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Cooperation in Geothermal Development at Great Rift Valley in Africa

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ABSTRACT

Aiming at promoting geothermal development in the developing countries, not only financial supports but also human resources development of public sector is indispensable. This paper examines that risk reduction by human resources development in geothermal development contribute to improvement of Expected Rate of Return (ERR) of its development, and to mitigation of the bottleneck of its development. Based on the discussion, Japan International Cooperation Agency (JICA) cooperates on both technical and financial needs to support for geothermal development. For technical needs, JICA focuses on fostering human resources to improve the success rate of exploratory drilling, the accuracy of evaluating geothermal reservoirs, and the acceleration of the geothermal development. Regarding financial support, there are two schemes, ODA loan and grant. Assistances of human resources development and financial support are fundamentally related to implement both and simultaneously to make greater impacts on risk mitigation in geothermal development.

1. INTRODUCTION

Geothermal development demand in African Great Rift Valley has lately attracted considerable fund from donor partners and capacity development of public sector which utilize the fund becomes increasingly important. In Ethiopia alone, the committed and planned projects for geothermal development are expected to produce about 1,115 MW capacities of electricity and more than US$ 2,190 million would be funded for these projects[1]. Although a great amount of fund is invested in East Africa for geothermal development, it has two big barriers for the development caused by extremely high risks at an exploration stage. One of the barriers is that large upfront investment is required without confirming underground conditions, knowing steam production capacity and estimating project profitability. Another barrier is that it is not easy to secure diverse human resources with scientific background for all development stages in geothermal development.

JICA has set up a basic policy in the energy development sector: energy with low-cost, low-carbon, and low-risk, so called 3L-Policy. In particular, geothermal energy development which is in great demand in developing countries accords with the 3L Policy as geothermal energy has the following features. In terms of "low-cost", the power generation cost of geothermal energy is at the same level as hydropower, coal, and LNG, in long-term operation. In terms of "low-carbon", the amount of carbon dioxide emissions is at the same level as solar power, wind power, and hydropower. In terms of 'low-risk", although high risks during the stages of up-stream development remain, it is indigenous energy therefore it is recognized as an important energy source for national energy security and is possible to be used as a base load power that is one of renewable energies enabling to deliver sustainable power without relying on weather conditions.

Aiming to realize 3L-Policy, JICA contributes to assist not only providing financial supports but also implementing capacity development and human recourse development in geothermal development for the developing countries. It is because that capacity development and human resource development would lead to risk mitigation of geothermal development directly. Kaneko (2013) illustrates project development risks by using an economical evaluation model that analyzes Expected Rate of Return (ERR) based on the survey results in Indonesia and argues how development risk is high in the geothermal development. In order to mitigate such risks, JICA provides cooperation to improve ERR on the geothermal development for developing countries through its capacity development by fostering human resources to improve their technical level in geothermal reservoir identifications and exploratory drilling skills. JICA also responds to financial needs by providing two schemes that are grant and ODA yen-loan. Assuming that these cooperation giving impacts on ERR, this paper will demonstrate how ERR is shifted depending on drilling success rate.

Firstly in this paper, two significant challenges for geothermal development will be discussed; 1. Improvement of drilling success rate including identification of geothermal reservoirs, and 2. Securing funding for its development; followed by recent trend of geothermal development in the developing countries. In the next section, how geothermal projects developed in Japan will be explained. Then, measures of risk mitigation will be discussed by illustrating ERR with an effect of drilling success rate and by explaining financial supports on favorable terms. In the last section, projects that are implemented in Kenya, Ethiopia, and Indonesia, and Japan are introduced as examples.

