International Geothermal Days Romania 2012

Groundmed Workshop

Paper n°1

GROUND SOURCE HEAT PUMPS FOR MEDITERRANEAN CLIMATE: PRESENT STATUS AND EXPECTATIONS FROM THE GROUND-MED PROJECT

Dimitrios Mendrinos*, Constantine Karytsas**

Centre for Renewable Energy Sources and Saving

**dmendrin@cres.gr*

***kkari@cres.gr*

SUMMARY/ABSTRACT

Thanks to the European support under the FP7 program, the Ground-Med partners, after three years of project activities, have developed a new generation of energy efficient ground source pump systems, including heat pumps, fan-coil units and air handling units, which have been installed and provide heating and cooling at the eight demonstration buildings of the project, located in South European EU member States. First estimates, based on COP laboratory measurements and monitoring data from project demo sites, indicate that the project objective of SPF>5.0 can be exceeded, even when considering at the calculations the electricity consumption of both the heat pump compressor and the external (BHE) pump. Apart from using energy efficient equipment, key parameters towards achieving maximum SPF, are the BHE and system design, system operating conditions and control methodology used.

INTRODUCTION

With more than 1 million installed units totaling 11 GWth in European Union and annual sales of 125000 units rising 10% annually, ground source heat pumps (GSHP) are an established and mature technology gaining market share in Europe. They have been providing efficient heating and domestic hot water in central and North Europe for the past few decades. During the last five years, GSHPs have also penetrated the markets of South Europe providing both heating and cooling.

GSHPs are one of the most energy efficient technologies for heating, cooling and domestic hot water provision, with measured seasonal performance factor (SPF) improved by 40% compared to air source heat pumps [Mendrinos, 2010]. Due to their high efficiency, they are considered as renewable energy technology according to the directive 2009/28/EC of the European Parliament and European Council of 23.04.2009.

1 THE GROUND-MED PROJECT

The main objective of project TREN/FP7EN/ 218895/GROUND-MED "Advanced Ground Source Heat Pump Systems for Heating and Cooling in Mediterranean Climate" is to develop and demonstrate a new generation of ground source heat pumps systems with measured seasonal performance factor (SPF) exceeding 5,0. SPF is defined as the ratio of the useful energy delivered to the building during a year in terms of heating, cooling and domestic hot water, divided by the electricity consumption during the same period. SPF equals to the average COP throughout the year. In cases where heating can be separated form cooling, a smaller period can be considered as well for the SPF calculation, such as the heating season or the cooling season.

GROUND-MED project started on 1 January 2009 and has duration of 5 years until 31 December 2013. Its budget amounts at around 7.25 million euro, including technology development, demonstration, monitoring and dissemination activities. It is supported by the European Union through its FP7 program with up to approximately 4.3 million euro.

GROUND-MED project is implemented by a consortium of 24 organizations across Europe, including universities and research institutes, heat pump manufacturers and industrial associations, GSHP systems installers and energy consultants and works contractors. They are:

- Centre for Renewable Energy Sources and Saving - CRES, (Greece) as project coordinator,
- Compagnie Industrielle d'Applications Thermiques –CIAT (France),
- HIREF spa (Italy),
- OCHSNER Wärmepumpen GmbH (Austria),
- Institute of Systems and Robotics - University of Coimbra (Portugal),
- University of Oradea (Romania),
- Gejzir Consulting (Slovenia),
- Ecoserveis (Spain),
- Edrasis – Ch. Psallidas SA (Greece),
- Eneren srl (Italy),

– University College Dublin (Ireland),
– Università degli Studi di Padova (Italy),
– Universidad Politécnica de Valencia (Spain),
– Commissariat à l'Énergie Atomique - CEA (France),
– Groupement pour la Recherche sur les Echangeurs Thermiques - GRETh (France),
– Instituto Politecnico de Setubal (Portugal),
– KTH – Royal Institute of Technology (Sweden),
– Geoteam GmbH (Austria),
– Groenholland BV (Netherlands),
– Besel SA (Spain),
– Centre Technique des Industries Aérauliques et Thermique – CETIAT (France),
– Fachinformationszentrum Karlsruhe GmbH – FIZ (Germany),
– European Heat Pump Association - EHPA,
– European Geothermal Energy Council - EGEC.

More information about the project, as well as on GSHP applications and news, are provided at the project web site, at the internet address:

– http://www.groundmed.eu/.

2 TECHNOLOGY DEVELOPMENT

2.1 Heat pump boundary conditions

GROUND-MED project regards GSHPs as an integrated system comprising the field of borehole heat exchangers (BHE), the water source heat pump, the external (outdoor) heat transmission circuit with its pump (circulator), the internal (in-building) heat transmission circuit with its pumps and the heat supply system, which depending on the site are fan-coils, in-wall pipes, radiators and/or air-handling units. Technology development concerns not only new energy efficient equipment, but system design and operation as well, aiming in maximizing overall energy efficiency in terms of SPF.

