2016 GSHP Convention

Deep and Coaxial Borehole Heat Exchangers for Ground Source Heat Pumps

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KTH GSHP Conference, 15th of September 2016

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Resurseffektiva kyl- och värmepumpssystem samt kyl- och värmelager

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- Deep BHEs: status / background
- Advantages
- Disadvantages
- Challenges
- Tests – Asker / Stockholm
- Future work and research?

Deep and coaxial BHEs

Deep boreholes: status

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- Deep(er) boreholes?
  - Deep for GSHPs but not "deep geothermal"
  - ≥ 300 m

Norway –

- Skoger skole 5 x 500 m – single 50 mm U-collector- 2011
- Vollen 9 x 500 m – single 50 mm U-collector – 2012
- Asker 2 x 800 m – pilot plant – Coaxial collector -2016

Sweden

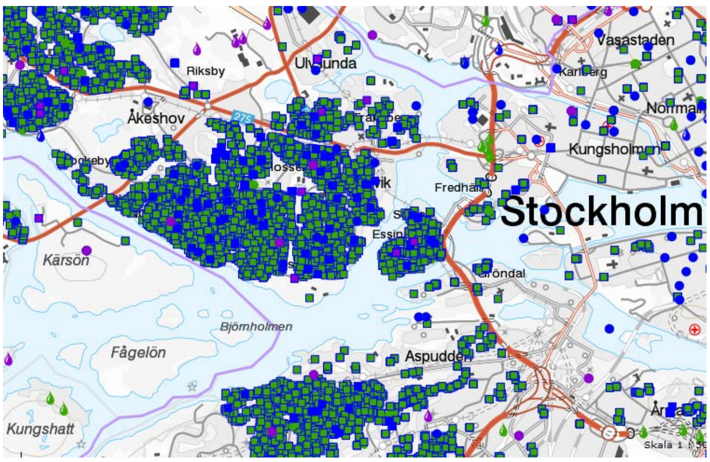
- Birger Jarlsgatan, 4x510 m
- Vallentuna, 1x550 m
- Helsingborg, 1x342 m
- Uppsala, 22x335 m grouted
- Stockholm, 1x500 m
- Stockholm, 2 other installations (more?)
- Täby, ?x600 m(?)
- Stockholm, 18x300 m
- Farsta, 14x300 m
- KTH live-in-lab, 225-350 m
- DN huset, ?x300 m

Deep and coaxial BHEs

Motivation?

Resurseffektiva kyl- och värmepumpssystem samt kyl- och värmelager

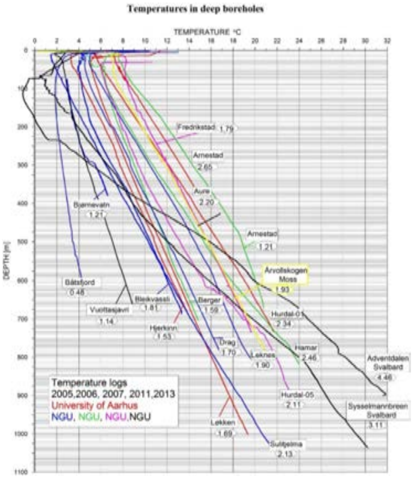
- Increased interest in drilling deeper holes: trend



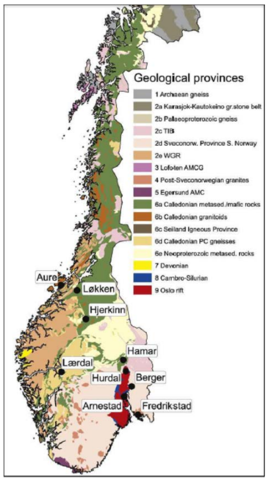
Deep and coaxial BHEs

SGU (2016)
Gehlin et al. (2016)

