

A background illustration showing a cross-section of the earth. At the top, a house is visible. Below the ground surface, there are two vertical boreholes. Red arrows indicate the flow of fluid between the surface and the boreholes. The boreholes are labeled with circled numbers 1 and 2. The ground is depicted with various geological layers and textures.

PROJECT GEOCOND:

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

Jose Manuel Cuevas on behalf of the project consortium

Project GEOCOND aims at improving substantially the operational efficiency of BHE systems associated to shallow geothermal energy by optimizing the materials of the individual components (pipes, configurations, 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.



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Plastic pipes and fitting elements with high thermal conductivity

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

** HDPE= High density Polyethylene



Technology




Objective

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

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

* at given maximum pressure conditions ranging from 0.6-1.2 MPa

** even short-time excess temperatures can damage pipes



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



Technology



Objective

- 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 $1.5 \text{ W}/(\text{m} \cdot \text{K})$; in American units, this means $0.85 \text{ Btu}/(\text{hr} \cdot \text{ft} \cdot ^\circ\text{F})$, 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.



Tailor-made solutions for grouting materials and innovative pipes configuration

20% Reduction in borehole length



Technology



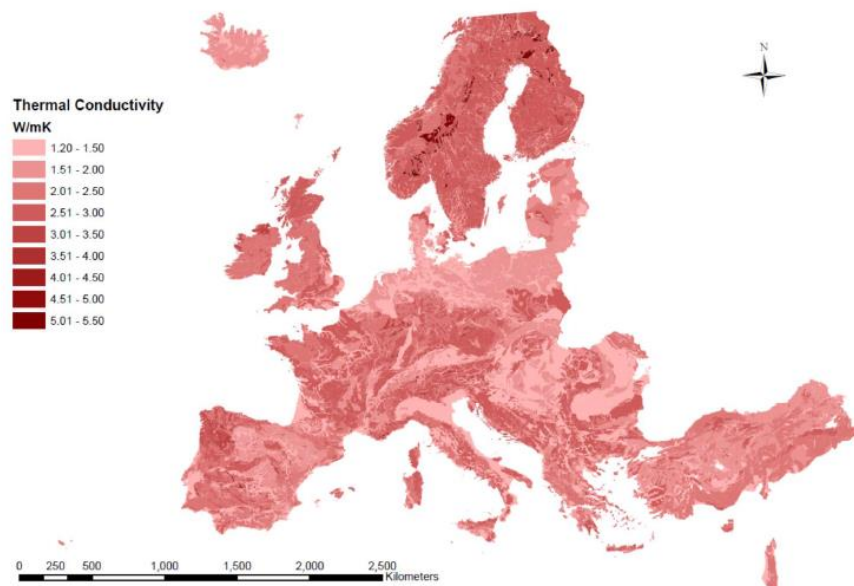
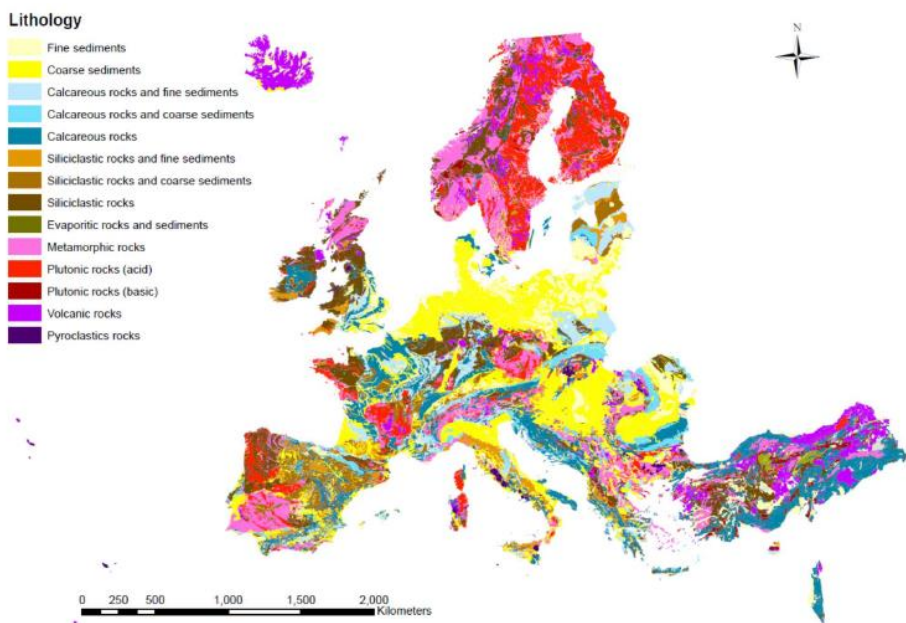
Objective

