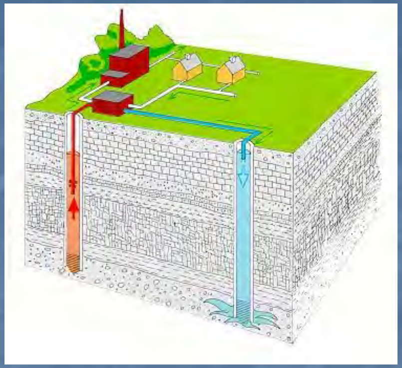




400,000 Ground-Source Heat Pumps (GSHP) installed
Ground source supplies 15 % of national heating demand
30-35 % of all single-family houses has a heat pump

UNDERGROUND THERMAL ENERGY STORAGE

Underground Thermal Energy Storage

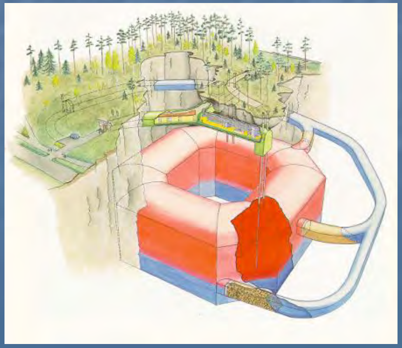


ATES – Aquifer Thermal Energy Storage

Sweden: ca 40 systems

BTES – Borehole Thermal Energy Storage

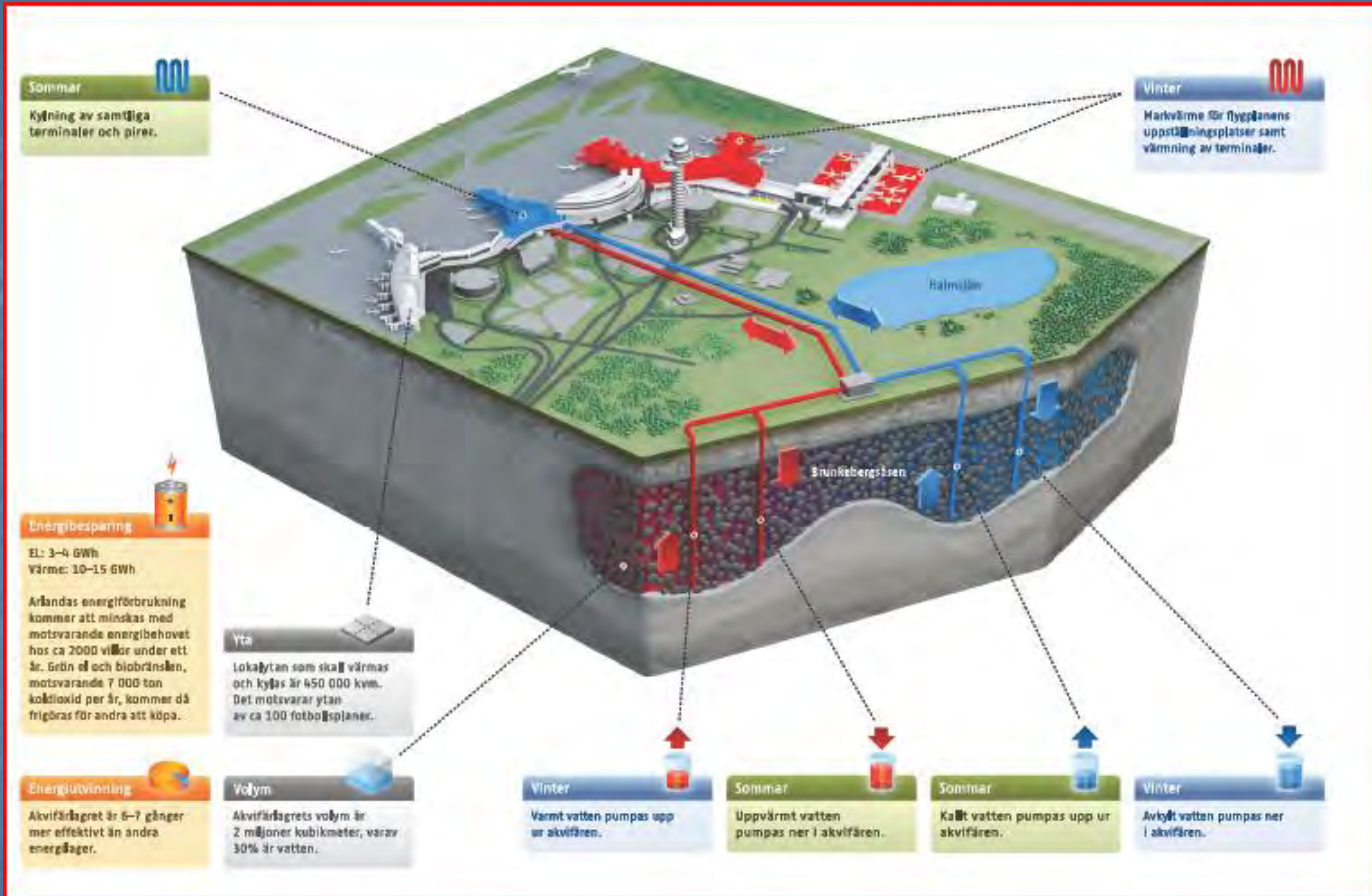
Sweden: ca 50 systems larger than 5000 m drilling



