IV SUPPLEMENTARY INVESTIGATION ON ENVIRONMENTAL AND SOCIAL CONSIDERATION

The JICA team performed an Environmental Impact Assessment (EIA), having the same level of Initial Environmental Examination (IEE), based on existing information, data and site surveys. This EIA included literature review on environmental and social consideration, and site survey and interview of local communities regarding the direct use of geothermal resources. Existing document review was performed during Phase I and site survey and other activities were performed during Phase II and later.

The objective of this investigation was collecting and summarizing basic information in order to develop a detailed investigation plan for environmental and social consideration which will be needed during the implementation period of the GDC master plan as a loan assistance project.

IV-1 Literature Review on Environmental and Social Assessment

IV-1.1 National policies and laws related to environmental and social assessment

a. EIA related Kenyan policy and domestic plan

The key legal instruments which provide the framework for environmental protection and management in Kenya include:

i. Constitution of Kenya
ii. Kenya Vision 2030, Session Paper No. 6 of 1999 on Environment and Development
iii. Environmental Management and Coordination Act (EMCA) of 1999; Amended in 2015

b. Relevant laws and agencies on environmental and social assessment

The EMCA is the law for environmental conservation and regulation in Kenya. It stipulates the environmental impact assessment (EIA) procedure and implementation in the country. EMCA's main objective is to provide a legal framework that would incorporate environmental considerations in the pursuit of economic and social development. In order to achieve this objective, the National Environment Management Authority (NEMA) was established. According to EMCA Section 174, the Minister in charge of environmental matters should coordinate with relevant agencies and implement regulations to achieve EMCA conditions.

c. EMCA amendment

The amended Environmental Management and Coordination Act (EMCA) was enacted in June 2015. Key points in the amended Act include the following:

- Voluntary environmental action by county and local community is encouraged and governance of protected area such as community conservancy is recommended. (including easements, leases, payments for ecosystem services and other such instruments) (Section 9)
- Cabinet Secretary, in consultation with NEMA, shall make regulations and formulate guidelines for the practice of Integrated Environmental Impact Assessment (IEIA). (Section 58)
- Penalty for perjury (falsification/misleading information) and other violation of the Environmental Impact Assessment process has been established. (Section 58)
- Transmission line that is lower than 66 KVA, will not be required to conduct an Environmental Impact Assessment.(Second Schedule of the Act)
- Regulation and enforcement are led by Nation and States heretofore but County will govern instead of Nation and States.

- County shall establish environmental standard value for their own county based on the minimum standard that is recommended by National government.

d. Laws and regulations on environmental and social considerations

Kenya has several laws and regulations to address various environmental and social issues. Relevant laws and regulations, international treaties ratified by the government, and the responsible authorities related to environmental and social concerns are summarized in Table IV-1.1 to Table IV-1.5 below, arranged according to the items in the checklist of JICA's Guideline for Environmental and Social Considerations (column 1). It can be observed that Kenya does not have an existing law or regulation related to soil contamination, land subsidence, landscape, and climate change. Moreover, the country's participation in international treaties seems limited.

As shown in Table IV-1.1 to Table IV-1.5, the National Environmental Management Authority (NEMA) and the Ministry of Environment and Natural Resources are mainly responsible for implementing environmental laws and regulations. On the other hand, different ministries (e.g. Ministry of Culture, Ministry of Land, Housing and Urban Development, Ministry of Transport and Ministry of Health) are in charge of different social aspects. It is worth noting that local governments play an important role in implementing national policies at the local level.

Table IV-1.1 Environmental and Social Laws, Regulations and Relevant Agencies (1)

Items	Kenya's Laws and Regulations	International Treaties	Relevant Agencies
Air Quality	・ Environmental Management and Coordination Act, 1999 ・The Environmental Management and Coordination (Air Quality) Regulations, 2008 (Draft)		NEMA
Water Quality	・Environmental Management and Coordination Act, 1999 ・Water Resources Management Rules, 2006 ・The Environmental Management and Coordination (Water Quality) Regulations, 2006 ・Water Quality Regulations, 2006		Ministry of Environment and Natural Resources, NEMA
Water Resources	・Water Act, 2002 ・Water Resources Management Rules, 2006 ・Lakes and Rivers Act ・Penal Code Cap 63		Ministry of Water
Offensive Odor	・Penal Code Cap 63		
Noise	・Environmental Management and Coordination (Noise and Excessive Vibration), 2009 ・Penal Code Cap 63		
Vibration	・Environmental Management and Coordination (Noise and Excessive Vibration), 2009		NEMA, Local Authority Government
Soil Pollution	None		

