DEPLOYMENT OF DEEP ENHANCED GEOTHERMAL SYSTEMS FOR SUSTAINABLE ENERGY BUSINESS

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ABSTRACT

The DEEPEGS project is a demonstration project supported by the European Commission. The goal is to demonstrate the feasibility of enhanced geothermal systems (EGS) for delivering energy from renewable resources in Europe. It is a four-years project led by HS Orka Iceland and in cooperation with partners from Iceland, France, Germany, Italy and Norway.

The project is testing stimulation technologies for EGS in deep wells in different geological settings, which will deliver new innovative solutions and models for wider deployments of EGS reservoirs with sufficient permeability for delivering significant amounts of geothermal power across Europe. The project demonstrates advanced technologies in three geothermal reservoir types that provide unique condition for demonstrating the applicability of this “tool bag” on different geological conditions. It will demonstrate EGS for widespread exploitation of high enthalpy heat (i) beneath existing hydrothermal field at Reykjanes (volcanic environment) with temperature up to 550°C and (ii) very deep hydrothermal reservoirs at Valence (crystalline and sandstone) and Vistrenque (limestone) with temperatures up to 220°C.

The consortium is industry driven with five energy companies that will implement the project goal through cross-fertilisation and sharing of knowledge. The companies are all highly experienced in energy production, and three of them are already delivering power to national grids from geothermal resources.

There is a special focus on business cases to demonstrate significant advances in bringing EGS derived energy (TRL6-7) routinely to market exploitation, with the potential to mobilise project outcomes to full market scales following the end of DEEPEGS project.

The consortium seeks to understand social concerns about EGS deployments, and will address those concerns in a proactive manner, where the environment, health and safety issues are prioritised, and awareness raised for social acceptance. Furthermore, the consortium will carry out risk analysis and implement, as a part of the R&D approaches and as a core part of the business case development, hazard mitigation plan.

1. EGS PERSPECTIVES IN THE WORLD AND IN EUROPE

For the world geothermal growth perspectives, the projections of IEA in 2050 (IEA, 2011), for the geothermal power production, are around 1,400 TWh/y, including 200 TWh/y for Europe, which will represent a share of 3.5% to the global electricity generation. To attain these expectations, the planned capacity is 200 GW of which 50% are derived from EGS technology (**Figure 1**). These projections are based on a significant development of EGS from 2020-2025 and the hypothesis of some sixty EGS plants representing a power capacity of 500 MW to 600 MW in 2020. In addition to the 10 EGS plants currently under development, at least 50 more with an average capacity of 10 MWe will be needed over the next 10 years to achieve the deployment levels envisaged in this road map.

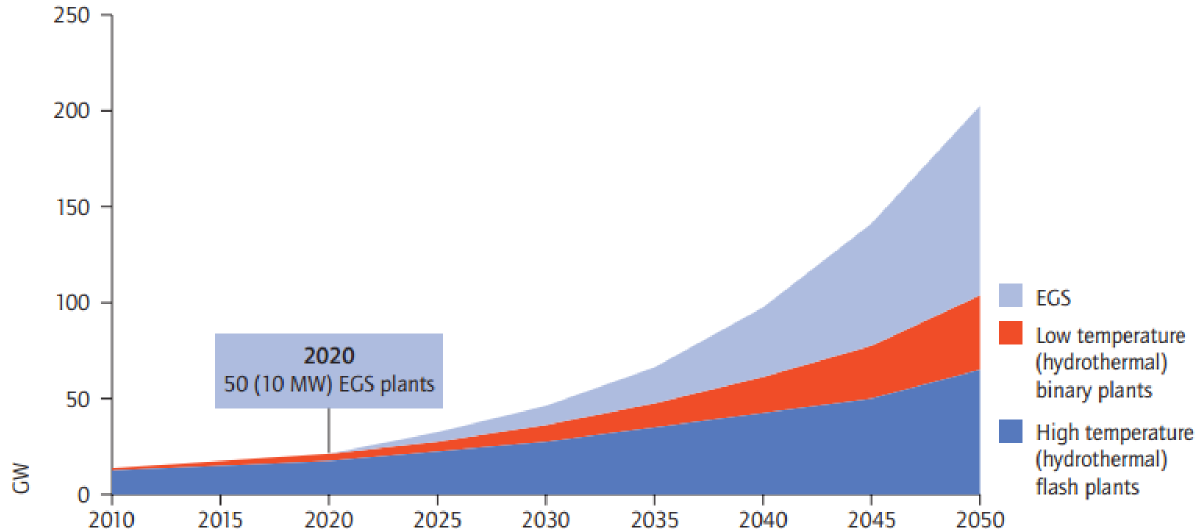

Figure 1: Growth of geothermal power capacities by technology (IEA: Technology Roadmaps, Geothermal heat and power, 2011)

