



# Cheap and efficient application of reliable Ground Source Heat exchangers and Pumps



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GA n. 657982-  
Duration: 4 years – Start June 1 2015  
Total project budget: 5.804.847,50 €  
EU contribution: 4.844.652,00 €



## General objectives

- ❑ To **reduce total cost of ownership** of shallow geothermal systems **by 20-30% compared to actual state of art**
- ❑ To **increase** the **deployment** of this technology **by 10%** versus current estimates
- ❑ To **contribute to the environment** with an additional **CO<sub>2</sub> emission reduction of 1800 T/y** and **to increase the safety**
- ❑ To **demonstrate the new technologies in civil** and **historical buildings** (6 real sites and 10 virtual cases)

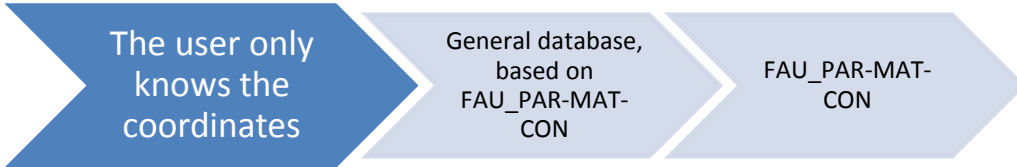
## Project innovations

- ❑ **Thematic geothermal mapping at local scale for better planning of geothermal systems**
- ❑ **Drilling machine developments** combined with **new Ground Source Heat Exchanger (GSHE) designs of co-axial and heat basket type** to reduce installation time, increase yield, increase safety, reduce permit needs
- ❑ **Design software for GSHE and heat pumps and Decision Support System (DSS)** for optimum selection, design and implementation of **complete systems** across different applications and soil conditions
- ❑ **Novel heat pump with improved performance at higher temperatures** to avoid having to change heating terminals in retrofitting of existing/historical buildings and **to increase efficiency**



# GEOLOGICAL DATABASE

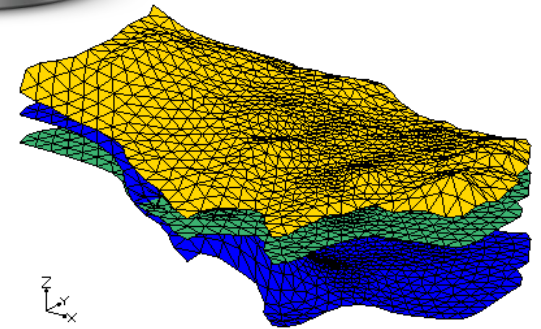
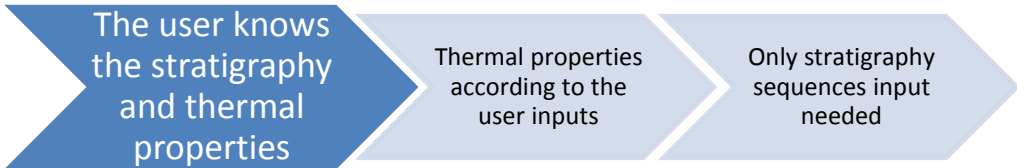
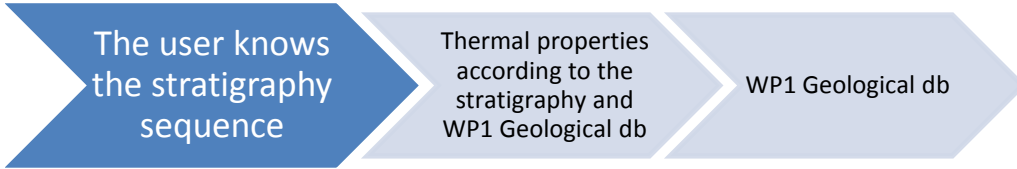
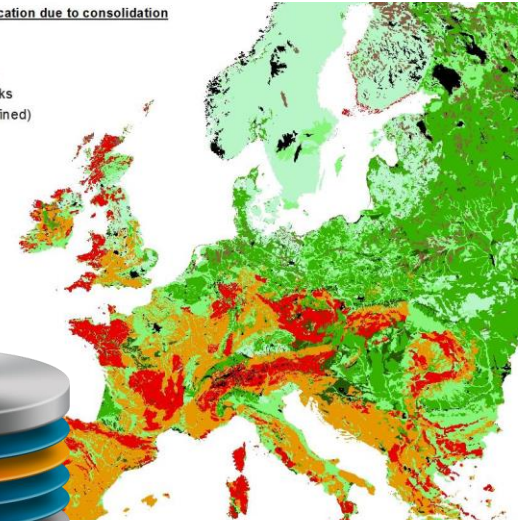
The geological database must to support the software tool and the DSS for every EU location. As result, it provides different information according to the user level of local geological knowledge.



