# DELIVERABLE D8.8
# TECHNICAL WORKSHOP SUMMARY

## WP8: COMMUNICATION, DISSEMINATION AND EXPLOITATION

| | |
|---|---|
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| Actual delivery date: | M19 |

**PROJECT INFORMATION**

| | |
|---|---|
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## DOCUMENT INFORMATION

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## DOCUMENT APPROVAL

| Name | Position in project | Organisation | Date | Visa |
|---|---|---|---|---|
| ALBERT GENTER | Project Coordinator | ES GEOTHERMIE | 31/10/2019 | OK |
| GHISLAIN TRULLENQUE | WP Leader | ULS | 08/11/2019 | OK |
| MARGAUX MAROT | Project Manager Officer | AYMING | 07/11/2019 | OK |
| ELEONORE DALMAIS | Internal Reviewer | ES GEOTHERMIE | 31/10/2019 | OK |

## DOCUMENT HISTORY

| Version | Date | Modifications | Authors |
|---|---|---|---|
| V1 | 28/10/2019 | 1st Version | P. Davrinche / ULS |
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| V4 | 30/10/2019 | Review | P. Davrinche / ULS |
| V5 | 30/10/2019 | Corrections | M. Marot / AYMING |
| V6 | 31/10/2019 | Corrections and inputs | E. Dalmais / ESG |
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| V8 | 04/11/2019 | Corrections | P. Davrinche / ULS |
| VF | 07/11/2019 | Final check | E. Dalmais / ESG<br>G Trullenque / ULS |

# CONTENT

# LIST OF FIGURES

# 1 TECHNICAL WORKSHOP

## 1.1 INTRODUCTION

The first MEET Technical Workshop was held on the 23rd and 24th of October 2019 in the Congress Palace of Arcachon, France.
This deliverable D8.8 has the objective to summarize the exchanges and to describe main topics that were discussed.

The main goal of this technical workshop was to present the first achievements and assessments of the project and to exchange with the participants on different topics related to deep geothermal energy.

Slides presented are in annexe of this deliverable.

This event gathered both MEET partners and external people coming from industry, association, academic research: 50 people attended the event in total.

### 1.1.1 Agenda

| 23/10/2019 - MEET workshop | | | | |
|---|---|---|---|---|
| | Remark | Speaker/chairman | Starting Time | Duration |
| | Welcome coffee and networking | | 09:00 | 01:00 |
| 1 | Introduction to MEET project and objectives, first results | ESG | 10:00 | 01:00 |
| 2 | Workshop sessions 1 - 2 - 3:<br>15 min of intro, 45 min of discussion, 15 minutes of consolidation | / | 11:00 | 01:15 |
| | Lunch and networking | | 12:15 | 01:30 |
| 3 | Workshop sessions 1 - 2 - 3: | / | 13:45 | 01:15 |
| | Coffee break | | 15:00 | 00:30 |
| 4 | Workshop session 1 - 2 - 3: | / | 15:30 | 01:15 |
| 6 | Conclusions and perspectives | ESG | 16:45 | 00:15 |
| | MEETING CLOSED | | 17:00 | |

| 24/10/2019 -Visits | | | |
|---|---|---|---|
| | Remark | Starting Time | Duration |
| | Pick up - bus | 08:15 | 00:20 |
| 1 | Visit of the eco-neighbourhood les Portes du Pyla district | 08:35 | 01:30 |
| 2 | Visit of the Grand Air HighSchool of Arcachon | 10:05 | 01:35 |
| | Visit closed | 11:40 | 01:30 |

### 1.1.2 First day

The first day was dedicated to presentations and exchanges.

Introduction and project overview was done by Dr Albert Genter (ESG), the project coordinator. A very detailed presentation of the project was done by focusing on the different geological conditions known in Europe. After a brief review about EGS definition and concept, a special focus on the ongoing work on several demo sites and relevant field analogues was presented like:

- Cold reinjection in an operational plant in fractured granite (Soultz-sous-Forêts, France) including corrosion and scaling issues,
- Soft stimulation in recent deep geothermal wells drilled in granite (Cornwall, UK)
- Heat application or electricity production from an ORC unit from existing oil wells (Paris basin, Aquitaine basin, France)
- Understanding of basic geological data collected in a 5km deep well in metamorphic rocks (Havelange, Belgium)
- Analogues studies of Variscan metasediments lying in Göttingen (Germany).

In order to attract investors, a preliminary version of a new decision making tool designed in MEET was briefly outlined.

Then three interactive sessions on the following topics were performed:

- Session 1: How can we optimize underground facilities for wider geothermal energy production?

- Session 2: How can we explore and enhance unconventional geothermal systems?

- Session 3: How can we boost deep geothermal across Europe?

The animation of the sessions went through the tool Slido.com on which we could make a live Q&A and polls to have feedbacks on questions that the MEET partners had in mind and wanted to ask to the audience.

### 1.1.3 Second day

The second day, two site visits were organised by the MEET partner Vermilion. The first visit was at the eco-neighbourhood les Portes du Pyla area, for which hot water of the district is coming from co-production in oil wells. Hot water is taken from the wells during the oil extraction, and redistributed to citizens with the help of a heat exchanger (Vermilion/Engie Cofely project). One presentation was done by Engie Cofely on district heating installation and another one was done by Eric Léoutre from Vermilion on the oil exploitation site which includes the wells and the heat exchanger. It was a good example of how heat could be redistributed to local citizens thanks to co-production activities.

The second visit was on the Grand Air High School of Arcachon. The geothermal heat exploitation of the high school was presented by the operating company SPIE: the high school heating system, composed by a heat pump installation that distributes hot water to the entire building, relies on two geothermal wells (15°C) that are used to cool down water from the heating loop, using a heat exchanger. Indeed, the temperature of the water at the end of the loop is too high to be used again directly in the heat pump.
This installation allows the high school to reduce its carbon footprint by 90% compared to the use of a gas boiler. Another project, using geothermal water from oil wells, will be achieved by Vermilion in collaboration with the same operator SPIE on the Condorcet High School of Arcachon (France) nearby.

## 1.2 LIST OF PARTICIPANTS

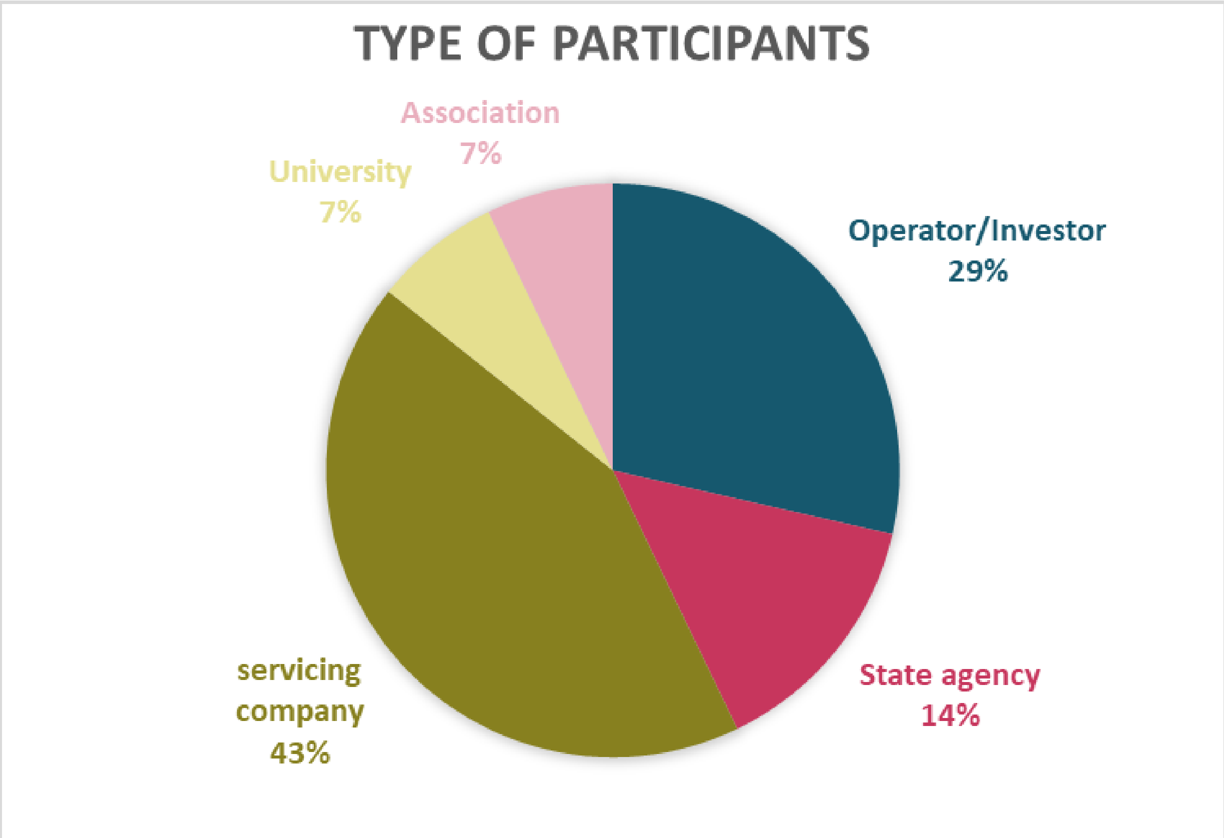
### 1.2.1 MEET consortium

All partners of MEET project had at least one representative in the workshop. In total 33 participants were from the consortium.

| Entity | Number of participants |
|---|---|
| ESG | 4 |
| ULS | 4 |
| GIM LABS | 1 |
| UCP | 1 |
| TUDa | 3 |
| UEG | 1 |
| UGOE | 2 |
| VERMILION | 3 |
| ENOGIA | 3 |
| GFZ | 2 |
| FEBUS | 1 |
| UNIZG FER | 2 |
| ICI | 2 |
| GSB | 1 |
| GeoT | 1 |
| AYMING | 2 |
| ***Total*** | ***33*** |

### 1.2.2 External stakeholders

17 participants coming from external entities joined the workshop. Most of them were either servicing companies or operators in oil&gas and geothermal industries.




| Entity | Profil |
|---|---|
| **TLS GEOTHERMICS** | Geothermal Operator |
| **BRGM** | State geological survey |
| **Volcanic Basin Petroleum Research AS** | servicing company |
| **Laboratoire GEOPS** | University |
| **Marubeni Europower Ltd** | Energy project development / oil&gas operator |

| | |
|---|---|
| **Diamant Drilling Services** | servicing company |
| **Field Equipment** | servicing company |
| **Reservoir Group** | servicing company |
| **Pluton DG** | servicing company |
| **CFG Services** | servicing company |
| **International Petroleum Corporation** | oil&gas operator |
| **Pole Avenia** | Association |
| **Netherlands Enterprise Agency** | State agency |
| **A.P. Møller Holding Geothermal** | Geothermal project development |

# 2 DAY 1 MINUTES

## 2.1 SESSION 1: HOW CAN WE OPTIMIZE UNDERGROUND FACILITIES FOR WIDER GEOTHERMAL ENERGY PRODUCTION?

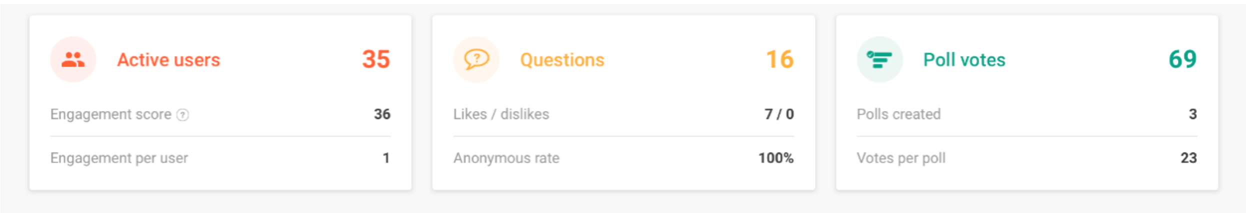
### 2.1.1 Plenary session

This session was chaired by Eric Léoutre, exploitation engineer at Vermilion Energy, leader of the work package 4 « Enhancing petroleum sedimentary basins for geothermal electricity and thermal power production ».
The panel of the session was composed of Eléonore Dalmais geoscience engineer at ESG, Olivier Seibel process engineer at ESG, Benoit Paillette commercial director at Enogia and Xavier Lopez, Bassin Aquitain Director from Vermilion.

- What are the technical bottlenecks?
- What could be the business models to reuse wells?
- What are the opportunities for subsurface energy industries to diversify into geothermal activities?

### 2.1.2 Interactive session

The interactive session was chaired by Eric Léoutre, using the slido.com tool.
This tool was used during the session 1 for the live session of Q&A (Questions & Answers) right after the plenary presentation and allowed attendees to ask questions to the panel (see list below).




List of the questions from the floor:

- *During low temperature injection you potentially get scaling both in injection well (casing) and reservoir. Do you plan to measure both during the tests?*
- *What would be the expected power generation capacity (in MWe) for instance at Parentis?*
- *If we reinject cold water in a confined geological structure, how can we avoid a rapid cooling of it?*
- *Is Vermilion planned to make business in Europe by selling integrated solutions for producing heat/electricity from oil fields?*
- *What type and duration of contract link the oil company to the customer? Are oil companies technically and legally ready to operate as energy providers?*

- *Why not extract the heat from the oil also, instead of heat from the water only?*
- *Could you reinject colder water in LPS well than 60 deg? What is your limitation? User demands, technical constrains, ...*
- *Given the range of Enogia's ORC electrical production capacity, how does the cost per kW vary from 200-10 kW for the ORC systems?*
- *What kind of yield can be expected from ORC power production from the oil wastewater at the temperature ranges found on Vermilion sites in France?*
- *ORC power price is it power production cost only i.e. thermal energy input is not valued?*
- *How does the expected power generation capacity (via Enogia ORC turbines) compare with on site use of energy for pumping, for instance at Parentis?*
- *What about converting gas wells to geothermal energy?*
- *Is oil/geothermal coproduction can be considered as EGS? These oil wells are not enhanced in those operation.*
- *Is coproducing heat and oil, a good factor for public acceptance for an Oil company?*
- *When we look at the ORC for a 70 deg C what would be the required temperatures for the cold side to get to the 3.5% efficiency?*
- *Does ORC impact the ERoEI (Energy Return on Energy Invested) of a geothermal plant regarding the technological investments?*

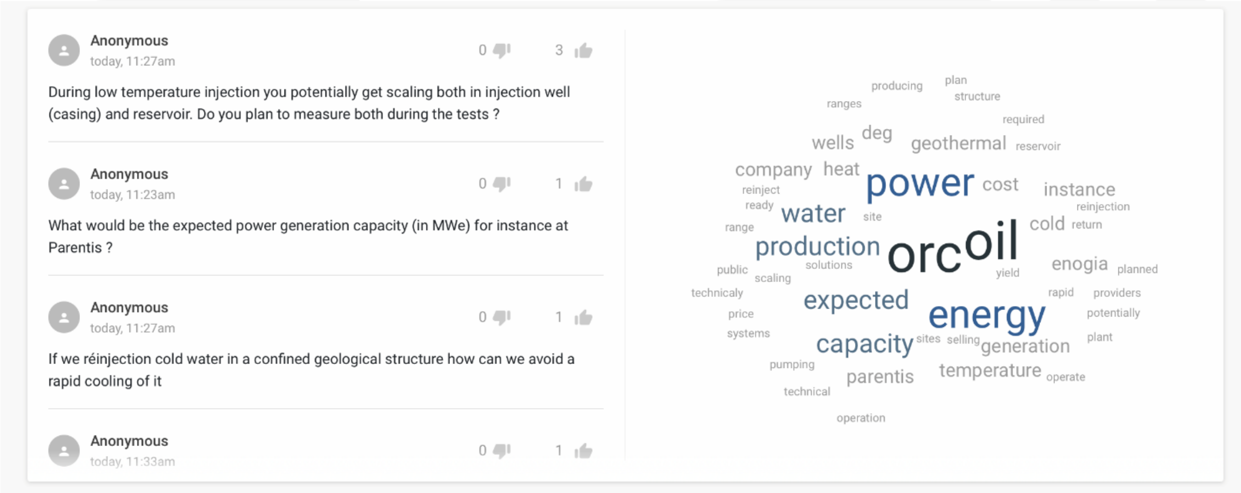
Slido was also used to display 3 polls (1 question with multiple choices and 2 open questions), and helped trigger the discussion:

- *Do you think that an oil well producing 99% water at 90°C makes more money by selling heat though a heat exchanger or, by selling the 1% of oil (at current oil price)?*
- *What conditions are necessary to transform uneconomic oil/gas/mine wells into profitable geothermal well (for heat)?*
- *Why do oil/gas/storage/mining companies not invest in geothermal energy projects?*

Several topics were assessed regarding the technical bottlenecks, such as the scaling and the reservoir issues: thermal shortcuts, the impacts of colder reinjection, the building a competitive and sustainable exploitation, thermo-mechanical characteristics and induced micro-seismicity. Many questions rose on coproduction and the profitability of oil/gas/geothermal exploitation, and the technical condition for the use of ORC.

Wrap-up of the session:

- There are still some challenges to overcome on a technical point of view, such as scaling and corrosion.
- The end-user is thinking more and more on the carbon footprints, and this is a key argument for developing synergies between Oil&Gas and geothermal.




## 2.2 SESSION 2: HOW CAN WE EXPLORE AND ENHANCE UNCONVENTIONAL GEOTHERMAL SYSTEMS?

### 2.2.1 Plenary session

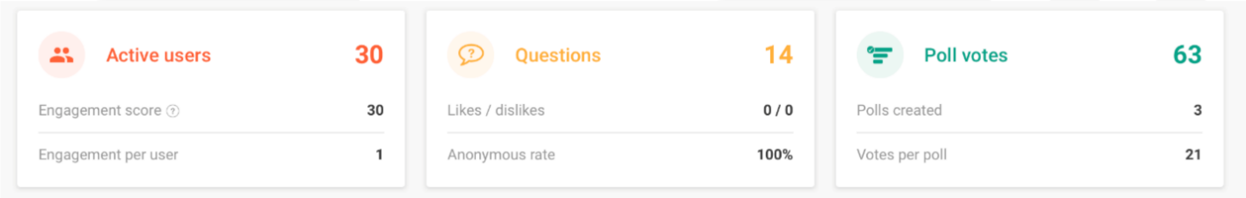
The chairman of the session 2 was Dr Ghislain Trullenque, structural geologist at UniLaSalle. He is deeply involved in the Work Package 5 about « Variscan Geothermal Reservoirs (Granitic and Metamorphic Rocks) ».
The panel was composed with Dr Bernd Leiss from the University of Göttingen, Dr John Reinecker from GeoT, Dr Kristian Bär from TUDa, Dr Albert Genter from ESG and Dr Yves Vanbrabant from GSB.

Main questions of the subject:

- How can we explore unconventional geothermal systems?
- How can we enhance unconventional geothermal systems?
- How to validate public acceptance for unconventional geothermal project?

### 2.2.2 Interactives sessions

The live Q&A was used 3 times, right after each topic presentation of the plenary session and 1 poll was created for each topic.




**"How can we explore unconventional geothermal systems?"** Many questions dealing with the geological challenges to overcome, replicate and explore geothermal potential in various geological contexts were asked. A particular interest was given to the Variscan sites of Göttingen and Havelange, such as their reservoir characteristics, permeability, influence of a sedimentary cover.

Discussion was triggered by the following question: *Is the exploration and exploitation strategy for the Göttingen site feasible*?

The **"How can we enhance unconventional geothermal systems?"** topic brought discussions on the chemical and hydraulic stimulations, with inputs from projects developers and operators on regulations and induced seismicity.

The poll associated with this topic was*: "Which strategy is the best to mitigate induced seismicity and enhance efficiency of stimulation in granite?"*

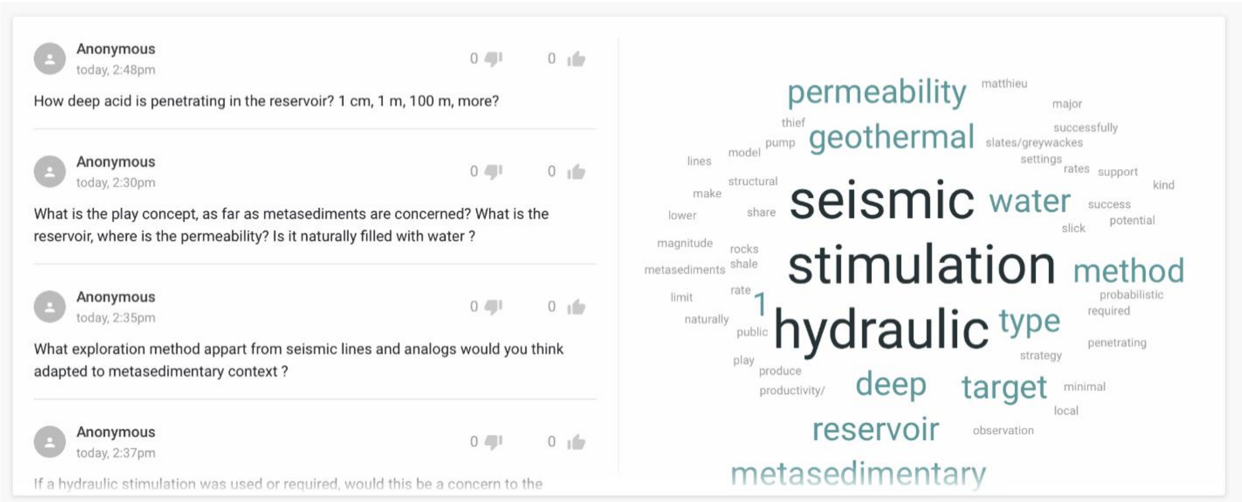
During the **"How to validate public acceptance for unconventional geothermal projects?"** interactive topic, the following pool was presented: *"What are the means to promote a better acceptance of deep geothermal project?".* This poll rose discussion on the global awareness of geothermal energy, on population involvement and education. A few various French cases where weight during the discussion, and best practices exchanged.

List of questions from the floor (from all sub-session):

- *What is the play concept, as far as metasediments are concerned? What is the reservoir, where is the permeability? Is it naturally filled with water?*
- *What type of development strategy do you envision? Chemical, hydraulic, other?*
- *What exploration method apart from seismic lines and analogs would you think adapted to metasedimentary context*
- *If a hydraulic stimulation was used or required, would this be a concern to the immediate public? Or would there be support as it is geothermal?*
- *As you are in extensional settings, does a major deep fault within slates/greywackes can constitute a potential target?*
- *Did you build a structural model do target faults anyway, even with the seismic? With some kind of probabilistic input?*

- *What was the first dataset or observation you had that make you think it is achievable for metasedimentary rocks?*
- *How deep acid is penetrating in the reservoir? 1 cm, 1 m, 100 m, more?*
- *What is the lower limit for flowrate not to need to apply any stimulation?*
- *1 per 10 Shale gas well fracked, produce successfully more than 2 years. Geothermal fracking success rate is?*
- *What is the magnitude of increase in productivity/ injectivity after stimulation in granite? How do you avoid thief zone?*
- *Do you need minimal initial permeability for hydrofrac a well?*
- *Even with a hydraulic fracture, you can control seismic activity based on pump rates, and type of frac delivery method you use. Slick water vs gelled water, etc.*
- *TLS geothermics is exploring in centre of France. Could Matthieu A. share his experience on local public acceptance?*

<u>Wrap-up of the session:</u>*Exploration:* New project in unknown geothermal context such as metasediments is a challenge that is necessary to overcome if we want to spread geothermal projects in various geological contexts.
*Enhancement of unconventional geothermal systems*: There are physical limits which are geological dependent and various solutions are available to enhance the wells but the replicability is challenging
*Geothermal projects acceptance*: Acceptance is related to political, cultural and political background



## 2.3 SESSION 3: HOW CAN WE BOOST DEEP GEOTHERMAL ACROSS EUROPE?

### 2.3.1 Plenary session

The session 3 chairwoman was Dr Bianca Wagner from the University of Göttingen. Together with Sara Raos and Tena Bilić from the University of Zagreb-FER, they presented the Work Package 7 outcomes and challenges focusing on « Economic and environment assessment for EGS integration into energy systems ».
Dr Wagner first gave some information about the GIS construction. Second, Mrs Raos and Mrs Bilić gave a presentation of the Decision Support Tool that they are building.

Main questions of the session:

- How to support decision making for deep geothermal project?
- What is needed to identify potential replication sites for deep geothermal?

### 2.3.2 Interactive session

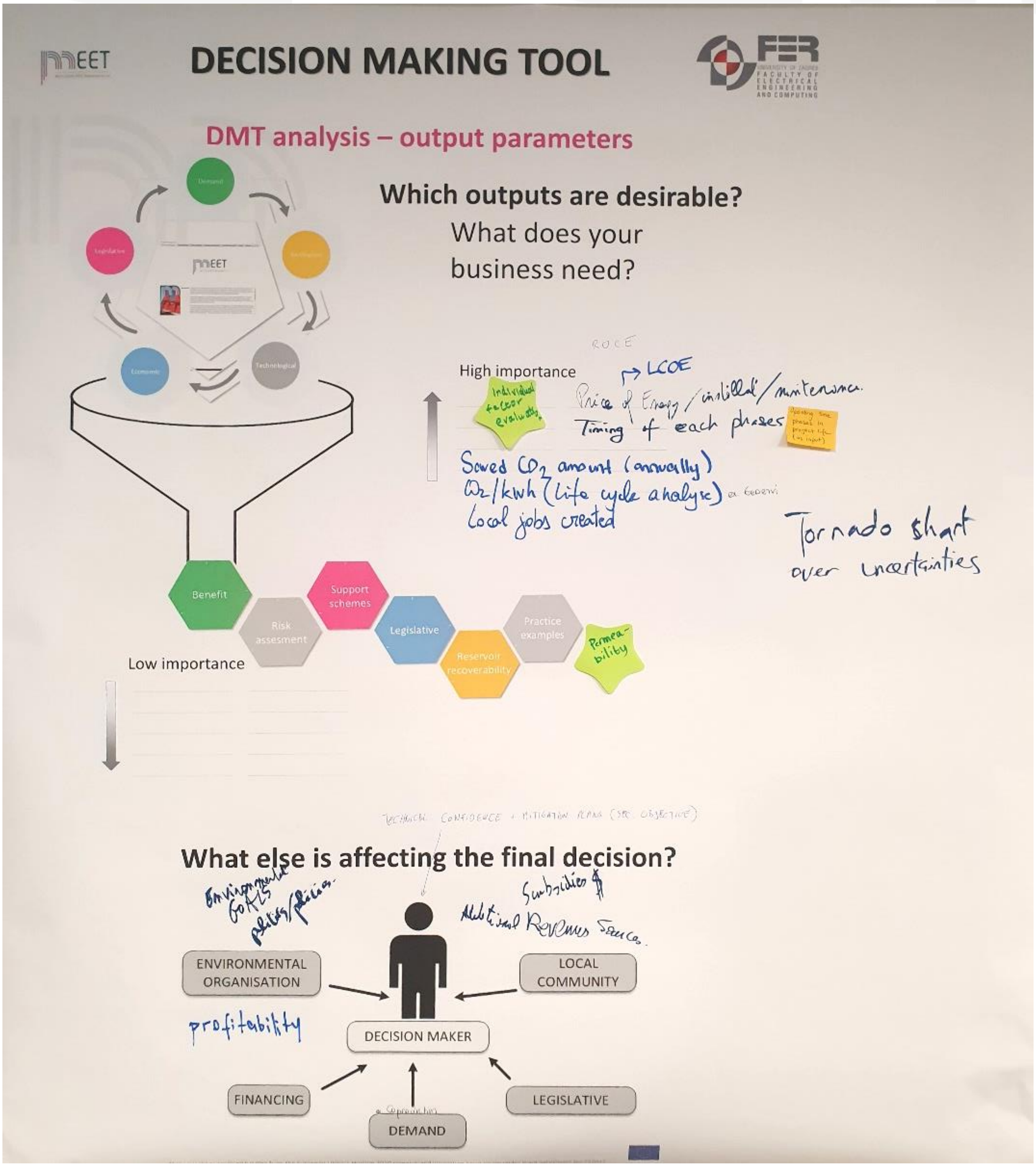
For the session 3 interactive session, the participants were split in 5 groups to work on posters and share their ideas and propositions on the following topics:

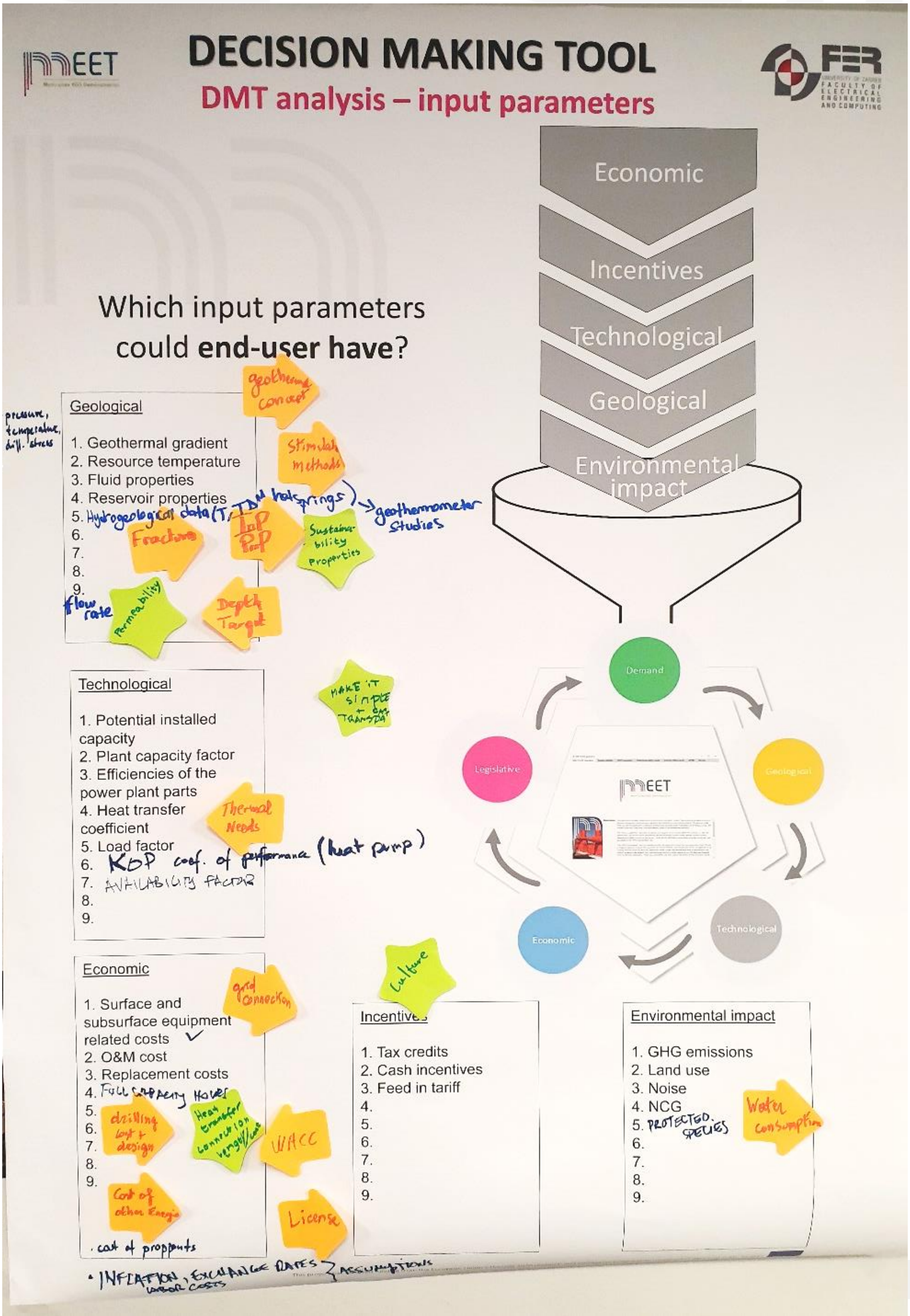
- Decision making tool: output parameters
*Which outputs are desirable? What else is affecting the final decision?*

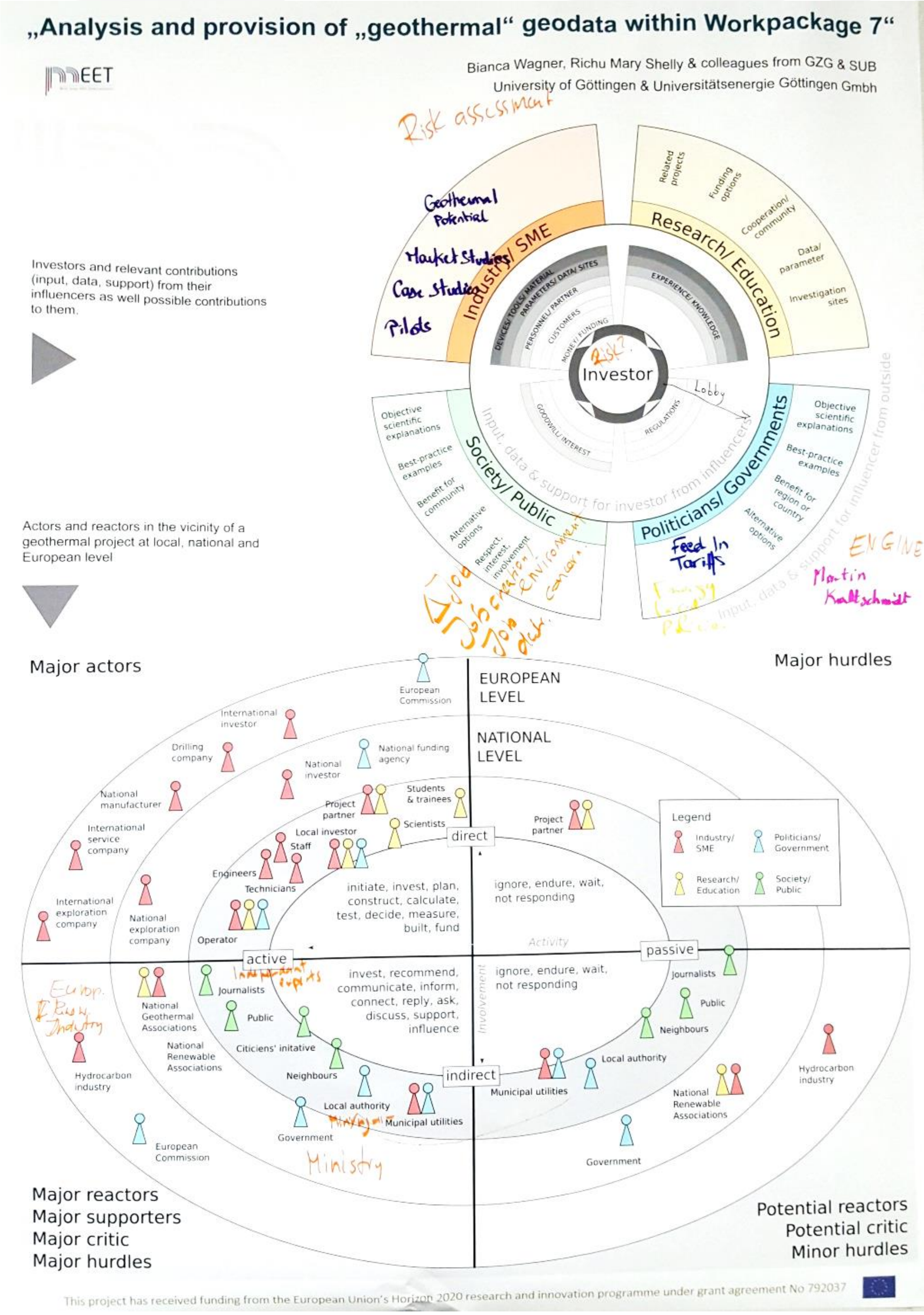
- Decision making tool: input parameters
*Which input parameters could end-users have?*

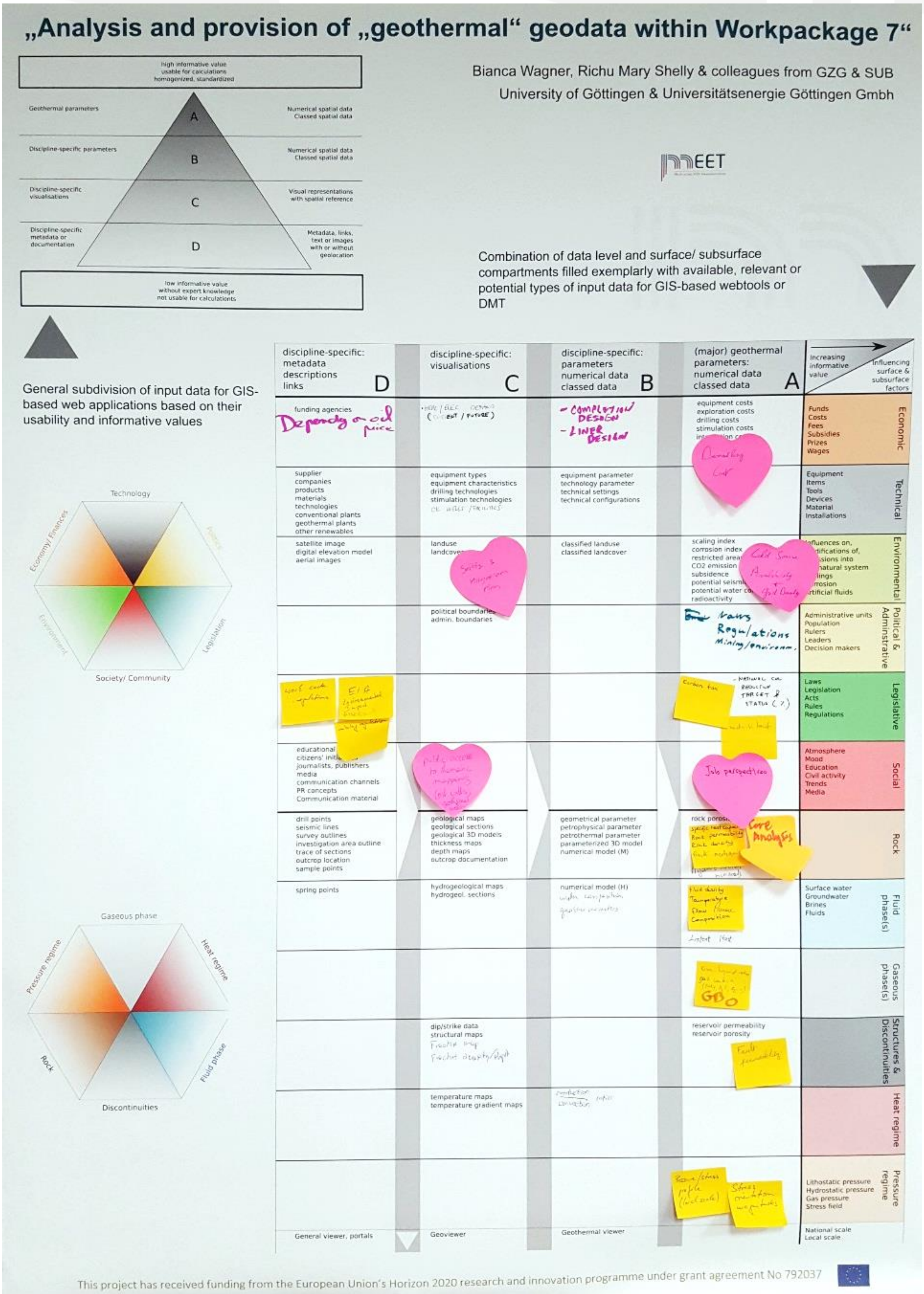
- Analysis and provision of ‘geothermal’ geodata in the framework of the WP7
*“Economic and environment assessment for EGS integration into energy systems”*
*Actors and reactors on the vicinity of a geothermal project at various scale/ Combination of data, timeframe.*

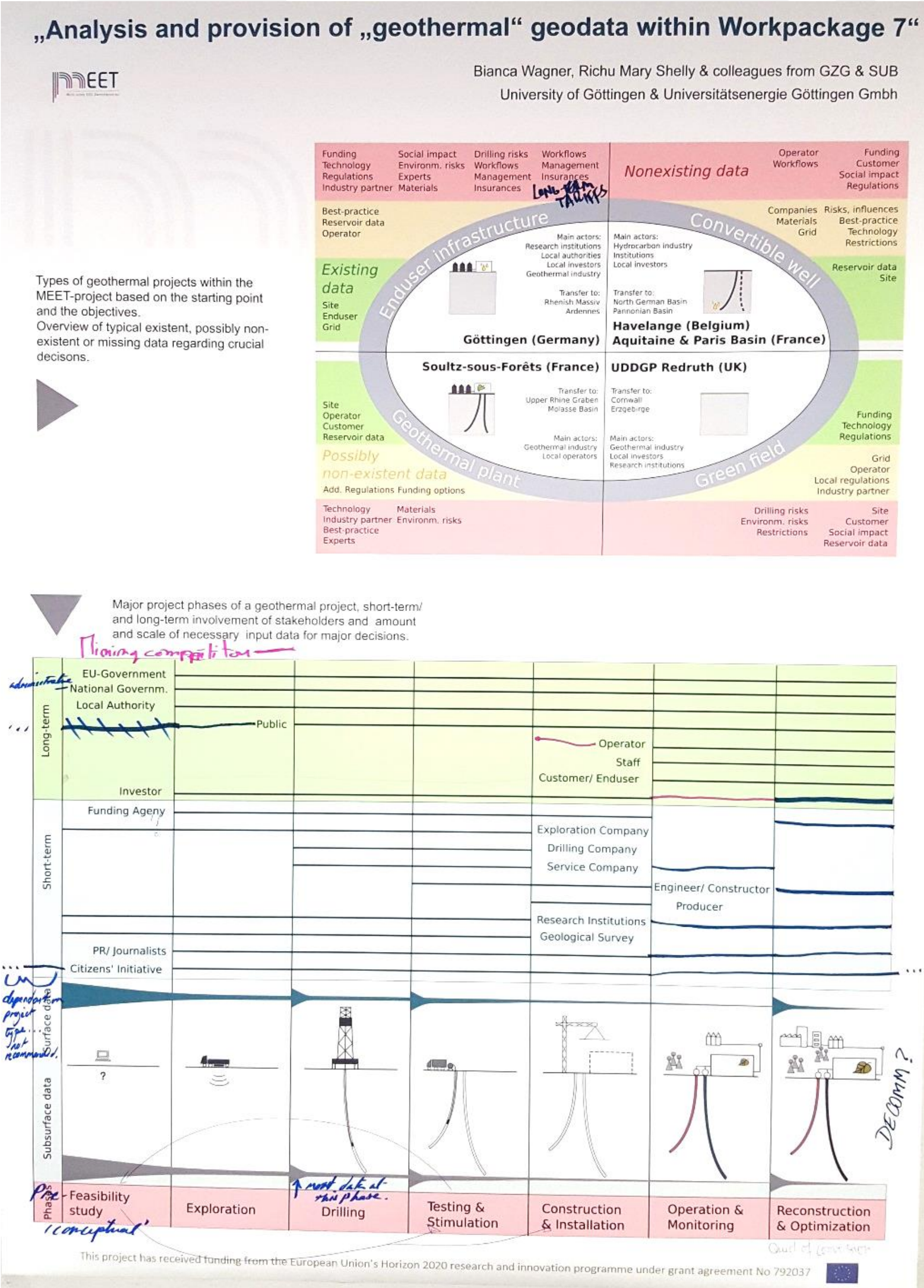
The University of Zagreb-FER (Tena Bilić and Sara Raos) showed two posters about the Data Management Tool and the University of Göttingen (Bianca Wagner) showed three posters about the analysis and provision of geothermal geodata that were discussed/enriched during a specific group session. Discussions that occurred around the posters will help MEET partners to make further developments on the different tools.