CTES – Cavern Thermal Energy Storage

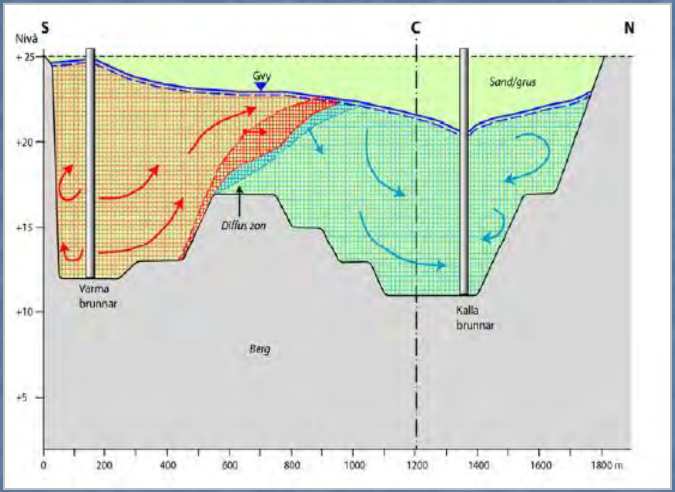
Sweden: 3 systems

ATES/Open loop - Arlanda Airport



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

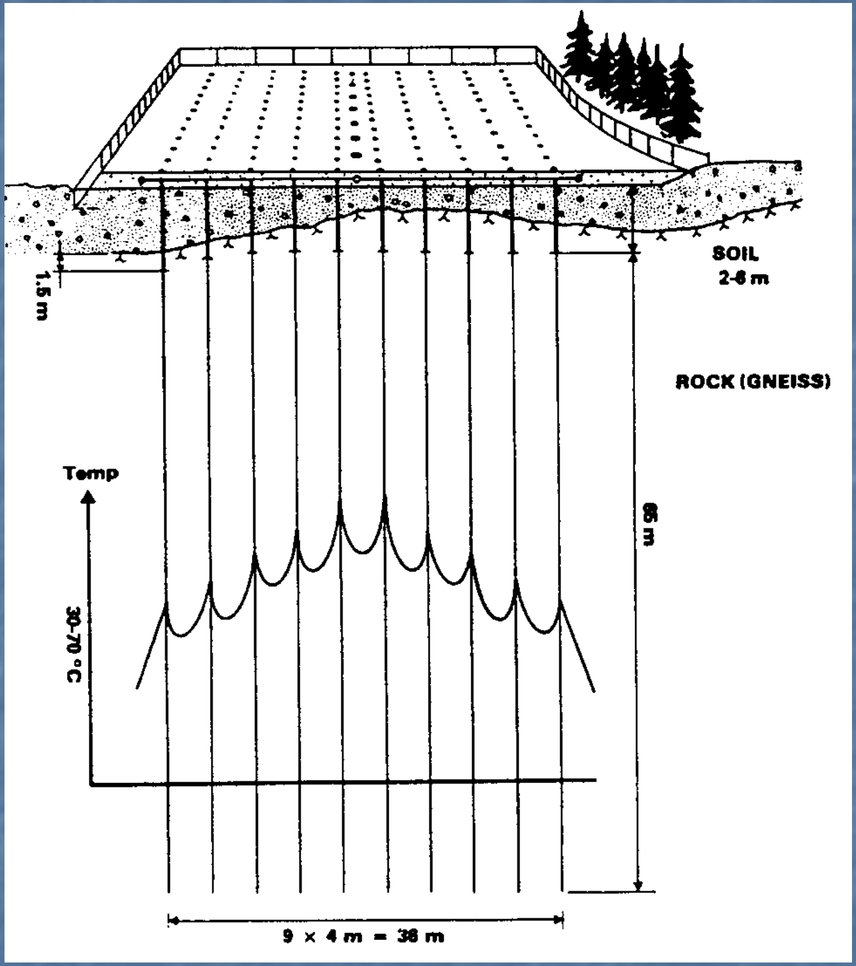


BTES - Project Lulevärme, Luleå

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

BTES - Luleå

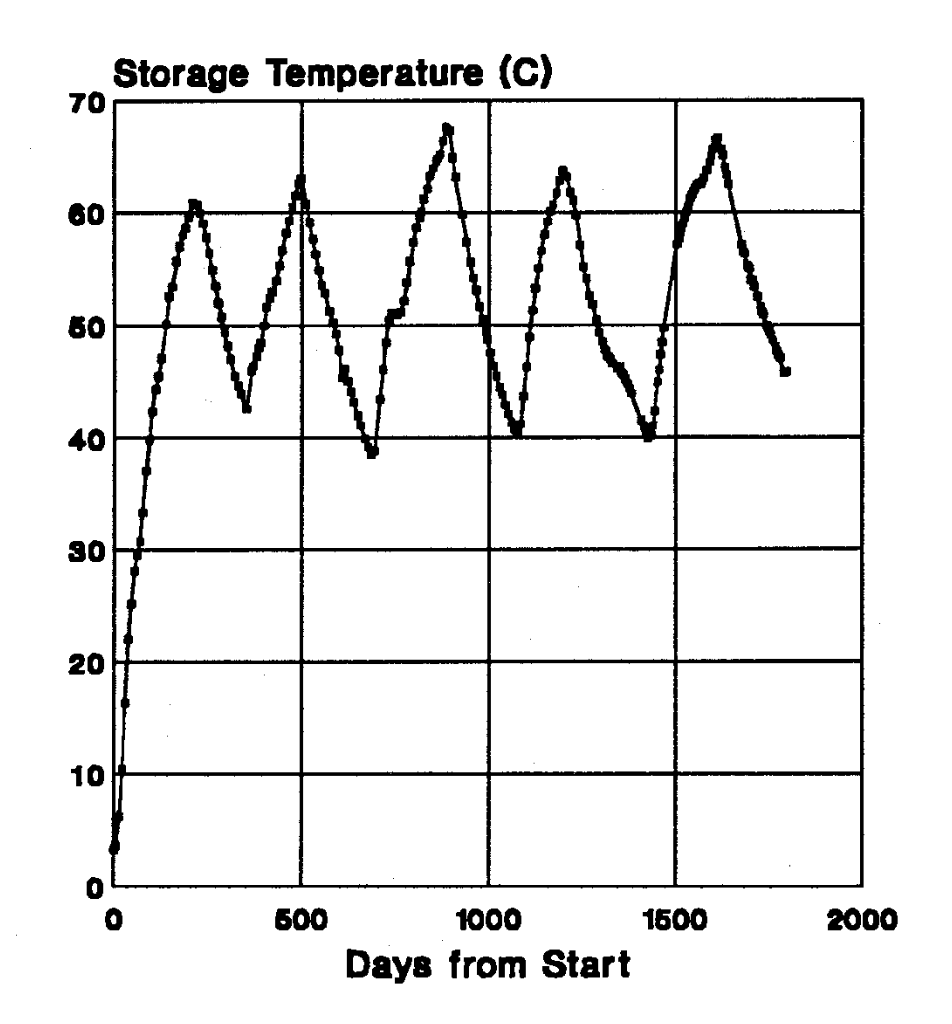


Borehole heat store: 120 boreholes depth 65 m

BTES - Luleå

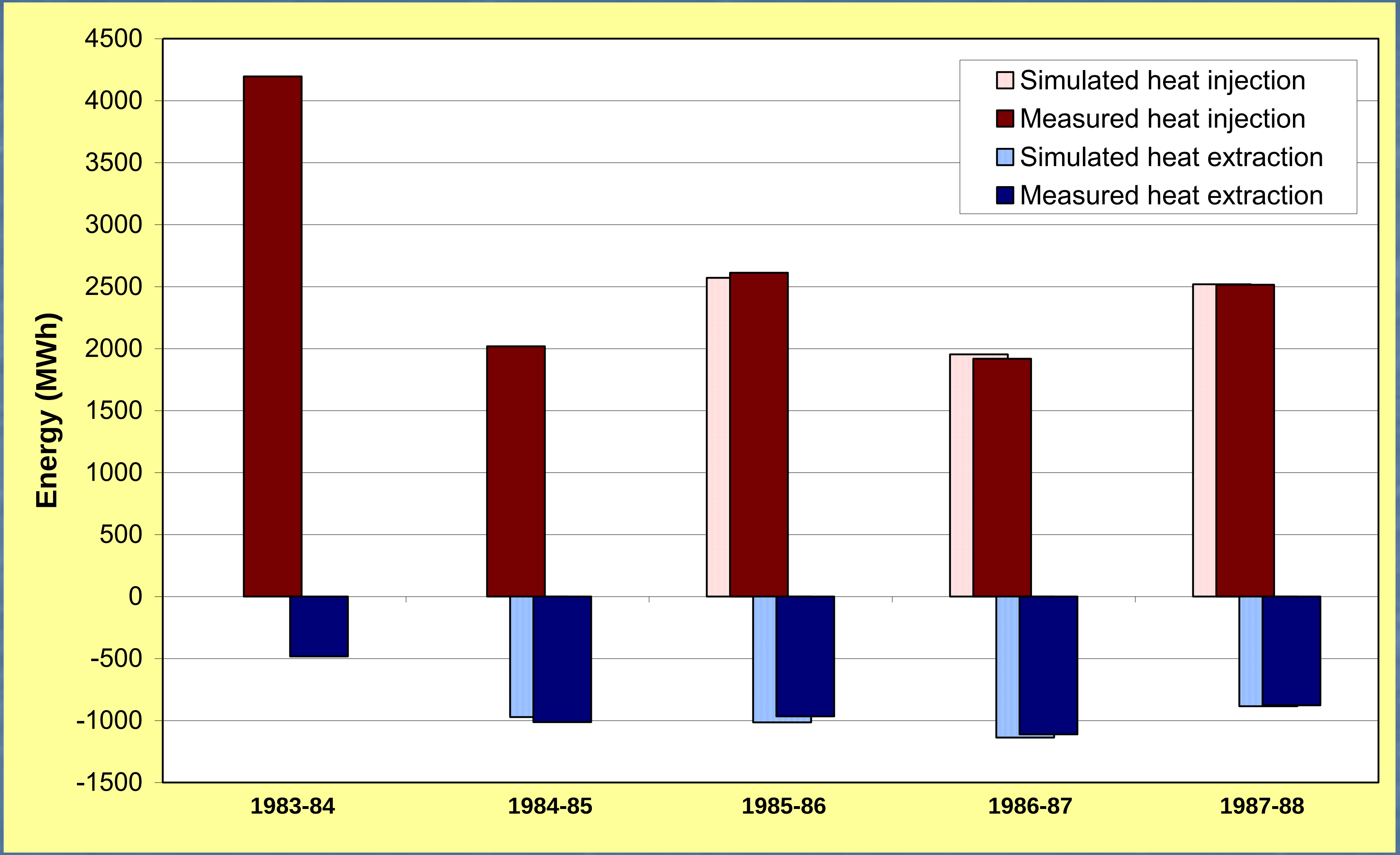
Connection pipes and manifold

BTES - Luleå



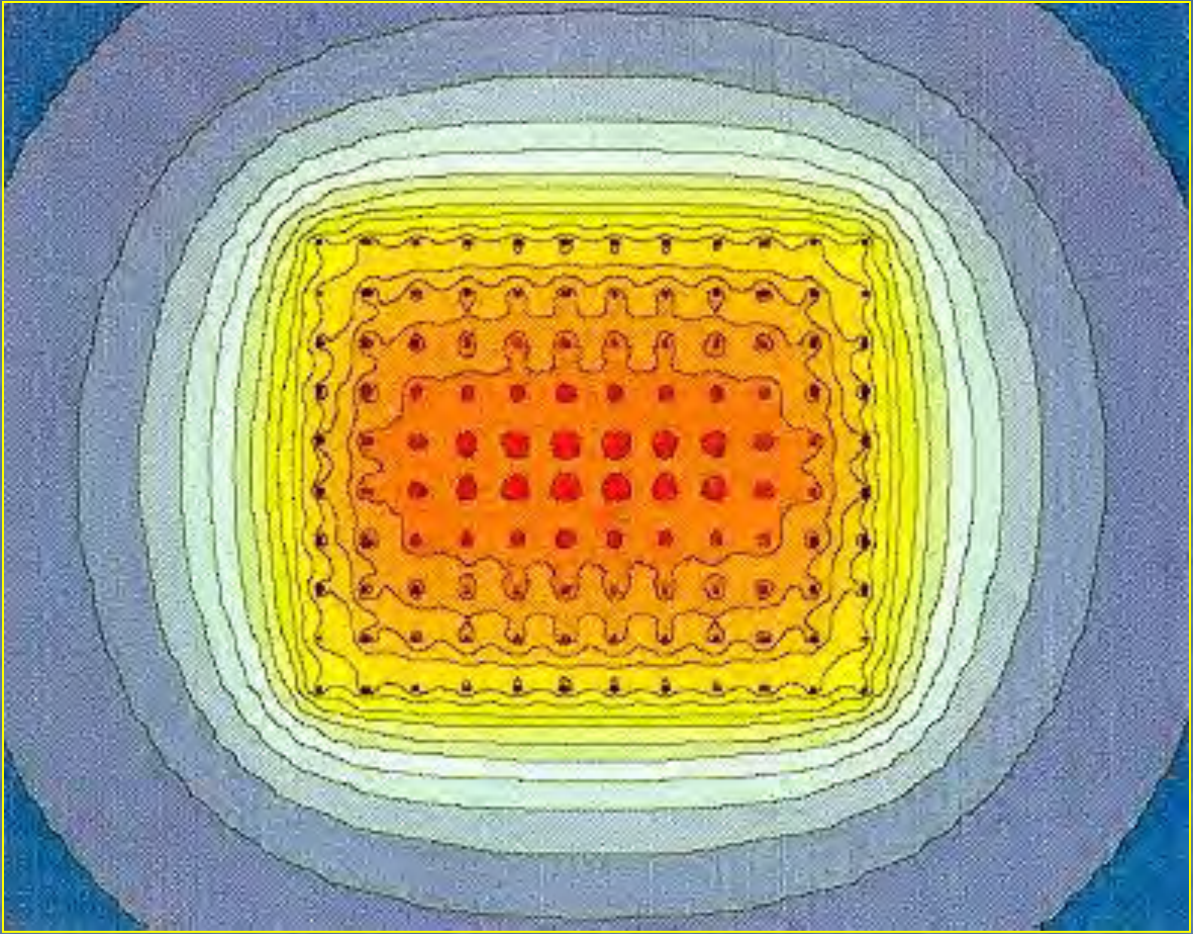
Measured temperature in center of store

BTES - Luleå



Measured and simulated energy balance 1983-1988

BTES - Luleå



Estimated ground temperature after charging

Simulation results in good agreement with measurements

BTES - Project Emmaboda

Seasonal storage of waste heat

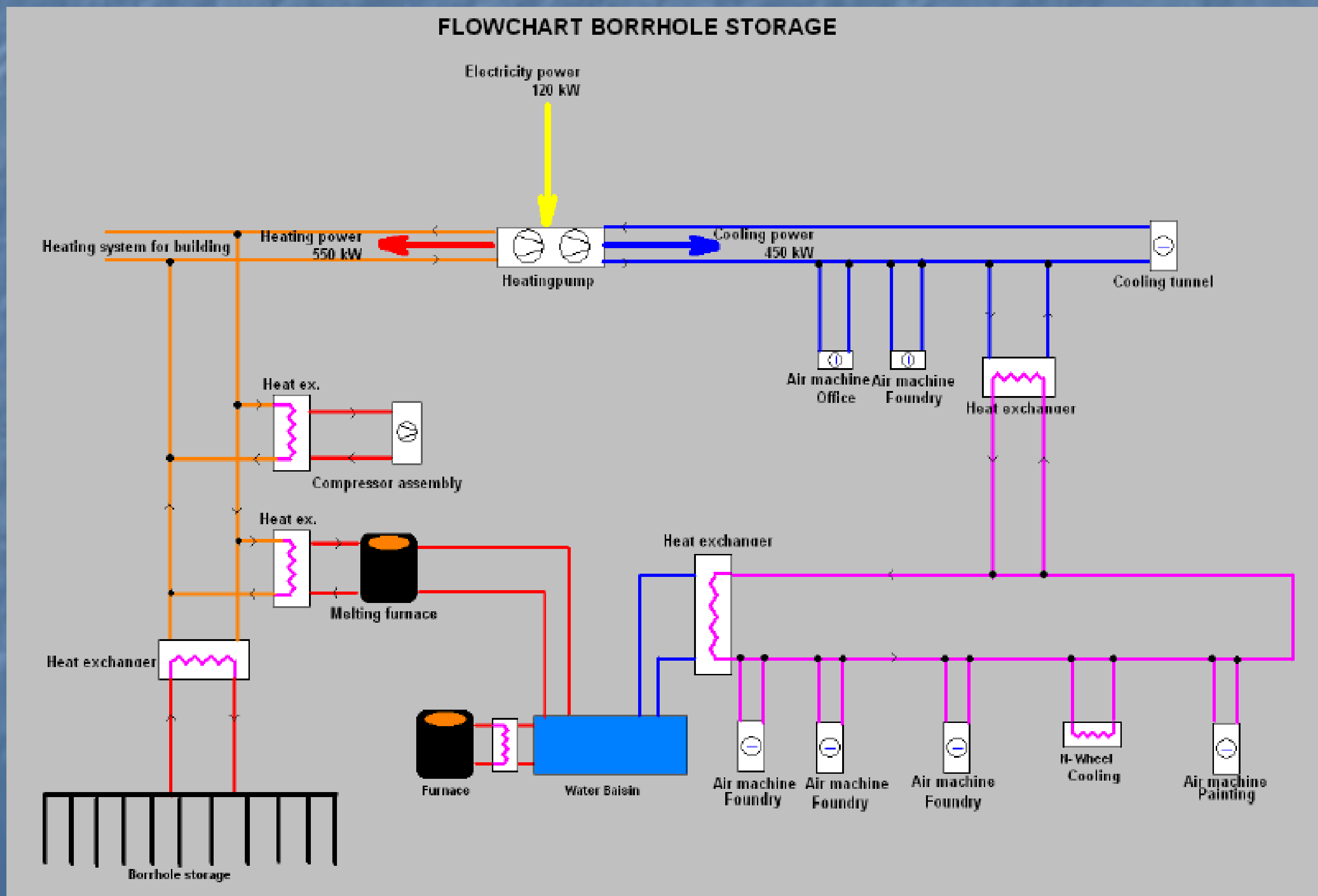
- Summer: Storage of waste heat from foundry
- Stored heat: ca 3600 MWh
- Winter: Factory building heated
- Extracted heat: 2000 MWh
- In operation 2010-

Heat source	Supply temp. (°C)	Direct use	To BTES storage
Directly from ovens	55-70	1 500	1 300
Heat pump produced	60	2 500	2 300
Minor sources	65-70	200	200
Totally	-	**4 200**	**3 800**