Temperature measurements in on-shore boreholes in Norway



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



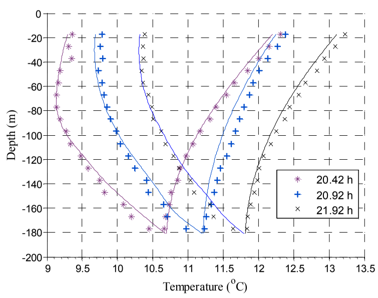
Source: Slagstad et al. 2009

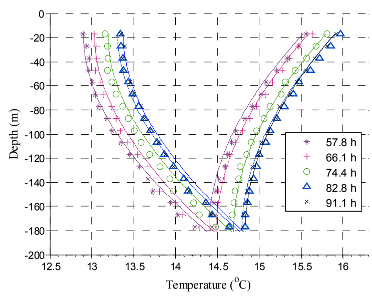
Deep and coaxial BHEs

Simulation of Coaxial BHEs

Simulation of BHEs - using TRCM models (in PhD)

Coaxial borehole heat exchanger – comparision with experimental results from Acuña 2013





Holmberg. H., Acuña. J., Næss. E., Sønju. K. O., Thermal Evaluation of Deep Coaxial Borehole Heat Exchangers. Renewable energy 2016. v 97, pp 65-76

Deep and coaxial BHEs

Simulation of deep dependency, using TRCM models

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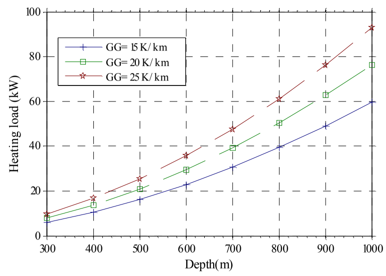
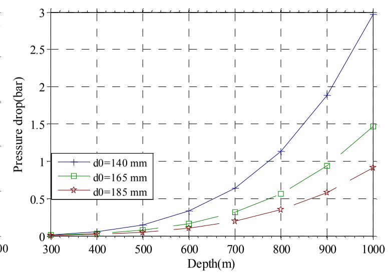
Depth dependency





Specific heat exctraction (W/m) increases

Holmberg. H., Acuña. J., Næss. E., Sønju. K. O., Thermal Evaluation of Deep Coaxial Borehole Heat Exchangers. Renewable energy 2016. v 97, pp 65-76

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Key findings:

Optimum configuration for a deep coaxial BHE for heat pump applications is a combination of a thin walled center pipe and a rather high mass flow rate.

Increase in system performance with increasing depth outweights the increase in pressure losses and pumping power.

Holmberg. H., Acuña. J., Næss. E., Sønju. K. O., Thermal Evaluation of Deep Coaxial Borehole Heat Exchangers. Renewable energy 2016. v 97, pp 65-76

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Deep boreholes, advantages

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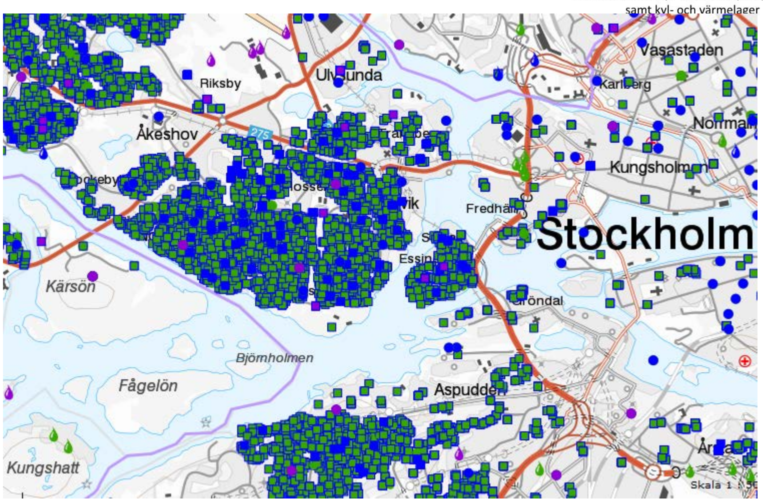

Deep and coaxial BHEs *SGU (2016)*

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Deep boreholes, advantages

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- Built-up areas: lack of space
- Large soil layer (casing)
- Higher temperatures at larger depths (better COP or more energy ((kWh/m) / year))
- Neighbor installations: low temperatures in shallow regions
- Possible in colder climate, northern Norway / Sweden
- Can use water as the heat carrier

Deep and coaxial BHEs *SGU (2016)* *Gehlin et al. (2016)*

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Deep boreholes, disadvantages

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- Economic limitations
  - Higher investment costs, drilling / collector?
- Risk- drilling depth / collector installation.
- (Only) for heat extraction
- Pressure drop has to be considered for deep U-collectors.
- Little experience with coaxial BHEs.

