Deep borehole heat exchangers

Henrik Holmberg, Asplan Viak AS and NTNU-Department of energy and process engineering.

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Henrik.holmberg@ntnu.no

Henrik.holmberg@asplanviak.no

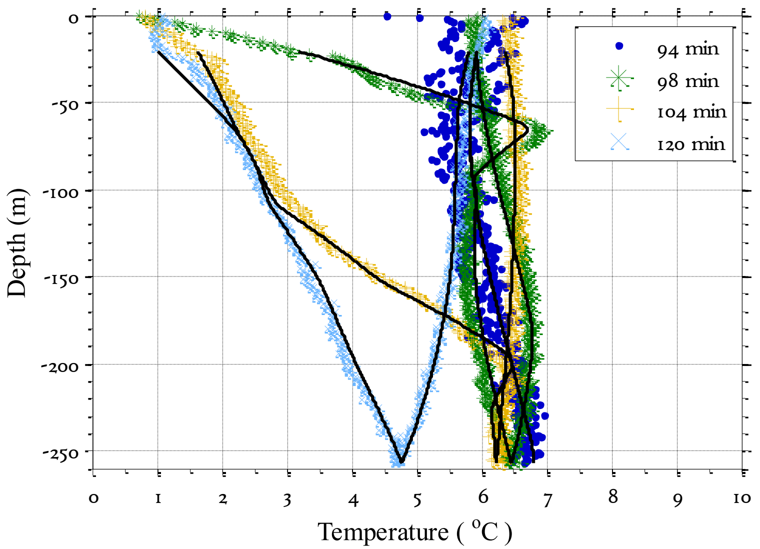
Layout:

- Background – motivation
- How to - Choice of collector ?
- Results from simulations – coaxial BHE
  - Parametric study
  - Long term performance
- Summary - Conclusions

Background:

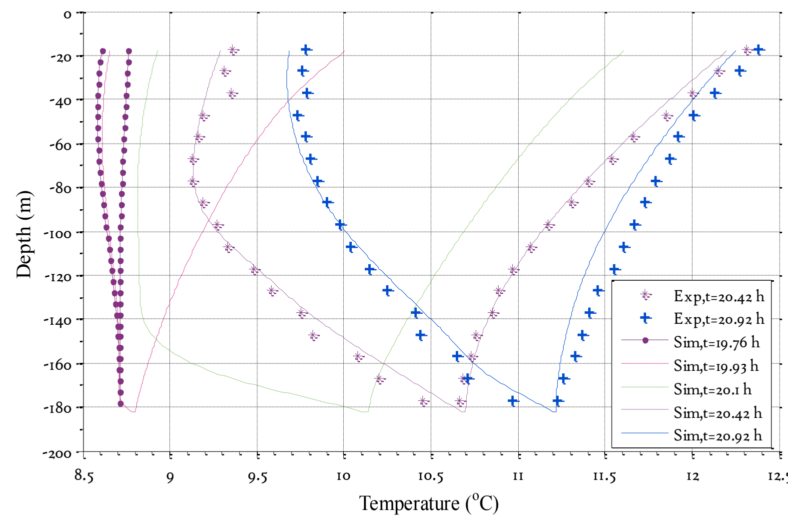
- Numerical simulation (TRCM-models) of single borehole heat exchangers (within PhD- at NTNU)

U-tube BHE



Simulation of heat pump operation – U-tube BHE

Coaxial BHE



Simulation of thermal responstest – coaxial (tube-in-tube) BHE

Holmberg. H., Acuña. J., Næss. E., Sønju. K. O., Numerical model for non-grouted borehole heat exchanges, part 2-Evaluation. (2014) Accepted for publication, Geothermics

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BHE installations in Norway using 500 m boreholes:

- Skoger skole, 5 x 500 m
- Maudbukta – residental building (Asker), 9 x 500 m

These systems use single U-tube collectors, (PEM50) – more on that later..

What is the motivation for these installations?

