

BEST PRACTICE DATABASE FOR GROUND SOURCE HEAT PUMPS

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Abstract: The Best Practice Database represents a crucial part of the IEE project GROUND-REACH which is aimed at promoting the application of ground source heat pumps (GSHP) for heating and cooling of buildings in Europe. Main purpose of the database is to provide reliable information on the high energy efficiency and low CO₂ emissions achieved with GSHP in practice, thereby encouraging the market penetration. In the course of the project at least fifty best practice case studies from twenty eight EU countries shall be compiled in the database. By the end of March 2008 thirty three case studies from thirteen countries had been included. An analysis of the best practice case studies compiled shall contribute to the discussion of performance criteria ("benchmarks") for the application of GSHP.

Key Words: *ground source heat pumps, best practice, database, case studies, website, IEE project, benchmarks*

1 INTRODUCTION

In contrast to the heating/cooling systems established on the market like oil and gas boilers or air-conditioners the benefits of heat pumps concerning primary energy saving and CO₂ emission reduction are repeatedly put into question by several interest groups. To overcome this barrier to a broader market introduction it is crucial to demonstrate the advantages of heat pumps through dissemination of reliable information derived from existing installations. Therefore an essential task of the IEE project "Reaching the Kyoto Targets by Means of a Wide Introduction of Ground Coupled Heat Pumps (GCHP) in the Built Environment" (GROUND-REACH) is to set up a best practice portal for the compilation and evaluation of heat pump best practice information from all over Europe.

2 BEST PRACTICE PORTAL

The best practice portal comprises the database and a chapter providing information on benchmarks for GSHP.

2.1 Database

Main purpose of the database is

- to provide reliable information on the high energy efficiency and low CO₂ emissions achieved with GSHP in practice
- to show the broad range of possible application areas for this sustainable heating/cooling technology all over Europe
- to reveal the national and regional differences regarding climate, geology, electricity mix, energy prices etc. and their influence on energy efficiency, economic competitiveness and environmental behaviour

- to form the basis for setting up recommendations for a successful design, installation and operation of GSHP systems

The database has been implemented into the project website (URL: www.groundreach.eu). A display of the six most topical case studies on the database homepage as well as an interactive map showing the regional distribution of case studies are available.

