IEA HPP Annex 29 (2004-2006)

Ground-Source Heat Pumps Overcoming Market and Technical Barriers

Ground-Source Heat Pump Systems in NORWAY

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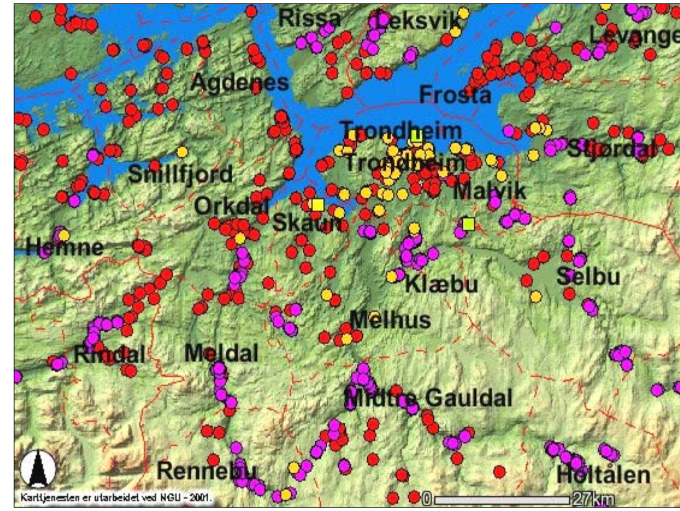
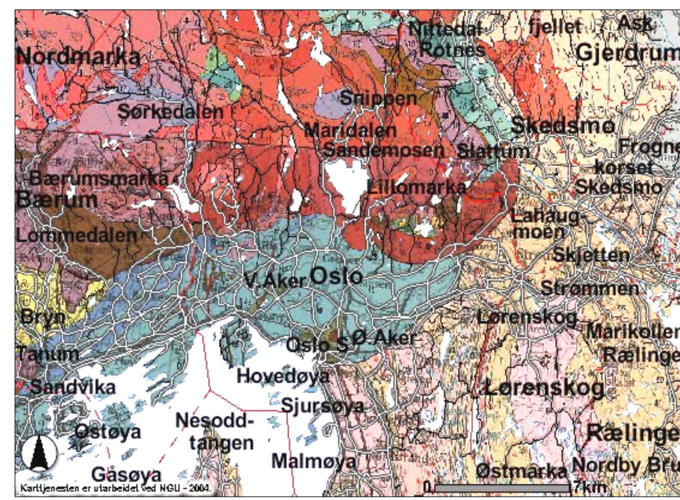
Outline

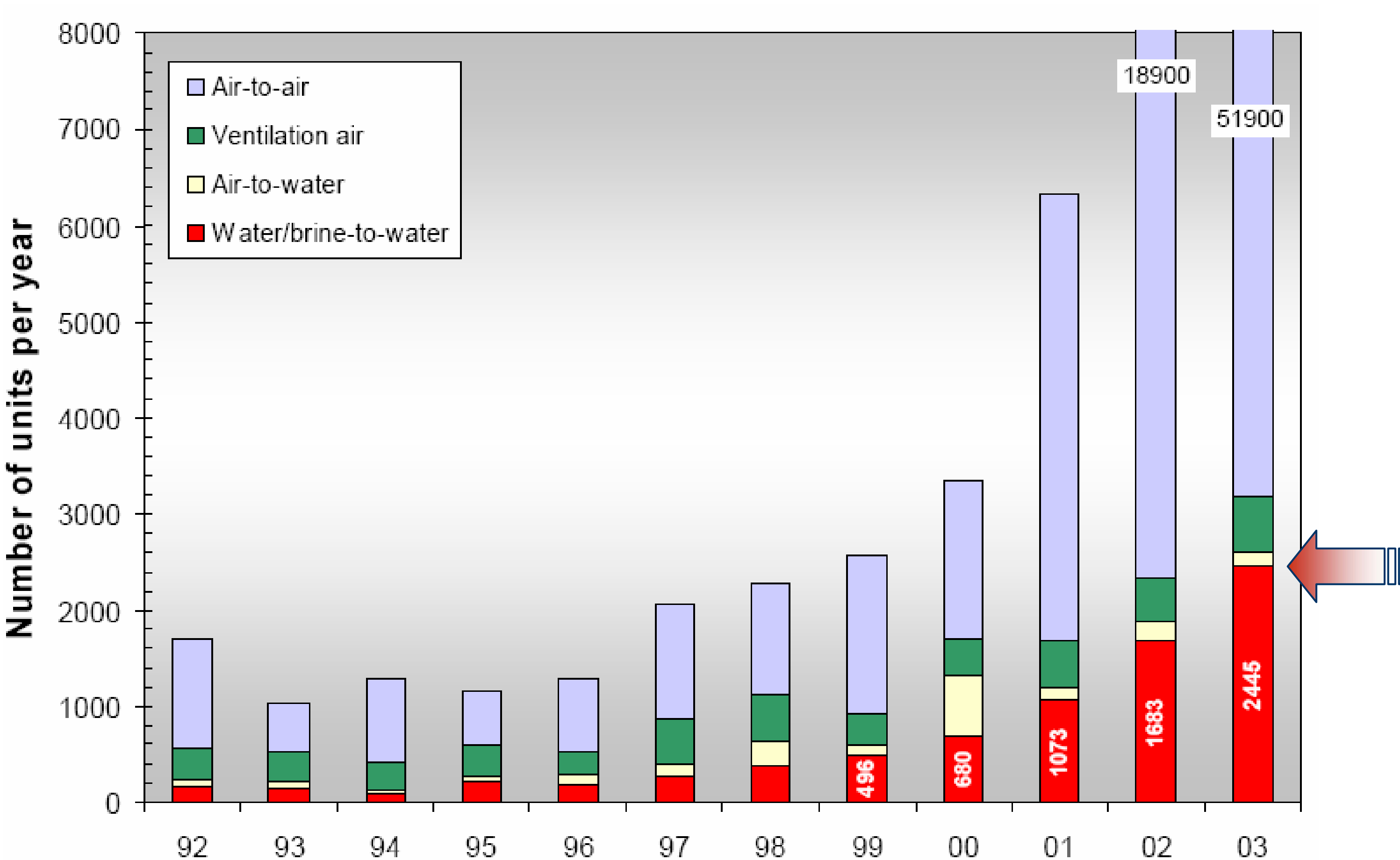
- The Norwegian heat pump market
- Ground water
  - Specifications – challenges
  - Aquifer thermal energy storage
- Bedrock
  - Specifications – challenges
  - Thermal response testing
  - Energy wells and thermal energy storages
- Installation examples
  - Office buildings
  - District heating and cooling systems
- Summing up





Heat Pump Market – Norway

Annual Installation Rate – Sorted by Heat Source/Sink



Data from Geir Eggen (COWI) and the Norwegian Heat Pump Association (NOVAP)

Ground-Source Heat Pumps

NORWAY

Norway: There is no geothermal direct heat use in the country; however, about 100 larger geothermal heat pump systems for commercial building or multi-family dwelling have been installed (Midttrømme, 2005). Traditionally, these systems are only used for heating, but some systems use the exhaust ventilation to recharge the boreholes. An increased interest in cooling in the commercial and industrial sectors is favoring ground source heat pumps and underground thermal energy storage systems. As of 2003, there were 55,100 heat pumps installed in Norway, of which 5% were geothermal (2,755). The largest installation in Europe is the heating and cooling of 180,000 m^2 of a school, shopping center, hotel, offices and residential area using 180 bores providing an output of 9 MWt heating and 6 MWt cooling (Curtis, el al., 2005). Today, the estimated number of installed units is 13,000 with a capacity of 450 MWt. Over 90% of these installations are vertical boreholes groundwater types with a single U-shaped pipe installed. No figure on annual energy use was report, but using 2,000 full load hours per year and a COP of 3.5, the annual energy use is estimated at 2,314 TJ/yr.

