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Project GROUND-REACH "Reaching the Kyoto targets by means of a wide introduction of ground coupled heat pumps (GCHP) in the built environment"

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ABSTRACT

During the three year period from 2006 to 2008, the 21 project partners identify present status and future potential of ground coupled heat pumps towards reducing CO_2 emissions and primary energy demand, analyse potential contribution of the technology towards the European Directive on the Energy Performance of Buildings, compile and evaluate best practice information from all over EU, define measures to overcome barriers and set up a strategic promotion plan for long term market penetration, and communicate the merits and benefits of ground coupled heat pumps to key professional groups through a variety of effective promotion tools, such as the International conference and exhibition, the GROUND-REACH website, the 18 national or regional meetings, the GROUND-REACH posters and brochures, publications to public, technical and trade press, emails, a quarterly newsletter and the European ground source heat pumps Committee.

1. INTRODUCTION

GROUND-REACH project aims to evaluate the importance of ground coupled heat pumps (GCHPs) to the EU in reaching Kyoto targets, as well as to communicate the availability, merits and benefits the technology. It is supported by the European programme Intelligent Energy for Europe, ALTENER action, contract N° EIE/05/105/ S12.420205.

The project commenced on 1 January 2006 and has a duration of three years. Its budget is 1.730.970 €, 40% of which is the contribution of the European Commission. The project consortium consists of the following 21 organisations from 16 member states:

- Centre for Renewable Energy Sources (coordinator)
- European Geothermal Energy Council EGEC
- European Heat Pump Association EHPA
- Arsenal research, Austria
- Bureau de Recherches Géologiques et Minières (BRGM), France
- Ecofys B.V., Netherlands
- The Energy Efficiency Agency, Bulgaria
- Escola Superior de Tecnologia de Setubal, Portugal
- Fachinformationszentrum Karlsruhe GmbH, Germany
- Geoteam, Austria
- Associazione Rete di Punti Energia, Italy
- SVEP Information & Service AB, Sweden
- University of Oradea, Romania
- BESEL S.A., Spain
- COWI A/S, Denmark
- Ellehauge & Kildemoes, Denmark
- Flemish Institute for Technological Research (VITO), Belgium
- Agence de l'environnement et de la Maîtrise de l'energie (ADEME), France
- Narodowa Agencja Poszanowania Energii S.A., Poland
- EnPro Engineers Bureau Ltd, Estonia
- GFE Energy Management, Italy

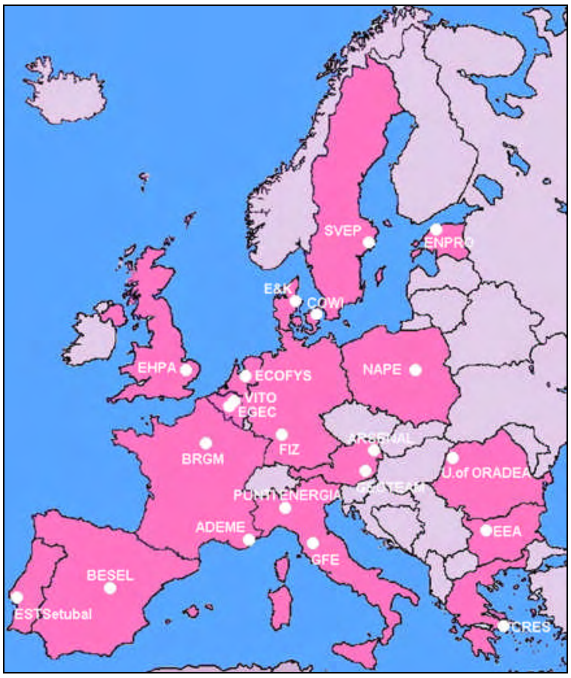

Figure 1: GROUND-REACH consortium includes 21 organisations from 16 EU member states.