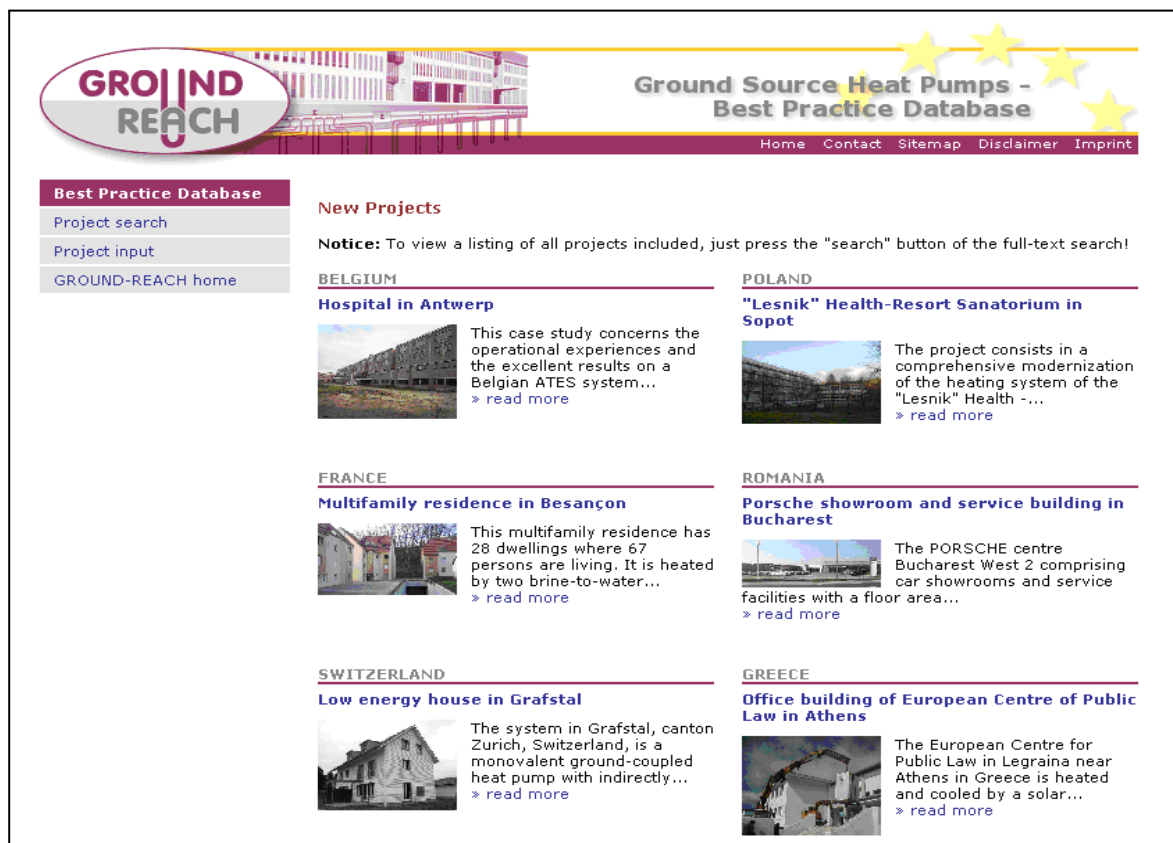


Figure 1: Screenshot of the Best Practice Database homepage

The data providers can make input to the database either online from the project website or submit a completed data input form. A data set to describe a case study comprises the following chapters:

- General Description (table)
- Summary
- Building, overall energy concept
- Heat pump system
- Operation experiences
- Costs, economic efficiency, incentives
- Regulations, guidelines, benchmarking
- References
- Characteristic values, performance data (table)
- Contacts, Links

According to the GROUND-REACH work programme at least fifty case studies from all European countries have to be compiled in the database. By the end of March 2008 thirty three case studies from thirteen countries had been included. The quality of information provided differs considerably from case study to case study, especially concerning the completeness and reliability of monitoring results. Recently twenty one of thirty three case studies provide measured values for the Seasonal Performance Factor (SPF).

Table 1: Selected information on thirty three case studies

Regions	Case studies	Building type			Heat source system		
		Residential buildings	Office buildings	Others	Vertical borehole HX	Ground water wells	Others
Europe	Total number						
Northern	0	0	0	0	0	0	0
Eastern	3	0	0	3	2	0	1
Southern	11	1	4	6	7	6	0
Western	19	12	3	4	9	7	3

2.2 Case studies

2.2.1 One-family house, Rudelzhausen, Germany



Figure 2: Exterior view of the house

This one-family house built in 1995 is located in Bavaria. It has a heated floor area of 340 m², was put up as a solid, well insulated building (bricks) and is heated by a ground water heat pump. The heat pump covers the total heat demand of 14,7 kW for space heating and domestic hot water for five persons.

For the heating season 2006/2007 the measured SPF for the heat pump system (including well pump) was 4,66.

The ground water heat pump (water-to-water) is operated monovalent. However, an auxiliary heating rod was installed in the buffer storage and the hot water storage as well (heating capacity 6 kW each). The heat source system comprises a supply and a return well with a ground water flow rate of about 3.000 litre per hour.

System parameters:

- Refrigerant: R22 / R407C
(R22 machine was replaced in July 1999 by a new heat pump using R407C)



**Figure 3: Heat pump
Dimplex/Siemens (Type WI 15C)**

- Heating capacity: 14,7 kW at W10/W35
- Electric power supply: 2,63 kW
- Heat distribution system: Floor/wall heating, 35°C supply temperature

Operational results (reference year 2001):

- Energy demand space heating: 31.230 kWh/a
- Energy demand hot water preparation: 4.480 kWh/a (incl. 200 kWh/a for electric flow heater)
- Electric energy demand: 7.870 kWh/a
- SPF: 5,51 (heat pump) / 4,57 (heat pump system, including well pump)

The house owner is satisfied with the operation experiences. From the beginning the system worked without any failure. In July 1999 the first heat pump was replaced by a Dimplex heat pump with the refrigerant R407C resulting in an increase of the heat pump system SPF from 4,2 to 4,55. The capacity of the well pump installed did not fit optimal to the needs of the system and the pump efficiency decreased over the years as well, both resulting in a lower SPF.