Deep and coaxial BHEs

Deep boreholes, challenges

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- Precision of the drilling: need to measure the boreholes position?
- Economical considerations – drilling / (collector)
- Collector design and installation
- Bouancy forces, U-collector
  - External pressure
  - Uplift
- Pressure drop / thermal effect

Deep and coaxial BHEs

Deviation measurements

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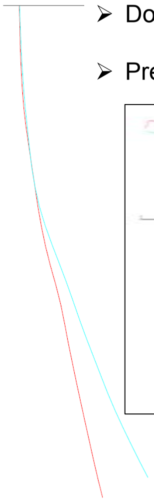
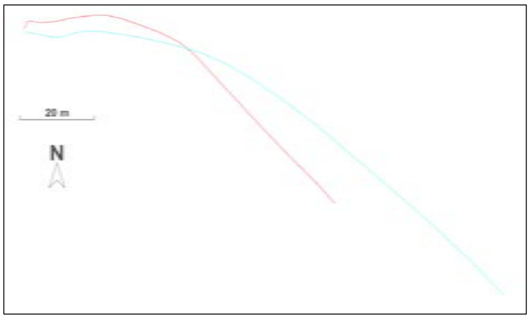
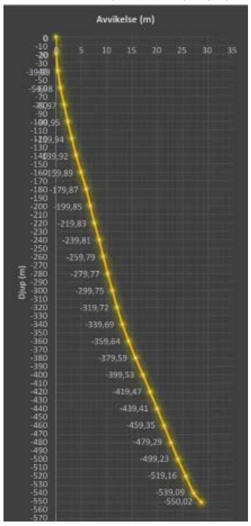
- Up to 29% deviation with respect to total depth
- Down to 5,5 %
- Preferred drilling direction?







Deep and coaxial BHEs

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Deep boreholes, limitations

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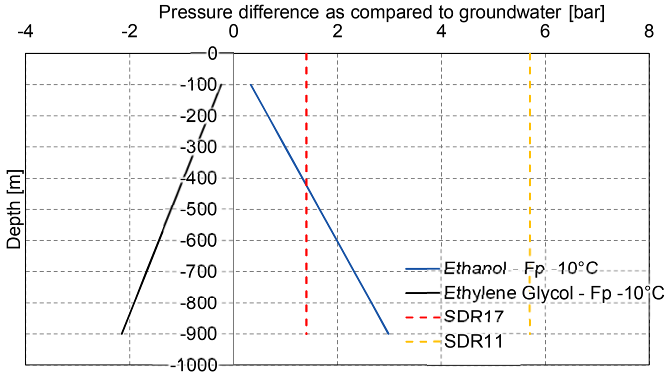

- Krushelnitzky and Brachman (2009): vertical differential pressures up to 30 bar in 100 mm HDPE DR11 & DR26 → no evidence of buckling but deformation into elliptical shapes

Deep and coaxial BHEs

Melinder (2007)
Gehlin et al. (2016)

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Asker - 800 m coaxial pilot plant

- Asker kommune
- Båsum boring
- Enova
- Innovasjon Norge
- Asplan Viak

Deep and coaxial BHEs

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Asker - 800 m coaxial pilot plant

- Drilling of 2 x 800 m (14.4 - 12.5.2016)
- 0- 200 m, Ø165 mm
- 200 – 800 m, Ø140 (east borehole) and Ø150 mm (vest borehole)

Rotary hammer drilling, with boster air compressor (65 bar)

