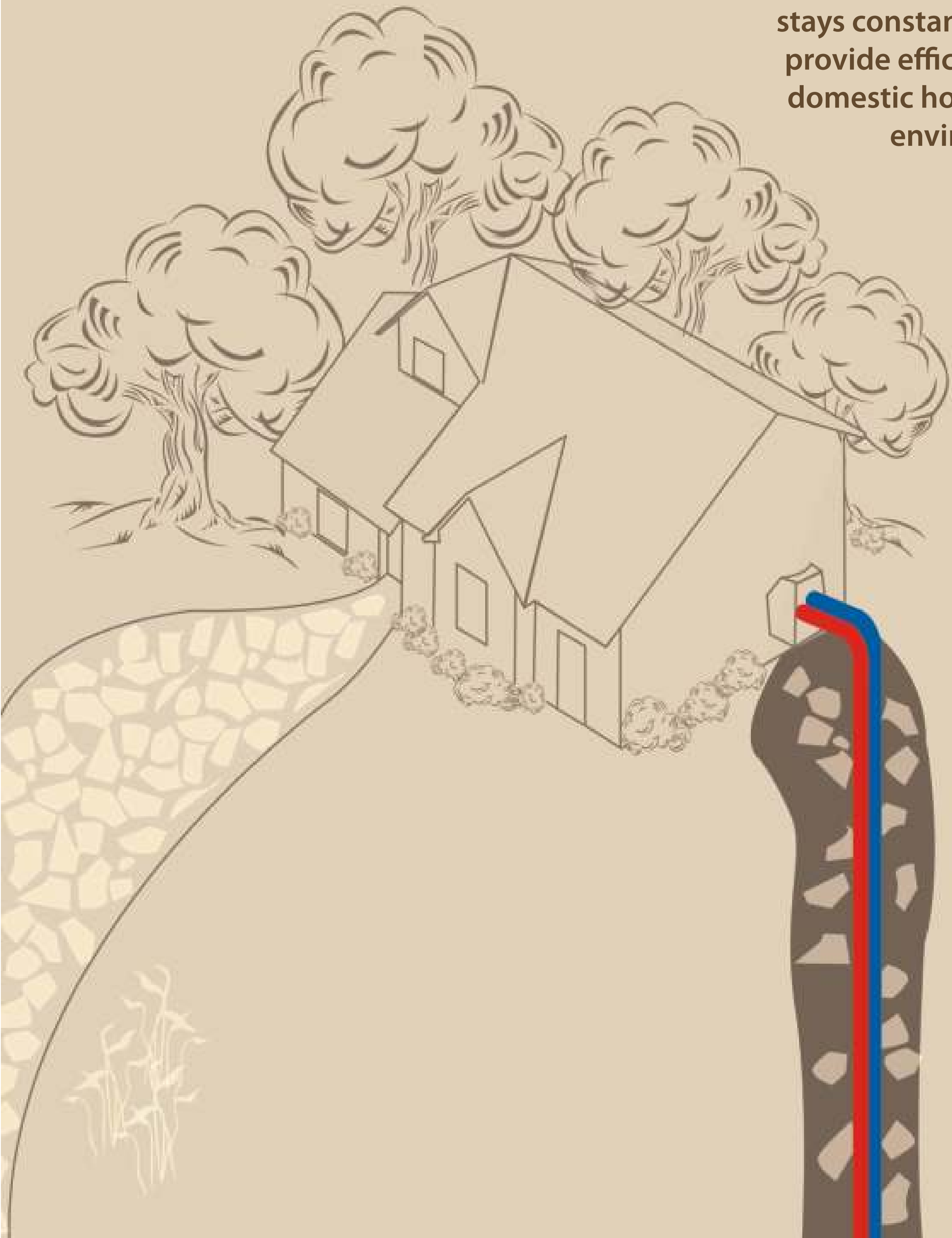
Intelligent Energy Europe

GROUND REACH

GROUND SOURCE HEAT PUMPS

Use low ground temperature, which stays constant throughout the year, to provide efficient heating, cooling and domestic hot water to buildings in an environmentally friendly way.