The primary energy demand of the heat pump system was 28.480 kWh/a compared to 52.350 kWh/a for an oil boiler and 46.190 kWh/a for a gas boiler. This resulted in a decrease of the primary energy demand by 46% and 38 % respectively (reference year 2001).

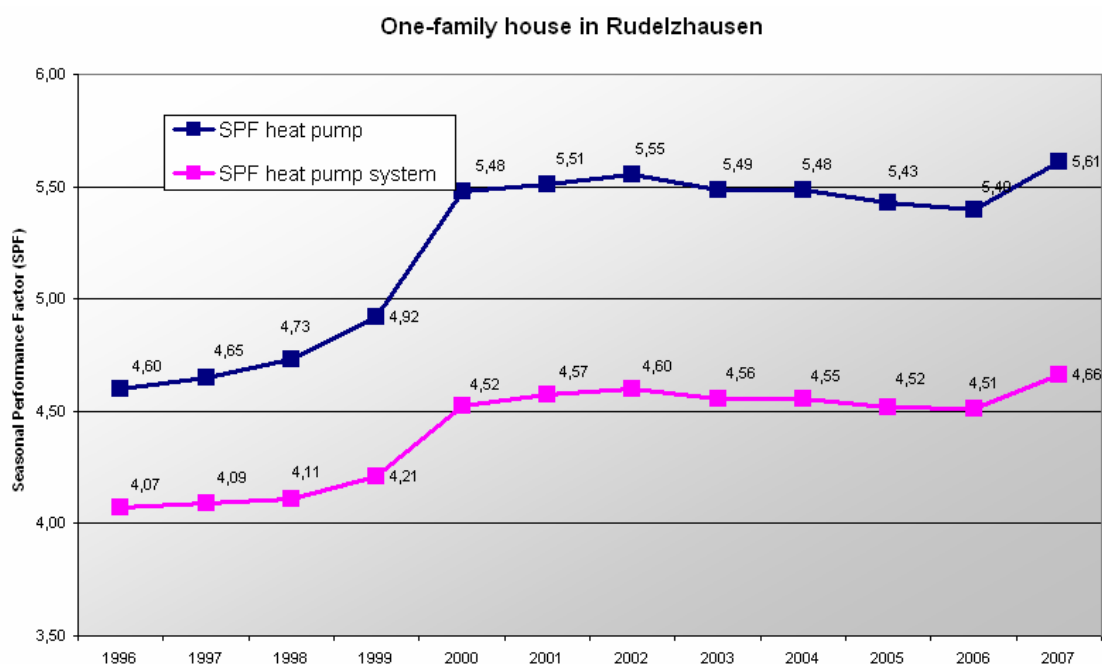


Figure 4: SPF development for the heat pump system in Rudelzhausen (1996-2007)

The total investment costs of the heat pump installation (without heat distribution system) were 16.600 Euro. These costs had been slightly higher than those of a comparable oil or gas boiler. Nevertheless, the family saved money. In the year 2001 the electricity bill was 610 Euro plus 56 Euro for the circulation pumps. The specific costs were 1,96 Euro/m² compared to 6,99 Euro/m² for oil heating (reference year 2001).

Incentives: The house owner got a funding of 400 DM (205 Euro) per kW electric power supply from the regional utility (former Isar-Amperwerke AG, now E.ON Bayern AG). Precondition for funding was a Coefficient of Performance (COP) of 4,0 at W10/W35.

2.2.2 Multifamily residence, Besançon, France



Figure 5: Exterior view of the house

This multifamily residence comprises 28 dwellings where 67 persons are living. It is heated by two brine-to-water heat pumps fed by a field of 10 borehole heat exchangers. The heated area is of 1.771 m². The two heat pumps, each with a heating capacity of 32,6 kW, are fulfilling the needs for heating and cooling. The hot tap water is provided through solar collectors in addition with electric water heaters.