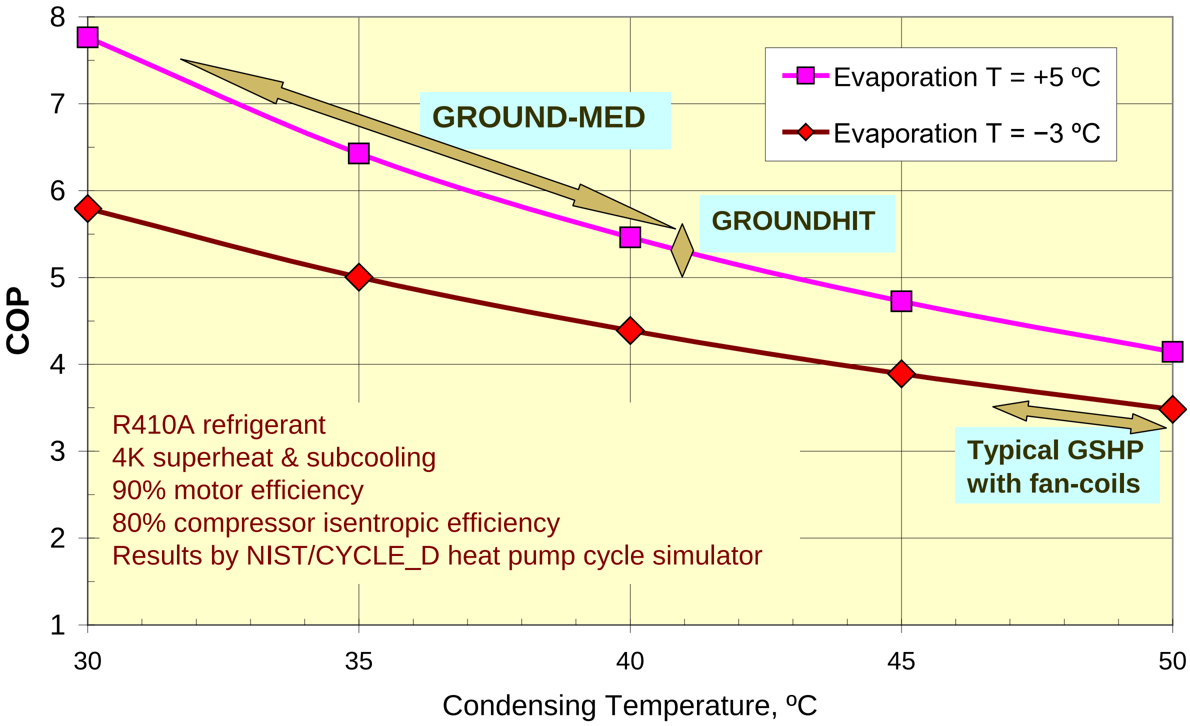

Figure 1: SPF improvement in GROUND-MED heat pump systems.

The GROUND-MED concept towards maximizing the seasonal performance of a GSHP is presented in Figure 1, which shows the heat pump COP as a function of the condensing temperature for two evaporation temperatures, one equal to -3ºC (dark red line) and another at +5ºC (pink line). Both lines have been calculated with the aid of the NIST/CYCLE_D heat pump cycle simulator, using the assumptions listed in Figure 1, which correspond to state of the art equipment as described below.

R410A refrigerant is the new trend in heat pump market, resulting in high energy efficiency, not only because of its heat transfer properties, but because the corresponding heat pump components are new; they have been designed and made available to the market recently, when energy efficiency is one of the main market driving forces. In addition, its wide adoption by the heat pump industry results in economies of scale and hence improved competitiveness. The latter is necessary in order to achieve maximum replication of the developed technology and increased project impact.

Superheat and subcooling of 4K are typical for efficient heat pump cycles, according to our 8 years experience in heat pump technology development; cycle optimization however, may further fine-tune these values.

Motor efficiency of 90% corresponds to the most efficient motors for compressors of low capacity, while motor efficiency of 95% can be reached in systems of high capacity, with maximum value of 97% for horizontal coaxial centrifugal compressors with magnetic cushion bearings.

Compressor isentropic efficiency of 80% corresponds to the best market available compressors operating at optimum pressure ratio.

Evaporation temperature of -3ºC corresponds to typical BHEs design with water and antifreeze as heat transfer fluid. It is encountered in the majority of GSHP installations as a compromise between energy efficiency and costs. In GROUND-MED project, larger BHE fields are used in terms of total length, as BHEs are designed for +5ºC evaporation temperature and water as heat transfer fluid. This improvement alone results in the heat pump to operate along the pink line of Figure 1, instead of the red one, with a corresponding improvement in the heat pump (compressor) COP in the range 20-35% depending on the condensing temperature. The same principle applies in cooling mode, where the longer BHE will result in lower operating temperature in the BHE and hence in improved heat pump COP.

As shown in Figure 1, the condensing temperature is of major importance to the determination of heat pump COP. Traditional design of fan-coil systems uses 45ºC as temperature of the water supplied by the heat pump to the fan-coil. This value was defined in the past, when energy costs were negligible and system reliability and users comfort were the main driving forces, whilst energy efficiency was of no importance at all. Resulting heat pump operation range is shown in the low right part of the graph of Figure 1, which corresponds to condensing temperature to a constant value in the range of 47-50ºC.

In the Groundhit project, which was the Ground-Med predecessor, the temperature supplied by the heat pump to the fan-coils was set to 40 ºC, which resulted in 25% higher COPs than standard systems.

GROUND-MED systems are designed in such a way, so that the temperature supplied by the heat pump to the fan-coils in heating mode varies depending on the load conditions, starting from 40ºC at peak load, and going down to 30ºC at low load conditions. The same principle applies during the cooling season as well, e.g. by cooling with 10ºC fluid at peak load conditions, increasing this temperature as the load drops and reaching a pre-defined maximum value, say 20ºC at minimum load requirements. This requires a temperature compensation function to be introduced in the heat pump controller and results in a further 25% COP improvement. In this function, the heating or cooling temperature delivered by the heat pump depends on the ambient temperature, which is the main parameter defining the heating or cooling load of the building. An example of user defined heating and cooling compensation functions is shown in Figure 2.