The European Union has ambitious goals in term of renewable energy growth; the "20-20-20 goal" (20% share of renewable energies, 20% energy savings and 20% CO_2 emission reduction until 2020) and this clearly calls also for more geothermal electricity. In the Union, a goal of 3 GWe EGS capacity has been proposed for the year 2020 (Rybach, 2014) and further substantial EGS growth (around twice) by European Geothermal Energy Council (EGEC, 2012) (**Figure2**).

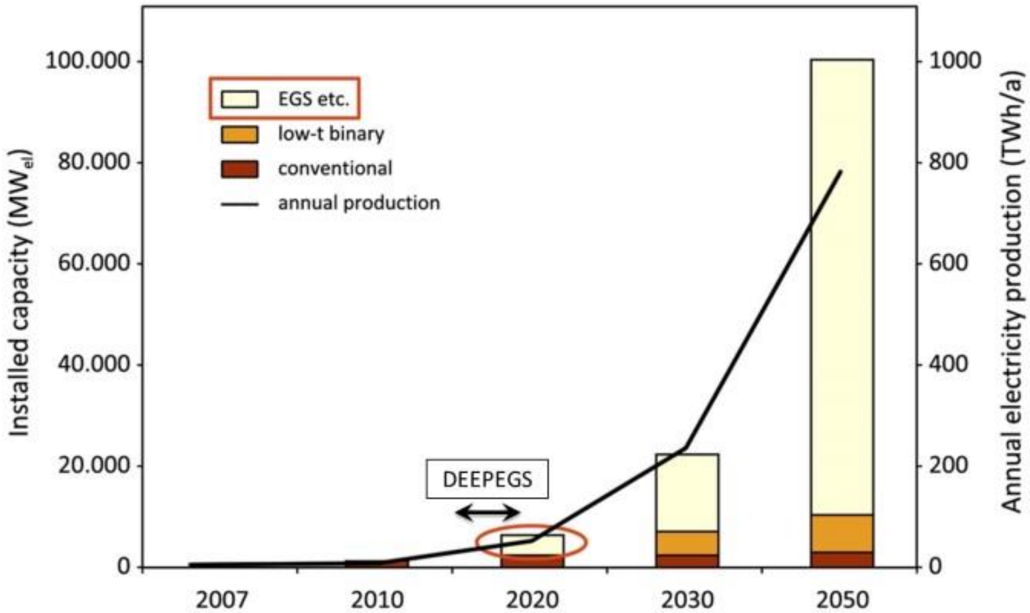

Figure 2: Vision of European Geothermal Energy Council (EGEC) about geothermal electricity growth until 2050, from EGEC 2012. The largest share should come from EGS.

2. THE DEEPEGS PROJECT

The DEEPEGS project goal is to demonstrate the feasibility of enhanced geothermal systems for delivering renewable energy to European citizens. The testing of technologies for stimulating EGS by deep drilling in different geologies should deliver new innovative solutions and models for wider deployments of EGS reservoirs.

The project is business driven and will demonstrate significant advances in bringing EGS derived energy to markets.

The project seeks to understand social concerns about EGS deployments, and will address those concerns in a proactive manner, where health, safety and environmental (HSE) issues are prioritised, and awareness raised for social acceptance.

The DEEPEGS project addresses the most relevant objectives for achieving successful demonstration of the widely available energy potential accessible through enhanced geothermal systems. Figure 3 shows an overview of the state of art knowledge and actions involved, where the combined know-how and transfer of expertise from earlier projects will be expanded and demonstrated in relevant different geologies.

