

JICA's Cooperation in Geothermal Development at Great Rift Valley in Africa

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Keywords

Geothermal, capacity building, Official Development Assistance (ODA), JICA, Japan, Kenya, Ethiopia, Djibouti, training, test well drilling, lending, grant

ABSTRACT

Since the late 2000s, the Japan International Cooperation Agency (JICA) shifted its focus of its global geothermal development cooperation to the Great Rift Valley in order to unlock the region's large geothermal potential. In 2010, JICA undertook a region-wide survey of geothermal potential, followed by country-level surveys in Kenya, Ethiopia, Djibouti, and Rwanda to prioritize prospective sites based on their geothermal potential and economic analysis. In 2016, JICA launched three training schemes in Japan: a six-month training course for geothermal engineers, a one-week executive program, and a six-week training program for drilling managers. In addition, numerous technical cooperation projects were launched or are currently being prepared in Kenya, Ethiopia, and Djibouti. In Ethiopia and Djibouti, JICA has decided to take upfront risks by conducting test well drilling at prospective sites. Three loan agreements for power plant construction were signed with the Kenyan government, with a total of 85.3 billion yen (approx. 775 million USD¹) to construct 418.7 MW of electricity generation plants. Also, a feasibility study for a Yen Loan is currently being conducted in Ethiopia. In this paper, JICA's energy policy as well as its philosophy for geothermal development will be discussed. Then, a brief history of JICA's approximately two decades of assistance in the Great Rift Valley will be provided. Finally, JICA's on-going and planned geothermal projects will be explained.

1. INTRODUCTION

The Japanese government and JICA have assisted partner countries in developing geothermal energy since the 1970s. From the 1970s to 2000s, JICA's assistance was concentrated mostly in Asia and Latin America. In the 2010s, JICA shifted its focus to the Great Rift Valley to help partner countries diversify their energy mix and move away

¹ 1 USD=110 yen

from heavy dependence on seasonally fluctuating hydropower and imported fossil fuels by unlocking their large geothermal potential—estimated to be 15,000 MW. In 2010, it undertook a comprehensive survey to understand the region’s geothermal potential, geothermal development policy, and capacity gaps.

The survey provided important information for JICA to ramp up its efforts in the region. Since then, master plan studies and reviews were conducted in Ethiopia (2015), Rwanda (2016), and Kenya (2017). In 2016, JICA launched three training schemes in Japan: a six-month training course for geothermal engineers, a one-week executive program, and a six-week training program for drilling managers. In addition, numerous technical cooperation projects were launched or are currently being prepared in Kenya, Ethiopia, and Djibouti. Three loan agreements for power plant construction were signed with the Kenyan government, and a feasibility study for a Yen Loan is currently being conducted in Ethiopia.

This paper discusses the main challenges that JICA’s assistance addresses with respect to geothermal development: (a) managing high resource development risks, (b) securing large upfront investment, and (c) improving cash flow alongside operation and maintenance of plants and reservoirs.

The paper begins with a broad overview of JICA and its energy policy, followed by a synopsis of its views on the advantages and challenges to exploiting geothermal energy. A brief history of Japan’s geothermal development is then discussed, followed by case studies highlighting JICA’s assistance to Kenya and Ethiopia. The paper concludes by discussing further challenges JICA and the Great Rift Valley confront in realizing the latter’s geothermal potential.

2. WHAT IS JICA?

JICA is a bilateral agency in charge of administering Japan’s Official Development Assistance (ODA). JICA has 96 field offices worldwide. JICA is guided by the Japanese government’s Development Cooperation Charter (Feb. 2015). In 2017, under the leadership of JICA’s new president Shinichi Kitaoka, it adopted a new vision that is in accordance with the aforementioned charter. JICA’s new vision is “leading the world with trust.” We have set out five guiding actions to achieve this vision, which are (a) to **commit** ourselves with pride and passion, (b) dive into the **field** (or “*gemba*” in Japanese), (c) think and act **strategically** with broad and long-term perspectives, (d) **co-create** by bringing together diverse wisdom and resources, and (e) **innovate** to bring about unprecedented impacts. JICA is currently reorienting its efforts to achieve this new vision.

JICA’s budget during Japanese fiscal year 2017² was approx. 1,585 billion Japanese Yen (approx. 14.4 billion USD). As far as portfolio size is concerned, it is currently the largest bilateral donor. JICA has three main instruments for its cooperation: (a) finance and investment, (b) grant aid, and (c) technical cooperation. As we will explain later, JICA

² The Japanese fiscal year is from April 1 to May 31.

combines these three instruments and tailors them to the needs of individual client countries.

- (a) Finance and investment is basically concessional lending denominated in Japanese Yen. This modality accounts for around 80% (approx. 12.7 billion USD³) of JICA's total portfolio. In Japanese FY 2014, roughly a third of the Yen Loan portfolio went to electric power and gas. From 2007 to 2015, JICA was the largest energy sector financier within the OECD. It alone was responsible for 19% of all energy investments made by OECD partners during this time period, exceeding the World Bank/IDA (16%), Germany (16%), EU (11%), USA (7%), France (6%), and others (OECD-DAC Statistics HP). As for the geothermal sub-sector, JICA currently has outstanding loans to five countries: the Philippines, Indonesia, Kenya, Costa Rica, and Bolivia.
- (b) Grant aid is a form of assistance whereby goods and services for socio-economic development are provided with no repayment obligation. This represents roughly 10% (approx 1.6 billion USD) of JICA's total portfolio. In Japanese FY 2014, roughly 5% of JICA's grant portfolio was allocated for energy interventions. One on-going geothermal grant project will install a wellhead power plant (5MW) in Ethiopia.
- (c) Technical cooperation aims to contribute to socio-economic development by sharing Japanese experience and expertise. Technical cooperation projects can take many forms, such as dispatching an expert (Ethiopia), a team of experts (Kenya and Indonesia), joint research with Japanese and host country universities (El Salvador and Indonesia), and short- and long-term training in Japan. JICA's budget for technical cooperation was around 10% (approx. 1.5 billion USD) of its total budget. In FY 2014, 4.5% of JICA's technical cooperation portfolio was directed to energy projects.