MEET
DECISION MAKING TOOL
FER
DMT analysis – output parameters
Which outputs are desirable?
What does your business need?
High importance
LCOE
Timing of each phases
Saved CO2 amount (annually)
CO2/kWh (life cycle analyse)
Local jobs created
Tornado chart over uncertainties
Benefit
Risk assesment
Support schemes
Legislative
Reservoir recoverability
Practice examples
Permea-bility
Low importance
What else is affecting the final decision?
Subsidies $
Additional Revenues Sources.
ENVIRONMENTAL ORGANISATION
LOCAL COMMUNITY
profitability
DECISION MAKER
FINANCING
DEMAND
LEGISLATIVE


DECISION MAKING TOOL
DMT analysis – input parameters
Economic
Incentives
Technological
Geological
Environmental impact
Which input parameters could end-user have?
Geological
1. Geothermal gradient
2. Resource temperature
3. Fluid properties
4. Reservoir properties
5. Hydrogeological data
Technological
1. Potential installed capacity
2. Plant capacity factor
3. Efficiencies of the power plant parts
4. Heat transfer coefficient
5. Load factor
Economic
1. Surface and subsurface equipment related costs
2. O&M cost
3. Replacement costs
Incentives
1. Tax credits
2. Cash incentives
3. Feed in tariff
Environmental impact
1. GHG emissions
2. Land use
3. Noise
4. NCG
Demand
Legislative
Economic
Technological


„Analysis and provision of „geothermal" geodata within Workpackage 7"
Bianca Wagner, Richu Mary Shelly & colleagues from GZG & SUB
University of Göttingen & Universitätsenergie Göttingen Gmbh
Investors and relevant contributions (input, data, support) from their influencers as well possible contributions to them.
Actors and reactors in the vicinity of a geothermal project at local, national and European level
Investor
Industry/ SME
Research/ Education
Society/ Public
Politicians/ Governments
Related projects
Funding options
Cooperation/ community
Data/ parameter
Investigation sites
Objective scientific explanations
Best-practice examples
Benefit for community
Alternative options
Respect, interest, involvement
Benefit for region or country
Input, data & support for investor from influencers
Risk assessment
Geothermal Potential
Market Studies
Case Studies
Pilots
Feed In Tariffs
Lobby
Major actors
Major hurdles
EUROPEAN LEVEL
NATIONAL LEVEL
direct
indirect
active
passive
initiate, invest, plan, construct, calculate, test, decide, measure, built, fund
ignore, endure, wait, not responding
invest, recommend, communicate, inform, connect, reply, ask, discuss, support, influence
Legend
Industry/ SME
Politicians/ Government
Research/ Education
Society/ Public
European Commission
International investor
Drilling company
National funding agency
National investor
National manufacturer
Project partner
Students & trainees
International service company
Local investor
Scientists
Staff
Engineers
Technicians
International exploration company
National exploration company
Operator
Journalists
Public
Neighbours
National Geothermal Associations
National Renewable Associations
Citiciens' initative
Local authority
Municipal utilities
Government
Hydrocarbon industry
Ministry
Major reactors
Major supporters
Major critic
Major hurdles
Potential reactors
Potential critic
Minor hurdles
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037


„Analysis and provision of „geothermal" geodata within Workpackage 7"
Bianca Wagner, Richu Mary Shelly & colleagues from GZG & SUB
University of Göttingen & Universitätsenergie Göttingen Gmbh
Combination of data level and surface/ subsurface compartments filled exemplarly with available, relevant or potential types of input data for GIS-based webtools or DMT
General subdivision of input data for GIS-based web applications based on their usability and informative values
Technology
Society/ Community
Gaseous phase
Discontinuities
discipline-specific: metadata descriptions links D
discipline-specific: visualisations C
discipline-specific: parameters numerical data classed data B
(major) geothermal parameters: numerical data classed data A
Economic
Technical
Environmental
Political & Adminstrative
Legislative
Social
Rock
Fluid phase(s)
Gaseous phase(s)
Structures & Discontinuities
Heat regime
Pressure regime
General viewer, portals
Geoviewer
Geothermal viewer
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037


„Analysis and provision of „geothermal" geodata within Workpackage 7"
Bianca Wagner, Richu Mary Shelly & colleagues from GZG & SUB
University of Göttingen & Universitätsenergie Göttingen Gmbh
Types of geothermal projects within the MEET-project based on the starting point and the objectives.
Overview of typical existent, possibly non-existent or missing data regarding crucial decisons.
Nonexisting data
Existing data
Possibly non-existent data
Enduser infrastructure
Convertible well
Geothermal plant
Green field
Göttingen (Germany)
Havelange (Belgium)
Aquitaine & Paris Basin (France)
Soultz-sous-Forêts (France)
UDDGP Redruth (UK)
Funding
Technology
Regulations
Industry partner
Social impact
Environm. risks
Experts
Materials
Drilling risks
Workflows
Management
Insurances
Operator
Customer
Best-practice
Reservoir data
Companies
Grid
Risks, influences
Restrictions
Site
Enduser
Add. Regulations
Funding options
Main actors:
Transfer to:
Major project phases of a geothermal project, short-term/ and long-term involvement of stakeholders and amount and scale of necessary input data for major decisions.
Long-term
Short-term
EU-Government
National Governm.
Local Authority
Public
Operator
Staff
Customer/ Enduser
Investor
Funding Ageny
Exploration Company
Drilling Company
Service Company
Engineer/ Constructor
Producer
Research Institutions
Geological Survey
PR/ Journalists
Citizens' Initiative
Surface data
Subsurface data
Phase
Feasibility study
Exploration
Drilling
Testing & Stimulation
Construction & Installation
Operation & Monitoring
Reconstruction & Optimization
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

Questions from the floor asked on Slido:

- *At the end of the project, are you going to apply for a patent for this DM tool?*
- *Will the decision making tool be commercially online after MEET project?*
- *What is the method employed in the background to calculate the power output of the system?*

# 3 MAIN OUTCOMES OF DAY 1 & 2

During the technical workshop, lots of questions were discussed between MEET partners and stakeholders. With a majority of industry-oriented stakeholders and servicing company engineers, most of the discussions dealt with practical applications close to the market.

On technical aspect, the small ORC unit of ENOGIA triggered the interest and questions from the audience. In addition to issue regarding the efficiency of such system, it is really its use in coproduction on oil wells at marginal cost that raised the interest. Indeed, some oil & gas companies showed their interest in MEET research and discussed with Vermilion on their experience on coproduction.

In the framework of MEET, a 6$^{th}$ demo-site is still pending for the last ORC. This workshop was an opportunity to find a potential candidate by a suggestion of Netherlands state agency's representative. This candidature will be further investigated by the MEET team.

On non-technical aspects, many questions turn out to concern social acceptability of deep geothermal project.

French developers, both in Alsace and Massif Central, shared their experience on how non-technical barriers contribute or not to the development of deep geothermal project. A special focus was raised around the local history of people in the vicinity of a project, where the mining past (even 2 generations before), still deeply influence the perception of a new subsurface exploitation project.

From an environmental point of view, the stakeholder representing public regulator from The Netherlands was very interested to the French best practices in seismological monitoring related to geothermal exploitation of fractured reservoirs like in Soultz-sous-Forêts (France). The main bottleneck in The Netherlands about geothermal exploitation is related to the induced seismicity risk related to the pumping of geothermal fluid embedded in fault. For this reason, the geothermal development of fractured rocks is stopped in the NL. In France, a series of environmental monitoring parameters is operational in order to secure the geothermal exploitation and could be transferred and probably adapted to the Dutch case.

Apart from exchanges around MEET topics, many attendants took time to discuss potential R&D ideas and share with the coordinating team around the building and management of such European research projects with high TRL.

Indeed, a company specialised in drill bits is looking for contacts and good practise to answer R&D calls to investigate an original idea that could provide significant evolution in drilling technology.

Also, new private actors from a Danish company were also very interested in the MEET Technical Workshop. They are looking for new opportunities related to the geological and geothermal conditions of Denmark. They mentioned that they are candidate for joining new consortium like MEET for a future European call.

Figure 1: Technical workshop (1)

**Figure 2: Technical workshop (2)**

**Figure 3: High school visit**


**Figure 4: Les Portes du Pyla visit**

# 4 ANNEXE – SLIDES PRESENTED

## 4.1 INTRODUCTION (ALBERT GENTER, ESG)

Power Point: MEET_Technical_Workshop_Introduction_AGenter

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# THE MEET PROJECT

Dr Albert Genter & the MEET consortium

24/10/2019

Arcachon, France

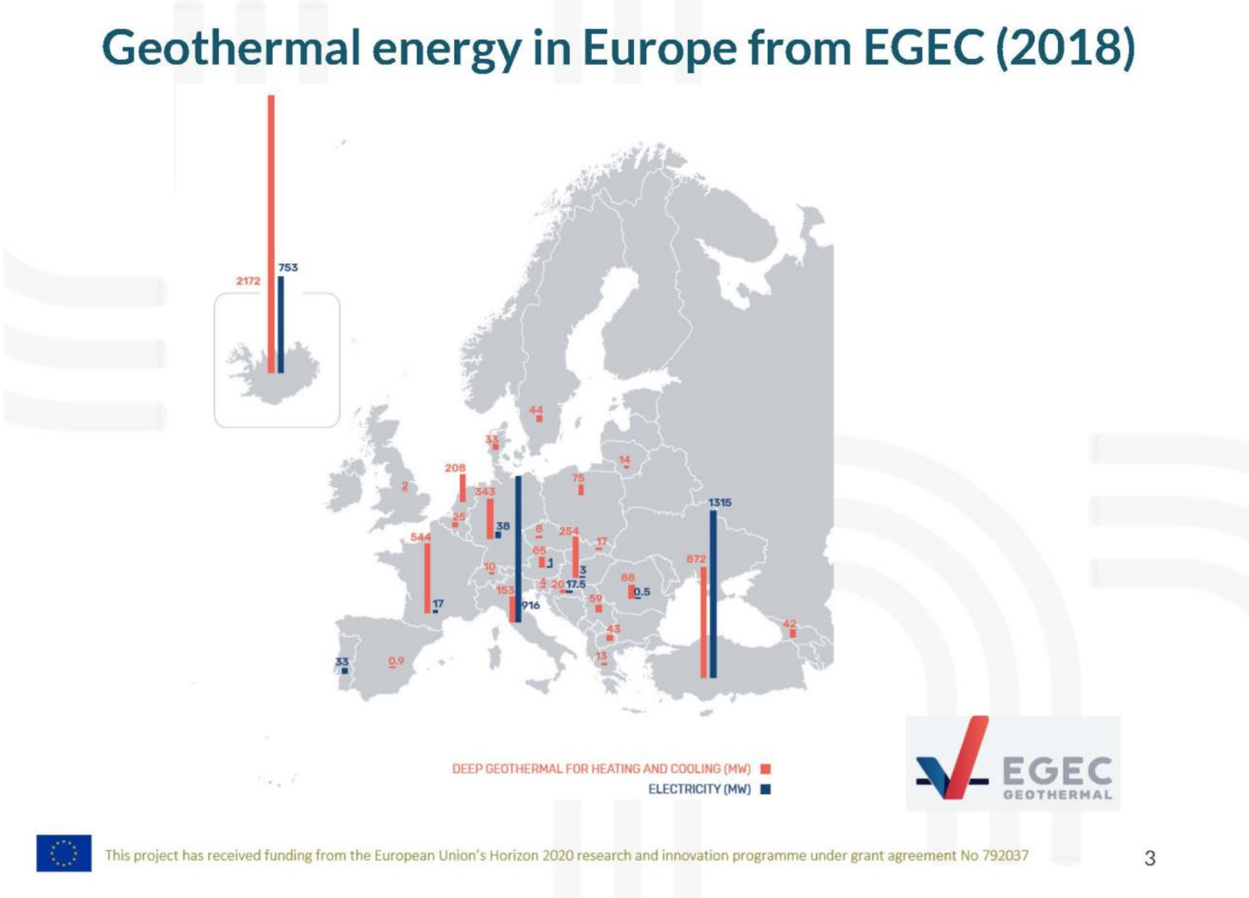
## Outline

EGS or Unconventional reservoirs

MEET project presentation

MEET first results

Discussion


Geothermal energy in Europe from EGEC (2018)
2172
753
44
208
343
75
1315
544
254
872
153
916
DEEP GEOTHERMAL FOR HEATING AND COOLING (MW)
ELECTRICITY (MW)
EGEC GEOTHERMAL
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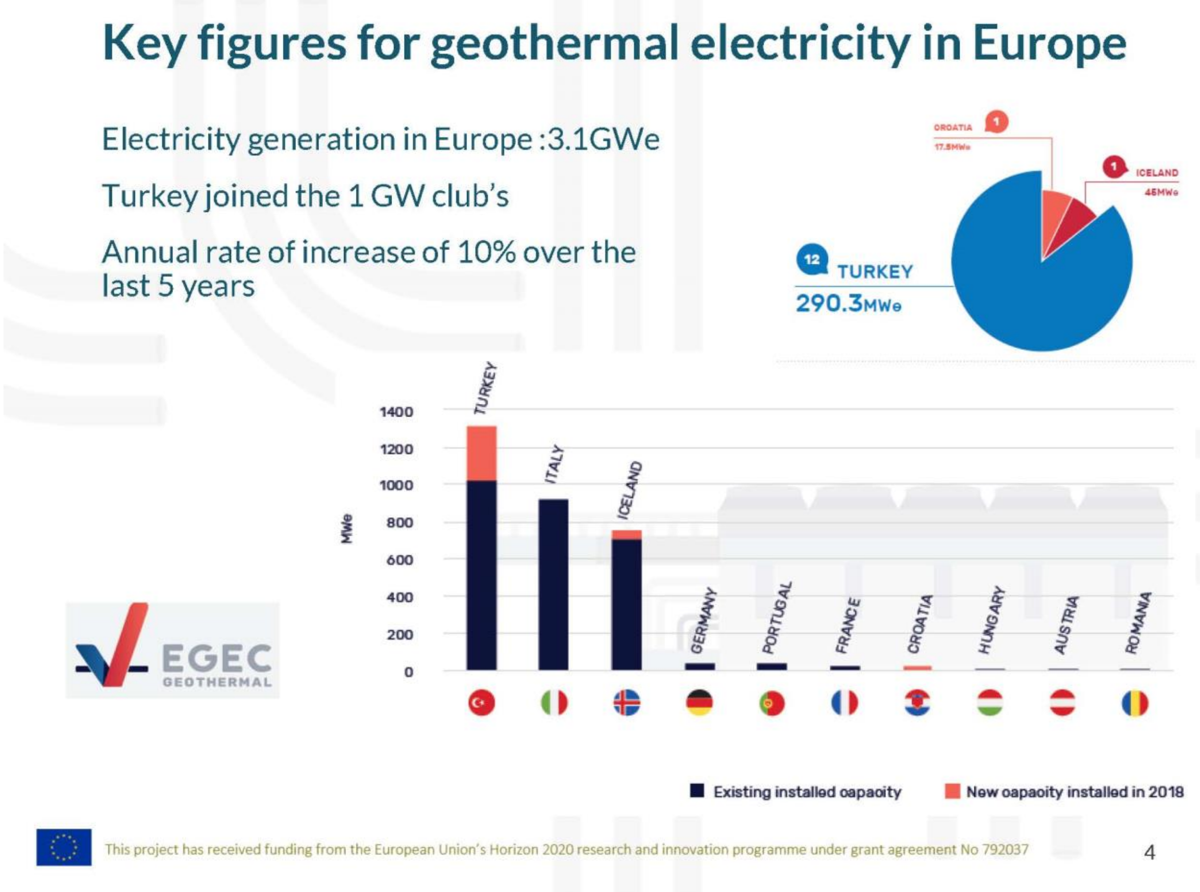
3


Key figures for geothermal electricity in Europe
Electricity generation in Europe :3.1GWe
Turkey joined the 1 GW club's
Annual rate of increase of 10% over the last 5 years
CROATIA
1
17.5MWe
1
ICELAND
45MWe
12
TURKEY
290.3MWe
TURKEY
ITALY
ICELAND
GERMANY
PORTUGAL
FRANCE
CROATIA
HUNGARY
AUSTRIA
ROMANIA
MWe
1400
1200
1000
800
600
400
200
0
EGEC GEOTHERMAL
Existing installed capacity
New capacity installed in 2018
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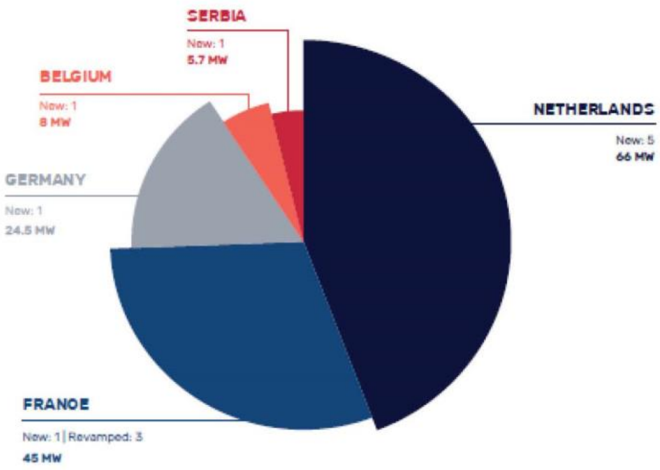
# Key figures for geothermal heat in Europe

In operation for a total of 5.1 GWh installed capacity

New heat and cooling operations in 2018: 12 plants and 149MWth

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## EGS Enhanced Geothermal System

Engineered Geothermal System

Unconventional reservoir

Which definition(s)?

Improve the initial low well permeability by applying THMC techniques

From industrial point of view, improving the hydraulic connection between the well and the reservoir

Do you know any EGS plants operating and producing electricity or heating Europe?

In the past: HDR, HWR, HFR, Petrothermal, .....

EGS is a technology or a geothermal concept? (keep it for discussion)

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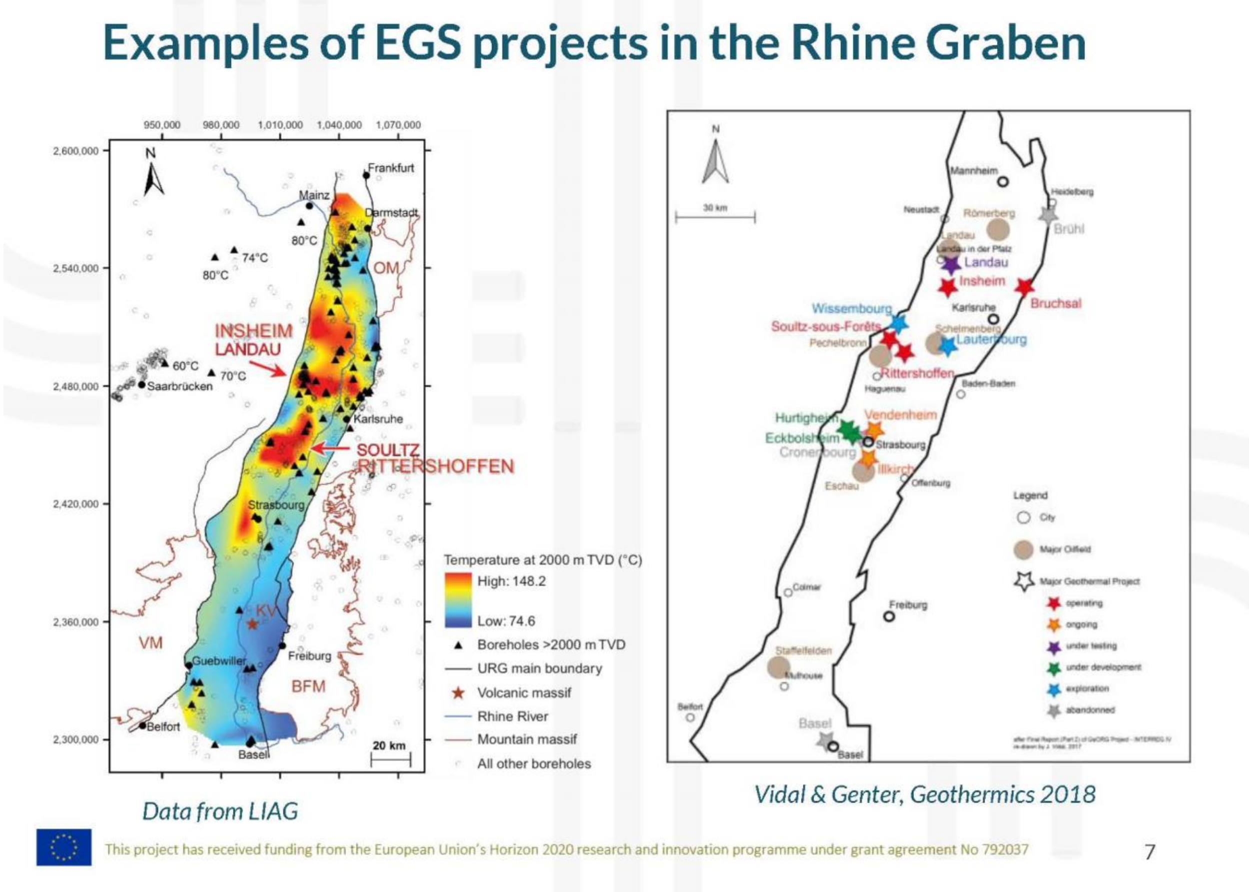
Examples of EGS projects in the Rhine Graben
Frankfurt
Mainz
Darmstadt
80°C
74°C
80°C
OM
INSHEIM
LANDAU
60°C
70°C
Saarbrücken
Karlsruhe
SOULTZ
RITTERSHOFFEN
Strasbourg
KV
VM
Guebwiller
Freiburg
BFM
Belfort
Basel
20 km
Temperature at 2000 m TVD (°C)
High: 148.2
Low: 74.6
Boreholes >2000 m TVD
URG main boundary
Volcanic massif
Rhine River
Mountain massif
All other boreholes
Data from LIAG
Mannheim
Heidelberg
Römerberg
Brühl
Landau
Insheim
Bruchsal
Wissembourg
Soultz-sous-Forêts
Karlsruhe
Lauterbourg
Rittershoffen
Baden-Baden
Hurtigheim
Vendenheim
Eckbolsheim
Cronenbourg
Strasbourg
Illkirch
Eschau
Offenburg
Legend
City
Major Oilfield
Major Geothermal Project
operating
ongoing
under testing
under development
exploration
abandonned
Colmar
Freiburg
Staffelfelden
Mulhouse
Belfort
Basel
Vidal & Genter, Geothermics 2018
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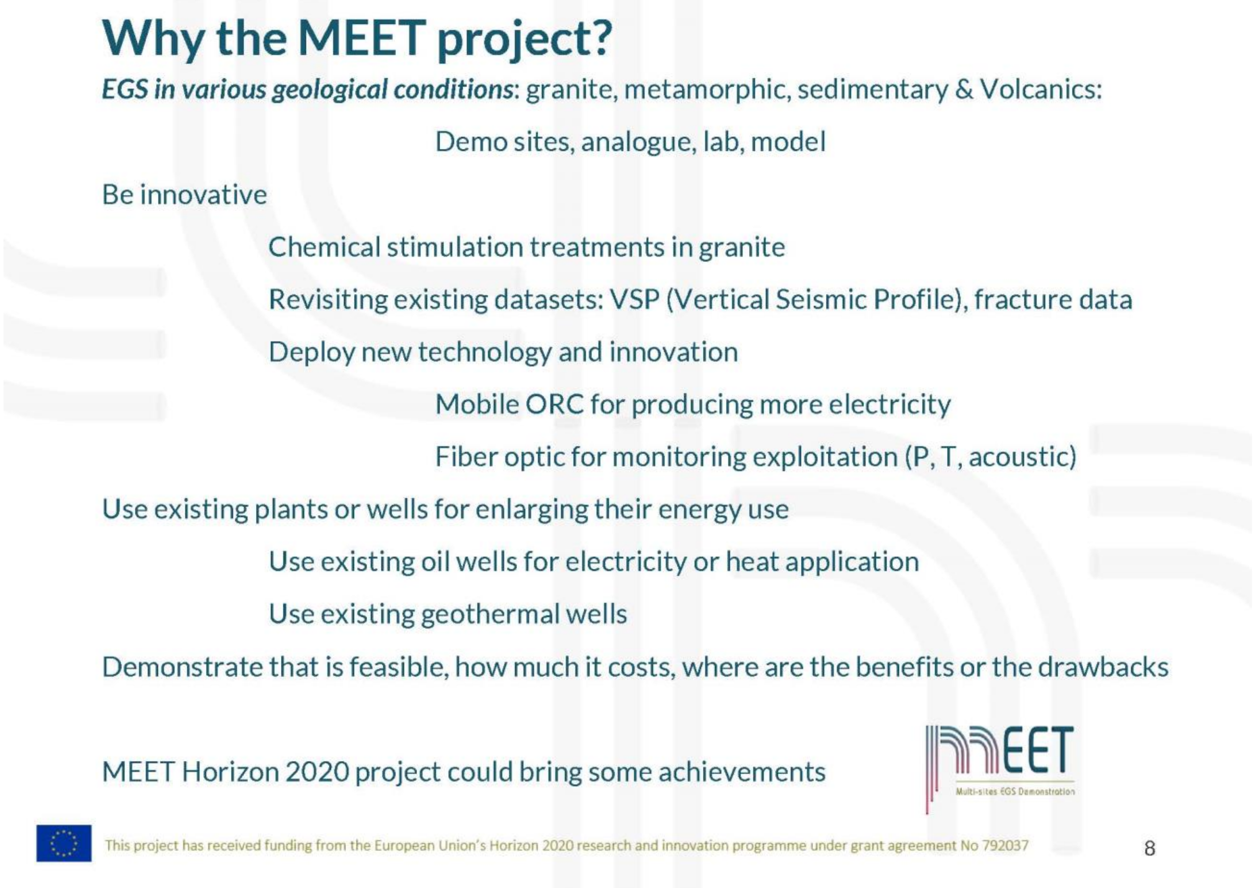
Why the MEET project?
EGS in various geological conditions: granite, metamorphic, sedimentary & Volcanics:
Demo sites, analogue, lab, model
Be innovative
Chemical stimulation treatments in granite
Revisiting existing datasets: VSP (Vertical Seismic Profile), fracture data
Deploy new technology and innovation
Mobile ORC for producing more electricity
Fiber optic for monitoring exploitation (P, T, acoustic)
Use existing plants or wells for enlarging their energy use
Use existing oil wells for electricity or heat application
Use existing geothermal wells
Demonstrate that is feasible, how much it costs, where are the benefits or the drawbacks
MEET Horizon 2020 project could bring some achievements
MEET
Multi-sites EGS Demonstration
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# MEET: Multi-site EGS demonstration


## TECHNICAL WORKSHOP

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# MEET Project presentation

The **MEET project** (Multidisciplinary and multi-context demonstration of Enhanced Geothermal Systems exploration and Exploitation Techniques and potentials) aims at demonstrate the EGS (Enhanced Geothermal Systems) application:

- On different geological contexts
- Through Europe
- Using several demonstration sites
- With an economical aspect

The MEET project is part of the H2020 programme Secure Clean and Efficient Energy, Call H2020 – LCE – 2016 – 2017 (competitive low carbon energy). MEET is an innovation action project, Grant Agreement number 792037.

| 16 | 5 | €11,73M | 42 |
|---|---|---|---|
| Partners | Countries | Total budget (€9,97m funded by EC) | Months May 2018 – October 2021 |

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

## OBJECTIVES

***The main objectives of the project are:***

- To gather knowledge of deep geothermal heat and power production in various geological settings
- To increase heat production in various geological reservoirs by different means
- To enhance heat-to-power conversion at low temperature (<90°C) by using smart mobile Organic Rankine Cycle (ORC) units
- To improve penetration of geothermal power and heat plants by promoting the technology developed within MEET

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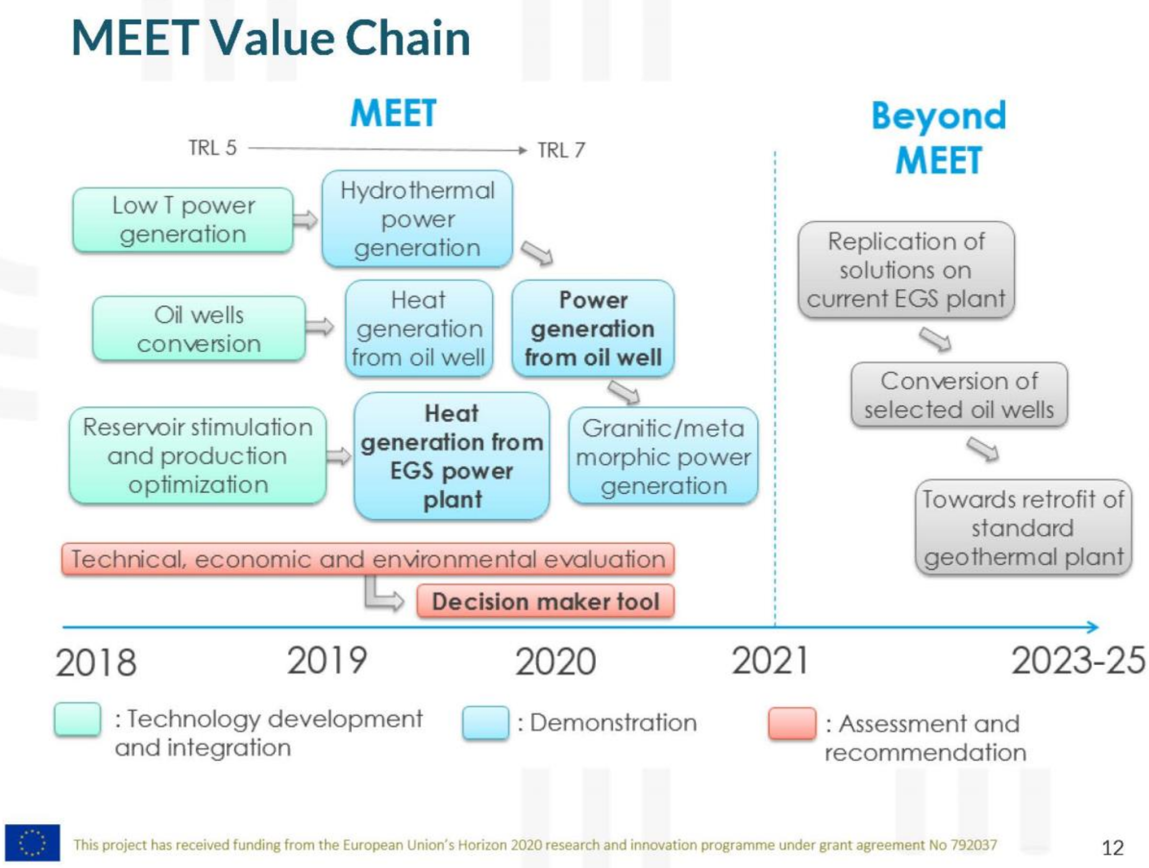
MEET Value Chain
MEET
TRL 5
TRL 7
Beyond MEET
Low T power generation
Hydrothermal power generation
Oil wells conversion
Heat generation from oil well
Power generation from oil well
Reservoir stimulation and production optimization
Heat generation from EGS power plant
Granitic/metamorphic power generation
Technical, economic and environmental evaluation
Decision maker tool
Replication of solutions on current EGS plant
Conversion of selected oil wells
Towards retrofit of standard geothermal plant
2018
2019
2020
2021
2023-25
: Technology development and integration
: Demonstration
: Assessment and recommendation
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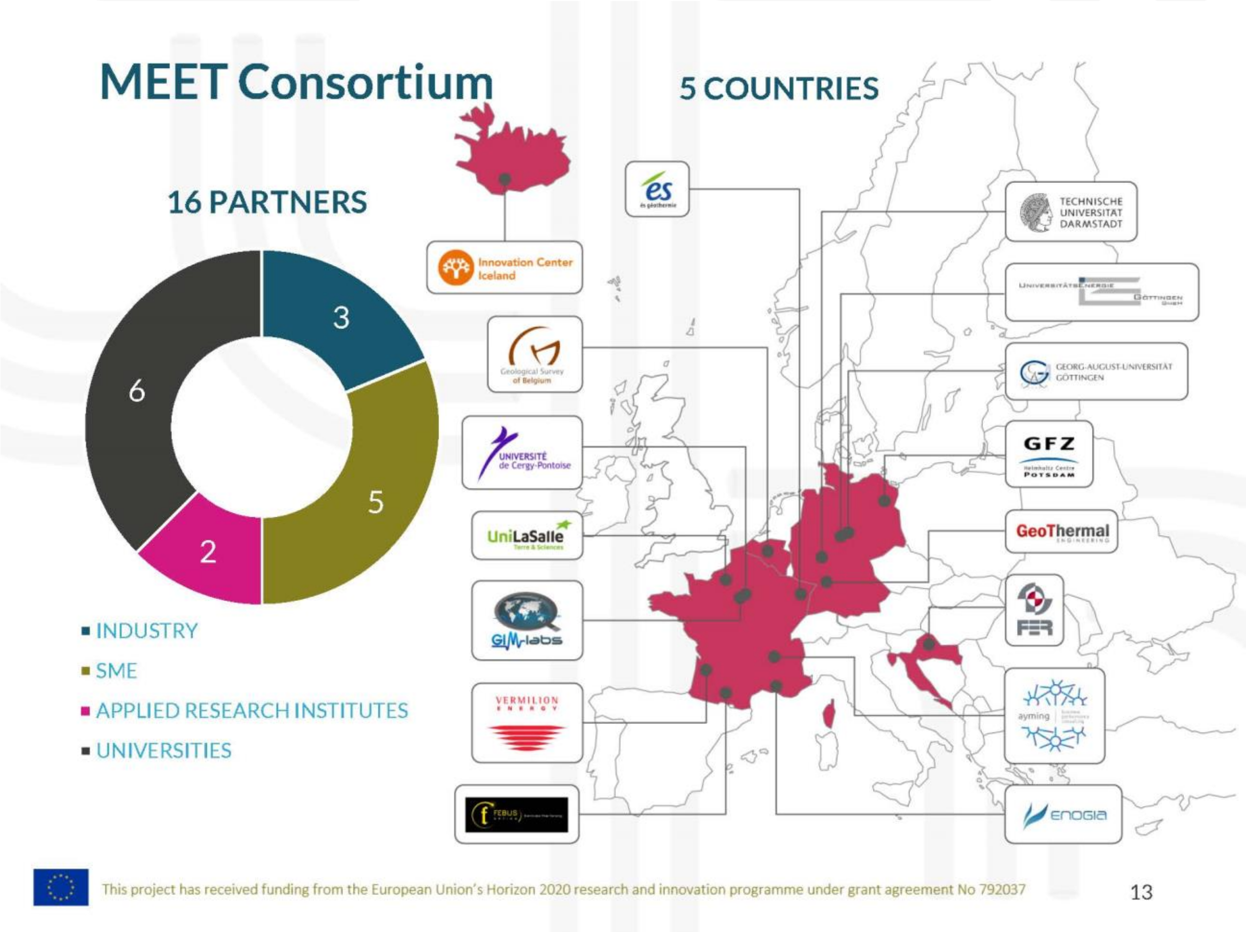
12


