Status of Japanese Supercritical Geothermal Project in 2022

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ABSTRACT

Japanese scientists have estimated that the nationwide potential of “Supercritical Geothermal Resources”, which has an origin in the subduction of oceanic plates, reaches tens GWs in Japan. Power generation using supercritical geothermal resources (supercritical geothermal power generation) in Japan can significantly contribute to energy security and reduction of emission of CO_2. The temperature range of the supercritical geothermal system for supercritical geothermal power generation is around 400 to 500 deg-C and the depth is expected to be less than several kilometers. It has been inferred that the depth of the supercritical system in northeast Japan is much shallower than the other area in the world, and it brings advantages in accessibility, economy, and safety in development. However, there are a lot of scientific unknowns about the nature of supercritical geothermal systems, especially in rock-mechanical and geochemical behavior under supercritical conditions. We also need technological breakthroughs, because temperature and pressure conditions in the supercritical geothermal systems are far beyond the current technological limitations, and experiences in the foregoing ultra-high temperature geothermal drillings suggest that the presence of acidic geothermal fluid should be expected. The Japanese government has identified supercritical geothermal power generation as one of the key technologies to establish a “Carbon-Free Society” in 2050 and is funding projects for detailed site survey and well design in the most promising area in northeast Japan and Kyushu as described in this paper.

1. History of supercritical geothermal projects in Japan

The establishment of a "Carbon-Free Society" is one of the most prioritized achievement goals in most of the developed countries, and the development of innovative technologies for the reduction of emission of CO_2, capture and storage of CO_2, and carbon-free energy sources has been accelerated within these few years. Geothermal energy has been considered as one of the most promising low CO_2 emission power sources which can supply base-load power demand in many of the volcanic countries. In Japan, energy policy has been drastically changed after the incident of the Fukushima-dai-Ichi nuclear reactor in 2011, and the government is trying to introduce as much renewable as possible. However, the presence of obstructive factors in the development of hydrothermal resources in Japan, including uncertainty in the reservoirs, difficulty in the development of high-quality resources in the national park, and co-existence with hot springs (onsen), do not allow rapid growth of the capacity of geothermal power generation. Two new power stations (40MW and 7MW), which development started after 2011, have started operation recently, but the current national-wide capacity of geothermal power generation is approximately 54MW (JOGMEC), which is approximately 0.2 % of the total power generation capacity in Japan.

Geothermal researchers in Japan started investigating to find a method to drastically increase the power generated by geothermal resources, and they have concluded that the development of high-temperature resources in brittle-ductile transition (BDT) is the most promising from viewpoints of the amount of energy, costs, and environmental negative impacts (Muraoka et al., 2014). After compiling geological and geophysical data collected some of the promising areas for the development of geothermal resources in BDT, the researchers have found that reservoirs within a temperature range from 400 to 500 deg-C can exist at a top of magmatic intrusion which has origin in the subduction of oceanic plates (Asanuma et al., 2019). Although there are still some uncertainties in the chemical properties of the geothermal fluid, the fluid can be in the supercritical condition (Watanabe et al., 2021) and, hence, we named this geothermal "Supercritical Geothermal Reservoir".

It has been revealed from the investigation of the geochemical behavior of silica solution around BDT that an impermeable sealing structure can be created by silica precipitation (Saishu et al., 2014). This sealing structure isolates supercritical geothermal reservoirs to shallow hydrothermal systems and reservoirs of hot springs, bringing fewer negative impacts to shallow systems when we develop supercritical geothermal systems. A model of a typical supercritical geothermal system in Northeast Japan is shown in Figure-1.

Further detailed evaluation of the amount of supercritical geothermal resources national-wide in Japan has not been made, but scientists inferred from the distribution of volcanos and distribution of seismicity that the total capacity of "Supercritical Geothermal Power Generation", which uses fluid produced from supercritical geothermal systems, can reach several tens GWs. The Japanese government recognized that supercritical geothermal power generation has the potential to reduce the emission of CO_2 associated with power generation, and supercritical geothermal power generation has been identified as one of the 14 key technologies in the Green Innovation Strategy (2021).