3. JICA'S POLICY FOR ENERGY AND INFRASTRUCTURE DEVELOPMENT

In 2013, JICA approved its energy sector position paper. In 2016, it published its position paper for achieving SDG7(JICA, 2016⁴). In that paper, JICA laid out a "3L Policy" as its basic modus operandi. The 3Ls stand for low-cost, low-carbon, and low-risk.

- (a) **Low cost** means to recommend the least cost option for our clients. Our emphasis is to consider the total life cycle cost of the project, rather than just the amount of initial investment. Also, from the perspective of reducing cost, high efficiency and low environmental impact are crucial. Leveraging private sector finance can also be an effective option to reduce project cost.

³ Exchange rate: 1 USD=100 JPY

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[http://knowledge.jica.go.jp/km/FSubject9999.nsf/3b8a2d403517ae4549256f2d002e1dcc/1c672a33f63b0a74492581f40023cb83/\\$FILE/Goal7%20Energy%20-%20JICA's%20Position%20Paper%20on%20SDGs.pdf](http://knowledge.jica.go.jp/km/FSubject9999.nsf/3b8a2d403517ae4549256f2d002e1dcc/1c672a33f63b0a74492581f40023cb83/$FILE/Goal7%20Energy%20-%20JICA's%20Position%20Paper%20on%20SDGs.pdf)

- (b) **Low carbon** development means that we contribute towards a zero-emission society. The bulk of CO₂ emissions come from national power grids. Therefore, for traditional power plants, improving efficiency is necessary. Also, scaling up the use of renewables while maintaining the stability of electrical grids is important. Reducing power transmission and distribution losses, along with promoting energy conservation, are also effective in lowering CO₂ emissions emanating from national power grids.
- (c) **Low risk** means to reduce the client country's risks that threaten stable energy supply. Specifically, JICA will support client countries in securing primary energy sources, realizing the best mix of energy, and ensuring power system stabilization.

In 2016, the Japanese government undertook several notable initiatives to promote quality infrastructure and energy development in Africa. In May 2016, Prime Minister Abe launched an initiative titled *Expanded Partnership for Quality Infrastructure* at the 24th meeting of the Management Council for Infrastructure Strategy⁵. The initiative aims to provide approx. 200 billion USD in financing to infrastructure projects around the world for five years starting from 2016. Later that month, the G7 Ise-shima Summit was held in Japan, during which the G7 Ise-Shima Principles for Promoting Quality Infrastructure Investment were announced. These five principles strive to align G7 member-countries' infrastructure investments in line with the following: the need to consider life-cycle cost, efficiency, resilience against external risks, job creation, capacity building, social and environmental considerations, climate change mitigation, and promoting private-public partnerships⁶.

In August 2016, the Sixth Tokyo International Conference on African Development (TICAD VI) was held in Nairobi, Kenya. The conference was led by Japan and co-organized with the UN, UNDP, the World Bank, and the African Union Commission (AUC). The Japanese government's delegation to TICAD VI was headed by Prime Minister Abe. Fifty-three African countries were represented at the conference and a business mission with leaders from 77 organizations, including Japanese businesses and universities, accompanied the delegation⁷. At the opening session, Prime Minister Abe announced that Japan will assist its partner countries in delivering electricity derived from geothermal sources to 3 million households by 2022⁸.

In addition, in April 2018, JICA's President Kitaoka showed his commitment to supporting geothermal development worldwide when he delivered a closing plenary speech during the 4th Iceland Geothermal Conference⁹.

⁵ http://www.meti.go.jp/english/press/2016/0523_01.html

⁶ <https://www.mofa.go.jp/files/000160272.pdf>

⁷ https://www.mofa.go.jp/af/af1/page3e_000551.html

⁸ https://www.mofa.go.jp/af/af2/page4e_000496.html

⁹ https://www.jica.go.jp/english/about/president/speech/180426_01.html

4. THE ADVANTAGES AND CHALLENGES OF GEOTHERMAL DEVELOPMENT

In this section, we will explain what are the advantages and challenges of geothermal energy and how JICA intends to tackle the latter. It will be followed by discussion on the government's roles in leading surface surveys and upfront risk taking, the need capacity development, and role of concessional financing. It will then explain JICA's assistance strategy for the global geothermal sector.

4.1 Advantages

Geothermal energy's advantages are that it is cheap, clean, stable, and a domestic energy source. Geothermal energy's global weighted average levelized cost of electricity (LCOE) in 2017 was around USD 0.07/kWh, which was only slightly higher than hydropower (USD 0.05/kWh) and onshore wind (USD 0.06/kWh) and lower than solar photovoltaic (PV) (USD 0.10/kWh) (IRENA, 2018). The amount of carbon emissions, meanwhile, is as low as hydro, wind, and solar (IRENA, 2017).

