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Meet Project: Toward Large Scale Deployment of Deep Geothermal Energy in Europe

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ABSTRACT

The MEET Project (Multidisciplinary and multi-context demonstration of EGS exploration and Exploitation Techniques and potential) aims at boosting the use of deep geothermal energy across Europe in various geological contexts (sedimentary, volcanic, metamorphic and crystalline settings) by different approaches. This project, funded under the EU Horizon 2020 grant program, has started in May 2018 and should last until October 2021.

One main focus of the MEET project consists of the rapid development of deep geothermal energy by optimising the usage of a wide variety of existing wells. As drilling costs represent a huge part of the investment for deep geothermal projects, the reuse of existing wells will enable a fast penetration of geothermal energy all across Europe and diminish its Levelized Cost of Energy (LCOE). For this purpose, the MEET team will demonstrate the valorisation of geothermal energy in different contexts:

- In the sedimentary basin, MEET will take advantage of existing oil wells in the Paris and Aquitanian basins to perform experiments on wells and depot sites in order to enhance heat and electricity valorisation. Regulatory aspects of oil to the geothermal conversion will be studied in order to ensure its feasibility and wider deployment. Economic scenarios will be established to evaluate the financial opportunities this conversion could represent.

- At existing EGS sites, MEET will optimise the reinjection temperature in order to valorise additional calories. On the Soultz-sous-Forêts geothermal plant, experiments will be conducted in order to lower reinjection temperature from 70°C to 40°C. The impact of this temperature change will be investigated in terms of corrosion and scaling issues in the surface facility as well as the reservoir changes at depth. For this second purpose, in addition to standard seismological monitoring, a fibre optic will be deployed in an observation well to continuously monitor in time and depth the pressure and temperature evolution.

- At existing volcanic sites, MEET will optimise low-temperature calories by testing a new mobile ORC that could use heat with an input temperature ranging from 70°C to 90°C. In addition to installation in Reykjanes, a well known geothermal power plant in Iceland, this ORC will also be deployed at a local farm, thus increasing the potential users of such equipment drastically. Specific attention will be paid to the choice of the appropriate material for the heat exchanger in order to avoid corrosion issues.

- More generally, this type of mobile ORC will be deployed on six sites to show its usability in a wide range of geothermal context. In addition to the previously mentioned sites, another granitic site should also be tested. The site is not selected yet but will probably represent a thermal resort where additional heat capacities could be turned into electricity.

Another main focus of the MEET project aims at investigating new geological settings where valorisation of geothermal potential needs to be proven. This concerns mainly Variscan metamorphic rocks which cover large European areas. For that purpose, the MEET team will approach the geothermal potential by developing structural and lithological conceptual models as well as analysing the petrophysical, mineralogical and geochemical characteristics of potential reservoir rocks and structures. Two main demo sites have been selected to MEET to conduct these investigations:

- Göttingen University campus in Germany, where the district heating system could be converted from a conventional gas based to a geothermal heat supply
- Havelange site in Belgium, where an existing gas exploration well provides key data from depths down to 5000 m

These investigations will be based on analogue site review and sampling in order to determine typical ranges of parameters to model reservoirs in these geological settings. These models will be used to test different stimulation strategies for further EGS deployments.

Stimulation strategies already performed in the different crystalline basement will also be reviewed in order to design and perform a new chemical treatment in Cornwall (UK) with custom-made environmentally friendly chemical composite agents.

At last, an attempt of generalisation of MEET results at European scale will be performed based on a multi-layer GIS approach that combines geological, technical, environmental, regulatory, political and social aspects. This GIS, coupled with an economic decision making support tool, calibrated on demo-sites previously described, should highlight areas were future deep geothermal projects could be developed.

1. INTRODUCTION

The MEET project or "Multidisciplinary and multi-context demonstration of EGS Exploration and Exploitation Techniques" is aiming at demonstrating the geothermal potential of Europe from real projects in a relevant industrial environment for attracting investors (Dalmais et al., 2019). In order to ensure the continuous development of deep geothermal energy, the MEET project works on two different aspects. Firstly, the reuse or optimisation of existing wells in a wide variety of geological and valorisation contexts should enable quick development of geothermal energy which requires low investments. Secondly, investigations of Variscan basement geological settings will help define appropriate stimulation strategies. Whereas this new EGS project requires high investments and risks, their long term development will ensure a broader coverage of Europe with this renewable energy.

2. SHORT TERM DEEP GEOTHERMAL BOOST

The key idea of the MEET project to quickly boost the development of deep geothermal energy consists of wider use of existing infrastructures. Indeed, in a lot of existing well with different usage, additional calories could be valorised. The MEET project is demonstrating the feasibility of this additional valorisation in different contexts. Usually, these additional calories are of low temperature, and the major challenge is the availability of a local heat user. To overcome this challenge, MEET is developing a mobile ORC (Organic Rankine Cycle) which will be able to produce electricity from a temperature range of 70 – 90°C and can easily be connected to an existing well.