BTES - Emmaboda

Borehole heat store: 141 boreholes depth 148,5 m

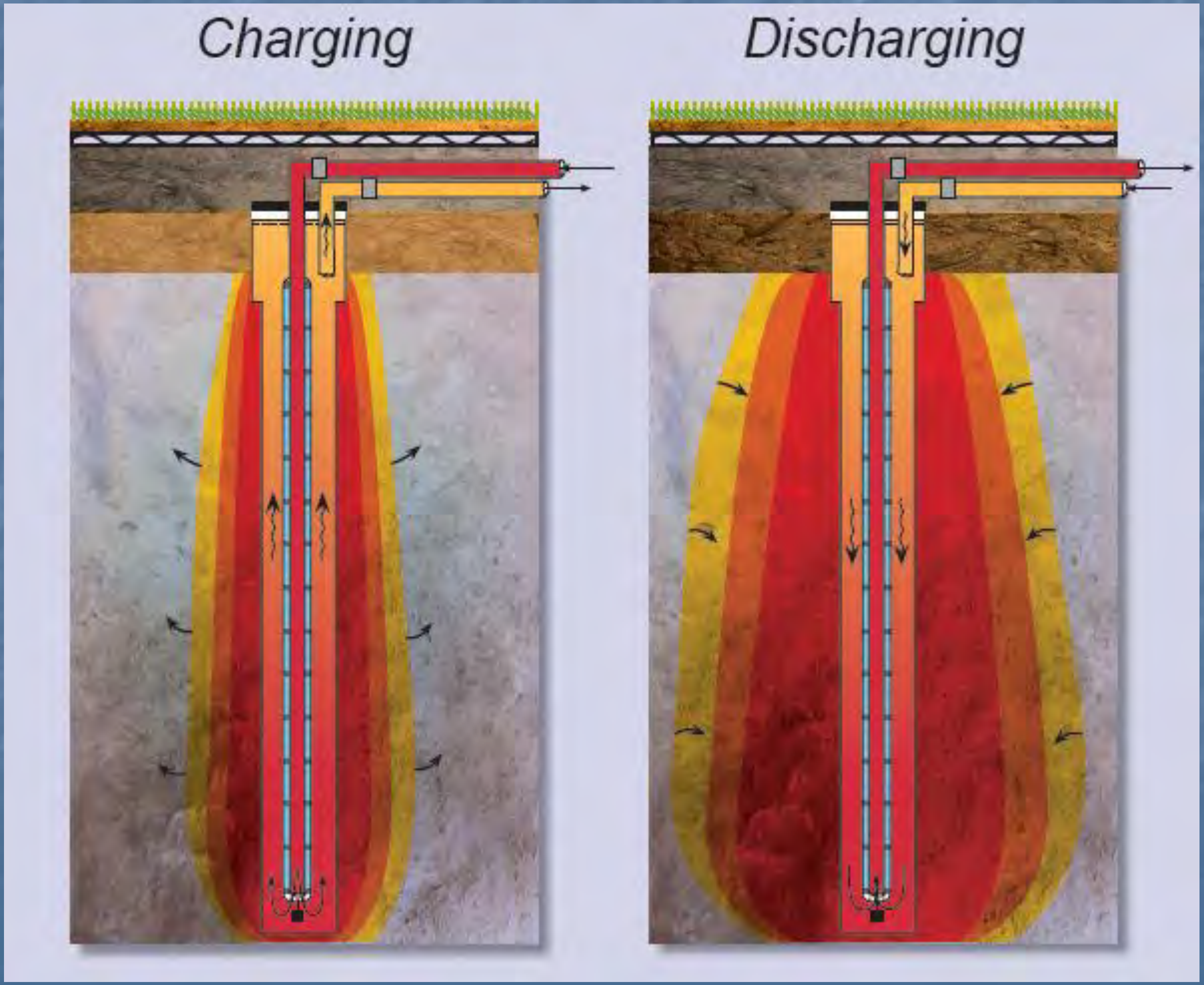
BTES Emmaboda
System layout



BTES Emmaboda
Borehole heat exchanger

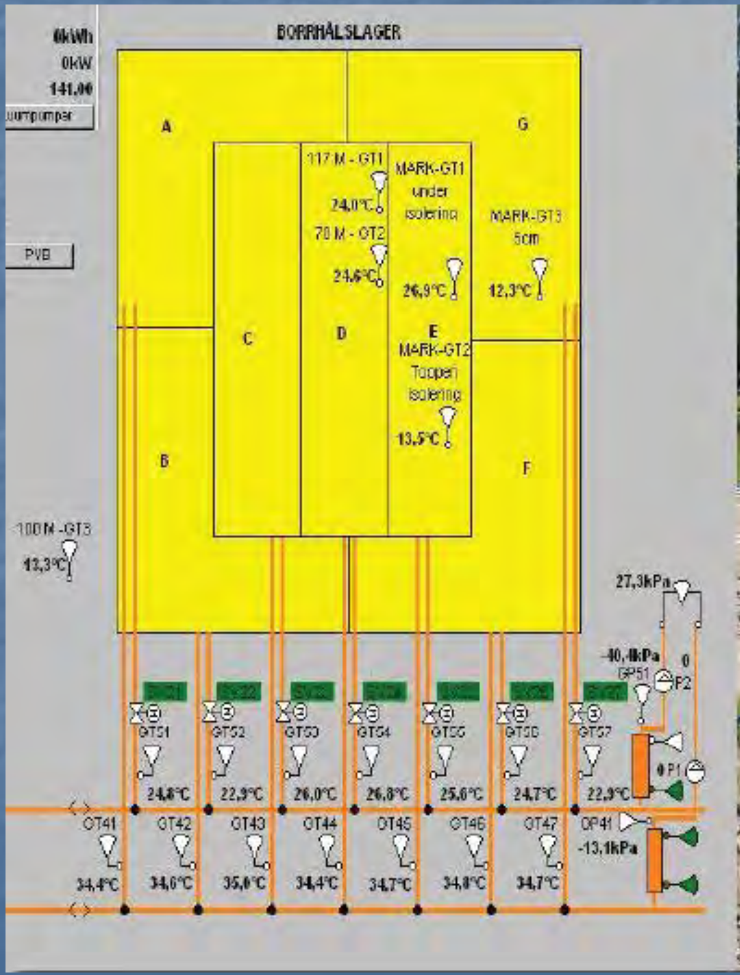
Open coaxial pipe of polypropylene

BTES Emmaboda
Borehole heat exchanger

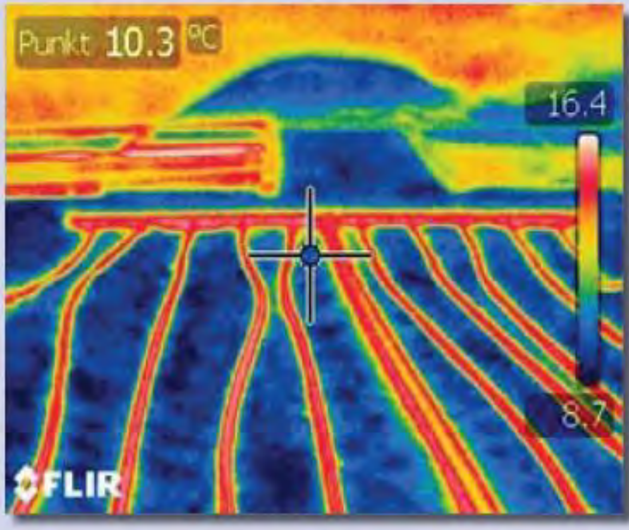


BTES Emmaboda

Connecting pipes



BTES Emmaboda
Connecting pipes



The insulation consists of 0.4 m expanded glass (foam glass)

