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GROUND SOURCE HEAT PUMPS (GSHP) IN EUROPE: CLIMATE & GEOLOGY SET THE FRAME FOR APPLICATIONS

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SUMMARY/ABSTRACT

Within Europe, a large variety of climatic and geological conditions can be found. Both have a strong influence on the opportunities for GSHP installation. While the climate (in conjunction with architecture etc.) dictates the heating and cooling loads, it also sets the basics on the ground temperature side by dictating the undisturbed ground temperature. Geology on the other hand controls thermal parameters of the ground (in particular its ability to transfer heat), and limits the choice of drilling methods. It should be kept in mind always that these parameters can not be changed by design, the design just can adapt to climate and geology!

INTRODUCTION

GSHP design needs to answer to two different kinds of site-specific parameters:

- Building-related parameters
  - building size, type of construction and architecture, building use, climatic conditions on site, etc.
- Ground-related parameters
  - On surface: available area, ownership, other site constraints like construction equipment, etc.
  - Below surface: geology and hydrogeology, thermal ground parameters

1 GEOLOGY

The geological situation is that part of GSHP design which **cannot be changed** by the planner. Design needs to adapt to geology, and thus requires knowledge of geological data:

- Rock type and hardness (affects GSHP drilling)
- Ground thermal characteristics (affects GSHP design and operation)
- Groundwater situation (affects GSHP design, drillling and operation)
- Natural ground temperature (affects GSHP design)

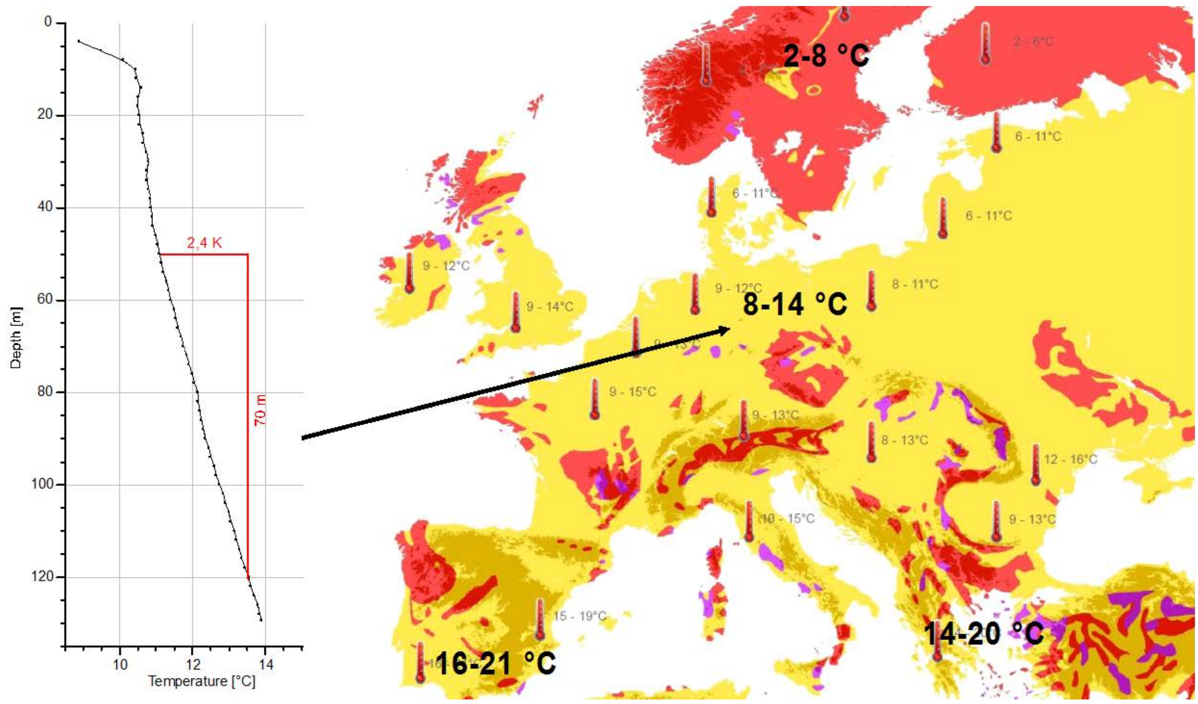

Figure 1: Ground temperatures throughout Europe (map prepared by BRGM for the Geotrainet project, temperature profile by UBeG)

Typical geological situations and their impact on drilling are presented in figures 2-x.