The idea is to adapt an existing ORC technology to the specificity of geothermal application, especially through the sourcing and testing of adapted, cost-effective, heat exchangers technology. The main challenge consists in the ORC being compatible with geothermal water chemistry variability originating from various geological conditions. Experiments are performed on potential material candidates in both laboratory and on-site tests to achieve this. The on-site tests are performed in different geothermal environments to obtain a more comprehensive overview of which heat exchanger materials are eligible for a given environment. The electricity production is evaluated on three main types of geological settings representative of the European situation:

- Granitic: on existing EGS plants and in a thermal resort,
- Sedimentary: on existing oil fields,
- Volcanic: on the existing geothermal power plant.

For each of these three types, one or two sites with different chemical, temperature and flow characteristics, will be tested. Three mobile and autonomous 40 kW ORC units with an integrated air condenser, installed on a truck's trailer are designed and manufactured to cover these sites with the necessary reactivity and flexibility. Their heat exchangers will be adapted to the different site conditions.

2.1 Lowering reinjection temperature on existing EGS plants in granite

In the Upper Rhine Graben, existing EGS plants usually exploit temperature ranging from 150-170°C at production to 80-70°C at reinjection (Baujard et al., 2018). The very saline brine circulating in deep-seated granite induces scaling and corrosion issues in surface equipment (Mouchot et al., 2019a). The reinjection temperature is the key factor that controls the scaling formation, and decreasing temperature may potentially introduce new scaling such as silica.

The MEET project aims at demonstrating the feasibility of decreasing temperature at reinjection down to 40°C. This feasibility is assessed regarding different aspects:

- Energy valorisation: to minimise thermal losses, mainly due to scaling.
- Operation process: to handle corrosion and scaling issues.
- Environment and social acceptance: to ensure that no induced microseismicity could be felt by the local population.
- Reservoir sustainability: to ensure that there will be no significant thermal breakthrough or flow rate decrease during the lifetime of the exploitation.

Different tests are conducted on the Soultz-sous-Forêts power plant to achieve this demonstration. The first test of temperature decrease has been attempted on 10% of the flow rate during three months between February and April 2019 (Ravier et al., 2019 and Seibel et al., 2020). The heat exchanger was designed with several tubes alloy in order to determine the best trade-off material between corrosion resistance in Upper Rhine Graben conditions and economic aspect (Figure 1). This alloy selection will also assess the impact of metallurgy corrosion on scales. The scaling and corrosion phenomena will be then investigated in great detail from the microstructural and geochemical point of views in order to understand all interaction processes involved and define an adequate way to exploit the geothermal brine at low temperature (Mouchot et al., 2019b, Ledésert et al., 2020).

Figure 1: Test heat exchanger installed in Soultz power plant in 2019 (Ravier et al., 2019; Seibel et al., 2020).

A second test at full flow rate will be attempted by the end of 2019, which should last between 4 and 6 months. The additional calories will be valorised with a mobile ORC that will generate electricity at 70°C. During this second test, a specific monitoring network will be deployed to record the effects of cold reinjection in the reservoir. This monitoring will be achieved with a reinforced seismological surface network and pressure measurements in peripheral wells together with a fibre optic system deployed in an observation well. This measurement will evaluate the thermo-mechanical impact directly in the reservoir. This monitoring will be operational at least one month prior to the colder reinjection and should help to anticipate any evolution in the reservoir and notably in term of induced microseismicity.

In parallel to these operational experiments, some studies are performed to model the reservoir behavior better and anticipate potential sustainability issues. Different works are on-going to gather more data and knowledge on granitic EGS system and more specifically on Soultz site. At first, some field campaigns on analogues are on-going to better assess the geometry of the fracture system as well as its degree of alteration and secondary mineralisation (Klee et al., 2020). The fracture distribution from Soultz and other EGS project will be reviewed in order to decipher some fractal lows which could serve as a basis for Discrete Fracture Network modelling (Trullenque et al., 2020 and Afshari Moein et al., 2020). Old offset vertical seismic profiles (O-VSP) data from the Soultz project will be reprocessed thanks to the innovative inversion method and current numerical capacities with the aim at major imaging structures in the deep granite around the wells (Barnes et al., 2020). All these data will help precisely the geological conceptual model of Soultz-sous-Forêts EGS site and will serve as a basis for the new THM(C) models to predict reservoir behavior with cold reinjection.

2.2 From oil and gas field to geothermal coproduction and conversion in the sedimentary basin

A huge number of wells exist in Europe for oil and gas exploitation, where the fluid temperature usually ranges between 20°C to 90°C. Given the fact that the oil-water ratio diminishes during exploitation time, most European fields, which are mature, have wells that usually produce more than 90% of water. Taking advantage of these wells will provide important additional geothermal capacities to Europe at low capital expenditure. In these conditions, well and field life extension by valorising geothermal energy becomes economically interesting. This last point is of crucial importance in France where a law was voted in 2017 to plan a progressive stop of oil and gas production by 2040. Conversion of oil fields into geothermal ones is, in this case, an elegant solution to ensure a long-term value of the assets.