The buildings are well insulated and they have been awarded with a high energy performance labelling. The heating demand is of 74,0 kWh/m² year. The heating and cooling system uses two identical non reversible heat pumps with a heating capacity of 32,6 kW each. Each heat pump is connected to 5 borehole heat exchangers with a depth of 100 m and a diameter of 32 mm. The cooling needs are fulfilled in free cooling mode. For the energy distribution a floor heating/cooling system was installed for each storey. The supply water temperature in the thermal floors is 30°C for heating and 18°C for cooling.

The electric heat pumps are brine-to-water machines. Each one is connected to five 100m deep borehole heat exchangers as heat source. An additional heating resistor of 15,0 kW is also available in case of very cold outdoor temperatures. Since 2003, it has been used only during 8 hours in 2005. The heating capacity of each heat pump is 32,6 kW. The nominal electric power supply is 7,2 kW, fed in three-phases. The nominal operating mode is 35°C (condenser output) and 0°C (evaporator input). The maximum supply temperature is 55°C. Each heat pump is filled with 6,8 kg of R407C refrigerant.



Figure 6: Brine-to-water heat pumps

The cooling is made in free cooling mode, without operation of the heat pumps. The cold water from the borehole heat exchangers is used in the floor heating/cooling system through an intermediate heat exchanger.

The hot tap water is produced through 52 m² of solar collectors in addition with 24,0 kW of electric water heaters.

The measurement campaign took place during the complete year 2006. It was funded both by EDF and ADEME during a campaign intended to monitor the performance of ground coupled heat pumps under real conditions.

The heating system was switched off from 8 June 2006 to 4 October 2006. During this period, the cooling system was turned on but operated really only between 20 July and 31 July 2006, during the hottest days of summer. One heat pump was operated during 1.577

hours (compressor and circulation pump running time) and the other during 2.286 hours. No operational problems were experienced.

The operating cost can be estimated at 3,3 Euro/heated m² during the year 2006 (based on an average electricity price of 0,13 Euro/kWh, excluding yearly subscription costs).

2.2.3 Pylaia town hall, Thessaloniki, Greece



Figure 7: Office building of Pylaia town hall

This office building is located in Pylaia, Thessaloniki. It was built in 2001 and has three storeys with a total floor area of 2.500 m². The geothermal system comprising borehole heat exchangers was installed in the year 2002 in order to cover the total heating/cooling loads of the building. A diesel boiler and a cooling tower are available as back up systems. The heating/cooling distribution system in the building consists of fan-coil units (FCU) and an air handling unit. Heating/cooling demands are estimated to be about 576.216 kWh and 168.000 kWh respectively.

The heating capacity of the geothermal system is 265 kW and the cooling capacity 280 kW.

The eleven electric GSHP (water-to-water) are operated in bivalent heating and cooling mode. They are using R22 as refrigerant. The borehole heat exchangers are filled with de-ionized water.

The total investment costs of the heat pump system were 161.410 Euro. Given that the cost of electricity was 0,1 Euro/kWh and the cost of oil is 0,6 Euro/litre simple pay-back time was calculated as follows:



Figure 8: Heat pumps installed in the basement

With a SPF of 4,0 and a Seasonal Energy Efficiency Ratio (SEER) of 3,5 the total operational costs of the heat pump system for heating and cooling amount to 19.205 Euro. The total operational costs of a conventional heating/cooling system are estimated to be 47.394 Euro. The maintenance costs are estimated as follows:

- geothermal system: 1,2% x capital cost = 1.937 Euro
- conventional system: 3% x capital cost = 4.155 Euro

According to this calculation, the simple pay-back time is estimated to be 0,8 years with an expected life-time of the system of 30 years.

The project was financially supported (100%) by the Center for Renewable Energy Sources (CRES)/Ministry of Development.