... Are a proven and reliable technology

...Reduce heating/cooling costs by between 25% and 75%

...Significantly reduce CO_2 emissions

...Increase the life cycle value of your building

...Provide high quality indoor comfort

...Protect the environment

...Promote sustainable energy development

The GROUND-REACH project

"Meeting the Kyoto targets through large scale introduction of ground source heat pumps (GSHP) in the built environment"

The **GROUND-REACH** project is expected to effectively assist in implementing EU policy for both short and long term market penetration of ground source heat pumps, through analysing the market for ground source heat pumps and providing best practices, guidelines for local/regional authorities and key professional groups, conferences, meetings, website, brochure and other promotional tools. It will facilitate: A better understanding of ground source heat pumps' merits and benefits and their importance in fulfilling Community policy objectives in relation to Kyoto targets and the building performance directive. An increased awareness, improved knowledge and perception of ground source heat pumps technology among key European professional groups for short-term market penetration.

The work is divided into the following work packages:

WP #1 - Project management

WP #2 - Estimating the potential of ground source heat pumps for reducing CO_2 emissions and primary energy demand for heating and cooling purposes in the built environment: evaluation of available statistical information, definition of competing heating/cooling technologies, analysis of existing calculation tools, CO_2 emissions calculation.

WP #3 - Compiling and evaluating existing ground source heat pumps best practice information in Europe: identifying and updating information from all European member states, including case studies, and technical guidelines.

WP #4 – Analysing the contribution of ground source heat pump technologies for meeting the objectives of the Building Performance Directive: Analysis of the technical, environmental and economic feasibility of ground source heat pump technologies; Guideline for supporting planners and architects with detailed technical aspects and general questions; Standards review, evaluation and proposals.

WP #5 – Defining measures to overcome barriers for broader market penetration and setting up a long term dissemination plan: identification of market barriers including legal/ regulatory, economical and technical, proposals for long term EU level interventions to overcome them, including a new directive on RES-Heat.

WP #6 – Launching a large scale promotional campaign on the European level: brochure, poster, promotional text, presentations, interactive Internet site, setting up the European Geothermal Heat Pump Committee, publications, international conference and exhibition, a series of regional meetings targeting key professional groups.

WP #7 – Common dissemination activities

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I. GROUND SOURCE HEAT PUMP SYSTEMS

A Ground Source Heat Pump **(GSHP)** system consists of three components:

- Ground source heat exchange system (ground heat exchanger or groundwater well)
- Ground Source Heat pump (GSHP) (mainly water-to-water)
- Heating and/or cooling system inside the building.

The GSHP system works like a reversible refrigerator by removing heat from one location and depositing it in another location i.e. in wintertime - from the ground to indoors (heating mode) and the reverse in summertime (cooling mode). In other words, the GSHP system allows the exchange of heat between ground and indoors.

A well-designed and constructed GSHP system operates with at least 30% higher energy efficiency than that of the best air-to-air heat pumps due to:

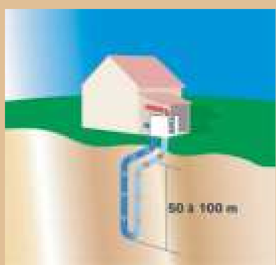
- The use of water since water has much better heat transfer properties than air.
- The stable temperature - supplied by the ground heat exchanger - which is higher than extreme ambient conditions in cases of peak heating load and lower than ambient extremes in peak cooling load.

I.1 Ground Source System

Ground Heat Exchangers, close loop system

- *Horizontal Heat Exchangers*: pipes buried in the ground in a horizontal layout in trenches, at a depth of between 0.6-2.0m depending on the local conditions.

- *Borehole Heat Exchangers (***BHEs***)*: pipes installed in the ground vertically in boreholes.



Typical piping material is HDPE (High Density Polyethylene), which has a life expectation of at least 50 years in this application, 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.

The refrigerant from the heat pump cycle can also flow through the ground source heat exchange system (direct expansion heat pump).