- Scarcity of available land/ construction area

- Heating dominated load

- Deep soil layers

- Increased heat extraction rate/ energy

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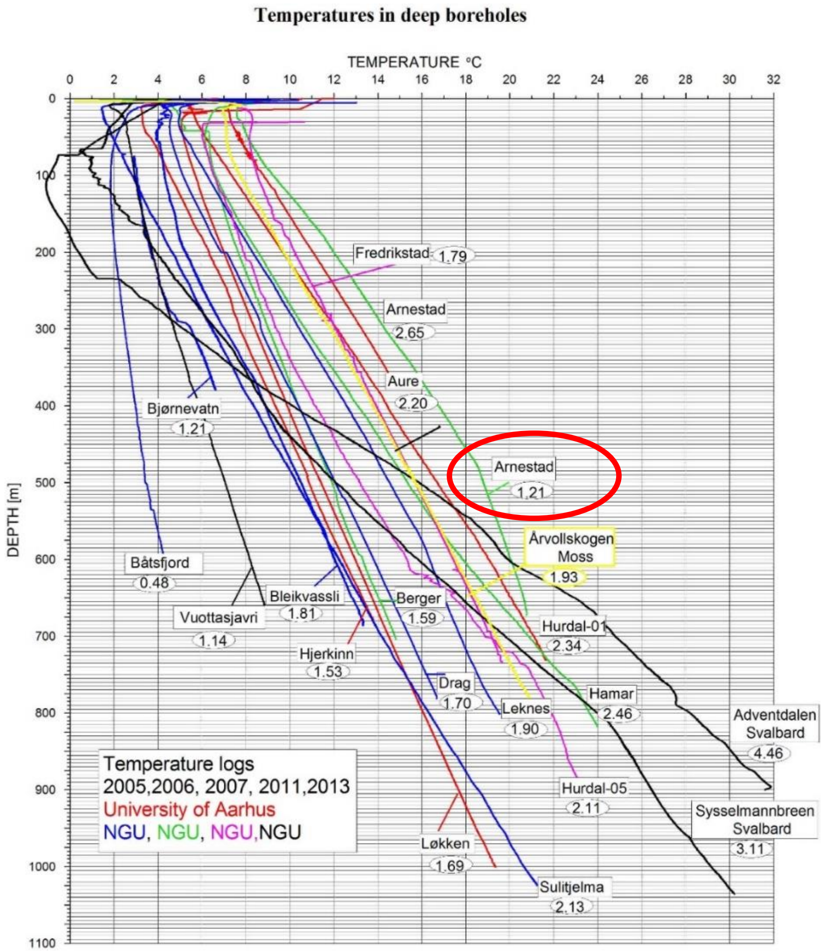
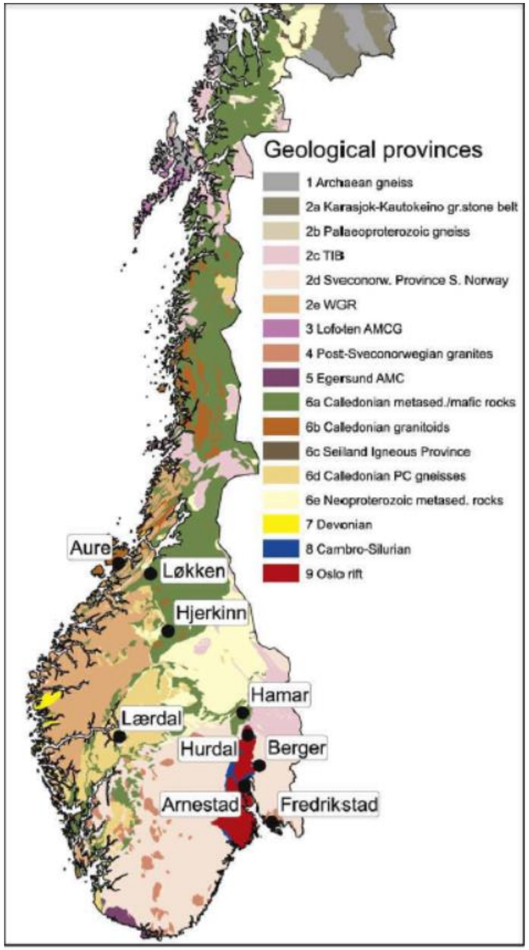
Temperature measurements in on-shore boreholes in Norway



Source: NGU Report 2013.008, Evaluation of the deep geothermal potential in Moss area, Østfold County.