2. BOTTLENECKS OF THE DEVELOPMENT AND EXPERIENCES IN JAPAN

Geothermal resource development needs large funds including initial stage drilling and confirmation stage drilling with high failure risks. Many developing countries depend on that private companies in geothermal resource development, however few companies participate in its development, as there is a possibility that cannot recover their investment cost. In fact, countries in which

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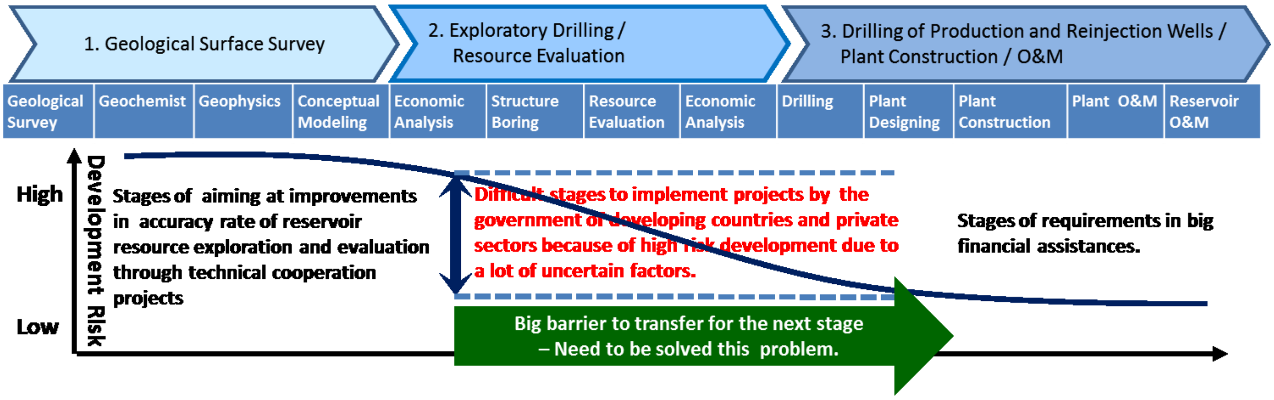
[1] It is based on Progress Report in May 2014 of the Project for Formulating Master Plan on Development of Geothermal Energy in Ethiopia that is conducted by JICA.

geothermal development proceeds such as El Salvador, the Philippines, Italy, Costa Rica, and New Zealand, the government conducts all or part of geothermal development stages, or it had been conducting in the past. In recent years, countries such as Kenya, Djibouti, and Tanzania of which the government takes responsibility in geothermal resource development and leaves the subsequent development to private companies after reduction of geothermal development risks, have been increasing. Such countries urgently need to secure human resources and funds.

2.1 Stages of Geothermal Development and Identification of Obstacles

Geothermal energy has two significant challenges that become a bottleneck for the development: improving the success rate of drilling boreholes, and securing funds, which can be an obstacle for development because considerable up-front investments are needed while the geological underground conditions are unknown. As Figure 1 below shows, the stages of geothermal development consists of: the exploration of geothermal potential prospects through geological surface survey, the estimation of the capacity of geothermal reservoirs through conceptual modeling, drilling boreholes for reservoir identification and evaluation, drilling production and reinjection wells, the installation of power plant, and operation and maintenance of plant and reservoir. Throughout these development stages, there are several bottlenecks. The drilling cost is extremely high, and the success rate of drilling boreholes for reservoir identification is below 50%. The rate drops below 30% if the geothermal resource is not confirmed. The estimated cost is approximately equivalent to US$ 6 million per well drilling with an 8-inches diameter.

Figure 1: Stages of geothermal development and bottlenecks



2.2 Obstacles of geothermal development and increasing of roles of government in risk mitigation

Thanks to Geothermal Risk Mitigation Fund that is the bear some of the cost of geological surface survey and exploratory drilling for government and private companies in order to reduce damages when it failed, the financial risk has been greatly reduced. And the capacity strengthening of the public organizations who use the funds is becoming increasingly important. Geothermal development requires diverse human resources, i.e. a scientific background, practical and technical experience in geology, geochemistry, geophysics, reservoir engineering, environmental studies, chemistry of thermal fluids, drilling, engineering of plant design and construction etc. (see the second line of Figure 1). For its development, most developing countries have taken advantage of private companies to develop geothermal energy.