Although there are high risks during the upstream development stages, geothermal energy can be used as a base load power for decades if it is maintained properly. As an example, last year in 2017, Japan's first geothermal power plant, Matsukawa Geothermal Power Plant, celebrated its 50th anniversary since being commissioned. Another example is Kenya's Olkaria I Units 1 to 3 that have generated power for more than three decades. The units will undergo rehabilitation, and we expect that the upgraded units will provide power for another three decades. For many countries, having a stable, non-variable, and domestic energy source is paramount to their national energy security.

4.2 Challenges and proposed measures

The main challenges pertaining to geothermal energy that JICA addresses are (a) high resource development risks especially during the test drilling stage, (b) large upfront investment, and (c) managing cash flow plus proper operation and maintenance of plants and reservoirs.

Resource risk and financial risk are extremely high in the early stages of geothermal development. There are two specific bottlenecks: the low success rate of drilling boreholes for reservoir identification and high drilling cost. On average, the success rate for drilling boreholes is below 50%. In the case of locations where the geothermal resource is not yet confirmed, the success rate drops below 30%. Yet the estimated cost to drill a borehole with a final diameter of 8-1/2 inches is approximately US\$ 6 to 8 million. Securing funding for this high-risk stage is challenging, as is improving the drilling success rate once funds are secured. Meeting that second challenge will depend not only on technical drilling skills, but also on the quality of surface surveys and conceptual modeling.

The following sections will discuss the role of governments in promoting geothermal development, need for capacity development of geothermal professionals, and role of concessional financing.

4.2.1 Role of governments in early stages of development

Geothermal resource development risk is usually beyond private companies' risk appetite because it is extraordinarily high. Indeed, it is very likely that the entire project will be seriously affected if a borehole fails to identify the geothermal resource. Considering such circumstances, the financial capacities of operators need to reach a certain volume for them to be able to tolerate the risk of underground exploration. Operators with enough financial means can spread risks by drilling in multiple locations, instead of drilling solely in one location. In that case, even if 6 out of 10 targeted drillings fail, the remaining 4 successful drillings would be sufficient to cover expenditures for the expected power plant (Kaneko, 2013).

Public sector can take or share upstream development risks that are usually too high for the private sector to cover. In fact, a series of surveys conducted by Japan's New Energy and Industrial Technology Development Organization (NEDO) from 1980 to 2010 was based on this model (see Box 1).

Given this situation, the public sectors of countries like Kenya, Ethiopia, Tanzania, Djibouti, Rwanda, and Uganda are now trying to assume—partly or entirely—the risk of underground exploration in order to accelerate geothermal development. In fact, the government of Kenya established the Geothermal Development Company (GDC) in 2009 to conduct surface surveys, exploratory drilling, and reservoir evaluations. Under these circumstances, which are marked by the transfer of risk and responsibility from the private sector to the public (governmental) sector—and apart from the necessary large-scale financial assistance—there is an urgent need to develop the capacities of core human resources in order to ensure further geothermal development. If the government proactively takes development risks in the upstream development stages by conducting surveys and publishing their results, it can contribute to lowering the private sector's risks and encourage their participation in geothermal development.

If governments can take the lead in improving the accuracy of geological surveys, developing supervising capacity for drilling operations, and evaluating geothermal reservoirs, then the achievements in each of these areas can positively impact all geothermal development stakeholders.

Geothermal development requires a long period of time for accumulating data on underground resources, as illustrated by the fact that the Japanese government undertook a series of surveys over three decades to find prospective sites in Japan. This laid the groundwork for two periods of accelerated growth in geothermal development in Japan. Based on lessons learned from Japan's experiences at home and abroad, it could be said that the following two measures contribute to accelerating geothermal development in developing countries.

- It is more realistic for the government rather than the private sector to take the risk of exploring underground resources. This risk can be significantly reduced by developing appropriate human resources.
- It is effective to provide financial support on favorable terms to governments for the exploration of geothermal resources.

Improving the Internal Rate of Return (IRR) of geothermal projects is indispensable to promoting this form of energy, all the more so now that it is increasingly competing against cheaper and more accessible resources such as solar and wind. JICA implements five activities, described below, to mitigate risks and remove barriers associated with geothermal development.

4.2.2 Need for capacity development

Geothermal development requires diverse and highly qualified human resources, i.e. professionals with a scientific background as well as practical and technical experience in geology, geochemistry, geophysics, reservoir engineering, environmental studies, chemistry of thermal fluids, drilling, plant design engineering and construction, etc. But these human resources cannot be developed overnight. Therefore, institutions responsible for developing geothermal resources must also have a long-term plan for developing their own staffs' capacities.

Training abroad, such as in Iceland, New Zealand, Italy, or Japan, is very effective in this regard. But overseas training is not sufficient to fill the large capacity gap of the Great Rift Valley. A study conducted by JICA in 2010 concluded that five surveyed countries (Kenya, Ethiopia, Djibouti, Uganda, and Tanzania) needed about 900 more geothermal professionals in the next ten years in order to develop their underground resources. Considering that UNU-GTP trains around 100 professionals in ten years and JICA's goal of training 480 professionals in Japan in ten years, it is evident that overseas training is not sufficient to fill the gap. In order to fill the gap, there should be a regional training institution, as well as internal training system in each geothermal development organization so that a wide range of staff are trained on the job. JICA's on-going technical cooperation with Kenya's GDC aims to train the trainers so that they can produce and update their own training modules.