Deep and coaxial BHEs

Asker - 800 m coaxial pilot plant

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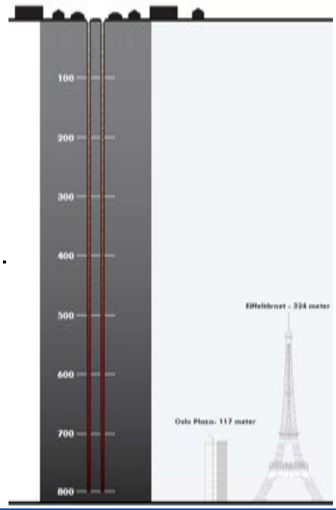
- Flexible outer flexible pipe (“hose”).
- PE 75mm SDR17 center pipe. 15.8.16
- First cooling DTRT performed 16.8.16 – 25.8.16.



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Deep and coaxial BHEs

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Asker - 800 m coaxial pilot plant

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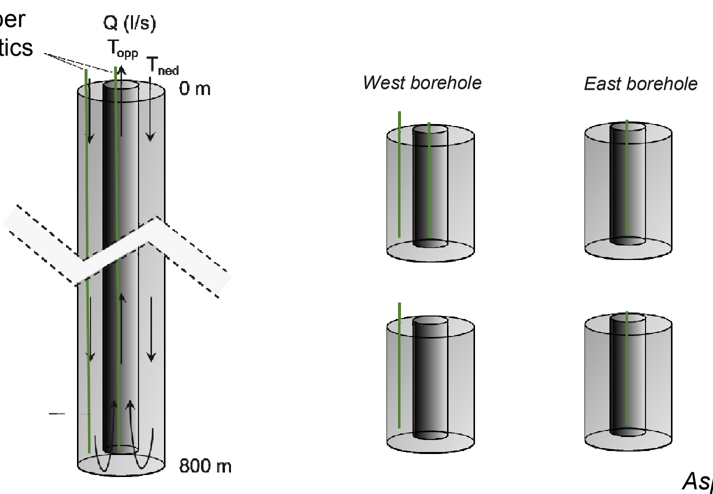

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Deep and coaxial BHEs

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Asker - 800 m coaxial pilot plant

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Installation of the center pipe + fiber

and coaxial BHEs

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Asker - 800 m coaxial pilot plant

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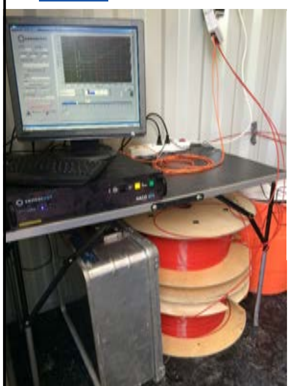

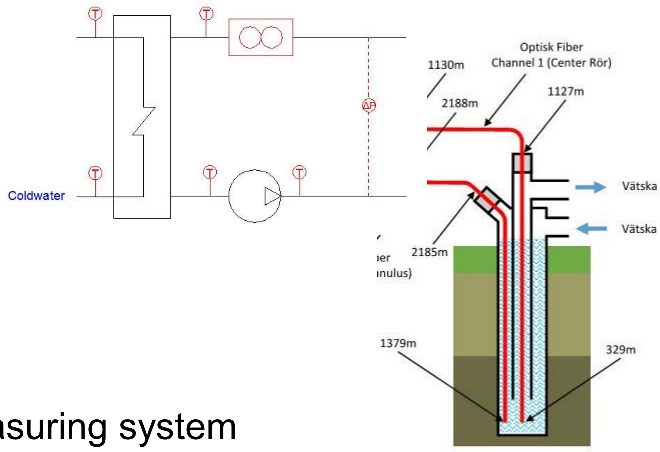

Fiber optic: measuring system

Deep and coaxial BHEs

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Asker - 800 m coaxial pilot plant

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Asker - 800 m coaxial pilot plant