Source: Slagstad et al. 2009

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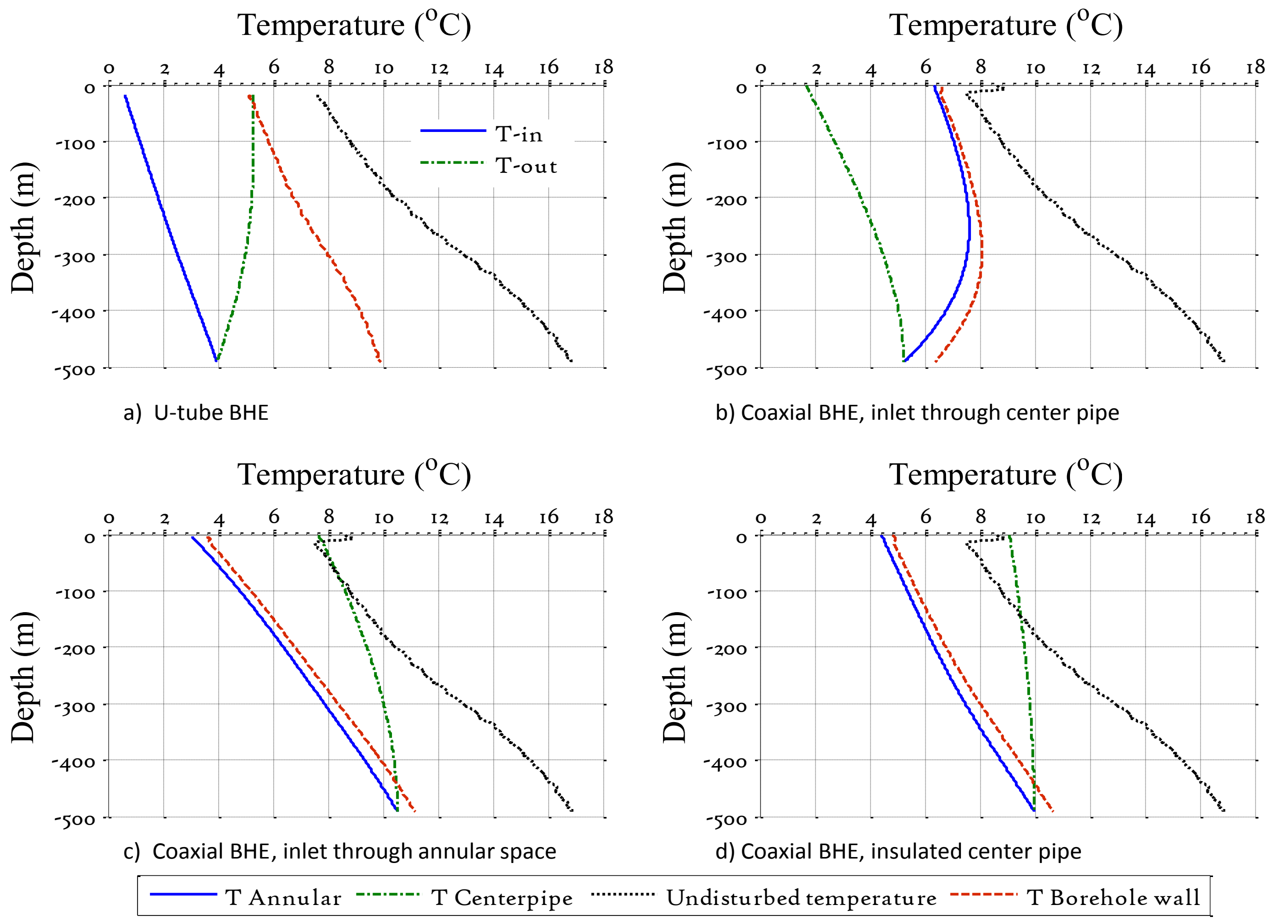
How to – choice of collector- Results from simulation based on undisturbed temperature profile from 490 m deep borehole- continuous heat extraction 40 W/m for 50 hours

Parameter	Value
k_g	3.53 W /m K
Active length BHE [m]	490
Borehole diameter [mm]	140
Collector (center pipe) [mm]	50 x 4.6
Collector (outer pipe) [mm]	139 x 0.4
k_c [W /m K]	0.42
k_{ins} [W /m K]	0.1
Heat carrier	Water
Mass flow rate [kg / s]	1
Specific thermal load [W /m]	40



a) U-tube BHE. b) Coaxial BHE, inlet through center pipe. c) Coaxial BHE, inlet through annular space.
d) Coaxial BHE with lower thermal conductivity of the collector material (0.1 W/ m K)

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Choice of collector when extending the borehole depth.

- Installation
- Economics
- Thermal performance
- Hydraulic performance

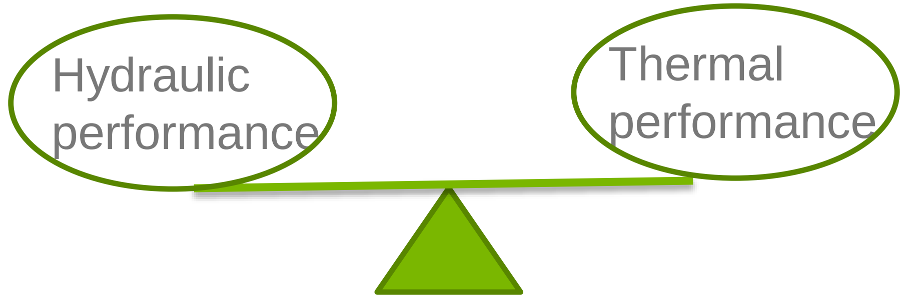
Do we need an thermally insulated center pipe?