Field manifolds have degassing valves

The BHE with dual pipes and a connection formed as a centralizer

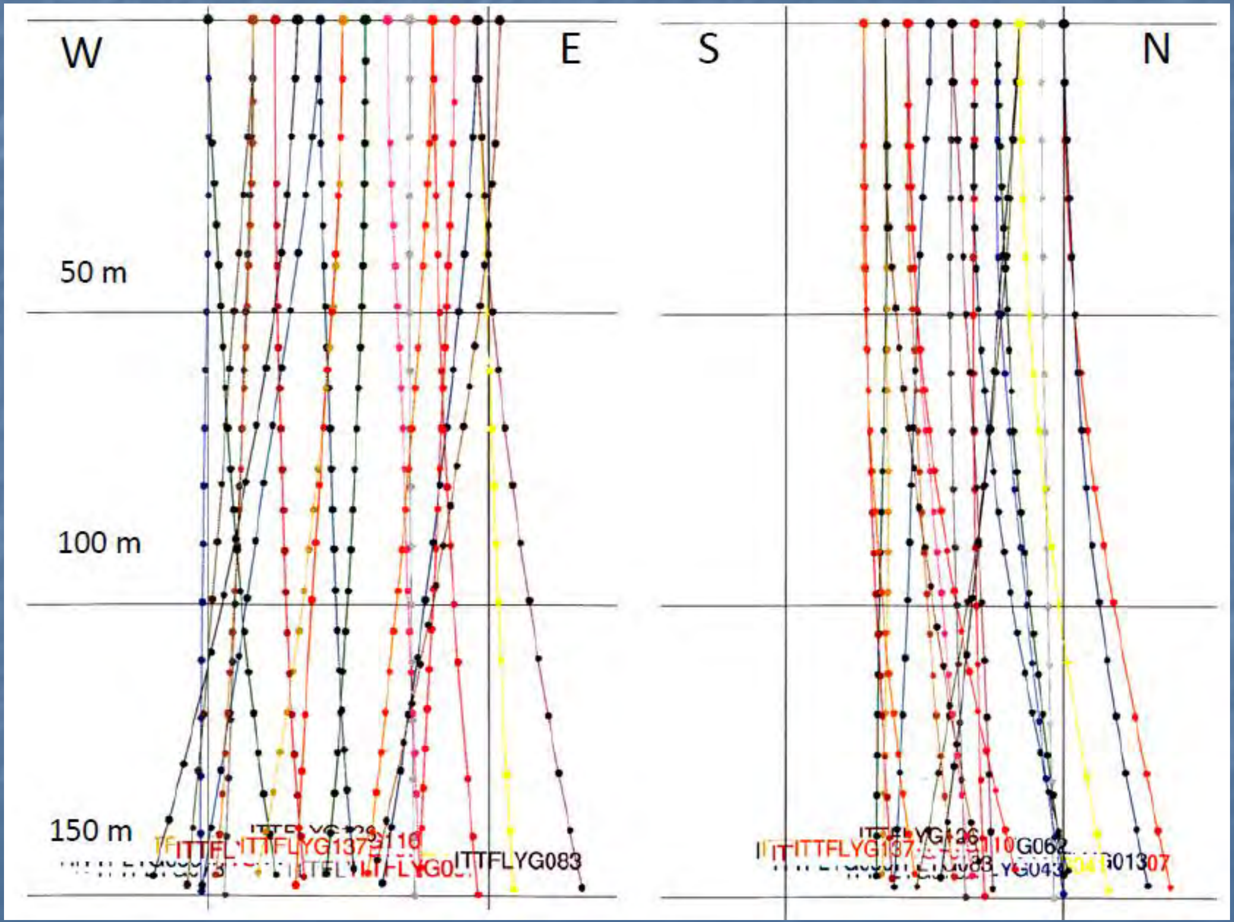
3000 m DN40 polypropylene pipes

14 manifolds

Foam glass insulation

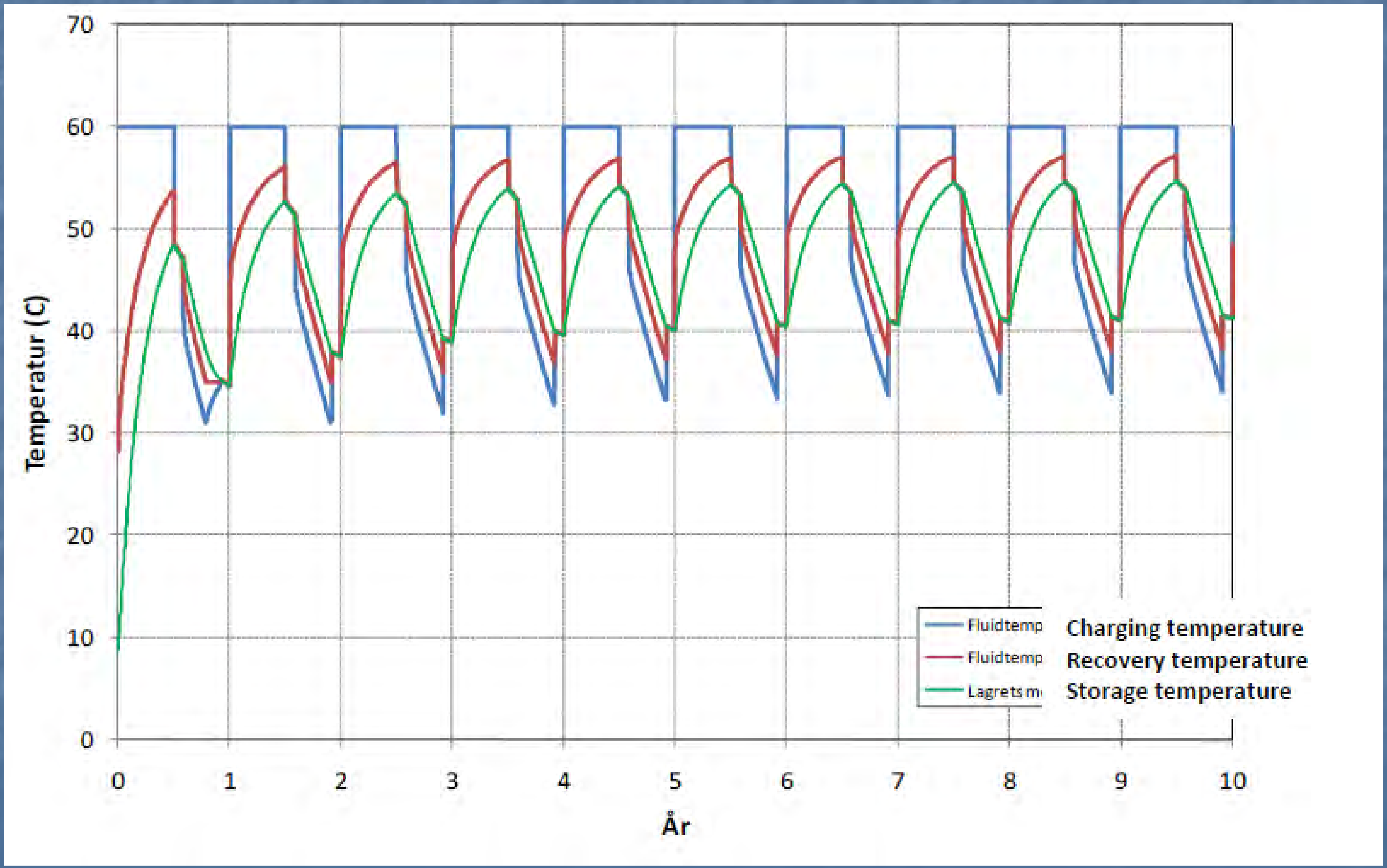
BTES Emmaboda

Boreholes



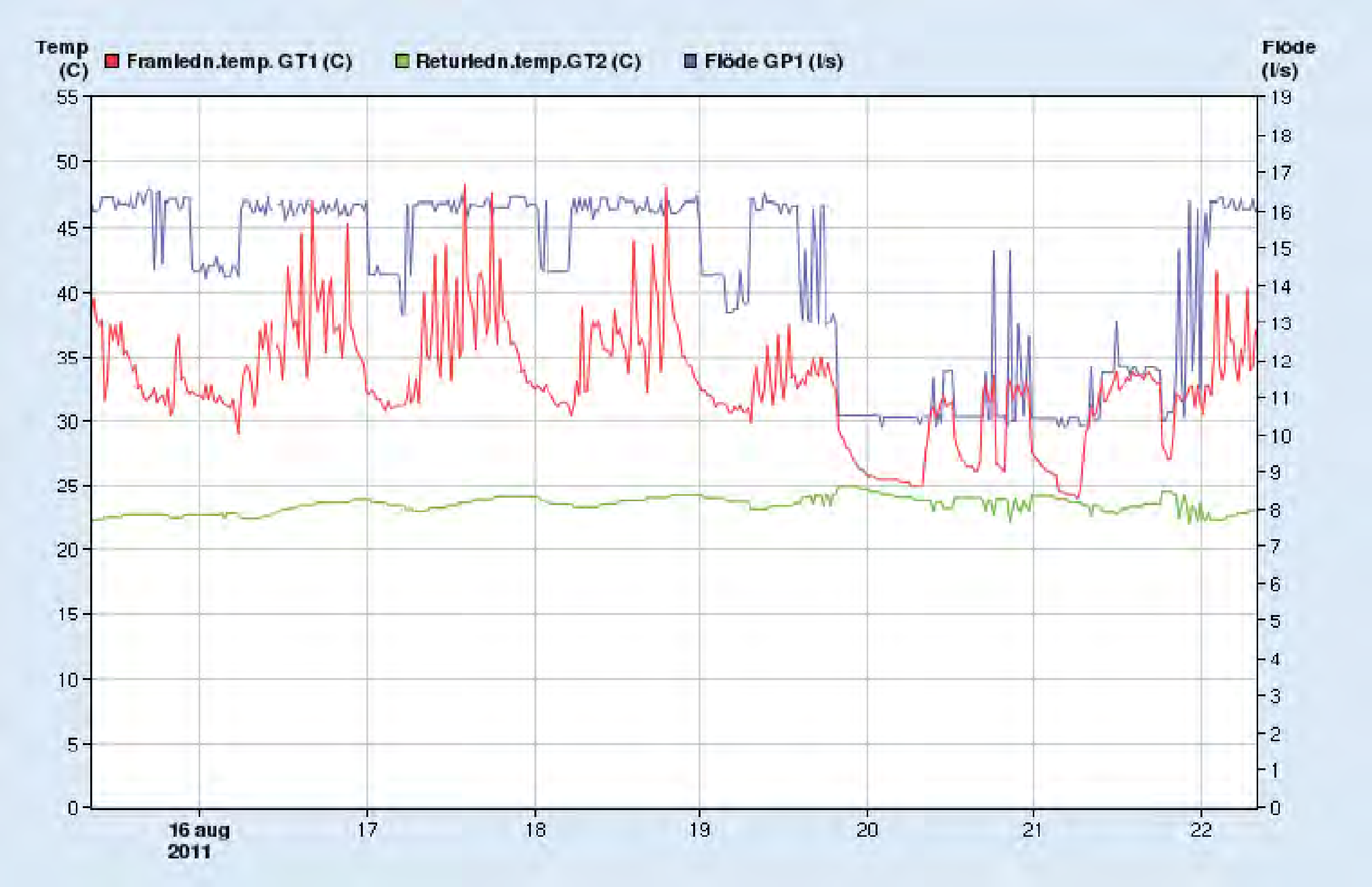
Measurements of borehole deviation

BTES Emmaboda
Operation strategy



Heat carrier fluid temperature

BTES Emmaboda
First operating experience

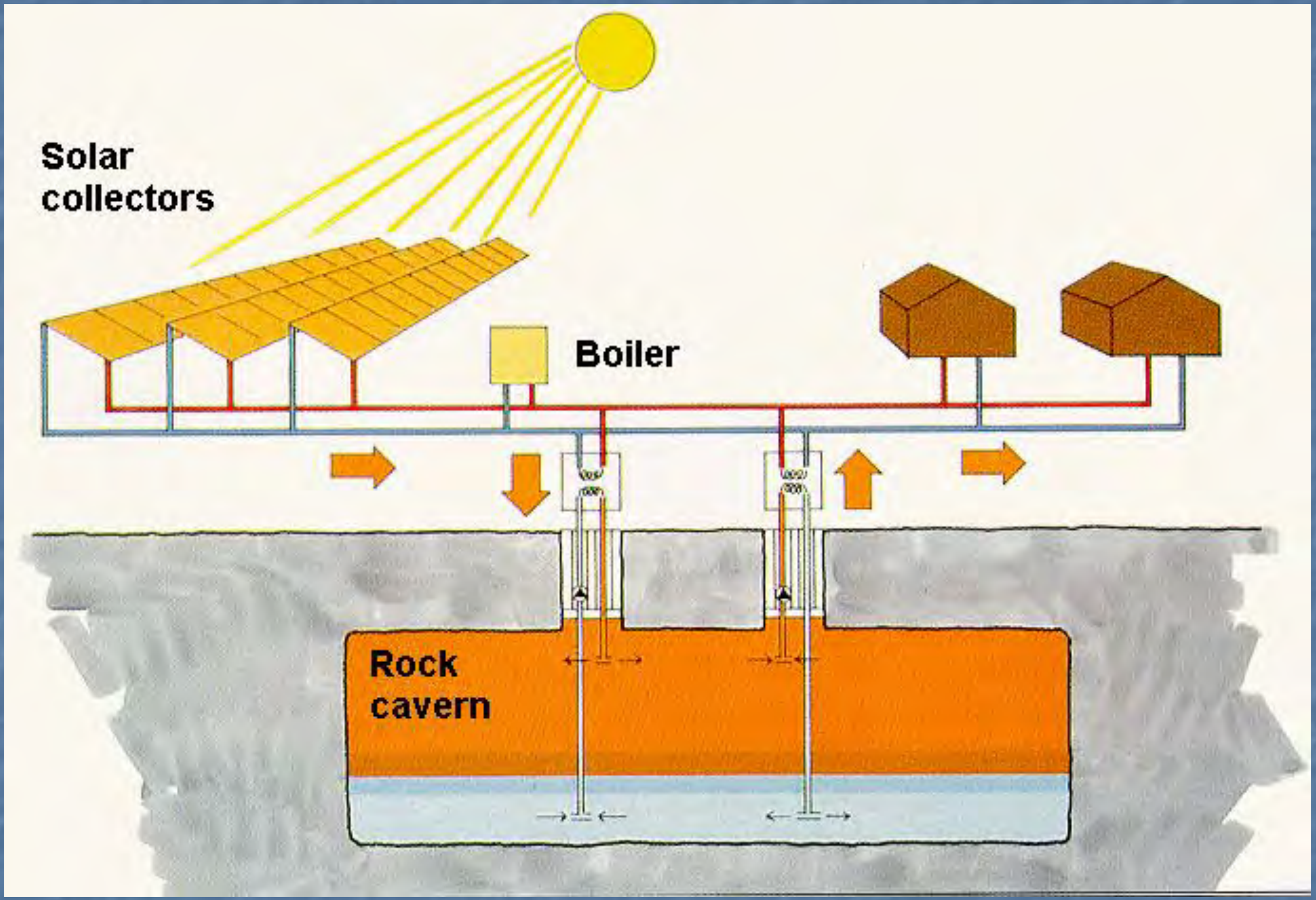


Charged energy: 900 MWh (2010), 3000 MWh (2011)

CTES
Lyckebo

- Volume of cavern: 104,300 m^3
- Storage capacity: 5,5 GWh
- Store temperature 60-90 ºC
- Used for seasonal storage
- Cost: 17,5 MSEK (1982)