For DEEPEGS, three different resource systems have been selected, representing different locations and geological formations in Europe, enabling this demonstration to be transferable to other geothermal sites with deep geothermal potential. The pathway to wider success for EGS deployment involves:

- enhanced understanding of the deep geothermal potential in Europe and worldwide,
- improved methodologies and technique to ensure efficient access to deep geothermal reservoirs,
- application of the technology to develop and enhance production at selected field locations,
- demonstration of the business case linked to the improved technology,

The DEEPEGS demonstration sites are located in three different geological settings:

- in high enthalpy volcanic environment sited beneath existing hydrothermal field at Reykjanes, Iceland, with expected temperature up to about 550 °C, and
- in two lower enthalpy deep hydrothermal reservoirs in southern France; at Valence, at the basement-sedimentary interface (metamorphic rocks and sandstone are expected), and in Vistrenque in a limestone environment, with temperatures up to 220 °C.

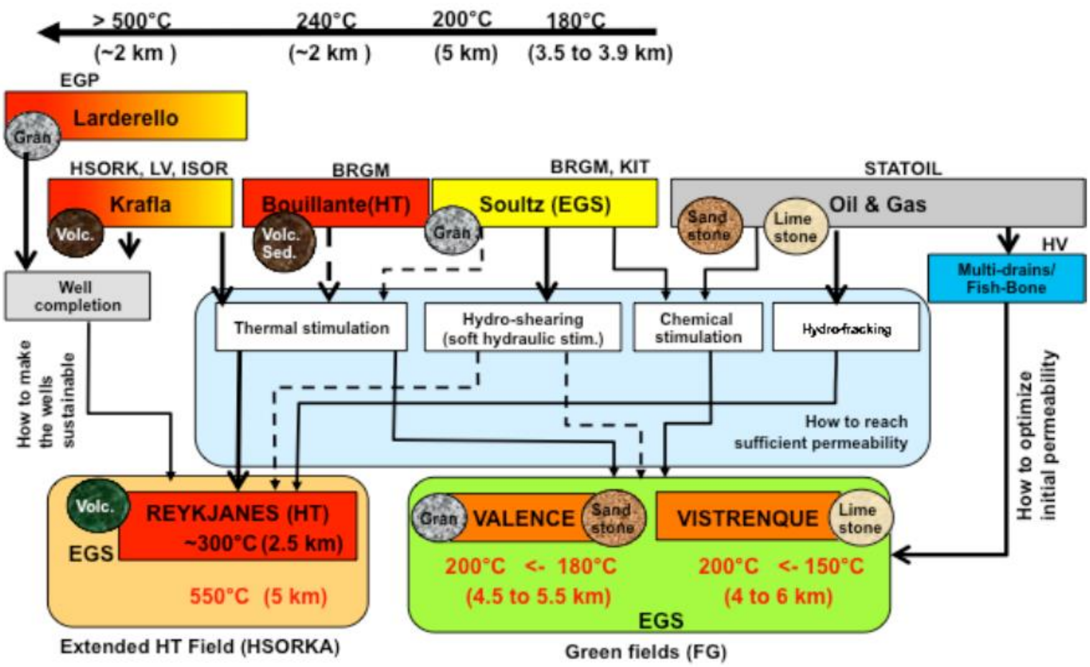

Figure 3: Testing of enhanced geothermal systems (EGS) in different geological environments.

2.1 Project consortium

The consortium is industry driven with five energy companies, which are complemented by three technology and research organisations, and an innovation-linked geothermal clusters, all targeting market acceptance of the DEEPEGS results. The purpose is to commercialize the applied technology. Business cases will be addressed as well as public acceptance, market and regulatory barriers, financing and other supply-side issues of relevance. Focus on potential business synergies between technologies, e.g. where emitted CO_2 can be recycled to produce methanol for the transport industry. One such CO_2 recycling company is already in operation within the HS Orka Resource Park.

The DEEPEGS consortium has experience in conventional volcanic geothermal fields (HS ORKA, LV, ISOR, EGP, BRGM), from first generation of EGS in France and Germany (KIT, BRGM), and in extensive hydrocarbon exploitation and harvesting (Statoil). Additionally, DEEPEGS benefits from first EGS wells into very deep sedimentary environment in Switzerland and Germany (KIT). It includes experience in thermal stimulation (EGP, HS ORKA, LV, ISOR, BRGM), hydro-shearing (KIT, BRGM), and chemical stimulation (Statoil, BRGM, KIT), in hydro-stimulation (Statoil) and Renewable Energy industrial development (Fonroche group). The knowledge transfer is schematically indicated in **Figure 3.** Further, the DEEPEGS project is a continuation of successful history of geothermal energy industry and research networks like the IDDP project, the Soultz project and other previous successful joint collaborative research and development projects in several EC funded projects.