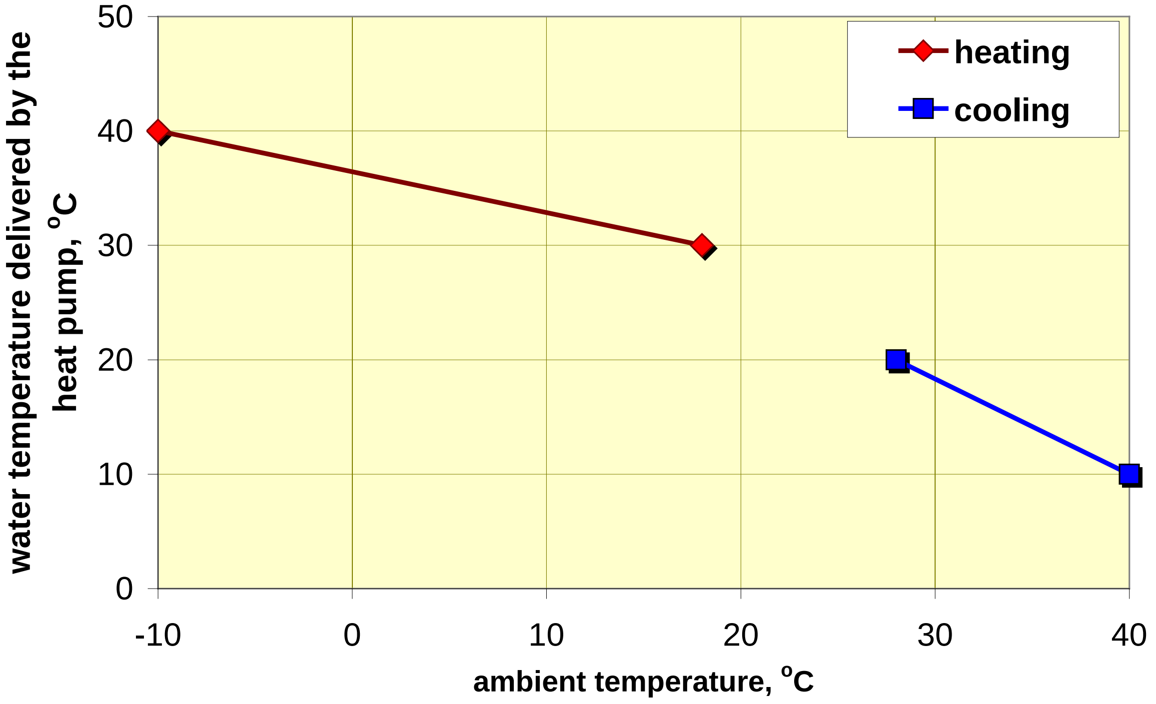

Figure 2: Sample temperature compensation functions for heating and cooling.

System control is done through the heat pump controller supplied by the heat pump manufacturers. In addition to temperature compensation, a smart control models and strategies are under development for testing and evaluation at different demonstration sites.

2.2 Heat pump prototypes

Eight heat pump prototypes have been developed for the project, each one tailor made for the needs of the corresponding demonstration site. Three heat pump prototypes have been developed by CIAT, two by HIREF and three by OCHSNER WP. All heat pumps are characterised by superior energy efficiency, using the methodology and experience already gained by previous technology development projects, such as the GROUNDHIT. It includes oversized evaporators and condensers, electronic expansion valves, refrigerant distribution device at the evaporator and compressors of high isentropic efficiency. Also COP optimization in terms of calculation and optimization of heat exchangers, refrigerant charge, optimization of refrigerant lines, definition and dimensioning of heat pump components.

The main difference of the GROUND-MED heat pumps is that the focus of the technology development is now placed on the SPF optimisation rather than the COP. COP reflects system performance under specific conditions, which may correspond to its operating parameters during limited time periods only. On the other hand, SPF is the parameter that reflects the actual energy efficiency of the installation throughout its operation during both heating and cooling seasons.

In order to optimize the heat pump SPF, two aspects are of major importance. The first one is the capacity control of the heat pump and the second is the flow directions at both the evaporator and the condenser.

The heat pump capacity control methodologies considered and studied with laboratory experiments were the following:

- Constant speed compressors with on-off capacity control.
- Inverter compressors with variable speed capacity control.
- Twin constant speed compressors in tandem.
- Two constant speed compressors of different capacity in tandem.
- One constant speed and one variable speed compressor in tandem.

Due to the high volumetric heat capacity of the water and the corresponding thermal inertia and thermal storage at the water distribution circuits, and in contrast to air-to-air heat pumps, on-off compressors perform quite satisfactory in ground source systems in terms of SPF. In addition, the compressors of the highest isentropic efficiency available in the market are constant speed scroll type ones. Three heat pump prototypes developed by OCHSNER WP use on-off control and R407C as refrigerant.

Inverter compressors have the advantage of achieving improved temperature approach between the refrigerant and the water circuits at low capacity [Mendrinos et al., 2011], as well as reduced in number and smooth compressor start-ups. Both result in higher heat pump SPF, while the latter also results in improved reliability and longer compressor life. However, in contrast to air-to-air systems, due to the superior heat transfer properties of the water the temperature approach difference is mitigated in ground source heat pumps, limiting that way the inverter control benefits.

On the other hand, additional electricity losses occur at the inverter resulting in lower SPF by 10% at peak load conditions. Moreover, both inverter and compressor motor efficiency tend to drop as the machine operates away from its nominal point (usually at peak load conditions). This drop in efficiency can become very profound at extreme frequencies. Furthermore, there is limited market availability of efficient inverter compressors. In order to evaluate this option, one heat pump prototype developed by HIREF and installed at its factory in Tribano, Italy, uses an inverter compressor and R410A as refrigerant.