2. GROUND COUPLED HEAT PUMPS

A ground coupled (or ground source, or geothermal) heat pump system consists of three components:

- ground heat exchanger or groundwater well,
- water source heat pump and
- heating / cooling system in the building.

2.1 Ground heat exchanger

The ground heat exchanger comprises pipes buried in the ground, either in a horizontal layout at 1,2-2,0 m depth within trenches (horizontal ground heat exchanger, fig. 2a and 3) or in a vertical layout within boreholes (borehole heat exchanger, fig 2b). Typical piping material is HDPE, which gives a life span of at least 50 years to the pipe, and typical external pipe diameters are 32 or 40 mm. Depending on the design operation temperature range, the pipe may be filled with water or a mixture of water and antifreeze. In horizontal systems, also the refrigerant from the heat pump cycle may flow through the ground pipes, and in vertical systems, borehole heat exchangers following the heat pipe principle have been introduced in recent years.

A further option are groundwater wells, where the water pumped from the ground is used as heat source or sink (open system, fig. 2c).

Although horizontal ground heat exchangers are of lower cost, the majority of installed systems use borehole heat exchangers (BHEs), which give better energy performance to the system, but most important, they have much less space requirements.

Typical BHE technology comprises a single or double U-tube (fig 4) placed within one or more vertical boreholes 50-100m deep each. The space between the U-tube and the walls of the borehole may be filled with groundwater (Scandinavian practice), if the local groundwater table is high enough, and interference between different groundwater horizons is not problematic, or, more often, it is filled by the grouting material (fig. 5). The grout isolates individual water bearing formations from one another, eliminating that way any vertical flow between them through the borehole. A good grout should adhere well to both the U-tube and the borehole walls, leaving no cavities which hinder heat transfer. Special thermally enhanced grouts are available in the market with high thermal conductivity and excellent heat transfer properties.

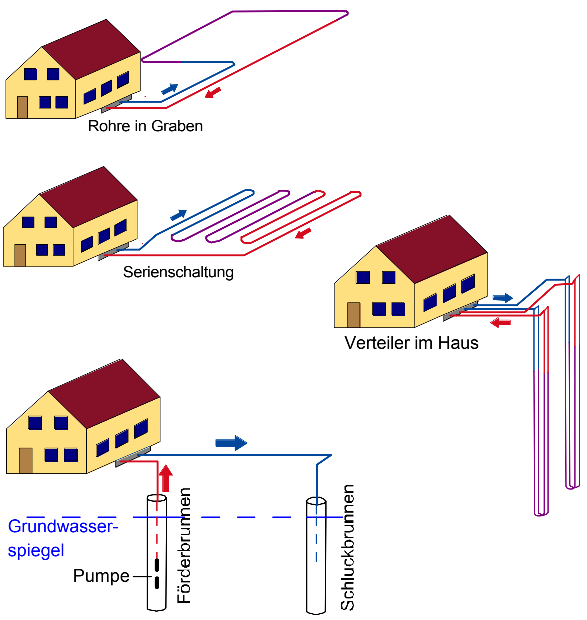

Figure 2: Ground heat exchanger types: horizontal (a), BHE (b), groundwater production and reinjection wells (c).

Meanwhile BHE are offered by several manufacturers as standard products, tested and certified (fig. 4). Also a range of other products (grouting material, connection pipes, manifolds, circulation pumps) have been designed especially for GHSP installations and can be bought off the shelf.

Design, installation and commissioning of all types of ground heat exchangers are described in detail in the German standard VDI 4640 (with English translation). A simplified version of some VDI 4640 regulations have been incorporated in the new standard EN 15450 "Heating systems in buildings – Design of heat pump heating systems". Countries with a mature GSHP market have also own regulations, like in Sweden and in Switzerland (SIA).

Figure 3: View of a horizontal ground heat exchanger during construction.