CTES
Lyckebo

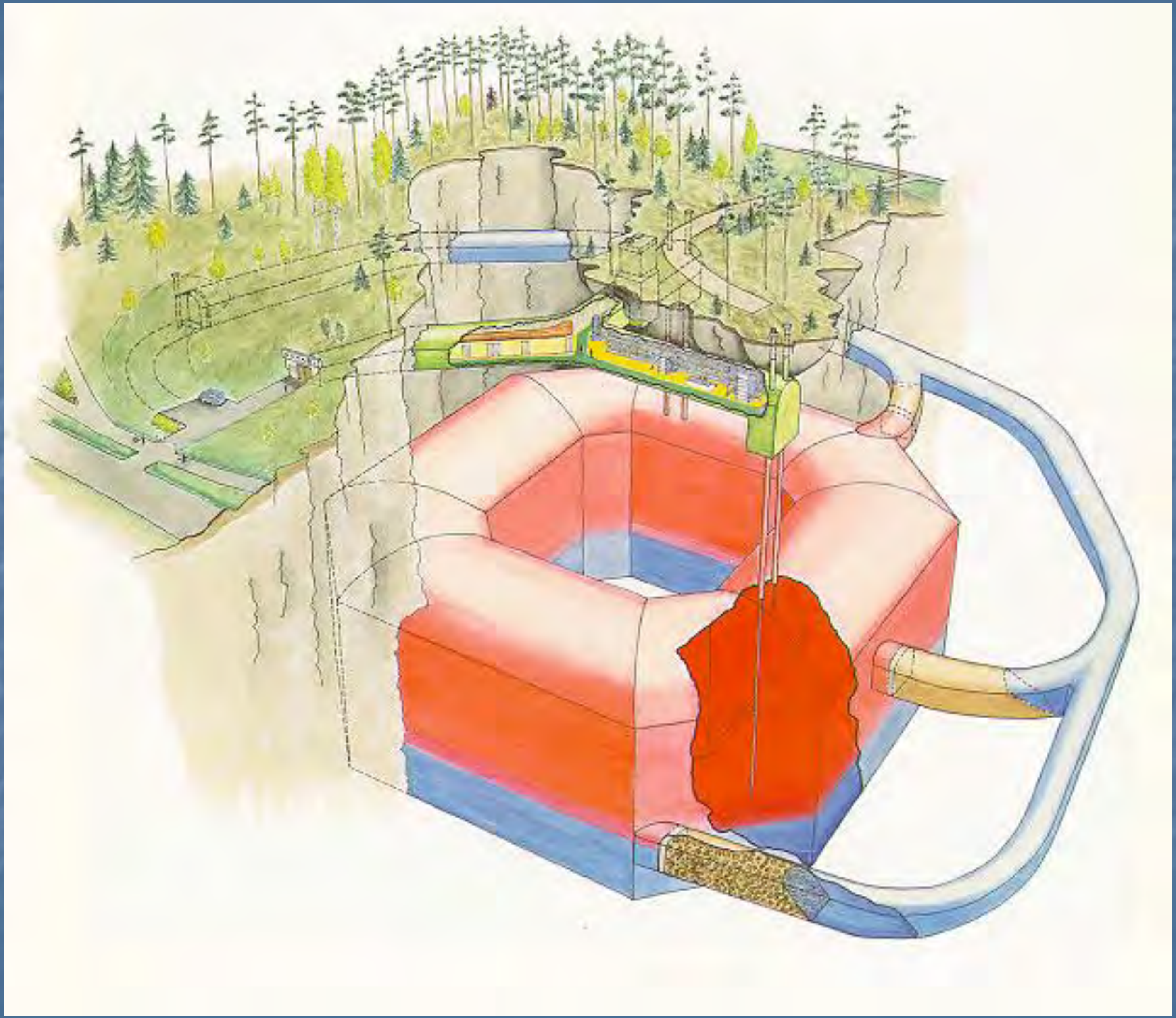


System design

CTES Lyckebo

Solar collector field

CTES Lyckebo

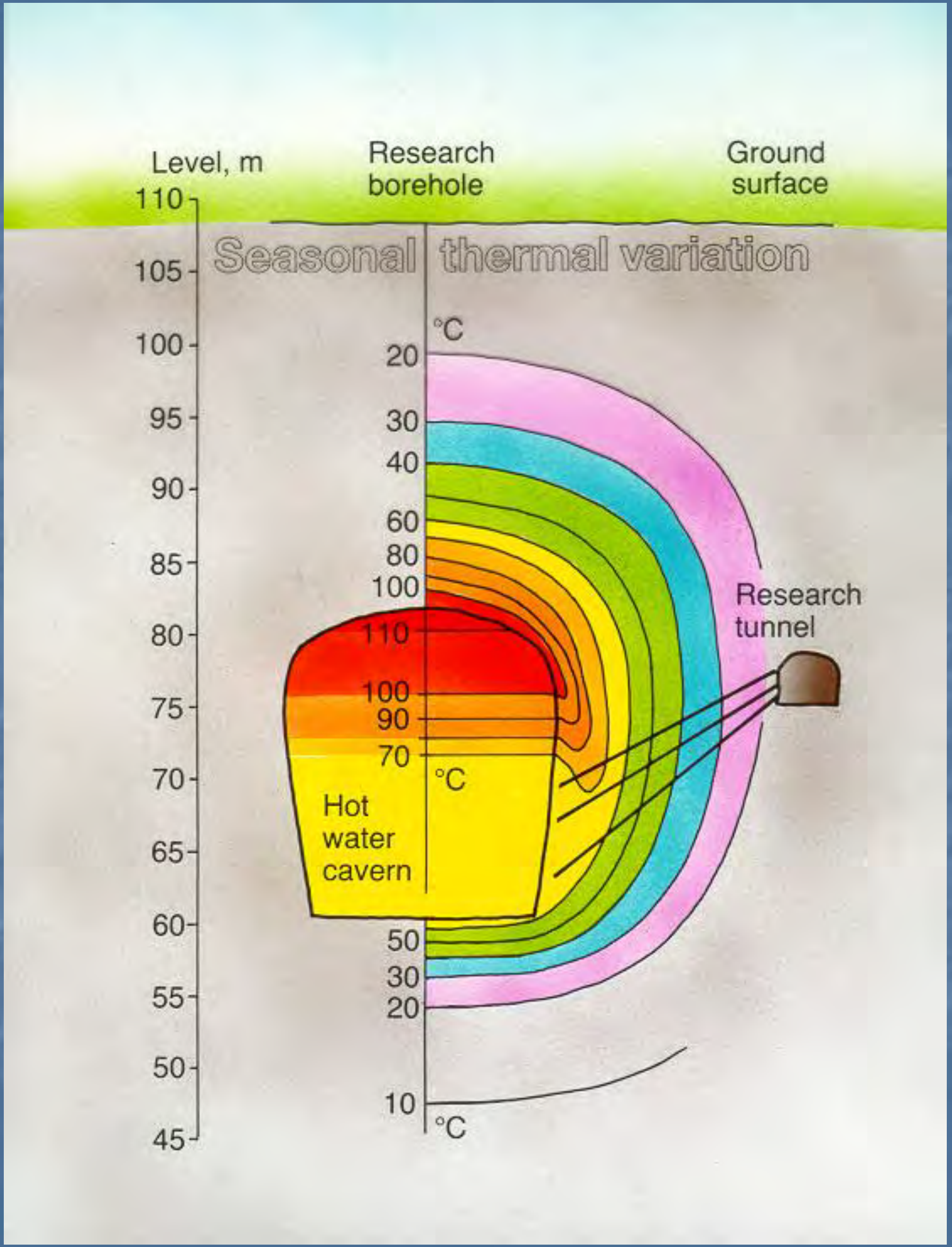


Rock cavern schematic

CTES
Lyckebo

Rock cavern during construction

CTES
Avesta



Temperature field

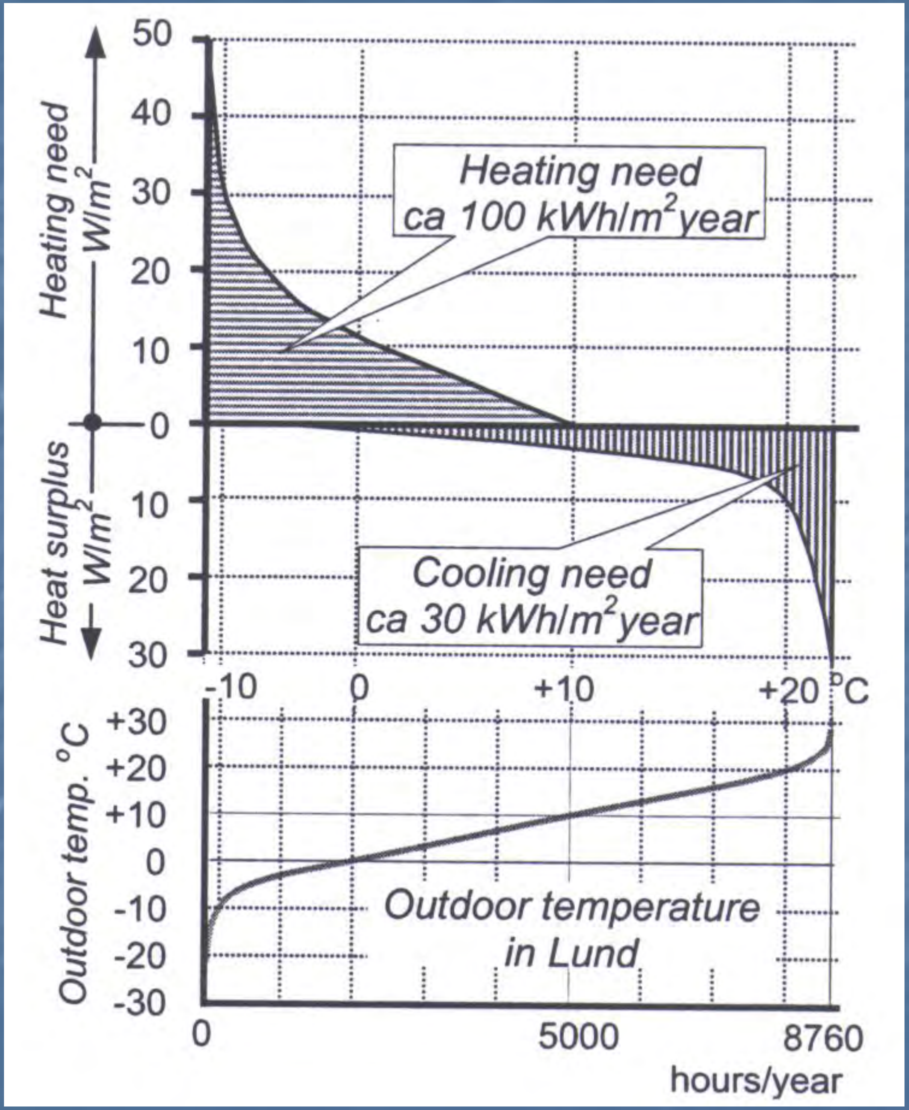
CLOSED LOOP
BOREHOLE HEAT EXCHANGERS

Astronomy Department, Lund

BTES heating and free cooling combined with district heating

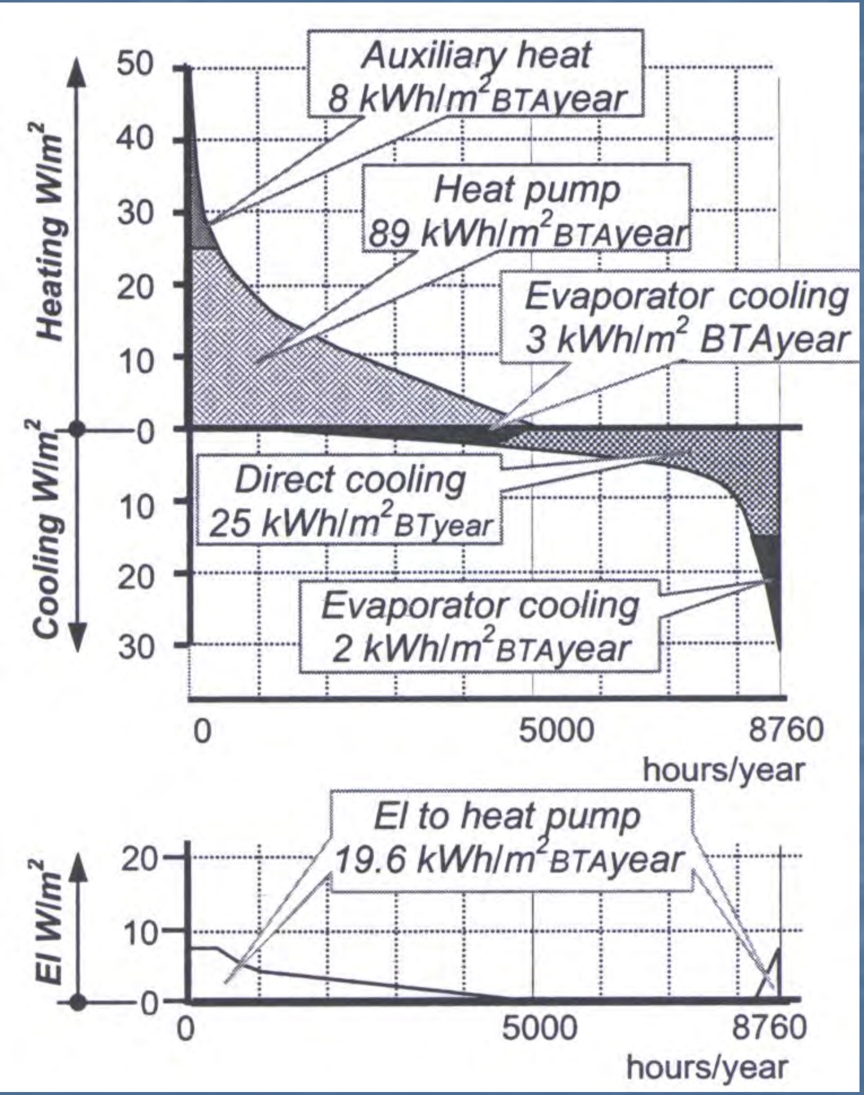
Office space 4.900 m^2

Energy load



Heating need W/m²
Heat surplus W/m²
50
40
30
20
10
0
10
20
30
Heating need
ca 100 kWh/m²year
Cooling need
ca 30 kWh/m²year
-10
0
+10
+20 °C
Outdoor temp. °C
+30
+20
+10
0
-10
-20
-30
Outdoor temperature
in Lund
0
5000
8760
hours/year

Energy supply



Energy balance

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

Key factors	Normal year (adjusted)	
Seasonal performance factor - heat pump (incl. circulation)		4,5
Seasonal performance factor - free cooling		47
Heating and cooling demand		126 kWh/m^2,yr
Bought energy		28 kWh/m^2,yr
Seasonal performance factor – ground source (heat pump + free cooling)		5,7
Seasonal performance factor – total (ground source + district heating)		4,4

Large Swedish BTES

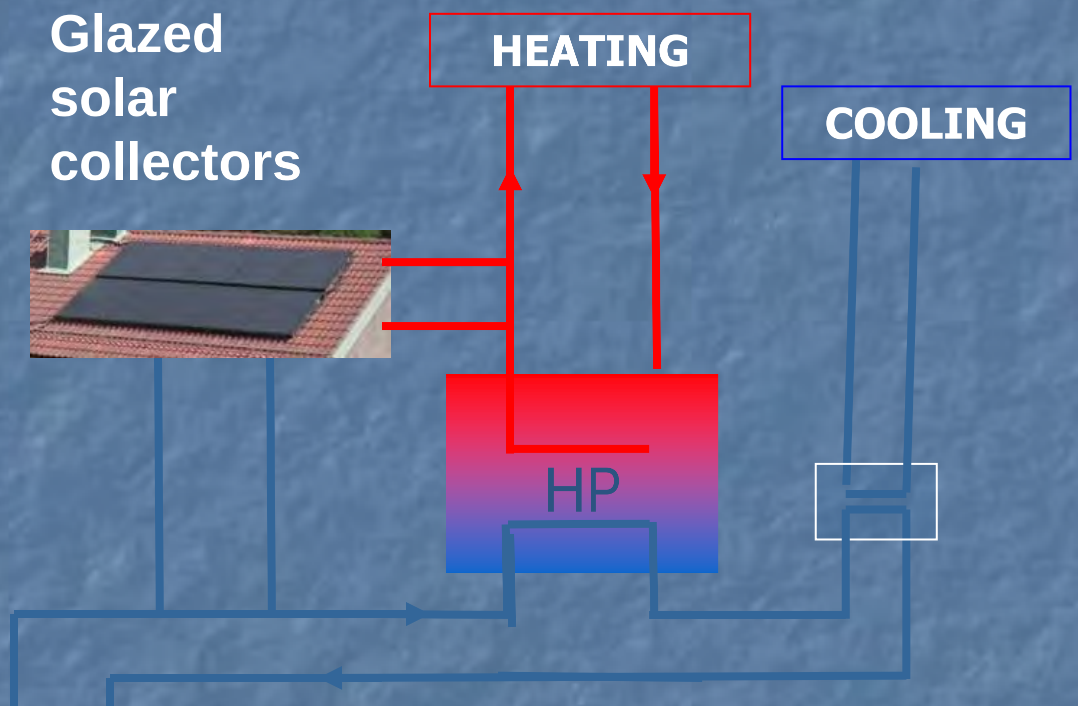
Project	Boreholes	Bore depth (m)	Total (m)
Brf. Ljuskärrsberget, Stockholm Saltsjöbaden	156	230	35880
Kemicentrum (IKDC), Lund	153	230	35190
Lustgården, Stockholm	144	230	33120
Vällingby Centrum, Stockholm	133	200	26600
Brf. Igelbodaplatån, Stockholm Saltsjöbaden	120	200	24000
Kv. Bergen, Stockholm Husby	98	215	21070
ITT Flygt, Emmaboda	140	150	21000
Kv. Galgvreten, Enköping	86	220	18920
Copperhill Mountain Lodge, Åre	92	200	18400
Centrala Gribbylund, Täby	87	210	18270
Thulehem, Lund	86	200	17200
IKEA, Uppsala	100	168	16800
NIBE, Markaryd	110	150	16500
Centralsjukhuset, Karlstad	80	200	16000
Backavallen, Katrineholm	91	172	15652
IKEA, Karlstad	100	120	12000
Musikhögskolan, Örebro	60	200	12000
Sjukhuset, Kristinehamn	55	210	11550
Vattenfalls Huvudkontor, Solna	53	200	10600
IKEA, Helsingborg Väla	67	150	10050
Stenungsbaden Yacht Club, Stenungsund	50	200	10000
Näsby Parks Slott, Stockholm	48	180	8640
Projekt Lulevärme, Luleå	120	65	7800

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



High-temperature seasonal energy storage

Seasonal storage of solar heat

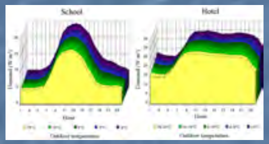
Examples: Neckarsulm, Germany, and Anneberg, Sweden