Groundwater well, open loop system

In case of groundwater wells, the water is pumped from the ground which is used as heat source or sink.

Although BHEs have a higher cost than horizontal loops, they are preferred in most cases due to two main advantages:

- Less space is needed in comparison with horizontal heat exchangers.
- There are no technical difficulties to overcome as in groundwater well systems.

Typical BHE technology consists of a single or double U-tube placed within one or more vertical boreholes, usually 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 a problem, or, more often, it is filled by grouting material.

Also, BHEs are offered by several manufacturers as standard products, tested and certified. Also a range of other products (grouting material, connection pipes, manifolds, circulation pumps) have been designed especially for GSHPs 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. A simplified version of some VDI 4640 regulations have been incorporated into the new standard EN 15450 "Heating systems in buildings – Design of heat pump heating systems".

Apart from the VDI 4640 guidelines, design methodology for ground heat exchangers is also described in the 1995 ASHRAE handbook on HVAC applications, in chapter 29 on geothermal energy. In addition, 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, as German-Swedish cooperation.

I.2 Ground Source Heat Pumps

Water-to-water GSHPs are mainly used for heating and cooling of buildings, as well as for supply of domestic hot water. They are installed in most GSHP systems although some manufacturers offer water-to-air types as well.

I.3 Building heating/cooling system

The energy performance of a GSHP system is enhanced, when the operating temperature of the building heating system is lower. For cooling operation, a higher temperature in 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.

II. GSHP Market

Although the technological know-how and market for GSHPs is well developed in Germany, Sweden, Switzerland, France and Austria, only Sweden and Austria are market leaders, where GSHPs are one of the "standard" systems for heating of buildings. In all other EU member States, however, we have a new market. The growth of the GSHPs market has accelerated since the beginning of 2006.

With the exception of the Netherlands, where large systems are dominant, elsewhere in the EU, small systems for household

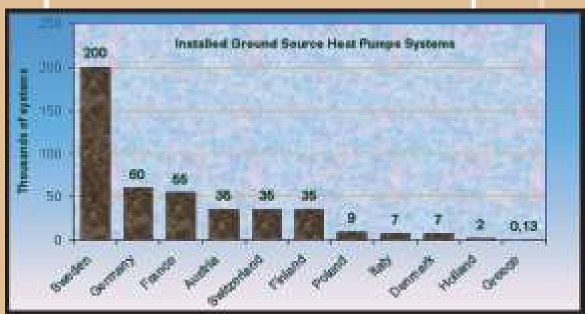
Compared to the situation 10 years ago, nowadays water-to–water high efficiency GSHPs are available on the market. Scroll compressors with on-off regulation are usually used and R407C or R134a as working fluids, with the trend being to change to R410A, which has better heat transfer properties and better performance for reversible systems for heating and cooling operation. Another future trend is the introduction of variable capacity compressors.

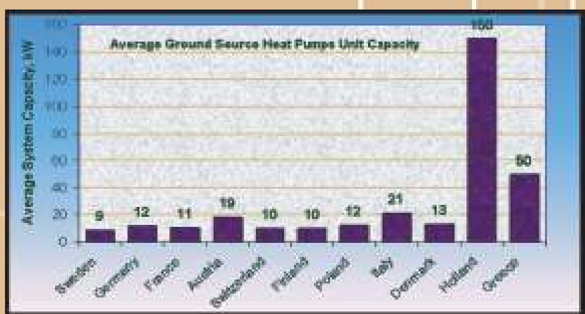
The coefficient of performance (**COP**) of GSHPs is defined as the ratio of useful energy delivered over the electricity consumption. Seasonal Performance Factor (**SPF**) is the integration of COP over the heating and/or cooling season. Values of both COP and SPF in the range of 3.5-5.0 are typical for operation with a ground heat exchanger and a floor heating system. If GSHP is coupled to a groundwater well instead, COP and SPF values in the range of 4.0-6.5 are typical.