2.2.4 Porsche showroom and service building, Bucharest, Romania



Figure 9: Car showrooms

The PORSCHE centre Bucharest West 2 comprising car showrooms and service facilities with a floor area of 3.507 m² was inaugurated in August 2006. The HVAC system, designed to cover heating load, cooling load, ventilation load and domestic hot water production, is based on the application of reversible heat pumps.

The results of the first monitoring period (2006-2007) show, that energy input was five times less, CO₂ emissions were ten times less and heating costs three times less compared to a conventional HVAC system.

The building construction, with a total unfolded area of 3.507 m², is metallic, structured in four distinctive parts, namely:

- a showroom of 360 m², made of steel and glass,
- a showroom of 795 m², from which 650 m² represent the area of car presentation, with glass surfaces on three sides and with metallic curved roof, and 145 m² represent the office area, on two levels with panoramic view to the showroom at the ground floor,
- a middle section made of metal and glass (421 m²), that links the metallic constructions of the two showrooms with a public destination room, having the role of coffee place, including an auto parts shop, services of invoicing and payments, sanitary and two distinctive areas for new car delivery with glass pliable sectional gates,
- an assembly room of 1.931 m², with thermally insulated lateral walls, with concrete struts and ribs, and a "sandwich" roof made of light materials comprising the following divisions: auto mechanics shop, car washing and cleaning, warehouse for spare parts, car reception and diagnosis, and social area.

According to the specific climatic conditions of the capital of Romania and to the imposed indoor temperatures the thermal loads resulting from the calculation are as follows:

- heating load during winter time: 308 kW
- cooling load during summer time: 313 kW
- domestic hot water preparation: 200 kWh/day

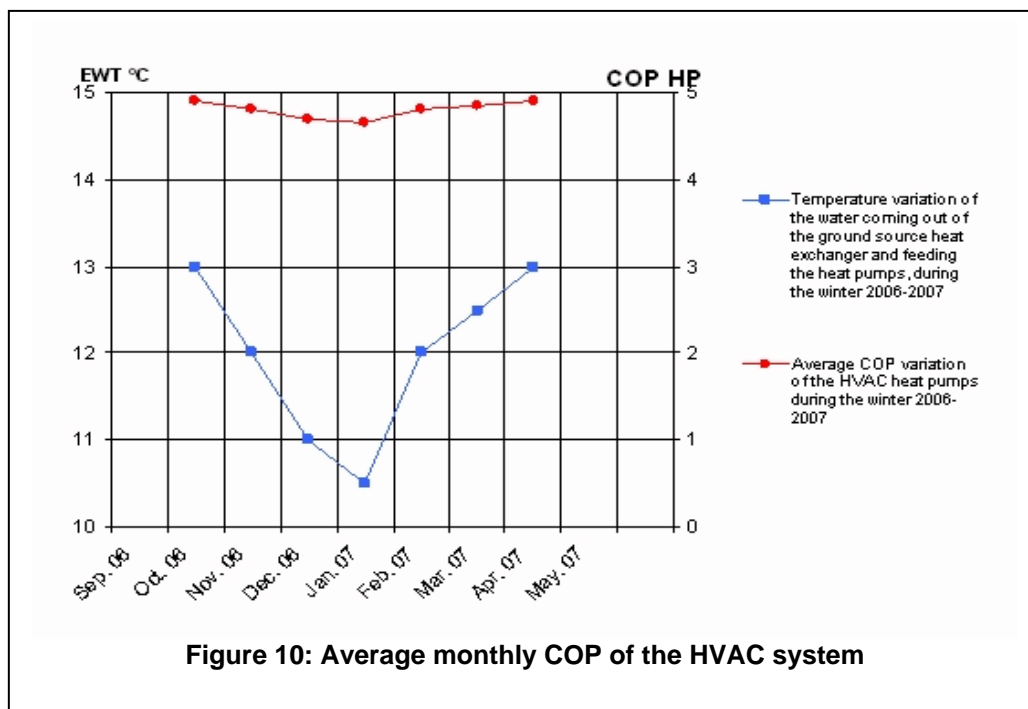
The heat source system consists of 128 vertical borehole heat exchangers of 70 m depth each which were installed on an area of 3.500 m², in order to ensure a energy exchange with the ground of 475 MWh for heating (including the domestic hot water) and of 393 MWh for cooling.