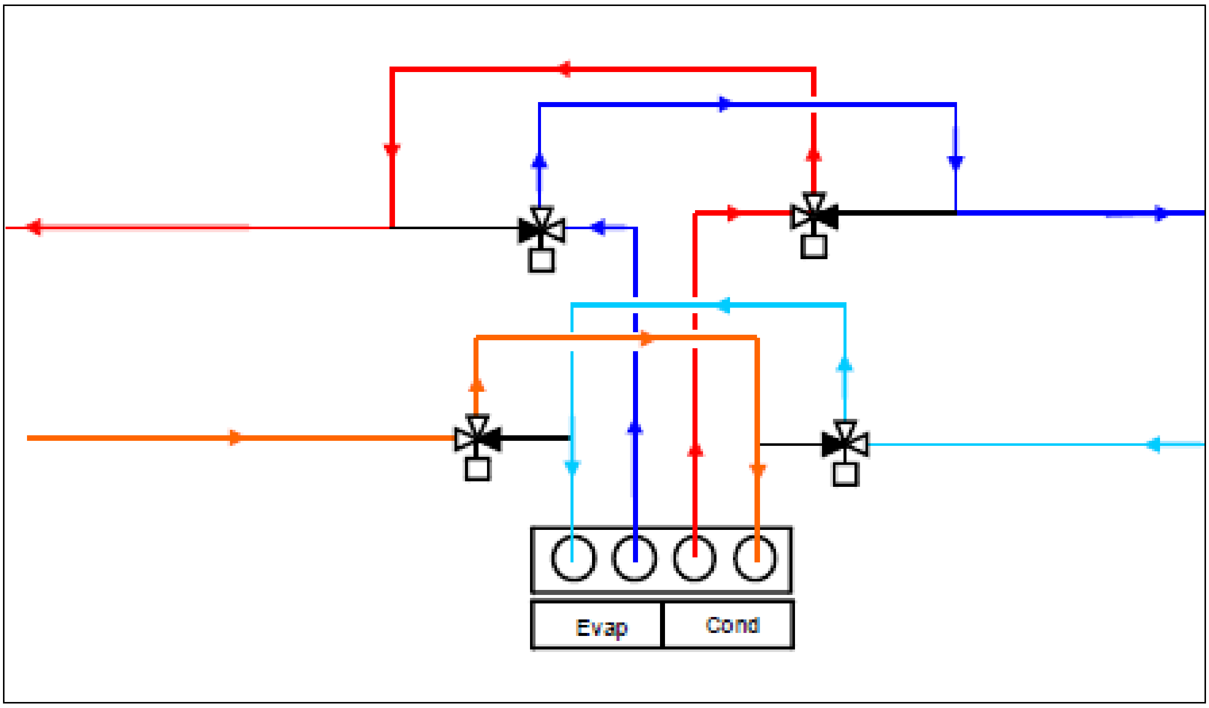

Figure 3: Water side reversible heat pump: schematic presentation of switching external flow with four 3-way valves [Institute of Systems and Robotics, 2011].

Compressors in tandem exploit the market availability of constant speed compressors of high isentropic efficiency, while achieving excellent temperature approach at both the evaporator and the condenser, as 80% of the time only one compressor runs using the entire heat exchange surface of the heat pump, which has twice the compressor's nominal capacity. Laboratory experiments done for the project indicated that the option of twin constant speed compressors in tandem results in the maximum possible heat pump SPF. The three CIAT heat pump prototypes and one HIREF heat pump prototype use twin constant speed compressors in tandem with R410A as refrigerant.

The temperature approach between the refrigerant and the water circuits at the heat pump evaporator and condenser is minimized (and hence SPF is maximized), when these fluids are in counter-flow. Market available ground source heat pumps are usually refrigerant reversible; when optimized for heating, their heat exchangers operate in counter-flow in heating mode, and in parallel flow in cooling mode. The reverse occurs if they are optimised for cooling. In order to maximize SPF, counter flow conditions are required in all modes. In GROUND-MED systems, when switching from heating operation to cooling and vice versa, this is achieved by also reversing the external flow together with the refrigerant flow, using either four 3-way valves, or two 4-way valves.

In case of water side reversible heat pumps, the hydraulic system is designed in such a way, so that counter flow conditions occur at the heat exchangers during all times, again using the four 3-way valves. A schematic presentation of a water side reversible heat pump is shown in Figure 3.

2.3 Fan coil units

The entire fan coil unit has been re-designed in order to minimize its electricity requirements, using brushless permanent magnet motors, low weight impellers and variable speed control. The new fan coils delivered by CIAT should be able to reduce electricity consumption by 75% compared to their predecessors, e.g. from 40 Watts to 10 Watts per unit.

In order to operate at the low temperature range required by the project, and as traditional fan-coils are designed for 45ºC water supply temperature, a new generation of fan-coils was developed, which ensures that user comfort is also achieved together with the energy efficiency improvement. Comfort is also aided by adjusting the fan-coil position and fan speed in order to exploit the "coanda effect" and maintain a small vertical air flow at the walls and a small horizontal air flow at the ceiling and floor. These fan-coils are able to provide users comfort at the same water supply temperature with the in-wall and floor heating systems, where its standard value is 35ºC.