The MEET project aims at demonstrating the feasibility of oil and geothermal energy coproduction. This will be assessed in different steps (Léoutre et al., 2020):

- Vermilion company, the first oil producer in France, has reviewed its assets in this country in order to quantify the thermal power of wells. Two wells and one oil depot have been selected for test sites (Paris and Bordeaux areas).

- In order to define the appropriate metallurgy for heat exchanger components, a corrosion experiment based on coupons installed in a pipe close to the wellhead on these demo-sites has been performed. These coupons have been installed and tested in a dedicated rack provided by the Innovation Center Iceland (ICI) for three months in a Cazaux oil well (Figure 2).

Figure 2: a set of 7 coupons installed in a dedicated rack for corrosion study installed in a Cazaux oil well (Source: Vermilion).

- A demonstration of heat coproduction will be carried on an oil depot site. After screening different potential end-users in the vicinity of their facilities, Vermillon has chosen to focus on the LEGE area that provides a combination of sizeable heat resource and nearby customers.. A techno-economic study is on-going on this demonstration site.

- On the two selected wells, a small-scale mobile ORC will be connected to the wellheads in order to produce electricity from brines at 90°C. These tests will last between 4 and 6 months in order to analyse the robustness and performance of the system. These pilots will validate the technical concepts and the expected electrical yield at such temperature range. The first ORC, which will be tested in Chaunoy field (Paris Basin), will start in September 2019 (Figure 3).

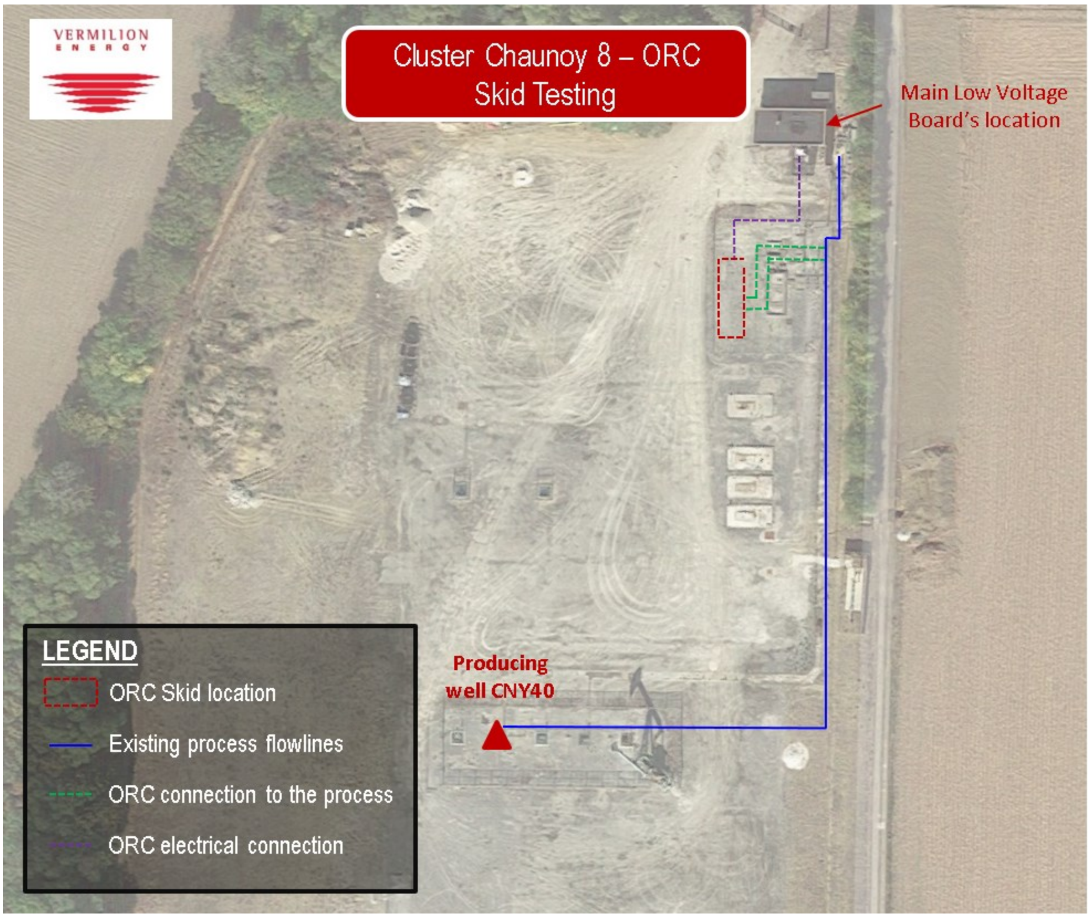


Figure 3: Schema of connection of ORC on an oil well in Chaunoy, France (source Vermilion)

- Based on the previous test, an economic analysis will be performed, and the profitability of such coproduction will be discussed. In particular, the technical and economic feasibility for converting uneconomic oil exploitation to geothermal exploitation will be evaluated. It will also serve as a case study to set up a Decision-Making Support Tool to identify the optimum scenario for converting oil fields into geothermal ones.