A floor heating system with more than 750 m² was installed in the show rooms and the public area for clients. The under floor piping systems are made of high density polyethylene, buried in cement capping and regularly placed near the glass walls. These systems are supplied by seventeen water-to-water heat pumps in wintertime with heating water and in summertime by cooling water.

Eight reversible water-to-air heat pumps are connected to ventilation channels mainly located in the false ceilings of the building. They are mixing the fresh air with the re-circulated air and function on the "auto change over" principle, meaning they switch automatically from heating mode to cooling mode, as a reaction to "building overheating".

All water-to-water and air-to-water heat pumps are manufactured by Florida Heat Pump (Ft. Lauderdale, USA) and use R410A as refrigerant.

For the time period under survey (October 2006 - April 2007) the monthly COP of the HVAC system was always higher than 4,8. That means a $SPF > 4,8$.



The average value of the specific effective electric energy consumption for the winter period (October 2006 - April 2007) was 6,83 kWh/(m² month). For an average price of the electricity of 72,86 Euro/MWh (exclusive VAT and excises) the specific operating costs of the geothermal system during winter for a total demand of 47,8 kWh/(m² year) were 3,48 Euro/(m² year).

The sum of the values of the monthly specific thermal energy consumption during winter amounts to 112,32 kWh/(m² year). According to law 372/2005 regarding the energy performance of buildings (Directive 91/2002/CE), the value of 112,32 kWh/(m² year), corresponding to class B of the energy classification scale for buildings in Romania, was correctly anticipated by the calculation of the global coefficient of thermal insulation and corresponds to the present demands imposed to new and mechanically ventilated industrial buildings.

2.3 Benchmarking

The analysis and evaluation of benchmark information related to GSHP is another task of the beat practice work package within the GROUND-REACH project. In general benchmarks are needed as determining factors for

- Rules and regulations (measure of quality)
- Incentive programmes (criterion for granting subsidies)

- Labeling schemes (rating scale)
- Standards and technical guidelines (measure of quality)

as well as for comparing heating and cooling systems in terms of energy efficiency, economic efficiency and environmental impact.

For GSHP the following benchmarks have to be considered:

- Energy efficiency
 - Heat pump device: COP / Energy Efficiency Ratio (EER)
 - Heat pump system: SPF / SEER
 - Different heating and cooling systems: Primary Efficiency Ratio (PER)
- Economic efficiency
 - Payback period
 - CO₂ emission avoiding cost
- Environmental impact
 - Total Equivalent Warming Impact (TEWI)
 - CO₂ emissions per year

A preliminary compilation and analysis of benchmark information on European level shows a pretty inhomogeneous situation. While the European standard EN 15450 (October 2007: Heating systems in buildings – Design of heat pumping systems) and guidelines published by the European Heat Pump Association (EHPA) comprise SPF requirements for new and existing buildings the EU Eco Label sets minimum values for COP plus SER, for new and existing buildings too. Also the application of benchmarks on national level including the default values given are still non-uniform.

3 CONCLUSIONS

The database has proven to be an excellent tool for the compilation of best practice information on GSHP installations and presents a good assembly of case studies from thirteen European countries. Nevertheless, there is a strong need for more case studies of good quality. Especially information from the Scandinavian countries are still missing. Several case studies will be completed by measurement results from ongoing monitoring and clear information on the system boundaries used for the determination of the SPF and SEER values shall be added wherever applicable.

Even though longer monitoring periods are necessary in order to get a solid basis for detailed analysis and elaborated recommendations benchmarking shall be started at a preliminary stage. The values of COP and SPF recently available in the database are however, a good indication of the high system performance achievable in practice and underline the value of heat pumps towards improving energy efficiency as well as reducing primary energy consumption and greenhouse gases emissions. Finally, it is recommended to extend the scope of the database after completion of the project from GSHP towards all heat pump types, thus providing an unique tool for dissemination of information on the advantages and capabilities of this sustainable heating and cooling technology.