2.4 Air handling unit prototype

Air handling units condition incoming air to the building, proving heating, cooling and de-humidification. During the summer, de-humidification is achieved by cooling the air in order to remove excess humidity and re-heating it to the desired temperature. In standard air-handling units an electrical resistor is used for re-heating the air, even during the summer. In GROUND-MED project, CIAT develops a new air handling unit prototype that uses condensing heat for de-humidification, improving that way the unit efficiency in terms of primary energy. The unit is also equipped with an inverter driven fan.

2.5 Thermal storage nodules

Thermal storage is a technology gaining acceptance for use with heat pumps, as it allows the reduction of peak loads and use of heat or cold produced during off-peak hours of the day (e.g. during the night), when electricity tariffs are lower. Apart from reducing heating and cooling operation costs, thermal storage results in improving primary energy efficiency, as it results in utilising otherwise lost electricity produced during off-peak hours, when electricity demand is less than the supply from coal plants, nuclear plants and wind farms.

Standard cold storage material is ice, which exploits the latent heat of water during its phase change from solid to liquid and vice-versa at 0ºC. In the GROUND-MED project new cold storage nodules are under development by CIAT. They use a material which changes phase at 8ºC, resulting in higher evaporation temperature at the heat pump, than in the case of ice, improving that way its SPF, as already explained in this paper.

In addition, at the Coimbra demonstration site, thermal storage will be also installed, but in order to store heat. A salt hydrate will be used, sodium thiosulfate pentahydrate in particular, which changes phase at ~46ºC, temperature sufficient to allow heating with 40ºC water at peak load conditions [Institute of Systems and Robotics, 2011].

3 DEMONSTRATION SITES

All eight project demonstration systems are now in operation, demonstrating the developed technology. Their main features are summarised in the next paragraphs [Mendrinos and Karytsas 2011].

CIAT commercial agency office building at Septèmes les Vallons, near Marseille, France, has 338 m² surface, heating requirements 25 kW and cooling needs 15 kW. It has 6 BHEs x 100 m deep each, with double-U PE pipes of 40 mm diameter and bentonitic grouting. The heat pump prototype has tandem compressors, R410A fluid, yielding SCOP=6.2 and SEER=7.3, as calculated from laboratory COP measurements according to the standard PrEN14825-2008. The indoor system comprises 14 CIAT fan-coils and one air handling unit prototypes. Cold storage prototype nodules will be also installed within 2012. Maximum system SPF is achieved by variable speed pumps and by 6 three-way valves, which allow counter-current flow at the evaporator and condenser in both heating and cooling modes, together with free cooling operation when possible.

The Regional Administration building of Coimbra, Portugal, is a renovated old milling factory. Its top floor is heated and cooled by another CIAT heat pump prototype, which covers heating needs of 34 kW and cooling needs of 48 kW. 7 BHEs x 125 m deep each have been constructed, using 32 mm double-U PE pipes and 3-8 mm graded sand grouting. The heat pump has tandem compressors, R410A fluid, yielding SCOP=5.65 and SEER=6.19, as calculated from laboratory COP measurements according to PrEN14825-2008. The indoor heating and cooling system comprises CIAT Coadis-2 roof fan-coil units of high efficiency and variable speed, as well as a 100 kWh PCM tank for heat storage.

The Municipal cultural centre of Benedikt in Slovenia, includes a large auditorium and offices, and has heating needs of 20.3 kW and cooling requirements of 19.2 kW. It has 3 double-U BHEs with 40 mm PE pipes of depths 166 m, 126 m and 97 m. An OCHSNER heat pump prototype of COP=6.1 at W10/35 has been commissioned. The system is able to provide free cooling as well.

At HIREF factory in Tribano near Padova, Italy, the installed heat pump prototype covers not only the heating (13.2 kW) and cooling (14.0 kW) needs of the factory technical office, but the sanitary hot water demand of the factory as well. It has 4 BHEs x 80 m deep each and bentonitic grouting. Both single and double U pipes are used for evaluation purposes. It is the only system that uses a heat pump with an inverter compressor. The heat pump is both refrigerant and water reversible with the aid of two 4-way valves. Its heating and cooling system includes variable speed pumps, and inverter driven brushless motor fan coils.

"La Fabrica del Sol" is an information centre for renewable energies, renovated from an old gas factory. It comprises a workshop, offices and social rooms. The ground floor area of 375 m² is heated and cooled by a 61 kW CIAT heat pump prototype, supplied by 7 BHEs x 110 m deep each, of single-U 40mm PE pipes. The heat pump prototype includes tandem compressors and temperature compensation function, yielding SCOP1=5.9 and SEER1=6.7, as calculated from laboratory COP measurements according to standard PrEN14825-2008. The indoor system includes an air handling unit and variable speed pumps of energy class A.

The faculty of visual arts of the University of Oradea in Romania is heated and cooled by a Ground-Med heat pump prototype of OCHSNER manufacture, which covers 38 kW heating and 31 kW cooling peak load. It has 10 BHEs x 130 m depth each in two lines, with single-U, 40mm PE pipe and coarse sand grouting material with a bentonitic plug above the water table. It is the only system that uses antifreeze at the BHE, in particular 10% monoethylene glycol water. The heat pump is reversible at both refrigerant and water sides, and has a COP of 5.64. It provides heating, active cooling, and free cooling through ~1 cm pipes embedded in walls, coupled to 4 fan-coil units.