2.3 On volcanic areas

The chosen demo sites in the volcanic area are located in Iceland. The high non-condensate gas content of such geothermal brines is challenging and the expertise of Icelandic know-how on corrosion issues will ensure that adequate alloy and design are chosen for the heat exchangers (Ragnarssdóttir et al., 2020).

The first demo-site is a well situated within the Reykjanes geothermal field. The Reykjanes geothermal system is on the Mid-Atlantic Ridge at the Reykjanes peninsula in south-western Iceland. This system is not like the other high-temperature geothermal systems in Iceland because the fluid in the system is seawater-recharged rather than meteoric water which is the case in most other geothermal systems in Iceland (Sigurðsson, 2012). The heat that drives the Reykjanes geothermal system arrives through dykes intruded at depth, since the system does not have any central volcanoes with shallow secondary magma chambers (Gudmundsson & Thórhallsson, 1986; Gudmundsson, 1995). The geothermal sites at Reykjanes are owned by HS Orka. The temperatures in the Reykjanes system reach over 250°C, and the fluid is acidic with quite a lot of chloride because of the seawater origin of the geothermal fluid.

The second demo-site is Grásteinn II in an Icelandic farm (Figure 4), close to the town of Hveragerði in southern Iceland. It is situated on the Suðurland transverse fracture zone. The farm is located on top of a low-temperature geothermal area. In 1995 a geothermal well was drilled at Grásteinn II with a depth of around 400 m. To increase the production of the well, it's depth was increased to 586 meters in 2010. That deepening resulted in higher flow rates and higher temperatures of the fluid coming from the well. The well's highest flow rate is between 8-9 l/s although currently it is kept at a minimum flow which is around 3.5 l/s. The well requires further development and the installation of a pump to acquire flow rates sufficient enough to run an ORC. This will be done in the near future. The maximum fluid temperature at the wellhead is 115 °C. Showing the potential in electricity generation at this small scale could boost local electricity production with an easy replication in numerous insular locations.

Figure 4: Grásteinn II geothermal wellhead.

Some coupons test experiments have been done on both sites, and corrosion analyses are on-going to determine best-suited material for heat exchangers. The first ORC test should start by the end of 2019.

3. EGS S DEVELOPMENT IN DIFFERENT EUROPEAN GEOLOGICAL SETTINGS

Optimisation of energy valorisation at existing infrastructure sites can boost the geothermal energy market penetration on a short-term basis. However, improving the knowledge to exploit EGS-reservoirs is mandatory to develop geothermal usage on both long term and large geographical extent.

In that perspective, different MEET subprojects aim at investigating potential reservoirs in the large areas covering the Variscan basement of Europe with its granitic as well as folded and trusted metasedimentary and metavolcanic rocks (Trullenque et al., 2018). Representative demo sites and outcrop analogues have been identified (Figure 5) to set up reservoir models for developing specific EGS and for quantifying the geothermal potentialsFigure 5.

3.1 Geological settings and related demo sites

(1) Variscan metamorphic successions overprinted by younger extensional tectonics: Target horizons consist of meta-greywackes and -sandstones, slates, meta-carbonates, quartzites and diabase. Primarily the Western Harz-mountains, but also the Rhenish massif serve as outcrop analogue field sites for the demonstration sites located on the Göttingen University campus where the younger Leinetal Graben structure overprints the Rhenohercynian fold and thrust belt bedrock. The Göttingen University campus was selected as a demo site since there is an existing district heating system for which a University-owned heat and power station supply heat. The University strongly aims at replacing the gas-fired turbine system by geothermal energy for heat supply. It is a demo site not only for developing the subsurface EGS but also for the conversion of the existing surface heat supplying by integrating the geothermal system and by optimising and harmonising both elements (Leiss et al. 2020).

