Country Update of Geothermal Energy Development in Japan and the Activity of JOGMEC

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ABSTRACT

In 2015 METI decided an energy policy for a year of 2030 and the amount of the electricity generated by renewable energy will be expected as the same as that generated by nuclear power. Geothermal power generation is expected to be more than 1,500MW installed capacity under this new policy, which is almost three times the current installed capacity. JOGMEC, a Japanese government enterprise under the umbrella of METI, organises financial support and technology developments to encourage developers to achieve the political goal of increased geothermal energy generation in 2030.

JOGMEC offers several types of financial support, including subsidy, equity capital, and liability guarantee. Subsidy will be applied during the survey period, equity capital during the exploration period and liability guarantee during the construction period of the power plant. JOGMEC also manages the R&D projects and develops the geothermal exploitation technologies. One survey project, two geophysical investigation technology developments, and one drilling technology development are being conducted.

1. Introduction

Electric power generation by geothermal energy commenced operations in 1966 in Japan and the Matsukawa geothermal power plant celebrates its 50th anniversary this year. In 2018 the Otake power plant, the second geothermal power plant in Japan, will also celebrate its 50th anniversary. Electric generation using geothermal resources has had smooth growth for the first 30 years. The last large scale and conventional geothermal power plant was the Hachijo Geothermal Power Plant in 2000, with an installed capacity of 3.3 MW. No conventional geothermal power plant using steam has been constructed since then. Moreover, all projects for geothermal energy development conducted by NEDO (New Energy Development Organization, currently New Energy and Industrial Science Development Organization) were suspended by a political decision taken in 2003 by

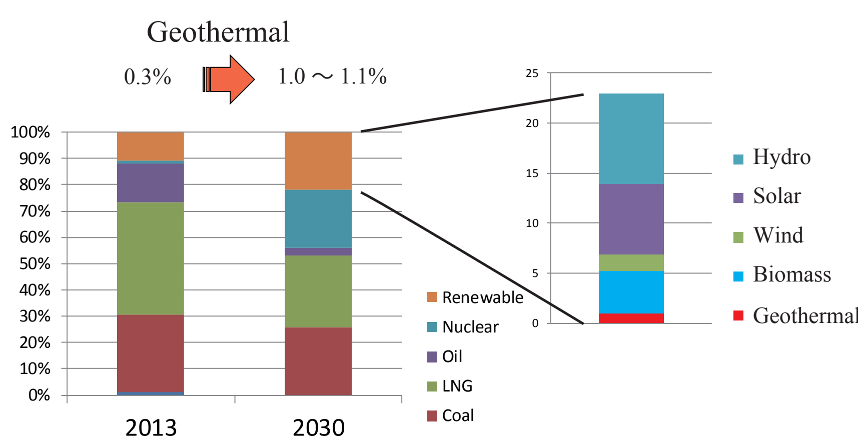


Figure 1. METI's "The Long-term Energy Supply and Demand Outlook", a policy of the Strategic Energy Plan. Geothermal energy is expected to increase threefold by 2030.

METI (Ministry of Economy, Trade and Industry). There are no continuing projects for technology development and no motivation for development. In fact, there were no more courses in some universities for geothermal energy development.

After the terrible Fukushima disaster happened in March, 2011, demand for a stable energy supply including geothermal energy has been increasing. The Japanese government made revisions of the JOGMEC (Japan Oil, Gas & Metals National Corporation) Act, which integrates the development and promotion of energies, resulting in that JOGMEC has added a new function which includes not only financial support but also research and development of geothermal energy.

METI approved and announced "The Long-term Energy Supply and Demand Outlook" on 16 July 2015 pursuant to the policies of the Strategic Energy Plan, where geothermal energy would be increased to 1.0-1.1% of primary energy generation by 2030 (Fig. 1). In this paper, we will describe the background of geothermal development in Japan including the history and players, followed by the role and the function of JOGMEC for geothermal resource development. The current projects for the technology developments conducted by JOGMEC are briefly introduced.