Risks of geothermal resource development, however, are beyond private companies' capacity to take and are extraordinarily high due to cost for drillings until to confirm an appropriate capacity of steam. If the financial capacities are as small as just allowing to drill one borehole only, risk mitigation becomes crucial, giving that especially for the initial drilling, the success rate is low. If the location of the geothermal source is missed, it is very likely that the project will be seriously affected. Considering such circumstances, the financial capacities have to reach a certain volume if they are intended to tolerant of the risk of exploring the underground. For example, if 6 out of 10 targeted drillings for the detection of geothermal sources turned out to be a failure, the remaining 4 successful ones – meaning the expected power plant – would be sufficient to cover the expenditures. In fact, as sites with expected high-potential geothermal sources like Kenya, different donors have started to assist drilling projects ranging from 9 to 30 wells.

Based on a data collection in geothermal development done by JICA in 2014, many countries that rely upon private sectors are not much active yet for its development (see the Table 1). Peru for example is relying upon the private sector to develop the exploration stages. Although it has been said that the country has a geothermal potential of approximately 3,000 MW, no steps leading towards a geothermal development have been taken. Currently, the policy and strategy have been reviewed in order to stimulate the geothermal development.

Given this situation, a recent trend shows that some countries like Indonesia, Kenya, Ethiopia, Rwanda, Djibouti, and Uganda are trying to - partly or entirely – take the responsibilities of the risk of underground conditions in order to accelerate their development. In fact, the government of Kenya for example is now taking responsibilities for underground risks and established Geothermal Development Company (GDC) in 2009 to conduct surface survey, exploratory drilling, and reservoir evaluations. Under these circumstances which are marked by responsibility transitions from the private sector to the public (governmental) sector, there is – apart from the necessary large-scale financial assistance – an urgent need to develop the capacities of core human resources in order to ensure any further development. Kaneko (2010) argues that conducting survey in up-stream development stages by government taking development risks and publishing its results contribute to improvement of risk mitigation and acceleration of entering private sectors in geothermal development.

JICA believes that in order to make greater impacts of financial support, it should come with human resource development and capacity development for improvement of skills and technologies. In particular, well siting, and ordering and monitoring of drilling contractor, so that it is urgently required to develop human resources of geologists, reservoir engineers and drilling managers. It is because that funding aiming at mitigating the risk of drilling projects is only helping to solve financial problems without tackling the actual problem, which is the low success rate of drilling to find geothermal sources. JICA expects that by human resource development of these developing countries, funds from other donor partners be also more effectively used. To realize risk mitigation in a selected region and/or the entire institutional for geothermal development, rather than individual project to be realized is only by implementation of human resource development and technology improvement are necessary. In order to optimize implementation of human resource development projects and financial supports for acceleration of geothermal development, the government takes geothermal development risks, and simultaneously cooperates with private sectors in improvement skills and technologies.

The roles of governments in geothermal development should be improvement of accuracy in geological survey, capacity of supervision in drilling, evaluation in geothermal reservoir and its analysis. Achievements of these would impact on all stakeholders of geothermal development.

Table 1: Comparison of development stages

STAGE / Country	Surface Survey	Drilling Evaluation	Plant Construction	Risk*	Existing power station + under development / geothermal potential	Note
Peru	Private			High	0 MW / 3,000 MW	Owner of responsibility in development risks might shift to the government.
Indonesia	Government	Government Private	Private		1,197 + 280 MW / 28,000 MW	
Kenya	Government(GDC)		Government (KenGen) Private	Low	212 + 280 MW / 7,000 MW	At Suswa, 300 MW project will be conducted by a private company.
Ethiopia	Government		Government (EEP) Private		5 + 1,115 MW / 5,000 MW	Structure is modeled after Kenya's system