Table IV-1.2 Environmental and Social Laws, Regulations and Relevant Agencies (2)

Items	Kenya's Laws and Regulations	International Treaties	Relevant Agencies
Land Subsidence	None		
Cultural & Historical Sites	・National Museums and Heritage Act, 2009 ・The Antiquities and Monuments Act, 1983 Cap 215	・UNESCO Convention for the Protection of the World Cultural and Natural Heritage	Ministry of Culture
Landscape			
Protected areas, National parks	・Wildlife Conservation and Management Act, 2013	・The Ramsar Convention on Wetland of International Importance Especially as Waterfowl Habitat ・UNESCO Convention for the Protection of the World Cultural and Natural Heritage	Ministry of Environment and Natural Resources, KWS
Protected forests	・Forest Conservation and Management Bill, 2014		KFS
Protected species; Important species in the region	・Wildlife Conservation and Management Act, 2013	・The Convention on the Conservation of Migratory Species of Wild Animals ・Convention International Trade in Endangered Species of Wild Fauna and Flora	Ministry of Environment and Natural Resources, KWS
Ecosystem	・Environmental Management and Coordination (Wetlands, River Banks, Lake Shores and Sea Shore Management) Regulation, 2009 ・ The Lake and Rivers Act, (Cap. 409)	・Convention on Biological Diversity	Ministry of Environment and Natural Resources , Ministry of Water, NEMA
Topology, Geology	・Constitution of Kenya	・United Nations Convention to Combat Desertification	Government of Kenya

Table IV-1.3 Environmental and Social Laws, Regulations and Relevant Agencies (3)

Items	Kenya's Laws and Regulations	International Treaties	Relevant Agencies
Resettlement	・Constitution of Kenya ・Land Act , 2012 ・The Land Registration Act , 2012 ・The Environmental and Land Court Act , 2011	・World Bank Safeguard Policy (OP 4.12)	Ministry of Land, Housing and Urban Development
Social Environment	・Land Act, 2012 ・National Land Commission Act, 2012 ・Land Registration Act, 2012 ・The Way Leaves Act Cap 292 ・The Registration of Titles Act Cap 281 ・The Land Titles Act Cap 282 ・Land Adjudication Act (Cap 284) ・Trust Lands Act Cap 288 of 1962 (revised 1970) ・Public Roads and Roads of Access Act (Cap. 399) ・The Local Government Act (Cap.265) ・The Physical Planning Act, Cap 286 ・The Land Planning Act (Cap. 303)		Ministry of Lands and Housing, Ministry of Transportation, Local Government
Minority Groups, Indigenous People	・Constitution of Kenya	・World Bank Safeguard Policy (OP 4.10) ・United Nations Declaration on the Rights of Indigenous Peoples	Government of Kenya
Water Discharge, Emissions	・Water Resources Management Rules, 2006 ・The Environmental Management and Coordination (Water Quality) Regulations, 2006 ・The Public Health Act Cap 242 ・Penal Code Cap 63		Ministry of Environment and Natural Resources, Ministry of Health, NEMA
Occupational Health and Safety, Infectious Disease	・Public Health Act Cap 242 ・Occupational Safety and Health Act, No. 15 of 2007 ・Use of Poisonous Substances Act(1983) ・Workmen's Compensation Act (1988) ・The Factories (Building Operations and Works of Engineering Construction) Rules, Legal Notice. No.40 (1984)		Ministry of Health

Table IV-1.4 Environmental and Social Laws, Regulations and Relevant Agencies (4)

Items	Kenya's Laws and Regulations	International Treaties	Relevant Agencies
Climate Change		・Kyoto Protocol to United Nations Framework Convention on Climate Change ・The United Nations Framework Convention on Climate Change	Ministry of Environment and Natural Resources
Waste	・Environmental Management and Coordination Act, 1999 ・Environmental Management and Coordination (Waste Management) Regulation, 2006 ・Waste Management Regulations, 2006 (Legal notice No. 121) ・The Local Government Act, (Cap. 265)		NEMA, Ministry of Environment and Natural Resources
Environmental Impact Assessment	・Environmental Management and Coordination Act, 1999 ・Environmental Impact Assessment and Audit Regulations, 2003 ・Environmental Impact Assessment Guidelines and Administrative Procedures, 2002 ・National Guidelines for Strategic Environmental Assessment in Kenya, 2012 ・The Physical Planning Act, Cap 286	・World Bank Safeguard 4.01-Environmental Assessment	NEMA
Strategic Environmental Assessment	・Environmental Management and Coordination Act, 1999 ・Environmental Impact Assessment and Audit Regulations, 2003 ・Environmental Impact Assessment Guidelines and Administrative Procedures, 2002 ・National Guidelines for Strategic Environmental Assessment in Kenya, 2012		NEMA