2. Geothermal Energy Development in Japan

2.1 Players for Geothermal Development in Japan

Three ministries are relevant organisations for geothermal development; the Ministry of Environment (MOE), the Ministry of Agriculture, Forestry & Fisheries (MAFF), and the Ministry of Economy, Trade & Industry (METI) shown in Fig. 2. MAFF gives permission for the use of the national forests as many geothermal fields are located in the national forests. The National Conservation Bureau of MOE is a regulatory agency from the point of the view of the conservation of the national parks, though the Global Environment Bureau of MOE is encouraging the use of geothermal energy for the reduction of CO_2 emissions. The deregulation has been made recently so that geothermal development in national parks will be permitted under some conditions, while still preserving the environment. Several local governments enacted ordinances for the development and launched a committee to discuss geothermal development because there are many small developments that affect other geothermal resources. Deregulation to the MAFF on the usage of the national forest is also expected to permit a wider area to use for development.

JOGMEC was established as Governmental Corporation, based on enforcement of the JOGMEC Act, with the merger of JNOC (Japan National Oil Corporation) and MMAJ (Metal Mining Agency of Japan) on 29 February 2004. The capital and the number of employees are about 752 billion JPY (Approx. 6.8 billion USD) and 542 as of 1st March 2016. The Agency of National Resources & Energy in METI is promoting geothermal energy development through JOGMEC and NEDO, which conduct administrative and business duties that are handled by the division charged with executing government policy. After the establishment of geothermal functions in JOGMEC, it now develops subsurface technologies. In partnership with the JOGMEC projects, NEDO now focuses on the development and improvement of the surface equipment such as increasing the efficiency of geothermal power plants and so on. Moreover NEDO has a project for the far future utilisation of geothermal energy with elevated temperatures exceeding the super critical temperature of water.

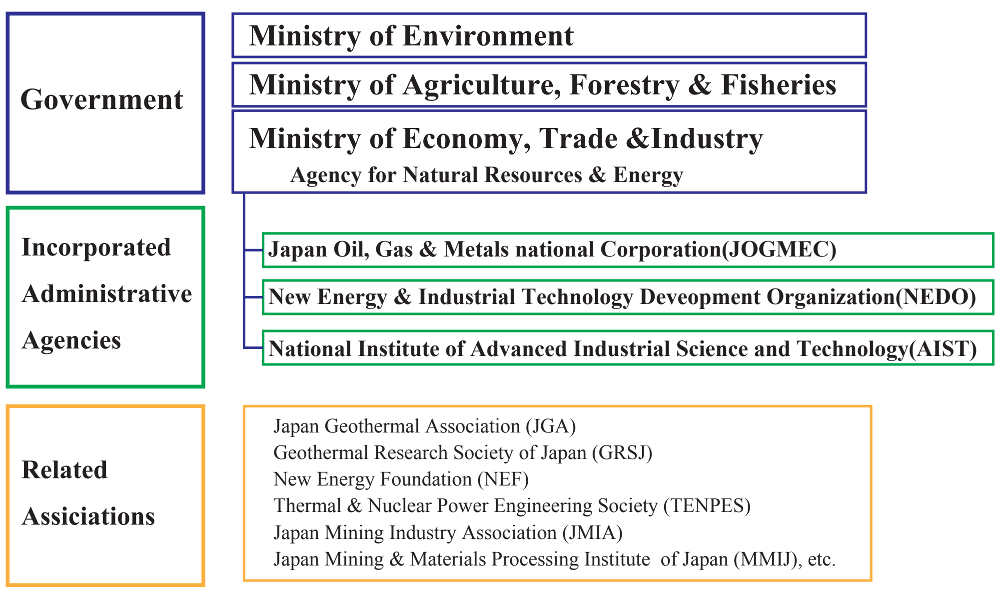


Figure 2. Relevant organisations and associations for geothermal development. Three ministries, policy makers, are related to geothermal development.

2.2 History of the Development

R&D projects for geothermal energy were first conducted in 1974, when the sunshine project office in MITI (Ministry of International Trade and Industry, currently METI) was established and the need for energy diversification increased, which aimed to establish energy sources independent from oil. The projects consisted of exploration and production technologies, material science and the HDR system. NEDO was also established in 1980 after the two oil crises happened in the 1970s to promote the development and introduction of the new, independent energy sources. The sunshine project office in MITI decided the policy and NEDO conducted the project.

In NEDO the development of three new energy types, solar power energy, liquefaction of coal, and geothermal energy, were major targets. Two departments were installed for geothermal energy in NEDO, one for survey projects and the other for production technology development for geothermal resources. The department for the survey organised the nation-wide geothermal survey named "The promoting survey project" and survey technology development was also carried out. The HDR project was conducted in the technology development department. NEDO also carried out financial support through subsidies. After the establishment of NEDO the budget increased year by year and reached to be about 15 Billion JPY (135 Million USD). In 2003 the METI budget for technology development in NEDO was, however, suspended by a political decision and no national project with government budget has been conducted since then.