Dominant Parent Material for classification due to consolidation (FAU\_PAR-MAT-CON)

- No Information
- Igneous & Metamorphic Rocks
- Consolidated Sedimentary Rocks
- Unconsolidated Material (undefined)
- Sand (unconsolidated)
- Clay (unconsolidated)
- Gravel (unconsolidated)
- Organic Material

Kilometers  
0 155 310 620 930 1.240



## Specifics on the key developments in drilling and heat exchanger design

### Drilling machine/method

Hollow dry auger  
400 mm diameter  
Drill bit to loose



### Heat basket



### Ground source heat exchanger

Basket diameter: 325 – 350 mm  
Pitch : 600 – 690 mm  
Coextruded piping of 20 – 25 mm

### Coaxial

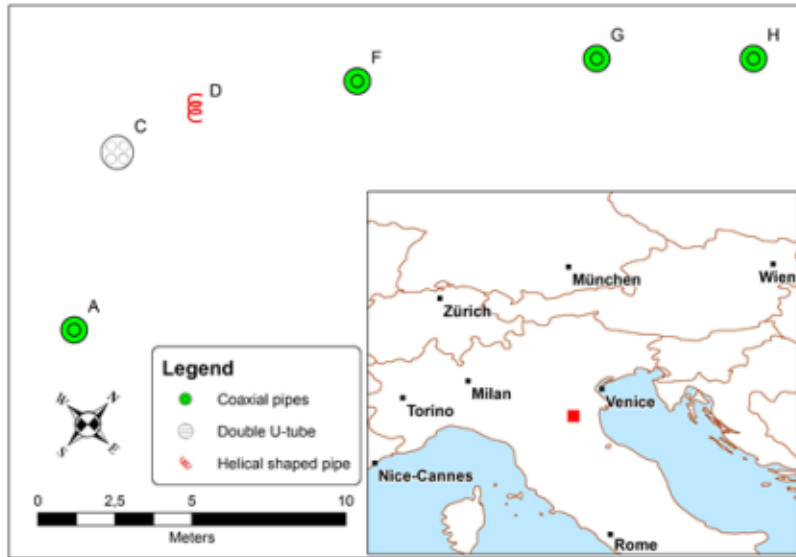
Installation via piling  
New drilling head



Cost optimized diameter: 76 mm  
External tube in Stainless Steel  
Foam insulated coextruded  
internal tube

## The pilot site of HYDRA at Molinella - Italy

New heat exchangers installed next to existing ones; TRT tests on all



Borehole	Type	Length [m]	Borehole diameter [mm]	Notes
A	Coaxial pipes	96	76.1	Outer pipe in stainless steel.
C	Double U-tube	50	125	Pipes in HDPE.
F	Coaxial pipes	50	101	Outer pipe in PVC with grouting material.
G	Coaxial pipes	50	50	Outer pipe in stainless steel.
H	Coaxial pipes	50	60.3	Outer pipe in stainless steel.
D	Helical shaped pipe	15	400	Helical pipe in PE-Xa and aluminium with grouting material.