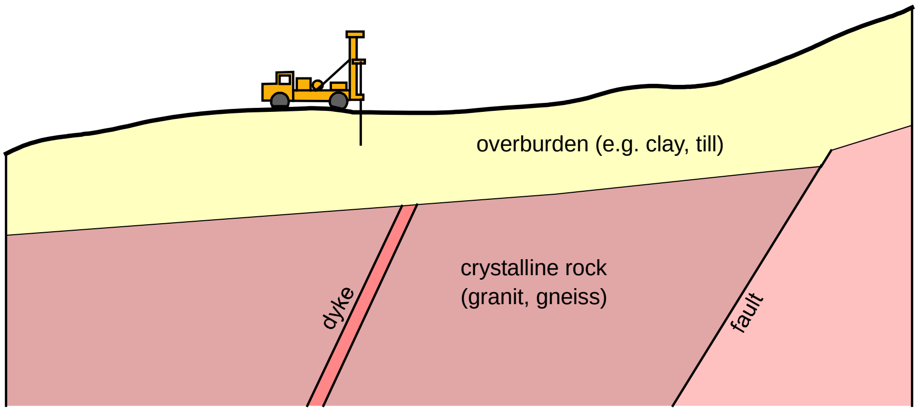

Figure 2: Crystalline rocks (e.g. Baltic-Scandinavian shield region), drilling using DTH, with over-burden casing if required

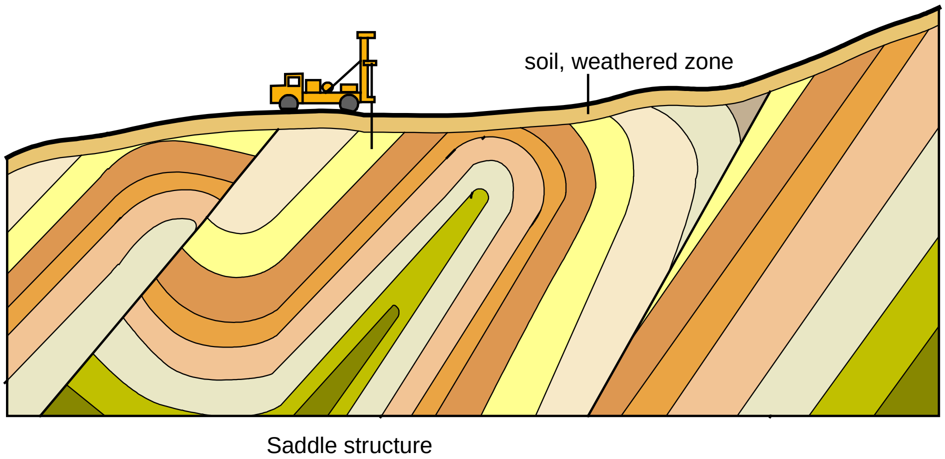

Figure 3: European fold belts, sedimentary rocks folded and faulted, drilling mostly using DTH, groundwater only in fissures and fractures, grouting always required

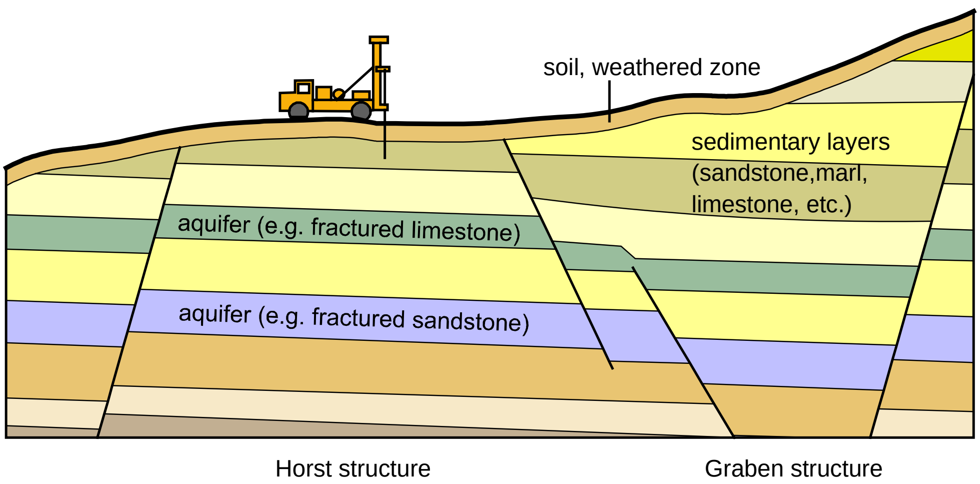

Figure 4: Mesozoic Europe, sedimentary layers of varying hardness and permeability; possibility of confined or artesian groundwater, drilling could be DTH or rotary, depending on rock hardness