Table IV-1.5 Environmental and Social Laws, Regulations and Relevant Agencies (5)

Items	Kenya's Laws and Regulations	International Treaties	Relevant Agencies
Monitoring	・The Environmental Management and Coordination (Water Quality) Regulations, 2006		NEMA
Geothermal Development	・Geothermal Resource Act of 1982 ・The Geothermal Resources Regulations Act, 1990 ・Energy Act Cap. 12		Ministry of Energy, GDC, KENGEN, KPLC and KETRACO

e. EIA system

The EIA procedures in Kenya are carried out in accordance to the Environmental Management and Coordination Act (EMCA) of 1999. The EMCA's main objective is to provide a legal framework for integrating environmental considerations into the country's overall economic and social development. The major institution established to implement and operationalize the objectives of EMCA is the National Environment Management Authority (NEMA). Under section 147 of the EMCA, the Minister is responsible for matters relating to environment on the recommendation of NEMA and, makes regulations for giving full effect to the provisions of the EMCA, upon consultation with relevant lead agencies.

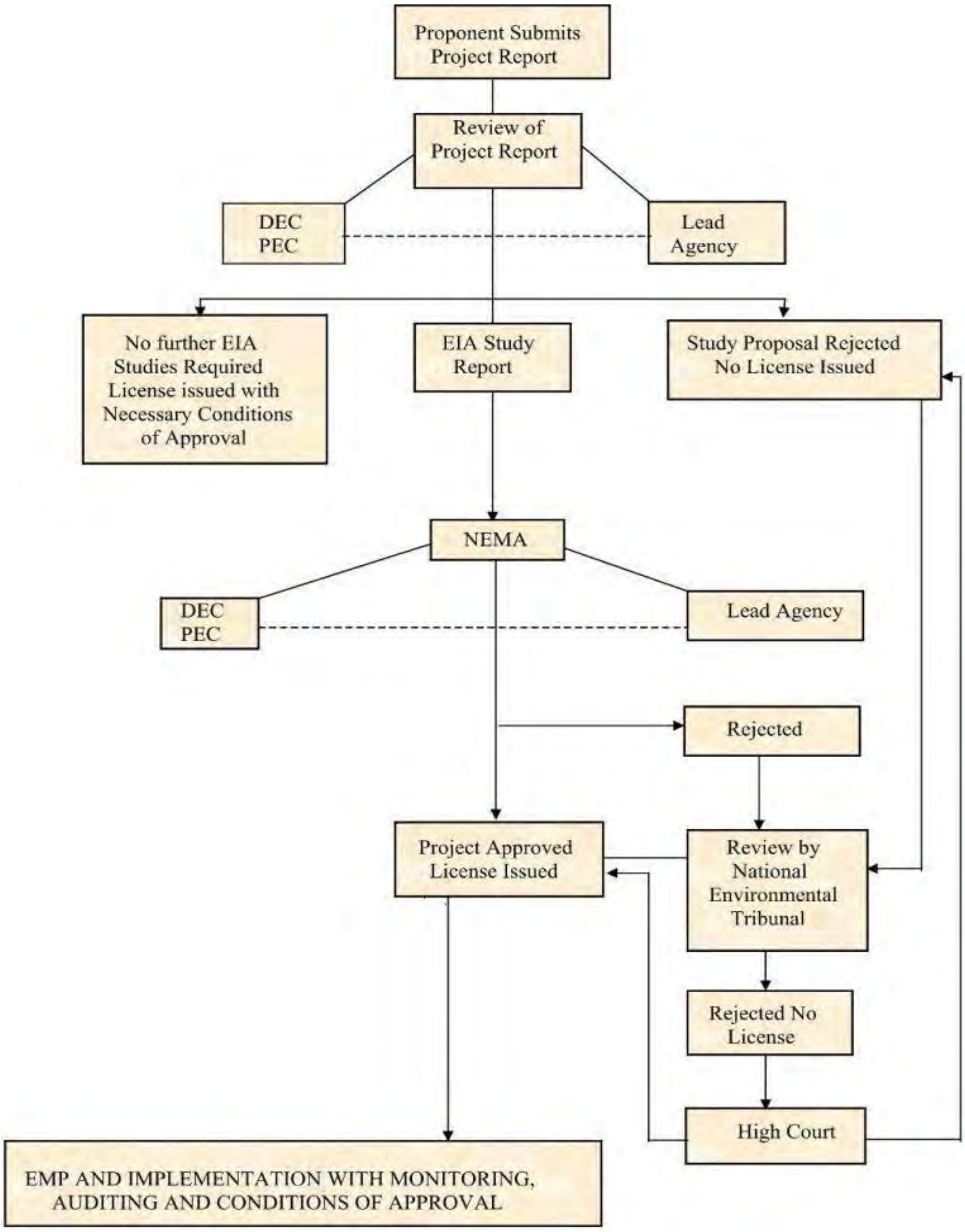
The EIA system is defined in the EMCA. Meanwhile, the concrete procedures and required content of an environmental and social impact assessment (ESIA) are stipulated in the Environmental (Impact Assessment and Audit) Regulations (2003).