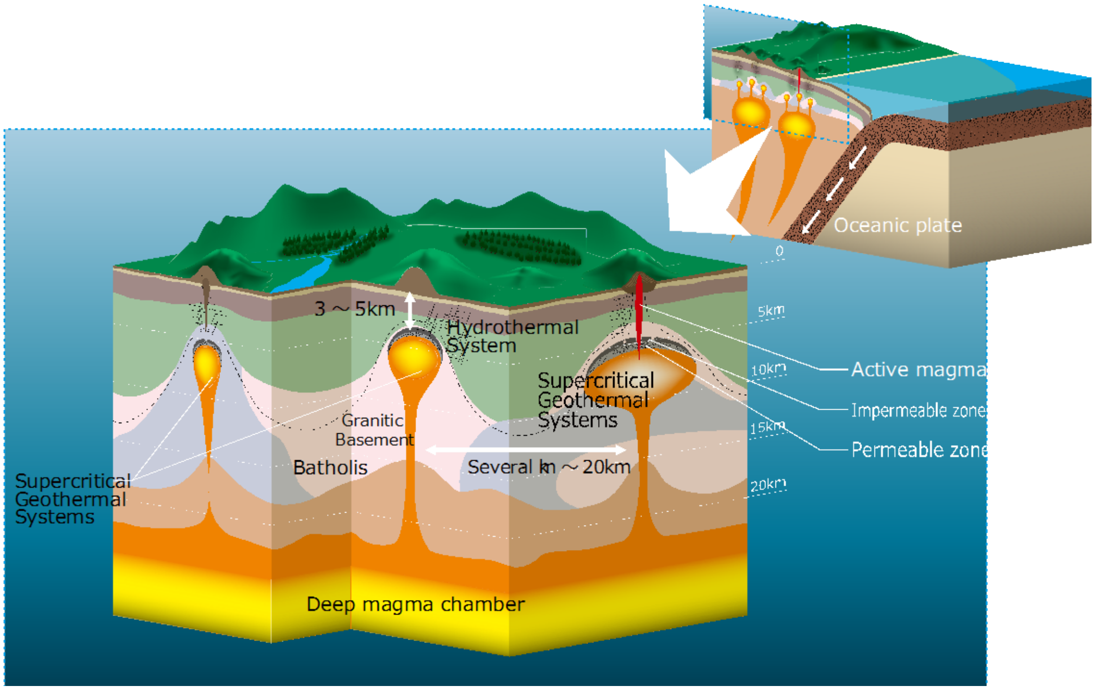

Figure 1: Typical model of supercritical geothermal systems in Northeast Japan.

New Energy and Industrial Technology Development Organization (NEDO), one of the funding agencies of the Japanese government has been funding to "Supercritical Geothermal Project" since 2014. In the NEDO-funded projects from 2018 to 2020, a simple model of supercritical geothermal systems has been identified from the interpretation of mainly geophysical and borehole data in 5 promising areas in Hokkaido, Tohoku (northeastern part of the main island), and Kyushu. Identified supercritical geothermal systems distributed around at depths from 3 to 6 km with a diameter of several kilometers in all the survey areas (ex. Yamaya et al., 2022, Kitamura et al, under review, Okamoto et al., 2021), and the results from simulations of thermal energy extraction showed that 100 MW of power generation with comparable costs can be realized for more than 30 years in most of the sites (NEDO, 2021).

2. Outline of supercritical geothermal projects from 2021 to 2024

NEDO started to fund 4 projects from 2021 to 2023/2024 for detailed modeling and evaluation of supercritical geothermal resources as a pre-stage of proof-of-concept drilling. The location of the sites and contractors are shown in Figure-2 and Table-1. Development of hydrothermal systems has been done/ongoing at each site and many geological, geophysical and geochemical data are available for these projects. Data obtained from the drilling of WD-1a in Kakkonda, of which bottomhole temperature exceeded 500 deg-C, will be also effectively used to estimate thermal structure at the site.

Figure-2: Location of survey area in NEDO 2021 to 2023/2024 supercritical geothermal projects

Table-1: List of ongoing resources evaluation projects

Location	Lead Contractors	Contractors
Kakkonda (Iwate)	AIST	Tohoku U., Akita U., Tokyo Institute of Technology, Kyoto U., Geo-E, IDC, SKE, GERD, JOE
Kujyu (Oita)	Kyushu U.	AIST, Akita U., Tokyo Institute of Technology, Kyoto U., Kobe U., WestJEC, Geo-E, IDC, SKE, GERD, JOE
Hachimantai (Iwate)	Mitsubishi Materials Techno	Geothermal Analysis
South Yuzawa (Akita)	Nittetsu Mining Consultants	

The main objective and research activities in the projects are:

(a) Detailed modeling/evaluation of supercritical geothermal systems: The model of supercritical geothermal systems identified in the previous projects will be updated by dense MT survey, seismic reflection/refraction survey, and microseismic monitoring and re-analyses of borehole and geophysical data. Uncertainty in the model, mainly in thermal structure and permeability, will be reduced by introducing AI and geostatistical estimation (Ishitsuka et al., 2021). The model will be validated by simulation of the static state of supercritical and hydrothermal systems in the area. Extractable geothermal energy and the most suitable development style will be considered by results from supercritical thermal extraction simulators. Demonstration of sustainable power generation of around 100 MW for more than 30 years is our final target.
(b) Planning of drilling and tests: The target of the pilot and main holes will be determined considering the location of supercritical geothermal systems, topology, and accessibility. Plan of data/sample collection and experiments will be made by a discussion with scientists and engineers. A drilling and completion plan will be built up along with the Health, Safety, and Environment (HSE) plan.
(c) Cost estimation: The cost of the supercritical power generation at each site will be estimated, and we will demonstrate that the power generation unit price is comparable to or less expensive than current geothermal power generation (10 to 15 JPY/kWh).
(d) Comprehensive evaluation: Amount of thermal energy, drilling difficulties, costs, regulation, and social conditions will be considered and advantages/disadvantages of each site will be summarized. Government/NEDO will rank each site for the following proof-of-concept drilling stage.

3. Summary

The Japanese government has listed supercritical geothermal power generation as one of the key technologies in power generation filed in the Green Innovation Strategy. It is expected capacity of commercial supercritical geothermal power generation reaches in the order of GW around/after 2040. Researchers contributing to the Supercritical Geothermal Projects in Japan are trying to demonstrate the presence of supercritical geothermal resources for 100MW of power generation at each promising site and to identify research and development plan from engineering and material points of view by 2030 through drilling and tests of proof-of-concept wells.

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