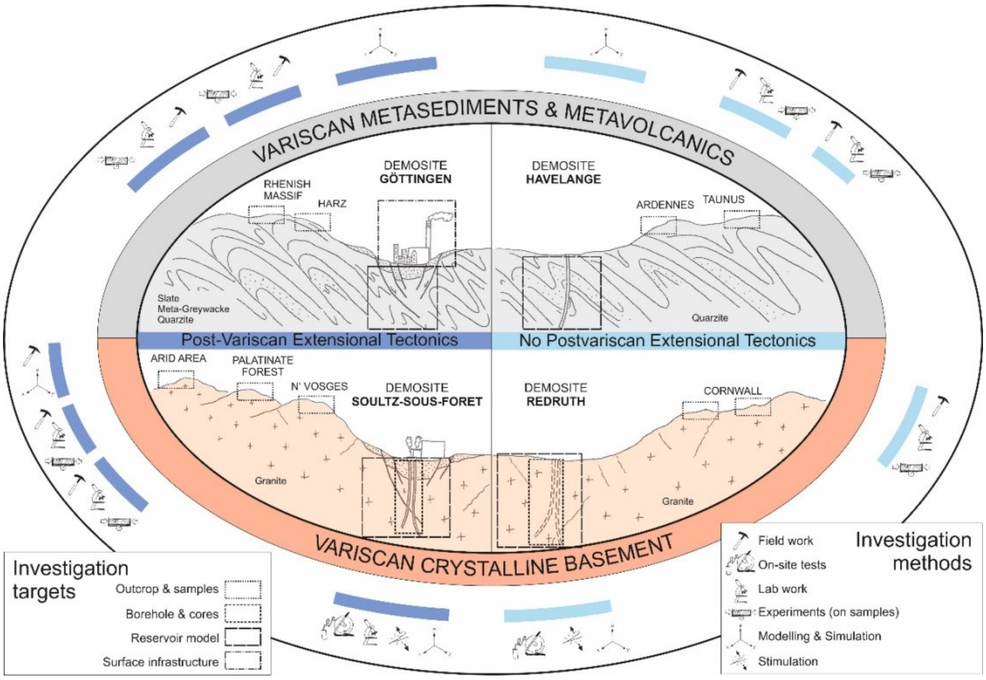


Figure 5: MEET demonstration sites and their corresponding outcrop analogue sites for four representative geological settings in regard to the Variscan granitic as well as for folded and trusted metasedimentary and metavolcanic zones. In addition, a possible post-Variscan overprinting is considered. For each site, the investigation methods are given.

(2) Variscan metamorphic successions not overprinted by younger extensional tectonics: Target horizons are primarily quartzites but also slates, diabase and meta-carbonates. Outcrop analogue field sites are the Rhenohercynian Ardennes- and Taunus-mountains of the Rhenish Massif. The 5000 m Havelange borehole in Belgium serves as a demonstration site, firstly because drill cores and hydraulic test data are available, but also because an in-situ test-site for new experiments would available in case of reopening the well.

(3) Variscan crystalline basement overprinted by post-variscan extensional faults: Target horizons are fractured granites or granitoids below a post-Paleozoic sedimentary cover. Analogue field sites are the Pfälzer Wald, the northern Vosges and the Odenwald (near field) and Noble hills, Death Valley, California in the USA (far-field, Trullenque et al., 2020). The geothermal test site at Soultz, France acts as the demonstration site, as mentioned previously in this article.

(4) Variscan basement not overprinted by younger extensional faults: Target horizons for the outcrop analogue study are the Carnmenellis granites outcropping in the quarries between Redruth and St. Austell, which were already under investigation in the 1980s for the Camborne project in Cornwall (Great Britain). The United Downs Deep Geothermal Project (UDDGP, Figure 6; Law et al., 2019) in Redruth/Cornwall, Britain acts as the demonstration site. This project just finished the second well drilling phase in mid of 2019. The MEET project will provide an innovative chemical treatment to improve fluid flow at the borehole wall for the deepest well.

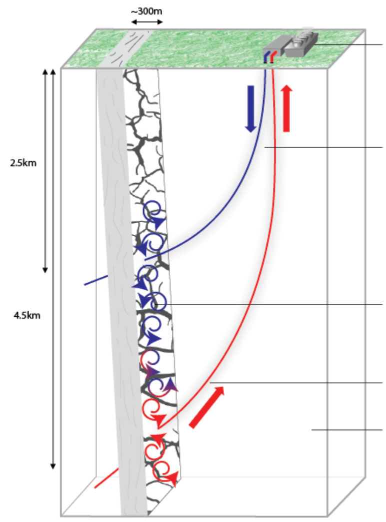


Figure 6: Sketch of the geothermal doublet under drilling operation in a faulted granite at UDDGP site in Cornwall, UK (Law et al., 2019).

(5) Additionally, the MEET consortium got access to the collection of cores from deep down Paris and Aquitanian basins provided by the oil companies Vermilion and Total (Sengelen et al., 2019). In consequence, these basin-related geological settings were added. Target horizons consist of schists, quartzite, micaschists, crystalline schists and gneiss. In that framework, rocks from Triassic reservoirs overlying Variscan basement will also be investigated.