Moreover, one of the partner (EGP) is leading a very similar project: DESCRAMBLE, its aim is to develop novel drilling technologies in a supercritical geothermal reservoir. The test site is an existing dry well in Larderello, Italy, already drilled to a depth of 2.2 km and temperature of 350 °C, which will be further drilled to 3-3.5 km to reach super-critical conditions Main expected outcomes are: improved drilling concepts in deep crustal conditions, new drilling materials, equipment and tools, physical and chemical characterization of deep crustal fluids and rocks

DESCRAMBLE will explore the possibility of reaching extremely high specific productivity per well, up to ten times the standard productivity, with a closed loop, zero emission, and reduced land occupation. Synergies between DESCRAMBLE and the Icelandic part of DEEPEGS will be very important and an effort towards common positive results will be performed, also trough joint working meetings and participation of experts of both projects to relevant similar activities. DESCRAMBLE drilling phase will start in 2017, immediately after the termination of Icelandic one.

2.2 Overall strategy / Structure

The project is divided into ten work packages (WP), which are illustrated in **Figure 4.** The diagram shows the conceptual project management structure in WP1, organised to coordinate the project and to ensure that the appropriate procedures are implemented within the timeframe and budget. Through WP2 (integration actions and results synthesis), WP1 is linked to all other WPs to guarantee flow of information and strong cross-cutting developments across the whole project. WP3 manages the business strategies and project exploitations and cuts across all the technical work packages (WPs 4-8). WPs 4 and 5 deal with design and technical innovation, focused on specific issues relevant for EGS developments. WPs 6-8 manage the core of the project’s technical demonstrations, addressing the risk management and the mitigation strategies necessary for successful implementation of the EGS technologies, developing the demonstration sites and moving the innovations towards wider business exploitation (WP3). WP9 manages disseminations and public outreach, and the open access to demonstration sites. WP10 will deal with all ethical issues.