Improving drilling capacity can also reduce the risks of individual geothermal projects and improve profitability. The rationale for this is that capacity development contributes to improving drilling success rates, which could then minimize project period and therefore cost. Saito and Sakuma (2002) conducted a comprehensive review of drilling problems due to human error that occurred within the geothermal group of Japan Metals & Chemicals Co., Ltd between 1988 and 2001. They categorized these observed problems into the following three main types;

- a) leaving tools and/or equipment behind around the well, resulting in accidentally dropping them down the hole
- b) stuck pipe due to well walls collapsing
- c) breakdown of machine or spare parts

Because these actions are human errors, they can be improved through capacity development training. Theoretically, if the frequency of human errors—such as dropping tools down wells—decreases, time wastage will decrease and the drilling period can be shortened. We therefore contend that capacity development contributes to improving the drilling success rate and economic efficiency.

Saito and Sakuma then suggest ways to improve operation management systems, among which the following actions stand out:

- a) train drillers
- b) renew stabilizers and other machines and implement recording systems of these machines
- c) reconsider the frequency of drill string examination and examination standards
- d) select machines based on the number of working days
- e) conduct regular maintenance

In JICA's on-going technical cooperation project with Kenya's GDC, the rate of penetration (ROP) of its drillers improved by two-fold from a baseline of 25 ROP m/day (2014) to 50 ROP m/day (2018). Also, during the project, 13 wells were drilled with no failed (unproductive) wells.

Enhancing reservoir identification skills and scientific technology can also impact the drilling success rate and economic efficiency. Therefore, JICA provides technical cooperation through on-the-job-training and various training courses to improve these skills.

4.2.3 Role of concessional financing

Besides capacity development, JICA offers financial assistance on favorable terms. Financial assistance and capacity development are both indispensable. For example, it would be difficult to start or continue a geothermal development project by solely implementing capacity development, since such projects require a huge amount of investment and can suffer from a lack of funds. Conversely, even if finance is available, if the development institution lacks the capacity to implement the project, it will experience difficulty such as delays, drilling failures, and cost overrun.

Concessional financing for geothermal power plants is effective because more than half of the geothermal power's generation cost is composed of capital cost. According to Kaneko (2013), the ratio of capital cost in generation cost of geothermal power plants around 70%, whereas that of coal-fired plants is around 30% (more than half of coal-fired plant's generation cost is the fuel cost). Therefore, if concessional financing can bring down the capital cost of geothermal, then it will reflect directly on the generation cost.

4.2.4 JICA's assistance strategy for the geothermal sector

JICA provides both technical assistance for capacity development and financial assistance through grants and/or ODA loans with favorable terms. As for technical assistance, JICA focuses on capacity development to improve various aspects of geothermal development, including the success rate of exploratory drillings and the accuracy needed for the evaluation of geothermal reservoirs. JICA's five activities for mitigating risks and removing barriers associated with geothermal development are;

- (1) Capacity building and human resource development to improve the success rate of drilling and reduce project time period.
- (2) Test drilling projects that contribute directly to identifying geothermal resources. JICA supports test drilling in high-risk greenfield areas. In order for JICA to take these risks, JICA convenes an external advisory group for test drilling projects that consists of professors and well-experienced developers and drillers. The advisory

group provides vital technical advice on selected targets and drilling plans in these countries.

- (3) Geothermal development policy and strategic planning to prioritize potential geothermal development sites in a country. JICA also provides technical advice to promote public-private-partnerships (PPP) and stimulate private investment.
- (4) Research development in exploration and drilling technology to improve the drilling success rate and establish a monitoring system for long-term utilization of reservoirs.
- (5) Concessional funds that consist of Japanese ODA grant aid, Yen Loan, and Private Sector Investment Finance (PSIF) for plant construction projects.

4. GEOTHERMAL DEVELOPMENT IN EAST AFRICA

The Japanese government and JICA have assisted partner countries in developing geothermal energy since the 1970s. From the 1970s to 2000s, JICA's assistance concentrated mostly in Asia and Latin America¹⁰. In the 2010s, JICA shifted its focus to include the African Rift Valley.

In 2010, JICA conducted a comprehensive survey spanning five countries; Kenya, Ethiopia, Djibouti, Tanzania, and Uganda to understand the region's geothermal potential, geothermal development policy and roadmaps, and the state of human resources and equipment in the sector. The survey, *Situation Analysis Study on Geothermal Development in Africa* (2010), concluded with several recommendations for how JICA can assist its partner countries. Following the survey, JICA conducted similar studies in 2013 in Rwanda and Southern African countries (Malawi, Mozambique, and Zambia).

The main findings of the Situation Analysis Study on Geothermal Development in Africa from 2010 were as follows.

- Governments should take a leading role in upstream development, since private companies are unlikely to participate in the development of areas where there are no exploration wells. The Kenyan government is currently playing a leading role in the country's geothermal development in precisely this manner. Therefore, the Kenyan model is recommended as a paradigm of success for the rest of East Africa
- The current number of equipment and geothermal professionals (engineers and geoscientists) in each country are seriously lacking. Currently, 368 geothermal professionals are employed across various institutions and by IPPs in the five countries, but 903 more are necessary (Table 1). Local universities are not well-equipped in terms of the capacity of lecturers to train geothermal engineers. The UNU-GTP program is popular due to its focus on providing practical skills, but the number of professionals it can train is limited (100 professionals in 10 years).

