

Shallow geothermal energy in Denmark – current status and trends

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Summary

Shallow geothermal energy is a renewable energy source with large potential for reducing CO_2 emissions. The application in Denmark, however, is limited compared to e.g. Sweden and Germany. Preliminary estimates indicate that the energy extraction from a 100 m closed loop borehole may be up to 40% lower for an unfavourable geological situation compared to a favourable situation. More know-how and experience under Danish geological conditions is needed and the project GeoEnergy aims at paving the way for a wider use by providing knowledge, tools and best practice.

Introduction

The temperature in the shallow subsurface is determined by absorption of solar energy controlled by the net insolation and the geothermal gradient is determined by the heat flux from the interior of the earth controlled by the deep geology, see Figure 1 with average values for Denmark. The low enthalpy heat (typically 8-11°C in the upper c. 100 m) is exploited in combination with heat pump technology that brings the temperature up (or down) to the desired operating temperature of the heating (or cooling) system. Heat pumps typically produce 3-4 times the amount of energy they consume in the form of electricity. Thus shallow geothermal energy is a competitive renewable energy source with large potential for reduction in CO_2 emissions. The energy extraction from the ground can be based on either open loop systems or closed loop systems. In open loop systems, groundwater from a production well is used directly as source for the heat pump and subsequently recharged to the same aquifer via an injection well. In closed loop systems, a carrier fluid (water with antifreeze) is circulated in the ground in high density polyethylene pipes and act as a heat exchanger. They can either be installed horizontally in a depth of c. 1 m, horizontal closed loop systems, or vertically in a borehole, a so-called borehole heat exchanger or vertical closed loop borehole.

Shallow geothermal energy in a Danish context

Despite the potential of the method the application of shallow geothermal energy in Denmark is relatively limited compared to e.g. Sweden and Germany. In 2008 the number of ground source heat pump installations were approx. 25.000 (Willumsen 2008), with the vast majority being horizontal systems. Only a few tens are groundwater based open loop systems and the number of closed loop boreholes is some hundreds. However, during the last couple of years the number of vertical systems has increased significantly and in 2011 more than a hundred new closed loop boreholes were constructed. The 3-year project GeoEnergy aims at paving the way for a wider use of closed loop boreholes by acquisition and dissemination of know-how and developing tools and best practice for the design and installation of systems.

In contrast to our neighbour countries, the main part of Denmark is situated in a sedimentary basin dominated by soft sediments and variable depth to the water table. Only few investigations of thermal properties of Danish sediments have been carried out (Balling et al. 1981; Porsvig 1986), and thermal conductivity values for different rock and sediment types published by e.g. Banks (2008) and VDI (2010) show large variations for sediments relevant in a Danish geological context. This indicates that more investigations of common Danish lithologies like clay, silt and till deposits are needed.

In order to roughly estimate the possible effect of the geological variations expected in Denmark, the energy extraction for a 100 m closed loop borehole has been calculated in four simple geological successions, Figure 2. The estimates are based on specific energy extraction rates from VDI (2001), assuming standard design and operating conditions and 1800 hours of production per year. These preliminary results indicate that the energy extraction may be up to 40% lower for the most unfavourable of the geological scenarios compared to the most favourable.







Calculated energy extraction from a 100 m vertical closed loop borehole (from left to right): 12537, 10373, 9576 and 7560 kWh

Figure 1 Schematic block diagram showing the geothermal gradient and magnitude of geothermal heat flux and insolation with average values for Denmark (modified from Banks 2008).

Figure 2 Four simple geological successions, with specific heat extraction rates from VDI (2001) and calculated possible energy extraction based on 1800 hours of production per year.

Conclusions

The use of shallow geothermal energy in Denmark is limited but increasing. Preliminary estimates indicate that there may be a difference of up to 40% in the energy extraction between sites with a favourable and unfavourable geology. Further investigations of thermal properties of Danish sediments as well as of possible energy extraction and optimal design and construction of systems are needed and hopefully the GeoEnergy project can pave the way for a wider use of closed loop boreholes by providing knowledge, tools and best practice.

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