Geothermal Energy Future Development

Technology | Geothermal Energy

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4. Geothermal Energy Future Development

4.1 Prospects for Technology Improvement, Innovation and Integration

Geothermal resources can be integrated into all types of electrical power generation systems, from large, interconnected continental transmission grids to onsite use in small, isolated villages or autonomous buildings.(Bromley et al., 2006).

The technology roadmap for Geothermal Heat and Power offers a strategic plan to maximise deployment of these energy resources by 2050. It projects that 1,400 TWh of electricity per year could come from geothermal power by 2050, up from 67 TWh at present.

Separate studies by the National Renewable Energy Laboratory (NREL) and the Massachusetts Institute of Technology (MIT) concluded over 100,000 MWe could feasibly be reached in the next 15 to 50 years, respectively, with a reasonable, sustained investment in R&D.

Since geothermal typically provides base-load electric generation, integration of new power plants into existing power systems does not present a major challenge. Indeed, in some configurations, geothermal energy can provide valuable flexibility, such as the ability to increase or decrease production or startup/shut down as required. In some cases, however, the location dependence of geothermal resources requires new transmission infrastructure investments in order to deliver geothermal electricity to load centres.

For geothermal direct uses, no integration problems have been observed. For heating and cooling, geothermal (including GHP) is already widespread at the domestic, community and district scales. District heating networks usually offer flexibility with regard to the primary energy source and can therefore use low-temperature geothermal resources or cascaded geothermal heat (Lund et al., 2010b). For technology improvement and innovation, several prospects can reduce the cost of producing geothermal energy and lead to higher energy recovery, longer field lifetimes, and better reliability. With time, better technical solutions are expected to improve power plant performance and reduce maintenance down time.

The main technological challenges and prospects are described below.

4.1.1 Improvements in Exploration, Drilling and Assessment Technologies

In exploration, R&D is required to locate hidden geothermal systems (i.e., with no surface manifestations such as hot springs and fumaroles) and for EGS prospects. Refinement and wider usage of rapid reconnaissance geothermal tools such as satellite-based hyper-spectral, thermal infrared, high-resolution panchromatic and radar sensors could make exploration efforts more effective.

Once a regional focus area has been selected, availability of improved cost-effective reconnaissance survey tools to detect as many geothermal indicators as possible is critical in providing rapid coverage of the geological environment being explored at an appropriate resolution.

Special research is needed to improve the rate of penetration when drilling hard rock and to develop advanced slim-hole technologies, and also in large-diameter drilling through ductile, creeping or swelling formations.

Drilling must minimize formation damage that occurs as a result of a complex interaction of the drilling fluid (chemical, filtrate and particulate) with the reservoir fluid and formation. The objectives of new-generation geothermal drilling and well construction technologies are to reduce the cost and increase the useful life of geothermal production facilities through an integrated effort

See the table below to review advanced geothermal researches

Complementary research & share knowledge	Education / training
Standard geothermal resource & reserve definitions	Improved HTHF hard rock drill equipment
Predictive reservoir performance modelling	Improved HTHF multiple zone isolation
Predictive stress field characterization	Reliable HTHF slim-hole submersible pumps
Mitigate induced seismicity / subsidence	Improve resilience of casings to HTHF corrosion
Condensers for high ambient surface temperatures	Optimum HTHF fracture stimulation methods
Use of CO_2 as a circulating fluid for heat exchangers	HTHF logging tools and monitoring sensors
Improve power plant design	HTHF flow survey tools
Technologies & methods to minimize water use	HTHF fluid flow tracers
Predict heat flow and reservoirs ahead of the bit	Mitigation of formation damage, scale and corrosion

Tab. 1 – Priorities for advanced geothermal research (HTHF: high temperature and high flow rate)

Improvements and innovations in deep drilling are expected as a result of the Deep Drilling Projects whose aims are to penetrate into supercritical geothermal fluids, which can be a potential source of high-grade geothermal energy. The concept behind it is to flow supercritical fluid to the surface in such a way that it changes directly to superheated (>450°C) hot steam at sub-critical pressures.

This would provide up to ten-fold energy output of approximately 50 MWe as compared to average high enthalpy geothermal wells (Fridleifsson et al., 2010). All tasks related to the engineering of the reservoir require a more sophisticated modelling of the reservoir processes and interactions to be able to predict reservoir behavior with time, to recommend management strategies for prolonged field operation and to minimize potential environmental impacts.

The “Drilling in dEep, Super-CRitical AMBient of continentaL Europe” (DESCRAMBLE) project is meant to drill in continental-crust, super-critical geothermal conditions, to test and demonstrate novel drilling techniques to control gas emissions, the aggressive environment and the high temperature/pressure expected from the deep fluids and to characterize the chemical and thermo-physical condition of the reservoir. The outcomes of the DESCRAMBLE project will be exploited through a subsequent project for a first demonstration pilot plant in Larderello.

Fig. 1 Geothermal Well at Iceland Deep Drilling Project – IDDP-2 well was completed at 4,659 meters depth searching for a supercritical steam zone

4.1.2 Efficient Production of Geothermal Power, Heat and/or Cooling

Equipment needed to provide heating/cooling and/or electricity from geothermal wells is already available on the market. However, the efficiency of the different system components can still be improved, and it is even more important to develop conversion systems that more efficiently utilize energy in the produced geothermal fluid at competitive costs. It is basically inevitable that more efficient plants (and components) will have higher investment costs, but the objective would be to ensure that the increased performance justifies these costs.

Combined heat and power (CHP) or cogeneration applications provide a means for significantly improving utilization efficiency and economics of geothermal projects, but one of the largest technical barriers is the inability in some cases to fully utilize the thermal energy produced.