First results encouraging for piling method with coaxial heat exchanger

**3 hrs** to pile coaxial heat exchanger of **76 mm 96 meters** in unconsolidated soil of clay and sand

**Borehole resistance values** of coaxial heat exchangers substantially **lower** than for double U

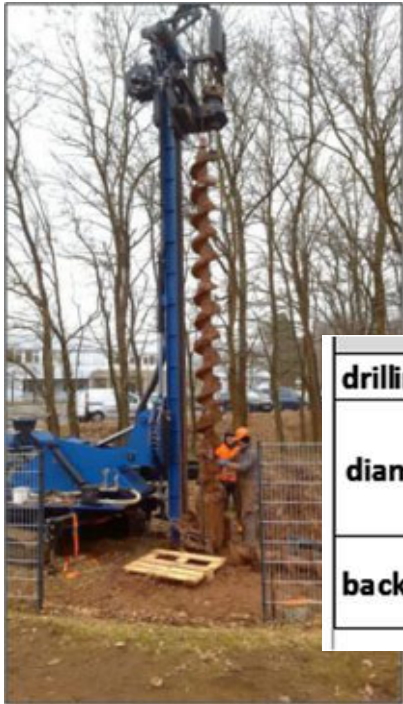
Coaxial in SS                      from 0,001 to 0,028 mK/W

Double U                              0,041 mK/W

Coaxial in PVC                      0,142 mK/W

## Demonstration site at REHAU premises in Erlangen (1/2)

- **4 basket heat exchangers** installed at 8 meters depth using dry and hollow auger
- Installation time ranging from 2 ½ to 4 hrs



4 different types of grouting

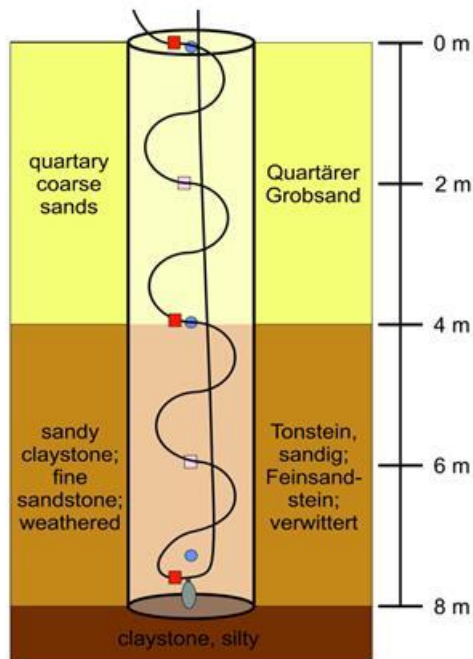
drilling method	auger + easy drill	auger	auger	auger
diameter [mm]	390 (auger) + 340 (inner Ø easy drill)	390	390	390
backfilling	in situ sediments + topsoil	30% Claypowder 70 % Sand	100 % Sand (0-2 mm)	15 % Bentonite 85 % Sand



## Demonstration site at REHAU premises in Erlangen (2/2)

- Monitoring : temperature and humidity sensors at different depths for each borehole
- Performance monitoring and TRT testing ongoing; results published February 28 2018