Geological aspects related to Shallow Geothermal systems:

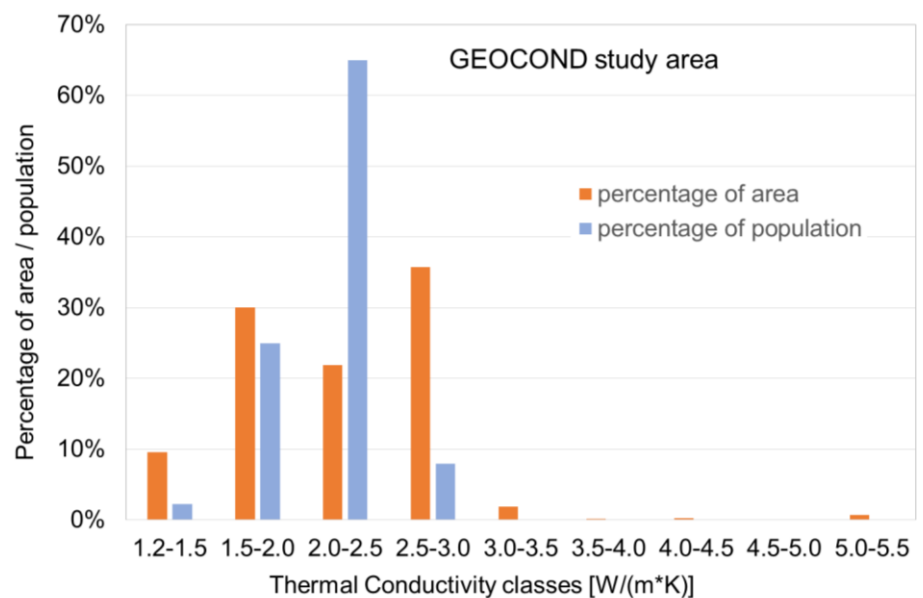
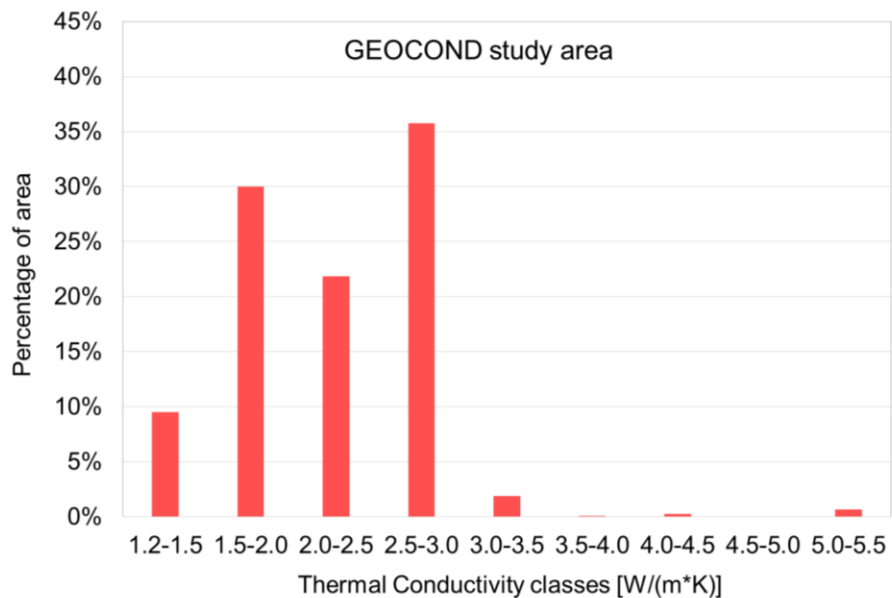
- Lithology and petrography
- Characterization including texture and structure of the rocks
- Hydrogeological setting
- Drillability (hardness and cohesion of rocks)
- ...