J.W. Lund, D.H. Freeston, T.L. Boyd, 2005: World-Wide Direct Uses of Geothermal Energy 2005

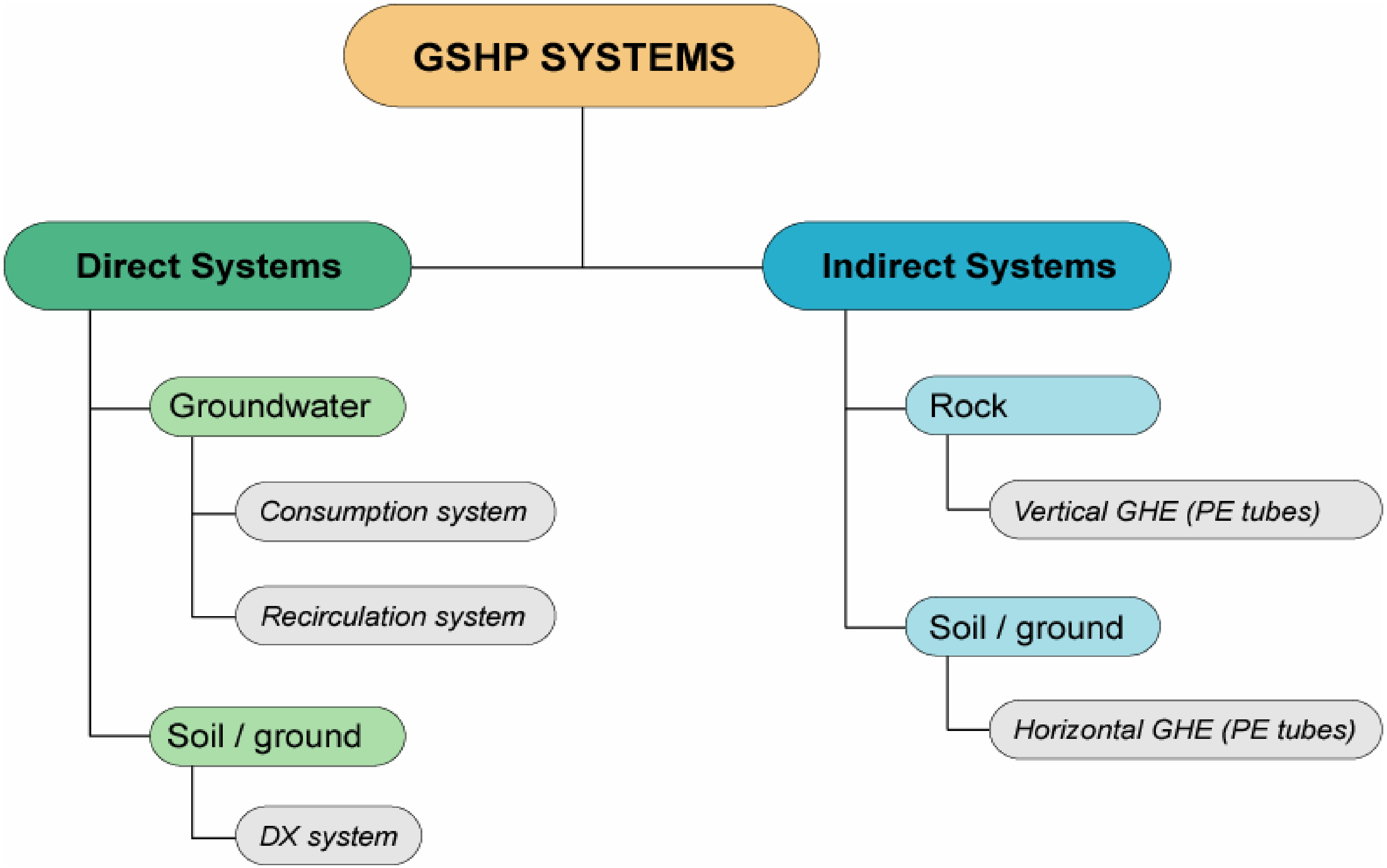
Ground-Source Heat Pumps – NORWAY

Country	Capacity MWt	Use TJ/yr	Use GWh/yr
Norway	450.0	2,314.0	642.8

%Use (TJ/yr) Increase 00-05	%Capacity (MWt) Increase 00-05	MWt/population
Norway	Denmark	Iceland
Denmark	Norway	Sweden
Chile	Netherlands	Denmark
Netherlands	Chile	Norway
Portugal	Belgium	Switzerland

