Tools for ground source heating and cooling based on closed loop boreholes

Summary
The project is aiming at providing knowledge and tools that can pave the way for a wider use of the closed loop technology through dissemination of the project results. By providing information on the variation of the thermal properties of different soil types and recommendations for system design with respect to environment and economy it will be possible to design more effective and profitable installations and hence overcome one of the main barriers for both private and commercial investors, being the time of payback.

Introduction

There has been increasing focus on reduction of CO2 emissions as a means of the global combat against climate change. As part of the endeavour to meet the demands of the Kyoto Protocol and ensure security of supply, Danish energy policy includes a long-term goal for a green-growth economy independent of fossil fuels. The road forward to fulfil this vision goes through energy savings, energy efficiency and an increased share of renewable energy. Switching to Ground source heat pumps is an opportunity for citizens, institutions and companies to invest in green-growth and contribute to energy savings and reduction of CO2 emissions.

The use of ground source heat pumps is limited, but increasing, in Denmark. Until now, mainly traditional horizontal closed loop installations with shallow buried pipes (1-1½ metre) have been applied. Such installations are however depending on relatively large areas for laying pipes and trench digging in the garden can be a barrier to many people. Open loop systems based on extraction and re-injection of groundwater can be very effective for both heating and cooling, but conflicts of interests already exists between adjacent installations and between installations and a groundwater resource under considerable pressure in urban areas.

Ground source heat pumps based on closed loop boreholes is a competitive alternative to traditional horizontal loop systems and open loop systems, excluding the need for large areas for pipe laying, and will not be a hazard to the groundwater resource if carefully planned, designed and installed.

Previous and current projects

Research within closed loop boreholes as source for heat pump systems started in Denmark in the seventies, where Teknologisk Institut, Copenhagen published several investigation reports about heat pumps for space heating /1/. During the eighties a relative small number of closed loop boreholes were installed for ground source heating. The low activity within ground source heating might be due to the great concern about groundwater protection in Denmark with a general opinion being that antifreeze liquid in the pipe systems might be able to contaminate the groundwater.

However, as a result of growing interest for cooling with ground water, rules about this topic were given in 2006 in the Statutory Order no. 1206 /2/. With the generally increasing focus on green energy also ground source heating has become a more interesting issue in Denmark in recent years, and in 2008 Danish Environmental Agency published a thorough investigation report on ground source heating technologies and the risk for related soil and groundwater contamination /3/. Based on this report a new Statutory Order on Ground Source Heating came into force in October 2009 dealing with horizontal as well as vertical installation of pipes /4/.

Until now nearly all newer ground source heat plants in Denmark are installed with horizontal loop design. The vertical types with borehole heat exchangers are not very well known in Denmark and are also thought of as being too expensive compared to the horizontal types. However with a dynamic market situation for drilling and installations there is a growing interest for closed loop

boreholes. One EUDP-project is already dealing with the vertical design (ENS-64009-0092) with special focus on energy storage /5/.

Outside Denmark design with closed loop boreholes are widespread for instance in Germany and Sweden. In fact Sweden already has 350.000 heat pumps installed – corresponding to one fifth of all single familiy houses in the country /6/. In the EU a specific project (IEE/07/581/S12.499061) deals with "Geo-Education for a sustainable geothermal heating and cooling market".

The project will build upon the results of the above mentioned previous and current projects and the activities will be coordinated with relevant national and international contacts.

Project description

The objective of the project is to provide knowledge and a set of tools that can be used for planning and designing minor and major heat pump systems based on closed loop boreholes and to contribute to developing a best practice for such installations in order to protect both the environment and the consumers. Focus will be on both heating and cooling of buildings and on energy storage. The work is organised in 8 work packages (see enclosure 2 for detailed WP1-8 work descriptions).

WP1 Database and dissemination

Relevant and necessary parameters for designing closed loop boreholes and heat pump systems will be identified and a knowledge sharing workshop with international partners will be hosted. A public database of thermal properties for Danish soil types will be established. The work will include an overview of the shallow geology in Denmark (0-300 m) and a concept for standard geo-reports for planning and designing ground source heat pump systems.