MEET Consortium
5 COUNTRIES
16 PARTNERS
3
5
2
6
INDUSTRY
SME
APPLIED RESEARCH INSTITUTES
UNIVERSITIES
Innovation Center Iceland
Geological Survey of Belgium
UNIVERSITÉ de Cergy-Pontoise
UniLaSalle
GIM-labs
VERMILION ENERGY
TECHNISCHE UNIVERSITAT DARMSTADT
GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN
GFZ
GeoThermal
FER
ayming
ENOGIA
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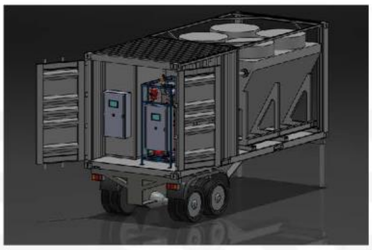
# MEET DEMONSTRATION APPROACH

*SHORT TERM DEEP GEOTHERMAL BOOST*

*Taking advantage of existing wells:*

- *Lower reinjection temperature on EGS plants*
- *Oil to geothermal conversion*
- *Mobile ORC adapted to different geothermal settings:*
  - 2 in granitic setting
  - 2 in sedimentary basin with oil wells
  - 2 in volcanic setting



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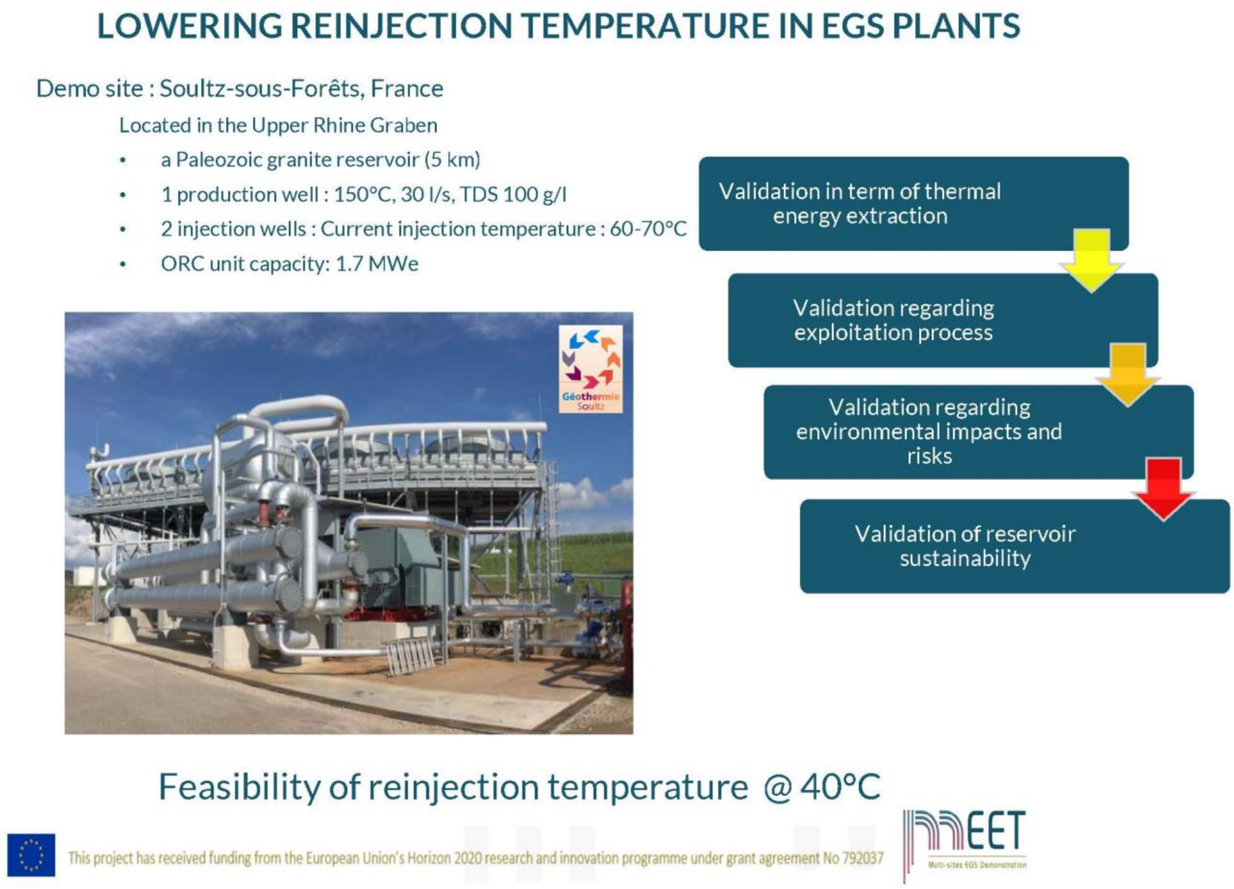
LOWERING REINJECTION TEMPERATURE IN EGS PLANTS
Demo site : Soultz-sous-Forêts, France
Located in the Upper Rhine Graben
• a Paleozoic granite reservoir (5 km)
• 1 production well : 150°C, 30 l/s, TDS 100 g/l
• 2 injection wells : Current injection temperature : 60-70°C
• ORC unit capacity: 1.7 MWe
Validation in term of thermal energy extraction
Validation regarding exploitation process
Validation regarding environmental impacts and risks
Validation of reservoir sustainability
Feasibility of reinjection temperature @ 40°C
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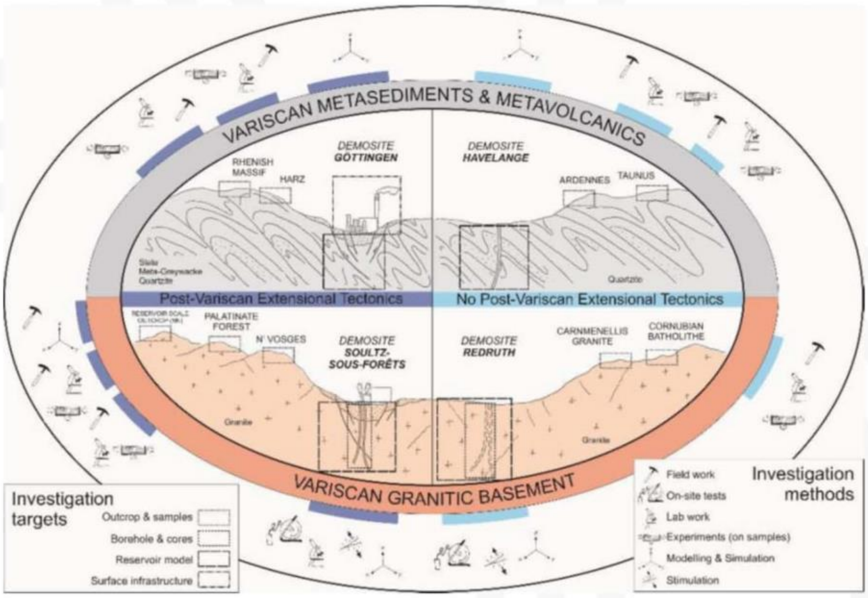
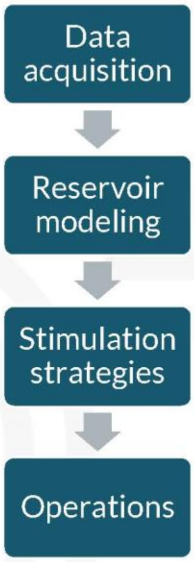
MEET
Multi-sites EGS Demonstration

# MEET DEMONSTRATION APPROACH

*LONG TERM EGS DEVELOPMENT*

Targeting new EGS reservoirs in Europe:
Variscan granitic and metamorphic rocks

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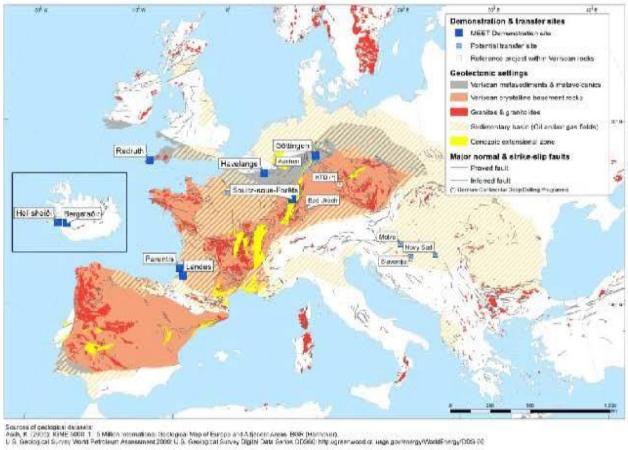
# GENERALIZATION AT EU SCALE

- 2 tools to upscale previous results at EU scale for non-scientific community
  - Decision making support tool will provide site-specific environmental and economic analysis
  - GIS based data compilation will highlight location of promising EGS sites




This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

## MEET First results

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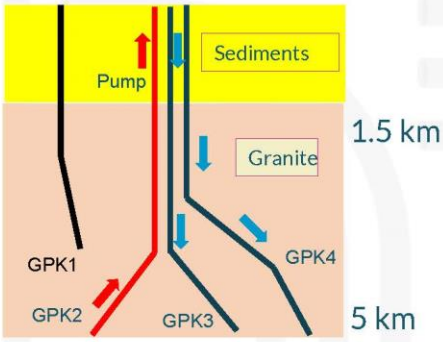
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

## Lowering temperature of a EGS plant in a granite reservoir


- Soultz-sous-Forêts
- Geothermal brine TDS 100g/L
- 1.4 $MW_e$ net (1.7 $MW_e$ gross)
- Existing ORC
- Availability > 90%
- Add a new small scale ORC unit

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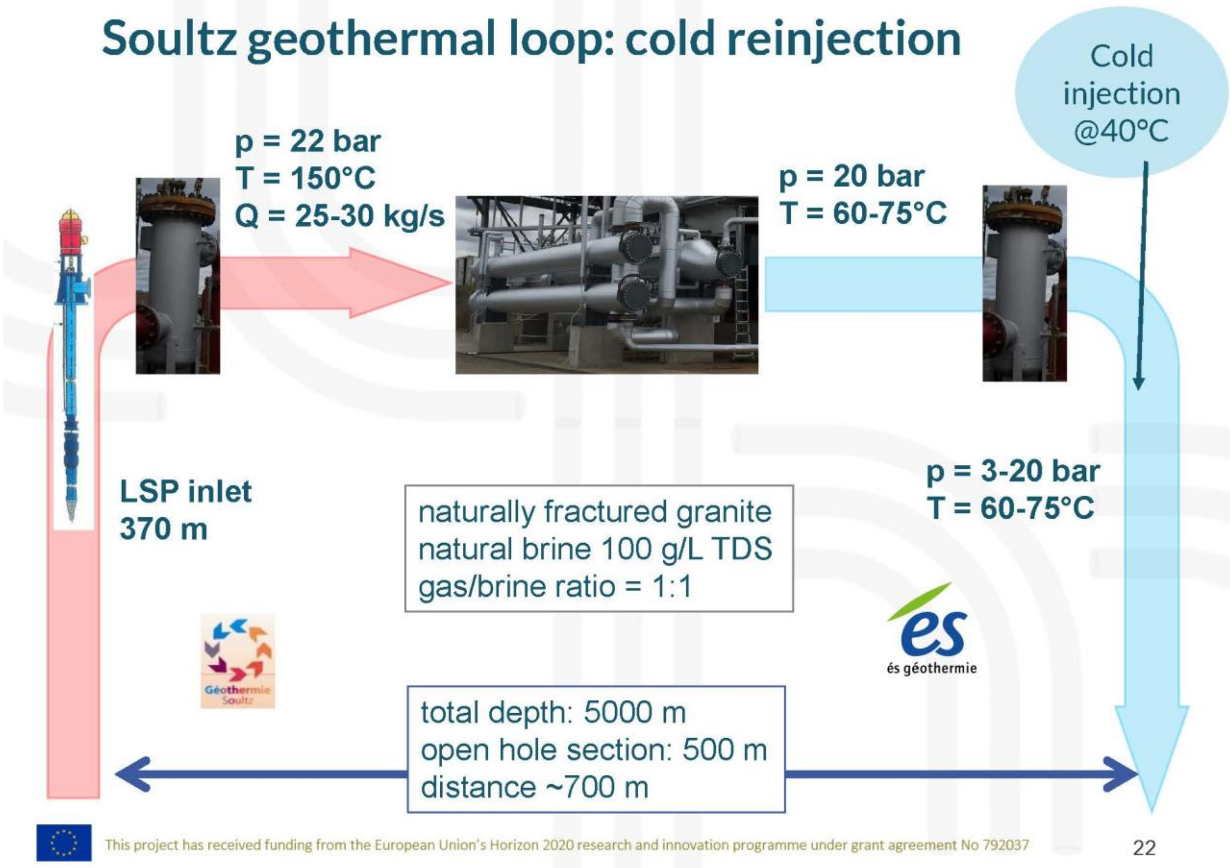
Soultz geothermal loop: cold reinjection
Cold injection @40°C
p = 22 bar
T = 150°C
Q = 25-30 kg/s
p = 20 bar
T = 60-75°C
LSP inlet
370 m
naturally fractured granite
natural brine 100 g/L TDS
gas/brine ratio = 1:1
p = 3-20 bar
T = 60-75°C
és géothermie
Géothermie Soultz
total depth: 5000 m
open hole section: 500 m
distance ~700 m
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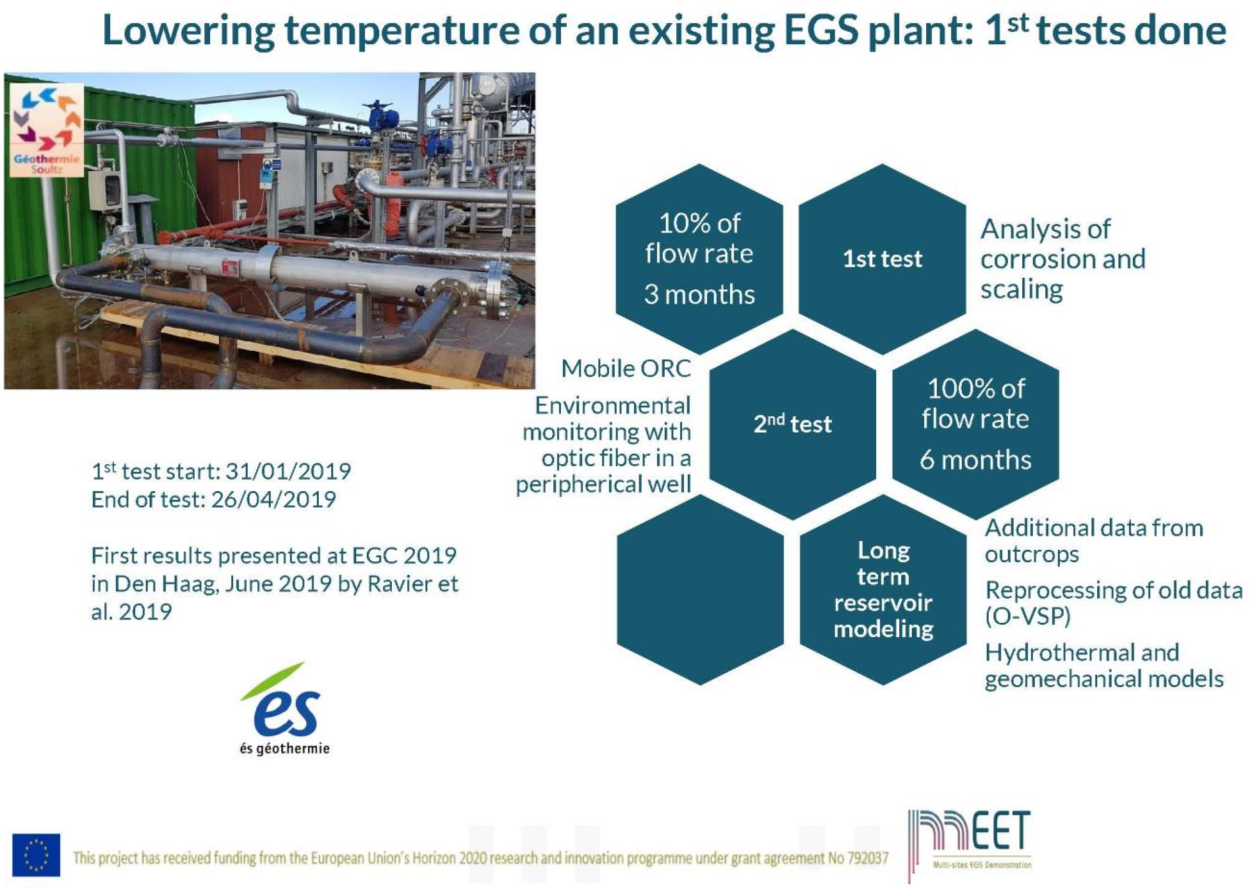
Lowering temperature of an existing EGS plant: 1st tests done
Géothermie Soultz
10% of flow rate
3 months
1st test
Analysis of corrosion and scaling
Mobile ORC
Environmental monitoring with optic fiber in a peripherical well
2nd test
100% of flow rate
6 months
1st test start: 31/01/2019
End of test: 26/04/2019
First results presented at EGC 2019 in Den Haag, June 2019 by Ravier et al. 2019
Long term reservoir modeling
Additional data from outcrops
Reprocessing of old data (O-VSP)
Hydrothermal and geomechanical models
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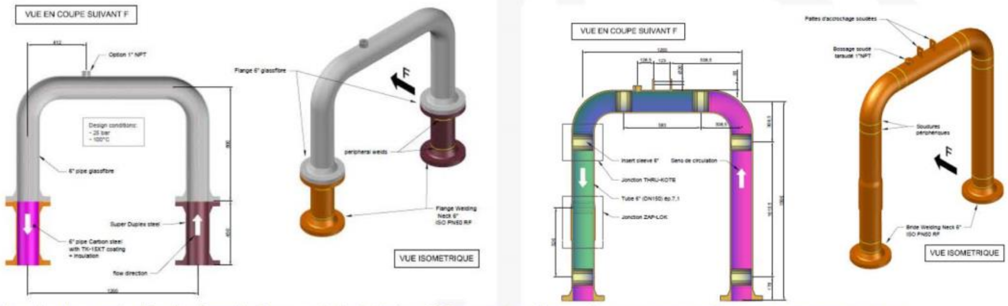
MEET Multi-sites EGS Demonstration

# On-site prototype heat exchanger

- 3 months test operation and analysis
- Evaluation of the potential energy valorisation
- Design of the piping for brine transport hot and cold part

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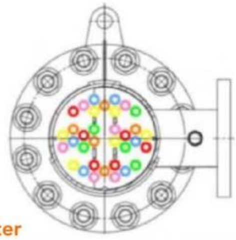
# Lowering temperature of an existing EGS

*Heat exchanger test – operation and first results*

**Result : Operation of test HEX from February to April 2019**

- Observation of quantity and adhesion of scaling in the HEX pipes



| | | Temperature | | |
|---|---|---|---|---|
| | | 64,2°C ± 3,6°C | 47,5 °C ± 3,8°C | 40,8 °C ± 4,2°C |
| Tube material | 904 L | 2 | 3 | 2 |
| | 254 SMO | 2 | 1 | 3 |
| | DX 2205 | 3 | 2 | 1 |
| | SDX 2507 | 1 | 1 | 3 |
| | Alloy 825 | 3 | 2 | 3 |
| | Ti Gr.2 | 3 | 1 | 3 |

Rating of quantity of scaling (1 : low , 3 : high)

| | | Temperature | | |
|---|---|---|---|---|
| | | 64,2°C ± 3,6°C | 47,5 °C ± 3,8°C | 40,8 °C ± 4,2°C |
| Tube material | 904 L | 2 | 1 | 1 |
| | 254 SMO | 1 | 1 | 1 |
| | DX 2205 | 3 | 3 | 3 |
| | SDX 2507 | 1 | 1 | 2 |
| | Alloy 825 | 2 | 2 | 1 |
| | Ti Gr.2 | 3 | 3 | 3 |

Rating of adhesion of scaling (1 : easy to clean , 3 : hard to clean)

First qualitative results:

- Ti Gr 2 and Alloy 825 (Ni) are not recommended
- SDX 2507 (currently used) is fine until at least 47,5°C
- 254 SMO is an interesting option for new project

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# Lowering temperature at Soultz

*Heat exchanger test – scaling and corrosion analyses*

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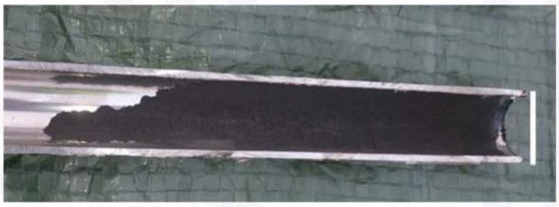

Tubular heat exchanger

Scales observed inside the tubes from the tested heat exchanger
19.05 mm (external diameter)

UNIVERSITÉ de Cergy-Pontoise

Rust spots and corrosion rings on some of the pipes

Innovation Center Iceland

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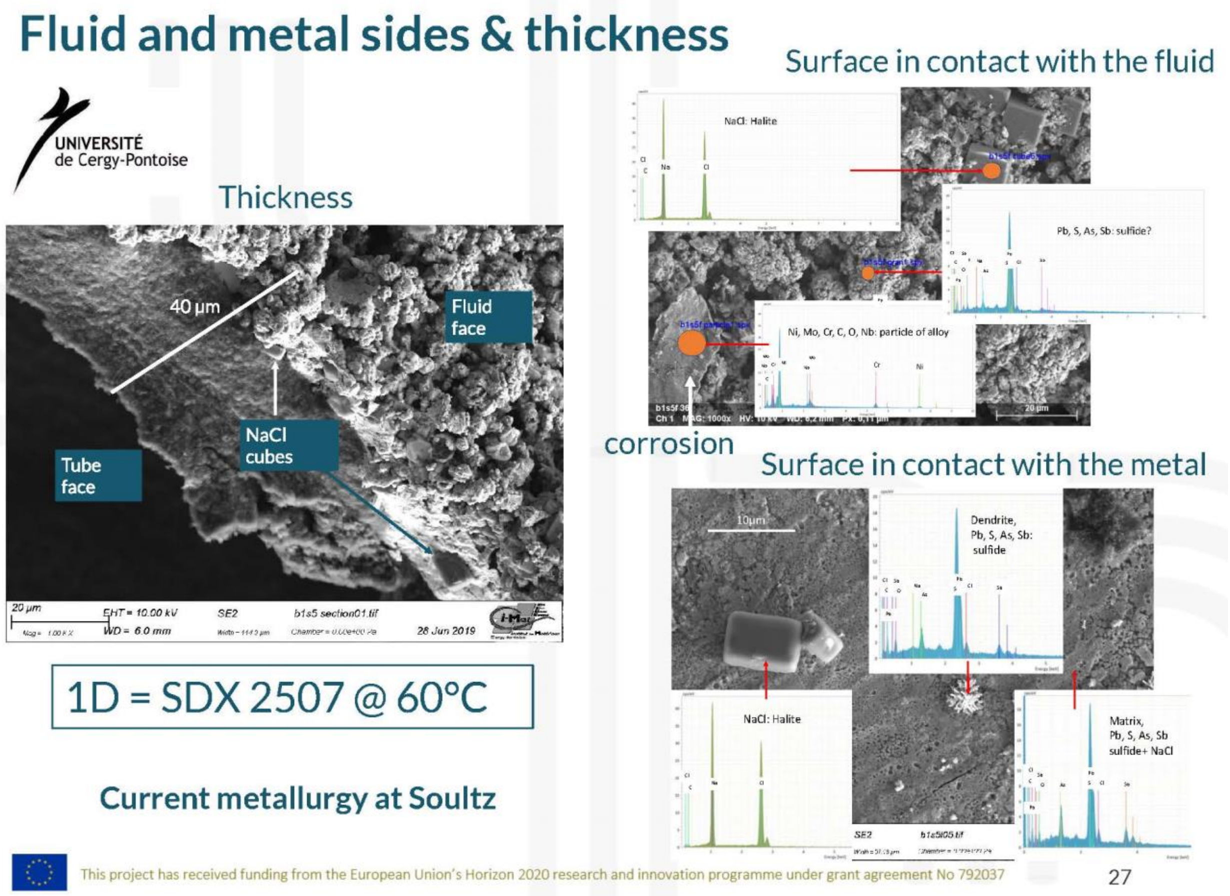
Fluid and metal sides & thickness
UNIVERSITÉ de Cergy-Pontoise
Thickness
40 µm
Fluid face
NaCl cubes
Tube face
1D = SDX 2507 @ 60°C
Current metallurgy at Soultz
Surface in contact with the fluid
NaCl: Halite
Pb, S, As, Sb: sulfide?
Ni, Mo, Cr, C, O, Nb: particle of alloy
corrosion
Surface in contact with the metal
Dendrite, Pb, S, As, Sb: sulfide
NaCl: Halite
Matrix, Pb, S, As, Sb sulfide+ NaCl
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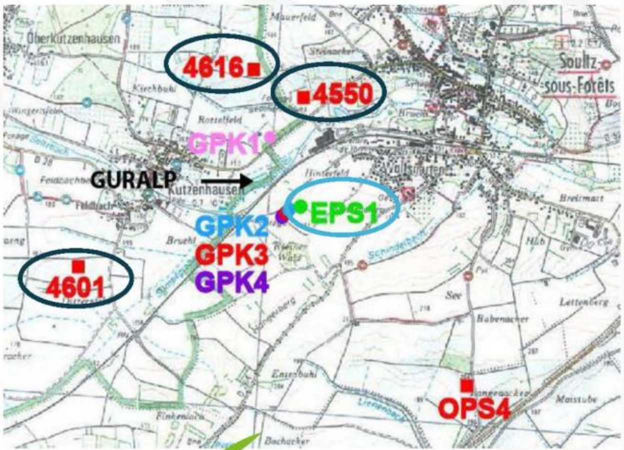
## Environmental monitoring of ORC test – Preparation phase

### Pressure and temperature survey during low-temperature reinjection

Observe temperature et pressure variations in the peripherical observations wells of Soultz-sous-Forêts geothermal plant during colder reinjection

3 standard piezometer (4616 – 4550 – 4601 wells) / 1 optic fiber (EPS1 well)




Optic fiber
Pressure
Temperature
Acoustic

@2230 m
Granite
Brine

és géothermie

FEBUS OPTICS

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# Hydrothermal modelling of cold reinjection

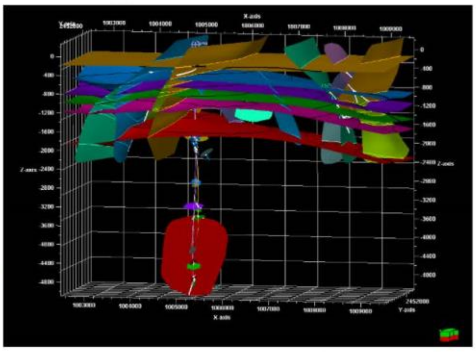
*Granite: first hydrothermal model using historic data*

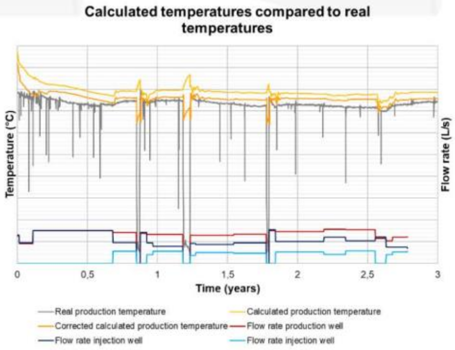
Complex structural model based on Sausse & al (2010)

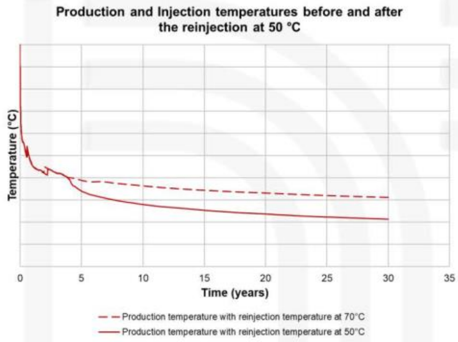
Less sophisticated hydrothermic model to keep important permeable fractures

Hydraulic parameter adjusted to fit on production (pressure & temperature)

First simulation of hydrothermal impact of colder reinjection on production well versus time






és géothermie

Poster presented in Karlsruhe at EGW (October 2019)

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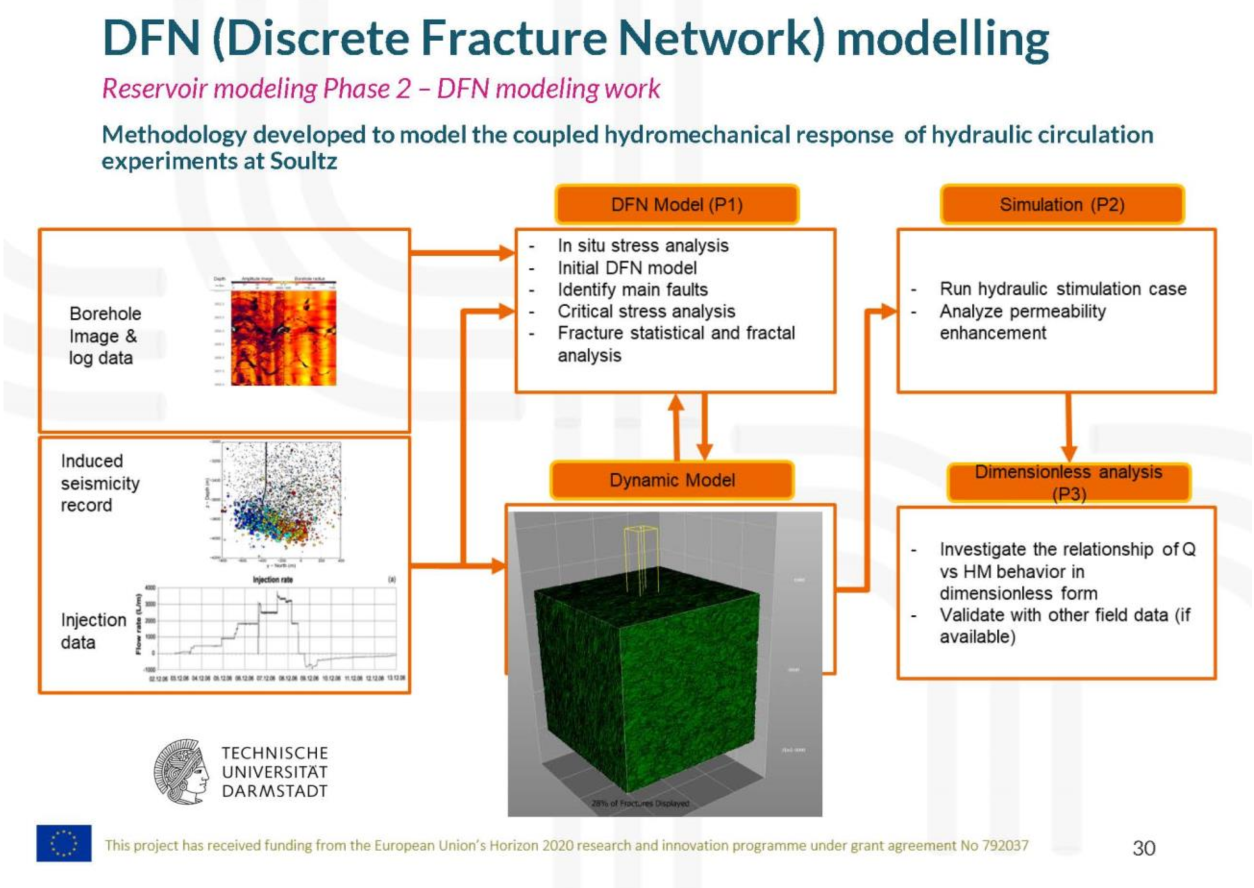
DFN (Discrete Fracture Network) modelling
Reservoir modeling Phase 2 – DFN modeling work
Methodology developed to model the coupled hydromechanical response of hydraulic circulation experiments at Soultz
DFN Model (P1)
- In situ stress analysis
- Initial DFN model
- Identify main faults
- Critical stress analysis
- Fracture statistical and fractal analysis
Simulation (P2)
- Run hydraulic stimulation case
- Analyze permeability enhancement
Borehole Image & log data
Induced seismicity record
Injection data
Injection rate
Dynamic Model
Dimensionless analysis (P3)
- Investigate the relationship of Q vs HM behavior in dimensionless form
- Validate with other field data (if available)
TECHNISCHE UNIVERSITÄT DARMSTADT
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# VSP treatment

*Reservoir modeling Phase 2 – OVSP work*

**1- The building of the 3D model of Soultz-sous-Forêts domain for Vp, Vs and density is achieved. 2D cross-sections going through the seismic source A0 and the GPK4 well have been extracted from the 3D model.**

**2- Adaptation of the FWI inversion code and optimization of the 3D seismic propagation is nearly achieved.**

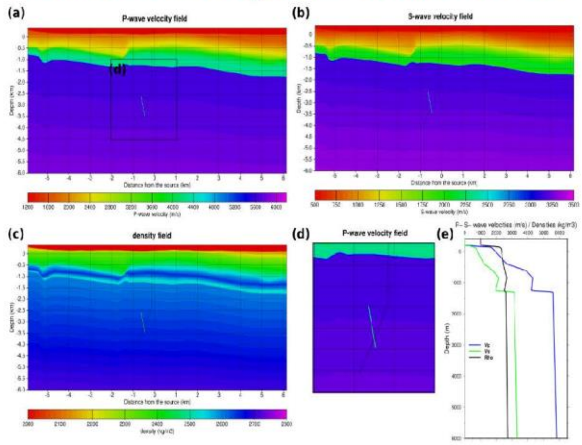
**3- Synthetic 2D inversion and parametric sensibility analysis have been performed for:**
- **The location of faults relatively to the well**
- **The faults dip & fault thickness**
- **The number of faults**
- **The number of shots**

**Real locations of the receivers have been used for the deviated GPK4**

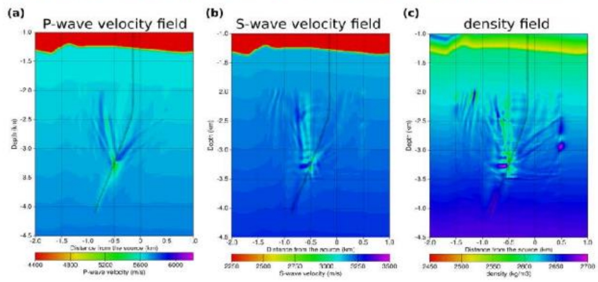
**4- A proceeding including the obtained results has been submitted to WGC2020.**

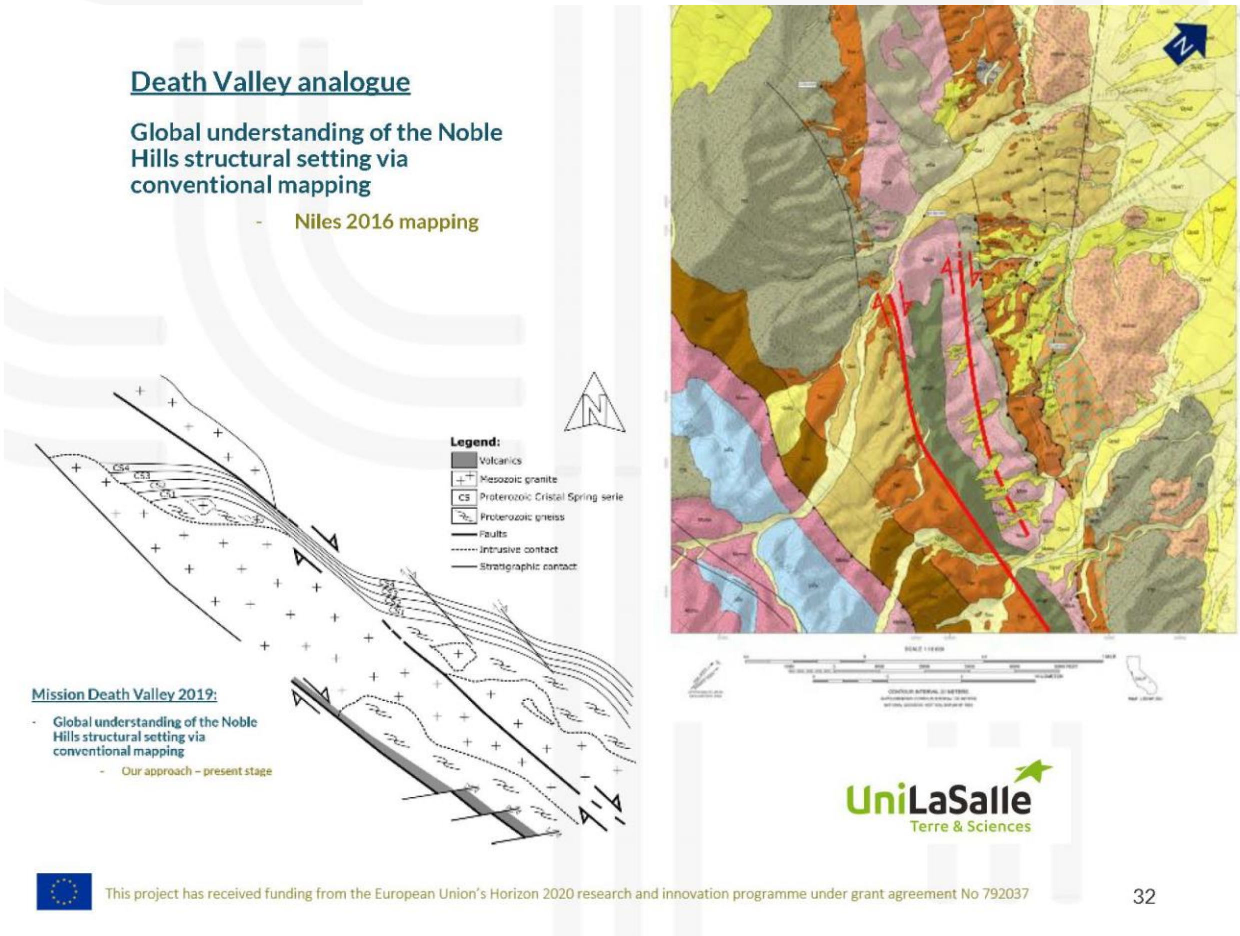
**5- The full 3D seismic modeling and inversion is planed to start next January 2020.**

