Comparative energy performance between a geothermal heat pump system and an air-to-water heat pump system for heating and cooling in typical conditions of the European Mediterranean Coast

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General motivation for doing GSHP research in our area

- Spain is one of the largest EU HVAC market
  - Very dynamic building sector
  - Climate conditions + increased social demand for thermal comfort
- Kyoto background + rising electricity prices + grid overload problems
  - Public and policy makers starting to move
  - New regulation (CTE norm) for more energy efficient buildings
  - Solar panels for space heating/domestic water give no answer to improved cool generation efficiency demand
- TES technologies largely unknown to the sector, specially regarding performance at our particular conditions
…but

- Research efforts at national level in the area of improved thermal systems have been...
  - scarce
  - largely dependent on foreign equipment manufacturer technology
  - uncoordinated

- … as a result of what the number of project in the area of TES technologies (except ATES) in Spain has been...
  - 0
THE FIFTH FRAMEWORK PROGRAMME

GEOCOOL

Geothermal Heat Pump for Cooling-and Heating along European Coastal Areas

Project No: NNE5 – 2001 – 00847, July 2002
Partners and Main figures

**Project Coordinator:**

UNIVERSIDAD POLITÉCNICA DE VALENCIA (UPV)  
GROENJOLLAND BV (GROHOL)  
COMPAÑÍA INDUSTRIAL DE APLICACIONES TÉRMICAS, S.A.(CIATESA)  
ARISTOTLE UNIVERSITY OF THESSALONIKY (AUTH)  
ENTE PER LE NUOVE TECNOLOGIE, L’ ENERGIA E L’AMBIENTE (ENEA)  
ASOCIACIÓN PARA LA INVESTIGACIÓN Y LA DIAGNOSIS DE LA ENERGÍA (AEDIE)

Duration: 3 years Feb. 2003 - 2006  
Total Budget: 1,87 MEur
OBJECTIVES

- To design, construct and demonstrate a GSHP case system in order to produce fair and rigorous data about the:
  - Energy saving potential in comparison to a realistic nowadays alternative system
  - Economic and technical feasibility of GSHP technology in our area

DESIGN of codes and procedures for an optimized GSHP systems

POLICY of diffusion of results; operative development of installation guides and procedures

GEOCOOL demonstration plant
Design and modelling

- Serious challenge….for very simple question
- Different model combinations were used to estimate comparative SPF performances of AW and GSHP systems
  - BHE: EED, GLHPro, …
  - Heat Pump analysis: ART (proprietary HP development code)
  - Air Source: ARI bin-hour procedure + climatic databases
- See contribution in the last 2005 WGC conference in Antalya (Turkey)
Ground Source HE
Why vertical BHEx?
# BTES main parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GROUND (test IN-SITU)</strong></td>
<td></td>
</tr>
<tr>
<td>Ground thermal conductivity</td>
<td>1.800 W/m·K</td>
</tr>
<tr>
<td>Volumetric heat capacity</td>
<td>2.4 MJ/m³·K</td>
</tr>
<tr>
<td>Ground surface temperature</td>
<td>18.5 °C</td>
</tr>
<tr>
<td><strong>BOREHOLE</strong></td>
<td></td>
</tr>
<tr>
<td>Configuration:</td>
<td>6 : 2 x 3, rectangle</td>
</tr>
<tr>
<td>Borehole depth</td>
<td>50 m</td>
</tr>
<tr>
<td>Borehole spacing</td>
<td>3 m</td>
</tr>
<tr>
<td>Borehole installation</td>
<td>SINGLE-U</td>
</tr>
<tr>
<td>Borehole diameter</td>
<td>0.14 m</td>
</tr>
<tr>
<td>U-pipe diameter</td>
<td>0.032 m</td>
</tr>
<tr>
<td>U-pipe thermal conductivity</td>
<td>0.430</td>
</tr>
<tr>
<td><strong>HEAT CARRIER FLUID:</strong></td>
<td>Water</td>
</tr>
<tr>
<td><strong>HEAT PUMP:</strong></td>
<td>IZE70 + R290 (CIATESA)</td>
</tr>
</tbody>
</table>
Ground Source HE

backfilling:
sand (course and fine)
or sand/bentonite
alternative use of spacers

3x7
PT100 thermoressistances
to measure soil response
GeoCool data acquisition system