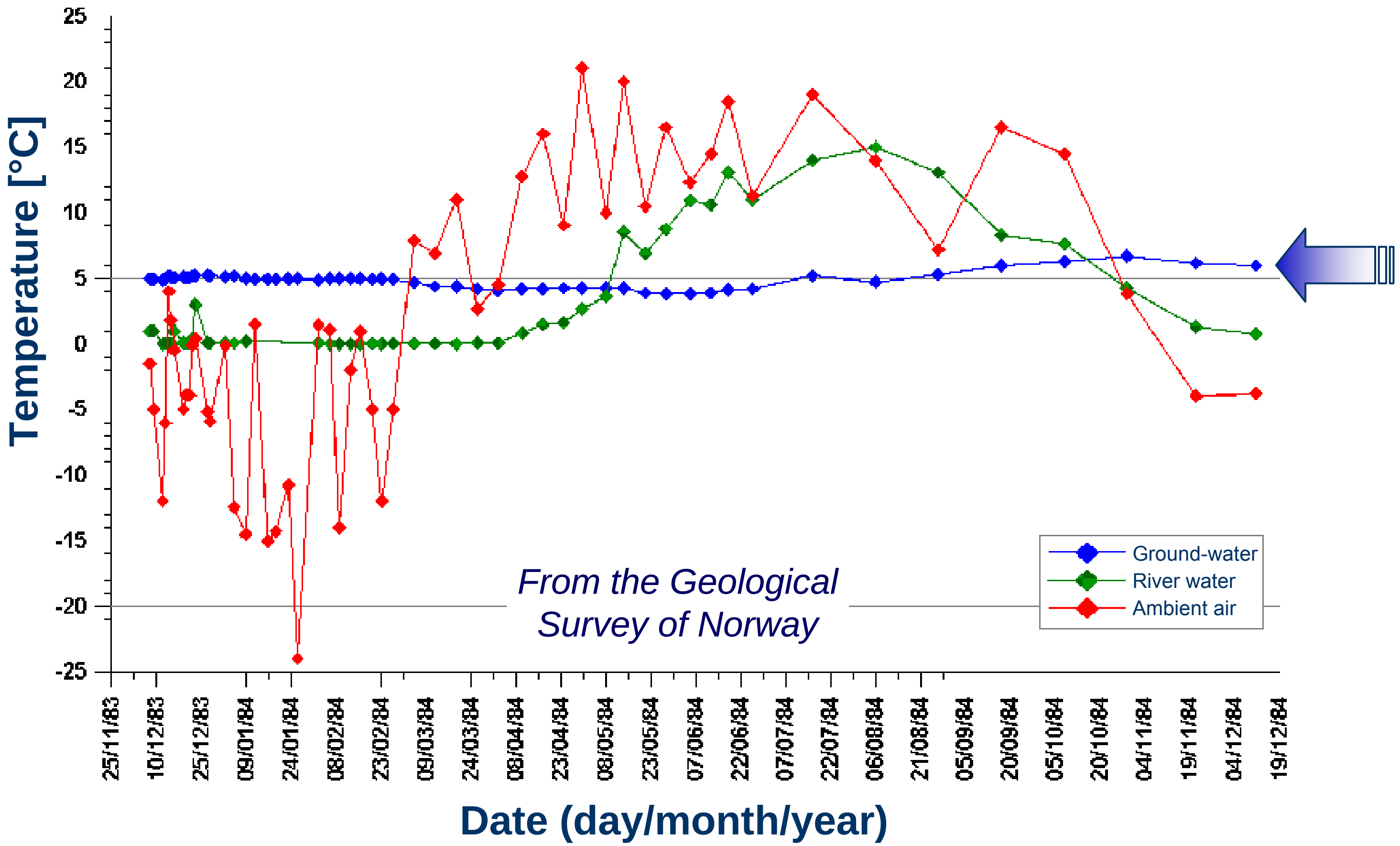
J.W. Lund, D.H. Freeston, T.L. Boyd, 2005: World-Wide Direct Uses of Geothermal Energy 2005

Classification – Ground-Source HP Systems



Ground Water

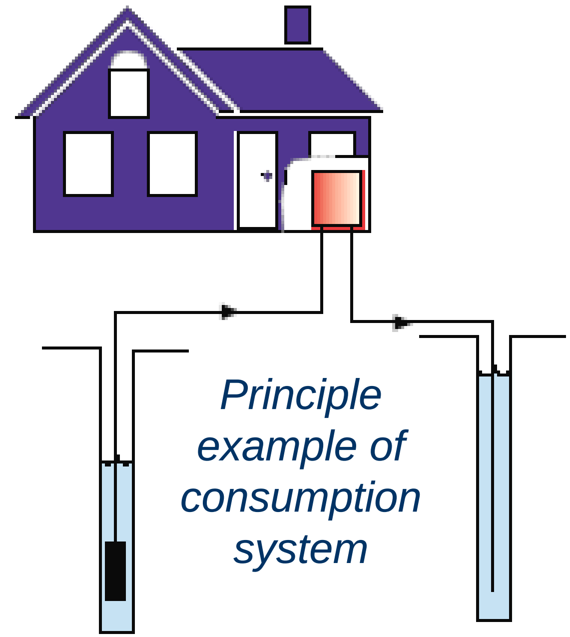
Temperature Variations for Air, River Water and Ground-Water



Ground Water

Typical Specifications and Challenges

- Mainly used as heat source/sink for medium and large capacity GSHPs
- Water from uncompacted material (gravel/sand) or fractured rock
- Well depth 10 – 40 metres
- Well diameter 150 – 200 mm
- Capacity 0.15 – 25 litres/second
- **Important to carry out preliminary testing of the water quality**