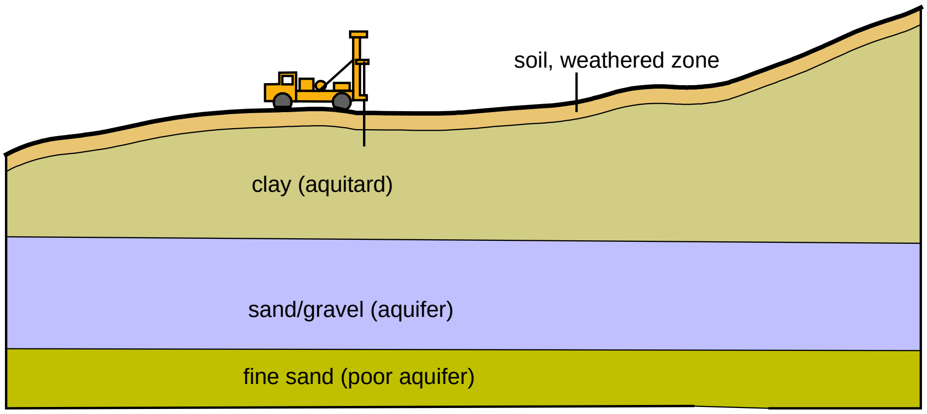

Figure 5: Sedimentary basins of Europe, unconsolidated sediments; possibility of confined or artesian groundwater, drilling with rotary and temporary casing

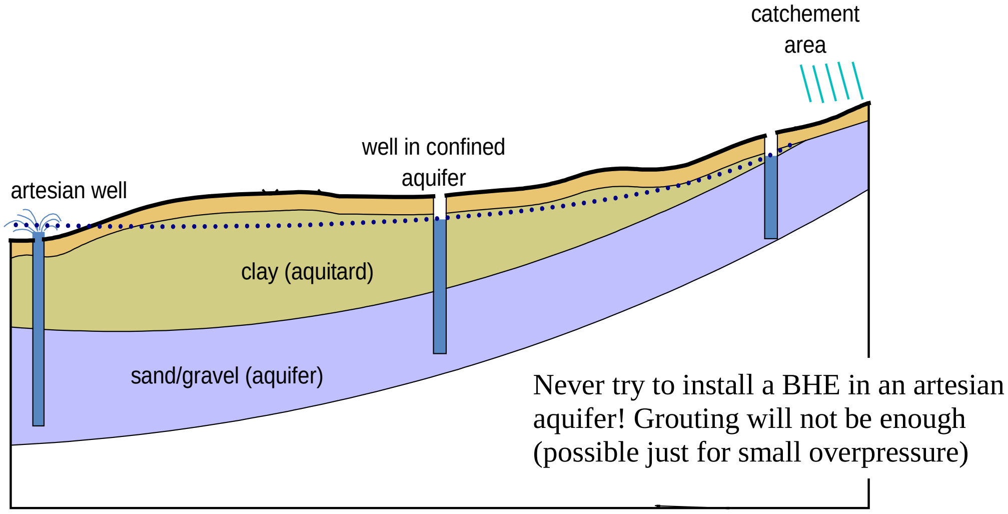

Figure 6: Possible groundwater pressure problems

2 CLIMATIC CONSTRAINTS

In Northern climate, the minimum ground temperatures while heating are typically the limit to application. In particular with larger BHE fields, re-heating the ground in summer is essential (with heat i.e. from space cooling, from solar collectors, etc.).

Like cooling down in Northern climate, heating up the ground in Southern climate is a limit to application. Balancing is required, re-cooling in winter or cold storage. Seasonal cold storage might not be sufficient, and cold from night needs to assist. Early examples for diurnal cold storage have been studied for a site in Egypt (1998), and diurnal cold storage now is e.g. designed for retail outlet in Jerez de la Frontera, Spain.