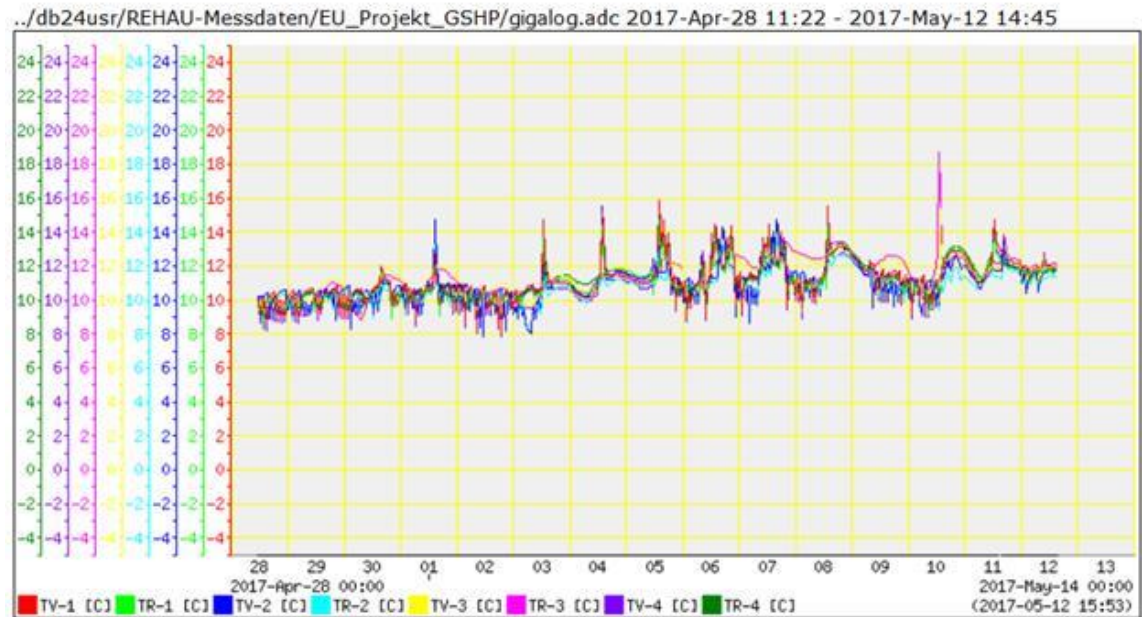
Installation plan Helix - REHAU test site  
Installationsplan Helix - REHAU Testfeld



- temperature sensor inlet pipe / Temperatursensor Vorlaufrohr
- temperature sensor borehole centre / Temperatursensor Bohrlochzentrum
- moisture sensor borehole centre / Feuchtesensor Bohrlochzentrum

File	Name	Inputs	Storage rate	Lines	From	To	Period	GPS
Files	<a href="#">gigalog</a>	54	1 m	~20000	2017-Apr-28 11:22	2017-May-12 14:45	14d 03h 23m	<a href="#">49.54..</a>

From date: 2017 : 04 : 28 00 : 00
  16 Days
  600 x 340



## Demonstration site: Bioclimatic office building of CRES

(Centre for Renewable Energy Sources & Saving)

**4 borehole HEs** (single-U, double-U, stainless steel coaxial and helicoidal)

**one pair of production-reinjection wells**, coupled to a water source heat pump of very high energy efficiency, for heating and cooling to a nearly zero energy building.

Monitoring system for online real time monitoring.

**New technologies demonstrated or tested on site:**

Innovative drilling rig and equipment; Coaxial BHE and piling method; Helix BHE and installation method.



**Monitoring period:** 18 September 2017 – 31 May 2019

## Demonstration site: Bioclimatic office building of CRES

(Centre for Renewable Energy Sources & Saving)

Thermal response tests indicate thermal conductivities 2.6-4.1 W/mK

BHE	depth, m	main geology	water level, m	effective thermal conductivity, W/mK	borehole thermal resistance, mK/W
Helicoidal	15	clay	15	4.129	0.115
Coaxial	50	clay	8	2.643	<b>0.050</b>
Single-U	119	clay, sandstone	8	3.196	0.130
Double-U	121	clav. sandstone	8	2.965	<b>0.073</b>

During normal operation of the heating system the coaxial BHE has a **31% better** heat transfer than the **double-U** as it has the lowest borehole thermal resistance.