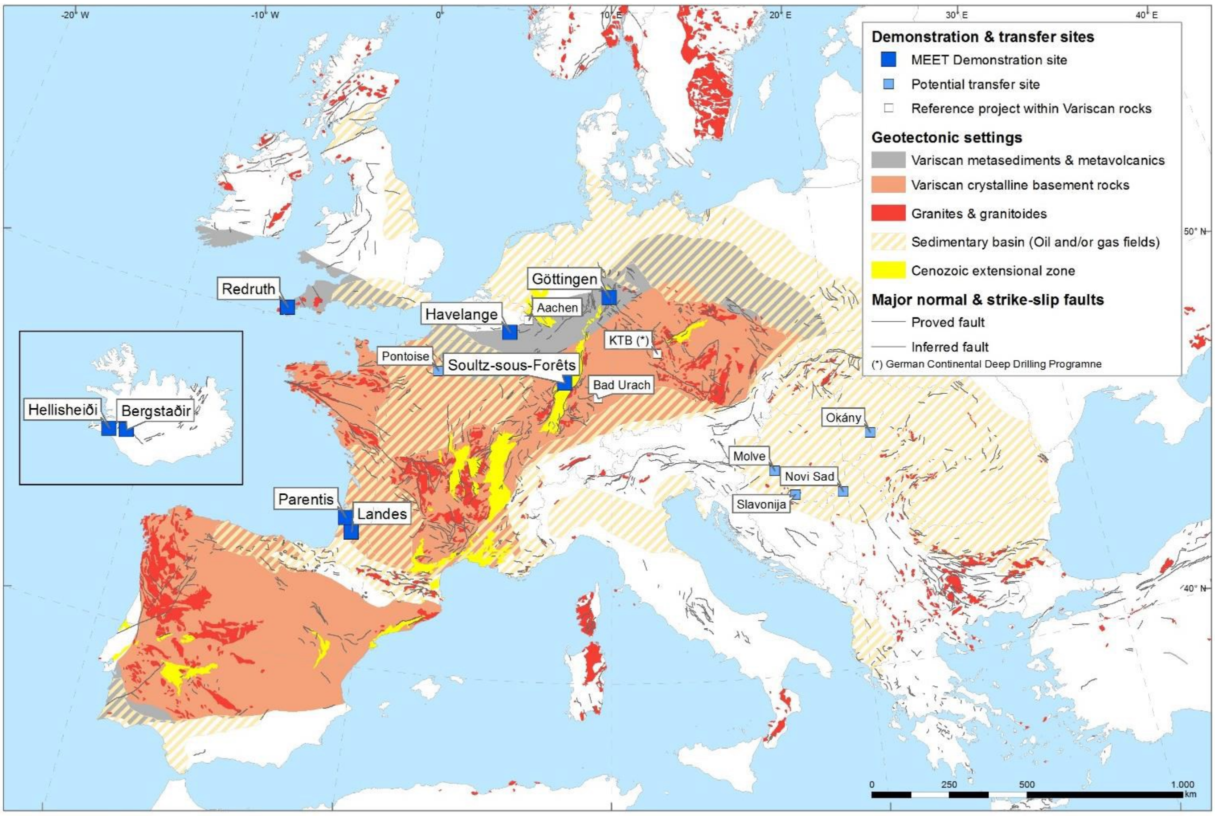
3.2 Methodology developed

Outcrop analogue studies are focusing both on the outcrop scale by mapping granitic types, the fold and fault within the metasedimentary successions, the adequate structure-related paleogeothermal and post-Variscan vein systems, fault damage zones, fracture networks and the extent and distribution of different rocks and alteration types (Figure 5, Figure 7). Field surveying is strongly supported by quantitative high-resolution photogrammetry, which is also assisted by drones, especially in large outcrops or areas of difficult access. From this mapping data, real structural 3D-models are generated. In the second step in representative conceptual 3D-models at the reservoir, scale is developed to integrate all fracture network-related properties from the micro- to the reservoir-scale (Ford et al. 2020).

Representative samples of selected rock types from analogues have been taken for lab investigation of the petrophysical and geomechanical properties, both under lab and in situ conditions (Figure 7). The studies include the evaluation of fluid-rock interaction and mechanical, thermal, and chemical effects of fracture healing. This will be accompanied by mineralogical and rock microfabric analysis to understand the processes that influence rock petrophysical properties. These data sets will be completed by fracture investigations and fluid analyses. This approach aims to minimize uncertainties by providing high-quality datasets measured at field analogue sites of potential reservoir rocks.

Petrophysical and rock mechanical property characterizations are carried out. Petrophysical measurements include grain and bulk density, porosity, permeability, compressive and shear velocity, thermal conductivity, thermal diffusivity, heat capacity, and radiogenic heat production. Rock mechanical property characterizations include uniaxial compressive strength, tensile strength, shear strength, cohesion, coefficient of friction, Poisson's ratio, Young's modulus, bulk modulus, shear modulus, compressibility, Biot, and Skempton coefficients. These characterizations are carried out on representative samples in the laboratory of Applied Geoscience Institute in the Technical University of Darmstadt in collaboration with project partners. All results will be compiled in one comprehensive dataset, as demonstrated in Bär et al. (2017).

This data basis in combination with Discrete Network Modelling (DFN) serves as input parameters for advanced thermal, hydrological, mechanical and chemical (THMC) simulations. These allow assessing the efficiency of stimulation operations and their sustainability at the different test sites. Based on these simulations and experiences of in-situ operations at some of the different geological settings, strategies, and operational recommendations (guidelines) for stimulation actions of Variscan reservoirs will be developed.