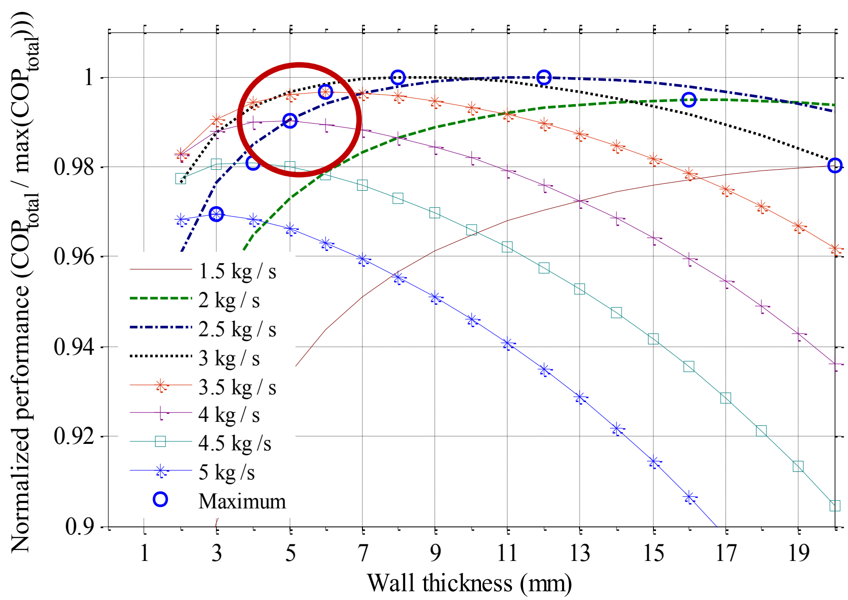
What temperatures can we get?

How much energy can we get?

Parametric study – Coaxial pipe-in-pipe BHE, influence of insulation of the center pipe.

- Parametric study with the overall system performance (COP) as the objective
- Varying center pipe wall thickness and mass flow rate.





Finding: The system performance (COP) is relatively insensitive to the center pipe wall thickness.

Increases with depth!

However..

Heat extraction rate, directly related to mass flow rate!

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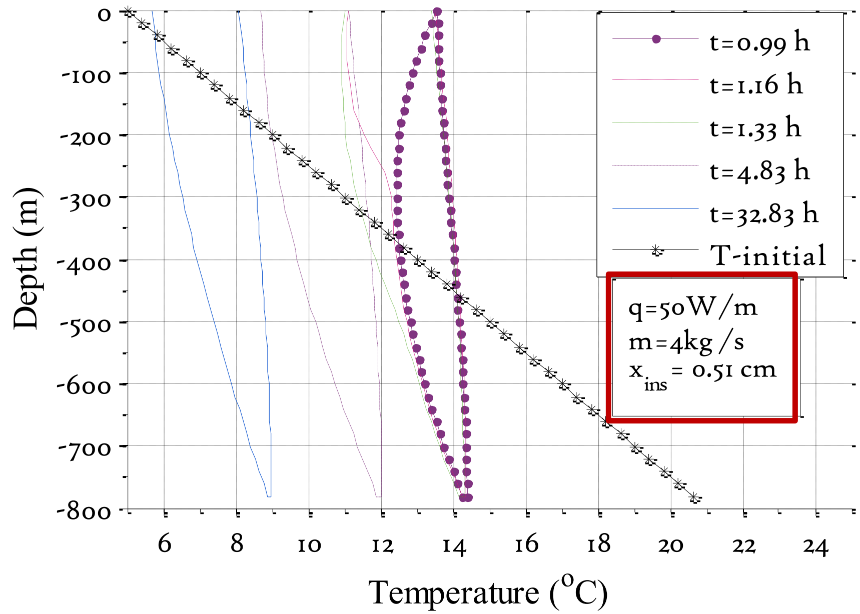
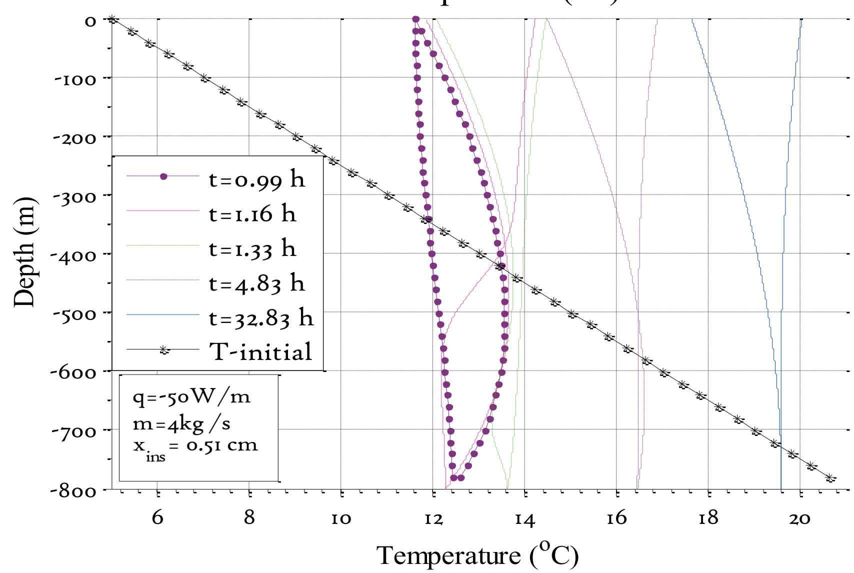
Temperature profiles in 800 m coaxial BHE