44 sensors in the loop (PT100, coriolis mass flowmeters and wattmeters)
On site automatic meteorological station w. 22 parameters
1 min sampling during 1 year
Analysis of data

\[ Q(t) = \dot{h}_{out}(t) - \dot{h}_{in}(t) = \dot{m}c_p(T_{out}(t) - T_{in}(t)) \]

• We are not characterizing heat pumps
GeoCoolizer Analysis system – instantaneous values

- Cooling/Heating
- Absorbed/Transferred capacity from/to the ground
- Instantaneous COP

\[ \dot{Q}(t) = \dot{m}c_p(T_{out}(t) - T_{in}(t)) \]

\[ COP = \frac{\dot{Q}}{\dot{W}} \]
GeoCoolizer system – integrated or averaged values

• Heating and cooling load
• Total energy absorbed/ transferred from/to the ground

• Electric energy

\[ Q = \int_{0}^{\Delta t} \dot{Q}(t) \, dt \]

\[ W = \int_{0}^{\Delta t} \dot{W}(t) \, dt \]

- From 7 a.m to 10 p.m
- The selected period (one week, all the season…)

• Seasonal Performance Factor (SPF)

\[ SPF = \frac{Q}{W} \]
GeoCoolizer analysis – statistical analysis

• Calculation of sample mean values (or statistical momenta):
  • Mean heating/cooling capacity
  • Mean electrical power
  • Mean COP
  • Mean external temperature

\[ \bar{X} = \frac{\sum_i x_i}{N} \]
Experimental results – comparative system performance in heating mode

![Graph showing comparative system performance in heating mode]
Analysis of data – dynamic behaviour
System cycling at different condition in heating

2nd February

14th April

Power consumption (kW)

Time (hours)

Heat Pump + Ext Circulation Pump
Fancoils + Int Circulation Pump

Heat Pump + Ext Circulation Pump
Fancoils + Int Circulation Pump

Time (hours)
Analysis of data – final energy savings

\[ SPF_{aw} = \frac{Q_{aw}}{W_{aw}} \quad SPF_{ww} = \frac{Q_{ww}}{W_{ww}} \]

Two systems with the same heating load

\[ Q_{aw} = Q_{ww} \]

\[ \frac{W_{aw} - W_{ww}}{W_{aw}} \times 100 = \left(1 - \frac{SPF_{aw}}{SPF_{ww}}\right) \times 100 = 42 \% \]
GSHP – system energy consumption distribution in heating
AW HP – system energy distribution in heating
Heating mode EWT
COP and SPF in cooling mode

![Graph showing COP and SPF values over time with a horizontal line at 60% and another at 2.72, and a vertical line at 4.36.]

- COP values: 60%
- SPF values: 2.72, 4.36
Analysis of data – Electricity saving from seasonal SPF

\[ SPF_{aw} = \frac{Q_{aw}}{W_{aw}} \quad SPF_{ww} = \frac{Q_{ww}}{W_{ww}} \]

Two systems with the same cooling load

\[ Q_{aw} = Q_{ww} \]

\[ \frac{W_{aw} - W_{ww}}{W_{aw}} \times 100 = \left(1 - \frac{SPF_{aw}}{SPF_{ww}}\right) \times 100 = 38\% \]
GSHP – Energy distribution in cooling
AW – HP Energy Distribution in cooling
Cooling mode - EWT
Comparison with design-expected results

**HEATING**
- Air-Water: SPF 2.96, 32%
- Water-Water: SPF 3.46, 11%

**COOLING**
- Air-Water: SPF 2.82, 3.5%
- Water-Water: SPF 4.6, 5%
Conclusions

- *In heating mode*, GSHP saves, in terms of primary energy consumption, **41% compared to the conventional one**.
- *In cooling mode* a 38% saving was obtained.
- **Capacity adaptation strategies** are needed to improve load factor and efficiency of (both) systems.
- The impact in electricity consumption of the **auxiliary elements** of the HVAC system was found to be large and should be taken into account to improve overall system efficiency.
- Improved control strategies should be implemented.
Further outlook

- **Rising interest in GSHP in our area**
  - 3 systems working outside Campus
  - 7 are under construction or advanced planning
    (2 of them >100 kW)
  - Increasing academic and social awareness

- **Barriers**
  - No one likes to be the first…!
  - Drilling costs
  - Market structure….
  - Lack of awareness and training …