Real time monitoring of the BHE energy output during heating indicates that in transient conditions the **coaxial BHE has the highest geothermal energy output per meter** (80-100 W/m compared to 50 W/m of the single and the double U)



## Demonstration site: Polytechnical University of Valencia (1/2)

The demonstration test site consists of **three typologies of borehole heat exchangers: single U (15 m), coaxial (15 m) and helix (10 m)**, installed in a triangle , 6 meters apart

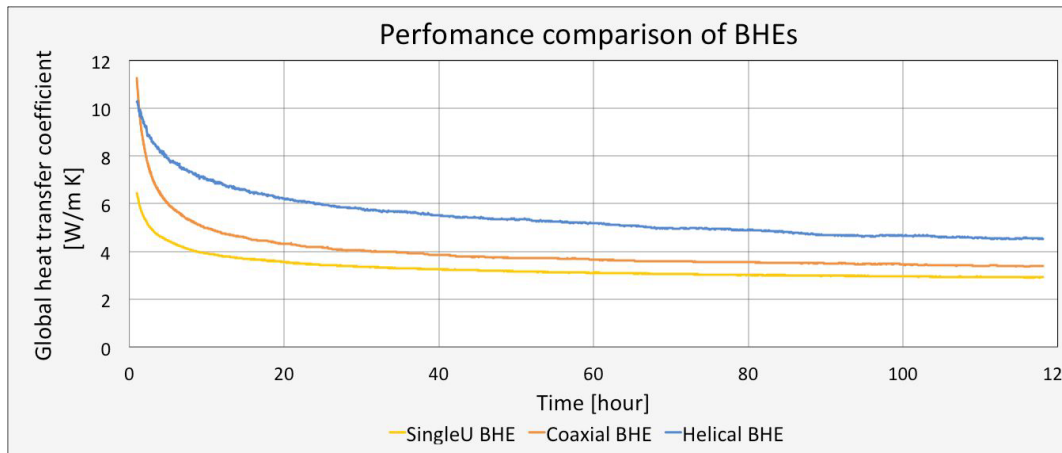
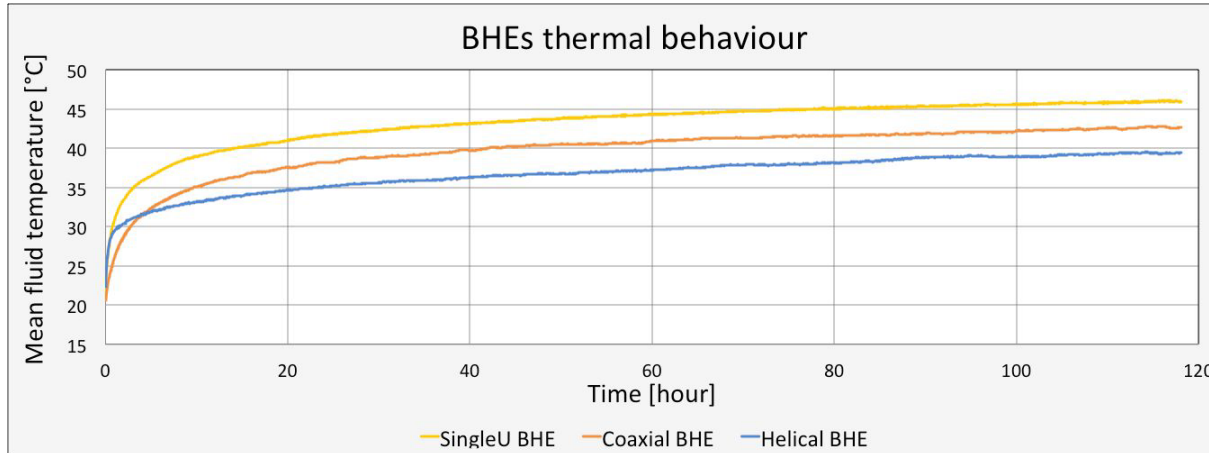


Thanks to an appropriate control system, it is possible to feed the borehole heat exchangers with **ideally constant hot/cold power input** with the aim to perform **Thermal Response Tests (TRTs)** or simulate a **thermal profile of a typical building**.