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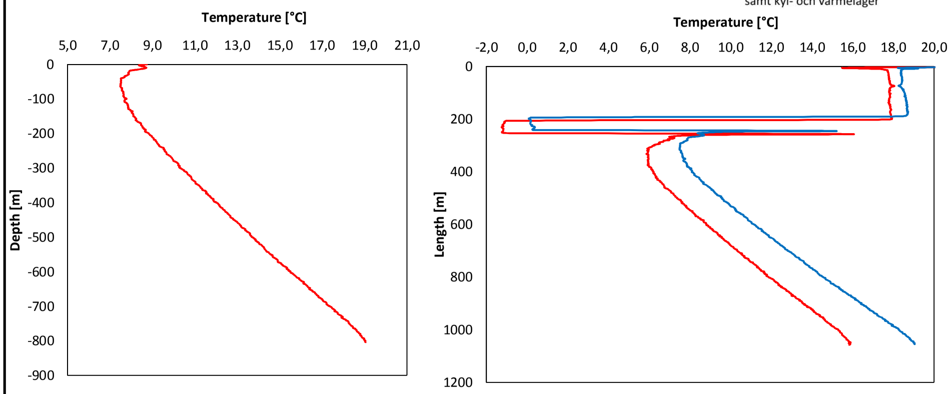

Calibration error

Temperature measurements

Deep and coaxial BHEs

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Deep boreholes, tests: 510 m borehole in Stockholm

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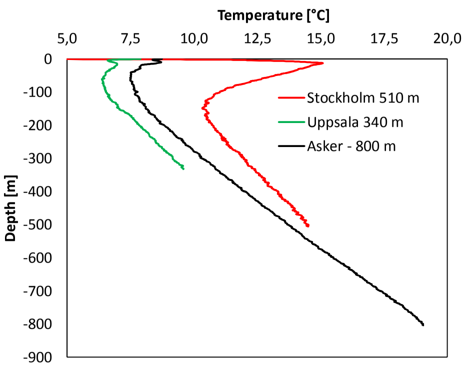

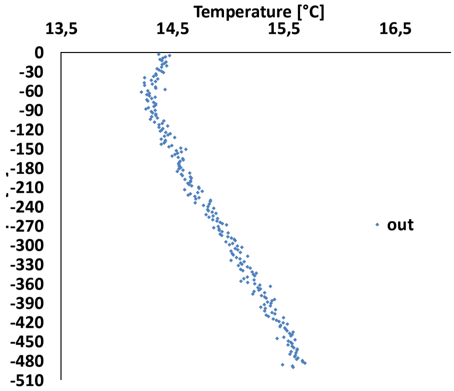

Temperature measurements

BRUGG CABLES Well connected.

WERMER FÖRNUFTIGA VÄRMELÖSNINGAR FÖR SMÅ OCH STORA HUS

Wessman Entreprenad AB

FBB Finspångs Brunnsborrning AB

NTNU

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Field tests / installations

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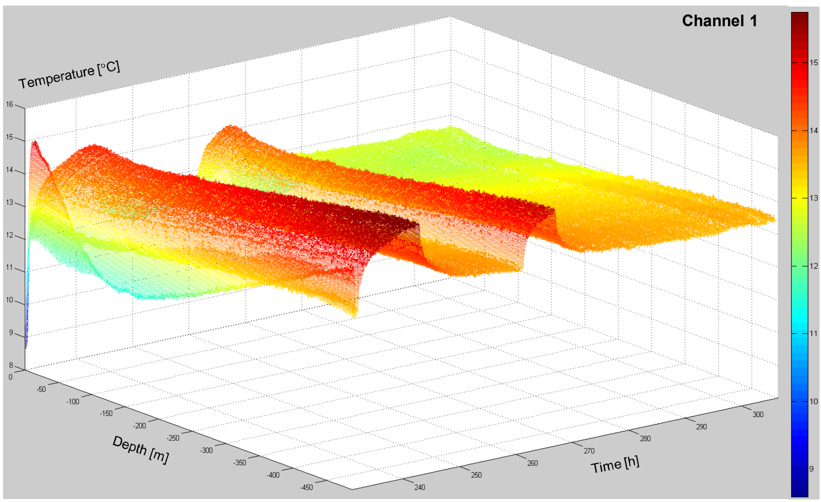
Raw data