Unlike air-to-air 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 GSHP system. *In general, the lower the temperature difference between the ground heat exchanger and the water of the building's heating and cooling system, the higher the COP.*

For cooling, the best systems are ceiling or wall cooling.

heating, small commercial applications or public buildings and offices are installed.





Pylaia Town Hall, Thessaloniki, GREECE

Heating and cooling demands of the Pylaia Town Hall with total area of 2500 m^2 are covered by a GSHP system with a diesel boiler and a cooling tower as back up. The heating and cooling capacities of the GSHP are P_{th}=265kW and P_c=280kW respectively.

The closed-loop GSHP system includes:

- Eleven water-to-water GSHPs operating in heating and cooling mode using electricity. R22 is used as refrigerant for the GSHPs.
- Twenty-one BHEs, each with a depth of 80 m.

According to measurements made during the first year of operation, COP of the GSHPs for heating and cooling are COP_{th}=4 and COP_c=3.5 respectively.
The heating/cooling distribution system in the building consists of fan-coil units and an air handling unit.

New housing estate De Teuge, Zutphen, NETHERLANDS

«De Teuge» is a new housing estate area in the city of Zutphen with a total number of 200 dwellings both for private ownership and (social) rental purposes. All dwellings are equipped with an open-loop GSHP system which consists of:

- Ground source wells
- Low temperature distribution grid
- Individual combi-heat pump connected to this grid

The whole GSHP system consists of 2 extraction wells and 3 injection wells, displacing a maximum flow rate of 200 m^3/h.

Regeneration of the ground is controlled by the passive cooling of the houses and a collective dry cooler, located in the area.
This combi-heat pump has a large integrated buffer barrel, good regeneration control, and moreover, a low noise level. The GSHP delivers space heating, space cooling and hot tap water and therefore, no additional electric boiler for hot tap water is required.

COP of the GSHP for heating and cooling -according to measurements of two-year-operation - are COP_{th}=4.5 and COP_c=4.0 respectively.

An important aspect of this project is that within a single dwelling, *two different low temperature heating systems* are applied:

- Floor heating for the ground floor area
- Ventilation convectors for the areas upstairs

The main advantage of distributing heating and cooling by ventilation is that spaces can be heated within a short period of time, whereas floor heating systems tend to have a slow response. Especially for areas that do not need to be acclimatized constantly, like bedrooms and studies, this transmission system is attractive.

One-family house in Rudelzhausen, GERMANY

This single-family house with a 340 m^2 area -located in Bavaria- is heated by a GSHP.

The open-loop GSHP system -including a water-to-water GSHP- covers the total heat demand of 14.7 kW for space heating -floor/wall heating- and domestic hot water for five persons.

However, an auxiliary electric resistance heating was installed in the buffer storage and the hot water storage as well (6 kW each). Its heating capacity is 14.7 kW and the system operates at temperatures of W10/W35.

The GSHP system is composed of a supply and a return well. Groundwater flow rate is about 3 m^3/h.
The seasonal performance factor (SPF) is 5.51 for GSHP and 4.57 for the GSHP system (including well pump).

One-family house in Gosau, AUSTRIA

This one-family house is located in Upper Austria around 800 m above sea level.

The house has a heated floor space of 240 m². The total heat demand of 11.3 kW for space heating is covered by a direct expansion heat pump. For domestic hot water production a second direct expansion heat pump was installed, with a heating capacity of 2.8 kW.

The GSHP operates with R410A as refrigerant. Its heating capacity is 7.9kW at S4/W35. The collector area is 260m² having 7x65m collector coils.

According to the monitoring results for one heating season, the Seasonal Performance Factor (SPF) was 4.78.

The heat distribution system includes 212 m² floor-heating with a maximum supply temperature of 35°C with a temperature difference of 5°C.

Office building of CAF de Lyon, FRANCE

The building is an office building for the French administration located in the centre of the city of Lyon. Lyon is the third largest city in France and is located in the southern part with a relatively warm climate.

The climate and the internal thermal loads due to office equipment (computers, copiers, etc.) lead to a need for both heating and cooling.