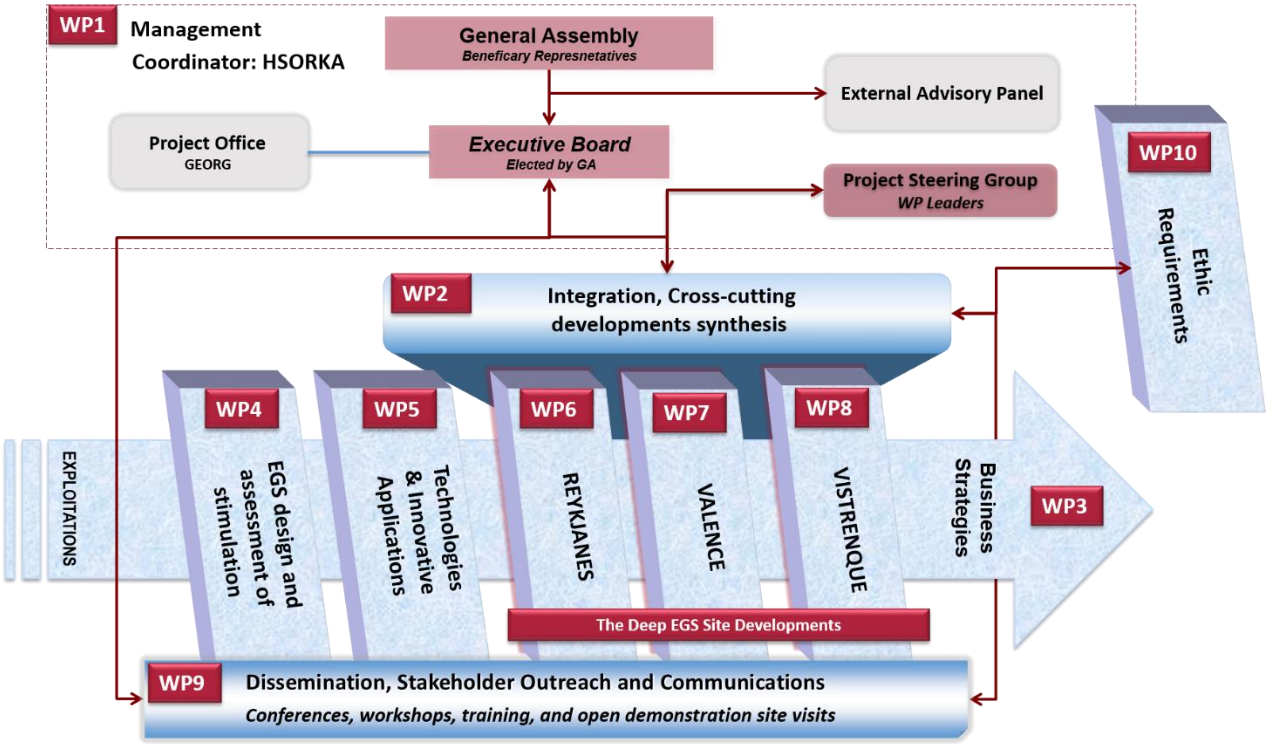

Figure 4: The conceptual DEEPEGS project design and project management organisation.

3. DEMONSTRATION SITES

The project test sites, pilot and demonstration facilities, and research infrastructures installed within DEEPEGS are available for practice oriented education, training and knowledge exchange.

The project site in Iceland is already extensively used for geothermal training at the UNU Geothermal Training Programme in Iceland– which ensures technology advances are forwarded to other geothermal nations. Partner Fonroche Géothermie (FG) is developing a project where several industrial actors, research centres and universities are involved, to develop training and tools (e.g. drilling simulators) for drillers in France.

3.1 Iceland

In the Reykjanes system the approach is relatively simple as shown by the conceptual model in **Figure 5**. The intention is to directionally drill a deeply cased well into/and underneath the exploited geothermal system. The production casing will be set at approximately 3 km depth, while the producing section of the well will be drilled to about 5 km depth. Most of the overlying production wells are 2–2.5 km deep with production casings to around 800 m depth. The temperature range in the production wells is 270-320 °C. The temperature at 4-5 km depth is expected to range between 400-550 °C. From seismic studies, the brittle/ductile boundary in the basaltic host rocks is expected to be at 6-7 km depth, with temperatures of 650-750 °C.

The deepest well to date at Reykjanes is just over 3 km deep. HS Orka will sacrifice an existing 2.5 km deep vertical production well for this EGS experiment. The well site is at the margin of the well field and will be directed towards the centre of the up flow zone. For safety reasons modification need to be made on the wellhead construction and casings in order to cope with potential hazard situations. Primary permeability is expected to be low in the basaltic rock formations, which dominantly consists of a sheeted dyke complex. Enhancement efforts will include thermal cracking by using cold drill fluid, during and after drilling, during stimulation. The field is in the middle of the active rift zone of the Mid-Atlantic Ridge, and thus seismically active while uninhabited. Chemical tracers will be applied to demonstrate that connection can be established between the deep well and the overlying surrounding wells of the field. The chemical tracers need to withstand temperatures of 400-500 °C.