The example in Jerez [Fernández et al., 2012] is discussed here in somewhat more detail, in order to show the chances of innovative balancing strategies, and because it highlights the ground-side design constraints. A little more than fifteen km from the Atlantic Ocean, Jerez is characterized by mild winters and very hot and dry summers, with 17.7 °C annual average. The extreme temperatures in August in a long-term average rise to 33.1 °C maximum and fall to 18.4 °C minimum, and the actual readings exceed 38 °C each year on several occasions. Thus cooling demand in this region exceeds any heating demand by far, in particular in commercial buildings with lot of internal heat sources. Designing a GSHP for cooling under these conditions requires unconventional solutions; seasonal storage is hardly feasible, with mean temperatures in winter not lower than 10 °C.

The company owning the retail outlet has equipped already a number of its large stores with GSHP, mainly in Northern Europe, but the one in Jerez is quite different for the specific climatic conditions it has to deal with. Given the climate of Jerez and the building design and concept used for the retail building, there is a totally unbalanced thermal energy demand:

Heating demand:	75 MWh/a
Cooling demand:	4’104 MWh/a

Thus heat accounts for only 1.8% of the demand for cooling. The monthly building loads are given in figure 7; even in winter, the monthly cooling demand is higher than heating demand!

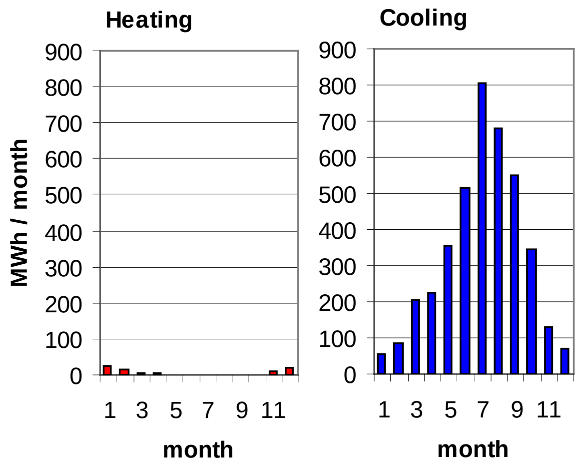

Figure 7: Monthly heating and cooling loads as to building design for Jerez retail outlet (after [Fernández et al., 2012])

The design target under these conditions was to create a geothermal HVAC system that covers the full (small) heating demand and a part of the total cooling demand as large as possible. For this extremely unbalanced situation, a substantial part of the cooling can only be covered if sufficient cold is stored in the underground, or in other terms, surplus heat is extracted from the underground. The final design hence did not only include cold storage in wintertime for a seasonal balancing, but also short-term cold storage during night in summer. With using all time available for heat extraction, considering the periods when ambient air temperature is sufficiently lower than ground temperature, a maximum annual cooling supply of about 700 MWh/a might be achieved.

For the BHE design, several thermal response tests (TRT) had been done in advance with a resulting thermal conductivity of 1.5 W/m/K. The undisturbed underground temperature was 19.8 °C, a rather high value compared to classical GSHP countries like Sweden or Germany.

From economic considerations, the maximum number of BHE was limited to 50, with a maximum distance of 8 m among each, and a maximum depth of 130 m. So the primary design task was to check what would be the maximum cooling that could be provided by a BHE-field of this size. Calculations using a standard approach resulted in the possible loads as shown in table 1; of the total annual cooling demand of >4 GWh, only about 7 % could be covered from the ground that way.

As the percentage of geothermal coverage of the cooling load is so small, an almost steady operation over the whole year for this very base load can be assumed. The heating in wintertime is only able to reduce the heat injection into the BHE field, but not to turn it into heat extraction. As a result, the operation would be dominated by continuous heat dissipation into the underground, and in consequence the ground temperature would rise constantly.

Even in summertime, ambient air at night can be colder than the temperature in the BHE field. As temperature in the underground will rise steadily over the years also when active re-cooling is done (the increase just being slower than in the standard case), the opportunities for re-cooling with nighttime ambient air will improve over time.