3. Financial Support

The committee in the Japanese Government reported that it takes about 25.9 billion JPY (Approx. 230 million USD) to construct a 30MW Geothermal Power Plant (Cabinet office, 2011). The construction of the power plant house and the installation of the turbine and generator need a large amount of money. Huge costs are also incurred in the exploration part of geothermal resource development. Even if a promising geothermal reserve is found at the exploration stage, major risks still remain, such as necessity of the long period between completing the construction of a power station and its being brought on stream. The report also pointed out the long development time, which is estimated to be more than 11 years to complete a 30MW Geothermal Power Plant project from start to finish (Cabinet office, 2011). To cope with these risks, JOGMEC offers several types of financial support, including subsidy, equity capital, and liability guarantee. For example, subsidies will be applied for a survey period, equity capital for an exploration period and liability guarantee for a construction period of the power plant for the development in Japan.

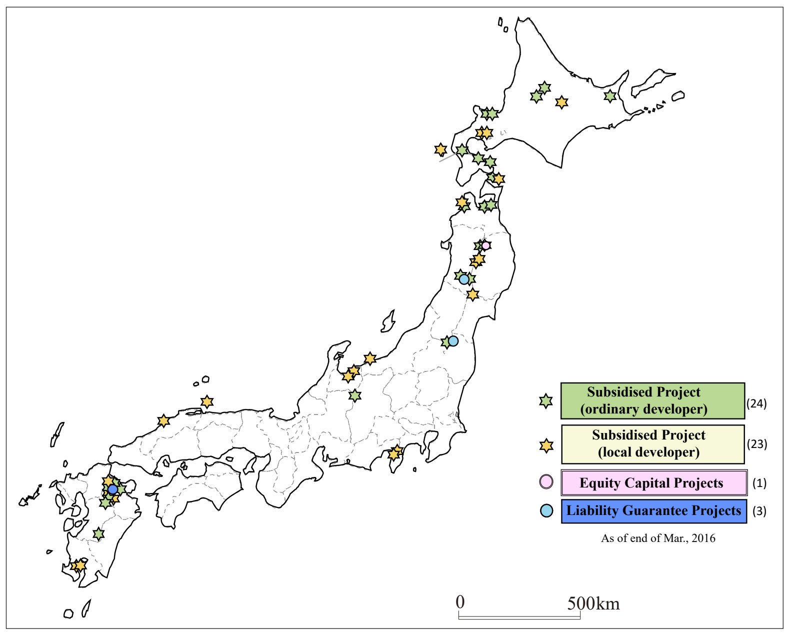


Figure 3. Map for the financial support projects adopted till end of Dec. 2015. In all, 51 projects were adopted. The numbers of project for subsidy, Equity Capital, and Liability Guarantee are 47, 1, and 3, respectively.

The subsidy is for the initial research and survey phase of projects in order to support Japanese entities such as ordinary developers and local developers. The subsidy rate for a local developer is higher than an ordinary developer to promote geothermal energy as a local energy source. The budget of about 10 billion JPY (Approx. $90 million USD) is supported by METI in 2016FY including the survey from a helicopter conducted by JOGMEC. The equity capital is provided to the developers for an exploration period up to 80% of the cost needed by drilling and flow testing. The liability guarantee is for a development period such as well drilling for production, pipeline installation and power plant construction. 51 projects were adopted for the subsidy, the equity capital, and the liability guarantee until the end of December 2015 (Fig. 3).

4. Technology Development

4.1 Geothermal Resources Survey Using a Helicopter

A nation-wide geothermal survey is widely required by both developers and researchers. The promoting survey projects conducted by NEDO had investigated more than 60 geothermal fields in Japan and five geothermal power plants commenced in operation. The new geothermal power plant (tentatively named the Wasabizawa Power Plant) is being constructed at the surveyed area in Yuzawa City and will start in 2019. Other planned geothermal plants are also using the results and data obtained in the survey project.