**1fault/1shot FWI synthetic experiment:**
True models used to generate the observed data




The estimated models ➔ one shot is not sufficient




Death Valley analogue
Global understanding of the Noble Hills structural setting via conventional mapping
- Niles 2016 mapping
Legend:
Volcanics
Mesozoic granite
CS Proterozoic Cristal Spring serie
Proterozoic gneiss
Faults
Intrusive contact
Stratigraphic contact
CS4
CS3
CS2
CS1
N
Mission Death Valley 2019:
- Global understanding of the Noble Hills structural setting via conventional mapping
- Our approach – present stage
UniLaSalle
Terre & Sciences
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037
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## Death Valley: granite analogue

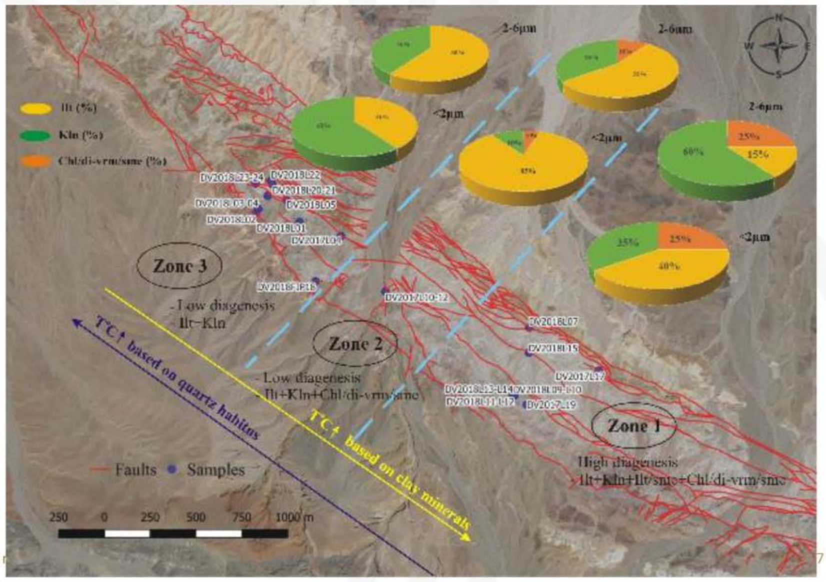
UniLaSalle Terre & Sciences — Université de Cergy-Pontoise

- Sampling campaign
  - Sampling approach along profiles both parallel and perpendicular to the reservoir
  - Sampling following deformation gradients
  - Sampling approach along one profile perpendicular to fresh granite unit
  - Fluid circulation history (baryte, oxide, carbonate)
- Scan line analyses along outcrops in one representative canyon
  - Statistical analysis of fractures
  - Nature of fracture filling (carbonates or iron oxides or both)

e under grant agreement No 792037 33

## Lab studies

- Microscopic characterization
  - Reservoir rock microfabric evolution along deformation gradients
  - Reservoir rock mineralogical evolution during fluid rock interaction processes (polarization microscopy, SEM-EDX cartography)
- XRD analyses on clay minerals
  - Outline of Temperature gradients parallel to the range
    - Higher temperature in the southern part of the range than in the northern part



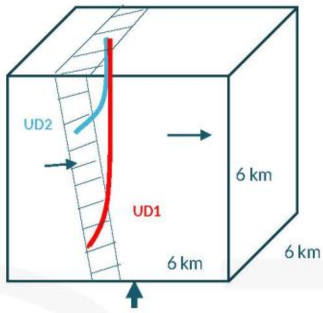

This project has r… 34

# Stimulation of granitic reservoir

UDDGP UnIted Downs Deep Geothermal Project

Cornwall (UK)

Fractured Zone




Two new deep wells UD1 (5.2km) & UD2 (2.4km)

Chemical treatment for improving the hydraulic performance

Analogue studies: rock samples

Fractures, mineralogy, mechanical and petrophysical characterization

Tests on cuttings for mineral dissolution

Tendering for chemical treatment is on-line (open until the 12th of November 2019, 12:00 o'clock CET). The tender in German and English can be found here: https://www.had.de/onlinesuche_langfassung.html?showpub=9FD2E7PPBHQQHJSR

All required documents can be found here: https://www.dtvp.de/Satellite/public/company/project/CXS0YDQYYRY/de/documents

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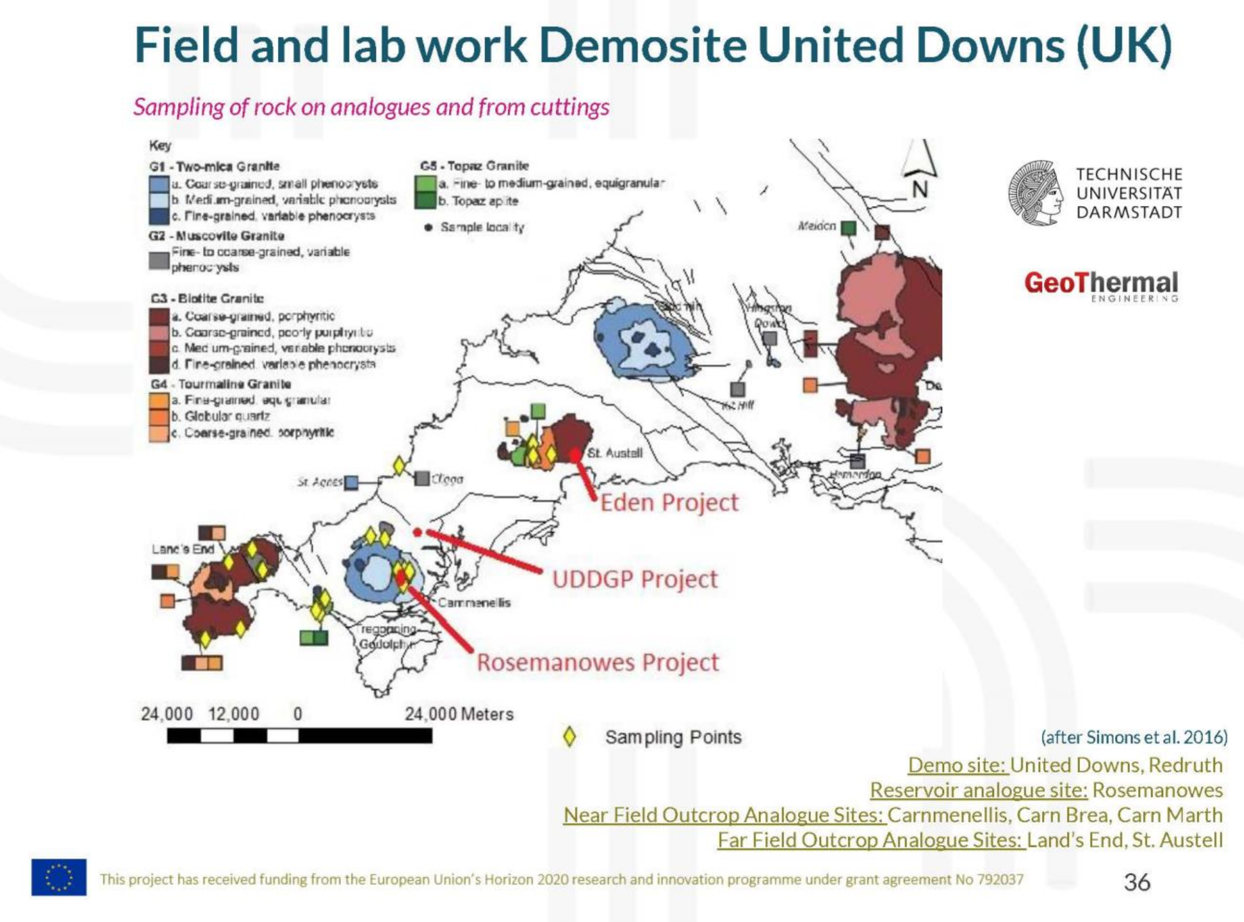
Field and lab work Demosite United Downs (UK)
Sampling of rock on analogues and from cuttings
Key
G1 - Two-mica Granite
a. Coarse-grained, small phenocrysts
b. Medium-grained, variable phenocrysts
c. Fine-grained, variable phenocrysts
G2 - Muscovite Granite
Fine- to coarse-grained, variable phenocrysts
G3 - Biotite Granite
a. Coarse-grained, porphyritic
b. Coarse-grained, poorly porphyritic
c. Medium-grained, variable phenocrysts
d. Fine-grained, variable phenocrysts
G4 - Tourmaline Granite
a. Fine-grained, equigranular
b. Globular quartz
c. Coarse-grained, porphyritic
G5 - Topaz Granite
a. Fine- to medium-grained, equigranular
b. Topaz aplite
Sample locality
N
TECHNISCHE UNIVERSITÄT DARMSTADT
GeoThermal ENGINEERING
St. Austell
Eden Project
St. Agnes
Land's End
UDDGP Project
Carnmenellis
Rosemanowes Project
24,000 12,000 0 24,000 Meters
Sampling Points
(after Simons et al. 2016)
Demo site: United Downs, Redruth
Reservoir analogue site: Rosemanowes
Near Field Outcrop Analogue Sites: Carnmenellis, Carn Brea, Carn Marth
Far Field Outcrop Analogue Sites: Land's End, St. Austell
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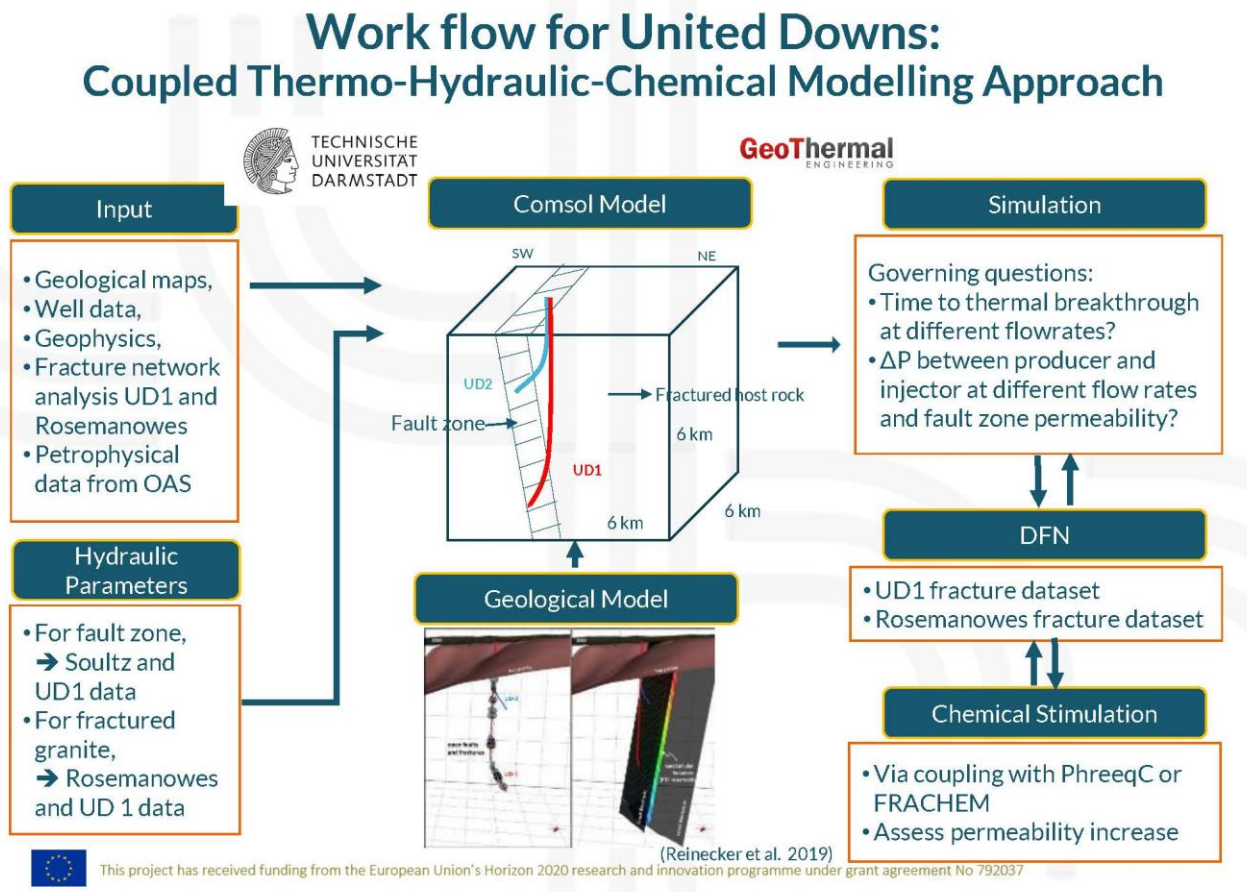

Work flow for United Downs:
Coupled Thermo-Hydraulic-Chemical Modelling Approach
TECHNISCHE UNIVERSITÄT DARMSTADT
GeoThermal ENGINEERING
Input
• Geological maps,
• Well data,
• Geophysics,
• Fracture network analysis UD1 and Rosemanowes
• Petrophysical data from OAS
Hydraulic Parameters
• For fault zone, ➔ Soultz and UD1 data
• For fractured granite, ➔ Rosemanowes and UD 1 data
Comsol Model
SW
NE
UD2
UD1
Fault zone
Fractured host rock
6 km
6 km
6 km
Geological Model
(Reinecker et al. 2019)
Simulation
Governing questions:
• Time to thermal breakthrough at different flowrates?
• ΔP between producer and injector at different flow rates and fault zone permeability?
DFN
• UD1 fracture dataset
• Rosemanowes fracture dataset
Chemical Stimulation
• Via coupling with PhreeqC or FRACHEM
• Assess permeability increase
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

# Demosite Paris Basin & Aquitain Basin

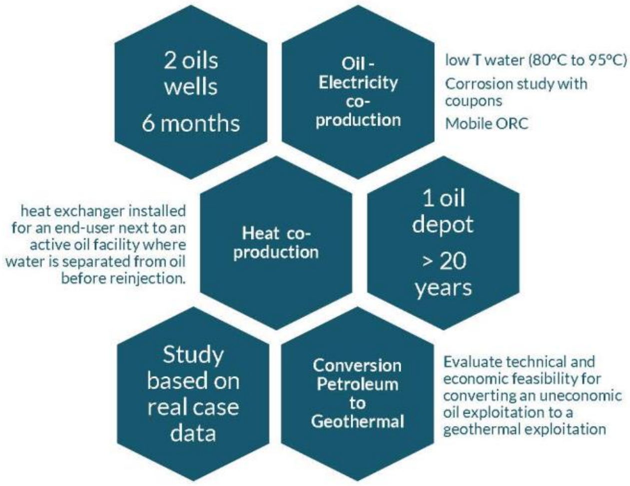
VERMILION ENERGY

## Sediments / Oil field

ENOGIA

Innovation Center Iceland

# CONVERSION FROM OIL TO GEOTHERMAL




1st pilot for power production to be commissioned by November 2019

VERMILION ENERGY

ENOGIA

Innovation Center Iceland

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

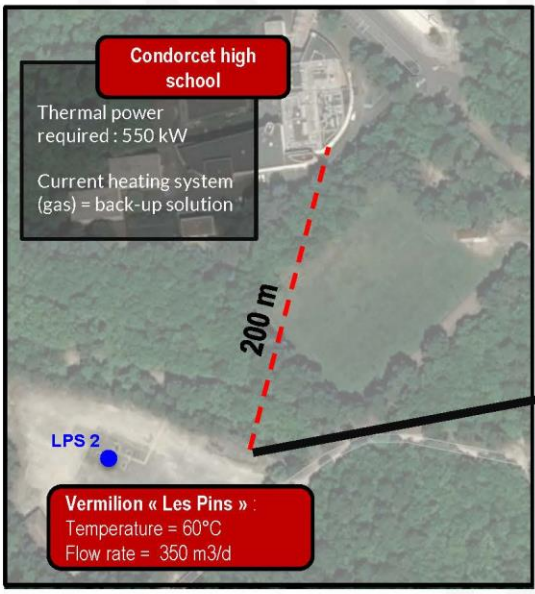
# Heat for the Condorcet high school close to Arcachon

Current heating system is gas

2018 useful energy consumption

- Space heating: 824 MWh
- Hot sanitary water: 90 MWh

GHG emission ~ 230 $tCO_2eq$/year


- ☑ Energy bills saving
- ☑ GHG emission avoided: *- 200 $tCO_2eq$/year*
- ☑ Renewable energy coverage rate *~ 83%*

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# Condorcet high school

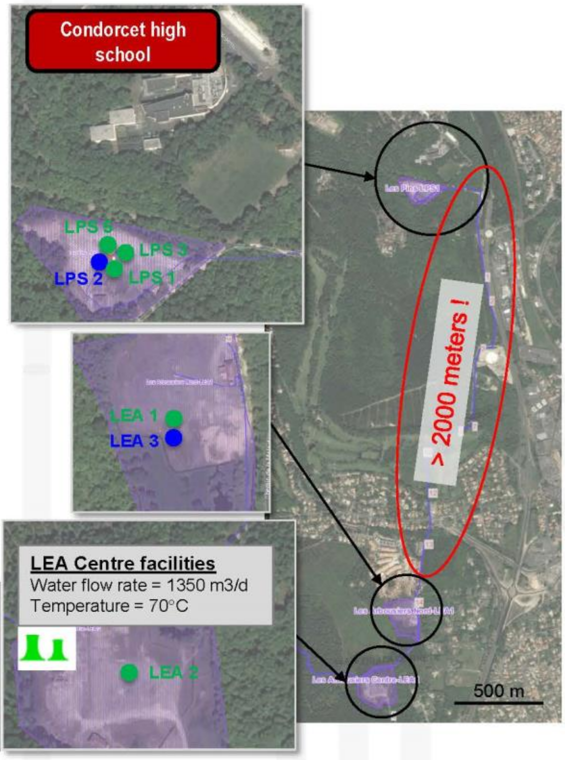
*Insulation feasibility study*

Conclusion: **no insulation**

- Costly investment for low heat gain (~80-100 k€)
- Risk of corrosion under insulation
- Constraint for Vermilion maintenance and operational surveillance

But in Q1 2020, increase of the heat resource by improving the injection capacity

VERMILION ENERGY




**Legend**

- Production well (oil + water + gas)
- Injection well
- Injection flowline

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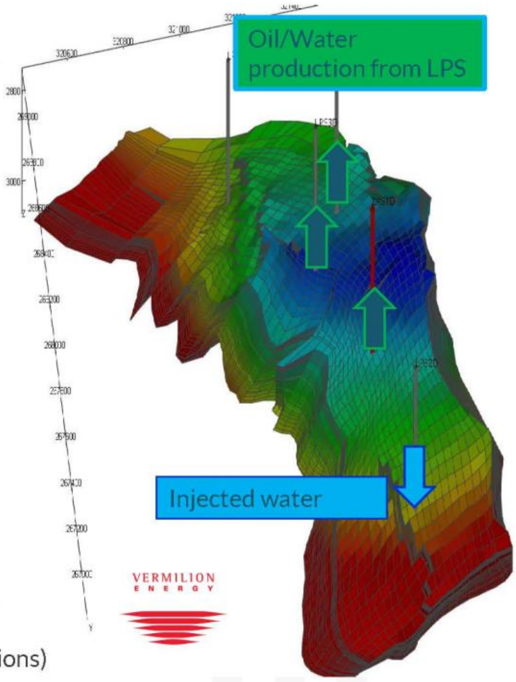
# Thermal model objectives on Les Pins field

*OBJECTIVES*

- Gather the available data to build a Les Pins thermal model
- Build a fit for purpose Les Pins thermal model
- What is the temperature today in the reservoir?
- Forecast reservoir thermal impact of future colder water reinjection once heat exchanger is installed on injection line.

*SETTINGS (Geocellular model)*

- Existing geomodel (Petrel/2006) used in Tnavigator (RFD)
- Structure from seismic horizons
- Grid: 25 x 57 x 29 (DX~30m, DY~43m, DZ~2.5m)
- Reservoir property populated using geostatistical methods
- Model hydrodynamically calibrated (pressure, fluid saturations)

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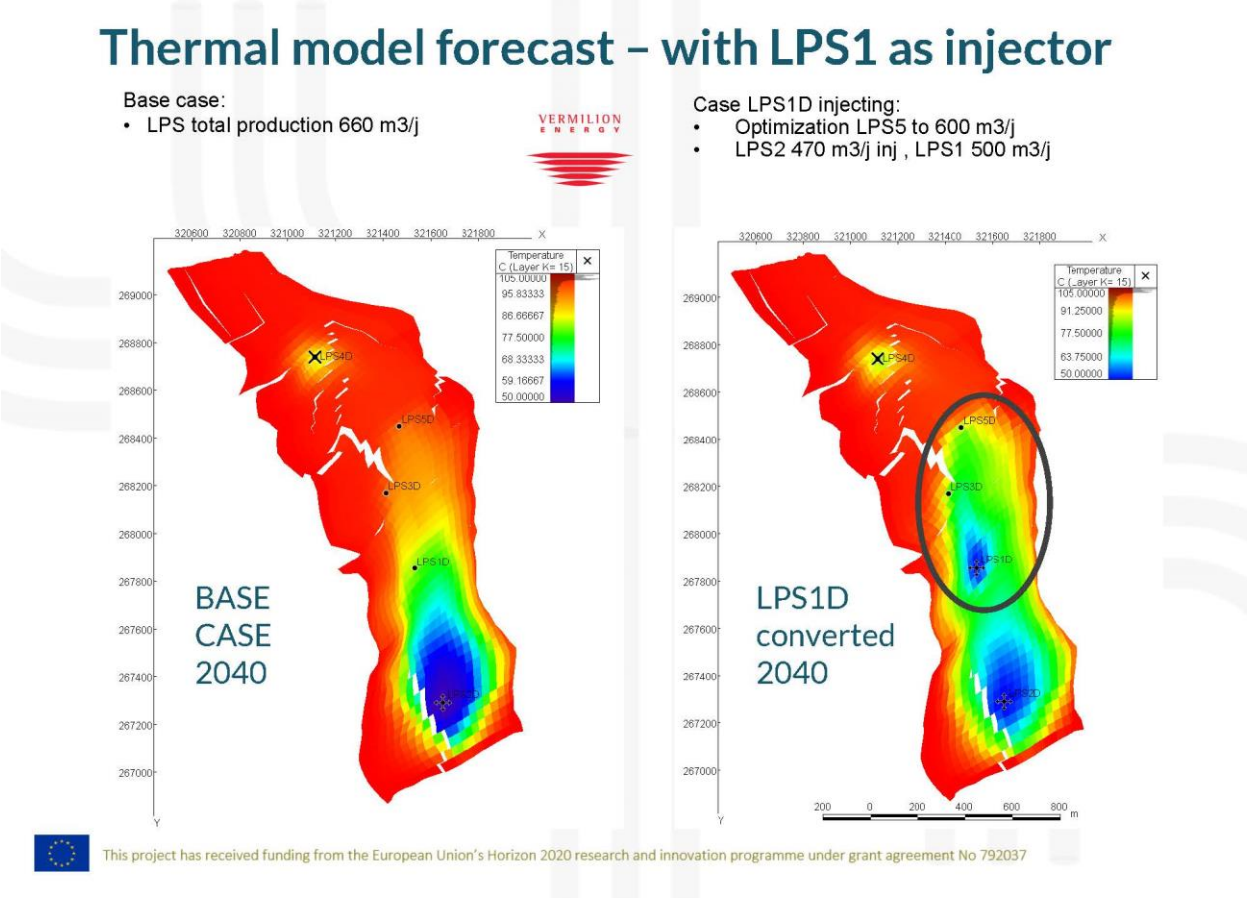
Thermal model forecast – with LPS1 as injector
Base case:
• LPS total production 660 m3/j
VERMILION ENERGY
Case LPS1D injecting:
• Optimization LPS5 to 600 m3/j
• LPS2 470 m3/j inj , LPS1 500 m3/j
BASE CASE 2040
LPS1D converted 2040
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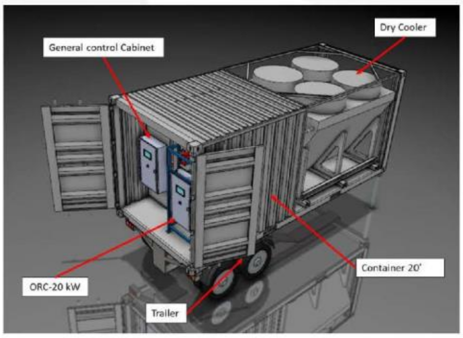
# Mobile ORC units deployed on 6 sites

ENOGIA

## ORC Design and Manufacturing

- Design and adapt 3 ORC for the 3 first demo sites;
  - Complete design of the ORC
    - Selection of the best material for HEX
    - Manufacturing of the 20 kW ORC Module
    - Factory test of the 20 kW ORC Module
    - Starting of the manufacturing of the 40 kW ORC Module

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# Period 1 main results/achievements

## ORC Design and Manufacturing

- Design and adapt 3 ORC for the 3 first demo sites;
  - Heat Exchanger Selection
    - > Gasketed plate-and-Frame Heat Exchanger
    - > Selected Material for Granitic and Volcanic: 254 SMO
  - Start the manufacturing of the 2 ORC 40 kW

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## Testing of samples for HEX materials

- Tested to choose appropriate material for different environments
- 4 separate material experiments
  - Reykjanes, an Icelandic geothermal power plant
  - Grásteinn, an Icelandic farm
  - Cazaux, a French oil field
  - Laboratory experiments
- 8 materials tested

| Material | Type |
|---|---|
| 2205 | Duplex stainless steel |
| 316L | Stainless steel |
| 2507 | Super duplex stainless steel |
| Ti | Titanium alloy |
| 904L | Stainless steel |
| 254SMO | Stainless steel |
| Alloy625 | Ni-Alloy |
| PVF | Plastic |

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In-situ testing for future ORC deployment
VERMILION ENERGY
Reykjanes
Grásteinn
Cazaux
ENOGIA
Innovation Center Iceland
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# Corrosion study on HX material

- 4 types of tests/analyses: Corrosion rate, tensite test, Stress corrosion, microstructural analysis
- Corrosion rate
  - **All** values below **0.1 mm/yr**
- Corrosion rate, tensile tests, stressed test
  - **All** values **within acceptable limits**
- Microstructural analysis
  - **Pitting** and **cracking** in most samples

| Reykjanes | | Cazaux | | Grásteinn | |
|---|---|---|---|---|---|
| Ranking no. | Material | Ranking no. | Material | Ranking no. | Material |
| 1 | Ti Gr.2 | 1-2 | 254 SMO | 1 | 904L |
| 2-3 | 904L | 1-2 | 904L | 2 | 254 SMO |
| 2-3 | 254 SMO | 3-4 | 316L | 3-4 | 316L |
| 4 | Alloy 625 | 3-4 | Alloy 625 | 3-4 | Alloy 625 |
| 5-7 | 316L | 5-6 | 2205 | 5-6 | 2205 |
| 5-7 | 2205 | 5-6 | 2507 | 5-6 | 2507 |
| 5-7 | 2507 | | | | |

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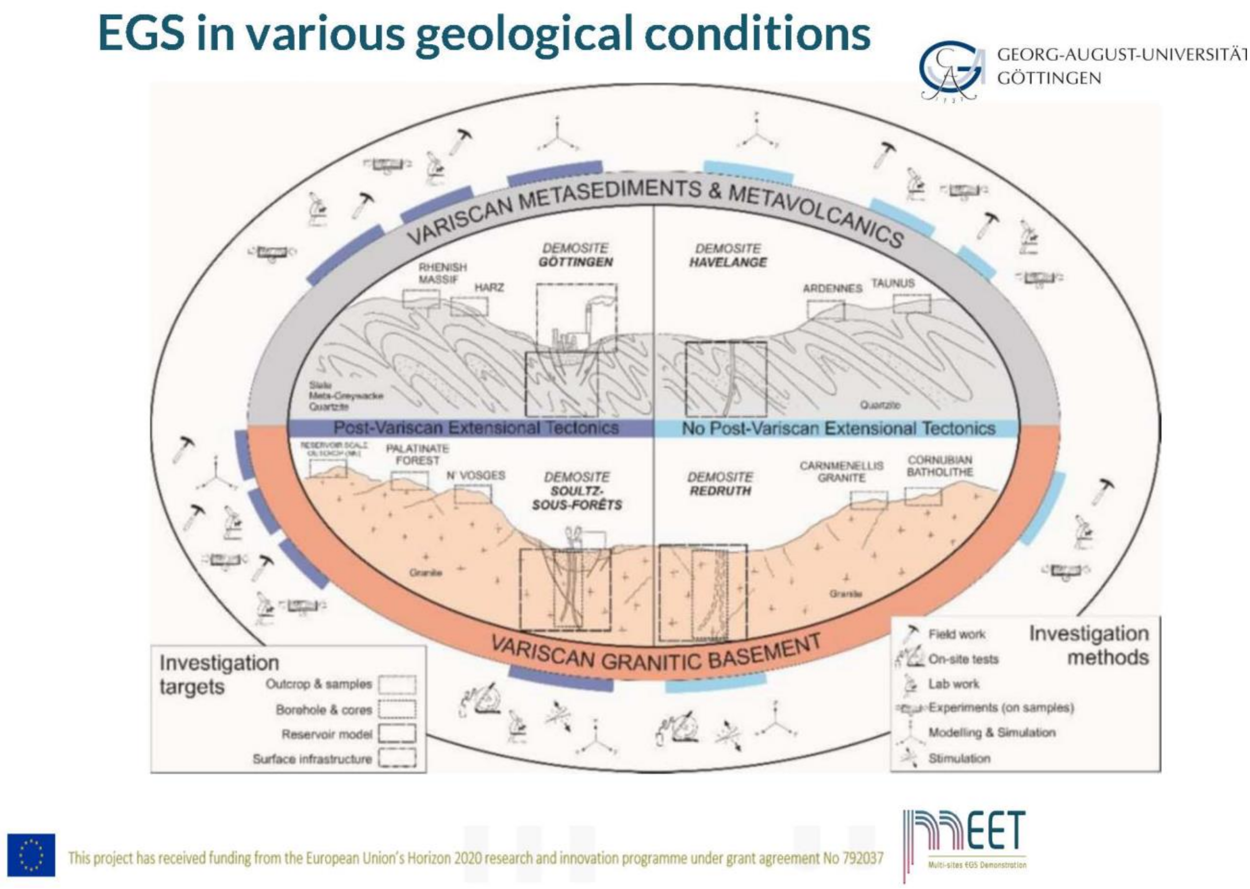
EGS in various geological conditions
GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN
VARISCAN METASEDIMENTS & METAVOLCANICS
DEMOSITE GÖTTINGEN
DEMOSITE HAVELANGE
RHENISH MASSIF
HARZ
ARDENNES
TAUNUS
Slate
Meta-Greywacke
Quartzite
Quartzite
Post-Variscan Extensional Tectonics
No Post-Variscan Extensional Tectonics
PALATINATE FOREST
N' VOSGES
DEMOSITE SOULTZ-SOUS-FORÊTS
DEMOSITE REDRUTH
CARNMENELLIS GRANITE
CORNUBIAN BATHOLITHE
Granite
Granite
VARISCAN GRANITIC BASEMENT
Investigation targets
Outcrop & samples
Borehole & cores
Reservoir model
Surface infrastructure
Investigation methods
Field work
On-site tests
Lab work
Experiments (on samples)
Modelling & Simulation
Stimulation
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## Demosite Göttingen