This office building has an area of around 16,500 m². The heating and cooling needs are fulfilled by two reversible GSHPs of 600 kW_{th}.

The GSHPs are fed by ground water from an aquifer through an open loop GSHP system with one well for extraction of water and another one for the injection. The well exploiting the water from the aquifer uses two variable-speed pumps of 100 m³/hour.

The GSHPs are water-to-water machines with compressors driven by electricity by using R134a as refrigerant. These pumps are called "*thermofrigopompe*" in French since they are *able to produce simultaneously both heating and cooling, through implementation of an additional heat exchanger*.

The supply/return temperatures for cooling are 7/12°C in summer and 10/12°C in winter. The operating points for heating are 35°C for 20°C outside and 45°C for 0°C outside.

The average SPF over the period 1998-2006 of the whole GSHP system (including the well pumps) is 3.83.

The distribution of heating and cooling is made through 4-pipe fan coil units. The hygienic ventilation of the building is made through double flux fan units.

A building management system operates the system, including lighting in the offices.

Office building of Universidad Politecnica Valencia, SPAIN

The GSHP system was installed in an academic building at the Universidad Politecnica de Valencia where *cooling requirements are dominant*. The total air-conditioned area is 250m² and includes a corridor, nine offices, a computer room, and a room with photocopiers and a coffee dispenser. All rooms are equipped with one or two fan coils except the corridor.

The GSHP has been modified for using propane (R290) as refrigerant. This unit is reversible water-to-water GSHP with nominal values of 15.9 kW and 19.3 kW of cooling and heating capacity respectively.

The air conditioning system consists of three main components: indoor loop, outdoor loop and a GSHP as described above.

The indoor loop is composed of 12 parallel connected fan-coils, a circulating pump, a storage expansion tank and piping. The loop serves and distributes the chilled water (cooling mode) produced at the heat pump to each of the fan coils.

The outdoor loop is composed of the ground heat exchanger, a circulating pump, a storage tank and the corresponding piping. The loop takes the heat exchanged at the pump (cooling mode) and rejects it to the ground. The ground heat exchanger consists of six boreholes in parallel at a depth of 50 m each, containing a polyethylene "U" pipe. The borehole diameter is 150 mm. Each borehole has a different grouting.

The Seasonal Performance Factor (SPF) of the whole GSHP system -according to measurements of one-year operation- are SPF_{th}=3.46 and SPF_c=4.36 respectively.

"Le Case del Borgo", ITALY

"Le Case del Borgo" is a luxurious hotel which includes ten buildings with stone walls, a service centre and an open swimming pool (300 m^2).

The heating-cooling system consists of a GSHP system and solar thermal panels connected by district heating pipelines.

The GSHP system entirely satisfies the summer requirement (cooling surface of about 1,500 m^2) of the hotel and 50% of peak winter thermal load. When needs for heating cannot be covered by the GSHP, an integrative condensing boiler, fed by LPG with a nominal power of 180 kW, works in parallel. All the buildings are heated through a radiant floor system and heaters in the bathrooms.

The GSHP system -located in the service centre basement- includes a water-to-water GSHP with a nominal value of 100 kW combined with ten BHEs with depth of about 135 meters. The system works with the ecological refrigerant R134a.

BHEs (made of high-density polyethylene) exchange heat with the ground through water mixed with glycol in a close-loop system. The boreholes have a diameter of about 11-13 cm and depth of 100-150 m.

During the winter, the fluid inside the BHEs, takes heat from the ground and transfers it to GSHP, which delivers it to the buildings, swimming pool and sanitary water. In the summertime, water for cooling, hot water for sanitary use and hot water for the swimming pool can be produced at the same time.

The COP of the GSHP for heating/cooling is about 4.

References

- Dimitrios Mendrinos, Costas Karytsas and Burkhard Sanner, *Project GROUND-REACH "Reaching the Kyoto targets by means of a wide introduction of ground coupled heat pumps (GCHP) in the built environment"*, Proceedings European Geothermal Congress 2007, Unterhaching, Germany, 30 May-1 June 2007.

- http://www.groundreach.eu/

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