At the University Polytechnic of Valencia, the second HIREF Ground-Med heat pump prototype provides heating (17 kW) and cooling (15 kW) to 250 m² of offices, computer and service rooms. It has 6 BHEs x 50 m deep each, with single-U 25 mm PE pipes using a variety of grouts. The heat pump prototype includes two Copeland compressors in tandem, R410A fluid and is both refrigerant and water side reversible. The heating and cooling system includes roof fan-coils and inverter pumps. Its data acquisition system has been recording system performance for almost one year now. A lot of experimentation took place in this system during the past 12 months yielding SPF values depending on the defined system operating parameters, and proving that the project objective of SPF> 5 is feasible, even when including the electricity consumption at the water pumps in the calculations.

At the Edrasis headquarters building near Athens international airport, the heat pump prototype of OCHSNER manufacture covers 55 kW base load heating and cooling, supplying already installed fan-coils. It has 12 BHEs x 110 m deep each as heat source/sink, with 32 mm PE pipes, and graded sand or gravel grouting with an upper 30 m bentonitic plug above the water table. The heat pump is water side reversible with COP of 5.92 at nominal conditions.

4 SYSTEM ENERGY PERFORMANCE

The project monitoring system includes local data acquisition equipment installed at each demonstration site. It includes National Instruments hardware and transducers with Labview interface and FTP communication to a central data management server, located at the Coimbra University.

The thermal energy taken from or supplied to the BHE and building water circuits by the heat pump is measured by heat meters from Brunata or other competent supplier. Electricity consumption at individual system components is measured by Carlo Gavazzi or Itron power meters. Data communication with the interface is done using the RS485 protocol (Modbus).

In order to evaluate the developed technology, the system design methodology and the control algorithms tested, four distinct seasonal performance factors are calculated from the acquired data. These SPFs equal to the ratio of the useful heat and cold delivered to the building divided by the electricity consumption in different system components as explained below.

- SPF1: heat pump compressor only.
- SPF2: heat pump compressor and external pump at the BHE.
- SPF3: heat pump compressor, external pump at the BHE and all internal pumps.
- SPF4: heat pump compressor, external pump at the BHE, all internal pumps and all fan-coils and air-handling units.

SPF1 is useful for the evaluation of the heat pump itself. SPF2 should be used when comparing ground source heat pumps with other heating and cooling systems, as the external pump is unique to GSHPs. SPF3 is useful for the evaluation of system hydraulic design and pumps efficiency. SPF4 is the measure of overall system efficiency, and should be used for the evaluation of the indoor system components, as well as of the control methodology adopted.

Apart from SPF values which are calculated for the entire season, for technology evaluation purposes, similar daily average COP values are also calculated, e.g. COP1, COP2, COP3 and COP4.

As the project data management system is expected to be fully operational in June 2012, only limited monitoring data were available during the preparation of this paper, mainly from the Valencia demonstration site. There, the GROUND-MED heat pump prototype replaced the one already developed for the GEOCOOL European project, which operated for five years using the same BHE and fan-coils.

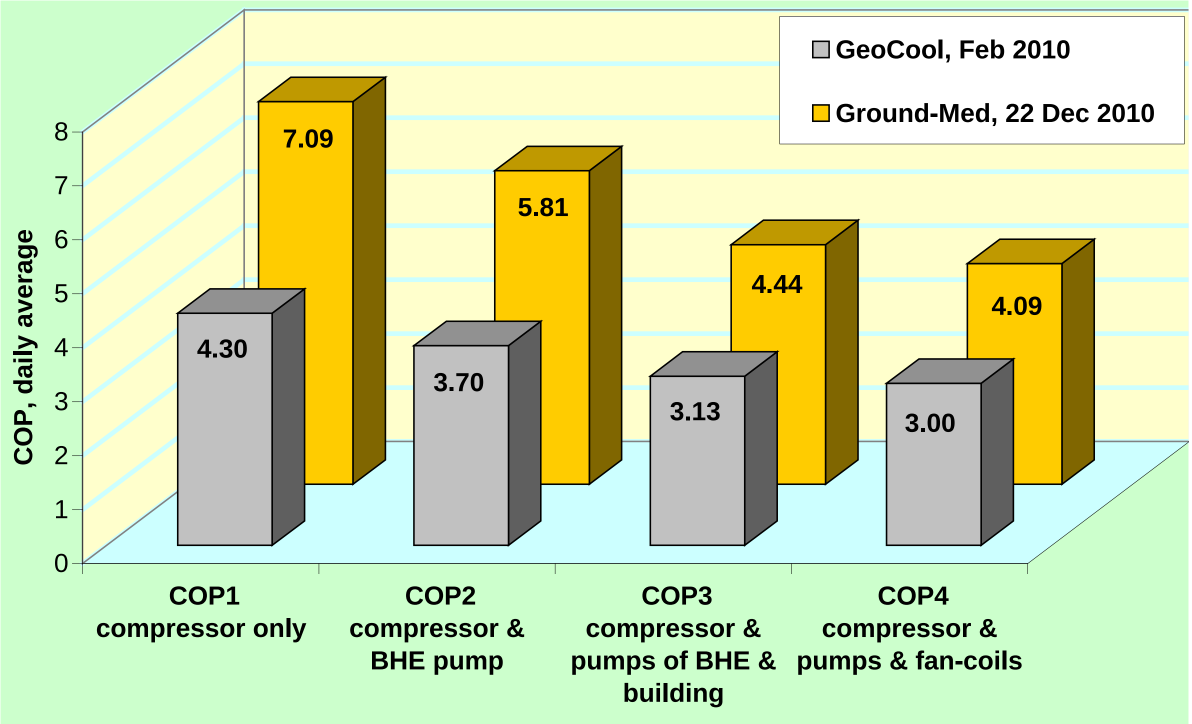

Figure 4: Daily average COP of the GROUND-MED heat pump in heating mode compared to its predecessor system (GEOCOOL) at the Valencia demonstration site.

