Summary R&D roadmap for Deep Geothermal Energy in Switzerland, 2014

Objectives:

To enable the large-scale exploitation of deep geothermal energy for electricity generation in Switzerland, solutions must be found for two fundamental and coupled problems: (1) How do we create an efficient heat exchanger in the hot underground that can produce energy for decades while (2) at the same time keeping the nuisance and risk posed by induced earthquakes to acceptable levels. There is general agreement that only by enhancing the permeability of the underground in a controlled way, can these goals potentially be met. We believe that in order to make progress in answering these questions as rapidly as possible without compromising safety, three overarching and complementary approaches will be conducted that supplement the SCCER capacity build-up.

1. Advance the capability to quantitatively model the stimulation process and reservoir operation

Numerical simulation is an essential tool for understanding the complex, coupled interactions of mechanical, hydraulic, thermal, and chemical processes active during reservoir creation and operation. Moreover, it allows scenario testing (e.g., the effect of different injection schemes) that may aid in decision making. This initiative will adapt and expand the capabilities of existing cutting-edge simulation codes by developing tools specifically targeted towards deep geothermal energy development. The new tools will allow the simulation of diverse mechanisms of permeability creation within explicitly rendered, geometrically complex geologic structures. Aside from simulating the evolution of permeability during stimulation injections, the tools will provide a basis for physics-based forecasting of seismic hazard, and also include fluid-rock interactions that are important for simulating changes occurring during reservoir operation. Interfaces with industry-standard reservoir rendering tools such as Gocad/SKUA, FRACA, FRACMAN or GOFRAC will be provided to allow the import of site-specific reservoir models, thus integrating numerical simulation into industrial workflows that will emerge with pilot and demonstration projects.

2. Advance process understanding and validation in underground lab experiments

This activity aims to better understand the processes activated by relatively high-pressure fluid injection into crystalline rocks under realistic conditions, thereby advancing the technology from overall TRL 3-4 to 4-5 (for Technology Readiness Level). Since many of the relevant processes for EGS, such as microseismicity and geophysical imaging, are scale invariant, meaningful experiments can be conducted safely within a deep underground lab (DUG-Lab) at depth of ≤1 km. Experiments conducted in the DUG-Lab under controlled conditions will allow: (a) to test concepts of reservoir creation and long term operation where there are numerous knowledge gaps that concern the nature of the permeability creation mechanisms activated by high-rate stimulation injections in fractured crystalline rock, and the development of stimulation strategies for controlling the process so as to optimally balance permeability creation against seismic hazard; (b) to test and validate methods for seismic hazard assessment and risk mitigation strategies, such as adaptive traffic light systems; (c) test new approaches to reservoir characterization for developing a 3-D structural discontinuity model of the reservoir from sparse data derived from borehole logging and geophysical imaging; and (d) test and refine exploration and monitoring techniques, such as full waveform tomography inversion and interferometry methods, for tracking fluid pressure propagation, and stress evolution. These insights will lead to the development of advanced numerical modelling tools, as well as petrophysics laboratory experiments, which can be used to extrapolate the results to the temperature and pressures at the P&D target depth of 4-5 km.

Within the DUG-Lab, we will conduct stimulation experiments at scales of 10-100 m with a high degree of experimental control. The experiments will explore the effects of stress/discontinuity geometry and injection design on stimulation efficiency. Within smaller scale-experiments (length of 1-10 m) the temperatures can be increased artificially. A dense network of seismic, pore pressure and strain/tilt sensors within and around the stimulation volumes, together with detailed characterization of the rock mass from mapping and geophysics, and the eventual exposure of at least part of the volume with mineback operations will provide a world-class dataset. The analysis of the data will be helped by the complementary, parallel effort to develop the robust reservoir simulation and seismic hazard forecasting tools, including the relevant physical processes of permeability creation and earthquake rupture mechanics. Such tools are key to upscaling the results of the 10-100 m scale DUG-Lab experiments to the higher-stress and temperature environment of the full-scale P&D projects.

The DUG-Lab will be operated by the SCCER consortium, under the leadership of ETH Zurich. Experiments will start in early 2015, for a first ten year phase, so that they can provide guidance and method validation for upcoming pilot and demonstration projects. They will also provide an opportunity for the SCCER teams and industry scientist to engage in trans-disciplinary research under operational constraints and with realistic data. Access to the data should be opened up to the entire scientific community no more than one year after an experiment was conducted. The DUG-lab should also be proposed as an international experimental facility, part of the EPOS rock laboratory infrastructure and proposed to the EU Horizon 2020 programmatic call LCE-02-2015.

3. Develop petrothermal P&D projects

The next deep geothermal project developed by industry will focus create a petrothermal reservoir in crystalline rock at about 4-5 km depth, most likely using multi-zone stimulation technology deployed in inclined wells. This project will be accompanied by a P&D project with the SCCER-SoE participation, designed and executed so that not only the safety of operation is maximized, but also the knowledge gain with respect to process understanding and risk governance. Therefore, additional measurements and analyses are required that may not be needed, or cannot be funded, solely from an operator's point of view. This includes exploration and monitoring to refine the description of the geological context of the site, background seismicity, in-situ stress conditions pre-existing natural fracture zones, and risk relevant faults with length exceeding 1 km in the project area. A high-resolution 3D seismic survey and interpretation that extends at least 5 km from the drill site in all directions is highly desirable. These R&D efforts will include an independent 'social site characterization' and continued monitoring of public perception and acceptance. Tools and methodologies for monitoring or estimating the reservoir porosity/permeability evolution, migration of induced seismicity, and fluid pressure propagation from surface and downhole measurements that have been optimized in DUG-Lab experiments will be applied in near-real time during the stimulation.