Risk*: Risks for private companies

(Data collection done by JICA, 2014)

2.3 Experiences and Risk Mitigation in Japan

Although there is stagnant period of geothermal development for the past decades in Japan, Japan is one of major counties in which develop geothermal energy in the world. It is because that our government takes geothermal development risks such as conducting surveys in underground resources, offering technical supports, and providing financial supports by Geological Survey of Japan (GSJ), New Energy and Industrial Technology Development Organization (NEDO), and other governmental sectors. Thus, our survey data, technology, practical experiences and knowledge regarding geothermal development have been accumulated and they contribute to geothermal development in Japan.

The first experimental drilling of a geothermal resource in Japan was successfully conducted in 1919 and the first geothermal power generation was installed at Beppu in Kyushu in 1925 with a capacity of 1.12 KW. Based on these experiences, the former national institution of the Advanced Industrial Science and Technology (AIST) (that was the Geological Survey of Japan established in 1882 under the Ministry of Agriculture and Commerce) started implementing survey in 1947 at a bigger scale. As the result, our first commercial geothermal power plant of 9.5 MW was established in 1966 in Matsukawa with vapor-dominated system, the one and only system in Japan, and has expanded to 23.5 MW gradually by increasing production wells and is currently stabilizing the power at 23.5 MW since 1993 (Hanano, 2003).

Since 1980, NEDO has conducted geological survey to identify geothermal potential areas and prospects where private sectors would not have implemented projects due to high risks of development, and to promote interventions of geothermal development by private companies. The result of survey was that 42 prospects out of 67 are identified with high temperature more than 200℃; and successfully steam[2] discharged at 26 prospects.

[2] In the result of the survey, NEDO classifies 3 ways of survey methods. A: survey area 100-300 km^2 for 3 years to identify existing areas of high temperature. B: survey area 50-70 km^2 for 3 years to identify existing geothermal reservoirs. C: survey area 5-10 km^2 for 2 to 4 years depending on expected steam production (more than 10,000 kW or not) to confirmation of geothermal resource capacity.

Beside exploration stages, a Japanese production technology for anti-corrosion turbines contributes to geothermal development, Japanese companies holding approx. 70% of the world market share regarding plant and equipment distribution[3]. It also can be said that NEDO's projects might to contribute to raise the level of technology in order to produce anti-corrosion turbines.

3. MEASURES OF RISK MITIGATION

In this section, what ERR would rise is examined by using Monte Carlo method, in case that the accuracy of reservoir prediction and drilling will be improved by human resource development.

3.1 How Much Impact on ERR through Capacity Development

Theoretically, capacity development of government sector would influence the geothermal development as follows; Improvements of skills and technology in government sectors would leads to improve drilling success rate; the improvement of drilling success rates reduces project period and cost; it would also contribute to design appropriate power plant; if managed to design an appropriate power plant plan, it would lead to improve ERR. In this paper, drilling stage is focused as it is a bottleneck. Having a hypotheses that capacity development of government sector would improve drilling success rate, ERR of geothermal development is examined using Monte Carlo Method.

Kaneko (2013) introduces 3 measures for risk mitigation for the geothermal development based on the analysis of ERR. One of the measures is that implementing feed in tariff system with rather high energy price as risk premium is considered. The second measure is that the government should take risks of up-stream development because private sectors would not take high risks normally and risk of geothermal development is too high for private sectors. The Survey on Geothermal Development for improvement in Japan conducted by NEDO from 1980 to 2010 was based on this model. Last one is to spread risks by drilling many places instead of solely drilling one location to marginalize the risk.