## Metasedimentary rocks

## Analogues

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

UNIVERSITÄTSENERGIE GÖTTINGEN GMBH

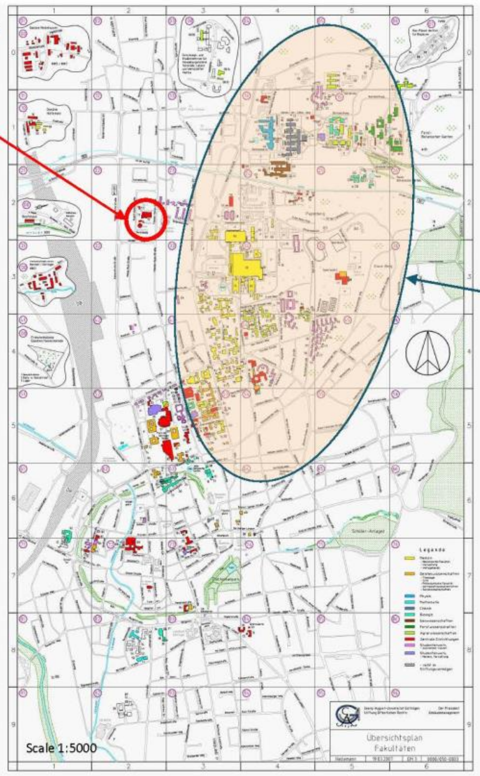
# Gottingen University campus

UniversitätsEnergie Göttingen GmbH

Georg-August-Universität Göttingen

500 m

**Combined Heat and Power Generation**

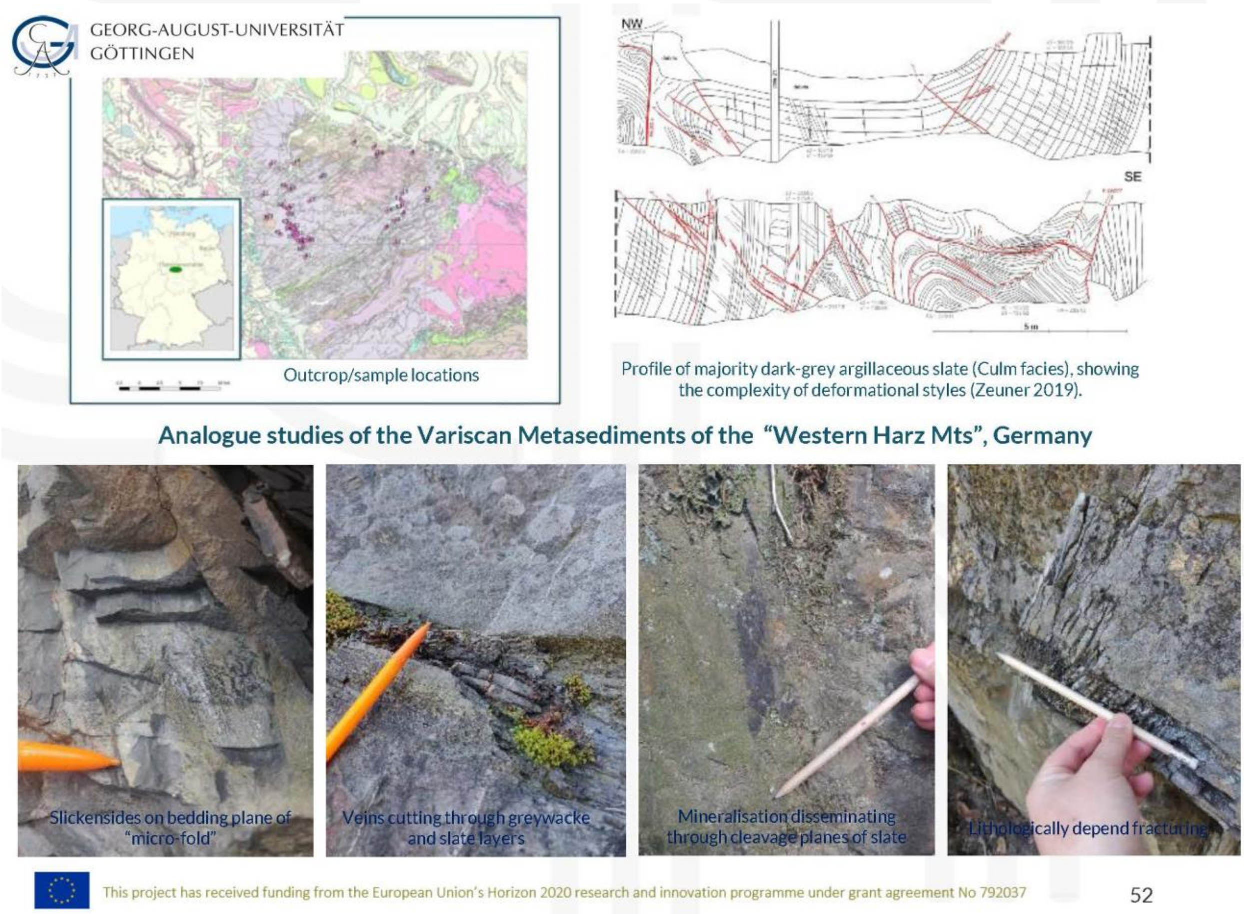




**District heating of the University:**

**13 km heating pipe**

**supplying**

**ca. 250 building units**


GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN
Outcrop/sample locations
NW
SE
Profile of majority dark-grey argillaceous slate (Culm facies), showing the complexity of deformational styles (Zeuner 2019).
Analogue studies of the Variscan Metasediments of the "Western Harz Mts", Germany
Slickensides on bedding plane of "micro-fold"
Veins cutting through greywacke and slate layers
Mineralisation disseminating through cleavage planes of slate
Lithologically depend fracturing
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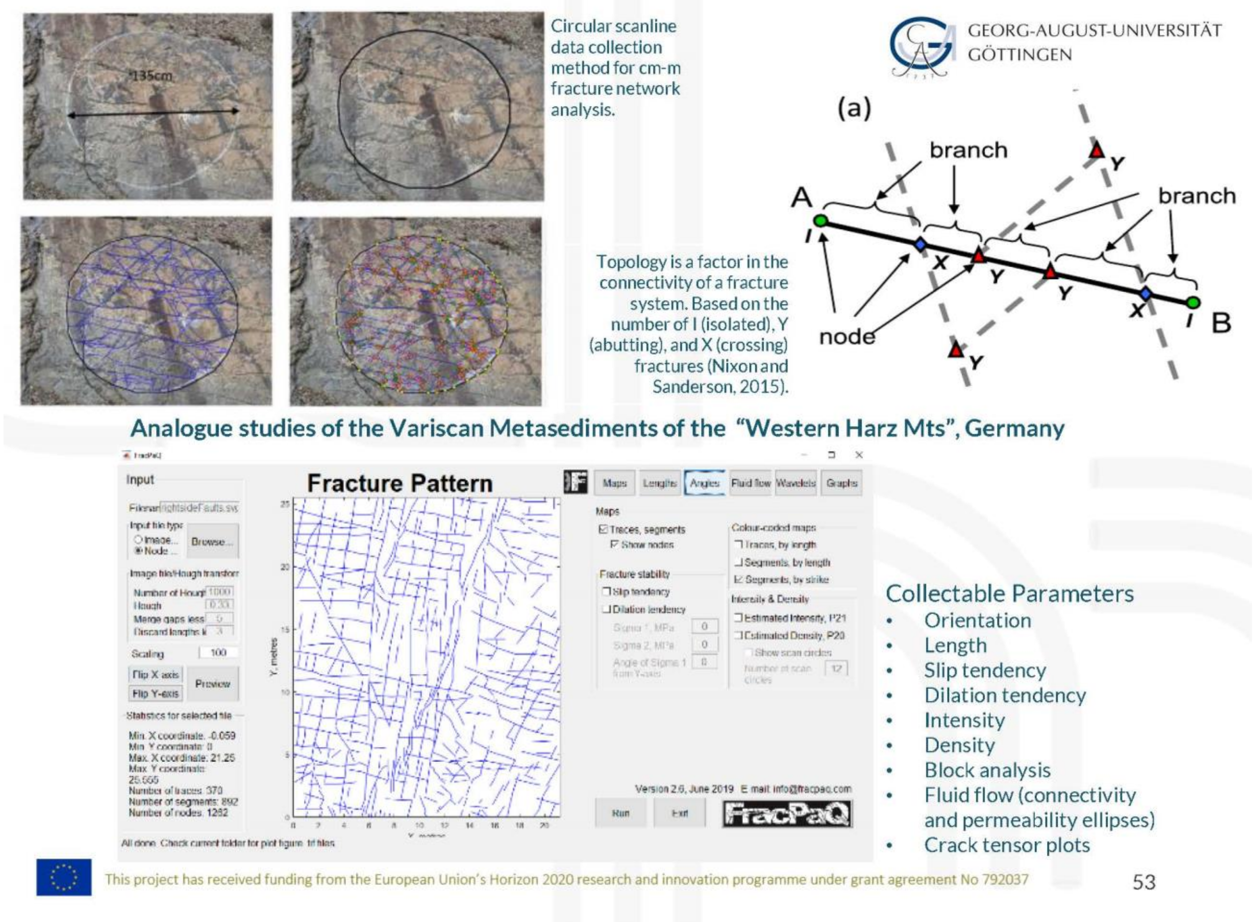
Circular scanline data collection method for cm-m fracture network analysis.
135cm
GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN
(a)
branch
branch
A
B
node
I
X
Y
Topology is a factor in the connectivity of a fracture system. Based on the number of I (isolated), Y (abutting), and X (crossing) fractures (Nixon and Sanderson, 2015).
Analogue studies of the Variscan Metasediments of the "Western Harz Mts", Germany
Input
Fracture Pattern
Maps
Lengths
Angles
Fluid flow
Wavelets
Graphs
Traces, segments
Show nodes
Fracture stability
Slip tendency
Dilation tendency
Colour-coded maps
Traces, by length
Segments, by length
Segments, by strike
Intensity & Density
Estimated Intensity, P21
Estimated Density, P20
Browse...
Preview
Flip X axis
Flip Y-axis
Scaling
Statistics for selected file
Min. X coordinate: -0.059
Max. X coordinate: 21.25
Number of traces: 370
Number of segments: 892
Number of nodes: 1262
Version 2.6, June 2019 E mail info@fracpaq.com
Run
Exit
FracPaQ
All done. Check current folder for plot figure .tif files
Collectable Parameters
Orientation
Length
Slip tendency
Dilation tendency
Intensity
Density
Block analysis
Fluid flow (connectivity and permeability ellipses)
Crack tensor plots
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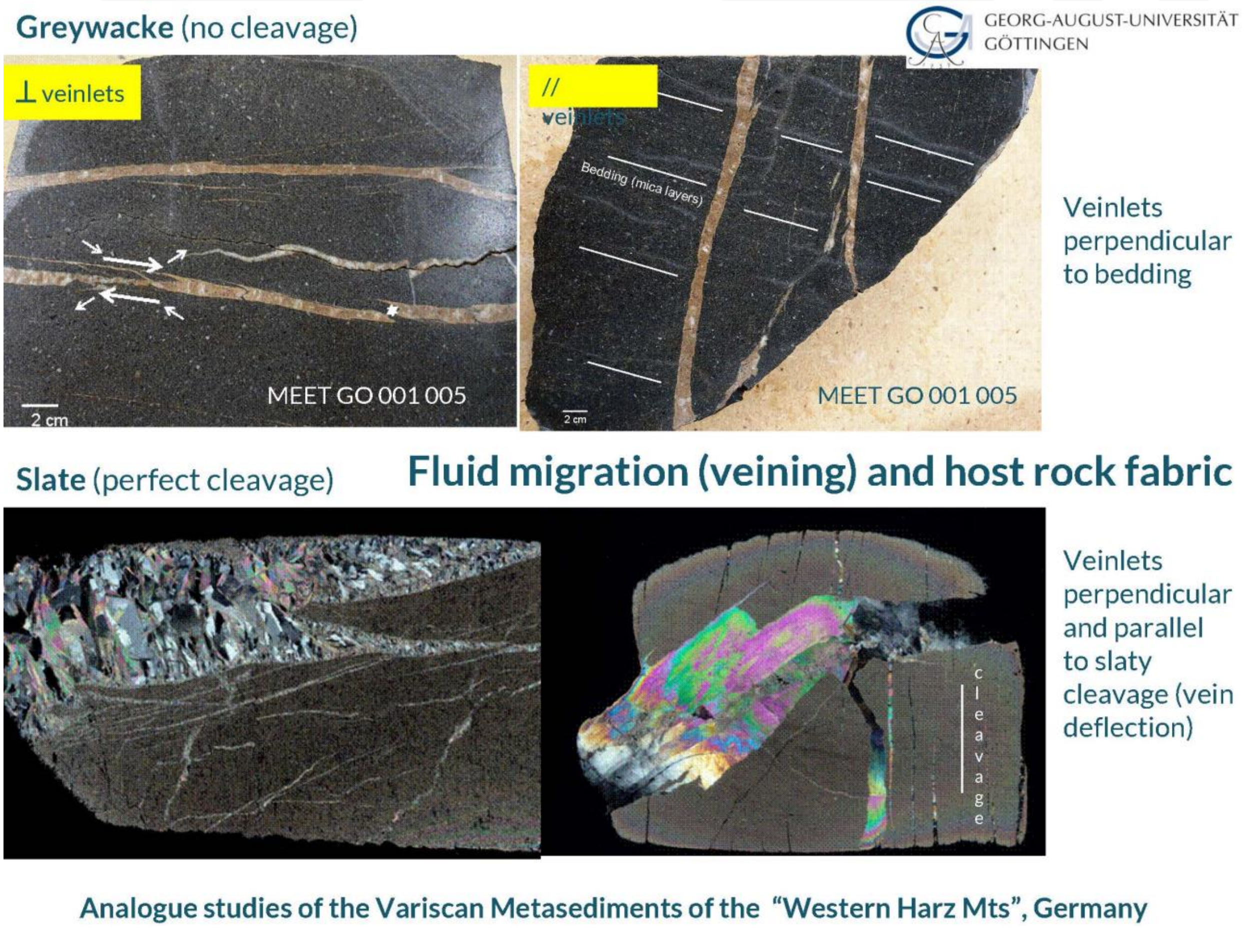
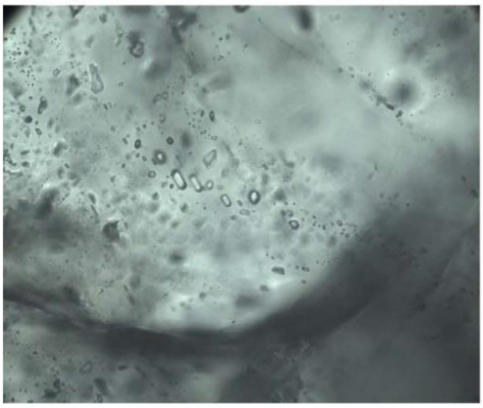

Greywacke (no cleavage)
GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN
⊥ veinlets
// veinlets
Bedding (mica layers)
2 cm
MEET GO 001 005
2 cm
MEET GO 001 005
Veinlets perpendicular to bedding
Slate (perfect cleavage)
Fluid migration (veining) and host rock fabric
cleavage
Veinlets perpendicular and parallel to slaty cleavage (vein deflection)
Analogue studies of the Variscan Metasediments of the "Western Harz Mts", Germany

### Analogue studies of the Variscan Metasediments of the "Western Harz Mts", Germany

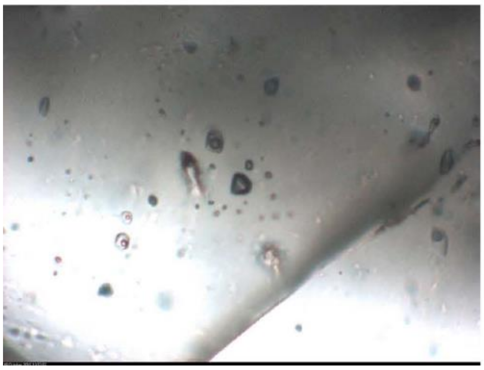
**Greywacke**



**Methane ± nitrogen** (one-phase inclusions)
Homogenization temperature = -83 to -92°C
Isotopic composition
$\delta^{15}N$ = -0.7 to -1.3 ‰
$\delta^{13}C$ ($CH_4$) = -31.7 ‰
Thermogenic $CH_4$: breakup of organic matter

**Minor water (two-phase inclusions)**
Homogenization temperature = 150-372°C
Low salinity = 0-1 wt% NaCl

**Slate**



## Fluid inclusions in the veinlets

**Water ± NaCl ± $CO_2$** (two-phase inclusions)
Homogenization temperature = 145 to 340°C
Clathrate melting = 6.2 to 9.3°C
Low salinity = 0-5 wt% NaCl

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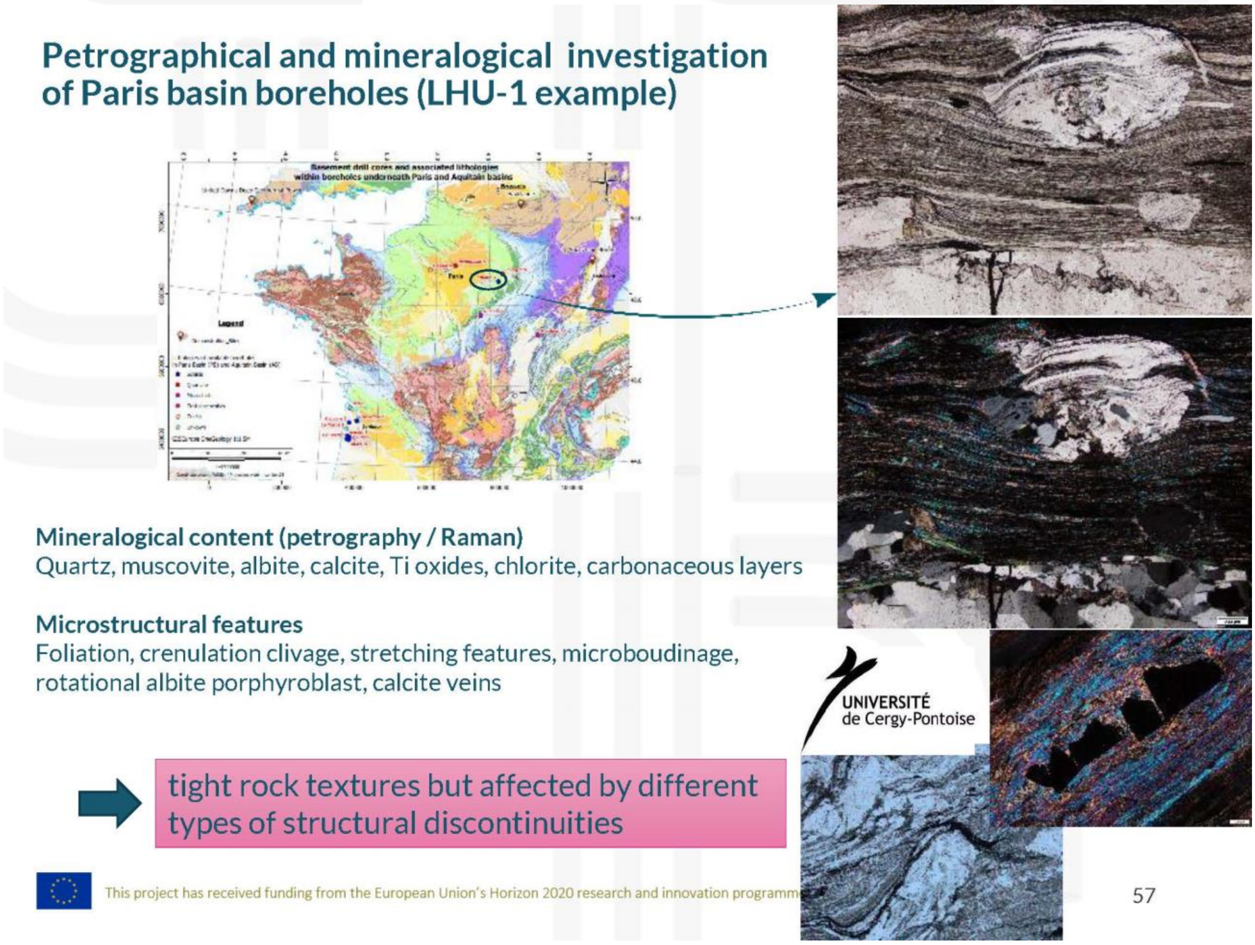
UNIVERSITÉ de Cergy-Pontoise

# Paris Basin (basement) Petrographic characterisation

# Metasedimentary rocks

VERMILION ENERGY


Petrographical and mineralogical investigation of Paris basin boreholes (LHU-1 example)
Mineralogical content (petrography / Raman)
Quartz, muscovite, albite, calcite, Ti oxides, chlorite, carbonaceous layers
Microstructural features
Foliation, crenulation clivage, stretching features, microboudinage, rotational albite porphyroblast, calcite veins
tight rock textures but affected by different types of structural discontinuities
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## Calcite content in metamorphic rocks below the Paris basin

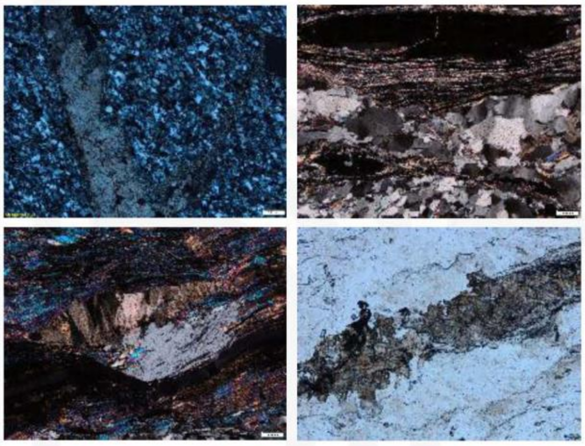
UNIVERSITÉ de Cergy-Pontoise

| Borehole | Sample | Calcite content (%) |
|---|---|---|
| CASSIN-1 | MEETPB001001 | 0,53 |
| | MEETPB001001 | 0,36 |
| | MEETPB001002 | 0,32 |
| | MEETPB001002 | 0,46 |
| | MEETPB001003 | 1,17 |
| | MEETPB001003 | 1,08 |
| | MEETPB001004 | 0,42 |
| | MEETPB001004 | 0,26 |
| | MEETPB001005 | 0,53 |
| | MEETPB001005 | 0,62 |
| | MEETPB001006 | 0,42 |
| | MEETPB001006 | 0,52 |
| LHUITRE-1 | MEETPB002001 | 0,69 |
| | MEETPB002001 | 0,67 |
| | MEETPB002002 | 1,06 |
| | MEETPB002002 | 0,83 |
| | MEETPB002003 | 2,63 |
| | MEETPB002003 | 2,49 |
| NANTOUILLET-1 | MEETPB004001 | 2,76 |
| | MEETPB004001 | 2,38 |
| | MEETPB004002 | 3,29 |
| | MEETPB004002 | 3,36 |
| QUENNE-1 | MEETPB005002 | 2,55 |
| | MEETPB005002 | 2,48 |
| SONGY-101 | MEETPB006003 | 0,69 |
| | MEETPB006003 | 0,62 |
| | MEETPB006004 | 0,74 |
| | MEETPB006004 | 0,62 |

2 calcimeters are used for each sample

Results consistent with petrographical observations:

MEETPB004001 MEETPB002003



MEETPB002002 MEETPB002002

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Geological Survey of Belgium

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

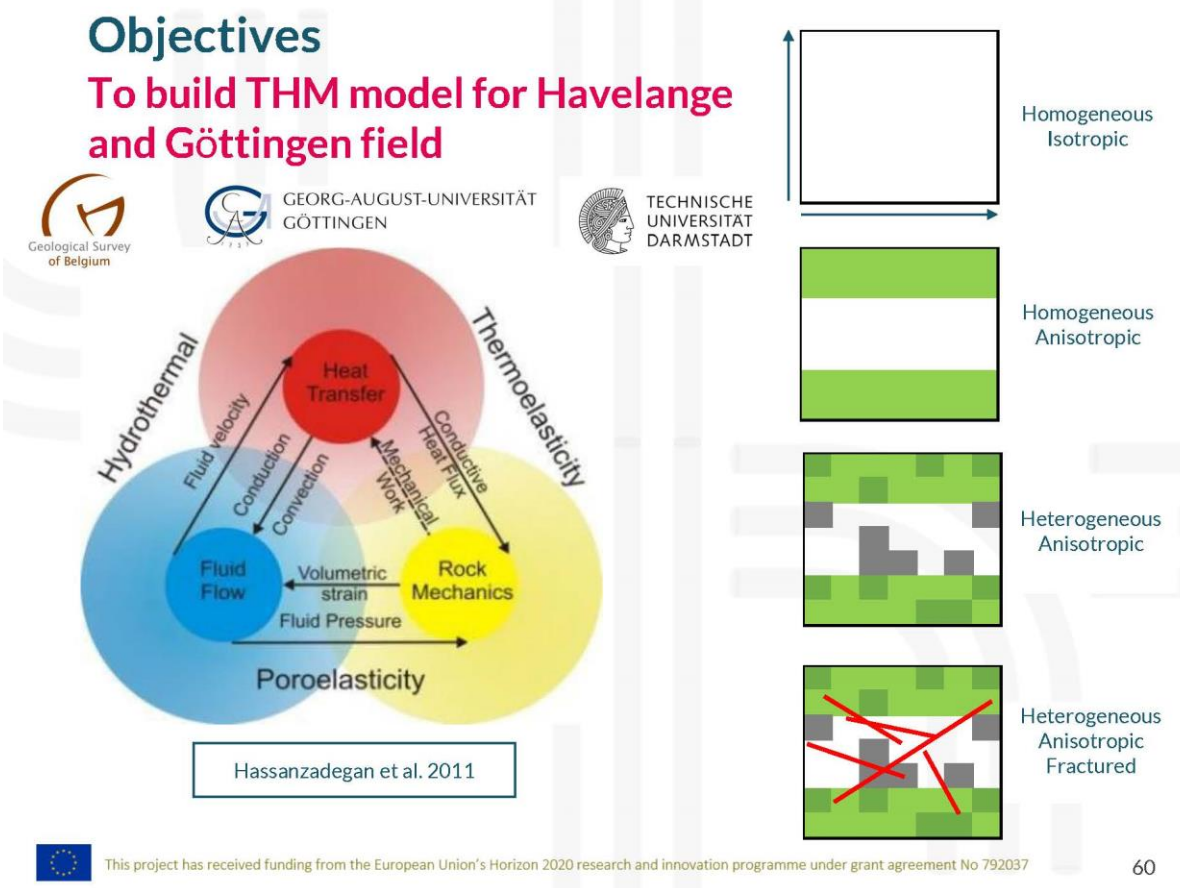
# Reservoir Modelling

# Demosites Havelange and Göttingen

# Metasedimentary rocks

TECHNISCHE UNIVERSITÄT DARMSTADT

UNIVERSITÄTSENERGIE GÖTTINGEN GMBH


Objectives
To build THM model for Havelange and Göttingen field
Geological Survey of Belgium
GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN
TECHNISCHE UNIVERSITÄT DARMSTADT
Hydrothermal
Thermoelasticity
Poroelasticity
Heat Transfer
Fluid Flow
Rock Mechanics
Fluid velocity
Conduction
Convection
Conductive Heat Flux
Mechanical Work
Volumetric strain
Fluid Pressure
Hassanzadegan et al. 2011
Homogeneous Isotropic
Homogeneous Anisotropic
Heterogeneous Anisotropic
Heterogeneous Anisotropic Fractured
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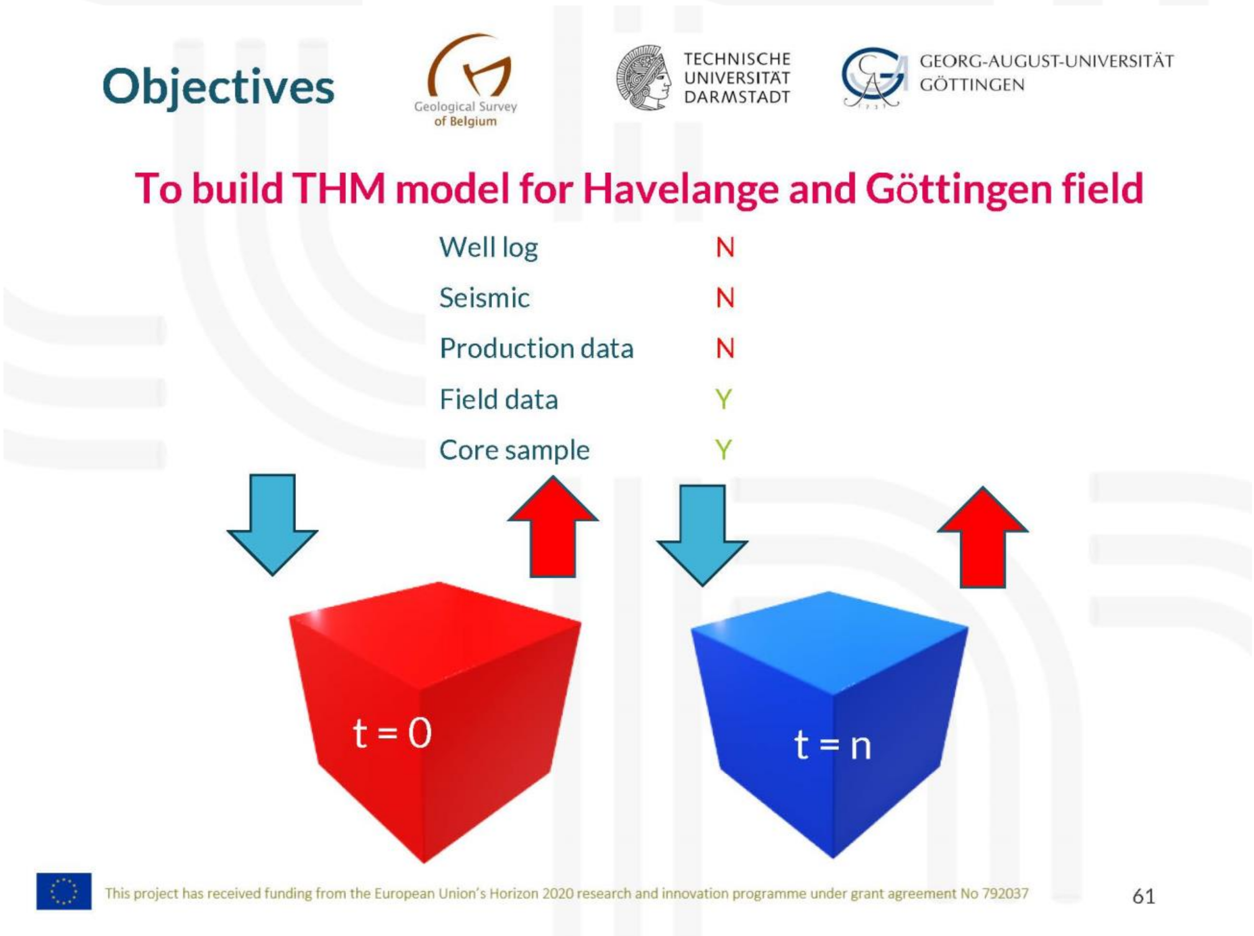
Objectives
Geological Survey of Belgium
TECHNISCHE UNIVERSITÄT DARMSTADT
GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN
To build THM model for Havelange and Göttingen field
Well log N
Seismic N
Production data N
Field data Y
Core sample Y
t = 0
t = n
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# Lab work
# Fluid-rock interactions

## Metasedimentary rocks

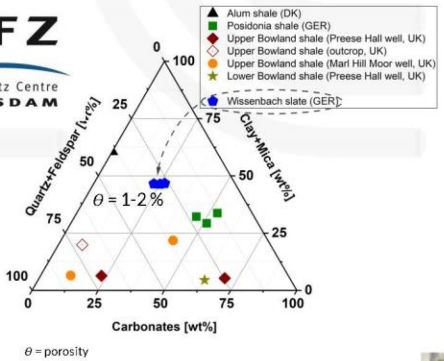
GFZ
Helmholtz Centre
POTSDAM

# Frac permeability: Samples and experimental setup

- Long-term fracture-conductivity experiments on Wissenbach slate samples (Hahnenklee well, depth ≈ 1150 m)
- Varying confining pressure ($p_c$ = 5 – 25 MPa), temperature (T = 20 – 90 °C) and differential stress ($\sigma$ = 7 -17.5 MPa) conditions
- Duration of experiments: ≈ 2 – 4 weeks; fluid: water; predefined roughness (saw cut)

## Sample composition

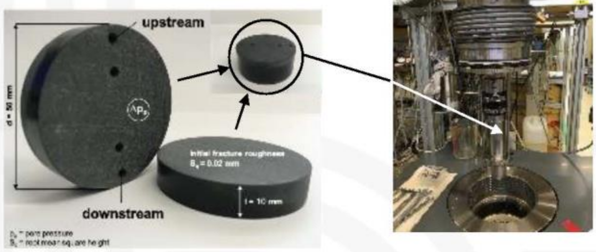
GFZ Helmholtz Centre Potsdam



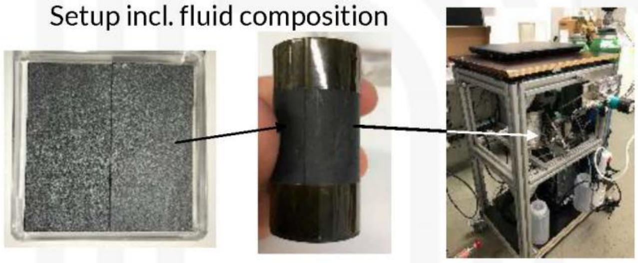

- Slate samples display a mixture of Clays + Mica (≈50 wt%), Carbonates (≈ 25 wt%) and Quartz + Feldspar (25 wt%)
- Wissenbach slate is more clay-rich than most European shales

## Experimental setup

Setup incl. differential stress




Setup incl. fluid composition



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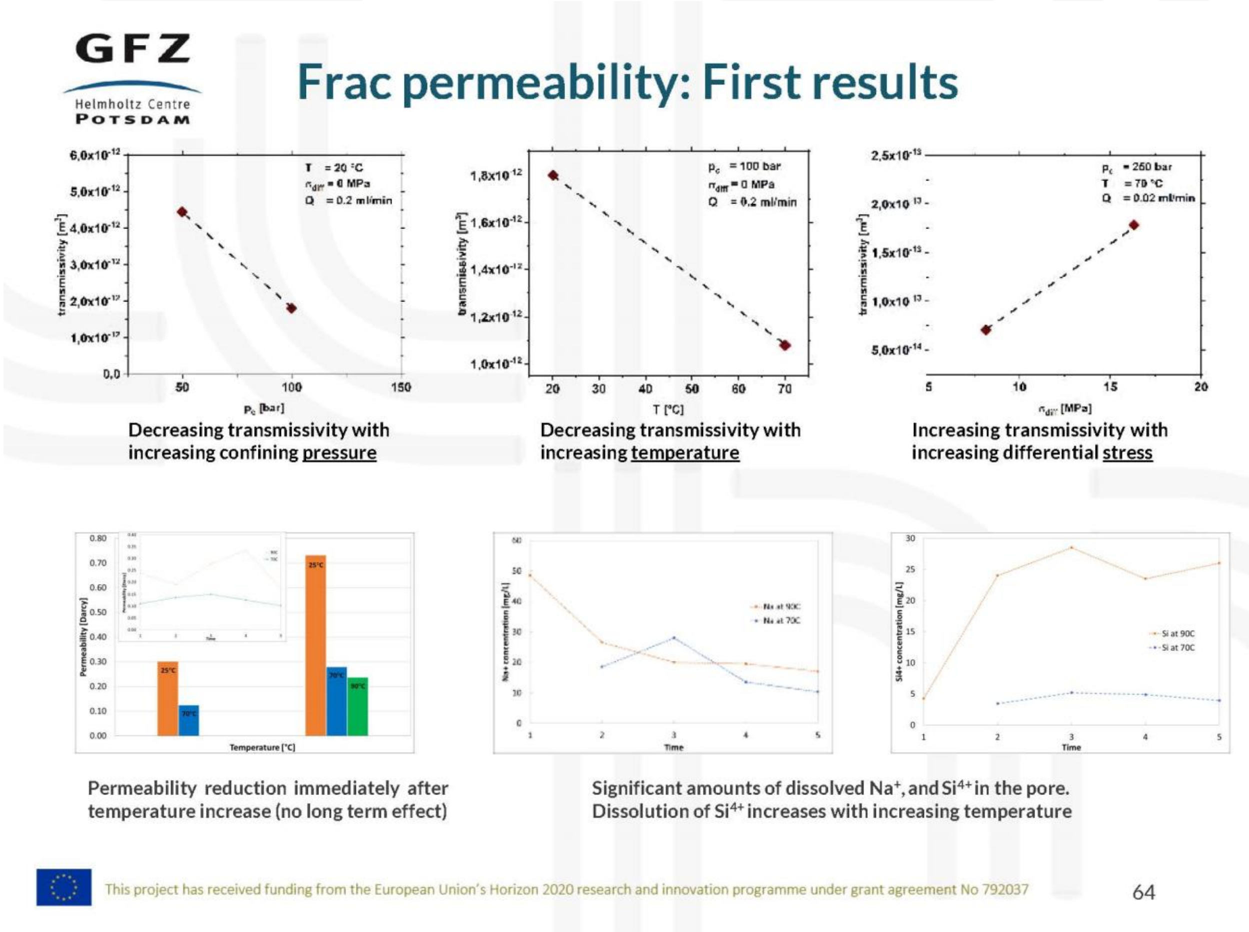
GFZ
Helmholtz Centre
Potsdam
Frac permeability: First results
T = 20 °C
σdiff = 0 MPa
Q = 0.2 ml/min
transmissivity [m³]
Pc [bar]
pc = 100 bar
σdiff = 0 MPa
Q = 0.2 ml/min
T [°C]
pc = 250 bar
T = 70 °C
Q = 0.02 ml/min
σdiff [MPa]
Decreasing transmissivity with increasing confining pressure
Decreasing transmissivity with increasing temperature
Increasing transmissivity with increasing differential stress
Permeability [Darcy]
Temperature [°C]
25°C
70°C
90°C
Na+ concentration [mg/L]
Na at 90C
Na at 70C
Time
Si4+ concentration [mg/L]
Si at 90C
Si at 70C
Permeability reduction immediately after temperature increase (no long term effect)
Significant amounts of dissolved Na+, and Si4+ in the pore. Dissolution of Si4+ increases with increasing temperature
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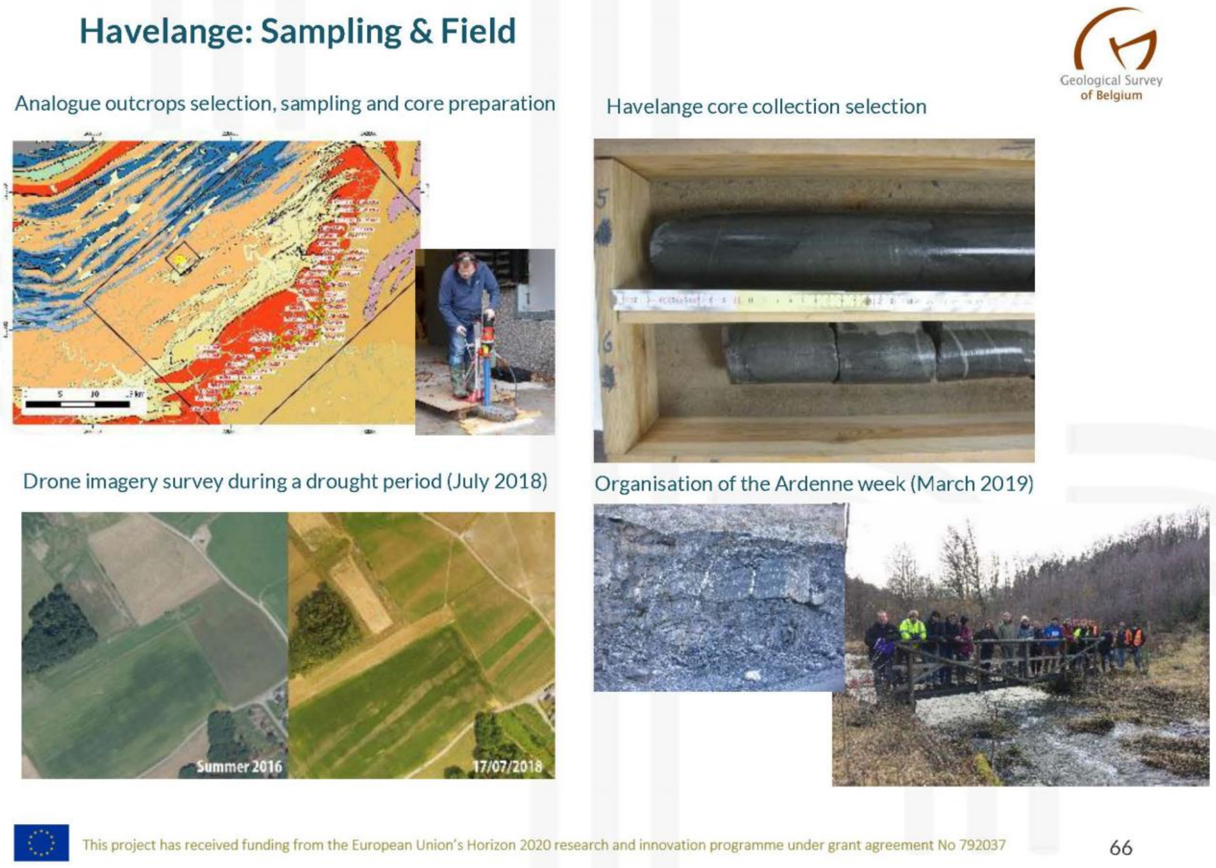
# Demosite Havelange

# Metasedimentary rocks


Havelange: Sampling & Field
Geological Survey of Belgium
Analogue outcrops selection, sampling and core preparation
Havelange core collection selection
Drone imagery survey during a drought period (July 2018)
Summer 2016
17/07/2018
Organisation of the Ardenne week (March 2019)
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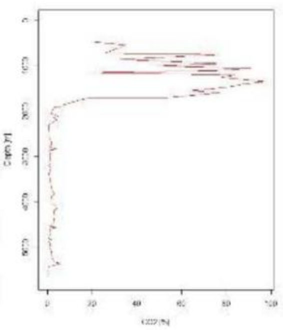
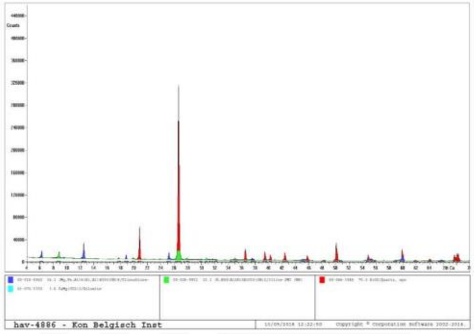
## Lab tests on the Havelange

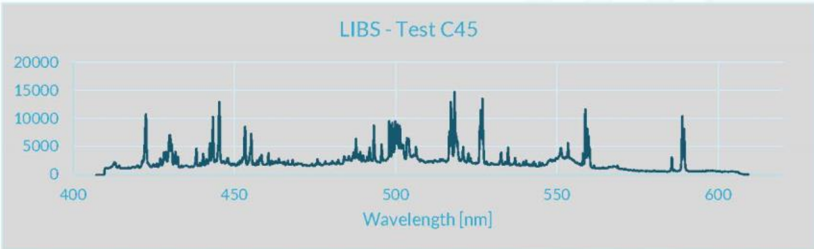
100 XRD spectra + 100 calcimetry measurements on the Havelange cuttings + cores






Geological Survey of Belgium

~800 LIBS spectra collected

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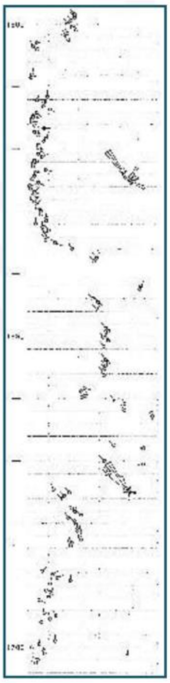
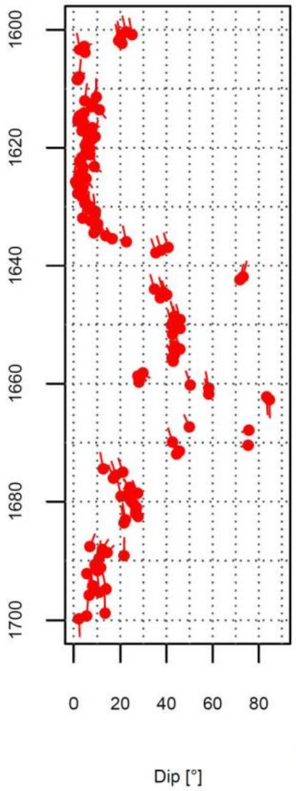
## Havelange: Well-Log digitizing & data integration