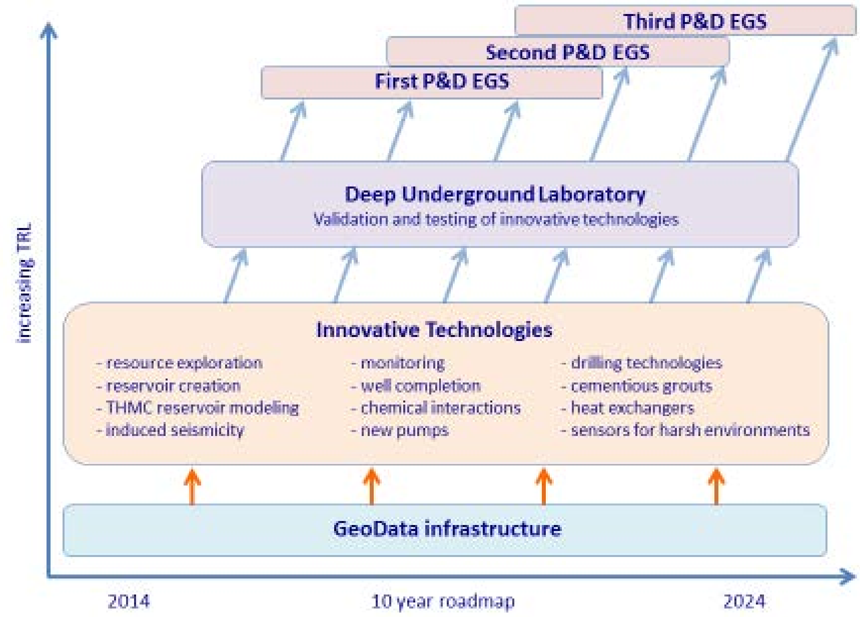
Reservoir characterization will focus on imaging intermediate-scale structures (i.e. 0.1 - 1 km) within the reservoir, because these structures are likely to have a major influence one the response of the rock mass to stimulation. Such structures cannot be resolved from surface seismics, but borehole seismic methods such Vertical Seismic Profiling (VSP) adapted to image steep basement discontinuities, are promising in this regard. New approaches to constrain the size distribution of discontinuities (from fractures to faults) from variations in stress orientation along the borehole, and the size distribution of micro-earthquakes, are under investigation, as are constraints imposed by fracture interaction during genesis (TRL 1-2). Improved methods are also under development to extract stress magnitude information from wellbore failure observations (TRL 3-4). Reactive tracer tests between wells in hot reservoirs are likewise considered a gap. Such tests, when combined with non-reactive tracer tests, can provide an estimation of the surface area and volume of flow paths linking the wells, which are key parameters for estimating production longevity. Reactive tracers for cool environments are available, but those for hot reservoirs, such as will be encountered in the P&D projects, require further development. Instrumentation development needs include a robust down hole seismometer that can operate for long periods at elevated temperature (TRL 3-4).

To maximise the funding and research strength available, the next P&D project should be proposed also as a European initiative under the LC-03-2015 call and should be classified as an IPGT test site. Data from the site should likewise be made available through an open data policy.

Longer-term goals

The focus of exploration and monitoring will in the long-term address the nationwide mapping of parameters of interest, such as subsurface temperature distribution, location and orientation of faults and fractures, stress orientation and magnitudes, and the presence of ambient fluids. It will also include the long term monitoring of induced seismicity specifically with the goal of distinguishing with confidence between natural and observed earthquakes. The publically available heat flow map of Switzerland should be updated by including data collected since 1999, and a 3-D model of temperature down to 5 km depth should be developed. In the longer term, a systematic effort should be made to secure subsurface temperature and stress information when the opportunity arises, particularly in the Alps where data is sparse or, in many areas, non-existent. Consideration could also be given to the reprocessing of seismic lines in the Alpine Foreland to better-define lithologic structure, and the location of the Permo-Carboniferous troughs, perhaps aided by gravity surveys. Exploration research will be greatly assisted by the establishment of a national repository for borehole information under Swiss Topo.

Drilling and completion are the major cost components in any geothermal system. Innovative approaches to drilling technologies, such as spallation drilling, offer the long-term prospect of substantially reducing these costs and thus constitute potential game-changing research. Improved cements for geothermal wells are being developed that reduce the likelihood of premature hardening during cementation of casing. Risk governance will focus in the long term on standardised tools and best practice during all phases of future projects. The ability to forecast before drilling the reservoir properties and seismogenic response will be critical to maximise the success rate of future projects. Finally, cost optimisation of all components will become a dominant theme once EGS technology has been proven to be feasible and safe.



Source: www.sccer-soe.ch; October 16,, 2014