Figure 4: BHE lower part or "footpart"; factory –made BHE from different producers

Figure 5: View of a grouted double-U BHE top

Typical operating temperature range of ground heat exchangers are -3°C→0°C in Sweden and -3°C→+2°C in Germany, where ground temperatures of 8,5-9,0°C respectively are observed in natural state. In these conditions a horizontal ground heat exchanger yields a typical geothermal energy supply to the heat pump of 8-32 W/m², and a borehole heat exchanger of 20-70 W/m, depending on subsurface geology and water saturation. In cases of strong horizontal groundwater flow heat extraction rates up to 100 W/m are possible for BHE, in single plants. In BHE fields (fig. 6), the mutual interdependence of the BHE must also be considered; such a field develops a clear storage effect.

Figure 6: Field of BHEs just after completion (at the German/Belgian border, photo EWS)

Figure 7: Piping connecting BHEs to the manifold

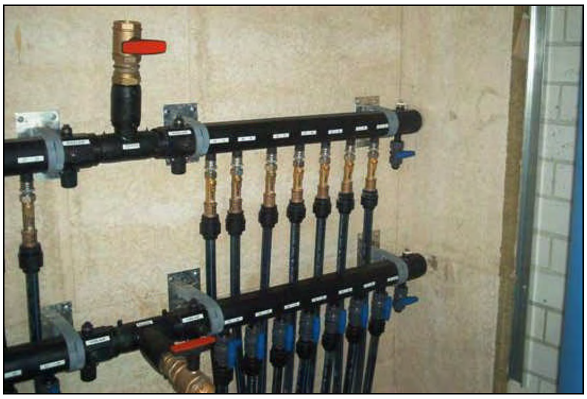

Figure 8: Manifold connecting BHEs to the heat pump(s).

In South Europe, where ground temperatures at natural state of 15-18°C are common, the above heat extraction values can be increased by 50% for the same operating temperatures of the ground heat exchanger. In case no antifreeze is used, the same heat extraction rates as in central Europe can be achieved, but with higher operating temperature of +3°C→+8°C within the ground heat exchanger. This fact also results in superior energy performance of the whole ground coupled heat pump system.

Apart from the VDI 4640 guidelines, design methodology for ground heat exchangers is described in the 1995 ASHRAE handbook on HVAC applications, in chapter 29 on geothermal energy, and a few computer codes are available, usually by the heat pump manufacturers. One such code is the "Earth Energy Designer" – EED, which has been developed by the University of Lund in Sweden, in a German-Swedish cooperation.

In large systems, where oversizing of the ground heat exchanger would result in severe cost penalties, the thermal properties of the ground and the thermal performance of the BHE can be measured by the thermal response test. During a thermal response test, heat is transferred to the fluid of a BHE and the output temperature is measured. The effective ground thermal conductivity and the thermal resistance of the BHE are two parameters that are calculated by using an approximation of the line-source-theory, or by fitting the resulting temperature transients from computer simulation with the measured ones. Usually the thermal response test is done immediately after the first BHE is constructed, and its role is to define with great accuracy the exact number of BHEs needed for a specific system.

2.2 Water source heat pumps

Water source heat pumps, mainly of water-to-water type are installed, but some manufacturers offer water-to-air types as well. This choice is dictated by the building practice in the different areas, with the hydronic system being the majority choice in central Europe. The heat pumps are used for heating and cooling of buildings, as well as for supply of domestic hot water. Because they use water, which has much better heat transfer properties than air, and because of the stable temperature supplied by the ground heat exchanger, which is higher than extreme ambient conditions in cases of peak heating load and lower than ambient extremes in peak cooling load, a well designed and constructed ground coupled heat pump system operates with at least 30% higher energy efficiency than the best air source heat pumps.

Figure 9: View of water source heat pumps at the Town Hall of Pylaia, Thessaloniki.

Despite what was the case 10 years ago, nowadays water source heat pumps of high efficiency are available in the market. They usually use scroll compressors of on-off regulation and R407C or R134a as working fluids with the trend being to shift to R410A, which has better heat transfer properties and better performance for reversible systems for heating and cooling operation. A future trend is also to introduce variable capacity compressors.