Table 1: Load data on building and ground side for two different scenarios for Jerez retail outlet (after [Fernández et al., 2012])

	supply to building	geothermal coverage *	expected SPF	BHE extraction for heating	BHE extraction from re-cooling	total BHE extract. / inject.
Standard case						
Heating	75 MWh/a	100 %	5	60 MWh/a	-	60 MWh/a
Cooling	300 MWh/a	7 %	3			450 MWh/a
Maximum cooling case						
Heating	75 MWh/a	100 %	5	60 MWh/a	420 MWh/a	480 MWh/a
Cooling	530 MWh/a	13 %	3	-	-	795 MWh/a

* percentage of total building loads

Weather data from nearby Cadiz were used to assess the amount of re-cooling that could be done during spring, summer and autumn (example for July given in figure 8). In order to use the cold from the ground efficiently, no geothermal cooling was assumed from November to March, as the lower ambient air temperatures in wintertime will allow for efficient use of air coolers. Using the ground for cooling is more desirable in summer, when ground temperatures are much lower than cooling water from air coolers. The software EED was also used here to calculate the temperature development, and eventually the load data as given in table 1 were deemed feasible.

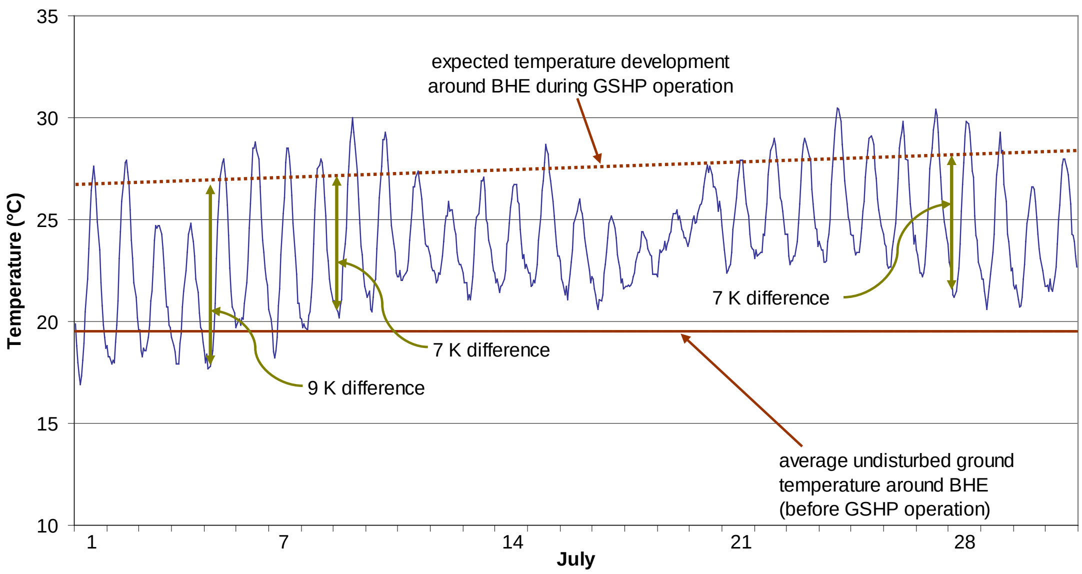

Figure 8: Hourly dry air temperature in July (data for Cadiz, from Spanish Meteorological Service) and ground temperatures in undisturbed situation and during GSHP operation (cf. [Fernández et al., 2012])

The complete geothermal system consists of borehole heat exchangers (BHE), heat pump and dry cooler(s). The 50 BHE were finished in 2010, and the underground thermal storage volume around the BHE now extends to about 553’000 m^3. Alas, by the time of writing, no monitoring data could be evaluated yet.

With this innovative design concept, adapted to Mediterranean climate and combining both diurnal and seasonal cold storage, the cooling output from BHE can be increased in a sustainable way. In summer, the underground works as a store of cold during the night and as a sink of heat during the day (diurnal storage). In wintertime, the regular operation of the heat pump for heating extracts some heat from the ground, and additional heat extraction (or re-cooling) is done by dry cooler (seasonal cold storage).

3 REFERENCES

Fernández, A., Mands, E., Sanner, B., Sauer, M., Novelle, L., 2012: Underground diurnal and seasonal energy storage for a cooling and heating system in a retail building in Jerez de la Frontera / Spain, Proc. Innostock 2012 Lleida, paper #INNO-U-24, 8 p

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