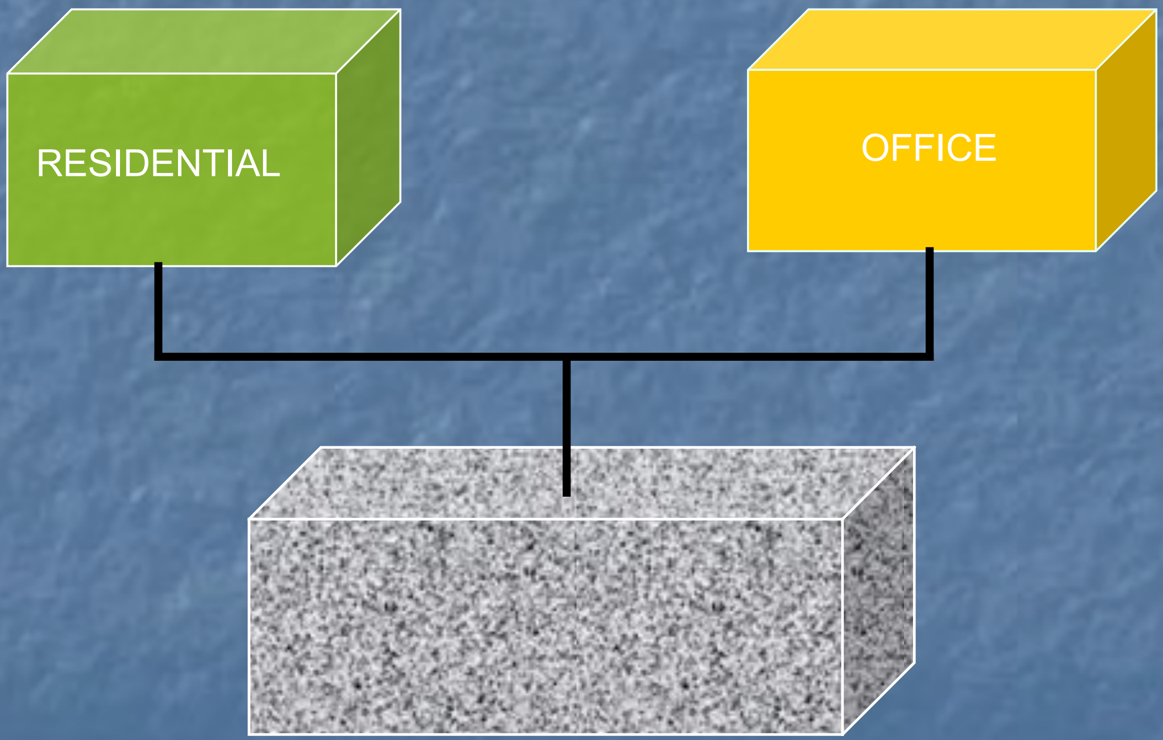
Sea Water

Hybrid system - Boreholes with summer recharge from lake

Combining ground-source for buildings with different load

Community clusters

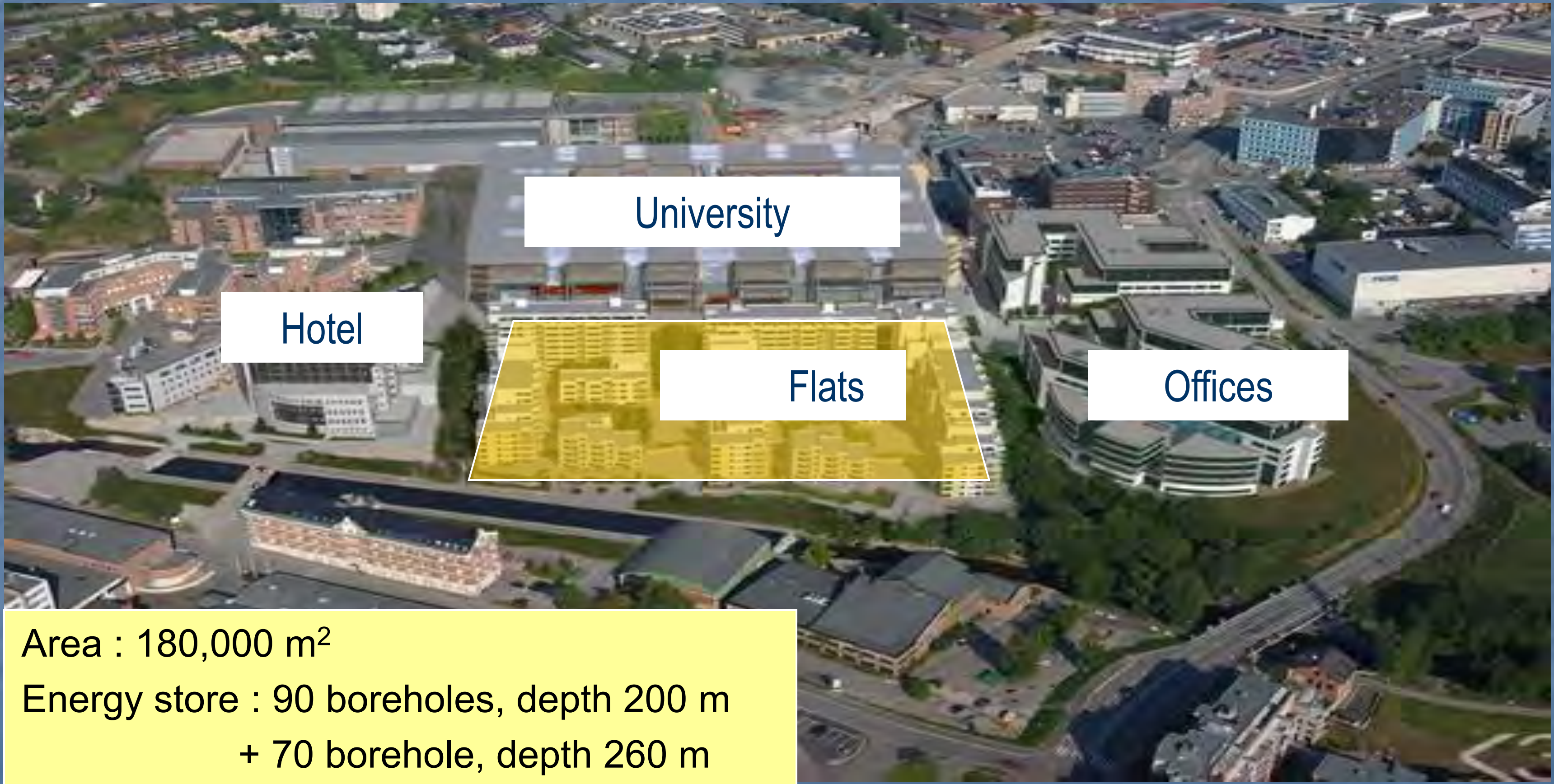




Common ground source

Combining ground-source for buildings with different load

Avantor-Nydalen, Oslo, Norway

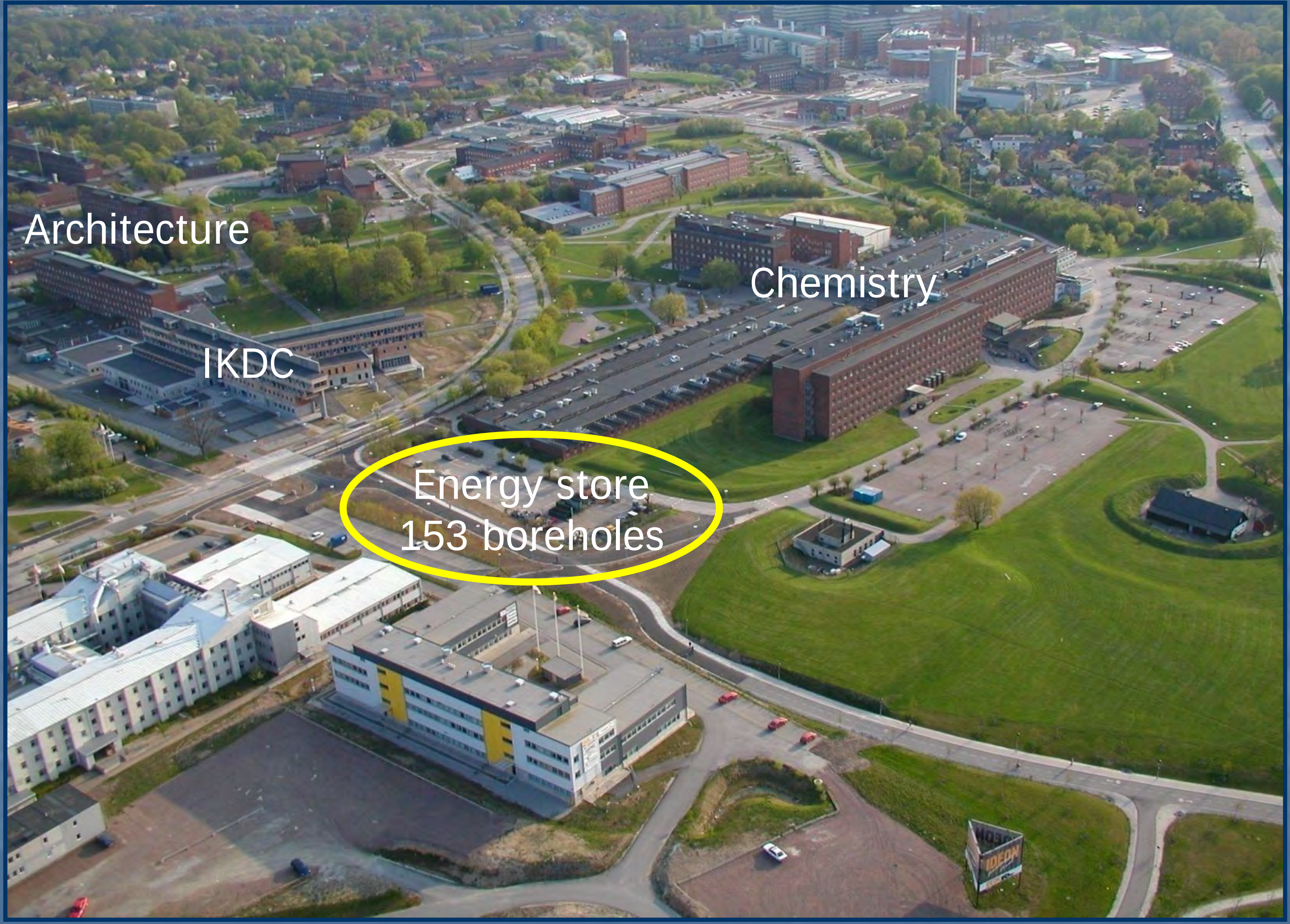


Area : 180,000 m^2

Energy store : 90 boreholes, depth 200 m

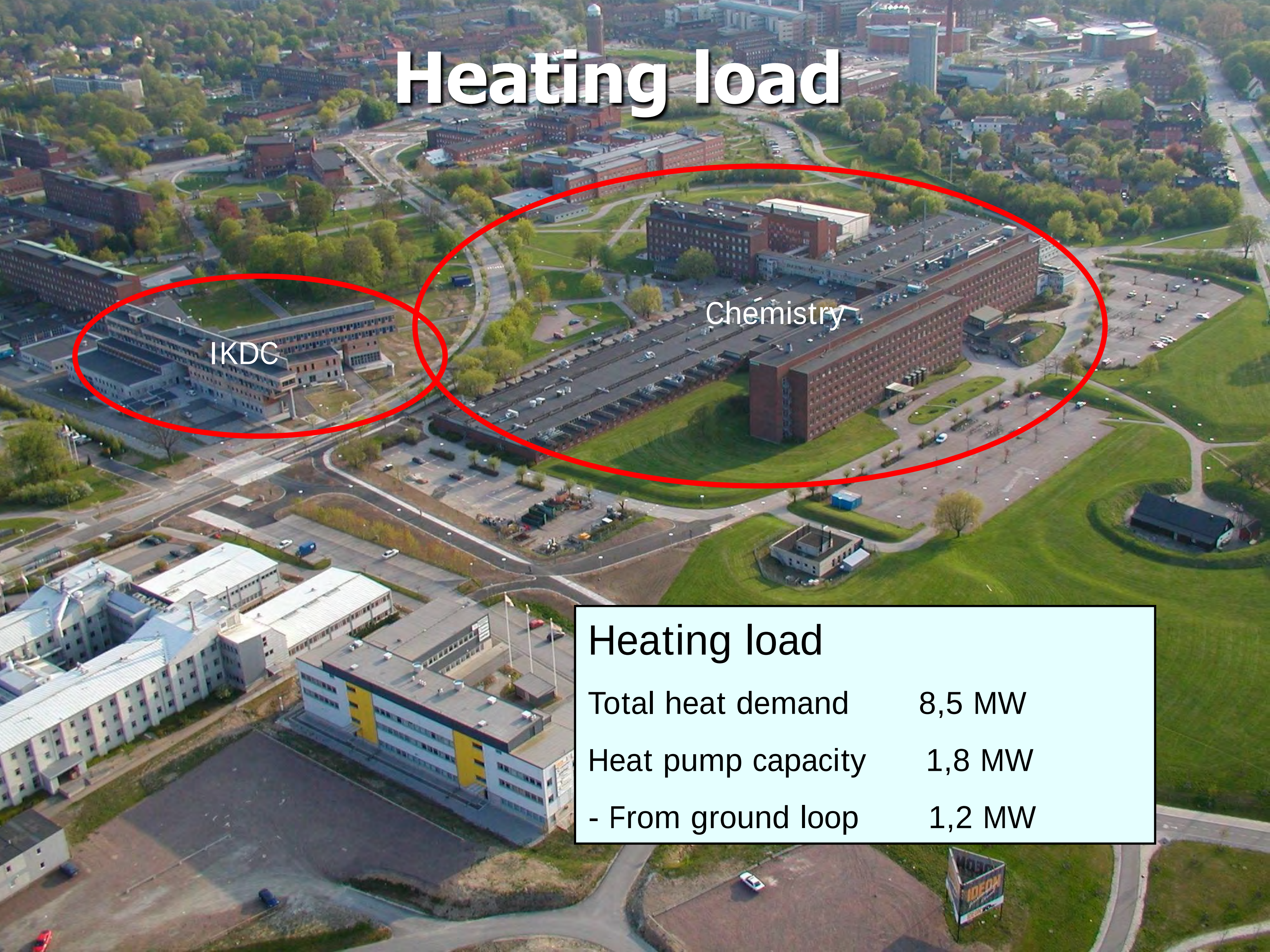
+ 70 borehole, depth 260 m

Chemistry Department, Lund



Energy balance by combining buildings with different load profiles

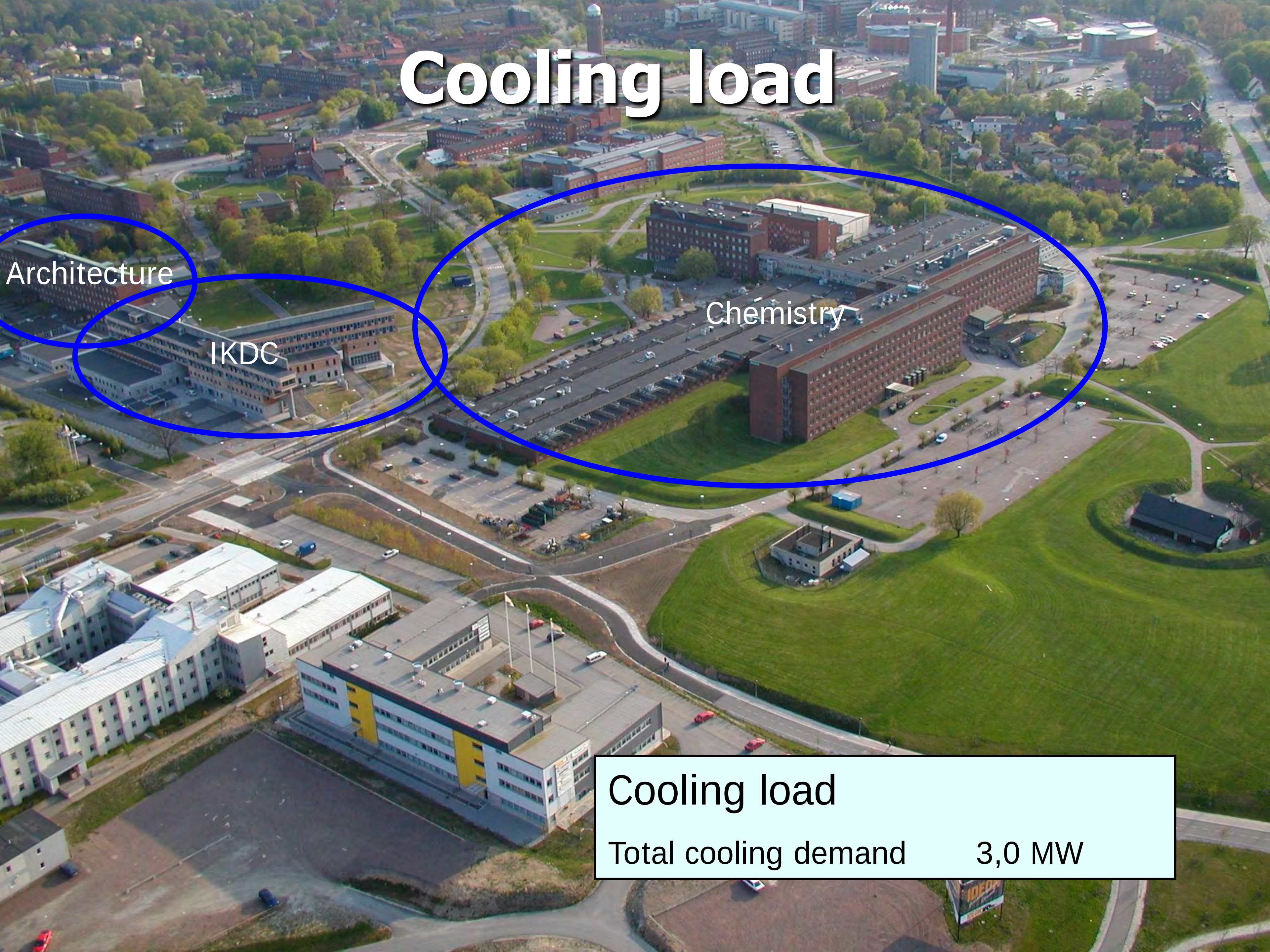
Heating load



Heating load

Total heat demand	8,5 MW
Heat pump capacity	1,8 MW