¹⁰ Since 1970s, 19 exploration and resource evaluation surveys were carried out in Asia, Latin America, and Africa. Training course for geothermal resource engineer also started in 1970. In 1977, the first loan agreement for geothermal development was signed between the Japan and Nicaragua. Between 1980s and 2000s, lending operation for geothermal development were concentrated in Philippines and Indonesia.

Therefore, a regional training institution is necessary. Moreover, 600 million USD worth of equipment for geo-scientific analysis, drilling, vehicles, weather stations, GIS, etc. is necessary.

Table 1: Summary of capacity and equipment gaps for the five countries (JICA, 2010)

Country	current number of engineers	additional engineers necessary for 2010-2020	necessary budget for additional equipment (million USD)
Kenya	211	401	447 (includes 14 rigs)
Ethiopia	72	285	131(includes 4 rigs)
Djibouti	22	57	7.5
Tanzania	35	83	7.6
Uganda	28	77	7.6
Total	368	903	600.7

The survey made the following recommendations for JICA's cooperation in the Great Rift Valley.

- JICA should take upfront development risks by undertaking initial surveys that include the drilling of several exploration wells.
- JICA should link the training programs in Japan with development projects in the trainees' countries so that they can directly utilize their skills on the job after returning to their country.

The following section highlights JICA's assistance in Kenya and Ethiopia, and Djibouti. A brief overview is as follows.

In Kenya, JICA is currently implementing a technical cooperation project to assist GDC to develop its capacity in resource exploration. A PPP advisor in Kenya is currently advising the Ministry of Energy on PPP policy and parastatal organizations (KenGen, GDC) on how to fully utilize PPP for geothermal development. JICA and UNIDO are preparing another project to assist KenGen to upgrade its operation and maintenance of Olkaria geothermal field using Internet of Things (IoT) technology.

In Ethiopia, JICA is conducting a feasibility study for a Yen Loan project to construct a geothermal power plant in Alto Langano. It is also providing grant aid to construct a wellhead geothermal generator in the area using steam from the two test wells drilled with assistance from the Japanese government and the World Bank. JICA is also taking upstream risks and preparing to drill test wells in Tendaho, Ethiopia.

In Djibouti, JICA conducted a nation-wide survey to understand geothermal development potential there and to prioritize prospective sites based on economic and technical

analysis. After three years of surface surveys, preparation is underway for a technical cooperation project focused on test well drilling in Hanle, Djibouti.

4.1 Kenya

The Kenyan government has prioritized geothermal development in the country's long-term development plan—*Vision 2030*—with the anticipation of generating 5,000 MW of electricity from geothermal resources. JICA has supported this goal since 2010 through three Yen Loan projects that increased power generation in the Olkaria geothermal field, three technical cooperation projects alongside the GDC and KenGen, and the dispatch of Public-Private Partnership (PPP) experts to the Ministry of Energy.

4.1.1. Yen Loan Projects

JICA has so far signed three ODA loans agreements with the Kenyan government for geothermal development. In total, these loans amount to JPY 84.5 billion (around 845 million USD) and will support construction of geothermal power plants with 418.7 MW of electricity generation capacity.

In 2010, JICA signed the first Japanese ODA loan agreement to construct Olkaria I Units 4 and 5, with 140 MW (2 x 70 MW) of capacity. The plant was commissioned in 2015. Utilizing the remaining loan balance, a contract for the construction of an additional Unit 6, with 70 MW of capacity, is expected to be signed before December 2018.

In 2016, a second Japanese ODA loan agreement was signed to construct Olkaria V Geothermal Power Plant Units 1 and 2, as well as for the installation of a steam gathering system, substation, and transmission line. The total capacity of this Plant is 158 MW, and construction is planned to be completed in mid-2019.

In 2018, JICA signed the third loan agreement to rehabilitate the oldest geothermal power plant—Olkaria I Units 1, 2, and 3. The first unit of Olkaria I started operations in the 1980s, so the plant has reached the end of its life-span. The plant's total current capacity is 45 MW (15 MW per unit). After rehabilitation, the plant's output will be upgraded to a total net capacity of 50.7 MW (16.9 MW per unit), and it will provide power for another 30 years.

JICA is also currently supporting the construction of a double circuit 400kV transmission line from Olkaria to Lessos (230km), a 220kV transmission line from Lessos to Kisumu (70km), and three substations. The loan agreement for these transmission lines was signed in 2010 and construction is to be completed in February 2019. The project will contribute to strengthening the grid in order to allow for additional generation capacity and to transmit power to the poorly connected western region of the country. The project will also act as gateway to the East African Power Pool connectivity, as AfDB is financing another transmission line from Lessos to Uganda.

4.1.2. Technical Cooperation Projects

<Capacity Strengthening of GDC>

In 2009, the Kenyan government established GDC to further accelerate geothermal development in Kenya. GDC was expected to take upfront risks associated with resource exploration and steam development. It was tasked with conducting surface surveys,

exploratory drilling, resource evaluation, and supplying steam to IPPs (Independent Power Producers).

In 2013, four years after GDC's establishment, JICA and GDC started a technical cooperation project, *The Project for Capacity Strengthening for Geothermal Development* in Kenya. The project aims to improve GDC's capacity to manage technical risks, so that it will be able to supply geothermal plant operators with sufficient steam. This project will be completed in August 2019.