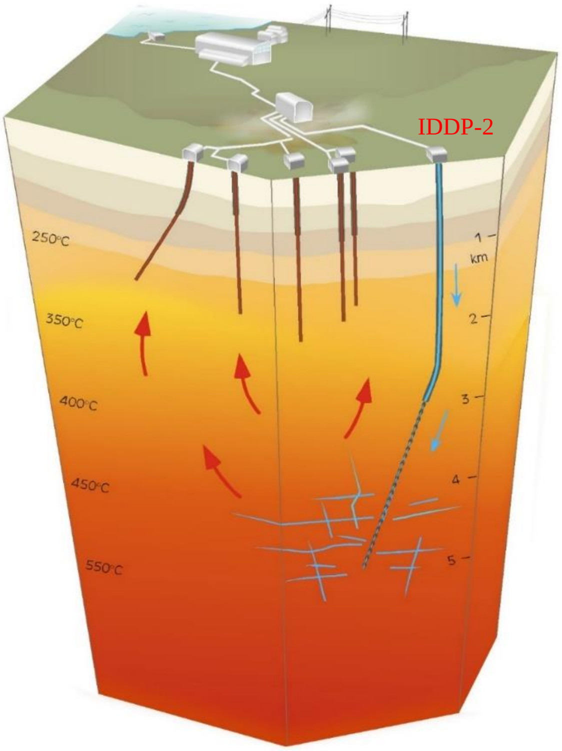

Figure 5: A conceptual model- showing the EGS system in the Reykjanes field

The Reykjanes deep drilling project is expected to take three to four years to complete. If successful it will end by a connection to a steam pipeline to connect the well to the HS Orka power plant. That would make it the first EGS of this kind to deliver electricity to the grid.

3.2 France

The demonstration sites for DEEPEGS in southern France are at two locations, Valence and Vistrenque.

The Valence's demonstrator will be implemented first, once the technical and administrative rules and regulations will be completed and accepted by the local authorities. The drilling phase will then be executed and followed by stimulation and testing. The project is expected to take about four years. Soon after its completion, the plan is to connect the wells to a geothermal power plant for commercial operation. The first drilling is expected to take place in month twelve, the fourth quarter of 2016.

During the drilling phase, a new mud-hammer tool will be tested. After drilling, and in accordance with the well monitoring, we anticipate being able to implement the multi-drain drilling method further (fishbone drilling). By drilling two or three multi-drain side-track boreholes, we expect to get higher fluid output from the main well by enhancing the permeability performance.

In Valence, the targets will be interface between the later Triassic and the basement rocks at 4.5-5.5 km depth, both formations being faulted. However, the primary permeability of these formations is low. For that reason, Fonroche aims to drill through the main faults in order to get good secondary permeability. A conceptual model is shown in **Figure 6** where, depending on the geological structure, two solutions can be carried out. First, production and injection through multi-drain wells in the same fault or in two adjacent faults.

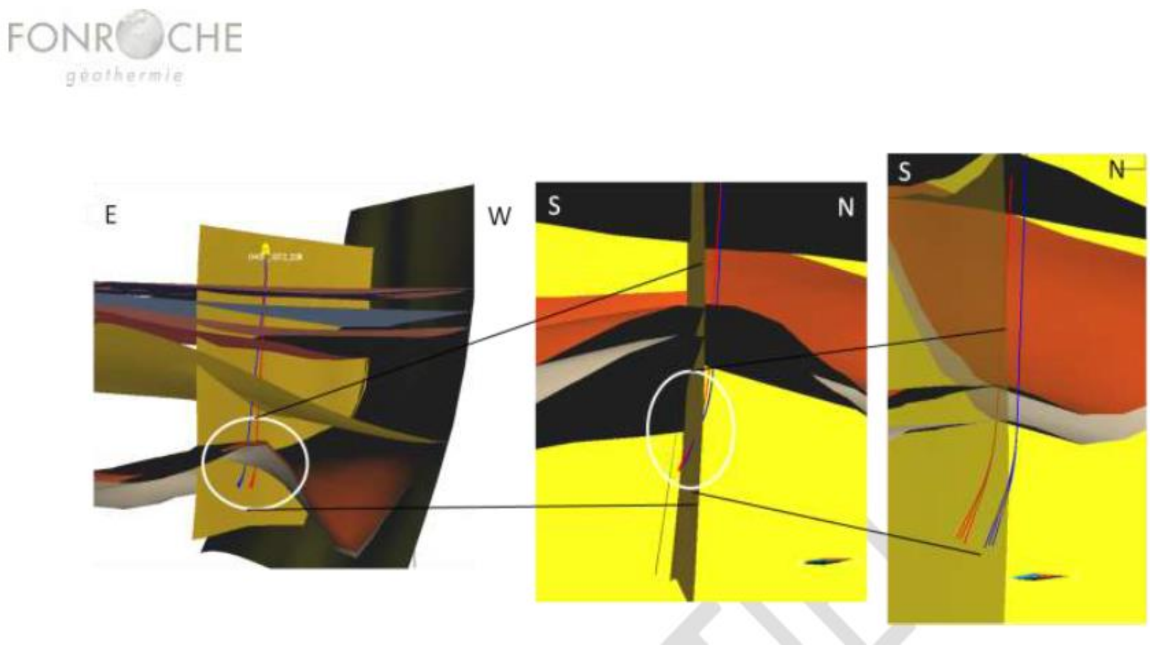

Figure 6: Multi- drain system in the Valence region

The second French demonstrator is planned at Vistrenque, near a field in operation (salt mining), and drilling and EGS work will start during the latter part of the Valence activities in DEEPEGS, scheduled for the second quarter of 2018, once the second well in Valence has been completed (**Figure 7**). The plan is to implement further the multi-drain drilling technology and stimulation technique for increasing permeability.