The coefficient of performance (COP) of ground source heat pumps is defined as the ratio of useful energy delivered over the electricity consumption. SPF is the integration of COP over the heating and/or cooling season. Unlike air source heat pumps, the values of COP and SPF of a ground source heat pump are closer to each other due to the stable operating parameters of a ground-coupled system. In general, the lower the temperature difference between the ground heat exchanger and the water of the building's heating/cooling system, the higher the COP. Values of both COP and SPF in the range of 4,2-5,0 are typical for operation with a ground heat exchanger and a floor heating system. In case the heat pump is coupled to a groundwater well instead, COP and SPF values in the range of 5,0-6,5 are typical.

2.3 Building heating/cooling system

As mentioned above, the energy performance of a ground coupled heat pump system is enhanced when the operating temperature of the building heating system is lower. In case of cooling operation, higher temperature of the cooling system results in better energy performance. Heating systems that require low operating temperature are floor heating and wall heating, followed by fan-coils and air handling units coupled with air ducts. In case of cooling, the best systems are ceiling or wall cooling.

Figure 10: Floor heating system.

Figure 11: Wall heating/cooling system.

Figure 12: Ceiling cooling system.

Figure 13: View of a fan-coil in CRES office.

3. GROUND COUPLED HEAT PUMP MARKET

Although the technological know-how of ground coupled heat pumps is well developed in Germany, Sweden, Switzerland, France and Austria, only in Sweden and Austria the corresponding market position of GCHPs is leading, where they are one of the "standard" systems for heating of buildings. Off course, in Germany, Switzerland, France and Finland there is a developed market for GCHPs, the growth of which has accelerated during the last 12 months. Elsewhere in EU, however, we have a new market.

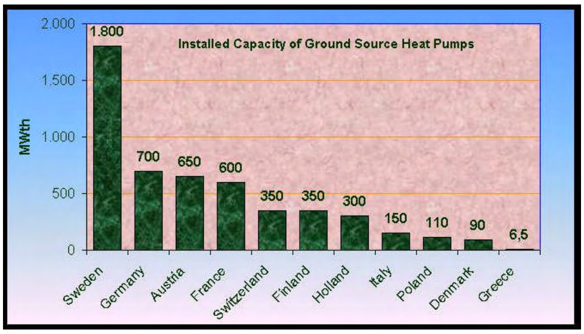

Figure 14: Installed capacity of ground coupled heat pumps in Europe.

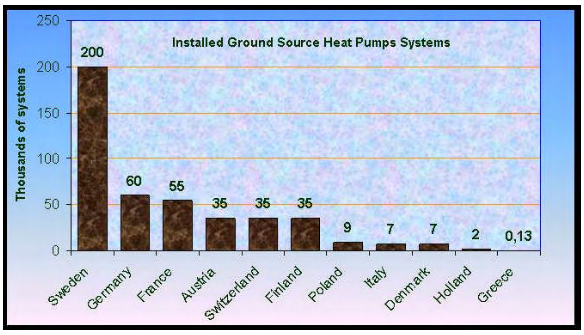

Figure 15: Number ground coupled heat pump systems in Europe.

With the exception of the Netherlands, where large systems are dominant, elsewhere in EU small systems for household heating or small commercial applications are installed. With typical heating needs of 15-20 kW per dwelling, from figure 16 we conclude that in most cases ground coupled heat pumps cover only a part of the dwelling's heating needs, with the remaining part covered by either electrical resistors or fossil fuels.

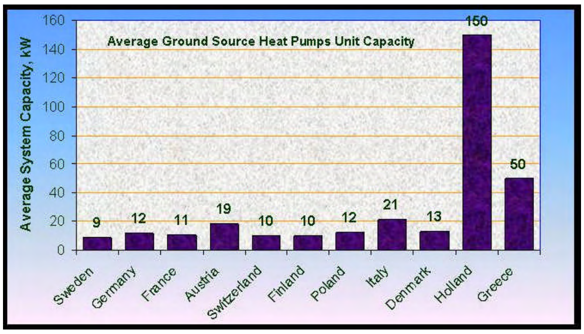

Figure 16: Average size of ground coupled heat pump systems in Europe.