Through this technical cooperation project, JICA experts train GDC staff on-the-job in geothermal fields, mainly in Menengai. Training is provided for the full spectrum of geothermal development, from surface surveys, exploration, and plant design. GDC staff is trained in geosciences, reservoir engineering, drilling, environmental and social considerations, direct use, plant engineering, and economic and financial analysis of projects. Each course is tailor-designed based on interviews with staff from each GDC department. The project will jointly produce training modules for GDC staff. At project completion, GDC is expected to conduct its own course, as well as to continuously improve its contents.

The project has so far trained a total of 421 personnel in seven professional areas; (a) geosciences and reservoir engineering, (b) drilling, (c) environmental and social considerations, (d) plant engineering, (e) direct use, (f) business development, and (g) project management and finance.

The rate of penetration (ROP) improved by two-fold in four years (from a baseline of 25 ROP m/day in 2014 to 50 ROP m/day in 2018). The success rate of drilling also improved. After May 2014 when the project started intensive drilling training, GDC have successfully drilled 13 wells, all them producing steam. The project also assisted GDC in reevaluating the Menengai geothermal reservoir for a 105 MW IPP project. This helped GDC to assure the IPP developers and financiers of the technical feasibility of its steam supply.

In 2014, a year after the GDC capacity development project started, JICA and GDC started another technical cooperation project, the Project for Reviewing GDC's Geothermal Development Strategy in Kenya.

This project re-evaluated five prospects: Arus, Baringo, Korosi, Chepchuk, Paka, and Silali. It also revised the estimates of resource potential at 8 sites¹¹ using the volumetric method, while detailed surveys, conceptual model, and well targets were developed for Paka, Korosi and Chepchuk. The project reviewed GDC's existing strategy and made recommendations. It was completed in 2017.

<IOT>

JICA is currently designing a technical cooperation project that aims to improve KenGen's capacity to maintain and operate its Olkaria geothermal field. In 2017, JICA

¹¹ Paka, Korosi, Chepchuk, Arus, Baringo, Barrier, Namarunu and Emurangogolak

conducted a preliminary survey for the project and suggested the following: (a) to establish a database system that integrates data from different power plants and wells, and (b) to develop KenGen staff's capacity to operate and maintain the power plants and the reservoir. The project will be an initial step for Olkaria geothermal field to evolve into an Internet of Things (IoT) system.

With the installation of the IT infrastructure in KenGen's geothermal power plants, it will be able to collect and store appropriate information and data related to O&M of its power plants and the geothermal reservoir. In addition, through JICA's O&M project, KenGen will be able to monitor plant operations in real-time, predict problems with analysis based on data storage, plan efficient and economical maintenance and repair schedules based on long-term operational data plus inspection data collected during maintenance, and manage the reservoir via measuring, monitoring, and modeling.

JICA is collaborating with UNIDO (United Nations Industrial Development Organization) in order to achieve a common goal of improving the efficiency of KenGen's power plant operation and improving its profitability as a result. UNIDO will be responsible for installing the IT infrastructure, and JICA will be responsible for training KenGen's engineers to improve its O&M. Both JICA and UNIDO's projects are expected to start in 2019.

<PPP Advisor>

Since 2017, JICA's public-private-partnership (PPP) experts have supported Kenya's Ministry of Energy by promoting private sector involvement in the country's power sector market. While the World Bank is supporting PPP promotion by establishing a PPP unit in the National Treasury, the PPP experts are advising the Ministry of Energy on policies such as Least Cost Power Development Plan (LCPDP) and Feed in Tariffs (FIT). They have conducted workshops for the MoE, KenGen, and GDC staff geared toward the development and analysis of project finance models. The experts' mission will finish at the end of 2018.

4.2 Ethiopia

4.2.1. Aluto Langano

At Aluto Langano, in Ethiopia, Japan has been supporting several projects including test well drilling, installation of wellhead generator, and feasibility study for construction of a power plant.

From 2010 to 2016, the Japanese government and the World Bank supported the drilling of two exploratory wells, reservoir evaluation, drilling training, and rig maintenance.

In December 2017, JICA signed an agreement with Ethiopia to provide up to approximately 1.8 billion yen in grant aid for the *Project for Installation of Geothermal Wellhead Power System* (installed capacity of 5 MWe). The wellhead power system will utilize the steam from the two exploratory wells. The installation of a power system is now ongoing.

Since 2017, JICA also has been implementing a preparatory survey a Yen Loan project, *Aluto Langano Geothermal Power Generation Project*. The main components of this

project will be the construction of a geothermal power plant (expected capacity of 35 MWe) and its related facilities. The survey will propose the design of the power plant and related facilities (such as transmission lines) based on resource evaluations of 22 well drillings in the Aluto area, including in Langano and Bobessa, (which the World Bank is supporting).

4.2.2. Test well drilling project in Tendaho-Ayrobera

From 2015 to 2017, JICA implemented a surface survey at both Tendaho and Boseti under the *Data Collection Survey for Geothermal Development in Ethiopia*. After calculation of geothermal potential of both sites, Tendaho-Ayrobera, with estimated geothermal potential of 25 MWe, was proposed as a hopeful site for test well drilling. The survey also formulated a conceptual reservoir model and drilling plan for the site.

Based on these data, JICA is now planning to support test well drilling at Tendaho-Ayrobera and detailed surface survey at Butajira. Capacity building of counterparts is planned to be conducted simultaneously.