Both Valence and Vistrenque demonstrators occur within tectonic collapse structures. The South-East Basin appears to be composed of several distinctive areas, where the central part is called the Rhone valley. Both projects are located in that sector. Their geological history is similar but their collapse level is different. The extent of the subsidence structure is greater in Vistrenque than in Valence, the basement being at 6 km depth. Consequently, the Jurassic formation, which is the main target, is located between 4- 6 km depths where temperature is expected between 150°C and 220 °C. The Jurassic rock formation is composed of limestone, of good permeability, mostly due to karstification. Fonroche aims to exploit this karst carbonaceous reservoir.

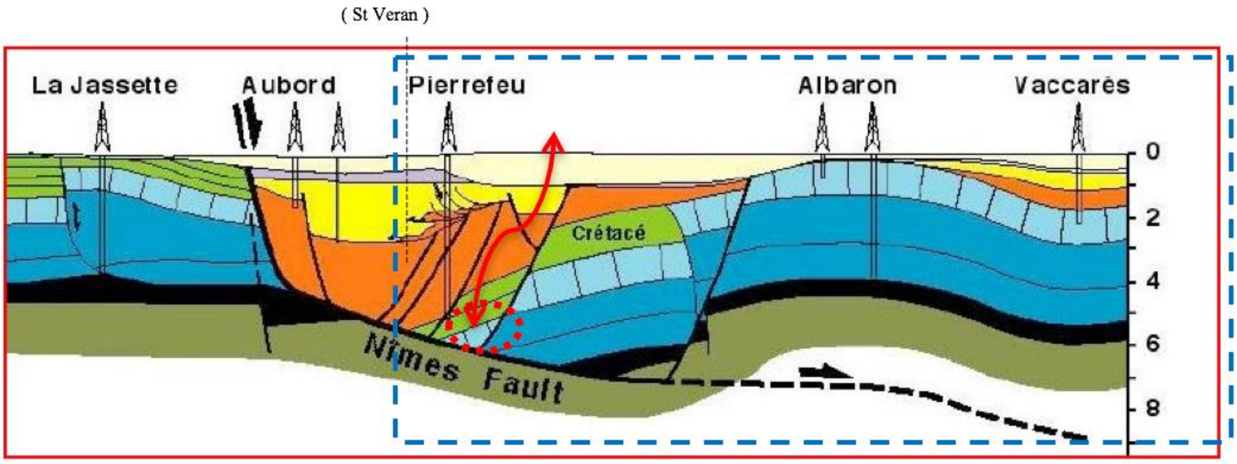

Figure 7: Vistrenque Section N°1 (adapted from Benedicto, 1996), and the Fonroche Vistrenque target is indicated by the red dotted circle and red double arrow.

4. CONLUDING REMARKS

If successful, the DEEPEGS project will contribute significantly to a new era of geothermal utilization worldwide by capturing and utilizing high temperature and high pressure fluids from depth within the earth's crust. The Reykjanes demonstration site will stimulate hot deep reservoir to increase productivity. Additionally, seek connection between very hot dense rocks (350-500 °C) at 4-5 km depths and conventional overlying hot fluid system (250-350 °C), gaining measurable rise in enthalpy and higher power efficiency than from conventional utilization methods. The Valence and Vistrenque demonstration sites will demonstrate the ability to exploit the heat in sedimentary basins, thanks to a toolbag of permeability enhancement methods. Improved technology on casing couplings, cementing and corrosion resistance will be demonstrated in DEEPEGS. The impact of Reykjanes demonstrator would not only affect Iceland, Italy and other volcanic areas in Europe, but also other high temperature systems around the world, e.g. in the circum-Pacific and African rift valley. The success of demonstrators in France (Valence and Reykjanes) would impact the development of geothermal energy exploitation in basins that represents a large part of geological contexts in Europe and also all over the world.