Heat extraction

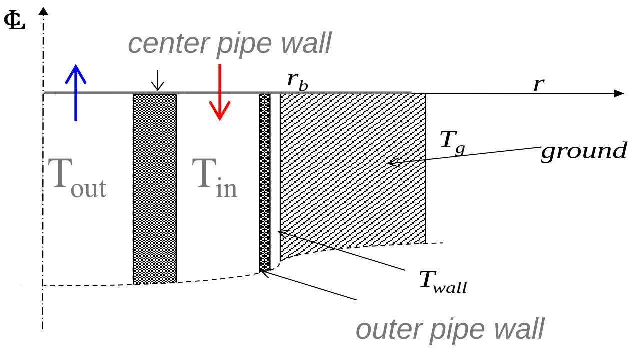


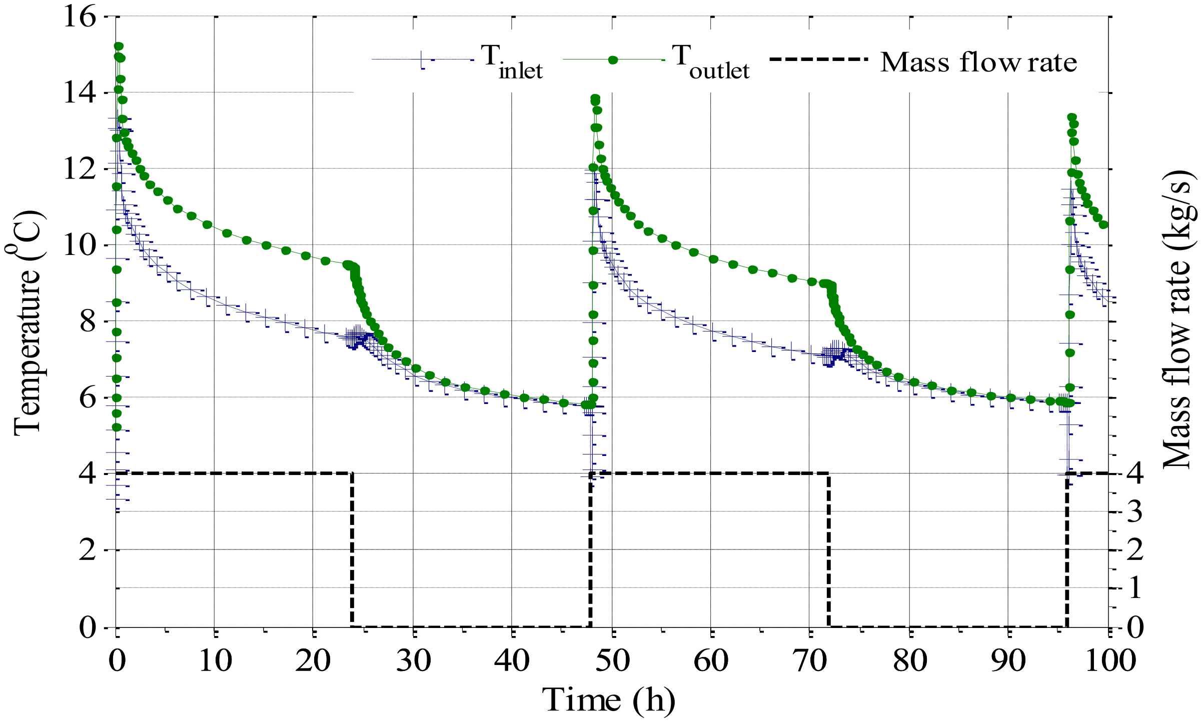
center pipe : 90 mm x 5.1 mm

Thermal recharge



Results from simulations – long term performance





- Constant heat load
- Constant mass flow rate

The BHE is simulated with a cyclic operation strategy using operation periods of 24 hours and a recovery period of 4 months. Total operation time/ year = 2900 hours ≈ 4 months