4.2.3. Master Plan

From 2013 to 2015, JICA conducted *The Project for Formulating Master Plan on Development of Geothermal Energy in Ethiopia*. The main purpose of the project was to enhance the capacity of Geological Survey of Ethiopia (GSE) by supporting the formulation of a master plan for geothermal energy development and through training programs in both Japan and Ethiopia.

The Project Team jointly composed of JICA consultants and GSE assessed geothermal resources of 22 sites in Ethiopia based on existing information, remote sensing analysis, field geological and geochemical survey followed by its laboratory analysis, and environmental-social impact assessment. The Team then prioritized the sites based on geothermal potential, social and environmental consideration, economic viability and generation cost.

The financial analysis revealed that the generation cost could be below the present domestic tariff level when the sites that ranked the highest are developed with very concessional financing programs such as Japan's ODA loans; The generation cost could then be below the present exporting tariff level sites are developed with concessional financing programs such as World Bank loans; the generation cost will exceed the both tariff levels if geothermal sites are developed with private funds. Therefore, if private investments are to be promoted, financial and/or institutional supporting policies will have to be established. The team also recommended that geothermal development should be implemented by a public entity that shall handle projects with public financing schemes.

The Team also conducted geophysical surveys in Tendao-Ayrobera and Boseti. Based on the geophysical survey conducted, the outer limits of geothermal reservoir were preliminarily inferred for each site, and targets of test wells were proposed. Training programs were conducted both in Japan and in Ethiopia in the following areas: remote sensing, geophysics, reservoir evaluation, geochemistry, database with 3D modeling, fluid analysis, simulation, drilling technology, advanced technology, and geothermal development.

4.2.4. Policy advice

In 2016, Japan's Agency for Natural Resources and Energy of the Ministry of Economy, Trade, and Industry, organized a joint workshop with the Ethiopian government to stimulate discussions and deliver suggestions on options for establishing an integrated institution for geothermal development. During the workshop, various ideas were proposed to the Ethiopian government regarding different roles the government and private sector can play to accelerate geothermal development. Different ideas and point of views were exchanged through the workshop. The dialogue covered the pros and cons of i) possible institutional structures to expedite geothermal development and ii) geothermal development by private companies and State-Owned-Enterprises. The discussions were based on JICA's analysis of different country models, characteristics of geothermal development such as development investment cost, and comparisons of practical experiences in other countries.

4.3 Djibouti

Djibouti is currently experiencing a very strong and rapid growth. Djibouti's energy demand is growing at around 5% every year. The Djiboutian government's Vision 2035 aims to transform from a power importing country to be self-sufficient. It aims to harness the rich geothermal resources that have remained untapped until now.

In 2013, when Prime Minister Abe visited Djibouti, H.E. President Mr. Ismaïl Omar Guelleh requested the prime minister to assist Djibouti to develop its geothermal resources. Following the request, JICA and ODDEC conducted a country wide survey and identified 13 potential sites to be developed. Out of these sites, Hanle-Garrabayis was selected as a site to be further explored. After nearly two years of surface survey, a conceptual model and a drilling plan for exploratory drilling in Hanle was developed. The test well drilling project aims to drill up to three exploratory wells, and at the same time, aims to develop ODDEC's capacity to supervise and manage geothermal drilling.

4.4 Training course and researches in Geothermal Development

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

In 2016, responding to requests from client countries, JICA started three new training courses for geothermal development in Japan. More than 35 organizations from the public sector, private sector, and universities are collaborating for these courses. JICA also has programs that offer Masters and Ph.D. courses to engineers and scholars from client countries. With a total of four (4) courses, and starting from 2013, JICA is aiming to host 480 African participants in these courses over 10 years as a commitment made at the Fifth Tokyo International Conference for African Development (TICAD V).

- **Geothermal Resource Engineer Trainig Course:** a 6-month course with an emphasis on practical training for engineers in geology, geochemistry geophysics, and reservoir engineering that has been implemented since 2016 by Kyushu University in collaboration with Tohoku University, National Institute of Advanced Industrial Science and Technology (AIST), developers, and consultants.
- **Drilling Manager Training Course:** 6-week course implemented since 2016 together with developers and drilling contractors that aims to enhance drilling managers'

capacity to supervise drilling contractors. A unique textbook including failure case analysis based on practical geothermal development experiences in Japan was prepared for this course.

- **Geothermal Executive Training Course:** One and a half week course for directors in geothermal development planning implemented since 2016 together with ministry officials, consultants, developers, and manufactures.
- **Kizuna Program and ABE Program:** Master's and Ph. D courses for engineers in geology, geochemistry, geophysics, and reservoir engineering, implemented since 2014.
- **Science and Technology Research Partnership for Sustainable Development (SATREPS):** A joint research program conducted by the 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. There are on-going projects in El Salvador and Indonesia, but none so far in Africa.

4.4 Securing funds for development

JICA can provide Japanese ODA loans for governments to take upfront risks for exploratory surveys, development of production and reinjection wells, plant construction, and O&M. Japanese ODA loans are available with low interest rates, long repayment periods, and generous loan terms and conditions.