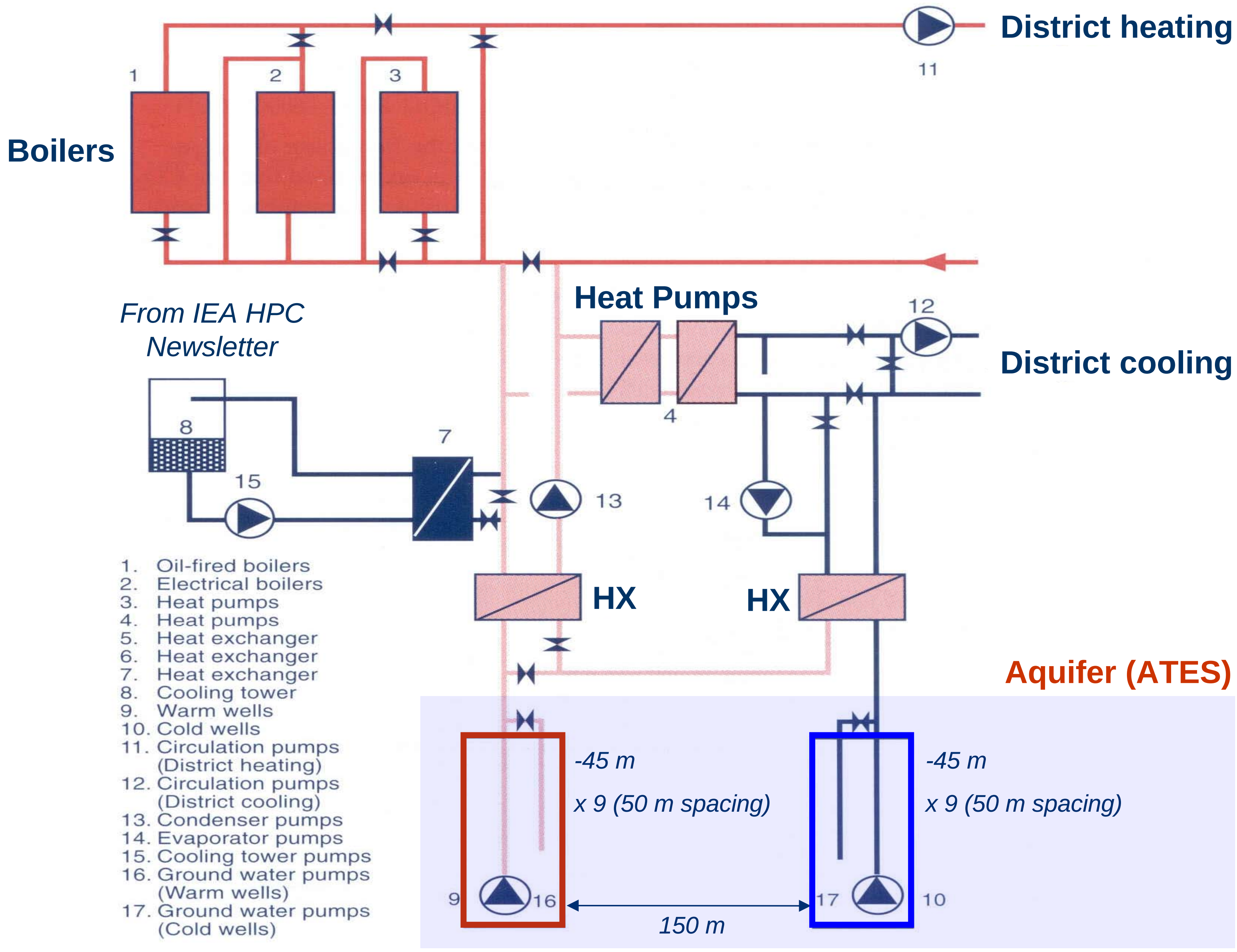


Ground water well drilled in gravel

Example – District Heating and Cooling

GSHP System at Oslo Airport, Gardermoen

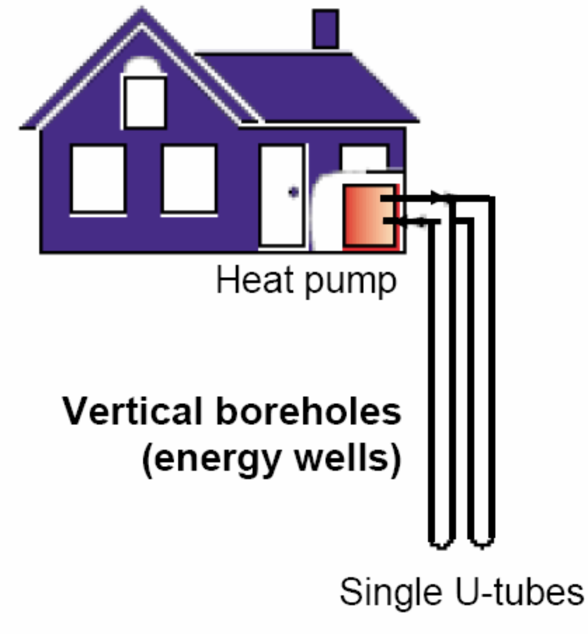
- Heating and cooling of Norway's main airport
- Energy central with heat pumps
  - 8.0 MW heating capacity
  - 6.0 MW cooling capacity
  - Heat source/sink – ground water
  - Working fluid – ammonia (NH_3)
- The ground water system
  - The largest ground water reservoir in Northern Europe
  - Utilizes as an Aquifer Thermal Energy Storage
  - 45 metres deep wells (ID 250 mm)
  - 9 cold wells – 9 warm wells – 50/150 metres spacing
  - Maximum 270,000 litres per hour


District heating
Boilers
1
2
3
11
From IEA HPC
Newsletter
Heat Pumps
12
District cooling
4
8
7
15
13
14
HX
HX
Aquifer (ATES)
1. Oil-fired boilers
2. Electrical boilers
3. Heat pumps
4. Heat pumps
5. Heat exchanger
6. Heat exchanger
7. Heat exchanger
8. Cooling tower
9. Warm wells
10. Cold wells
11. Circulation pumps (District heating)
12. Circulation pumps (District cooling)
13. Condenser pumps
14. Evaporator pumps
15. Cooling tower pumps
16. Ground water pumps (Warm wells)
17. Ground water pumps (Cold wells)
-45 m
x 9 (50 m spacing)
-45 m
x 9 (50 m spacing)
9
16
17
10
150 m

Boreholes in Bedrock

Typical Specifications and Challenges

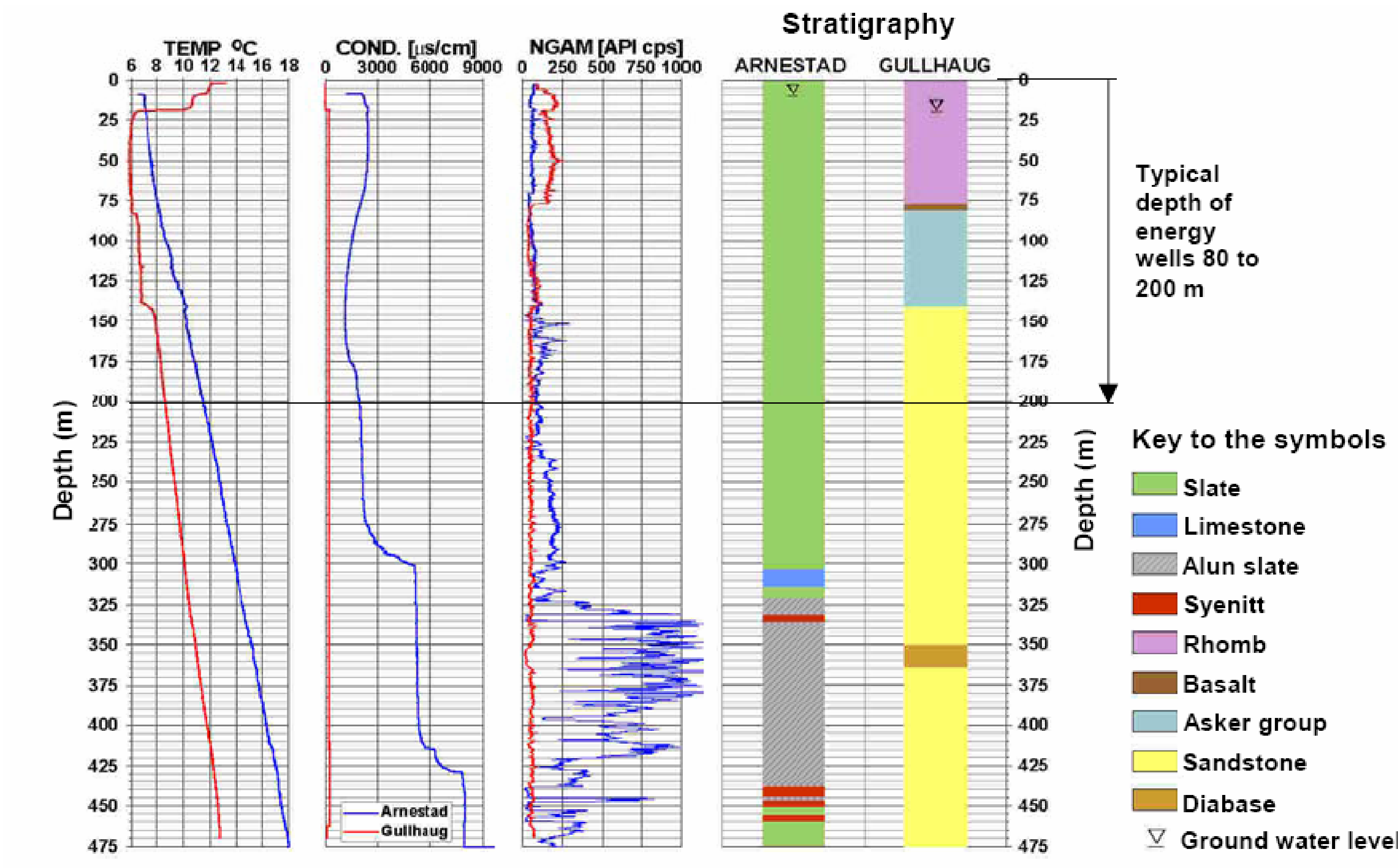
- Used as heat source/sink for GSHPs in residential and non-residential buildings
- Borehole depth 80 – 200 (300) m
- Borehole diameter 130 – 165 mm
- GHE – type/design
  - PEM, PN 6.3
  - OD/OD 40/35 mm
  - Single U-tubes (standard)
  - Double U-tubes used occasionally
  - Brine (anti-freeze) – denaturated ethanol
- Well casing required in unfixed masses