- From ground loop	1,2 MW

Cooling load

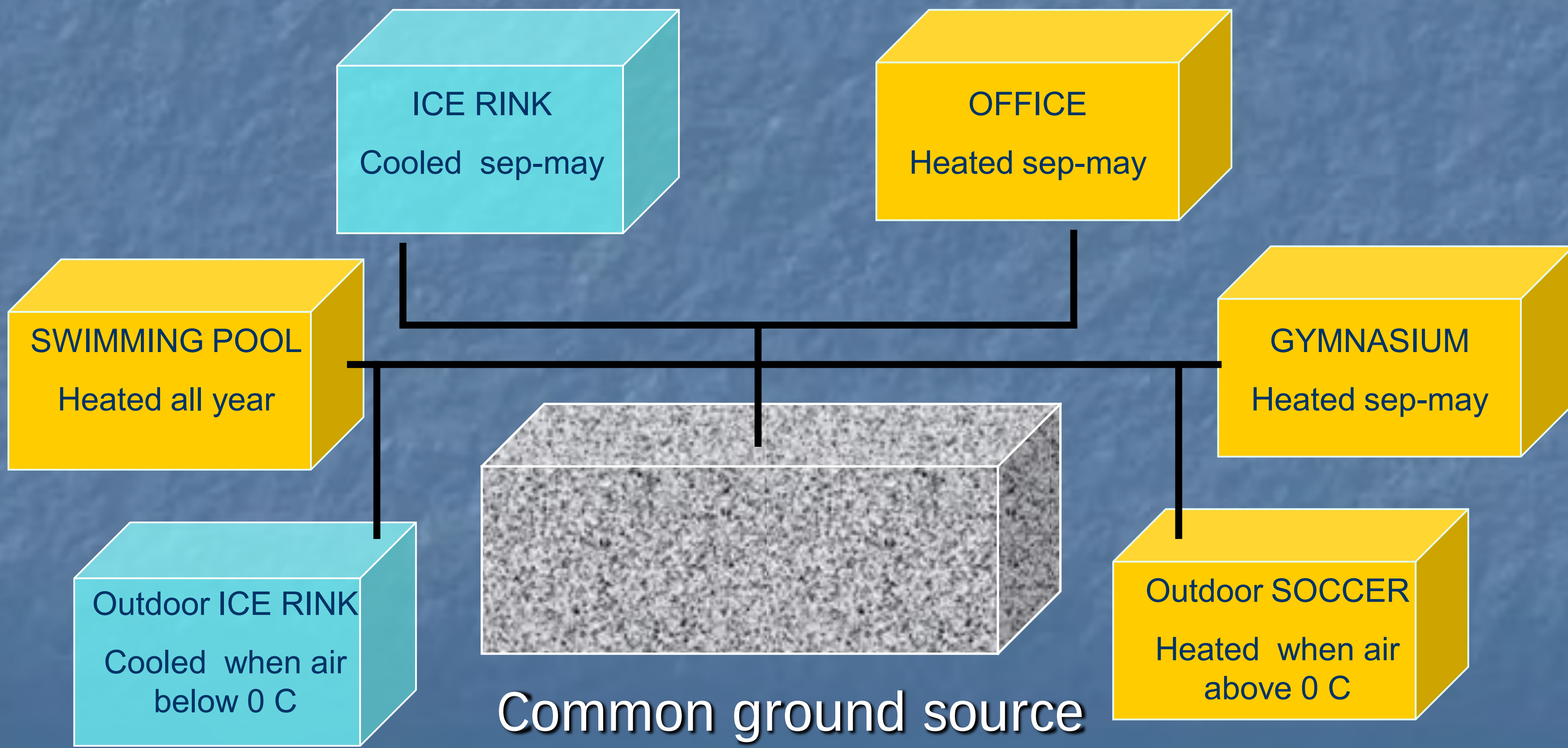


Cooling load

Total cooling demand 3,0 MW

Katrineholm Sport Centre

Community clusters



IKEA – Applications in Sweden

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 contruction 2012 (BTES)

IKEA – Applications in Sweden

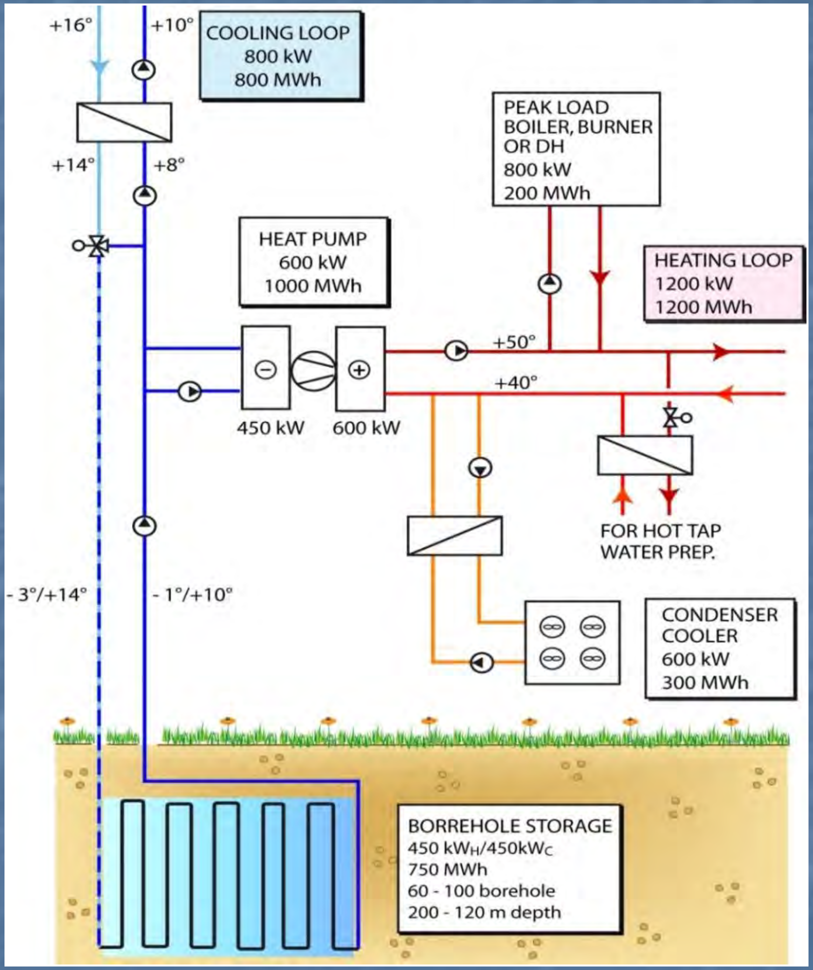
General for a 25 000 m² store in Swedish climate
(European system design)

- 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)

IKEA – Store 25,000 m^2, Karlstad

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

IKEA – Store 44,000 m^2, Malmö

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

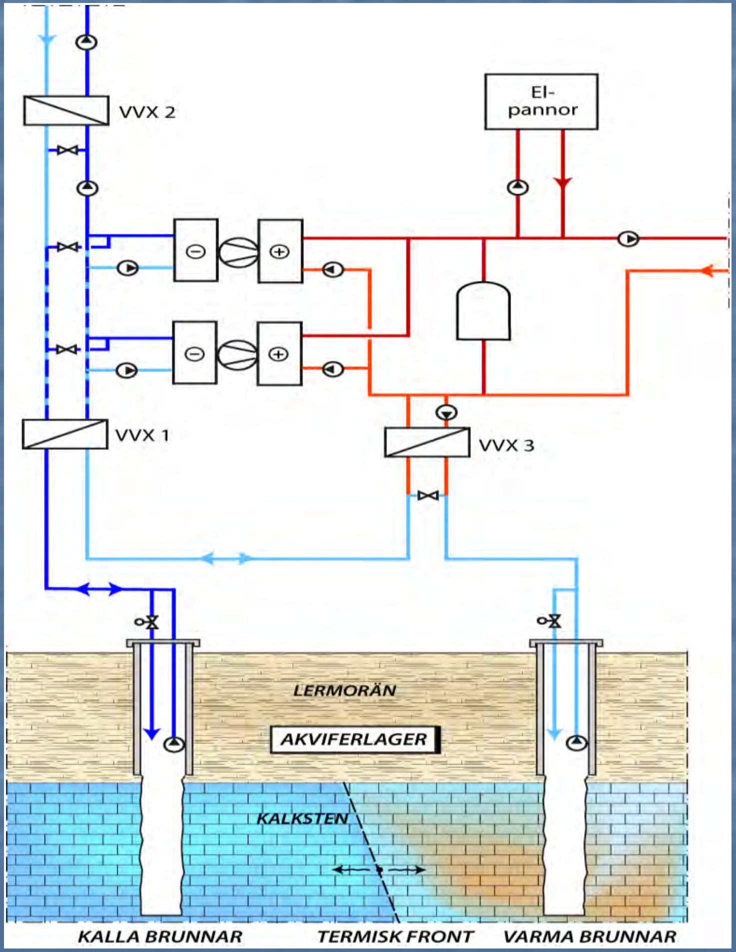
- Max load, 1 300 kW
- Energy, 2 350 MWh/year