In Sweden, a rule of thumb is to size the ground coupled heat pump at approximately 67% of peak load, which corresponds to 95% of heating needs. That way, the economics of the system are improved considerably and ground coupled heat pumps can effectively compete with fossil fuels and air source heat pumps with typical payback times between 5-10 years.

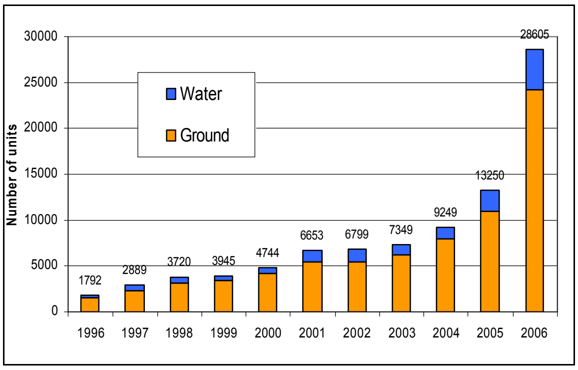

Figure 17: Ground coupled heat pumps market evolution in Germany (after sales data collected by BWP, see www.waermepumpe-bwp.de).

4. THE PROJECT

4.1 Activities

The GROUND-REACH project is divided into 7 work packages, the last of which corresponds to common dissemination activities with other European projects.

Work package 1 integrates project management activities.

Work package 2 leads to the achievement of the objective corresponding to the evaluation of ground coupled heat pumps potential contribution towards Kyoto targets. Firstly the current status of the space conditioning and of the ground coupled heat pumps markets in Europe are defined (Subtasks 1 and 2); then the evaluation methodology is prescribed and specifications to the necessary input information are defined; next data are collected from every EU member and candidate state; and finally the necessary calculations are made in order to produce a quantified result in terms of CO_2 emissions reduction. Two scenarios are considered, one for the national energy mix and one for the EU energy mix. The results are expressed in terms of past, present and future values.

Work package 3 is intended for the achievement of the objective corresponding to the presentation of the merits and availability of ground coupled heat pumps through best practice examples. Firstly the data sources and input specifications are defined; secondly a total of 50 best practice examples are collected from every EU member or candidate state; thirdly the collected cases are evaluated in terms of their suitability for promotion purposes; finally the selected and evaluated best practice examples are presented in a common form and exhibited at the GROUND-REACH internet pages (http://www.groundreach.eu).

Work package 4, leads to the achievement of the objective corresponding to the evaluation of ground coupled heat pumps potential contribution towards the implementation of the buildings performance directive. Firstly the framework conditions for the GCHPs analysis are defined; secondly the computer models to be used in the quantification are designed; thirdly energy consumption of GCHPs compared to other heating/cooling technologies is quantified; fourthly the comparison is made in terms of capital and operational costs and environmental performance; and finally guidelines and checklists are prepared. Furthermore, existing standards on GCHPs are reviewed, evaluated and improvements are proposed.

Work package 5, leads to the achievement of the objectives corresponding to the identification of the barriers to market penetration of the technology, their removal and the formulation of a strategic dissemination plan for long term market penetration. Four activities are necessary, one for putting together the legislation governing GCHPs of every EU member and candidate state, one for identifying the market barriers, one for evaluating the barriers and proposing measures to overcome or remove them, and a final one for drafting the strategic dissemination/action plan.