Since 2010, JICA has financed approximately 85.3 billion Japanese Yen (approx. 77.5 million USD) for geothermal development projects in Kenya, with an expected installed power capacity of 419 MW (Table 2: List of ODA Loan Project for geothermal development

Loan Agreement (L/A)	Project name	date of agreement	Cost of Loan (mil yen)	Interest rate (%)	repayment / grace	Installed capacity (MW)	Remarks
First L/A	Olkaria I Unit 4 and 5 Geothermal Power Project	March-10 2010	29,516	0.2	10/30	140	Completed
	Olkaria I Unit 6	-	-	-	-	70	Unutilized balance of the first L/A.
Second L/A	Olkaria V Geothermal Development Project	March-16 2016	45,690	0.2	10/30	158	Commission mid 2019
Third L/A	Rehabilitation of Olkaria I Unit 1, 2, and 3	March-16 2018	10,077	1.0	10/30	51	
Total			85,283			419	

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5. CONCLUSION

Since the late 2000s, the Japanese government and JICA have actively engaged in the Great Rift Valley region to unlock its vast geothermal capacity. JICA is combining financial assistance with improvement of government capacity in order to effectively accelerating geothermal development. It has been shown that capacity development contributes to the improvement of individual projects' economic viability. This capacity development will contribute not only to the success of individual projects, but also to that of other ongoing and planned projects—thus accelerating geothermal development in a comprehensive manner.

Box 1: Experiences of Geothermal Development in Japan

Japan's history of its geothermal development can provide an example on the role of governments to take upfront risks or to share risks with the private sector by undertaking exploratory survey. Japan experienced two spurts of growth in geothermal development growth in the past. This section explains some of the reasons for this growth.

The first experimental drilling of a geothermal resource in Japan was successfully conducted in 1919, and the first geothermal power generation station—with a capacity of 1.12 KW—was installed in Beppu city in 1925. In 1947, the Geological Survey of Japan ¹² (GSJ, now Advanced Industrial Science and Technology (AIST)) began conducting a nation-wide geological survey. As a result, in 1966 Japan's first

¹² GSJ was established in 1882 under the Ministry of Agriculture and Commerce

commercial geothermal power plant—which uses a vapor-dominated system to produce up to 9.5 MW of electricity—was commissioned in Matsukawa.

From 1980 to 2010, in order to promote private sector participation, NEDO undertook a series of geological surveys to identify areas with geothermal potential but where the private sector was reluctant to implement projects due to high development risks. As a result, 42 out of 67 sites surveyed were identified as having temperatures of more than 200 Celsius. Also, steam was discharged successfully at 26 sites.

Japan experienced a major period of growth from 1972 to 1999 (see Figure 1). Although geothermal development in Japan stagnated during the 2000s, efforts to accelerate it resumed after the Great East Japan Earthquake in 2011.

One of the reasons that Japan was able to promote geothermal development is that the Japanese government, through GSJ, NEDO, and other governmental actors, proactively took upfront risks by conducting exploration surveys, offering technical support, and providing financial support. Thus, the resulting accumulation of survey data, technology, practical experiences, and knowledge regarding geothermal development contributed to the rapid formulation of geothermal development in Japan.

It should be noted that Japanese production technology for anti-corrosion turbines has contributed to global geothermal development, and this is one reason why Japanese companies hold approximately 70% of the world market for plant and equipment distribution. By improving the level of Japanese technology, NEDO's projects may have contributed to the production of anti-corrosion turbines.

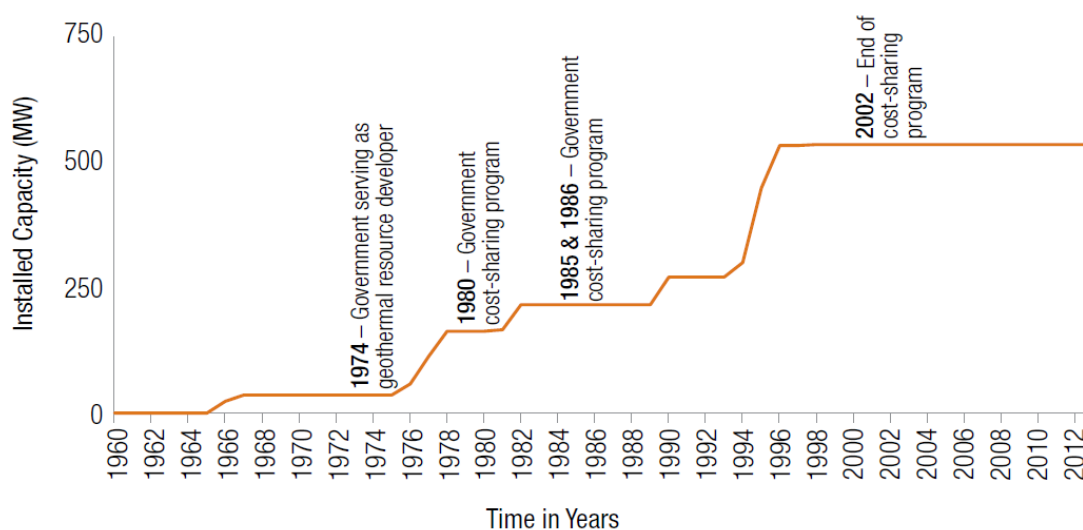


Figure 1: Installed Geothermal Power Capacity over Time in Japan (ESMAP, 2016)

ACKNOWLEDGEMENTS

The team would like to acknowledge the following JICA staff for their contribution: Stace Nicholson for editing; Takahiro Suzuki, Yukio Takahashi, and Evanson Njenga for their

inputs and editing for Kenyan case study; and Gaku Saito for his inputs and editing for the Ethiopian case study.

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