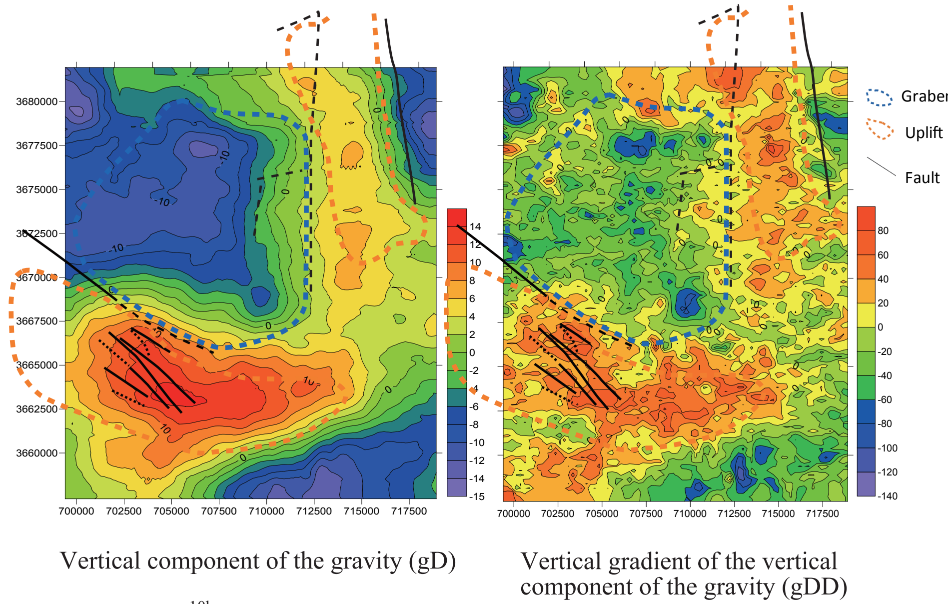


Figure 4. Survey result of gravity gradient measurement. Vertical component of the gravity (gD) is shown in the left figure. Vertical gravity gradient (gDD) is also shown in the right figure. The gravity gradiometer survey method measures the spatial variation of the gravitational acceleration to measure the gravity with high resolution compared with conventional gravity surveys.

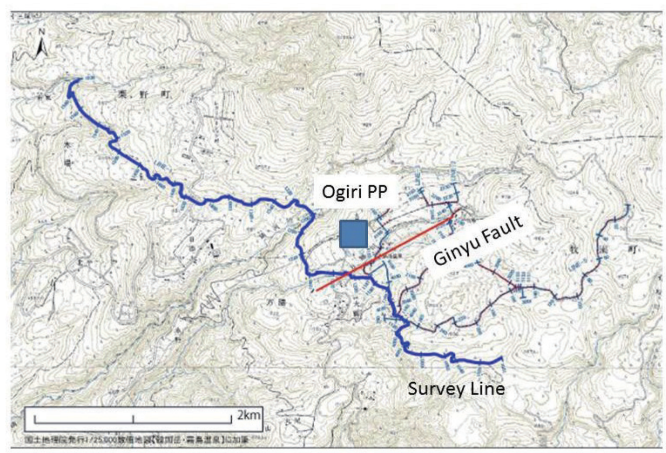
JOGMEC started another survey project just after geothermal energy development was transferred from NEDO. An airborne survey using a helicopter (hereafter referred to a heli-borne survey), which aims to acquire basic data for the evaluation of geothermal resources in order to promote geothermal development, is planned to be conducted all over Japan, especially in the Kyushu, Tohoku, and Hokkaido regions, where many geothermal power plants are located and installed.

The geothermal fields in Japan are mostly associated with Quaternary volcanoes and distributed in mountainous areas or within national parks, where it is difficult to access and to investigate. Surveys are restricted for the development in the national parks. Some of the national parks are located near volcanoes and geothermal resources are associated with the volcanoes. About 80% of the geothermal resources in Japan are located in the national parks. The heli-borne survey is an effective method to acquire data over a broad area without modification of the land surface.

Gravity gradient and resistivity are measured by the heli-borne survey. The survey using a helicopter has an advantage of its lower flight altitude and slower speed than that using an aircraft, resulting in stronger signals and denser survey points. The investigation area of 300 to 500 km^2 is basically selected where the geothermal resources are expected. Spatial filters are applied to the heli-borne gravity gradient data and some filters reveal the geological structure concordant with the faults and fractures.