New and cost-effective materials for pipes, casing liners, pumps, heat exchangers and other components for geothermal plants is considered a prerequisite for reaching higher efficiencies.

Another possibility for an efficient type of geothermal energy production is the use of suitable oil fields. There are three types of oil and gas wells potentially capable of supplying geothermal energy for power generation

1. medium- to high-temperature (>120°C or so) producing wells with a sufficient water cut;
2. abandoned wells due to a high water cut;
3. geo-pressured brine with dissolved gas.

The primary benefit from such a possibility is that the drilling is already in place and can greatly reduce the first costs associated with geothermal project development. However, these savings may be somewhat offset by the need to handle (separate and clean up) multi-phase co-produced fluids, consisting of water, hydrocarbons and other gases.

The potential development of valuable by-products may improve the economics of geothermal development, such as recovery of the condensate for industrial applications after an appropriate treatment, and in some cases recovery of valuable minerals from geothermal brines (such as lithium, zinc, high grade silica and in some cases, gold).

4.1.3 Technological and Process Challenges in Enhanced Geothermal Systems

Enhanced Geothermal Systems (EGS) require innovative methods, some of which are also applicable to power plants and direct-use projects ased on hydrothermal resources.

An Enhanced Geothermal System (EGS) is a man-made reservoir, created where there is hot rock but insufficient or little natural permeability or fluid saturation. In an EGS, fluid is injected into the subsurface under carefully controlled conditions, which cause pre-existing fractures to re-open, creating permeability. Increased permeability allows fluid to circulate throughout the now-fractured rock and to transport heat to the surface where electricity can be generated. While advanced EGS technologies are young and still under development, EGS has been successfully realized on a pilot scale in Europe and in the United States.

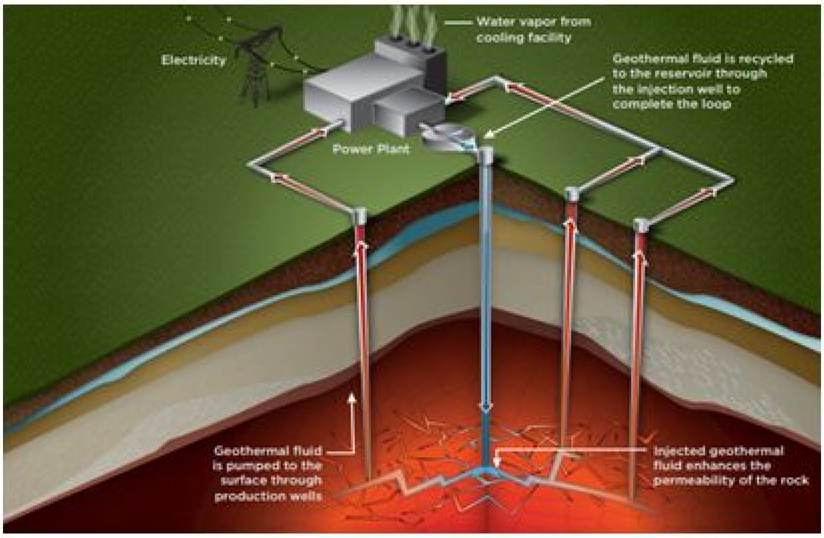

Fig. 2 Enhanced Geothermal System illustration (U.S. Department of Energy)

Benefits of Enhanced Geothermal Systems

- EGS emits little to no greenhouse gases. Most geothermal power plants use a closed-loop binary cycle power plant and have no greenhouse gas emissions other than water vapor that may be used for cooling
- EGS could facilitate geothermal development outside of traditional hydrothermal areas

Innovative methods for the further development of EGS are

- Improvement and innovation in well drilling, casing, completion and production technologies for the exploration, appraisal and development of deep geothermal reservoirs
- Improvement of methods to hydraulically stimulate

reservoir connectivity between injection and production wells to attain sustained, commercial production rates.

Reservoir stimulation procedures need to be refined to significantly enhance the productivity, while reducing the risk of seismic hazard. Imaging fluid pathways induced by hydraulic stimulation treatments through innovative technology would facilitate this.

Technology development to create functional EGS reservoirs independent of local subsurface conditions will be essential:

- Development/adaptation of data management systems for interdisciplinary exploration, development and production of geothermal reservoirs, and associated teaching tools to foster competence and capacity amongst the people who will work in the geothermal sector.
- Improvement of numerical simulators for production history matching and predicting coupled thermal-hydraulic-mechanical-chemical processes during development and exploitation of reservoirs. In order to accurately simulate EGS reservoirs, computer codes must fully couple fl ow, chemistry, poro-elasticity and temperature. Development of suitable fully coupled reservoir simulators, including nonlinear deformability of fractures, is a necessity. Modern laboratory facilities capable of testing rock specimens under simulated down-hole conditions of pressure and temperature are also needed.
- Improvement in assessment methods to enable reliable predictions of chemical interactions between geo-fluids and geothermal reservoir rocks, geothermal plants and equipment, enabling optimized, well, plant and field lifetimes.
- Performance improvement of thermodynamic conversion cycles for a more efficient utilization of the thermal heat sources in district heating and power generation applications.

The possibility of using CO_2 as a working fluid in geothermal reservoirs, particularly in EGS, has been under investigation. Recent modelling studies show that CO_2 would achieve heat extraction at higher rates than aqueous fluids, and that in fractured reservoirs CO_2 arrival at production wells would occur a few weeks after starting CO_2 injection.

A two-phase water-CO_2 mixture could be produced for a few years followed by production of a single phase of supercritical CO_2 (Pruess and Spycher, 2010). In addition, it could provide a means for enhancing the effect of geothermal energy deployment for lowering CO_2 emissions beyond just generating electricity with a carbon-free renewable resource.

References

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