Pneumatically operated drilling rig

Bedrock Data and Bedrock Maps

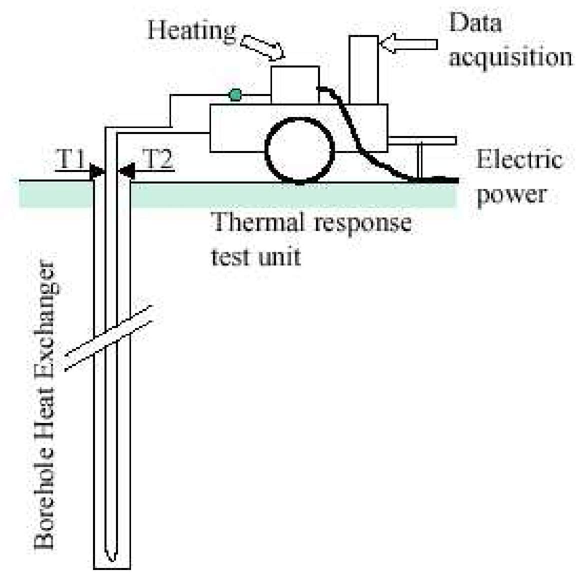
Example – Stratigraphy, Geothermal Gradients, Groundw. Level



From The Geological Survey of Norway

Thermal Response Testing

Developed at Luleå Technical University

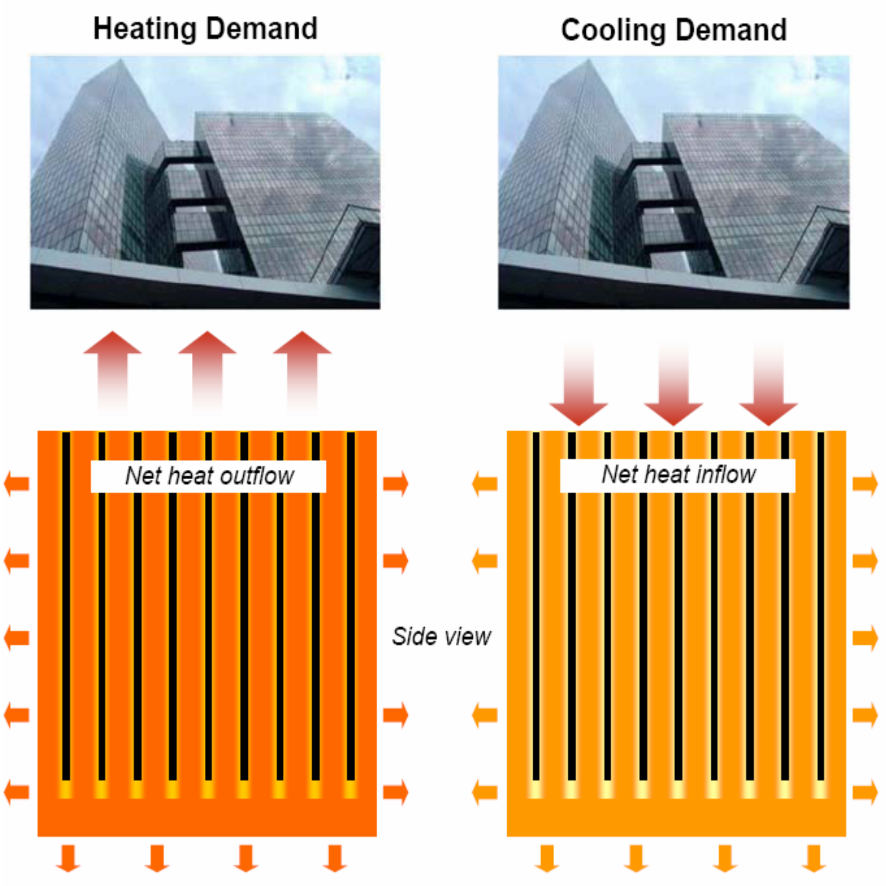


- Simple mobile test rig (TRT rig)
  - Electric heater
  - Circulation pump
  - Control system
  - Data acquisition system
- Measurement of thermal resistance and maximum heat transfer rate
- Testing time 60 – 80 hours
- Enables more accurate design of energy wells and energy storages
- Utilized by some Norwegian companies

S. Gehlin, Sweden, 2002

Recharging and Thermal Energy Storage

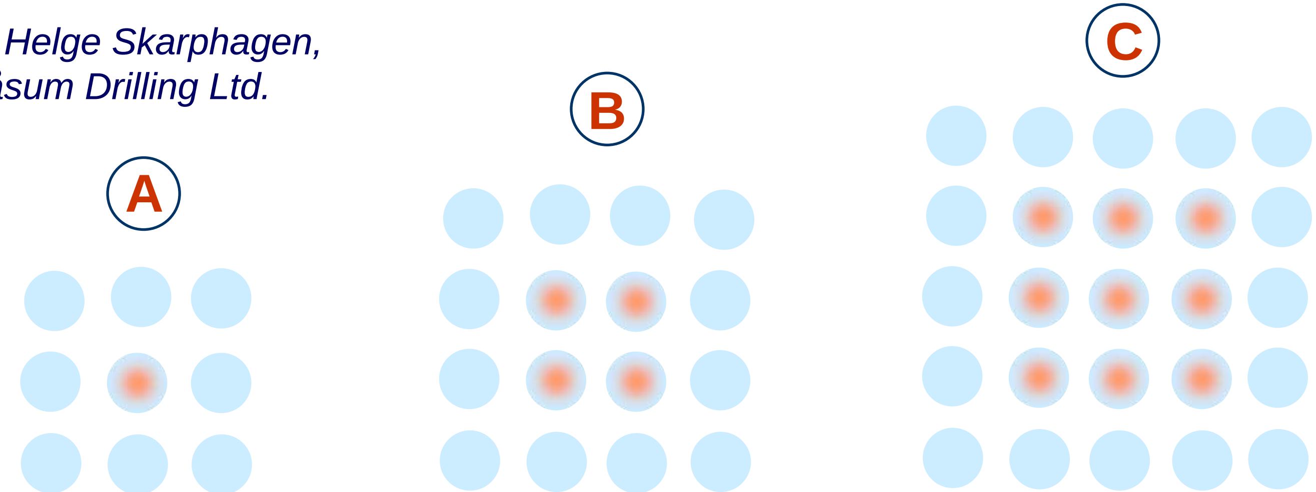
- Recharging req. depends on
  - No. of boreholes
  - Borehole configuration
  - Ground water flow
  - Properties of the bedrock
- External recharging by
  - Excess heat from cooling system
  - Excess heat from ventilation air
- Thermal energy storage
  - For larger buildings/systems
  - Closed thermal energy storage
  - Focus on annual energy balance