4.2 Seismic Reflection Survey and Analysis

Seismic reflection is one of the most precise geophysical survey methods to detect geological structure. The reflection survey is commonly utilised



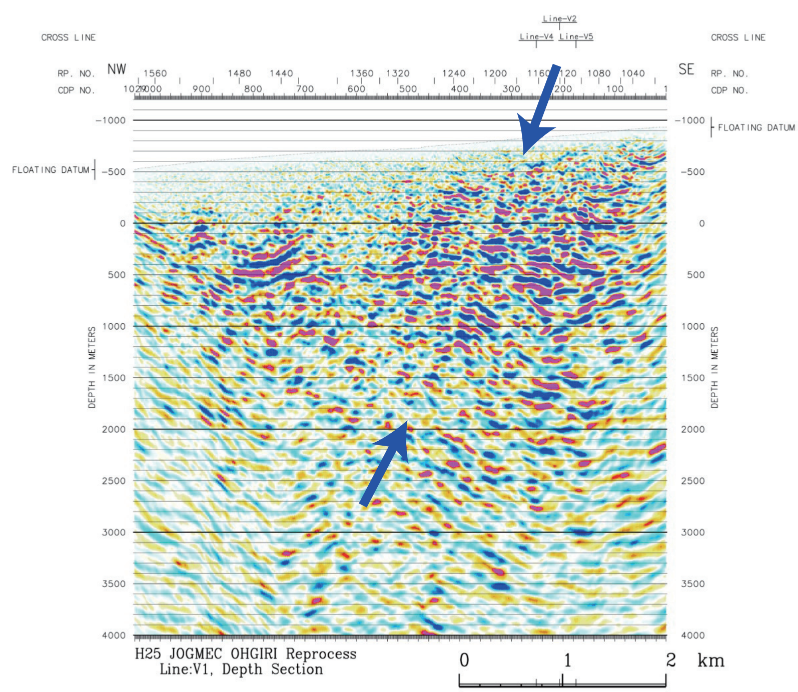


Figure 5. Result of re-analysis of the seismic reflection data taken in the Ogiri geothermal field. The Ginyu fault indicated by two arrows is clearly shown.

to find anticline structures for oil and gas exploration and was conducted at several geothermal fields to detect fractures associated with geothermal resources. However, fractures were not always detected clearly by the reflection data.

The survey line should be designed as straight as possible for the 2D reflection analysis, though most of the geothermal field in Japan are located in mountainous areas and it is hard to set a straight line for the 2D survey. This is one reason why the seismic reflection survey is not a common survey method in the geothermal field. Mizutani (2012) re-analysed 2D seismic data and showed fractures in a geothermal field. The success of the analysis was partly due to recent technology developments that make the performance of the computer much better and complex calculations faster.

We selected four geothermal areas in Japan where seismic reflection data are available and applied a modern analysis technique. Fig. 5 shows the result and the fault was identified. The analysis revealed the fracture structure in the geothermal field. We also carried out a 3D seismic reflection survey in the Yamakawa geothermal field located at Ibusuki, Kyushu Island. The survey was designed to confirm the performance of the seismic method and to demonstrate the reflection method as an important tool for geothermal development. The survey was conducted in 2015 and the data are now under analysis.

4.3 Electromagnetic Survey Technology Development

Resistivity surveys are of importance in the exploration of geothermal resources. Low resistivity can indicate the existence of clay-rich cap rocks and/or the geothermal fluid. JOGMEC has developed a TEM (transient or time-domain electromagnetic) survey system using a high-temperature SQUID (superconducting interference device) magnetometer to intensify the exploration depth of the measurement (Arai et al., 2002). The system, which is named SQUITEM, was originally developed to explore for subsurface metal resources. The SQUITEM system, where magnetic field (B) is measured, is expected to be more sensitive and accurate in detecting deep geological structure than a conventional TEM system, which measures time-derivation of the magnetic field (dB/dt) using an induction coil. We have conducted the SQUITEM resistivity survey in a geothermal field in order to detect issues in the operation and analysis. A survey using the SQUITEM system was carried out at the Ogiri geothermal field, where electromagnetic surveys by CSMT and MT methods were carried out (Takakura et al., 2001). The resistivity distribution obtained by the SQUITEM agreed well with that obtained by the CSMT method (Fukuda et al., 2015).

4.4 Geothermal Reservoir Management Technology

The shortage of the steam resulting from the imbalance between the steam production rates and the natural water recharge can make problems in the geothermal power plant and cause superheated conditions, resulting in the corrosion of surface facilities and the production of highly acidic fluid. These problems are widespread, and occur not only in existing geothermal power plants, but also in new geothermal power plants and in newly developing areas.