Work package 6, leads to the achievement of the objective corresponding to the short term (during the contract period) market penetration of ground coupled heat pumps. It includes establishing the European GCHPs Committee as promotion coordinating agent (the committee met for the first time in March 2007 in Frankfurt, Germany), preparation of promotional material (GROUND-REACH internet pages, brochures and posters, promotional text, on-screen presentations), press releases to 7,500,000 recipients, e-mail campaign and e-questionnaire survey to 3,600 recipients, a quarterly newsletter, as well as organising one meeting with the Commission, 18 meetings around Europe with key professional groups (total ~500 participants but with high expected market impact) and one international conference with at least 400-500 participants the time of EGC 2007, the following national events have already been finalised:

- Promotion meeting #1 in Watford, UK, June 2006
- Promotion meeting #2 in Vienna, Austria, Jan. 2007
- Promotion meeting #3 in Orleans, France, in March 2007
- Promotion meeting #4 in Milano, Italy, in April 2007
- Promotion meeting #5 in Sofia, Bulgaria, in April 2007
- Promotion meeting #6 in Setubal, Portugal, in May 2007
- Promotion meeting #9 in Utrecht, NL, in May 2007

The presentations from these events are for download from the groundhit website.

Future activities comprise:

- Promotion meeting #8 in Gleisdorf, Austria, June 2007
- Promotion meeting #7 in Denmark (postponed)

Beside these events, internal meetings had been arranged as well as two meetings with members of the European Commission The project group also did meet persons from other similar initiatives, like ThERRA.

Work package 7 aims in fulfilling the objectives for common dissemination tasks, according to Commission requirements.

Project results are published at the web pages http://www.groundreach.eu/, which also include the best practice case studies, as well as a lot of information on ground coupled heat pumps.

4.2 Target groups

In order to accelerate the market penetration of ground coupled heat pumps, GROUND-REACH projects aims to communicate the merits and benefits of the technology to the key organisations or professional groups as follows.

Policy makers and decision makers need to understand how GCHPs aid their policy towards improving local environment, reducing primary energy consumption and greenhouse gasses emissions, as well as towards reaching their objectives for renewable energy use. They include the European Commission, as well as national, regional and local authorities. As they define the legal framework and regulations for the heating and cooling market, their positive attitude towards GCHPs will effectively aid its market penetration.

House owners need to understand the benefits of GCHPs in terms of thermal comfort, better local environment and low annual operation costs. After all, they are the ones who will own and use the system in their daily life. In addition, house owners are the ones who make the final decision in case of renovating their property.

House business market actors such as brokers and investors need to understand the added value GCHPs give to a property during its life time, which justifies a premium price to the property.

House building market actors such as buildings contracting companies, architects and engineers should also understand the added value a GCHPs gives to a building, as they are the ones who decide which heating and cooling system will be installed. The end user has no choice on this matter, as he buys a dwelling with its heating and cooling system already installed. Furthermore, during renovation they advise the end user on the selection of the heating/cooling system. They should also acquire the technical knowledge needed, in order to be able to design and install GCHP systems.

GCHPs market actors such as heat pump manufacturers, works contractors (system installers), geologists and others (system designers), should be able to understand the need to provide GCHP systems of both high quality and high energy efficiency, in order to have a sustainable market.

Last but not least, power utilities share common interest with the project, as GCHPs are using electricity improving their customer base, but as they consume 30-50% less power than air source heat pumps, they tend to reduce peak loads and improve the load factor of existing power plants, eliminating the need for large investments for new power infrastructure.

5. CONCLUSIONS

Ground coupled heat pumps are a mature technology comprising a ground heat exchanger, a water source heat pump of high energy efficiency and a low temperature heating/cooling system within the building. They exploit the mild subsurface temperature, which is independent from ambient conditions in order to provide efficient heating, efficient cooling and domestic hot water in an environmentally friendly way.

In Europe, the corresponding market is developed in Sweden, Germany, Switzerland, Austria, France and Finland, but it is a new market in all other EU member states.

GROUND-REACH project effectively communicates the merits and benefits of the technology (reduction of primary energy demand and greenhouse gases, improving local environment, adding value to the building due to low operational costs, high quality comfort, etc.) to key organisations, professional groups and end energy users, contributing that way to the acceleration of GCHPs market growth, observed during the last 12 months.