JICA considers that improvement of human resource capacity in the government sectors, which implement projects of geothermal development will also give impacts on ERR and affects its development risks. The hypothesis is that capacity development would contribute to the improvement of drilling success rate that could impact on project period and project cost. Saito and Sakuma (2002) review man-induced drilling problems that occurred during the last 14 years from 1988 to 2001 within JMC-Geothermal group and analyze types of these problems statistically. They categorized problems into three main types; the first is leaving the development tools or equipment behind the well as they fall apart or incidentally drop at the time of drilling, the second is stuck pipe due to the collapse of the wall, and the third is the breakdown of machine or spare parts, and suggest for the improvements to strengthen maintenance and management of operation systems. The following actions are raised as examples: implementation of recording system on stabilizer and other machine; renewal of these machines; reconsideration on frequency of drill string examination and drilling examination standard; training drillers; selection of machine based on working days; and construction fee, conducting maintenance, and so on. These actions can be improved through capacity development training because they are human errors. Theoretically reduce the frequency of human errors such as dropping tools in the well, drilling period would be shorten and time wasted by losing material would be less. Therefore supposing capacity development contributes to the improvement of drilling success rate and economic efficiency. Here, how ERR shift will be examined below.

Figure 2 shows the effect of drilling success[4] rates on ERR when conducting the Monte Carlo method 1,000 times. The simulation model of Monte Carlo experiments is the same version of what Kaneko (2013) used. It was preconditioned to follow a probability density function of each normal distribution of the depth of production well at 2,000 meters in average, the standard deviation at 400 meters, the power output of production well at 8 MW per well, and the standard deviation at 2.5 MW per well. In the graph, there are 3 different lines, a dotted line, a broken line, a solid line. The dotted line with 15%, 30% and 60% indicates 15% success rate for drilling initial wells as exploration level, 30% success rate for drilling confirmation wells, and 60% success rate for drilling production wells. The broken line with 20%, 40% and 70% indicates 20% success rate for drilling exploratory wells, 40% success rate for drilling confirmation wells, and 70% success rate for drilling production wells. The solid line with 25%, 50% and 80% indicates 25% success rate for drilling exploratory wells, 50% success rate for drilling confirmation wells, and 80% success rate for drilling production wells. Among these three lines, the solid line shows realistic ratios based on experiences in Japan. The increase of ERR would lead to the following scenarios, as the grey arrows in the graph show: risks can be mitigated as frequency of probability 0-5% becomes lower (see the grey arrow ① in the graph); the peaks of ERR shifts to right side from 8-9% (dotted line) to 11-12% (solid line) (see the grey arrow ②); and distribution ranges become wider (see the grey arrows ③). It means improvements of drilling success rates contributes to improve ERR of the geothermal development project.

[3] According to Japan Geothermal Developers Council, as of 2010, the world of the total geothermal plant capacity was 10,683 MW and its share was 24% for Mitsubishi Heavy Material, 24% for Toshiba, 20% for Fuji Electric, 11% for Ansaldo/Tosi, 10% for Ormat, and 11% for others.

[4] The definition of "success" rate for drilling in the model is that exploration level and confirmation level of wells are the same size of production well; even 5 MW if steam for power production can be confirmed at each level of drillings, drilling is succeeded.