Principle of a thermal energy storage

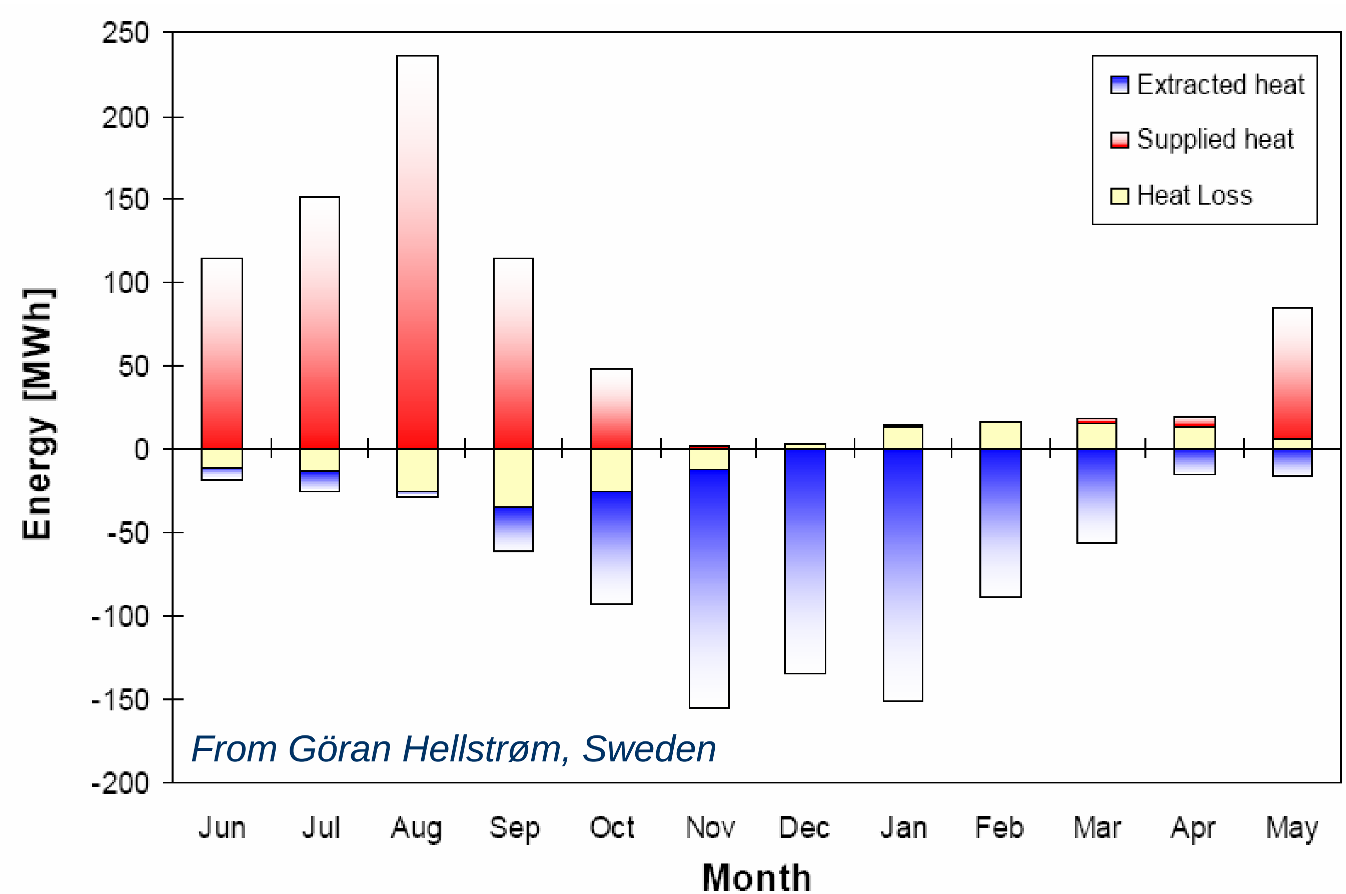
Recharging and Thermal Energy Storage

From Helge Skarphagen,
Båsum Drilling Ltd.



- Extraction/rejection of thermal energy from/to energy wells in bedrock
- Some charging with excess temperature possible in the central wells
- The larger the storage, the less the relative energy loss (A → C)
- **Advanced computer programmes required for accurate design**