What are the main GEOLOGICAL ASPECTS ?

- Thermal conductivity maps considering the European geological setting (derived from EGD) 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.

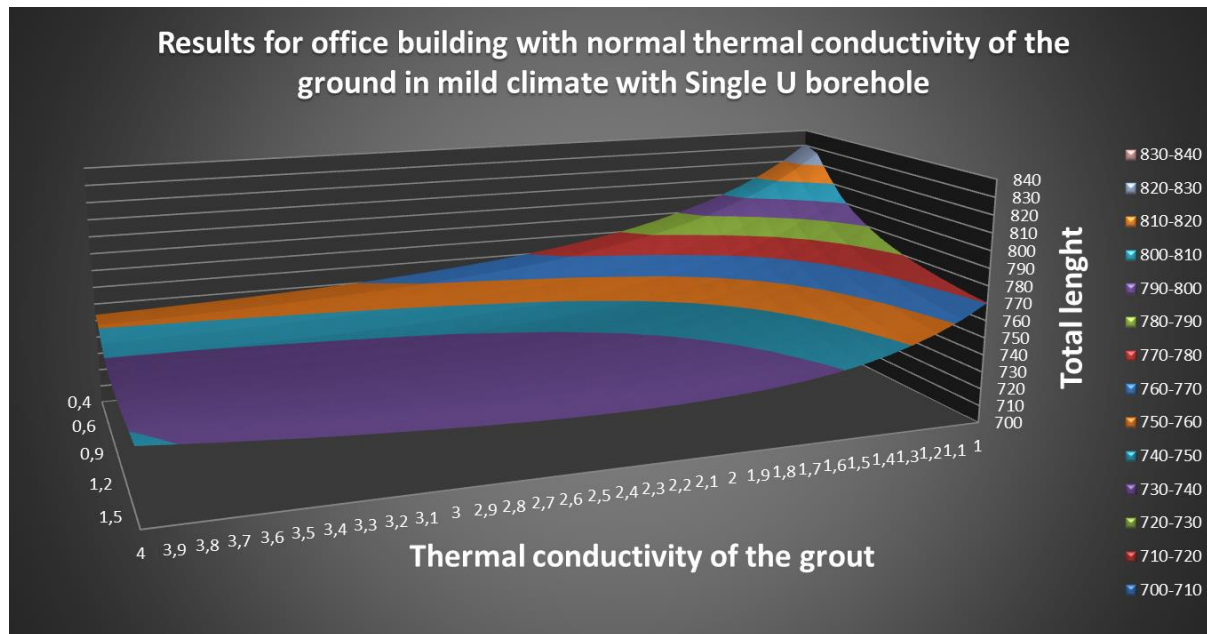


	Germany	Israel	Italy	Spain	Sweden	Turkey	UK	GEOCOND study area
Area [km ²]	356'496	28'264	298'614	504'083	443'494	779'164	239'721	5'812'513
Therm. Cond. [W/(m*K)]	% area	% area	% area	% area	% area	% area	% area	% area
1.2-1.5	16.5	19	9.7	0.54	0.01	10	6.9	9.5
1.5-2.0	37.5	8	30.6	34.2	11.7	25	5.7	30.0
2.0-2.5	18.7	69	24.0	36.2	5.7	50	31.0	21.8
2.5-3.0	25.2	4	34.1	23.5	75.8	15	53.5	35.7
3.0-3.5	1.9	0	1.0	2.8	3.4	0	3.0	1.9
3.5-4.0	0.02	0	0.6	0	0	0	0	0.1
4.0-4.5	0.23	0	0	2.7	0.07	0	0	0.3
4.5-5.0	0	0	0	0	0	0	0	0
5.0-5.5	0	0	0	0	3.3	0	0	0.7



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 analyzed with some “shocking” results. A bad mixing procedure of a enhanced grout may results 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.

Keep in touch

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