Sources of geological datasets:
Asch, K. (2005): IGME 5000: 1 : 5 Million International Geological Map of Europe and Adjacent Areas. BGR (Hannover).
U.S. Geological Survey World Petroleum Assessment 2000: U.S. Geological Survey Digital Data Series DDS60: http://greenwood.cr. usgs.gov/energy/WorldEnergy/DDS-60

Figure 7: MEET demonstration sites and potential areas to which results are transferable in regard to the defined and investigated geotectonic settings. Variscan fold and thrust belt, granite/granitoid dominated areas and sedimentary basins

(conversion of oil and gas wells to geothermal wells) illustrate the new terrains where MEET concepts will enable the production of heat and/or power.

4. TRANSFERABILITY OF THE TECHNOLOGY AT EUROPEAN SCALE

In order to attract investors for the long-term development of EGS in Europe, the results gathered on MEET demo sites need to be upscaled in a comprehensive manner for the non-scientific community. The development of two user-friendly tools is planned in the framework of the MEET project to achieve this objective: a Decision-Making Support Tool and a Geographical Information System (GIS) database.

4.1 Decision Making Support Tool for Optimal Usage of Geothermal Energy (DMS-TOUGE)

Considering high up-front costs of deep geothermal projects and many influencing factors, such as the extraction technologies, energy prices at the market as well as the other geological and infrastructure settings, that have an impact on the desired project, the holistic approach in the decision-making process is paramount, to facilitate the investor's decision. Therefore, the Decision-Making Support Tool for Optimal Usage of Geothermal Energy (DMS-TOUGE) will be modelled and developed. The parameters that will be evaluated are the available water temperature and flow rate, cooling conditions, heat extraction technology, descriptions of the power plant specifications, proximity to the final user, etc., which will be enabled as inputs from the DM itself or as default values from the internal database. In addition, the risk analysis (CVaR) will be conducted, including different important aspects. However, among persisting variables, some of the events and possible scenarios over the project lifetime should be predicted via a specially developed forecasting algorithm.

Within the multiple stages of the tool development, as a subprocess, the multiple-criteria decision-making (MCDM) matrix analysis will be conducted, where the technological, environmental, social and economic aspects will be evaluated for the initial stage of the project feasibility since, so far, some of the obtained criteria (social and environmental) were neglected. Within the MCDM matrix, the weights will be added to each criterion considering the DM's preferences. By joining different weights to criteria, the relative importance of each criterion is set. The approach in the DMS-TOUGE consists of evaluating the energy potential of different geothermal sites, and by use of the weighting method, the final result would vary according to DM's preferences. On the side of tool completion, the verification and validation of the currently operating EGS sites and data related to any other geothermal sites will be carried out. It has to be accentuated that the tool is still under the development, modelling stage according to the depicted model (Figure 8) (Raos et al., 2019)

4.2 GIS-analysis at European scale to locate and initiate promising EGS projects

In addition to the development of DMS-TOUGE tool, which is considering local conditions, a complementary research aspect is focusing on multi-scale and multi-thematic geospatial data analysis to upscale the outcomes of previously mentioned results (sections 2 and 3) at European scale. As they are achieved by investigating several types of demo sites and associated analogue sites, the resulting geospatial data are provided at a local scale. To make them available to a wider group of future users and to transfer those achievements to similar regions in Europe, they have to be transferred and translated into geospatial data of larger scales. This challenging task has to cope with three main obstacles that are the high complexity of a geothermal project, the huge number of participating experts and stakeholders, the wide range of scales and the heterogeneity and accessibility of existing online geospatial data.

To deal with these challenges, in a first step, a fundamental concept is elaborated to take all major aspects of a geothermal project over the complete lifetime into account. This should be starting with the first prospection steps and ending with the optimization of an already operating geothermal plant. The main goal of this activity is to discriminate the key parameters that mainly influence the successful realization of geothermal projects and to understand the needs of all participating stakeholders and experts to generate appropriate and adapted results.

One part of the fundamental concept is dedicated to the analysis of those discipline-specific and geothermal parameters that are major characteristics of the subsurface part of the system – the potential geothermal reservoir prior to technical maintenance. A first version of the "Hexagon concept" is presented and described in detail in Wagner et al. (2020). It is the base for the following categorization of subsurface parameters and their related geospatial representation in terms of relevance, informative value, scale, availability, and other factors. In the next step, such subsurface parameters are picked out, compiled, and provided as exemplary sets of geospatial data at the local scale that are relevant for the exploration and exploitation of the demo sites investigated within MEET. On the other hand, parameters are identified that should be analyzed and provided at larger scales to establish an updated European geothermal potential map. In this map, low- to medium-enthalpy target zones within Variscan and pre-Variscan intrusive and low- to high-metamorphic rocks are incorporated and visualized to give potential users and groups a tool to look for prospective sites beside high-enthalpy regions.

Parallel to this, a screening of online data sources is performed to identify sources of adequate, reliable, complete, and accessible geospatial data sets and their metadata. This will feed the aimed Web-GIS tool, based on state of the art, open-source technologies, and open data standards. The proposed web application will enable visualization as well as exploratory data analysis between projects in the same geotectonic zone and the best-practice examples.