New numeric data: GR, Dipmeter, sonic

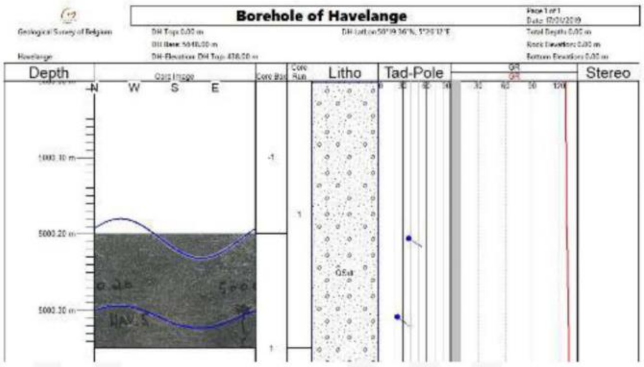





Integration of data in borehole model (Core Base, DMT):

- Core scan;
- Numerical well-logs;
- Calcimetry;
- Illite Crystallinity Index (from Dandois, 1985)
- Lithology description;
- Mineralogical composition (XRD);
- Geochemical composition (LIBS);

Geological Survey of Belgium




This proj 1 2020 research and innovation programme under grant agreement No 792037

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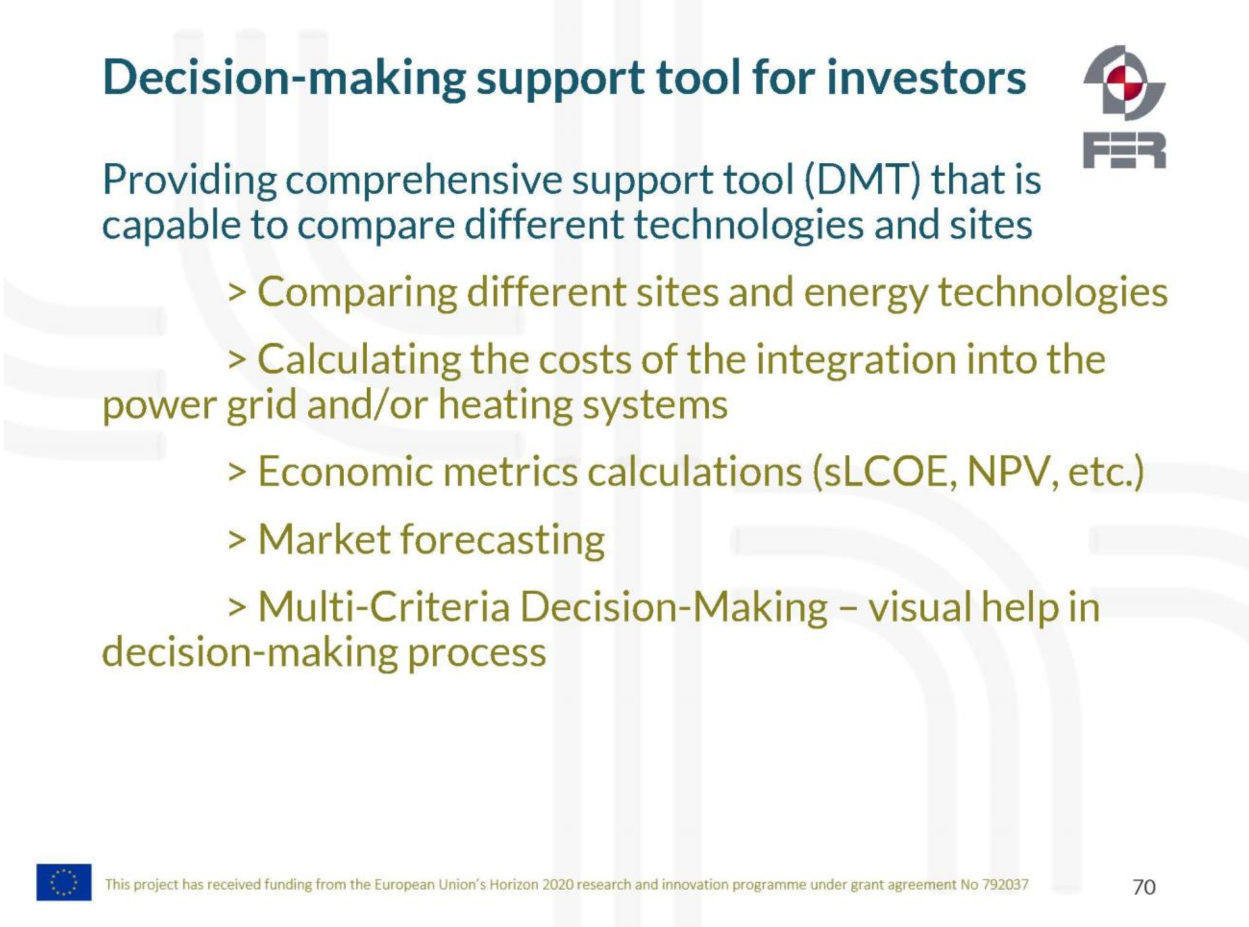
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

## Upscaling

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

## Decision Making

FER


Decision-making support tool for investors
FER
Providing comprehensive support tool (DMT) that is capable to compare different technologies and sites
> Comparing different sites and energy technologies
> Calculating the costs of the integration into the power grid and/or heating systems
> Economic metrics calculations (sLCOE, NPV, etc.)
> Market forecasting
> Multi-Criteria Decision-Making – visual help in decision-making process
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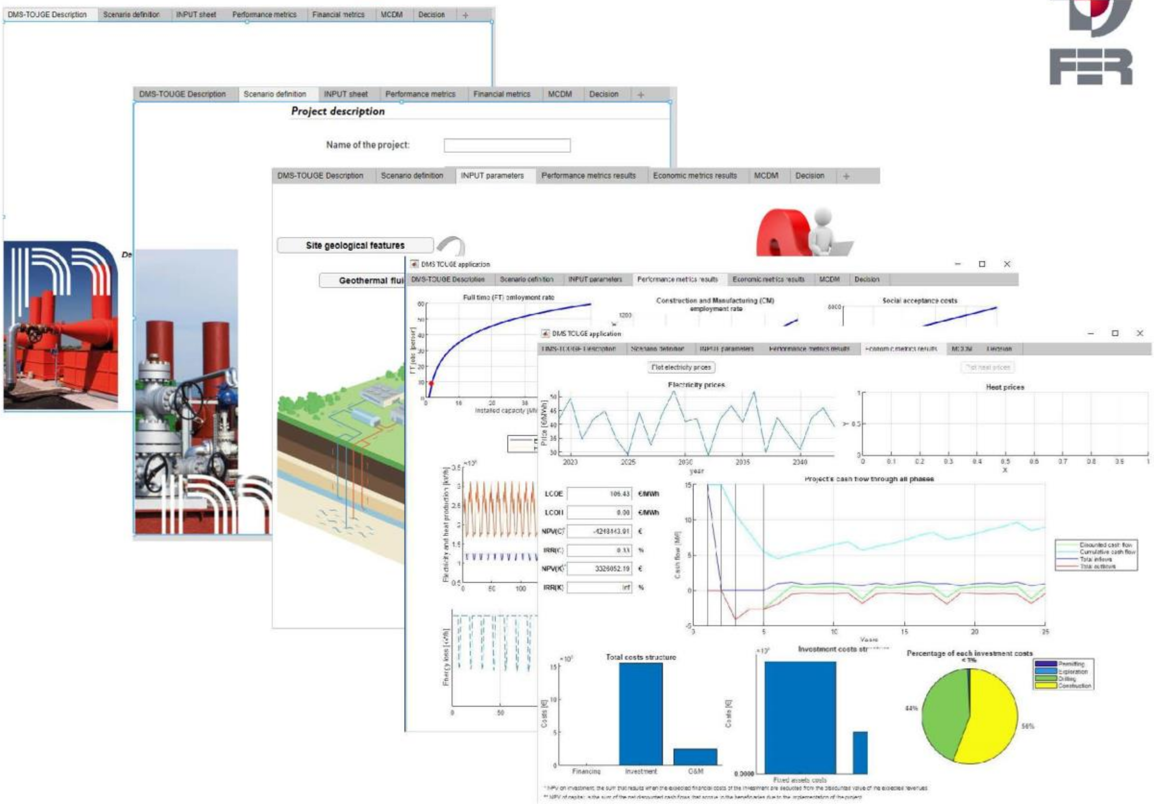
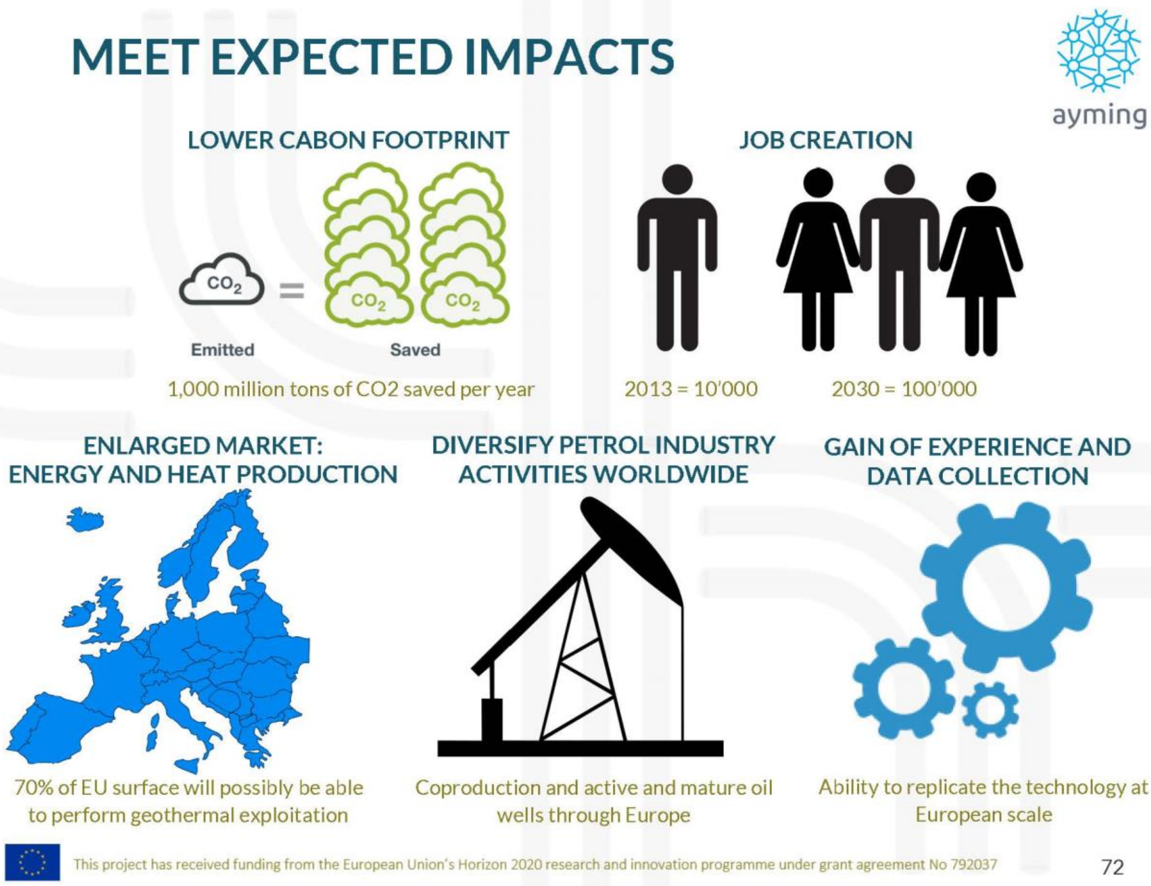
# Decision Making Tool: workflow




MEET EXPECTED IMPACTS
ayming
LOWER CABON FOOTPRINT
CO2
Emitted
Saved
1,000 million tons of CO2 saved per year
JOB CREATION
2013 = 10'000
2030 = 100'000
ENLARGED MARKET:
ENERGY AND HEAT PRODUCTION
70% of EU surface will possibly be able to perform geothermal exploitation
DIVERSIFY PETROL INDUSTRY ACTIVITIES WORLDWIDE
Coproduction and active and mature oil wells through Europe
GAIN OF EXPERIENCE AND DATA COLLECTION
Ability to replicate the technology at European scale
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# CONCLUSION & PERSPECTIVES

- MEET project at 18/42 months thus <50%

- MEET will boost deep geothermal development
  - Reusing existing infrastructure, thus diminishing LCOE
  - Developing new EGS strategies for a wide range geological settings
  - Providing tools for stakeholders
  - Improve knowledge on geothermal energy
    - Summer schools
    - Publications, PhD, conferences (WGC2020)
    - Workshops with local stakeholders like today

- We need your feedback !

**More information: www.meet-h2020.com** MEET EU Project

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## Thank you for your attention!

More information:

www.meet-h2020.com

in MEET EU Project

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## 4.2 SESSION 1

Power Point: MEET_TechnicalWorkshop_Session1_VF

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

# Technical Workshop

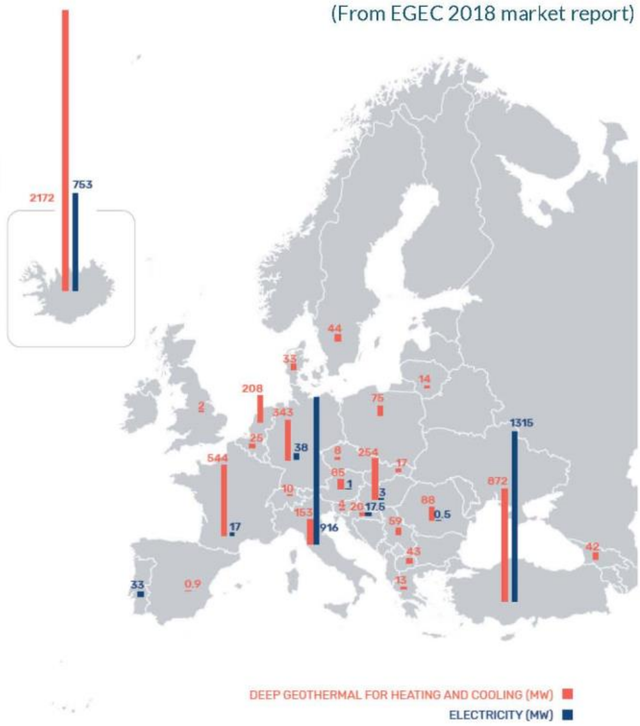
## *23 October 2019, Arcachon, France*

## Session 1 – How can we optimize underground facilities for wider geothermal energy production?

Eléonore Dalmais, ES Géothermie
Olivier Seibel, ES Géothermie
Benoît Pailette, ENOGIA
Xavier Lopez, VERMILION
Eric Léoutre, VERMILION

## Geothermal Energy in Europe : current plants

(From EGEC 2018 market report)




**Electricity**

- ✓ developped where high temperature is available (T > 150°C)
- ✓ 120 plants = 3 GW installed capacity
- ✓ 2018 capacity addition in Turkey, Iceland, Croatia
- ✓ 34 plants in development + 144 planned

**Deep geothermal heating & cooling**

- ✓ Supply to district heating
- ✓ New projects driven by businesses (agri-food, industry process) investing in a secure and renewable supply of energy (e.g. The Netherlands)
- ✓ 11 TWh produced in 2018 [~1 Mtep]
- ✓ 304 existing plants + 212 in development/planned

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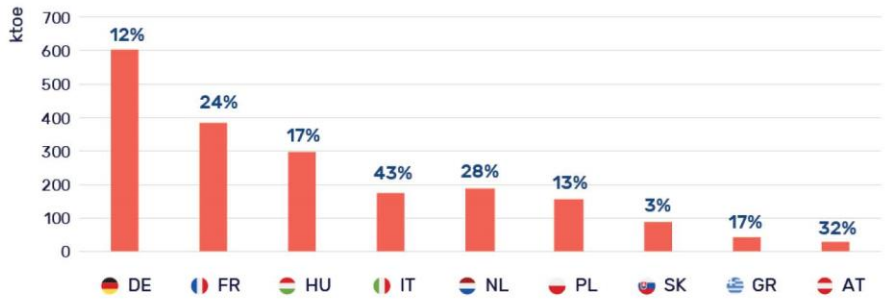
2

# Geothermal Energy in Europe: reality vs. ambition

- ✓ Geothermal energy is accepted as renewable, dispatchable (electricity), baseload and flexible source.
- ✓ It provides a local solution to communities and businesses

However:

- ✓ Slow progress towards the EU 2020 renewable energy / geothermal targets
- ✓ As example, not a single EU Member State has completed even 50% of their objective for deep geothermal heating and cooling (figure below).




(From EGEC 2018 market report 2019) **% COMPLETION NREAP OBJECTIVE**

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## Bottlenecks for massive upscaling

- ✓ Geological uncertainties: risk-to-reward profile of geothermal energy is viewed as unfavorable
- ✓ Capital is risked at the front-end: exploration, drilling, plant costs

However

- ✓ Geothermal projects can emerge where public financing is strong, either directly and /or through insurance schemes
- ✓ Energy market : shift from a €/Mwh view to reliability, local and sustainability criteria ?

**MEET** offers:

Re-use of existing wells and facilities

Oil to geothermal conversion study

Subsurface uncertainties assessment (from field to lab to models)

Field tests to improve heat exchanger reliability and optimise turbines

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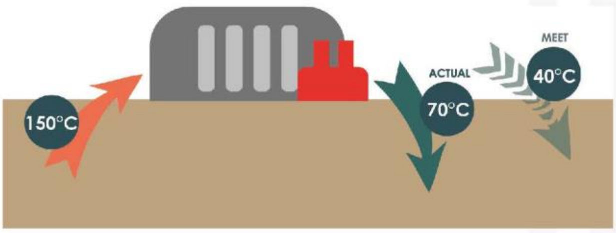
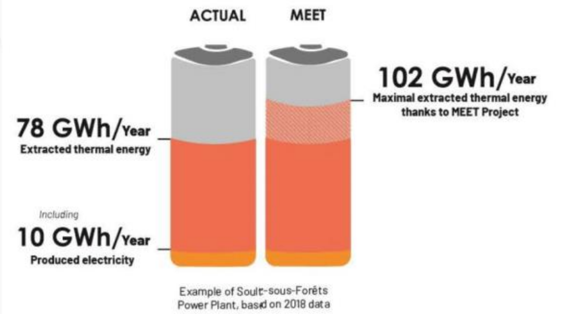
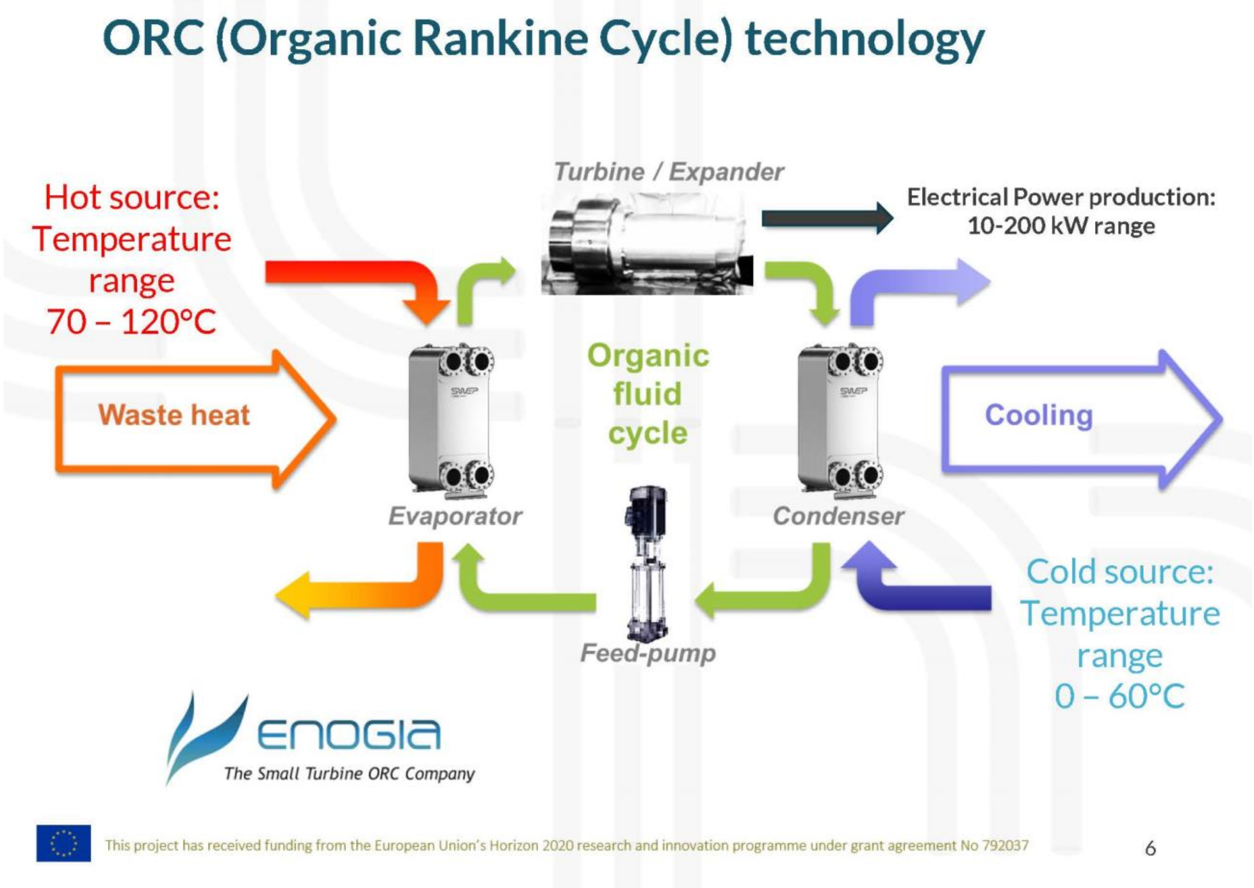
# Geothermal plant enhancement with ORC

- ✓ Current EGS plants in Upper Rhine Graben reinject brine at ~70°C
- ✓ Maximize energy extraction by lowering reinjection temperature: objective of 40°C in MEET pilot
- ✓ Expected gain is 31% (heat)




This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037 5


ORC (Organic Rankine Cycle) technology
Turbine / Expander
Electrical Power production:
10-200 kW range
Hot source:
Temperature
range
70 – 120°C
Waste heat
Organic
fluid
cycle
Cooling
Evaporator
Condenser
Feed-pump
Cold source:
Temperature
range
0 – 60°C
ENOGIA
The Small Turbine ORC Company
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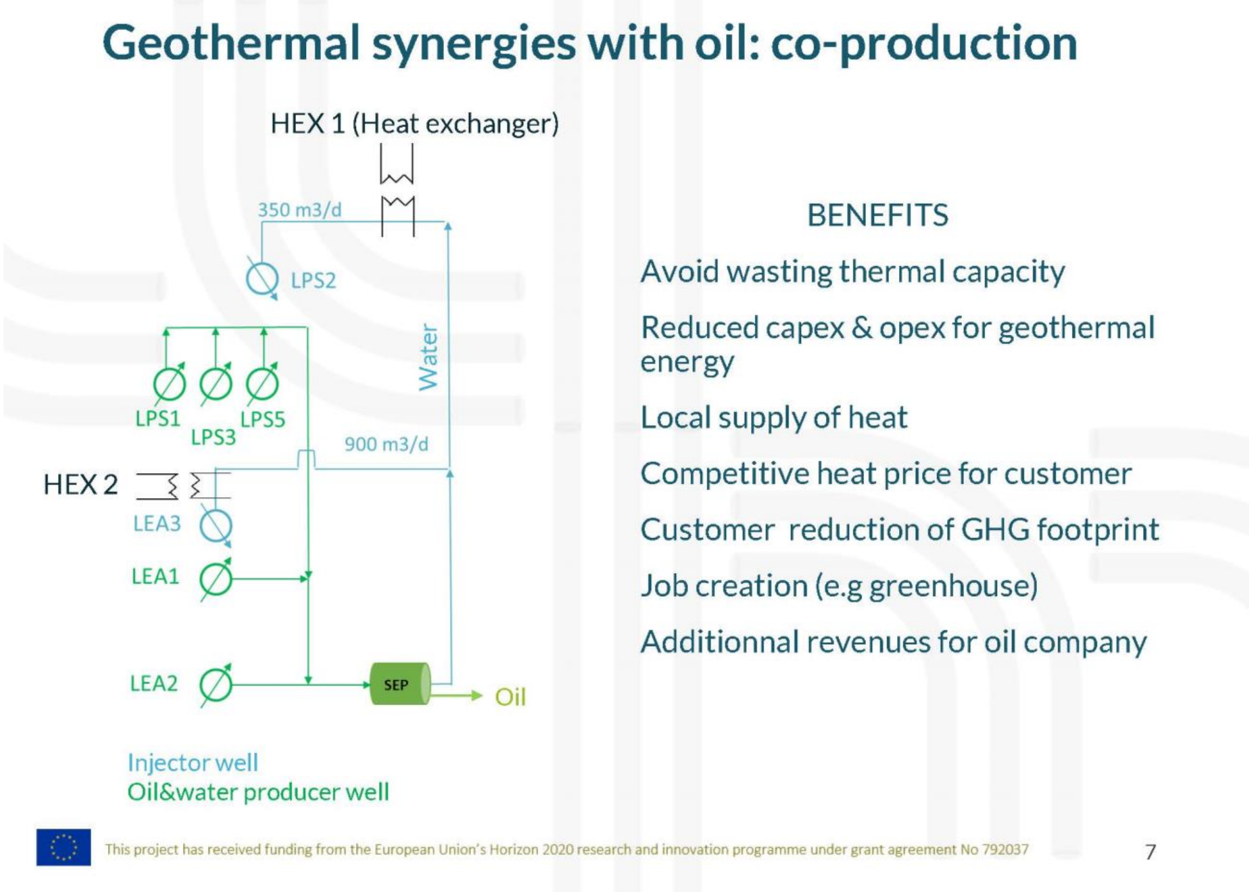
6


Geothermal synergies with oil: co-production
HEX 1 (Heat exchanger)
350 m3/d
LPS2
Water
LPS1
LPS3
LPS5
900 m3/d
HEX 2
LEA3
LEA1
LEA2
SEP
Oil
Injector well
Oil&water producer well
BENEFITS
Avoid wasting thermal capacity
Reduced capex & opex for geothermal energy
Local supply of heat
Competitive heat price for customer
Customer reduction of GHG footprint
Job creation (e.g greenhouse)
Additionnal revenues for oil company
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# Geothermal synergies with oil: co-production

## CHALLENGES

- Find customer
- Thermal ressource capacity: oil well productivity << geothermal well productivity
- Economic feasiblity is challenging if heat user is far and energy need is small
- Oil and water production optimisation objectives can be contradictory
- Reservoir « thermal shortcut » can reduce long-term ressource availability
- Impact on injector wells scaling tendency ?
- Thermal output dependant on oil well economics : conversion is seldom energy-efficient in mature oil field because high fluid rates require submersible pumps

## MEET WORK

- Inventorise heat ressource
- Mapping of current/future heat needs around our facilities
- Screening most robust projects
- Thermal isolation feasibility study
- Thermal models calibrated to data
- Chemical analysis
- Oil/geothermal conversion analysis methodology and practical case

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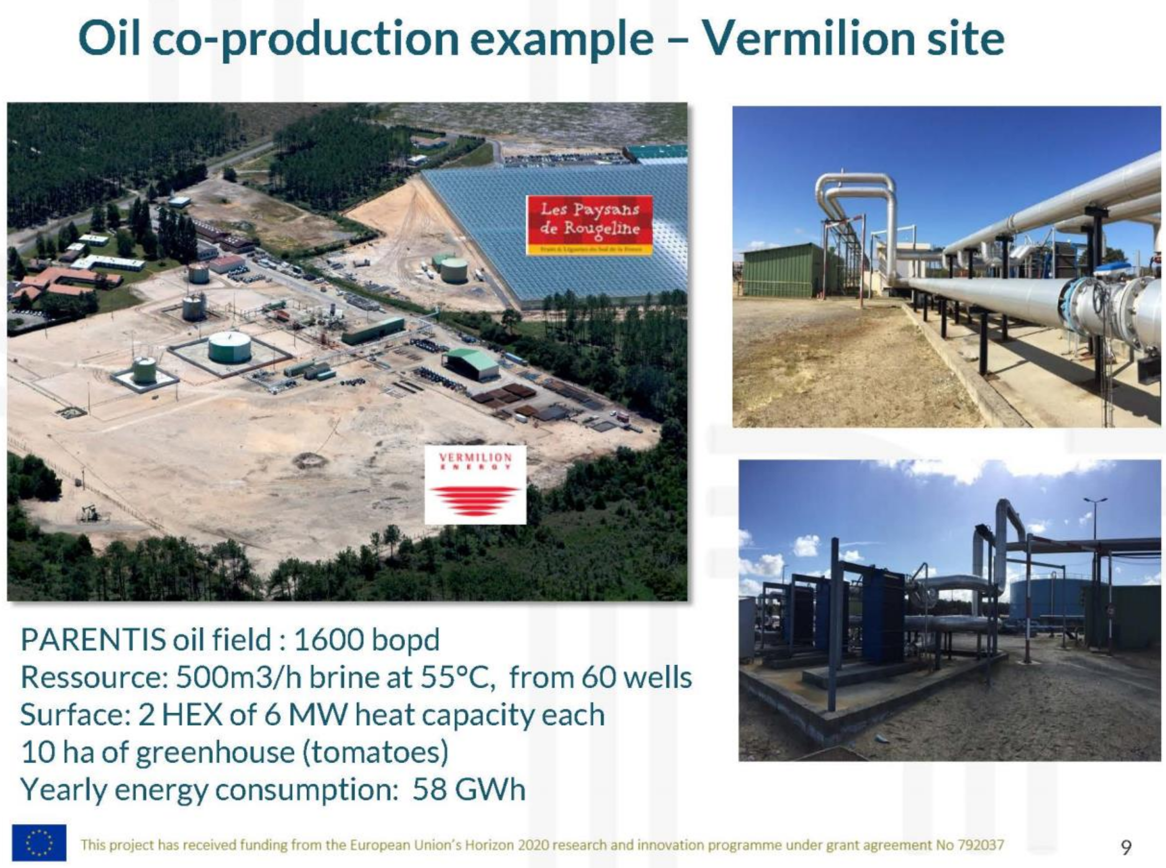


## 4.3 SESSION 2

Power Point: MEET_TechnicalWorkshop_Session2_VF

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

# Technical Workshop

*October 23rd 2019, Arcachon, France*

## Session 2

### How can we explore and enhance unconventional geothermal systems?

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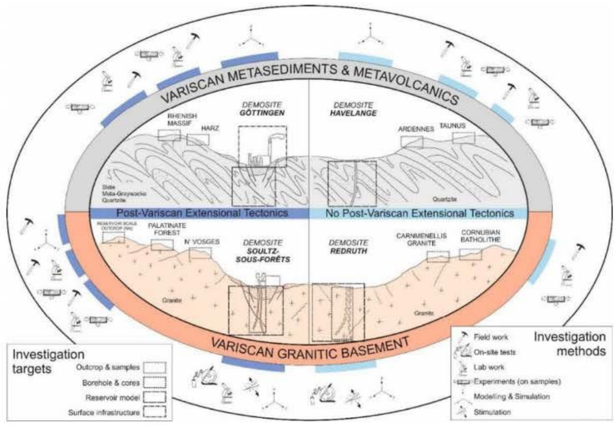
# Let's first define what is an unconventional geothermal system




Schematic overview of the four representative European Variscan geotectonic settings including the outcrop analogue areas, the demonstration sites and the necessary site-specific investigation methods

*Topic 1:*

## How can we explore unconventional geothermal systems ?

*Topic 2:*

## How can we enhance unconventional geothermal systems ?

*Topic 3:*

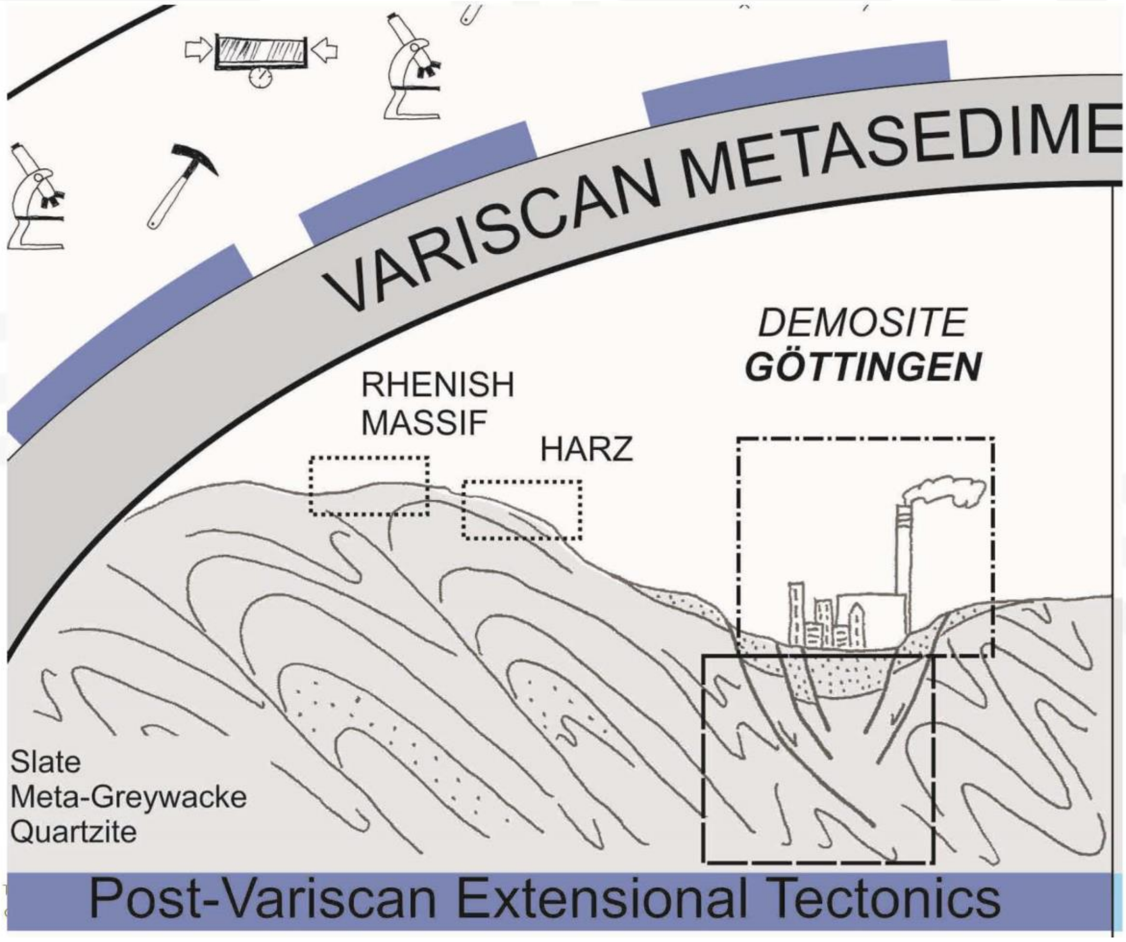
## How to validate public acceptance for unconventional geothermal systems ?