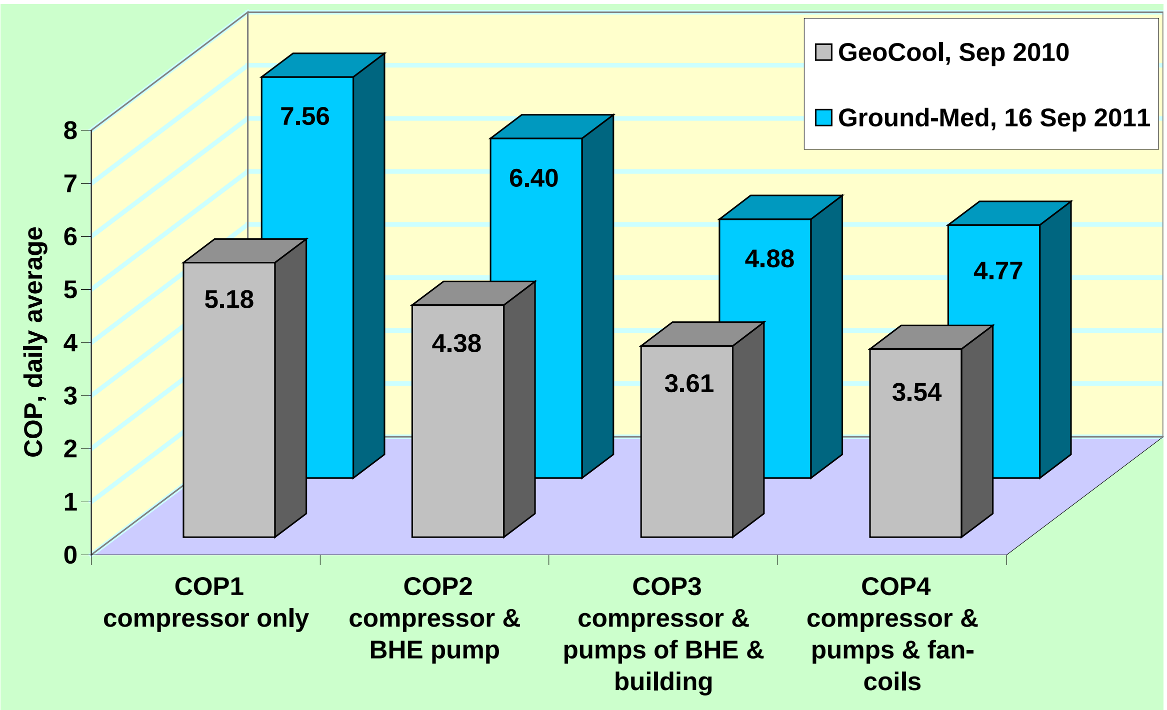

Figure 5: Daily average COP of the GROUND-MED heat pump in cooling mode compared to its predecessor system (GEOCOOL) at the Valencia demonstration site.

Comparisons between sample measurements in terms of daily average COPs of the GROUND-MED heat pump [Universidad Politécnica de Valencia, 2011] and monitoring data from the GEOCOOL project [Montagud et al., 2011] are presented in Figure 4 for heating and in Figure 5 for cooling. Although the GROUND-MED data correspond to selected days, they are indicative of what the technology can achieve in terms of energy efficiency, provided that the heat pump operates according to the boundary conditions described above.

As can be derived from Figures 4 and 5, project objectives can be achieved in terms of SPF1 and SPF2, but additional effort is necessary for SPF3 and SPF4 in order to achieve the target value of 5.0. In addition, during the GEOCOOL project, the electricity consumption at the pumps corresponded to the 26-29% of the overall electricity consumption of the system, value that was increased to 34-35% in the GROUND-MED installation, as the heat pump efficiency increased, resulting in lower power consumption at the compressor. Due to the low occupancy of the conditioned offices, only one or two fan-coils are in operation, resulting in their corresponding electricity consumption to account for 2-4% of the total in GEOCOOL and 2-8% in GROUND-MED.

This implies that the pumps and fans correspond to a large fraction of system electricity use and special attention should be paid to them as well. Electricity consumption at the pumps can be minimized by selecting energy class A inverter driven pumps only and regulating the flow according to the load demand from the building.

Preliminary monitoring data are also available from the Coimbra and Barcelona demonstration sites. In Coimbra, the daily average COP1 was calculated from measurements as 6.03, during the first day of its operation for heating [Institute of Systems and Robotics, 2011].

