PROJECT GEOCOND:
ADVANCED MATERIALS AND PROCESSES TO IMPROVE PERFORMANCE AND COST-EFFICIENCY OF SHALLOW GEOTHERMAL SYSTEMS AND UTES

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Project GEOCOND aims at improving substantially the operational efficiency of BHE systems by optimising the materials for individual components (pipes, grout) and the overall setup.

Participants of the kick-off meeting of project Geocond at Universitat Politecnica de Valencia, 10 May 2017
Technical Project Goals

Plastic pipes and fitting elements with high thermal conductivity

2x Higher thermal conductivity compared to currently commercial HDPE** pipes

** HDPE = High density Polyethylene
**Technical Project Goals**

New high conductivity borehole filling (grouting) materials, including low temperature PCM*

12% Lower borehole thermal resistance and higher heat storage capacity

* PCM = Phase Change Materials

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**Technology**

**Objective**

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Project Co-ordinator: UPV-VLC  
GA: 727583  
www.geocond.eu
Technical Project Goals

Tailor-made solutions for grouting materials and innovative pipes configuration

20% Reduction in borehole length
• Universitat Politecnica de Valencia, Valencia, Spain  (coordinator)
• AIMPLAS, Asocacion de investigacion de materiales plasticos y conexas, Paterna/Valencia, Spain
• RISE CBI Betonginstitutet AB, Stockholm, Sweden
• Sabançî Universitesi, Istanbul, Turkey
• Silma srl, Poggio a Caiano, Italy
• CAUDAL Extruline Systems S.L., Puerto Lumbrera, Spain
• Carmel Olefins Ltd., Haifa, Israel
• ÇİMSA Cimento Sanay ve Ticaret AS, Üsküdar Istanbul, Turkey
• UBeG Dr. Erich Mands und Marc Sauer GbR, Wetzlar, Germany
• Exergy Ltd, Coventry, England
In practice, HDPE-pipes dominate the market in Europe. The main reasons are:

**Cost and corrosion**
- Plastic pipes have superior corrosion resistance compared to plain metals in the same cost range
- Corrosion-resistant metals are much more expensive

**Handling**
- BHE made of plastic pipes can be delivered to the drilling site in coils, factory-finished and for the full length
- Most metals would mean sections of rigid steel tubes to be connected during installation on site.
- Corrugated metal tubes with thin walls (stainless steel) could also be pre-fabricated and coiled, but at much higher cost
State of the art - pipes

Pipe material properties, selected values from VDI 4640-2 (2015)

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal conductivity</th>
<th>Maximum operating temperature for 50 years pipe lifespan *</th>
<th>Maximum operating temperature for 1 year pipe lifespan *</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE100</td>
<td>0.42 W/(m·K)</td>
<td>40 °C</td>
<td>70 °C **</td>
</tr>
<tr>
<td>PE100-RC</td>
<td>0.42 W/(m·K)</td>
<td>40 °C</td>
<td>70 °C **</td>
</tr>
<tr>
<td>PE-RT</td>
<td>0.42 W/(m·K)</td>
<td>70 °C</td>
<td>95 °C</td>
</tr>
<tr>
<td>PE-X</td>
<td>0.41 W/(m·K)</td>
<td>70 °C</td>
<td>95 °C</td>
</tr>
<tr>
<td>PA</td>
<td>0.24 W/(m·K)</td>
<td>40 °C</td>
<td>70 °C</td>
</tr>
<tr>
<td>PB</td>
<td>0.22 W/(m·K)</td>
<td>70 °C</td>
<td>95 °C</td>
</tr>
</tbody>
</table>

* at given maximum pressure conditions ranging from 0.6-1.2 MPa
** even short-time excess temperatures can damage pipes
• The supposedly first publication on the idea of grout with enhanced thermal conductivity is Remund & Lund (1993).

• In the mid-1990s, a thermally enhanced grout (with siliceous sand) came on the market in the USA, with a thermal conductivity of almost 1.5 W/(m*K); in American units, this means 0.85 Btu/(hr*ft*°F), leading to the name of thermal grout 85.

• Experiments in 1996-1999 at Brookhaven National Laboratory in USA targeted different additives for increased thermal conductivity (Allan & Philippacopoulos, 1999).

• Developments in Germany around 2000 resulted in grout mixtures with addition of either quartz powder or graphite, under the brand names Stüwatherm and Thermocem, resp.
• Also in VDI 4640-2 (2001) the addition of quartz sand was suggested to improve thermal properties.

• In the meantime, numerous brands of grout ready for use are on the market. The thermally enhancing additives are either siliceous sand, quartz powder or graphite.

• A specific issue at least in Germany is the behaviour of the grout during freezing-thawing-cycles (Anbergen et al, 2012), when damage of the grout texture and increase of hydraulic permeability (loss of sealing properties) may occur. In draft VDI 4640-2 (2015), a routine for testing the grout while freezing is proposed in appendix C.