# *Topic 1:*

## How can we explore unconventional geothermal systems ?

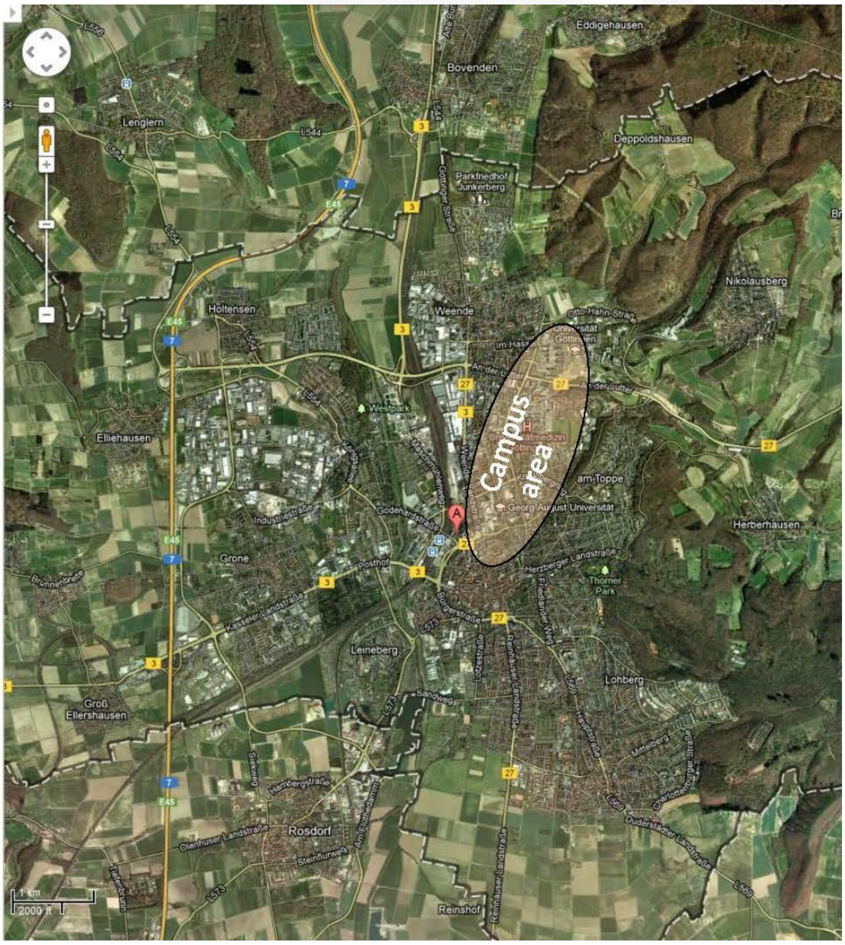
*Dr. Bernd Leiss*

*University of Goettingen*


VARISCAN METASEDIME
DEMOSITE
GÖTTINGEN
RHENISH
MASSIF
HARZ
Slate
Meta-Greywacke
Quartzite
Post-Variscan Extensional Tectonics


University of Göttingen,
Lower Saxony,
Germany

Population: ca. 120.000
Students: ca. 30.000



## What do we have at the demo site Göttingen?

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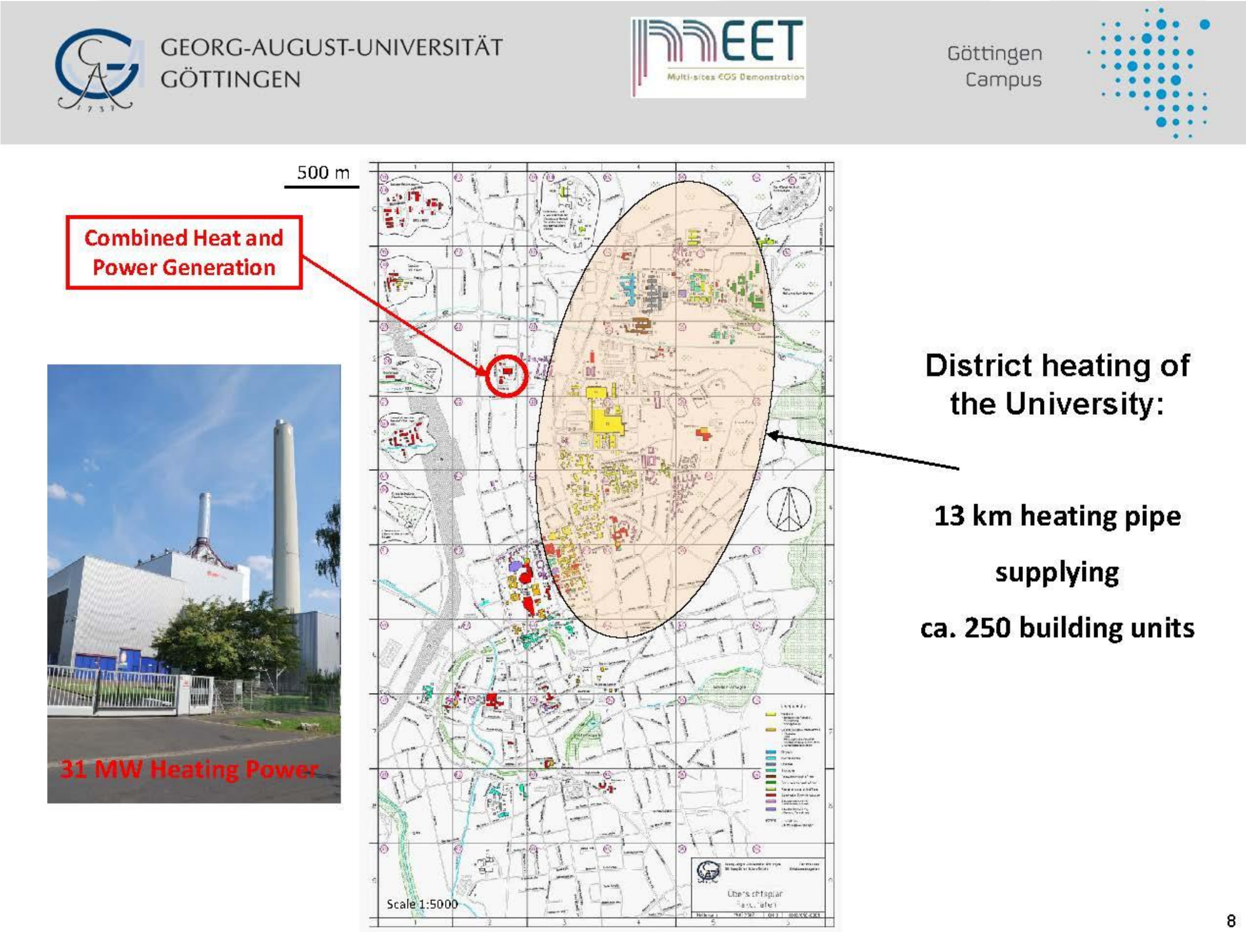
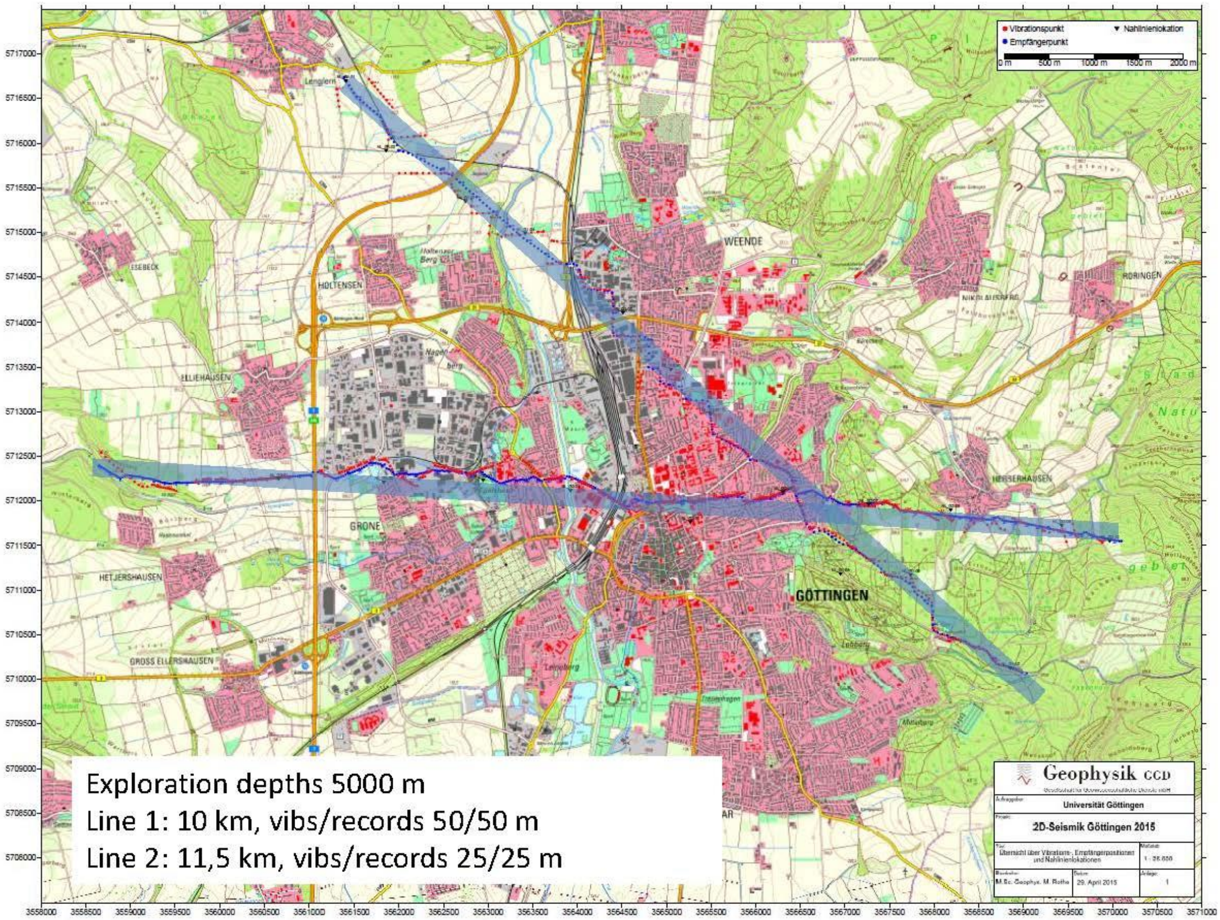

GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN
Göttingen
Campus
500 m
Combined Heat and
Power Generation
31 MW Heating Power
Scale 1:5000
District heating of the University:
13 km heating pipe
supplying
ca. 250 building units
8


Seismic exploration campaign in Göttingen 2015 (University library in the background)


Exploration depths 5000 m
Line 1: 10 km, vibs/records 50/50 m
Line 2: 11,5 km, vibs/records 25/25 m
GÖTTINGEN
WEENDE
HOLTENSEN
ELLIEHAUSEN
GRONE
HETJERSHAUSEN
GROSS ELLERSHAUSEN
ESEBECK
HERBERHAUSEN
ROHRINGEN
Vibrationspunkt
Empfängerpunkt
Nahlinienlokation
Geophysik GGD
Universität Göttingen
2D-Seismik Göttingen 2015

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Göttingen Campus

Seismic Profile GOE_2015_02: length 11,5 km, depth 5 km

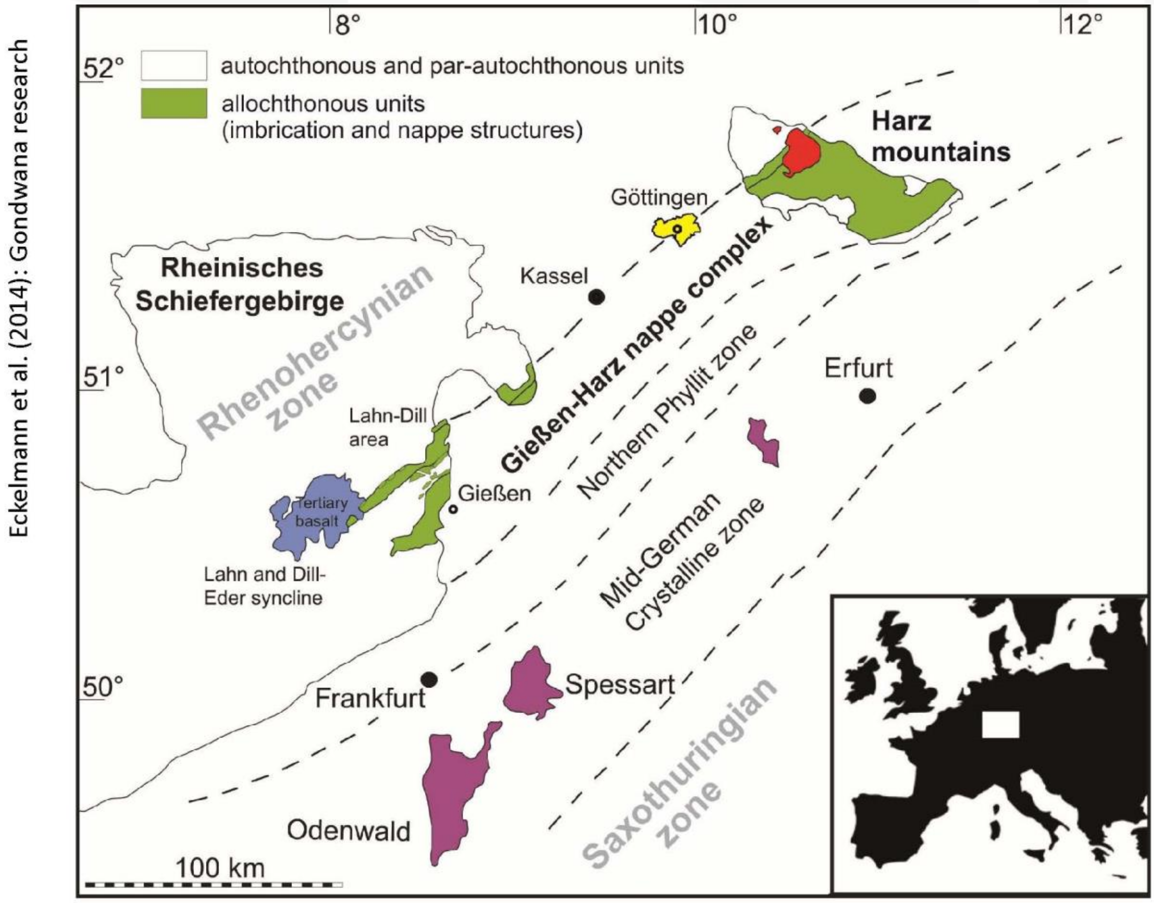
Mesozoic sedimentary cover + Graben structure

Zechstein salt layer

*Seismic profile still confidential*

Variscan fold and thrust belt
Metasedimentary rocks mainly greywackes and slates

11



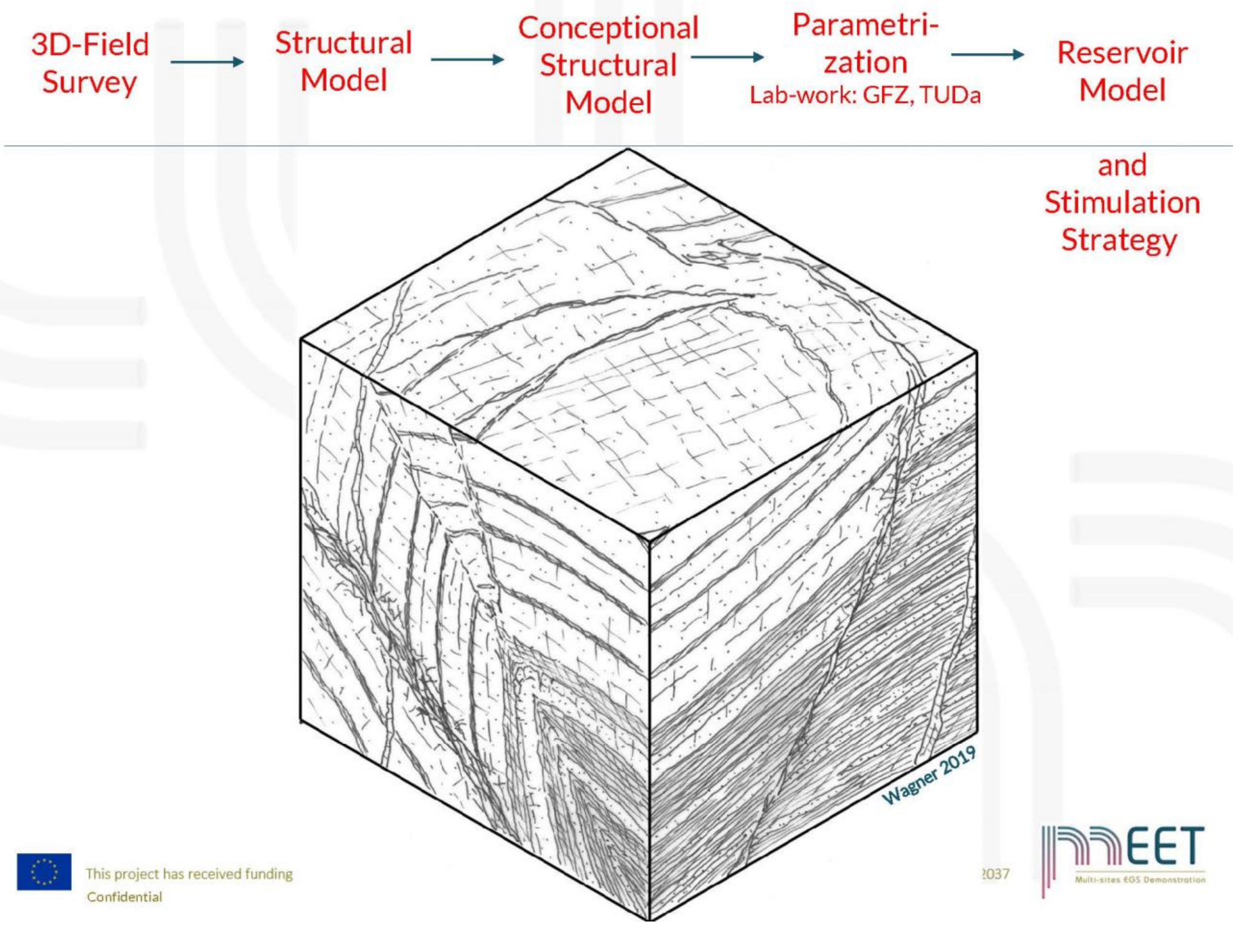

Variscan Basement: sequence of greywacke and slates, granites, reef carbonates


Carboniferous slates, Schulenberg fold, Harz


Folded and thrusted Carboniferous Greywacke layers, Innerste Valley, Harz
Geologe
Geologe


Traget horizon for Göttingen site:
Greywacke/Sandstone/
Quarzite-slate alternations
(Harz-Mountains)

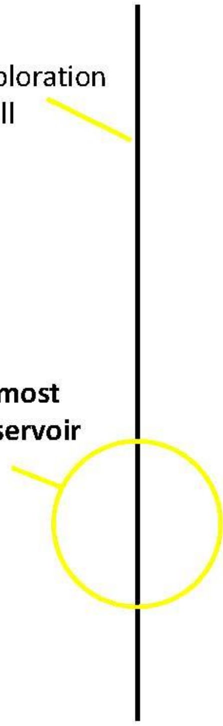

Traget horizon for Göttingen site:
Greywacke/Sandstone/
Quarzite-slate alternations
(Harz-Mountains)


3D-Field Survey
Structural Model
Conceptional Structural Model
Parametri-zation
Lab-work: GFZ, TUDa
Reservoir Model
and Stimulation Strategy
Wagner 2019
This project has received funding
Confidential

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Göttingen Campus

## Unconventional exploration and exploitation strategy




*Seismic profile and further exploitation strategy still confidential*

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## What do we have at the demo site Göttingen?

- existing consumption infrastructure
- geothermal energy has the highest priority as renewable energy at presidium of the University/stakeholders
- two own seismic exploration lines
- an unconventional reservoir characterised by MEET
- an unconventional exploration and exploitation strategy devloped by MEET
- green light from the „German Federal Ministry for Economic Affairs and Energy“ to apply for a research well (2000 m)

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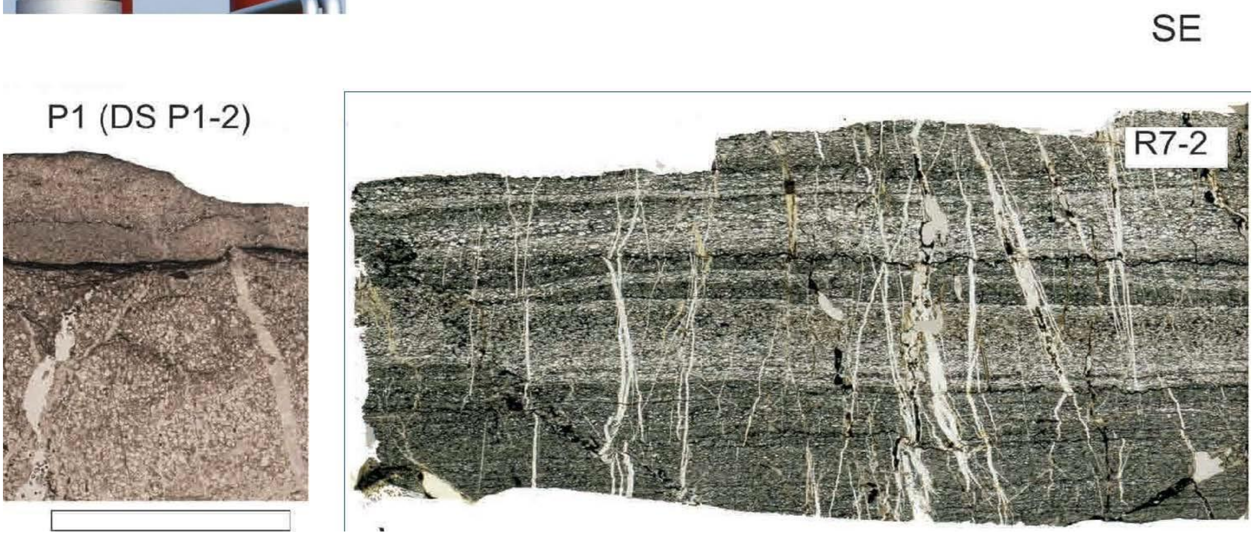
# THANK YOU FOR YOUR ATTENTION



## *Topic 2:*

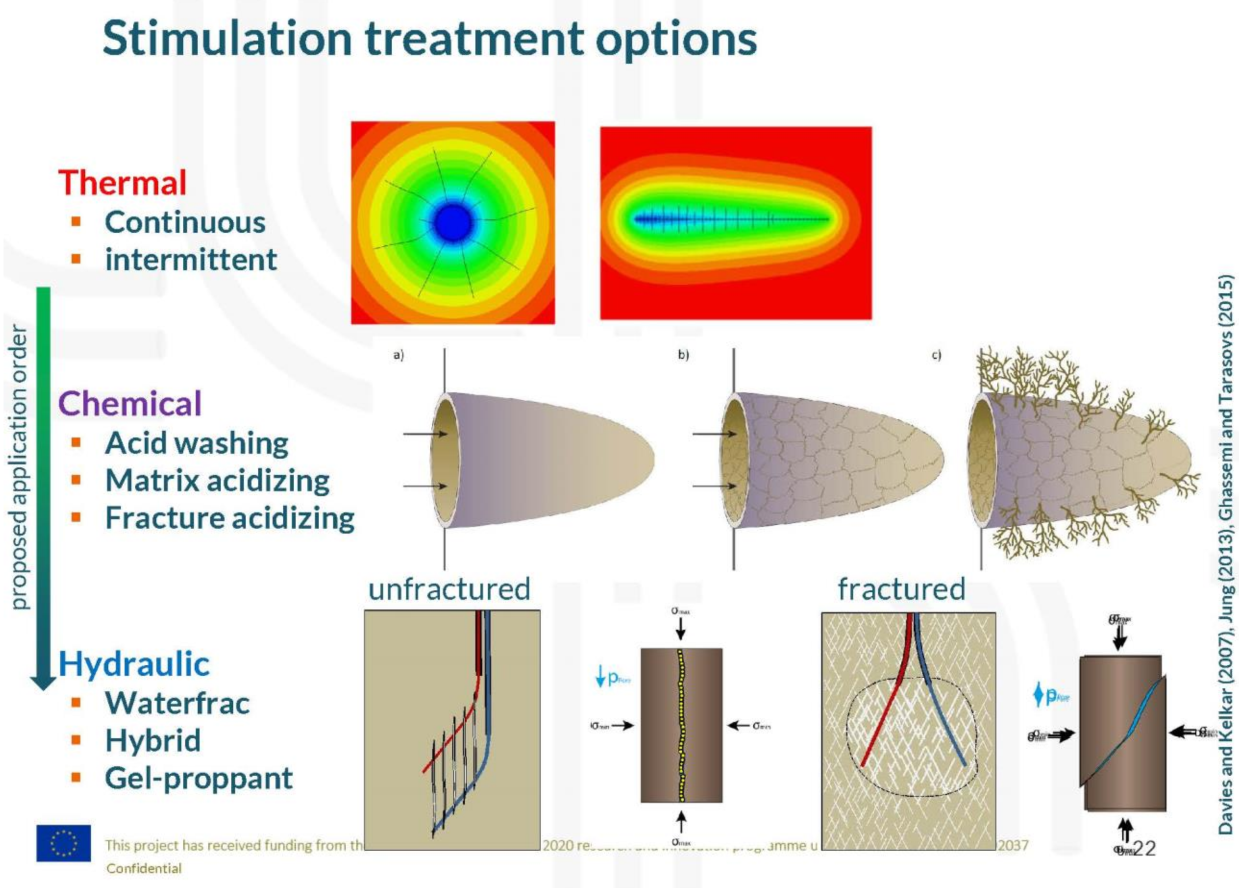
## How can we enhance unconventional geothermal systems ?

*Dr. Kristian Bär*

*University of Darmstadt*

*Dr. John Reinecker*

*GeoT Engineering*


Stimulation treatment options
Thermal
Continuous
intermittent
Chemical
Acid washing
Matrix acidizing
Fracture acidizing
Hydraulic
Waterfrac
Hybrid
Gel-proppant
proposed application order
a)
b)
c)
unfractured
fractured
Davies and Kelkar (2007), Jung (2013), Ghassemi and Tarasovs (2015)
Confidential
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# Enhancement of Open Geothermal Systems

⇒ use of any technique / physical process to enhance either the reservoir permeability or the hydraulic link between well and reservoir in order to increase flow rate (production and/or injection)

proposed application order

| Technique | Description | Benefits | Disadvantage | Risks |
|---|---|---|---|---|
| *well cleaning* | | part of the well testing procedure | none | none |
| *shock pumping* | cleaning of fractures in the vicinity of the borehole by pulsed pumping | can be part of the well testing procedure | none | none |
| *thermal stimulation* | opening preexisting fractures by thermal contraction of the formation through cold water injection; needs proppant | easy to perform | - only on the injection side<br>- needs permanent cold water injection if not propped<br>- scaling issues | - induced seismicity |
| *chemical stimulation* | dissolution of fracture mineralisation | no induced seismicity | - needs proper handling of chemicals<br>- spatially limited extend of effect<br>- contaminated flowback | - no public acceptance<br>- chemical reactions not as predicted<br>- spill of stimulation acid |
| *hydraulic stimulation* | open preexisting fractures in the borehole vicinity by pressurising the well; needs proppant | relatively easy to perform | - induced seismicity<br>- not applicable in unfractured reservoirs | - low public acceptance<br>- undesired fluid pathways and contamination |
| *hydraulic fracturing* | creating new fractures to engineer the reservoir by pressurising packered sections | applicable in tight reservoirs | - induced seismicity<br>- not applicable in naturally fractured reservoirs<br>- contaminated flowback | - no public acceptance<br>- undesired fluid pathways and contamination |
| *drilling a sidetrack* | increasing open hole section within the reservoir | predictable added value | costly | - drilling risks<br>- limited added value due to proximity to the first borehole (hydraulics) |
| *drilling additional wells* | increasing open hole section within the reservoir at considerable distance to other wells | flexibility in managing well use (change injection-production, workover/maintenance) | very costly | - drilling risks<br>- POS |

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# Enhancement of Open Geothermal Systems

Physical limits to stimulation treatments

- Maximum allowable treating pressure.
- Well design.
- Site location size and infrastructure.
- Pumps and compressors.
- Isolating zones in open hole section.

Typical reservoir constraints are

- Production failures: gas influx, formation sanding
- Physical location of the zones and their thicknesses

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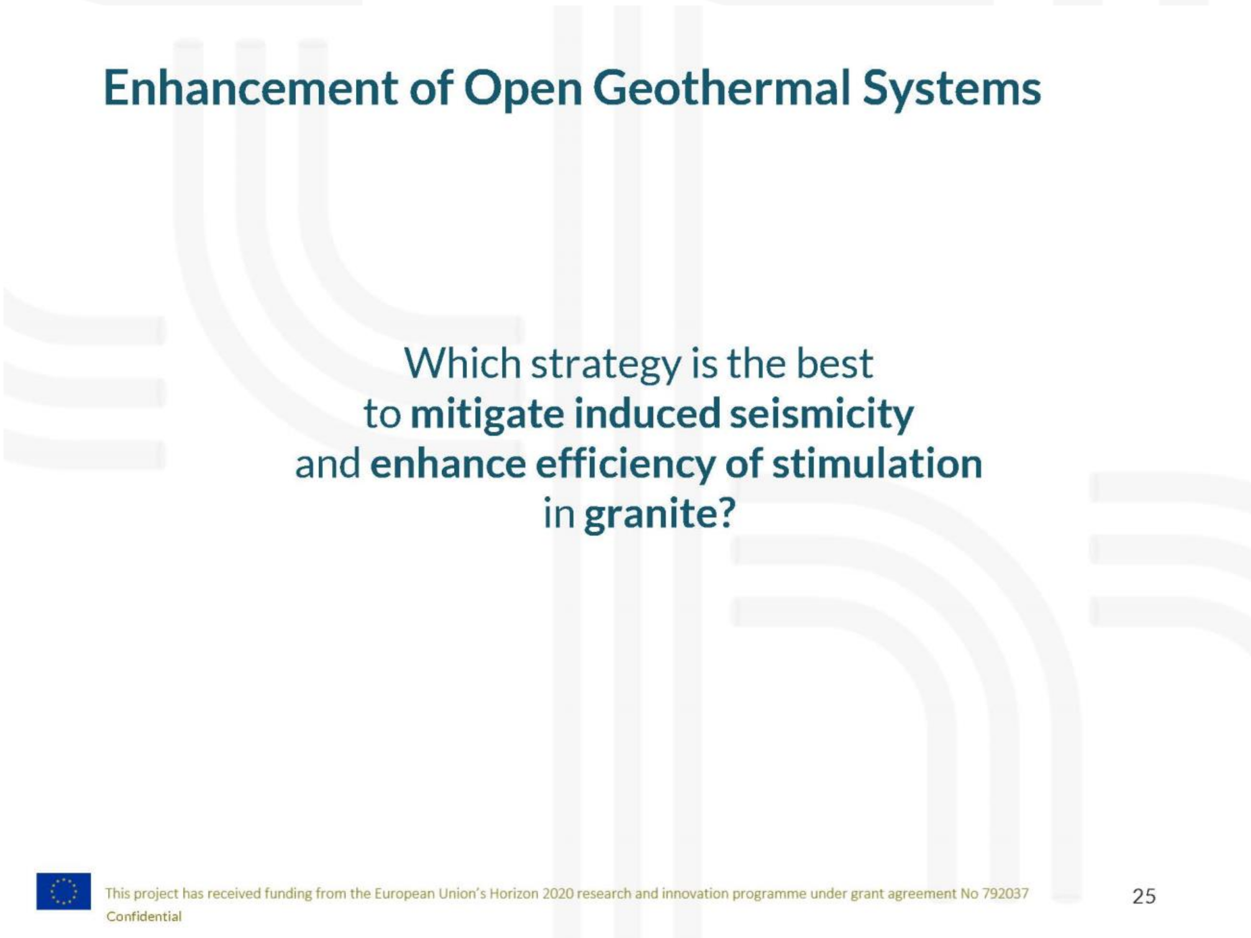
Enhancement of Open Geothermal Systems
Which strategy is the best
to mitigate induced seismicity
and enhance efficiency of stimulation
in granite?
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037
Confidential
25

# *Topic 3:*

## How to validate public acceptance for unconventional geothermal systems ?

*Dr. Albert Genter*

*ESG*

## How public perceives deep geothermal energy?

*Application to the Upper Rhine Graben geothermal context*

| | Contextual | Cultural | Social-psychological | Personal |
|---|---|---|---|---|
| | Technology, institutional structure, spatial context | Responsability, trust, impact on local wildlife & ecosystem, visual impact | Knowledge & direct experience, environmental & political beliefs | Age, gender, class, income |
| | EGS technology<br>Fractured granite reservoirs | Old oil fields<br>Territory<br>Farmer | Soultz 2003 IS M2.9<br>Basel 2006 IS M3.4<br>Landau uplift 2013<br>Lochwiller (GHP) | |
| | Induced seismicity,<br>Natural radioactivity | Low visual impact<br>Low footprint | No felt IS with new plants<br>Local employment | |
| | | | | |
| Rural | Drilling | Trust in developers<br>« Musée du pétrole » | Strong territory attachment | Retired people |
| Urban | Fracking, new player | Low trust in developers | | Counter reference |

(Public responses to low carbon technologies, STOA, 2019)

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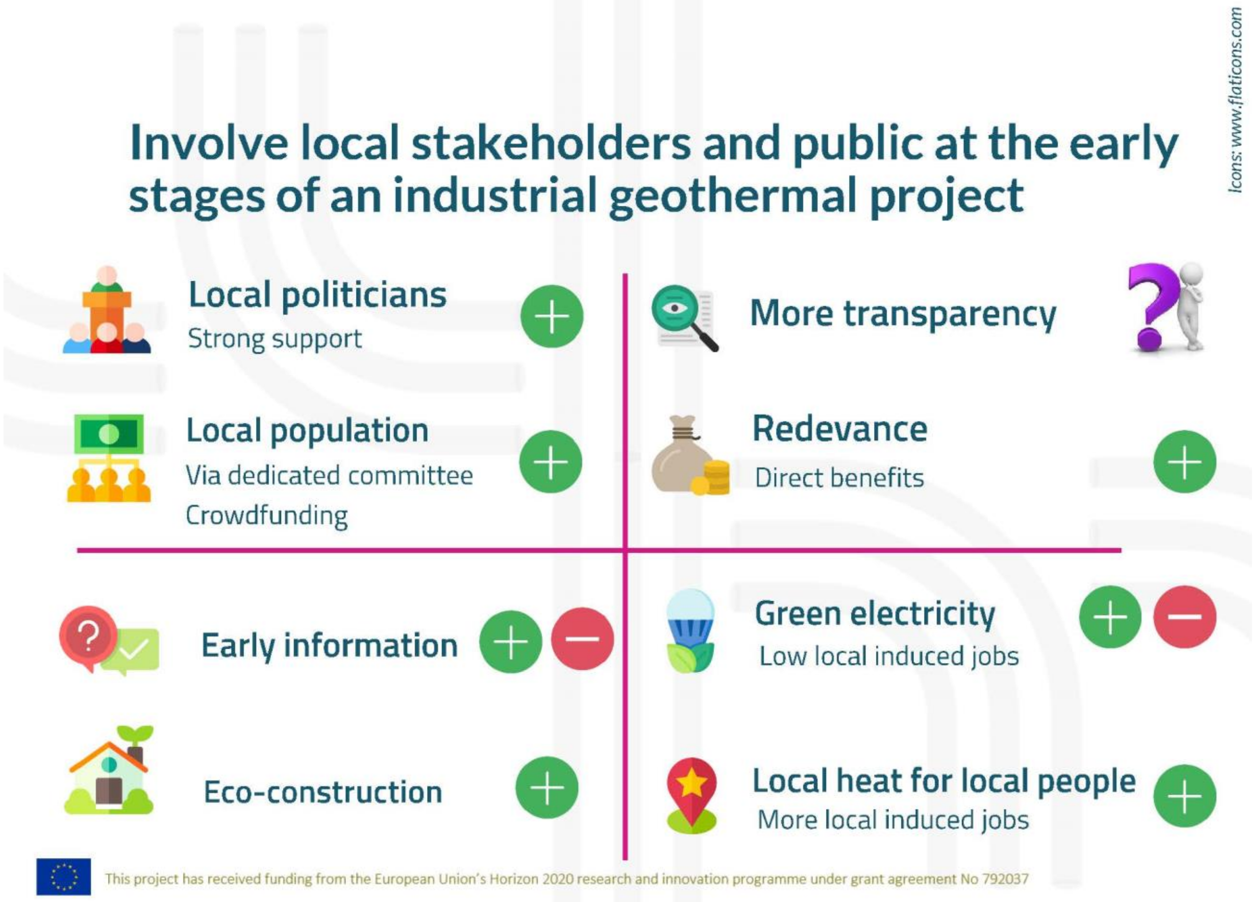
Icons: www.flaticons.com
Involve local stakeholders and public at the early stages of an industrial geothermal project
Local politicians
Strong support
More transparency
Local population
Via dedicated committee
Crowdfunding
Redevance
Direct benefits
Early information
Green electricity
Low local induced jobs
Eco-construction
Local heat for local people
More local induced jobs
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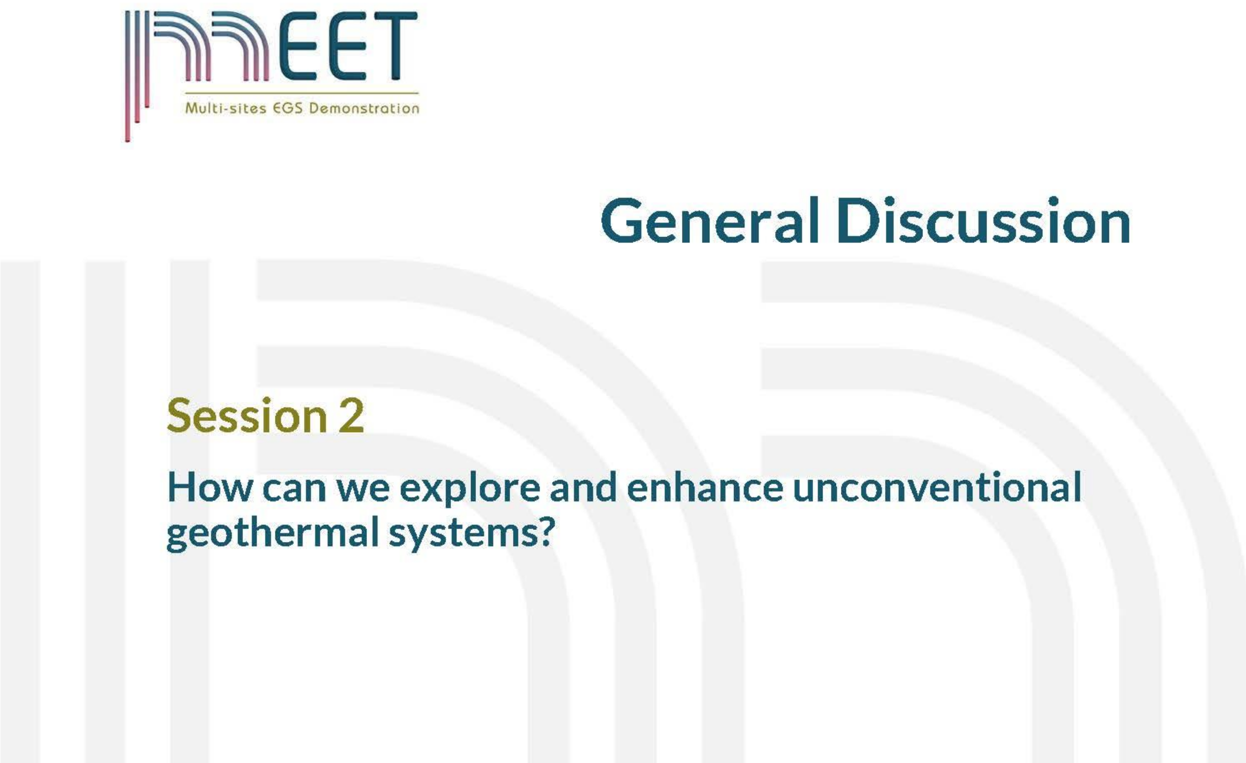


## 4.4 SESSION 3

Power Point: MEET_TechnicalWorkshop_Session3_BWagner

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# Workpackage 7:

# GIS-based analysis of "geothermal geodata"

Bianca Wagner, Richu M. Shelly & colleagues from GZG & SUB
University of Göttingen & Universitätsenergie Göttingen Gmbh