## Demonstration site: Polytechnical University of Valencia (2/2)

### BHEs results injecting the same specific thermal load (80 W/m)



## Demonstration site : residential eco-house in Belgium (1/2)

6 BHE's at 78 meters depth:

- ✓ 2 double U's,
- ✓ 2 coaxials of 50 mm,
- ✓ 2 coaxials of 76 mm (one with an insulated internal tube).



**Thermal energy meters** installed on each coaxial and on the pair of double U's monitor thermal performance of each BHE type under normal operation of the heat pump.



**Feasibility of the piling method** in hard clay layers (Boom clay) **demonstrated** : coaxial BHE installed at 80 meters at rates of 2 meters/min.

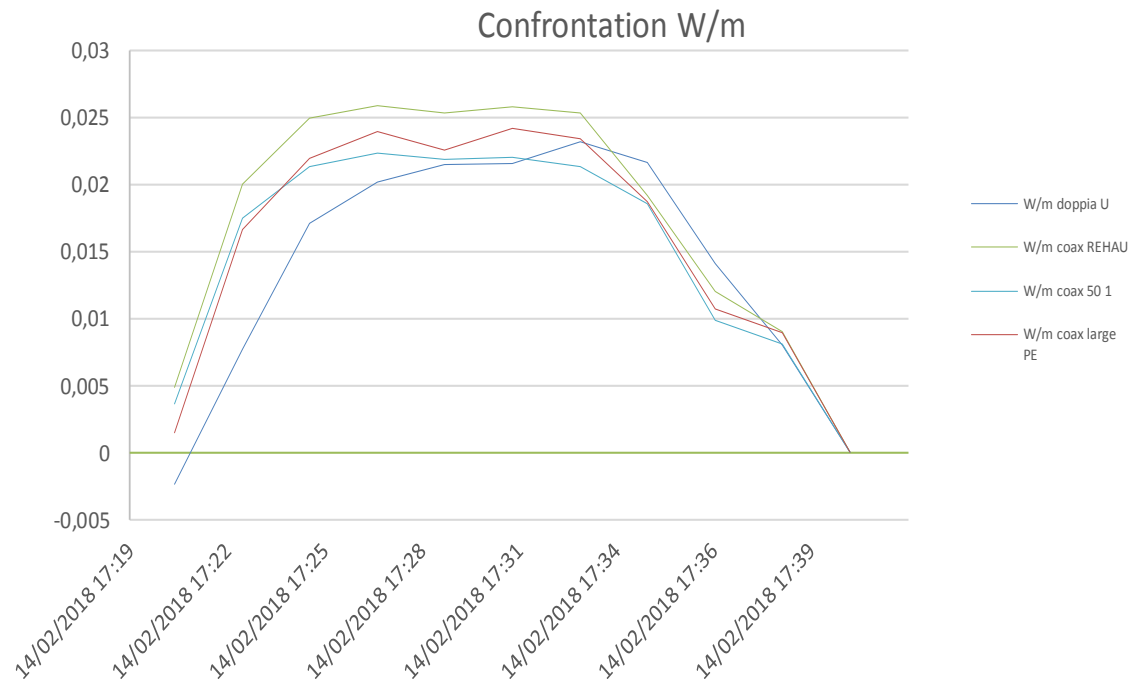


## Demonstration site : residential eco-house in Belgium (2/2)

Thermal response tests confirm the lower borehole resistance of the steel coaxial BHE's

BHE	Borehole resistance (K/Wm)	Conductivity (W/mK)
Coax 76 mm w/insulated	0,036	2,06
Coax 76 mm w/o insulated	0,061	2,27
Double U	0,076	2,16
Coax 50 mm	0,048	2,31

During normal operation of the heating system, the large coaxial BHE's show the highest thermal extraction performance in transient conditions: **10 - 20 % better than the double U** and **10 % better than the small coaxial BHE's**



## Demonstration site: Belfield house , University College Dublin

Estates Office Building

**5 kW heat pump** connected to a **Single-U 40mm** in a **150m borehole** for Partial Space Heating of Energy Centre Building