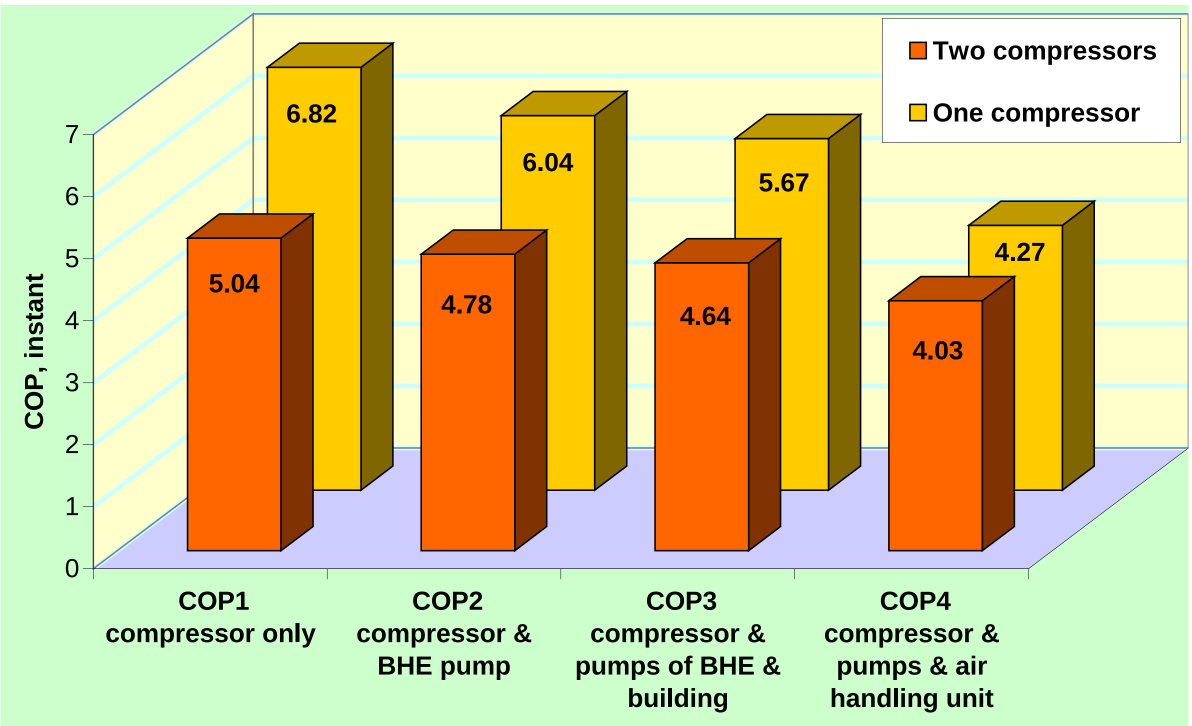

Figure 6: Instant COP of the GROUND-MED heat pump in heating mode at the Barcelona demonstration site.

In Barcelona, only instant COP values have been calculated from thermal and electrical power measurements, again in heating mode [Alsius 2011], which are presented in Figure 6. There, the pumps are energy class A inverter driven ones according to project requirements, resulting in their electricity consumption to account for 7% of total electricity consumption of the system in full load with two compressors running and in 13% in part load with one compressor on. At this site the electricity consumption at the air handling unit is of major importance, which amounts as 13% of total consumption at full load, rising to 25% of total consumption at half load.

5 CONCLUSIONS

The GROUND-MED partners have developed a new generation of integrated ground source heat pump systems, comprising borehole heat exchangers of innovative design, water source heat pumps of extraordinary efficiency, pumps and fans of low electricity consumption, as well as smart system controls with built-in temperature compensation function. This technology is demonstrated in eight buildings of South Europe.

BHE main features used in the majority of the project sites include grout of coarse sand (fine gravel) within the water table and bentonitic above, more total borehole meters, and water as heat transfer fluid.

Laboratory measurements and first monitoring data from demonstration buildings indicate that the overall project objective to achieve measured seasonal performance factors SPF higher than 5.0 will be exceeded for SPF1 and SPF2, and may become feasible even for SPF3, when considering the electricity consumption in the external and all internal pumps in the calculations.

As seasonal performance is the key objective of the project, instead of the heat pump COP at pre-defined conditions, capacity control has been an issue of major importance. Studies, experiments and measurements done during the project proved that twin compressors in tandem outperform the single on-off and the inverter compressor. SPF is further improved by either water reversible, or both refrigerant and water reversible heat pumps, so that both the evaporator and the condenser always operate in counter flow.

As electricity consumption at the pumps and fans corresponds to a significant part of total system electricity consumption, advanced fan-coils and air handling units have been developed, while energy class A inverter driven pumps and fans are also used. Systems are designed in order to provide low temperature heating, high temperature cooling, while also maintaining high users comfort.

Due to the already developed technology, the system design and control methodology adopted and the first promising results from the demonstration sites, we expect the GROUND-MED project to become exemplar for future ground source heat pump systems, effectively contributing towards improving energy efficiency and renewable energy use.

6 REFERENCES

Alsius A.E., 2011: Ground-Med deliverable D6.6. Ecoserveis sun factory demo system in Barcelona, Spain, pp 29.

Institute of Systems and Robotics, 2011: Ground-Med deliverable D6.3. University of Coimbra demo system in Portugal, pp 11, 31.

Mendrinos, Dimitrios, 2010: Ground source heat pumps: latest technology and advancement through European projects, in Energy Bulletin No 1 [8], international sustainable Energy development centre under the auspices of UNESCO (ISEDC), Moscow, Russia, pp 70-76.

Mendrinos, Dimitrios, Corberan, Jose Miguel, Da Riva, Enrico, Del Col, Davide, Montagud, Carla, 2011: Ground Source Heat Pumps for Heating and Cooling in the Mediterranean Countries, in Proc., international conference «Sources/Sinks alternative to the outside Air for Heat Pump and Air-Conditioning Techniques (Alternative Sources - AS)», Padova, Italy 5-7 April, pg 113-122.

Mendrinos, Dimitrios, and, Karytsas Constantine, 2011: Ground-Med demo sites, in Proc., Ground Med "the International European project conference", Marseille, France 6-7 October, pp 40-41.

Montagud C., Corberan J.M., Montero A., Urchueguia J.F., 2011: Analysis of the energy performance of a ground source heat pump system after five years of operation, in Energy and Buildings 43, pp 3618–3626.

Universidad Politécnica de Valencia, 2011: Ground-Med deliverable D6.5: University Polytechnic of Valencia demo system in Spain, pp 30.

Project GROUNDMED is supported by the European Union within the 7th framework program