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 groud and river source

Karlstad’s Hospital, Sweden

Energy demand (=bought energy)

BEFORE (2000)	
District heating	26,4 GWh/year
Electricity	23,6 GWh/year
Total	50,0 GWh/year

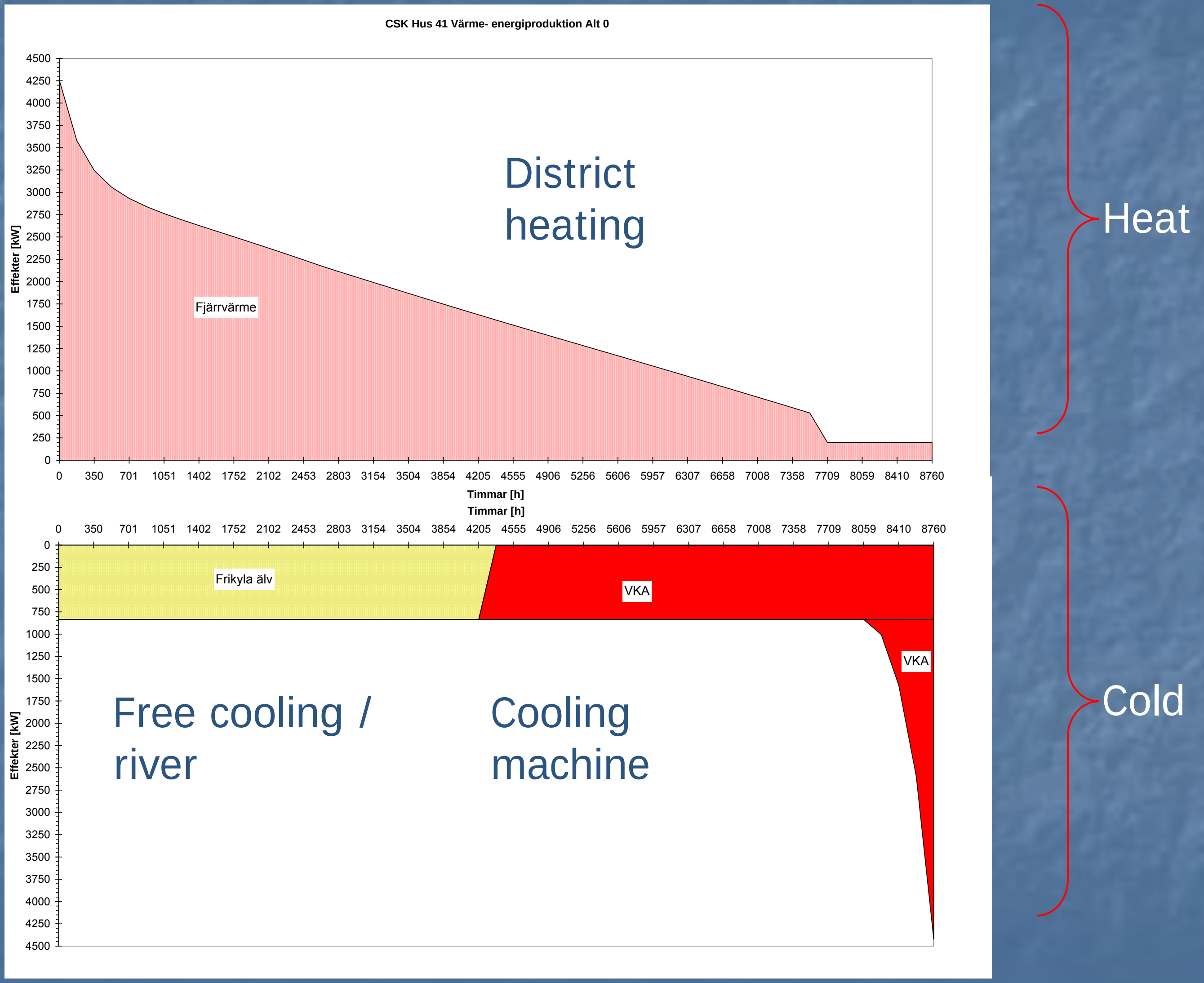
Step 1. Energy efficiency measures
- Changing windows, improving thermal insulation

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

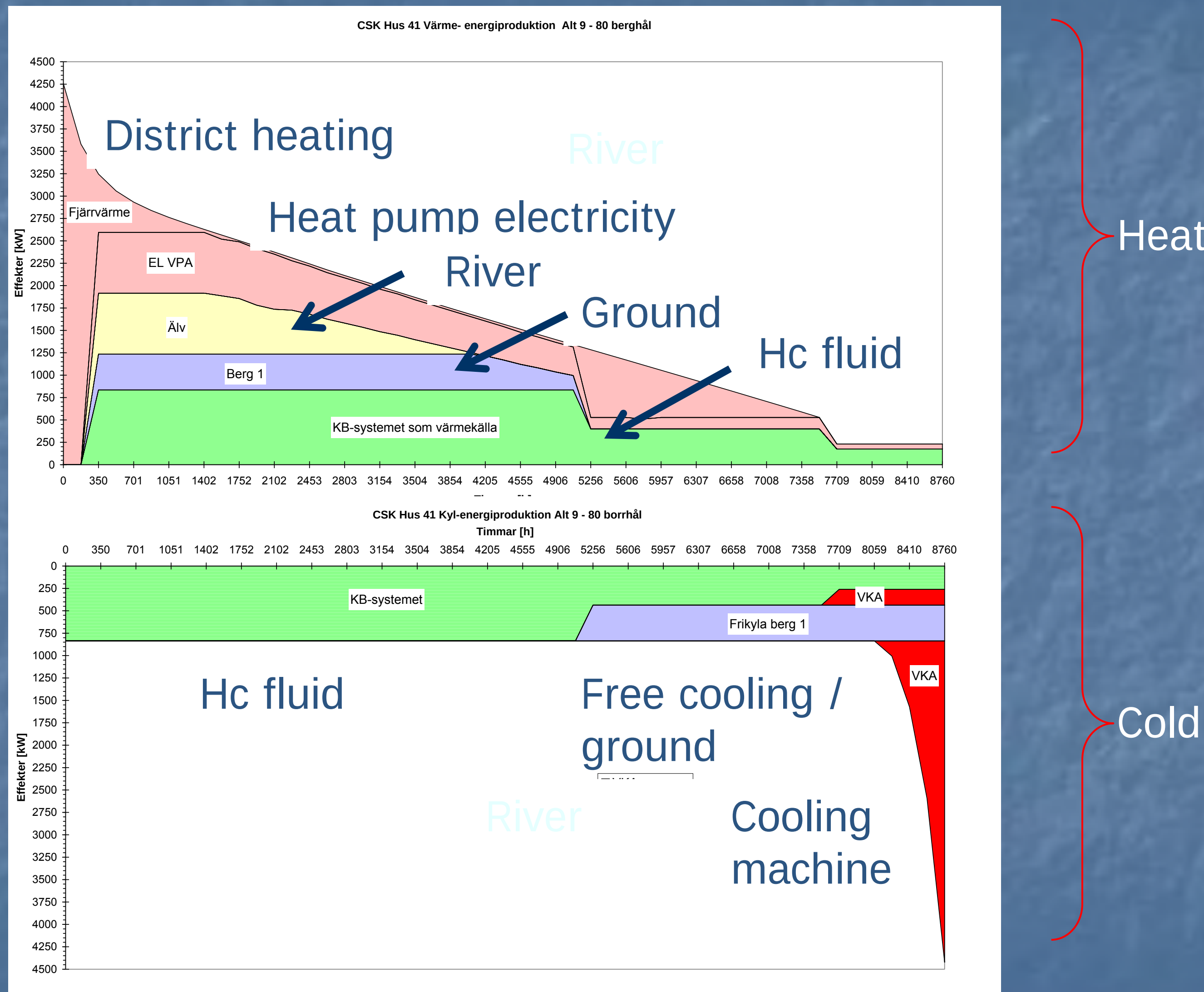
AFTER (2011)	
District heating	2,5 Gwh/year
HVAC/GSHP electricity	22,2 GWh/year
Total	24,7 MWh/year

Savings 24,1 GWh heat (91 %) 1,4 Gwh electricity
Payback time 5 years

Energy supply - before



Energy supply - after



Kristinehamn's Hospital, Sweden

Energy demand (=bought energy)

BEFORE

District heating	2135 MWh/year
HVAC electricity	605 MWh/year
Total	2740 MWh/year

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

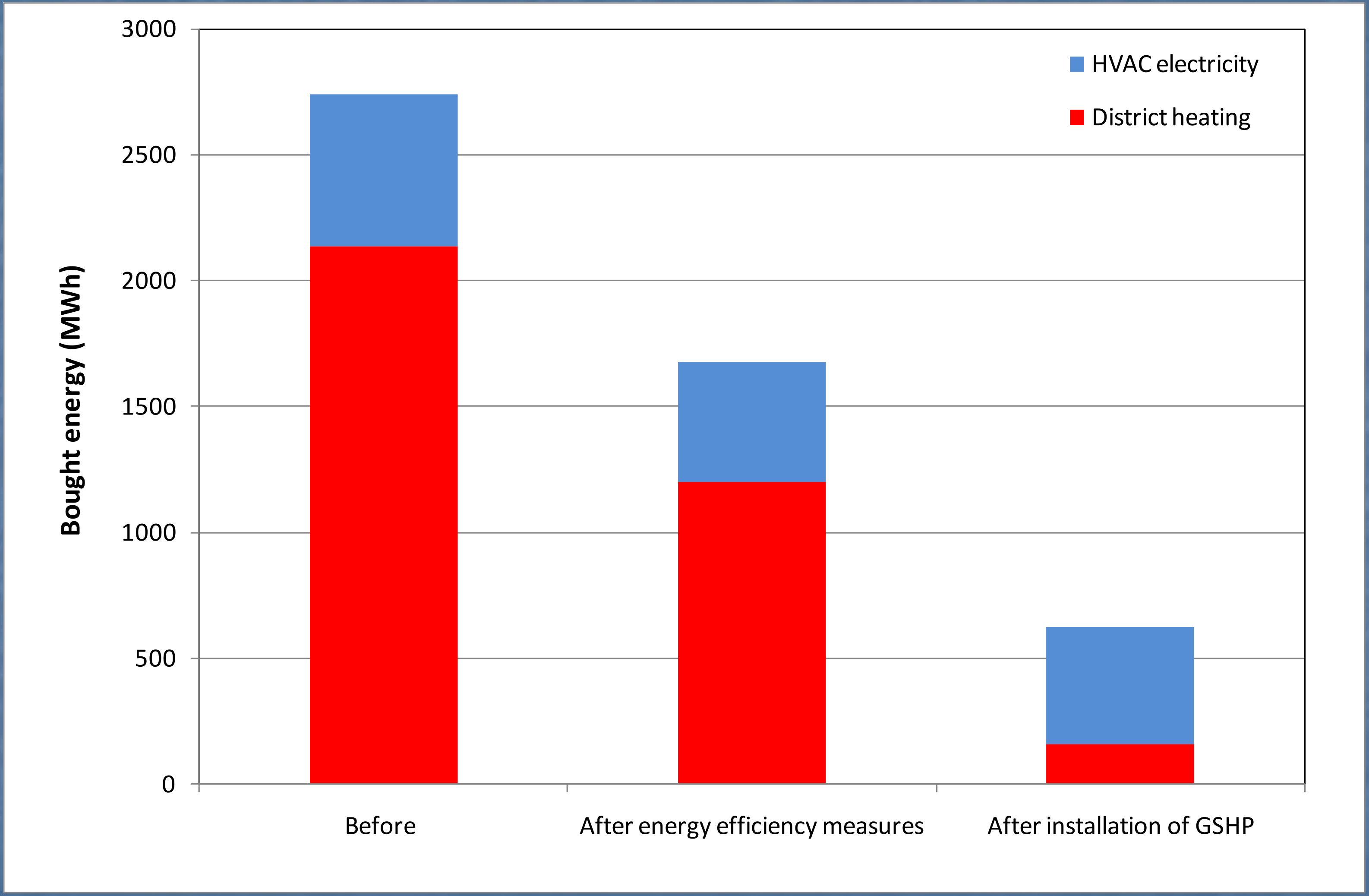
Step 2. Change of energy production
- Installation of ground-source heat pump/energy storage with free cooling during summer and preheating of outdoor air during winter

AFTER

District heating	155 MWh/year
HVAC electricity	465 MWh/year
Total	620 MWh/year

Savings 2120 MWh (78 %) **Payback time 5 years**

Kristinehamn's Hospital, Sweden



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

Thank you!