### Summary of the installation

	Helix	Coaxial
Diameter	325mm	76mm – 32mm inner tube
Depth	9.2m	35m
Material	PEX-a	Stainless Steel 304L
Finished Drilling Diameter	455mm	90mm
Drilling Method	Auger to 9.2m	DTH to 35m with 152mm casing
Grouting material	Sand & Excavated material	Thermally Enhanced Grout
Pitch	50mm	N/A
Thread Sealant	N/A	Loctite 270 & Activator 7649

## Demonstration case : Technical Museum Nicola Tesla, Zagreb

An exhibition room is heated and cooled using fan coils and a **prototype Heat Pump** of 30 KW **operating in heating mode at temperatures of 60 – 70°C**

The Heat Pump is connected with **6 Borehole HE's**:  
3 double U's and 3 coaxials of about 100m depth.

The **monitoring system** will measure the **COP** of the Heat Pump and the thermal performance of one double U and one coaxial heat exchanger.

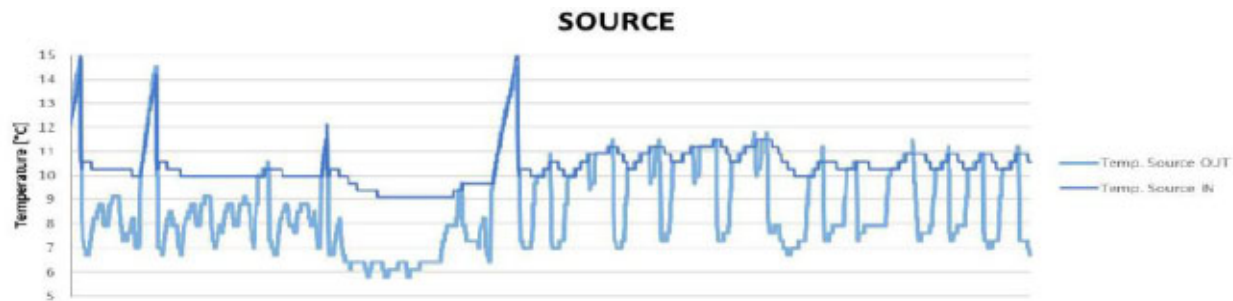
For **didactical purposes**, the technical room will give visibility to the equipment and to the key performance parameters of geothermal heating and cooling systems



## Development of new ground source heat pump of high temperature with CO2 refrigerant

After 1 month of operation during heating season:

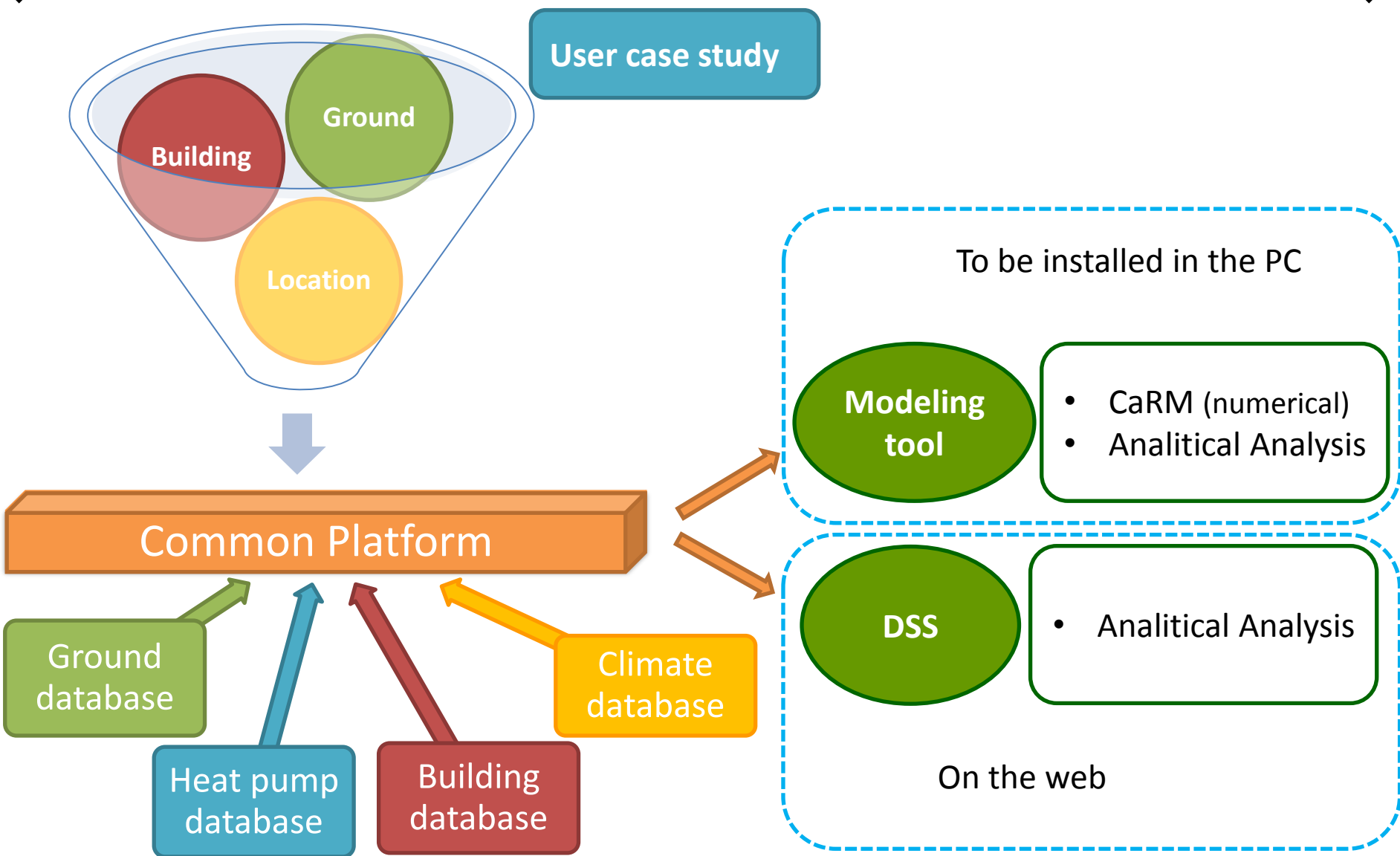
	Helix
Thermal energy provided	632 kWh
Electricity consumption	253 kWh
Energy provided by BHEs	393 kWh
COP	2,5



## Tools developed within the project

- ❑ **Decision Support System (DSS):**  
Offers different solutions and suggests the optimal one based on the user preference. Pre-feasibility study including costs, savings and other RES.  
Can be used by expert and non-expert users
- ❑ **Design tool**  
Makes possible to size the GHEs field.  
Two options:
  - simplified method based on ASHRAE
  - detailed method based on CaRM model





## Main learnings at this stage of the project

### Heat basket and hollow auger drilling

- Very safe due to its limited depth
- Suitable technology in soft, unconsolidated soil (clay, sand) with tendency to collapse
- Particularly adapted for residential low to near zero energy houses

### *Aspects to be improved at this stage:*

- the installation practices (holding bars for the spirals , bottom up grouting)
- reduce/minimize the pitch
- the decoupling operation of drill bit to loose

### Coaxial and piling

- Technology with good potential to achieve project objectives
- High piling speed in sand, soft clay (1m/min) and hard clay (2m/min)
- Room to decrease manipulation times (drilling shafts, coaxial tubes)
- High thermal exchange rates in transient operation mode

### *Aspects to be improved at this stage:*

- reduce costs of coaxial tube connections
- drill bit developments to pile through gravel layers
- improve the reliability of tightening the external tube connections



*Thank you for your  
attention!*

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