Deep and coaxial BHEs

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Deep and coaxial BHEs project

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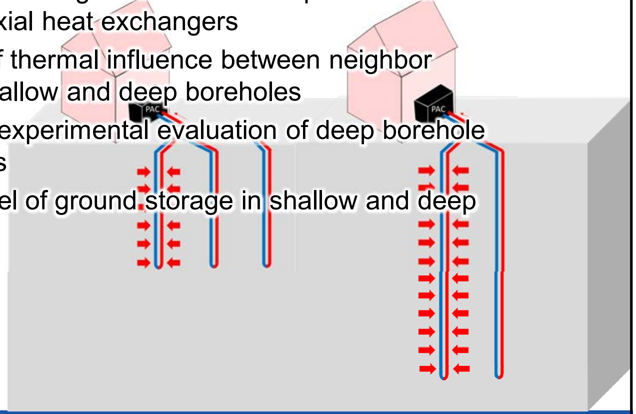
1. Deep boreholes: advantages and drawbacks for existing and new projects
2. Development of a design method for multiple borehole fields using coaxial heat exchangers
3. Quantification of thermal influence between neighbor systems with shallow and deep boreholes
4. Installation and experimental evaluation of deep borehole heat exchangers
5. Laboratory model of ground storage in shallow and deep boreholes



Deep and coaxial BHEs

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Thank you!

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Deep and coaxial BHEs

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Temperature measurement with optic fiber

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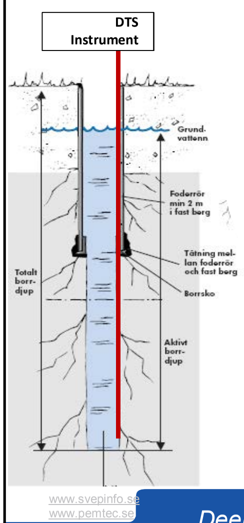

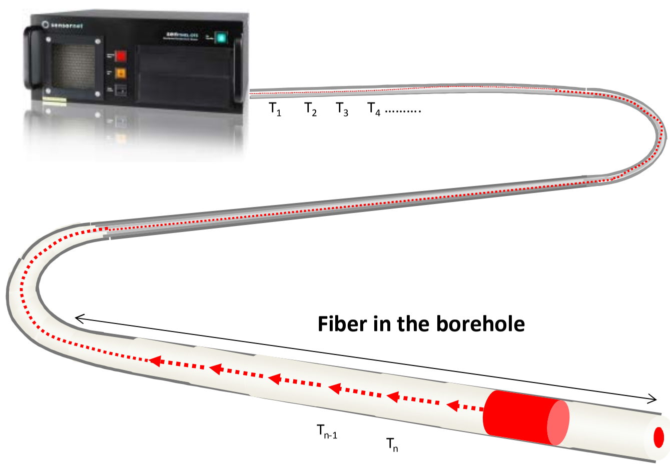

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Temperature measurement with optic fiber

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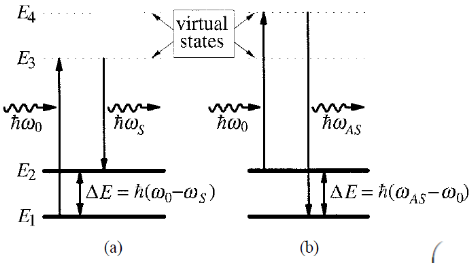
- The Raman effect (Raman scattering)



Farahani and Gogolla (1999)

$$\Delta P_{AS} = \wp_{AS} \Gamma_{AS} P_0 \cdot \Delta z$$

$$\Delta P_S = \wp_S \Gamma_S P_0 \cdot \Delta z$$

$$T\left(z, \frac{P_S}{P_{AS}}\right) = \frac{\Delta E / k}{\ln \frac{P_S}{P_{AS}} + \ln \frac{R_{AS}}{R_A} + \ln\left[\left(\frac{\lambda_S}{\lambda_{AS}}\right)^4\right] - \Delta\alpha z}$$

Calibration

Hausner et al. (2011)

Deep and coaxial BHEs