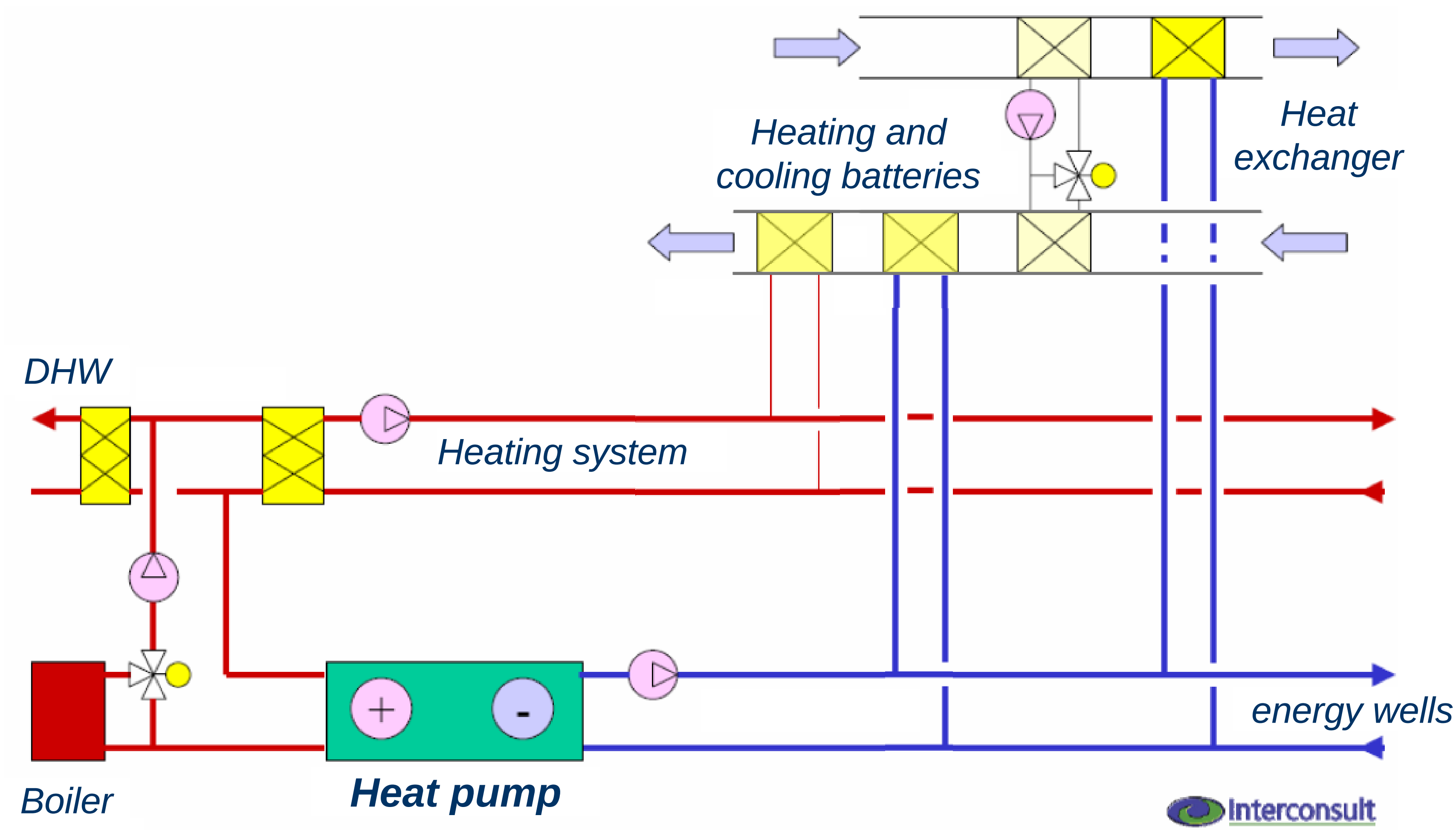
Thermal Energy Storage – Energy Balance



Supplied and extracted heat should be in the same order of magnitude

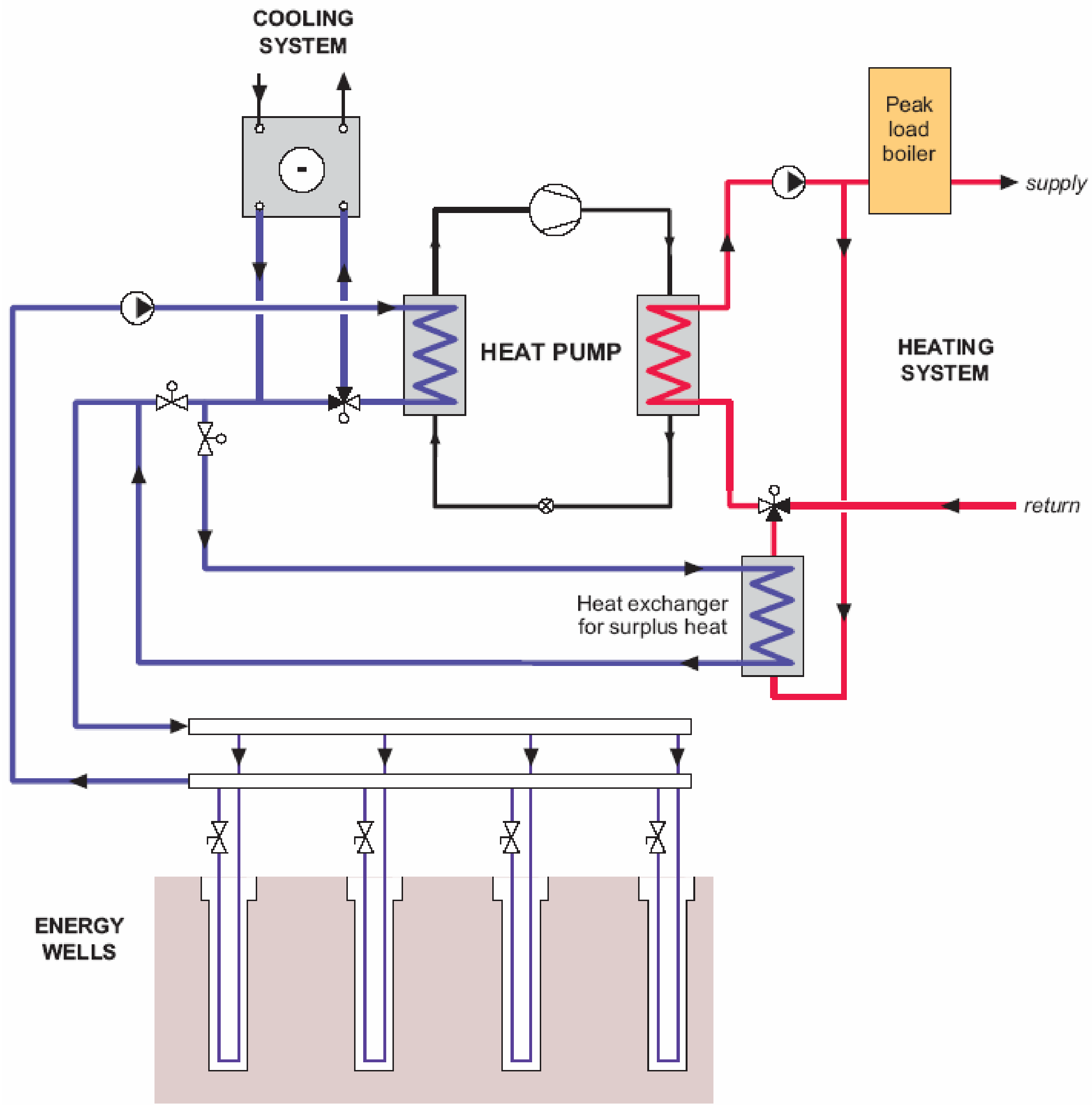
Recharging – Thermal Energy Storage

Principle Example of Heat Pump System



Recharging – Thermal Energy Storage

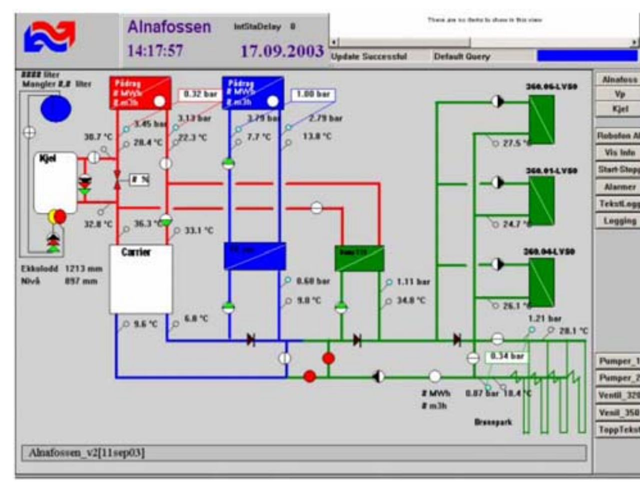
Principle Example of GSHP System



Example – Office Building

GSHP System at Alnafossen Kontorpark

- Heating and cooling – 35.000 m^2
  - Hydronic distribution systems
- Energy central with heat pumps
  - 1200 kW heating capacity
  - 800 kW cooling capacity
  - Oil-fired boilers for peak load and back-up
  - Installed, operated and maintained by the energy utility Bærum energiverk (Fortum)
- The ground-source system
  - Designed as a thermal energy storage
  - Single U-tubes (OD 40 mm)
  - 54 boreholes x 200 m