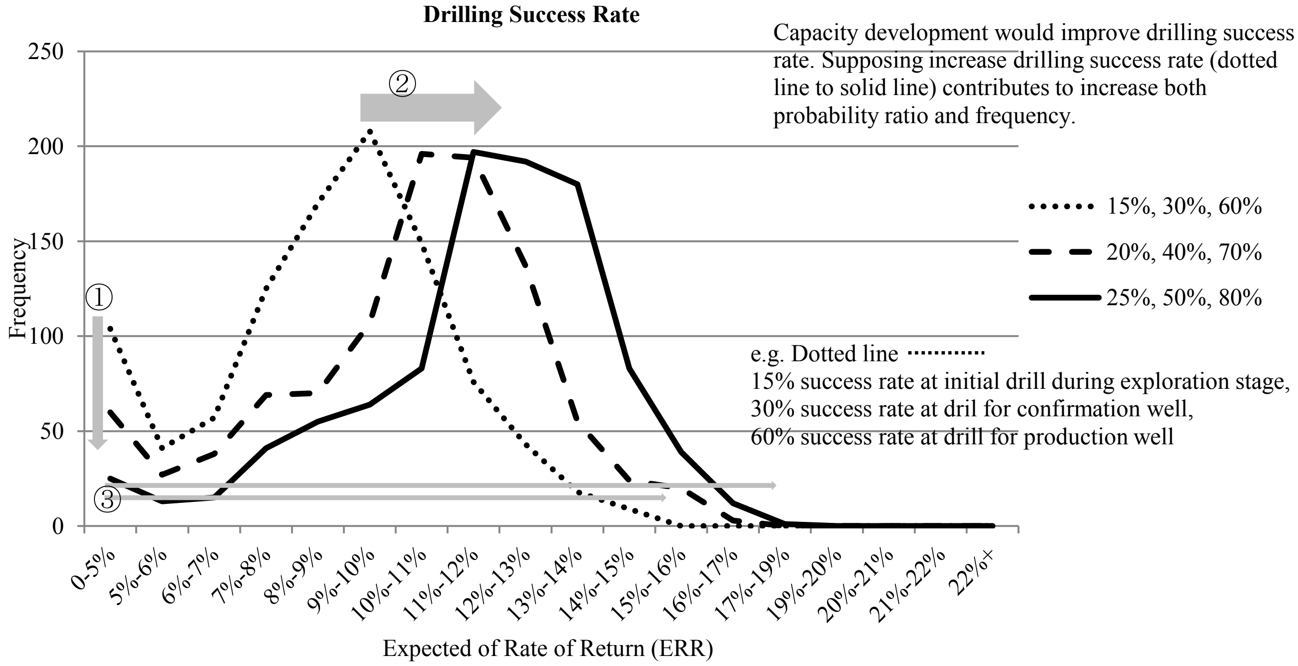


Figure 2

Capacity development of human resources and improvement of scientific technology contribute to the enhancement of reservoir identification skills and drilling skills that would impact on drilling success rate and economic efficiency. Therefore, JICA provides technical cooperation with on-the-job-training and various training courses for capacity development which would lead to the improvement of ERR directly.

3.2 Financial Assistance

Besides capacity development, JICA offers financial assistance on favorable terms. Financial assistance and capacity development are both indispensable. Implementation of capacity development solely, for example, the geothermal development project would be difficult to start or to continue due to lack of funds as it requires a huge amount of investment. According to the Japan Geothermal Association, the cost of the geothermal development with 50MW is estimated approximately US$ 300 million and its breakdown is: US$ 100 million for plant construction, US$ 150 million for drilling of production and reinjection wells, US$ 20 million for surface survey with exploratory drilling and resource evaluation, and others including US$ 30 million for EIA (Environmental Impact Assessment). The breakdown of the estimated cost is not always applicable to every project, but what we can see here in particularly is that considerable funds are required for drilling production and reinjection wells and plant construction.

Kaneko (2010) argues that implementation of financial assistance such as Feed-in Tariff, tax-reduction, government subsidy for survey and construction cost, and soft loans will bring significant benefits both to the government and to the society. For example, in his paper, he estimates impact on electricity price if the subsidy has been issued to construction of the geothermal power plant based on Japanese model. He compares cases of the subsidy from 0% to 50% to be granted for construction costs of the geothermal power plant. Based on his estimation and comparison, when the subsidy is granted 20% of the construction cost instead of 0%, the selling price could be economized by USD 1.3 cent /kWh less. Specifically, when subsidy is granted 20 %, the electricity price was estimated at USD 10.6 cent/kW, while subsidy is not granted at all, the electricity price was estimated USD 11.9 cent/kWh.