JOGMEC started an R&D project of new and general countermeasures to the problems of the steam shortage by the recharge of river water through an injection well. The project aims to develop and verify our artificial water recharge technology in a geothermal field. We will evaluate the technology in the view point of effectiveness and cost reduction and then collate these comprehensive measures into a new set of guidelines to ensure a stable supply of geothermal energy. Artificial water recharge was successfully applied and shown to increase steam supply in The Geysers (e.g., Khan, 2010) and the Larderello geothermal fields. The R&D project consists of survey and the modelling of the field, design and construction of an injection well, performance monitoring of the recharged water and so on (Okabe et al., 2015). The project contains a joint study with EPRI (Electric Power Research Institute) in the US.

4.5 Drilling Technology for Geothermal Development

Geothermal resources are located in the subsurface geological layers and it is essential for the geothermal development to drill a well. Drilling costs account for 97% of exploration costs and about 30% of the construction of the geothermal power plant. The goal of this development is cost reduction of the drilling stage. We are going to achieve it by enhancing the rate of penetration (ROP), and life-span extension of drill

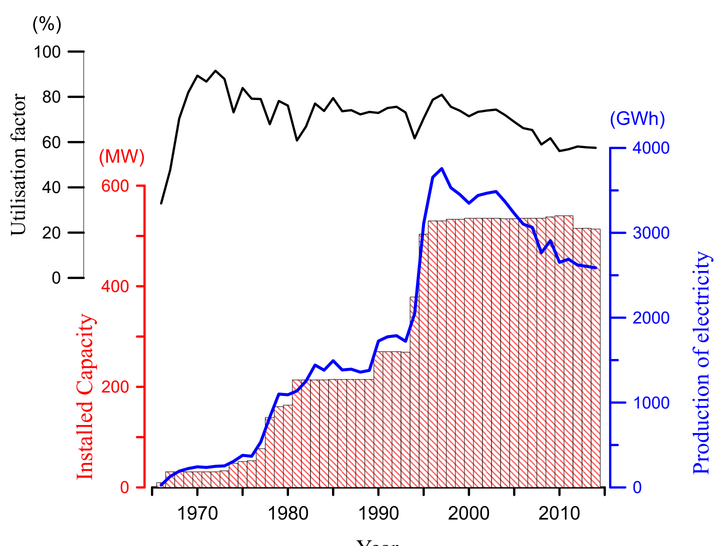


Figure 6. Geothermal power generation in Japan from 1966 to present. Current capacity of geothermal power units are only 525 MW in total, 2% of the potential of Japan's geothermal resources. This contributes only 0.3% of primary energy. Production of electricity from geothermal power plants has been decreasing gradually for the past dozen years or so.

bit for round-trip reduction. To achieve this, we will work on developing the PDC bit cutter and the body. The PDC bit is commonly used in the oil and gas industry. The key technology for geothermal usage is developing high temperature, heat resistant components.

5. Concluding Remarks

After the suspension of supplying electricity by nuclear power plants following the Fukushima accident, the revision of the JOGMEC Act was made in September 2012 and JOGMEC took on the additional function of supporting geothermal resource development in Japan, which covers technological developments as well as financial support such as subsidies, equity capital finance and liability guarantees.

As to the survey program, the heli-borne geophysical survey is conducted by JOGMEC, though NEDO conducted the surface survey as "the promoting survey project". The gravity gradient tensor is measured in the heli-borne survey and shows the geothermal reservoir associated with fault and fracture systems. The data obtained by TEM surveys are now under analysis. Seismic and electromagnetic technologies are also being developed. The seismic reflective method will be applied to geothermal fields with the modern data processing and interpretation. The SQUIDTEM using the SQUID device will be applied to the field to identify the geothermal reservoir indicated by the low resistivity region. PDC bits for drilling in geothermal fields are also being developed for cost reduction. The management technology is of importance as many geothermal power plants have problems with decreases in the amount of steam for the production of the electricity. This technology leads to EGS technology and the JOGMEC project will be transferred to the development of EGS technology.

We are willing to make a joint R&D study with overseas organisations. The management technology development has a joint project with EPRI and we are discussing about a new R&D project with GNS Science, New Zealand under the umbrella of the MOU between JOGMEC and GNS International.

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