Holmberg. H., Acuña. J., Næss. E., Sønju. K. O., Deep borehole heat exchangers, application to ground source heat pump systems, Proceedings World Geothermal Congress 2015, Melbourne, Australia. 19 -25 April 2015. - presented by Davide Rolando

Parameters used in the simulation

Table 1. Case specific parameters

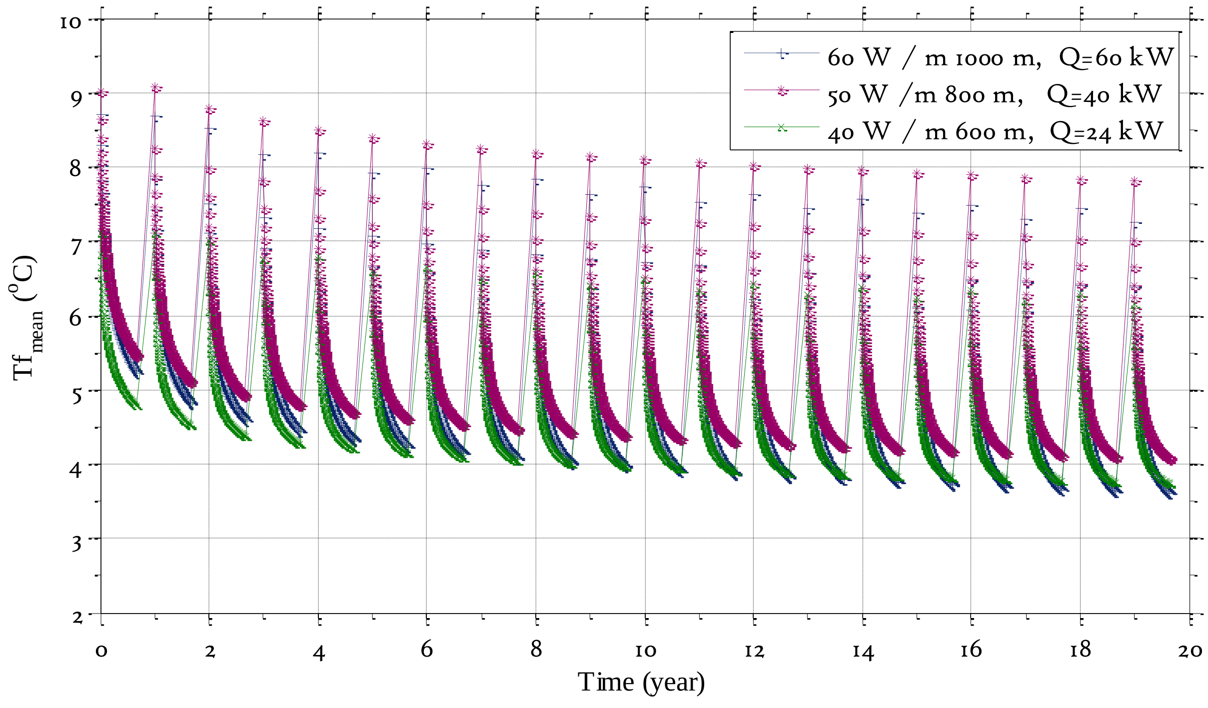
Parameter	Value	Value	Value
Active length BHE [m]	600	800	1000
Collector (center pipe) [mm]	75 x 4.3	90 x 5.1	90 x 3.5
Mass flow rate [kg / s]	3.5	4.0	5
Thermal load [W /m]	40	50	60
Pressure drop[1] [bar]	1.0	1.0	1.7
Pump power required[2] [kW]	0.47	0.53	1. 33

[1]It is assumed that the annular space is confined within a smooth-walled outer pipe.
[2]Assuming $\eta_{pump}=0.75$.