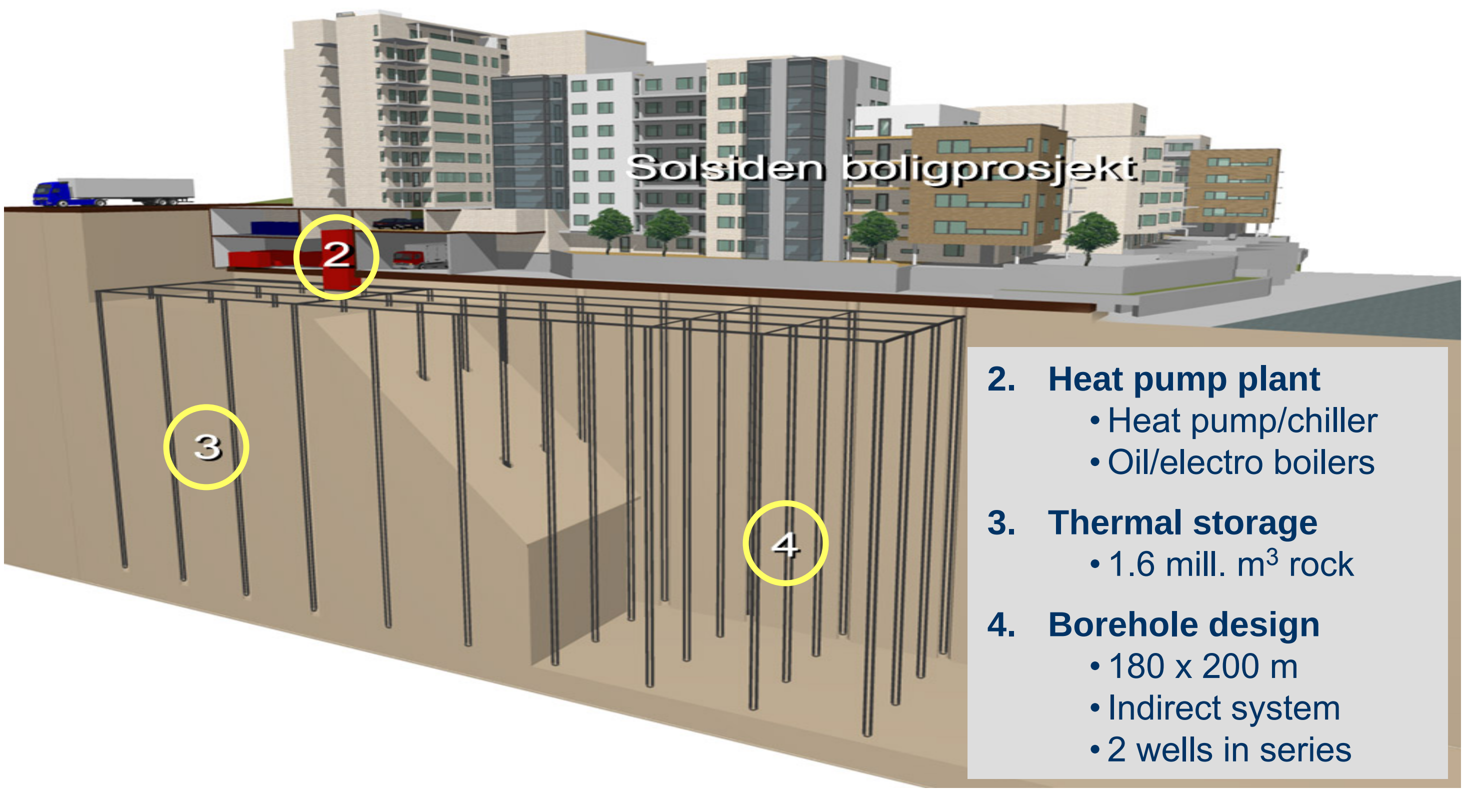
Example – District Heating and Cooling

GSHP System Nydalen Næringspark, Oslo

- 180.000 m^2 apartment buildings, hotel, office buildings, school
- Energy central with heat pumps
  - 6.0 MW heating capacity – rock as heat source/sink
  - 9.5 MW cooling capacity – incl. cooling by river water
- The ground-source system
  - Single U-tubes (OD 40 mm) - 2 wells in parallel
  - 180 boreholes x 200 metres
  - The largest thermal storage in Europe (1.6 mill. m^3)
- Commissioning and start-up in 2004/2005

Example – District Heating and Cooling

GSHP System Nydalen Næringspark, Oslo



Grunnvarmebaserte varmepumpesystemer

for oppvarming og kjøling av bygninger

SINTEF

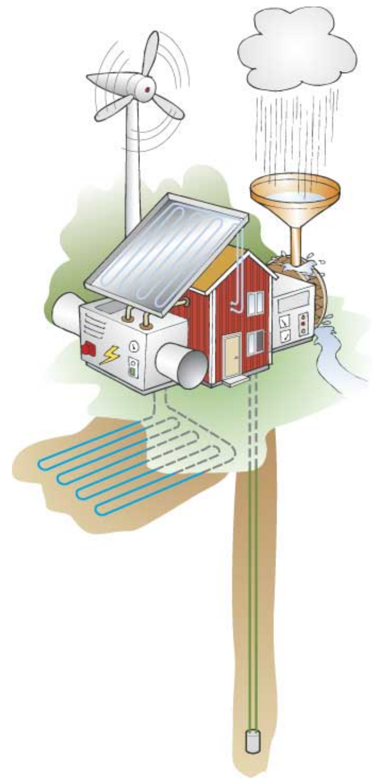
IEA Heat Pump Programme Annex 29 (2004-2006) - Ground-Source Heat Pumps Overcoming Market and Technical Barriers

- Hovedside
- IEA Annex 29
- Grunnvarme
- Eksempler
- Publikasjoner
- Lenker
- Nyheter
- Forskning

Grunnvarme er en fellesbetegnelse på uttak og lagring av lavtemperatur termisk energi i berggrunnen, grunnvann og jord. Ved hjelp av varmepumper kan grunnvarmesystemene utnyttes til energieffektiv og miljøvennlig oppvarming og kjøling av alle typer bygninger. I de senere årene har antall grunnvarmebaserte varmepumpeanlegg økt betraktelig i mange europeiske land, Canada og USA.

Innen **IEA Heat Pump Programme** er det startet opp et internasjonalt prosjekt (Annex 29) med tema grunnvarmebaserte varmepumpesystemer. Hensikten med prosjektet er å utvikle mer kostnads- og energieffektive løsninger, identifisere/analysere markedsbarrierer, bidra til teknologioverføring samt synliggjøre energisparepotensialet og miljøgevinstene for denne typen systemer.

IEA Annex 29 løper fra mars 2004 til oktober 2006, og deltakerlandene er Canada, Japan, Norge, Spania, Sverige, USA og Østerrike. Norges deltakelse er finansiert av **ENOVA SF**, mens **SINTEF Energiforskning AS** har ansvaret for planlegging og gjennomføring av prosjektaktivitetene.



Although this homepage has been established to serve Norwegian users, there is plenty of information in **English** under *IEA Annex 29*, Eksempler (*Installations*), Publikasjoner (*Publications*), Lenker (*Internet Links*), Nyheter (*News*) and Forskning (*Research Activities*)

http://www.energy.sintef.no/prosjekt/Annex29/

Summing Up

- The Norwegian GSHP market
  - Boreholes in bedrock – growing interest for residential systems
  - Boreholes in bedrock – growing interest for larger systems with thermal recharging or thermal energy storage
  - Ground water – limited to areas where the water has acceptable purity
- Challenges and important boundary conditions
  - High quality GSHP system requires engineering expertise
  - New building codes and EU directive "Energy Performance of Bldgs." (2006)
  - Hydronic floor heating systems in 50% of new residences
- The Norwegian IEA HPP Annex 29 status report is found at:

http://www.energy.sintef.no/prosjekt/Annex29/