WP2 Equipment and measurements

Existing equipment for measuring thermal properties on soil and materials will be tested and, if needed, further developed. Measurements will be performed on a representative number of soil samples in order to ensure sufficient geographical and geological coverage, as well as on different materials used in installations. Results will feed into the public database in WP1. A set of guidelines for equipment, methods, calibration etc. will be provided with respect to international standards and norms.

WP3 Temperature gradients and surface temperatures

A desk study will be performed on surface temperatures and yearly variations in Denmark based on existing available information as well as on temperature gradients in the upper 300 m of the subsurface. Knowledge gaps regarding temperature gradients will be identified and supplementary measurements performed using geophysical well logging. The results will form part of the public database established in WP1.

WP4 Drilling methods and grout techniques

The work will include collection of existing experience with boreholes for closed loop heat pump systems. Different equipment will be tested and drilling and grout techniques will be optimized with respect to environment and economy. As part of the testing, five boreholes to 30-80 m depth will be drilled and subsequently used for test site in WP5. Input to WP8 will be produced regarding guidelines for drilling as well as installation and sealing of pipes and hoses.

WP5 System design and energy balance

System design with respect to energy balance and economy will be investigated. What are the important elements and what information is needed? Calculations and evaluations will be based on experience from existing installations and a new test site. A collection of different examples of installation types with respect to size, design, purpose and geological conditions will be produced

and an informal network of installation owners will be formed and hosted during the project. The new test site will be established using the five boreholes drilled in WP4 and different closed loop systems as well as drilling and completion techniques will be tested. The closed loop systems will be connected to a heat pump and theoretical calculations will be compared to measurements of actual performance of the five test holes. The results of WP5 will be synthesized and guidelines and recommendations for designing systems produced.

WP6 Training and education
This work package will focus on providing courses in ground source energy on existing educations for engineers, architects, designers and planners etc. and training of drillers, consultants, authorities etc. The need for training and education will be analysed and relevant course material produced.

WP7 Interaction with ambient groundwater system
Existing model codes for subsurface heat flow modelling will be reviewed. The selected code will be used to analyse the potential of a heating/cooling system under Danish conditions by formulating different scenarios reflecting typical geological and hydrogeological conditions in Denmark and varying in physical properties with respect to heat conductance, as depicted in WP2. The scenarios will include field conditions similar to the test sites in WP5, and model simulations will be used to support the analyses of the test sites. Possible effect on groundwater quality of heating/cooling of the adjacent soil matrix will be evaluated qualitatively by experts in microbiology and geochemistry. Similarly, potential harm from system fluid leakage to the groundwater system will be evaluated by expert judgement and existing studies.

WP8 Guidelines and final dissemination
The results of WP4, WP5 and WP7 will be assessed with respect to existing legal framework and practical experience. On this basis, recommendations for administrative guidelines for issuing permits for closed loop energy boreholes will be produced, including requests for monitoring and risk evaluation and management. Potential areas of synergy as well as conflict of interest will also be investigated, i.e. interplay with existing district heating infrastructure, water catchment etc. A project website will be established and updated during the project with progress and results. The final dissemination of project results will include an open workshop presenting results to stakeholders and other interested parties as well as a folder for laymen and other publishing material to be used on public websites.

References

/1/ Balstrup, T.(1977): *Varmepumpeanlæg. Varmeovergangsforhold i jord*. Teknologisk Institut.

/2/ *Bekendtgørelse om varmegenvinding og grundvandskøleanlæg.* BEK. nr. 1206 from 24/11/2006)

/3/ Willumsen, B. (2008): *Jordvarmeanlæg – Teknologier og risiko for jord- og grundvandsforurening.* Miljøprojekt Nr.1238 udarbejdet af COWI.. Miljøstyrelsen 2008

/4/ *Jordvarmebekendtgørelsen.* BEK nr. 1019 from 25/10/2009

/5/ Testing af lodret varme med solvarmeakkumulering. EUDP-projekt nr. ENS-64009-0092). www.solvarmeakkumulering.dk

/6/ Written information from Anne-Lee Bertenstam, Svenska Värmepump Föreningen, http://www.svepinfo.se/om-svep/kontakt/