Regarding soft-loan he also discussed impact on the geothermal electricity price and government benefits if the government is given soft-loan to survey of geothermal power plant construction and to construction of geothermal plant. According to his estimation, incase if interest rate of 3.5% is applied instead of 6.5% to initial stage survey and to geothermal plant construction, the electricity price will decrease USD2.0 cent / kWh and government benefit (as value of policy cost) will increase USD 1.2 cent / kWh. On the basis of above discussion, JICA provides soft loan for development projects to contribute geothermal development in the developing countries.

4. JICA COOPERATION FOR RISK MITIGATION OF GEOTHERMAL RESOURCE DEVELOPMENT

JICA provides both technical assistance through capacity development and financial assistance by grant and/or ODA loan on favorable term. As for the technical assistance, it focuses on capacity development to improve various aspects for geothermal development including the success rate of exploratory drillings and the accuracy needed for the evaluation of geothermal reservoirs to accelerate geothermal development. Hereafter, projects implanted in Kenya, Ethiopia, and Japan are introduced as examples.

4.1 Geothermal development in Kenya

The Government of Kenya has prioritized in "Vision 2030" geothermal development to generate 5,000 MW from geothermal resource while the current figure is only 540 MW. The government had decided to cover some financial risks for underground explorations, whereas the GDC (Geothermal Development Company) established in 2009, conducts surface survey, exploratory drilling, and resource evaluation, and supplies steam to IPPs (Independent Power Producers) directly. GDC is receiving financial support from other development partners. One of JICA's projects in geothermal development in Kenya focuses on human resource development to improve their capacity and skills in order to enhance drilling success rate and accelerate geothermal resource development.

The project name is the "Project for Capacity Strengthening for Geothermal Development in Kenya". The overall goal is that GDC will be able to provide stable steam to power generation utilities and the objective of the project is to enhance human resources of GDC which contribute to technical risk mitigation in geothermal development. The project started in 2013 and its duration is of 4 years. The most distinguished aspects of the project is that the training program is conducted on-the-job training in GDC's own field; and each course program has been designed based on requests received from individual interviews with local staff members in each section. This training cooperation is made based on the needs of the counterpart, and comprehensively dispatching experts of each stage of geothermal development.

4.2 Master Plan in Ethiopia

Considering the policy of Ethiopian government to achieve stable energy mix and sustainable power supply by promoting geothermal energy development, JICA conducted already "Data Collection survey on Geothermal Development in Africa" in Ethiopia in 2010. However, the current situation is that the most of geothermal prospects were not yet explored and even surveys already conducted were incoherent as they were conducted by various donor organizations in a different method and for different purposes. Therefore, these un-unified data sets are making difficult for GSE to evaluate geothermal resources and prioritize them in a scientifically coherent protocol.

JICA conducts "the Project for Formulating Master Plan on Development of Geothermal Energy in Ethiopia" that started in 2013 and will be ended in May 2015. The project goals are that the capacity of GSE will be developed and ready to commence geothermal development projects; and geothermal power development in Ethiopia will be promoted through formulating master plan of geothermal energy development and database development of geothermal prospects. The project activities are as follows:

- Data collection and desk review
- Nation-wide survey of geothermal energy
- Training in Japan
- Database and master plan development

In this project, training program is also conducted on-the-job-training both in Japan and Ethiopia carefully programmed based on the requests from our counterpart GSE. Regarding training in Japan, trainees participate in theoretical and practical courses depending on their needs and following subjects are covered: a basic program course consists of learning remote sensing, geophysics, reservoir evaluation, geochemistry, database with 3D modeling for engineers; an advance program consists of learning fluid analysis, simulation, drilling technology, advanced technology, geothermal development for both engineers and directors levels; and some workshop and field visits are also prepared for both levels. On top of the training in Japan, on-the-job training in Ethiopia also has been conducted especially in database establishment of geothermal resources so that GSE staff members will be able to operate "G star Base" software after these training courses and will be possible to maintain their underground information visibly from the stages of surveys until geothermal power plant establishment.