Based on the mentioned "Hexagon concept," an extension is developed to categorize and weight those surface parameters (economic, technical, environmental, political, legislative, and social) that have any kind of spatial reference and can be translated into geospatial data sets. The main goal is to combine the two major aspects of a geothermal project – the natural subsurface reservoir and the various surface conditions – in just one application.

Finally, a catalog of important spatial data sets for further GIS-analysis on regional to local scale will be compiled to summarize the results of all GIS-based investigations within MEET. These guidelines will be handed over to future users to enable them to look for and select the right data sets on the national, regional, and local levels and to investigate promising targets in more detail.

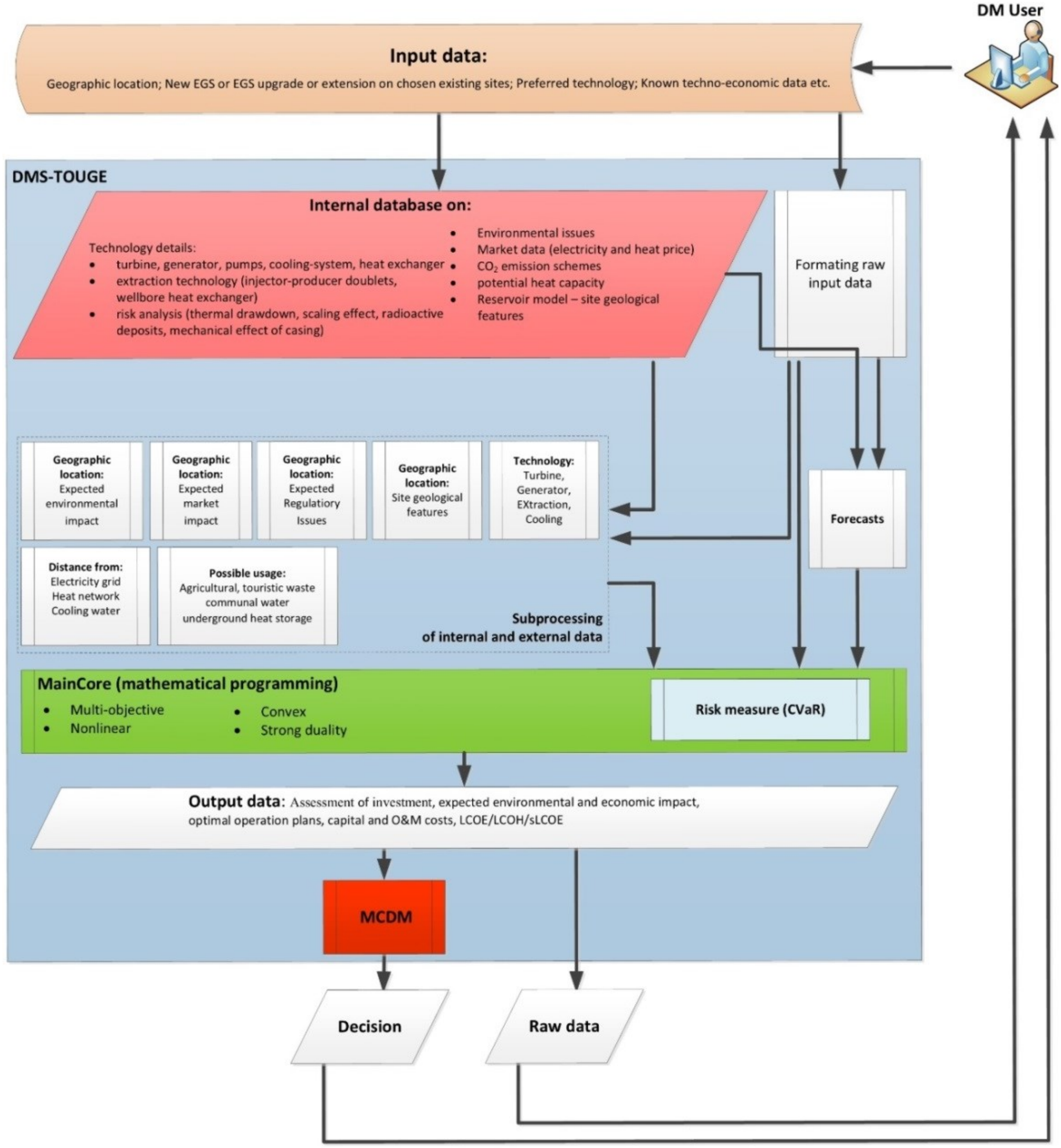


Figure 8: Schematic of the DMS-TOUGE process

5. CONCLUSION

The MEET European project done in the framework of Horizon 2020 has started in Mid-2018 and aims at important cost competitiveness of geothermal energy for potential investors. The two-steps approach combining the optimization of energy valorization on existing infrastructures, which could be easily reproduced and a deeper investigation on promising new EGS settings should provide to Europe new opportunities to develop deep geothermal energy.

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