A relatively high mass flow rate is used – reduces need for thermal insulation

The geothermal temperature gradient is constant at 20 K / km

Long term simulation,

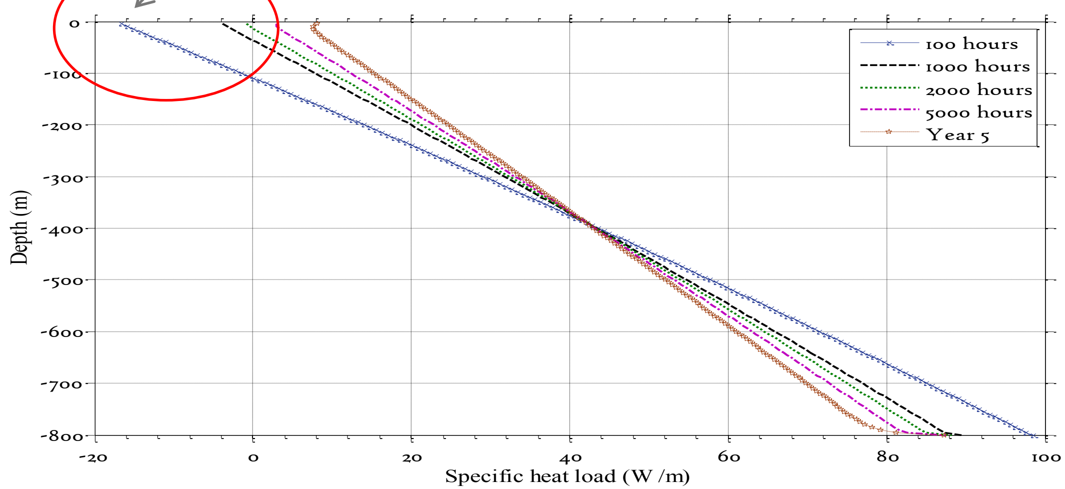


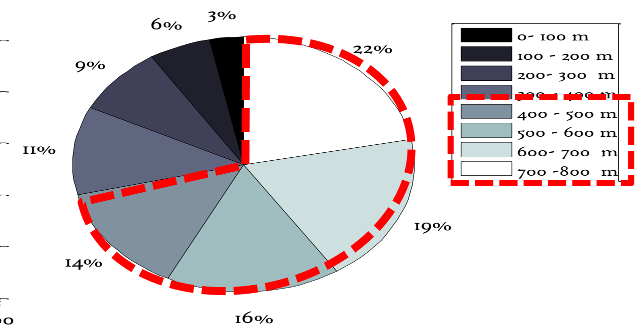
Yearly energy production

Depth (m)	MWh_{th}/ year
600	70
800	117
1000	175

Distribution of specific heat load (W/m)