Photo 1: Training in Japan

4.3 Training course and researches in Geothermal Development

JICA is preparing the following training courses; some are newly established and some are strengthened based on requests from developing countries.

- 6 months course for engineers in geology, geochemistry geophysics, reservoir engineering that emphasis on practical training will be implemented from 2016 together with Kyushu University, Tohoku University, National Institute of Advanced Industrial Science and Technology (AIST), developers and consultants.

- 6 weeks course for drilling managers in enhancement of capacity to order and to supervise drilling contractors will be implemented from 2016 together with developers and drilling contractors. A unique textbook that includes failure case analysis based on practical experiences of geothermal development will be prepared.

- 2 weeks course for directors in geothermal development planning will be implemented from 2016 together with ministry, consultants, developers, and manufactures.

- Master's and Ph. D courses for engineers in geology, geochemistry, geophysics, reservoir engineering have been implemented from 2014.

- 2 weeks course of Enhancement of the Planning Capacity of Geothermal Power Development for managers and decision makers in governmental organization is implemented.

- Science and Technology Research Partnership for Sustainable Development (SATREPS) is a joint research program conducted by Japan Science and Technology Agency (JST) and JICA. It implements based on the needs of developing countries and leads to research outcomes of practical benefit to both local and global society.

4.4 Securing funds for the development

JICA also provides Japanese ODA Loan for geothermal development when developing countries request financial assistance. In case government takes responsibility to survey underground resource, develop production and reinjection well, plant construction, and O&M, Japanese ODA loans are available with low interest rate, long repayment terms and generous loan terms and conditions.

It is said that the Republic of Indonesia is blessed with the world largest geothermal potential, constituting 40% of the geothermal potential of the entire world (JICA, 2007). The government of Indonesia has promoted a strategy of energy diversification, intending that 40% out of the planned power development of 10,000 MW – according to the new power plant development plan from 2010 and 2014 – should be produced by geothermal. So far, geothermal power plant has been installed in 9 fields, namely Kamojang, Darajat, Wayang-Windu, Salak, Dieng, Sibayak, Lahendong Ulubelu, and Ulumbu, which generates 1,341MW as of 2012. In Table 2, recent projects for geothermal development assisted by JICA's ODA loan are shown as a reference.

Table 2: List of ODA Loan Project for geothermal development

	date of agreement	Cost of ODA Loan (million yen)	Interest rate (% per year)	Term of repayment / term of measures	Installed power capacity
Geothermal Development Acceleration Program (Tulehu Geothermal Power Plant Project) – Indonesia	2013 Mar.	5,104	0.3	40/10	20 MW
Lumut Balai Geothermal Power Plant Project – Indonesia	2011 Mar.	26,996	0.3	40/10	-
Kamojang Geothermal Power Plant Expansion project - Indonesia	2006 Mar.	995	0.75%	40/10	Expansion 60MW
Ulubelu Geothermal Power Plan Project – Indonesia	2005 Mar.	20,288	0.75%	40/10	110 MW
Lahendong Geothermal Power Plant Expansion Project – Indonesia	2004 Mar.	5,866	0.75%	40/12	20 MW
Laguna Colorada Geothermal Power Plant Construction Project - Bolivia	2014 Jul.	2,495	0.65	40/10	50 MW
Las Pailas II Geothermal Project (Guanacaste Geothermal Development Sector Loan) – Costa Rica	2014 Aug.	16,810	0.6	40/10	-
Olkaria I Unit 4 and 5 Geothermal Power Project - Kenya	2010 Mar.	29,516	0.20	30 /10	140 MW

5. CONCLUSION

In addition to financial assistance, the risk mitigation based on the capacity improvement of the government will contribute effectively to accelerate and promote geothermal development. Based on ERR analysis it was shown that capacity development contributes improvement of ERR of individual project. While it was examined by simulation to rise in ERR due to human resource development, JICA would like to verify them in practical field and project as one of our missions and challenges.

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