## University of Goettingen (Germany)

GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN

E 9°56' N
51°32'
1737
30.000
12.500
13
2
8 + 11
44

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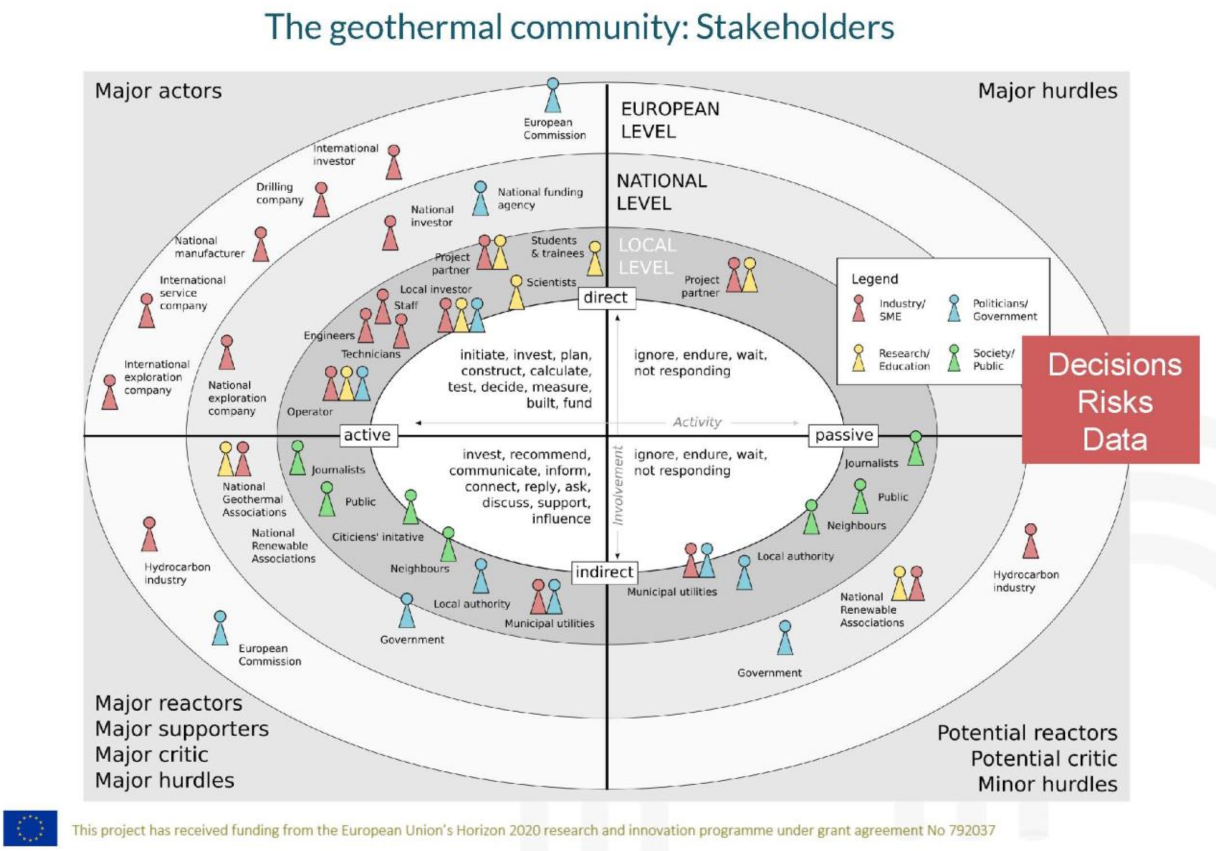
The geothermal community: Stakeholders
Major actors
Major hurdles
EUROPEAN LEVEL
NATIONAL LEVEL
LOCAL LEVEL
European Commission
International investor
Drilling company
National funding agency
National investor
National manufacturer
International service company
International exploration company
National exploration company
Project partner
Students & trainees
Scientists
Local investor
Staff
Engineers
Technicians
Operator
Project partner
Legend
Industry/ SME
Politicians/ Government
Research/ Education
Society/ Public
Decisions
Risks
Data
direct
indirect
active
passive
Activity
Involvement
initiate, invest, plan, construct, calculate, test, decide, measure, built, fund
ignore, endure, wait, not responding
invest, recommend, communicate, inform, connect, reply, ask, discuss, support, influence
ignore, endure, wait, not responding
National Geothermal Associations
Journalists
Public
National Renewable Associations
Citiciens' initative
Neighbours
Local authority
Municipal utilities
Government
Hydrocarbon industry
European Commission
Journalists
Public
Neighbours
Local authority
Municipal utilities
National Renewable Associations
Government
Hydrocarbon industry
Major reactors
Major supporters
Major critic
Major hurdles
Potential reactors
Potential critic
Minor hurdles
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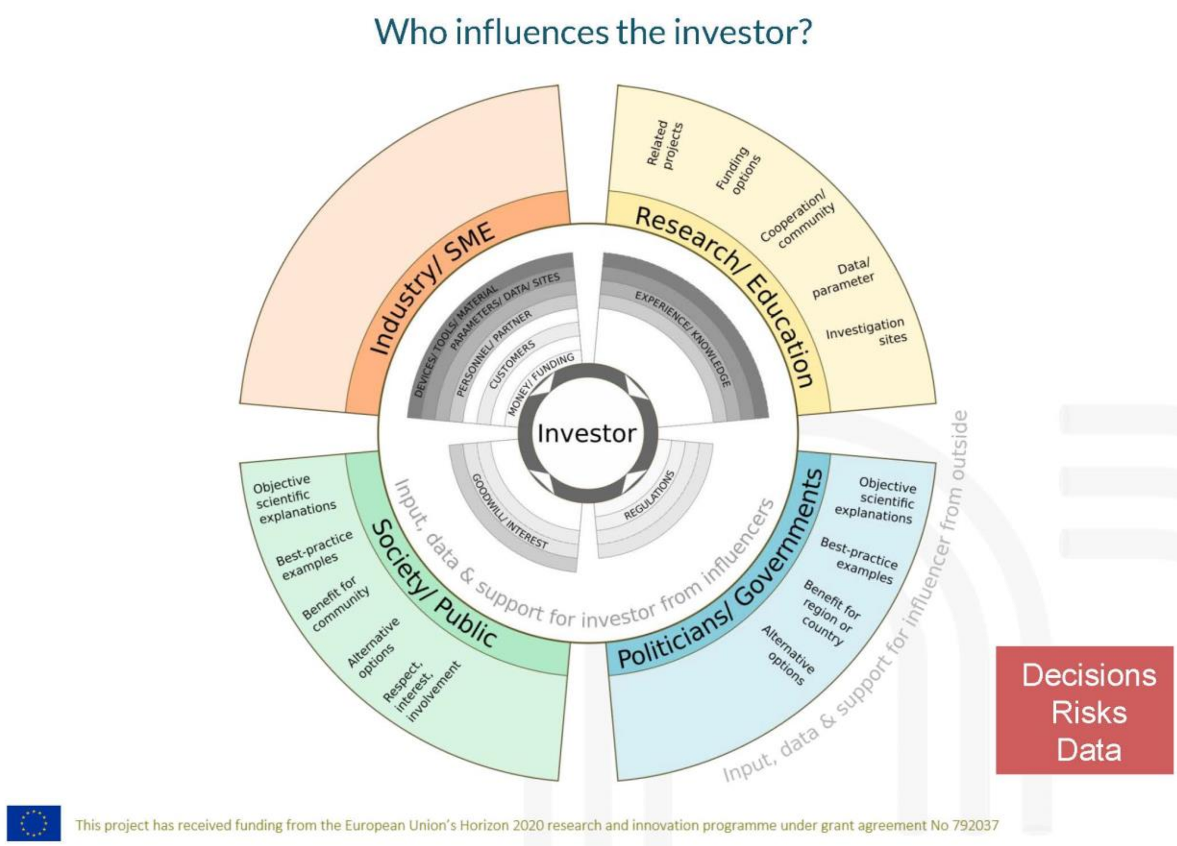
Who influences the investor?
Industry/ SME
DEVICES/ TOOLS/ MATERIAL
PARAMETERS/ DATA/ SITES
PERSONNEL/ PARTNER
CUSTOMERS
MONEY/ FUNDING
Research/ Education
EXPERIENCE/ KNOWLEDGE
Related projects
Funding options
Cooperation/ community
Data/ parameter
Investigation sites
Investor
GOODWILL/ INTEREST
REGULATIONS
Society/ Public
Objective scientific explanations
Best-practice examples
Benefit for community
Alternative options
Respect, interest, involvement
Politicians/ Governments
Objective scientific explanations
Best-practice examples
Benefit for region or country
Alternative options
Input, data & support for investor from influencers
Input, data & support for influencer from outside
Decisions
Risks
Data
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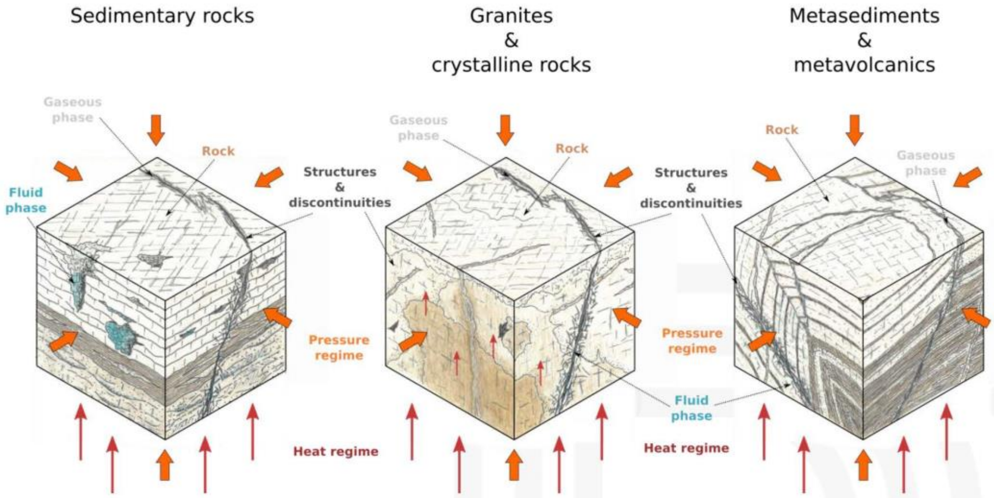
## Types of geothermal projects within MEET

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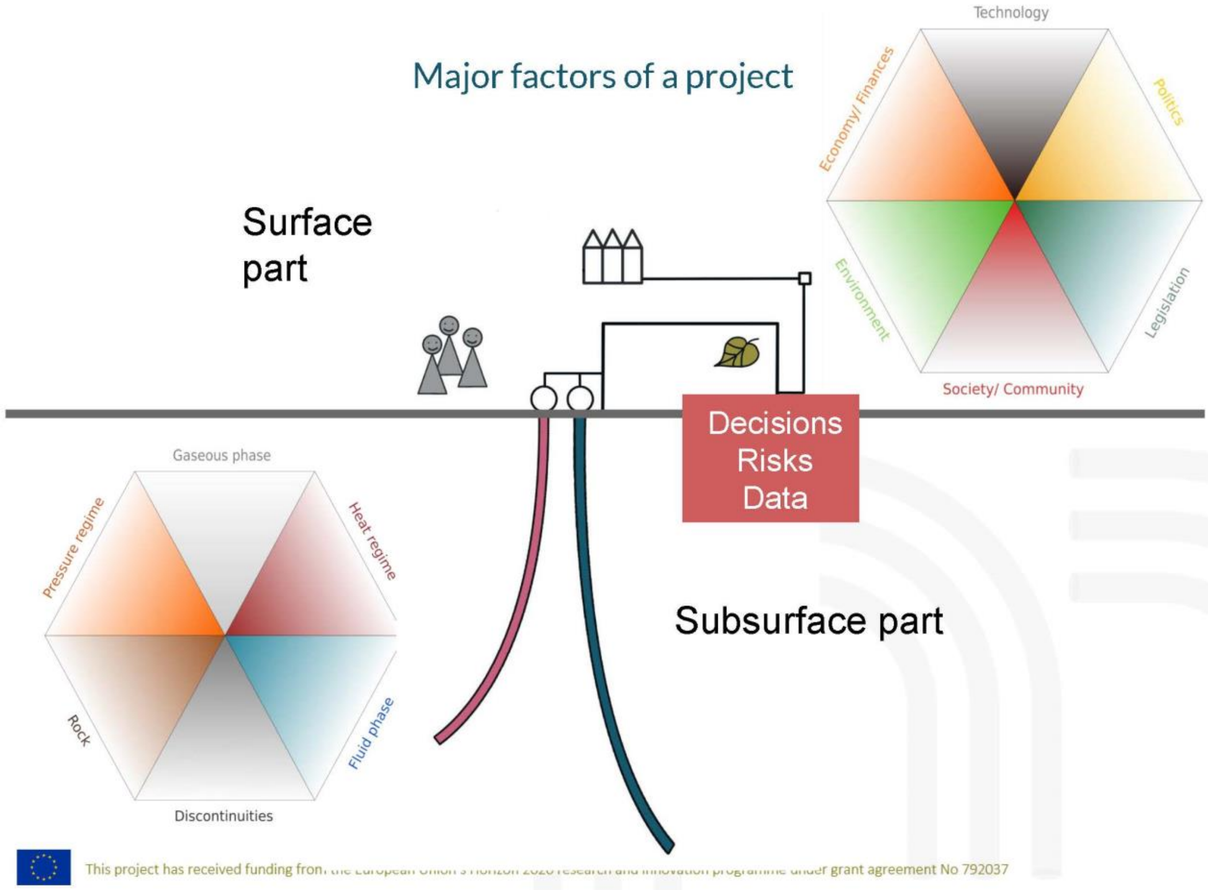
Major factors of a project
Technology
Economy/ Finances
Politics
Environment
Legislation
Society/ Community
Surface part
Decisions
Risks
Data
Gaseous phase
Pressure regime
Heat regime
Rock
Fluid phase
Discontinuities
Subsurface part
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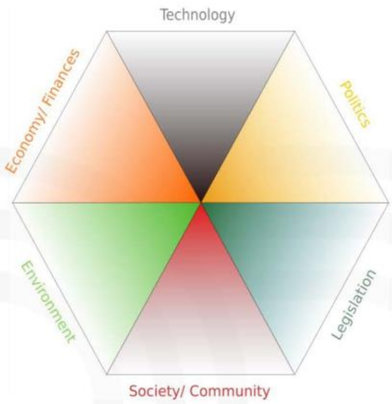
## Surface compartments and data level

| discipline-specific: metadata descriptions links D | discipline-specific: visualisations C | discipline-specific: parameters numerical data classed data B | (major) geothermal parameters: numerical data classed data A | Increasing informative value → Influencing surface & subsurface factors |
|---|---|---|---|---|
| funding agencies | | | equipment costs<br>exploration costs<br>drilling costs<br>stimulation costs<br>integration costs | **Economic**<br>Funds<br>Costs<br>Fees<br>Subsidies<br>Prizes<br>Wages |
| supplier<br>companies<br>products<br>materials<br>technologies<br>conventional plants<br>geothermal plants<br>other renewables | equipment types<br>equipment characteristics<br>drilling technologies<br>stimulation technologies | equipment parameter<br>technology parameter<br>technical settings<br>technical configurations | | **Technical**<br>Equipment<br>Items<br>Tools<br>Devices<br>Material<br>Installations |
| satellite image<br>digital elevation model<br>aerial images | landuse<br>landcover | classified landuse<br>classified landcover | scaling index<br>corrosion index<br>restricted areas<br>CO2 emission<br>subsidence<br>potential seismicity<br>potential water cont.<br>radioactivity | **Environmental**<br>Influences on,<br>Modifications of,<br>Emissions into<br>the natural system<br>Scalings<br>Corrosion<br>Artificial fluids |
| | political boundaries<br>admin. boundaries | | | **Political & Adminstrative**<br>Administrative units<br>Population<br>Rulers<br>Leaders<br>Decision makers |
| | | | | **Legislative**<br>Laws<br>Legislation<br>Acts<br>Rules<br>Regulations |
| educational resources<br>citizens' initiatives<br>journalists, publishers<br>media<br>communication channels<br>PR concepts<br>Communication material | | | | **Social**<br>Atmosphere<br>Mood<br>Education<br>Civil activity<br>Trends<br>Media |

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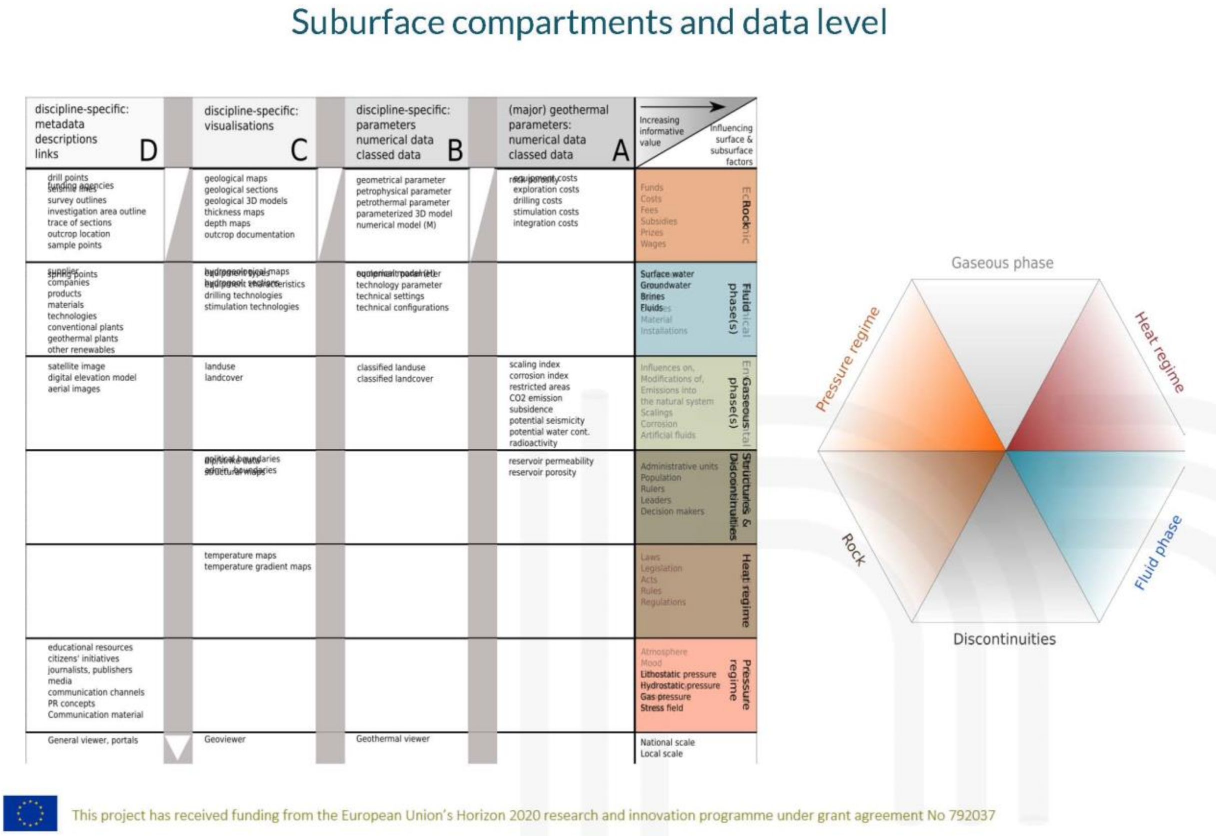
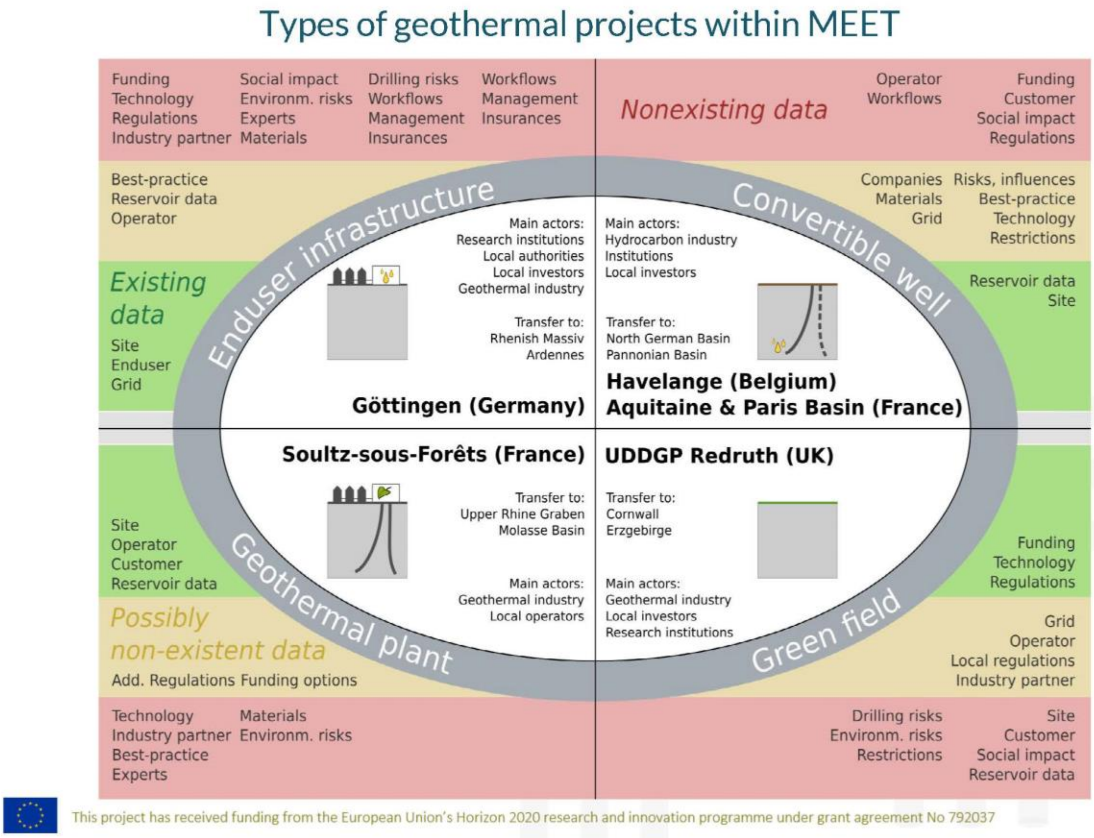

Suburface compartments and data level
discipline-specific: metadata descriptions links D
discipline-specific: visualisations C
discipline-specific: parameters numerical data classed data B
(major) geothermal parameters: numerical data classed data A
Increasing informative value
Influencing surface & subsurface factors
survey outlines
investigation area outline
trace of sections
outcrop location
sample points
geological maps
geological sections
geological 3D models
thickness maps
depth maps
outcrop documentation
geometrical parameter
petrophysical parameter
petrothermal parameter
parameterized 3D model
numerical model (M)
exploration costs
drilling costs
stimulation costs
integration costs
Rock
companies
products
materials
technologies
conventional plants
geothermal plants
other renewables
drilling technologies
stimulation technologies
technology parameter
technical settings
technical configurations
Surface water
Groundwater
Brines
Fluids
Fluid phase(s)
satellite image
digital elevation model
aerial images
landuse
landcover
classified landuse
classified landcover
scaling index
corrosion index
restricted areas
CO2 emission
subsidence
potential seismicity
potential water cont.
radioactivity
Gaseous phase(s)
reservoir permeability
reservoir porosity
Structures & Discontinuities
temperature maps
temperature gradient maps
Heat regime
educational resources
citizens' initiatives
journalists, publishers
media
communication channels
PR concepts
Communication material
Lithostatic pressure
Hydrostatic pressure
Gas pressure
Stress field
Pressure regime
General viewer, portals
Geoviewer
Geothermal viewer
National scale
Local scale
Gaseous phase
Pressure regime
Heat regime
Rock
Fluid phase
Discontinuities
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037


Types of geothermal projects within MEET
Funding
Technology
Regulations
Industry partner
Social impact
Environm. risks
Experts
Materials
Drilling risks
Workflows
Management
Insurances
Workflows
Management
Insurances
Nonexisting data
Operator
Workflows
Funding
Customer
Social impact
Regulations
Best-practice
Reservoir data
Operator
Companies
Materials
Grid
Risks, influences
Best-practice
Technology
Restrictions
Existing data
Site
Enduser
Grid
Reservoir data
Site
Enduser infrastructure
Main actors:
Research institutions
Local authorities
Local investors
Geothermal industry
Transfer to:
Rhenish Massiv
Ardennes
Göttingen (Germany)
Convertible well
Main actors:
Hydrocarbon industry
Institutions
Local investors
Transfer to:
North German Basin
Pannonian Basin
Havelange (Belgium)
Aquitaine & Paris Basin (France)
Soultz-sous-Forêts (France)
Transfer to:
Upper Rhine Graben
Molasse Basin
Main actors:
Geothermal industry
Local operators
Geothermal plant
UDDGP Redruth (UK)
Transfer to:
Cornwall
Erzgebirge
Main actors:
Geothermal industry
Local investors
Research institutions
Green field
Site
Operator
Customer
Reservoir data
Funding
Technology
Regulations
Possibly non-existent data
Add. Regulations Funding options
Grid
Operator
Local regulations
Industry partner
Technology
Industry partner
Best-practice
Experts
Materials
Environm. risks
Drilling risks
Environm. risks
Restrictions
Site
Customer
Social impact
Reservoir data
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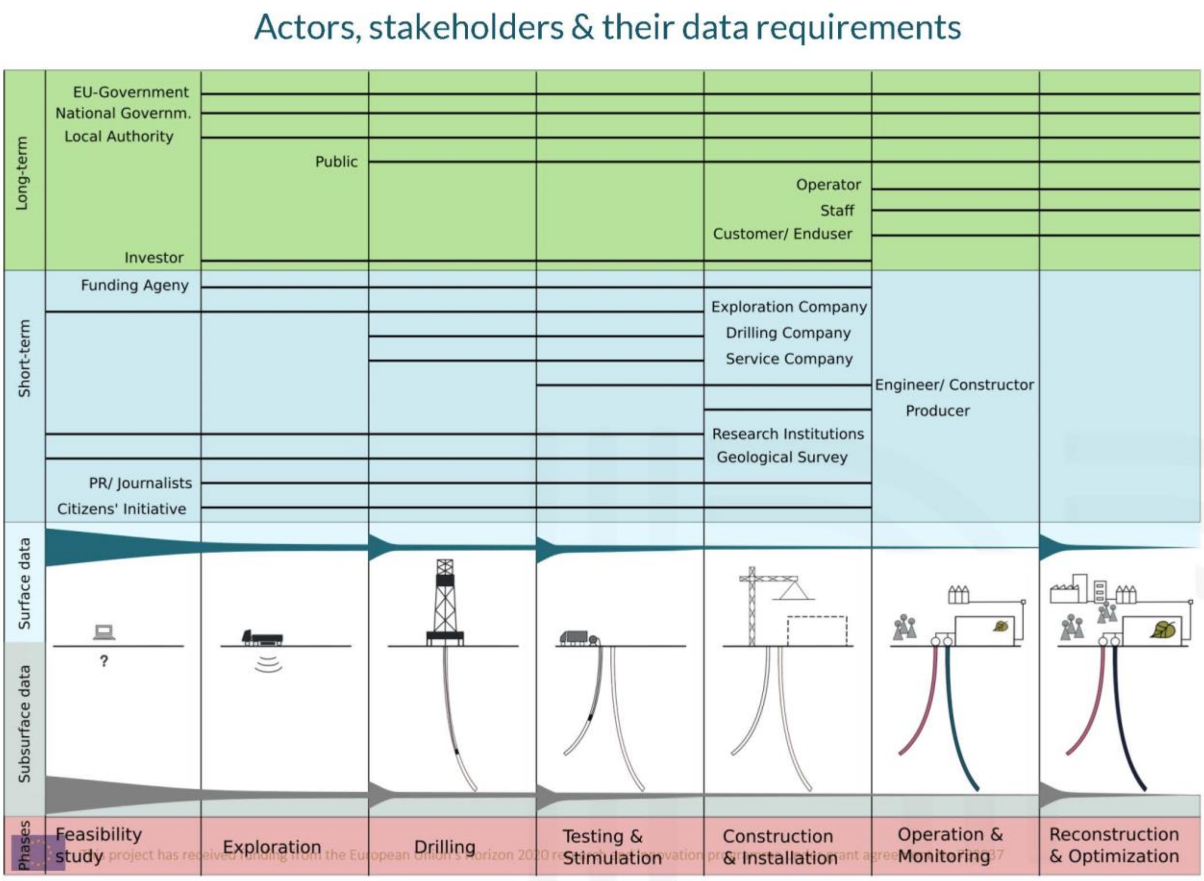


Power Point: MEET_TechnicalWorkshop_Session3_Raos_Bilic

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## PLENARY SESSION

# DECISION-MAKING SUPPORT TOOL

UNIZG-FER

Sara Raos & Tena Bilić

# Faculty of Electrical Engineering and Computing

- → **largest** technical faculty in Croatia
- → **35 lecture halls**
- → more than **60 laboratories**
- → **12 departments**
- → **160 professors** and **210 teaching and research assistants**
- → around **3300 students** at the undergraduate, graduate level and PhD students

The Faculty has developed valuable **international cooperation** with many research institutions around the world, either directly or through inter-university cooperation.

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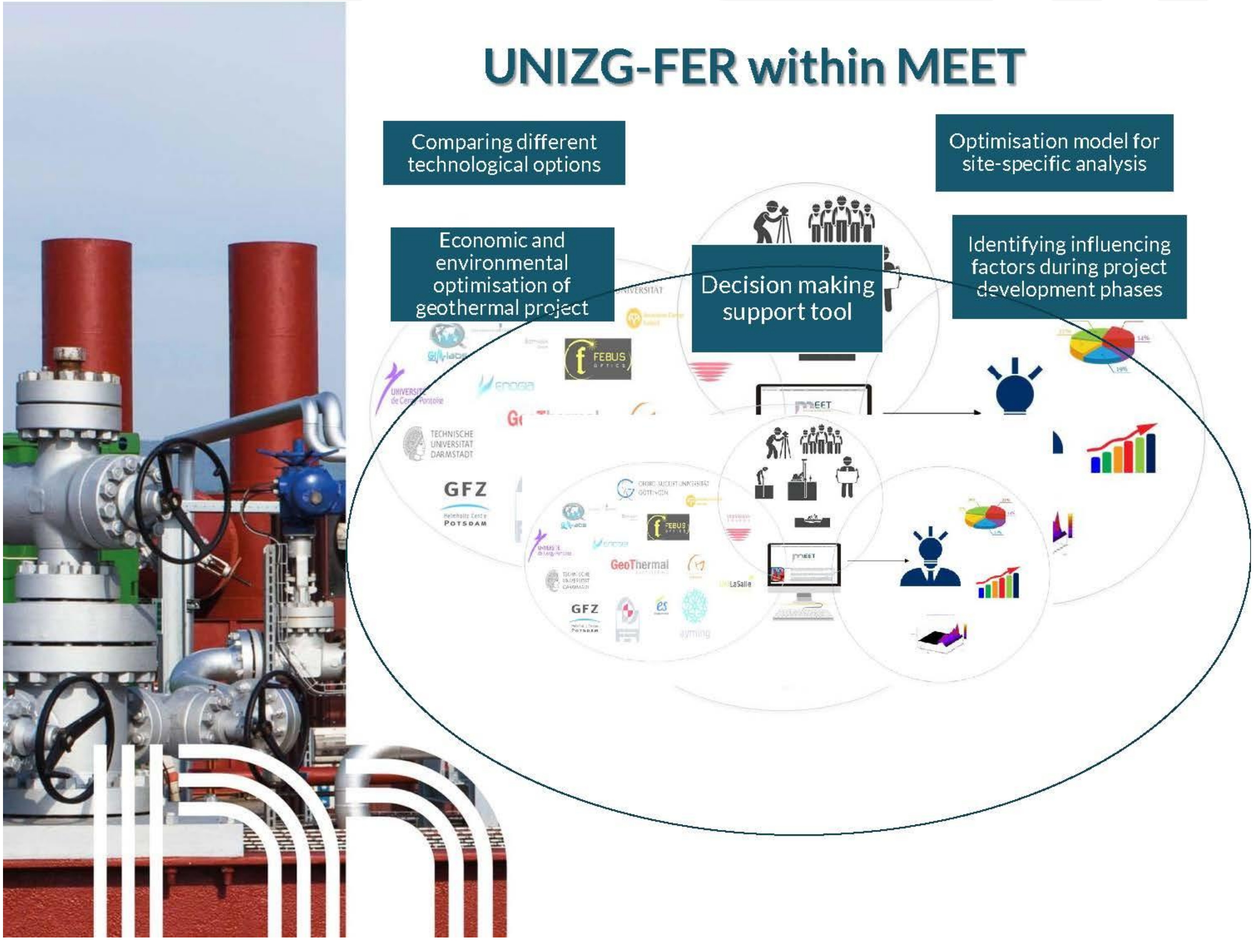
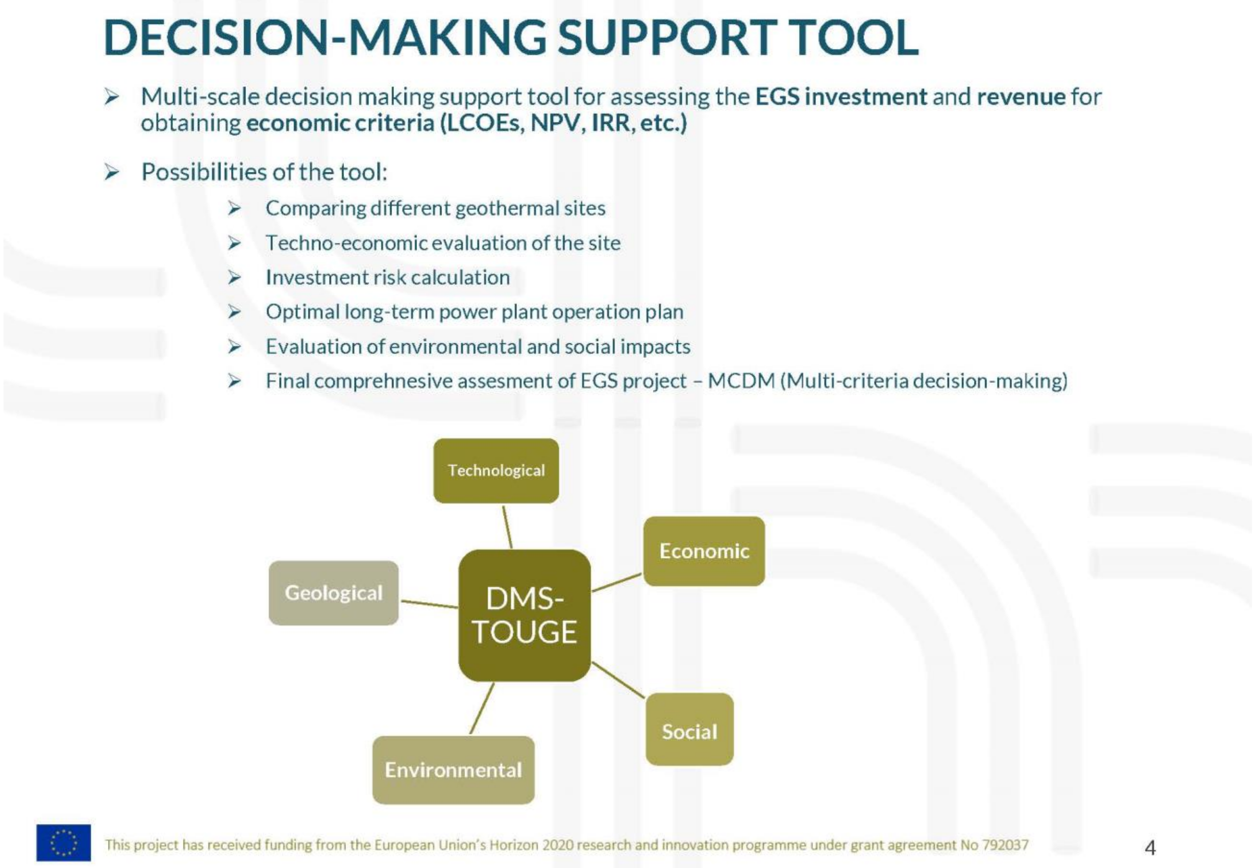

UNIZG-FER within MEET
Comparing different technological options
Optimisation model for site-specific analysis
Economic and environmental optimisation of geothermal project
Decision making support tool
Identifying influencing factors during project development phases


DECISION-MAKING SUPPORT TOOL
Multi-scale decision making support tool for assessing the EGS investment and revenue for obtaining economic criteria (LCOEs, NPV, IRR, etc.)
Possibilities of the tool:
Comparing different geothermal sites
Techno-economic evaluation of the site
Investment risk calculation
Optimal long-term power plant operation plan
Evaluation of environmental and social impacts
Final comprehnesive assesment of EGS project – MCDM (Multi-criteria decision-making)
Technological
Economic
Geological
DMS-TOUGE
Social
Environmental
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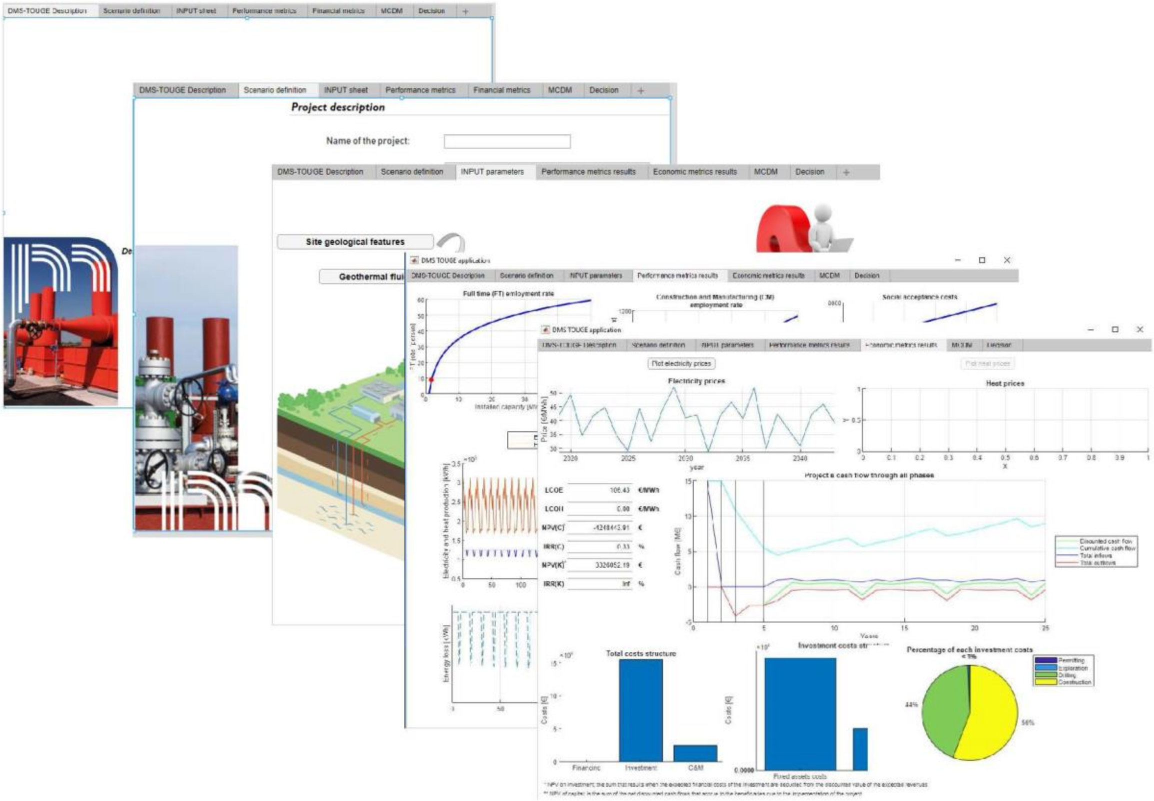
4

# DECISION-MAKING SUPPORT TOOL



# INTERACTIVE SESSION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