Heat losses in the upper part of the borehole

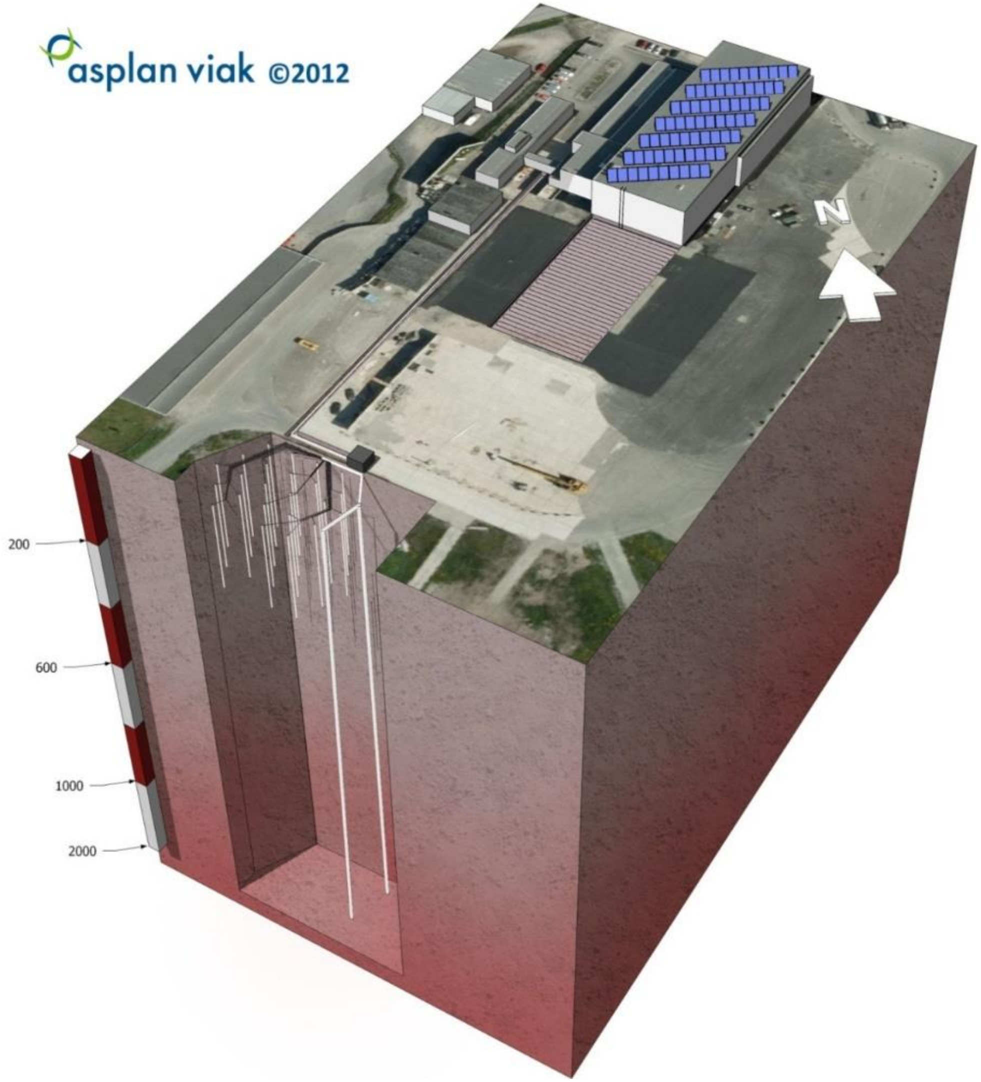




≈ 70 % of the thermal energy from 400 – 800 depth

Larger distance required between the lower part of the boreholes

Deep BHEs in combination with shallow BTES.



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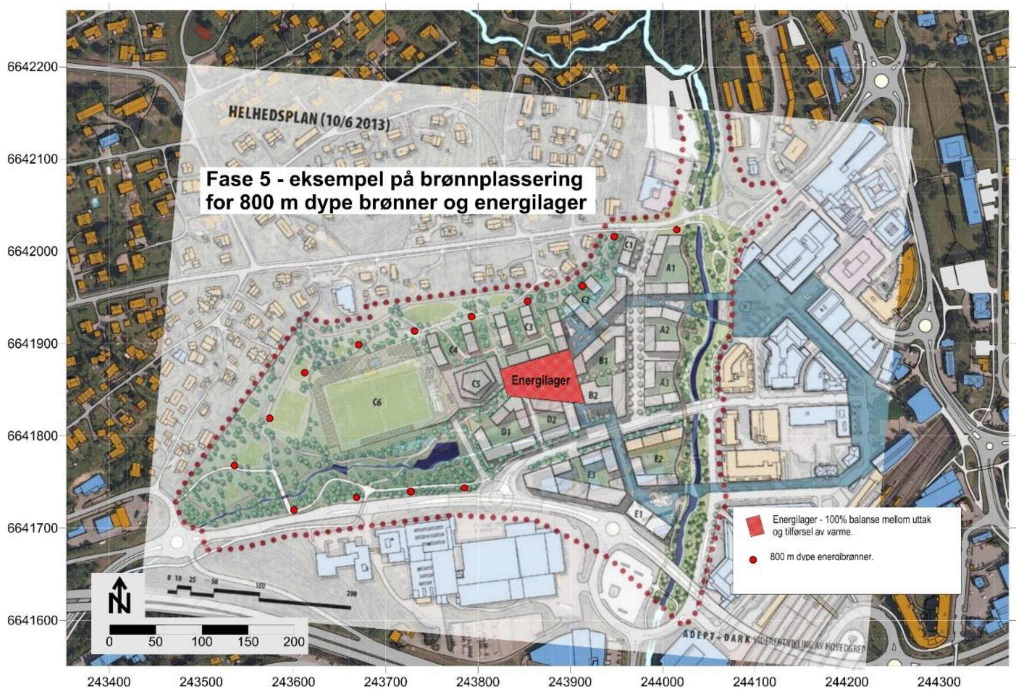
Ongoing project in Asker municipality



Summary - conclusions

- Due to higher temperature level in the borehole the deep BHEs can sustain a higher average specific heat load than conventional BHEs
- Best performance with a relatively high mass flow rate – reduces need for thermal insulation
- Most energy is extracted in the lower part of the borehole, making deep BHEs insensitive to thermal influence from neighboring BHEs (shallow or deep) in the upper part
- The required energy for circulation of the heat carrier fluid in the cases shown is on the order of 1-2 % of the produced thermal energy and can be reduced using a larger borehole diameter
- Deep BHEs are, therefore, a viable option for GSHP installations in areas with scarcity of space and negatively balanced loads.