• Any new mixtures with enhanced thermal conductivity will have to meet also the sealing requirements.
What have we learnt from the project?

- Thermal conductivity maps considering the European geological setting with very good correlation with well known areas have been produced. Other maps with more information related to relevant aspects such as HDD, CDD, population density, etc have been created.
<table>
<thead>
<tr>
<th>Area [km²]</th>
<th>Germany</th>
<th>Israel</th>
<th>Italy</th>
<th>Spain</th>
<th>Sweden</th>
<th>Turkey</th>
<th>UK</th>
<th>GEOCOND study area</th>
</tr>
</thead>
<tbody>
<tr>
<td>356'496</td>
<td>28'264</td>
<td>298'614</td>
<td>504'083</td>
<td>443'494</td>
<td>779'164</td>
<td>239'721</td>
<td>5'812'513</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Therm. Cond. [W/(m*K)]</th>
<th>% area</th>
<th>% area</th>
<th>% area</th>
<th>% area</th>
<th>% area</th>
<th>% area</th>
<th>% area</th>
<th>% area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2-1.5</td>
<td>16.5</td>
<td>19</td>
<td>9.7</td>
<td>0.54</td>
<td>0.01</td>
<td>10</td>
<td>6.9</td>
<td>9.5</td>
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<tr>
<td>1.5-2.0</td>
<td>37.5</td>
<td>8</td>
<td>30.6</td>
<td>34.2</td>
<td>11.7</td>
<td>25</td>
<td>5.7</td>
<td>30.0</td>
</tr>
<tr>
<td>2.0-2.5</td>
<td>18.7</td>
<td>69</td>
<td>24.0</td>
<td>36.2</td>
<td>5.7</td>
<td>50</td>
<td>31.0</td>
<td>21.8</td>
</tr>
<tr>
<td>2.5-3.0</td>
<td>25.2</td>
<td>4</td>
<td>34.1</td>
<td>23.5</td>
<td>75.8</td>
<td>15</td>
<td>53.5</td>
<td>35.7</td>
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<td>3.0-3.5</td>
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<td>0</td>
<td>1.0</td>
<td>2.8</td>
<td>3.4</td>
<td>0</td>
<td>3.0</td>
<td>1.9</td>
</tr>
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<td>0</td>
<td>0.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>4.0-4.5</td>
<td>0.23</td>
<td>0</td>
<td>0</td>
<td>2.7</td>
<td>0.07</td>
<td>0</td>
<td>0</td>
<td>0.3</td>
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<tr>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5.0-5.5</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>3.3</td>
<td>0</td>
<td>0</td>
<td>0.7</td>
</tr>
</tbody>
</table>

- **GEOCOND study area**

- **Graphs:**
  - Bar graph showing the percentage of area in different thermal conductivity classes.
  - Column chart showing the percentage of area and population in different thermal conductivity classes.
What have we learnt from the project?

- Models and simulations shows that the best possible configurations combining pipes and grouting thermal conductivity are in ranges of thermal conductivity of pipes around 1-1.4 and thermal conductivity of the grouts between 2-3 W/mK.

- The importance of the mixing procedure of grouts has been deeply analysed with some “shocking” results. A bad mixing procedure of an enhanced grout may result in very low thermal conductivity values!!
At this stage, the target materials and additives cannot yet be disclosed; however, the main pathways are:

- Plastic pipes with thermal conductivity around 1 W/mK has been produced at lab scale and it is being upscaling to real scale heat exchangers.
- New plastic geometrical configurations optimised in terms of heat exchange and pressure loss has been designed and simulated. Presumably, those pipes will be soon upcaled.
- New additives for grouts to increase thermal conductivity and provide tailor-made performance while improving handling and bounding characteristics; inclusion of phase change materials (PCM) in additives to enhance thermal storage capacity, in particular for UTES applications.


- Deep analysis of the mixing procedure of groutings was achieved and it is allowing to perform new generation of grouts.
- A Material Selection Support System, based on multi-objective simulation and optimisation within a simulation software, is under development to allow rational selection of best material specifications for a range of applications. These selection based in multi-criteria analysis algorithms consider not only the efficiency of the systems but other items such as production costs, LCA, associated carbon footprint, etc.
Validation of performance increase will be done in two steps in 2019-2020:

- first with samples of ca 15 m length in a well-explored test field at the Universitat Politecnica de Valencia
- then in the frame of some real BHE installations in Germany and Finland (BTES or UTES associated to district heating).

The whole activity is accompanied by investigation of environmental, social and economic feasibility of the concepts.
Project GEOCOND aims at improving substantially the operational efficiency of BHE systems by optimising the materials for individual components (pipes, grout) and the overall setup. This improvement in technical efficiency shall be translated into cost savings in installation and operation, allowing for a leap in economic benefits of shallow geothermal technology. Furthermore, a significant reduction of the drilled meters and the amount of pipes used to fulfil the same heating and cooling needs enables a decrease of environmental impact.
Keep in touch

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