The DEEPEGS project will bring together the existing IDDP and Soultz-sous-Forêt framework knowledge, with cross-fertilisation with oil and gas fields and will team up with leading European energy companies and research organisation(s) to expand the scope for more rapid EGS developments and proof of concept for the potential of deep geothermal energy as a future reliable RES alternative for Europe. The project will focus on three different geological environments as key demonstrators and business cases that can lead to rapid widespread deployment to other areas in Europe.

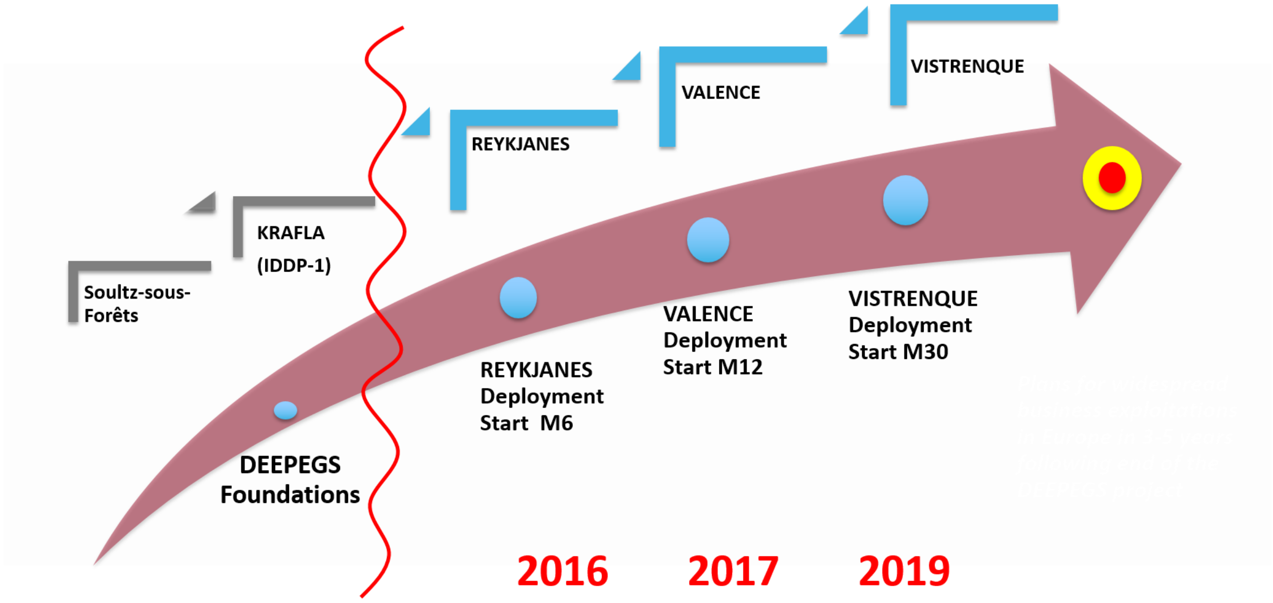

Figure 8: Schematic of the stepwise transfer of experience and know-how across the project leading to accessible demonstrator deployments that integrates and mobilises existing critical geothermal industrial expertise and existing core infrastructures in Europe.

The DEEPEGS project will primarily use well-proven technologies at the three deep drilling demonstrator sites (WPs 6-8). Some new technologies covered by WP4 and 5 will be tested to ensure maximum EGS results where needed. The experience and technologies resulting from the previous work at Krafla during the IDDP-1 drilling and developing the Soultz-sous-Forêts will be channelled into the preparations for the other geological environments in Reykjanes and in France. The staged timeline for the DEEPEGS developments at the key demonstration sites for EGS are: (i) Reykjanes starting by month six into the project, then deployment will start in France with (ii) Valence at month 12. The DEEPEGS overall project concept can thus be described as an escalating build-up of EGS developments involving the other partners on an intensive learning curve leading to the deployment to launch (iii) Vistrenque demonstrator drilling in month 30.

For further information on the project and to follow up on the project development visit the project website www.deepegs.eu. Or contact the project office team at GEORG through info@deepegs.eu

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