In terms of geothermal development, which is the scope of this report, all related activities (e.g. construction of power stations, electrical transmission lines and electrical substations, as well as drilling for the purpose of utilizing groundwater resources including geothermal energy), are subject to an ESIA.

f. EIA procedure and approval system

The EIA review procedure is a two-stage process. The proponent of a project submits the project report to NEMA for screening in order to determine the level of EIA required. NEMA reviews the project report and either issues an EIA license or recommends a full ESIA study. In the case of the latter, a comprehensive report must be submitted to NEMA for further review and decision making. In the case of the Olkaria V project, it was subjected to a full ESIA study and underwent the stage review process.

In reviewing an ESIA report, NEMA seeks the opinion of other relevant ministries, agencies and local governments. NEMA issues an EIA license to the proponent if the review concludes that the project will not impose a significant impact on the environment. The ESIA must be prepared by professionals who satisfy NEMA's qualification standards and who are registered with NEMA. Figure IV-1.1 shows the EIA procedure.



Source: Environment Impact Assessment Guidelines and Administrative Procedures (NEMA,2002)

Fig. IV-1.1 Flowchart of the EIA procedure

g. EIA implementing agency

Environmental Impact Assessment (EIA) must be conducted by certified professionals who comply with the certification requirements and those registered to NEMA. Generally, an environmental consulting firm and a group consisting of several university professors in Kenya, conduct EIA. The Geothermal Development Company (GDC) usually evaluates the EIA implementing agency according to its performance (e.g. reporting ability related to environmental and social considerations, financial condition) against other competing candidate agencies.

h. EIA information disclosure procedure

a) Information disclosure

The ESIA and related documents submitted to NEMA are disclosed to the public. There is a possibility of not publicizing information obtained regarding the approval from NEMA, on the basis of commercial confidentiality and national security.

Also, the ESIA submitted to NEMA is sent to relevant agencies and to the environmental council (composed of community members, groups, and organizations which will be impacted by the project) of the regional government in order to seek opinions and concerns.

b) Related procedures to environment and social assessment

The stakeholder consultation, part of the EIA procedure, is basically conducted during the planning phase of the project, the operation stage, and the disposal stage. The participants should be composed of people who will be affected by the project, private businesses, and relevant ministries, among others.

In a stakeholder consultation, technical workshops and meetings with affected communities, interaction, dialogue with community leaders, question and answer, and a participatory approach to regional assessment are conducted.

The stakeholder consultation, which includes local residents, is announced through posters, newspaper ads, and radio announcement using the local language/dialect (e.g. English and Swahili). Moreover, in a stakeholder consultation for local residents, the project background and impacts are explained and comments/opinions are obtained either verbally or in writing.

i. Functions and activities of agencies relevant to EIA and environmental health

a) National Environment Management Authority (NEMA)

NEMA has a mission to safeguard and enhance the quality of the environment through coordination, research, facilitation and enforcement, while encouraging responsible individual, corporate and collective participation towards sustainable development.

NEMA is a government parastatal established to exercise general supervision and co-ordination over all matters relating to the environment. The Authority is the principal instrument of the Government to implement all policies relating to the environment. Section 9(2) of EMCA details 17 statutory functions that NEMA shall undertake.

b) Kenya Wildlife Service (KWS)

KWS is a state corporation established by the Act of Parliament Cap 376. It is mandated to conserve and manage wildlife in Kenya, and to enforce related laws and regulations. KWS manages the biodiversity of the country, protecting and conserving the flora and fauna. KWS manages national parks and national reserves in all of Kenya, which include 22 National Parks, 28 National Reserves and 5 National Sanctuaries. Also under KWS management are 4 Marine National Parks, 6 Marine National Reserves at the coast, and 4 sanctuaries. KWS has 8 offices which look after each of the conservation areas. Figure IV-1.2 maps out the locations of national parks, reserves and sanctuaries in each conservation area in the country.

With regards to the potential development sites of the project, there is a need to contact KWS Lake Nakuru Office for Central Rift Conservation Area and KWS Kitale Office for Western Conservation Area, which includes Turkana County.

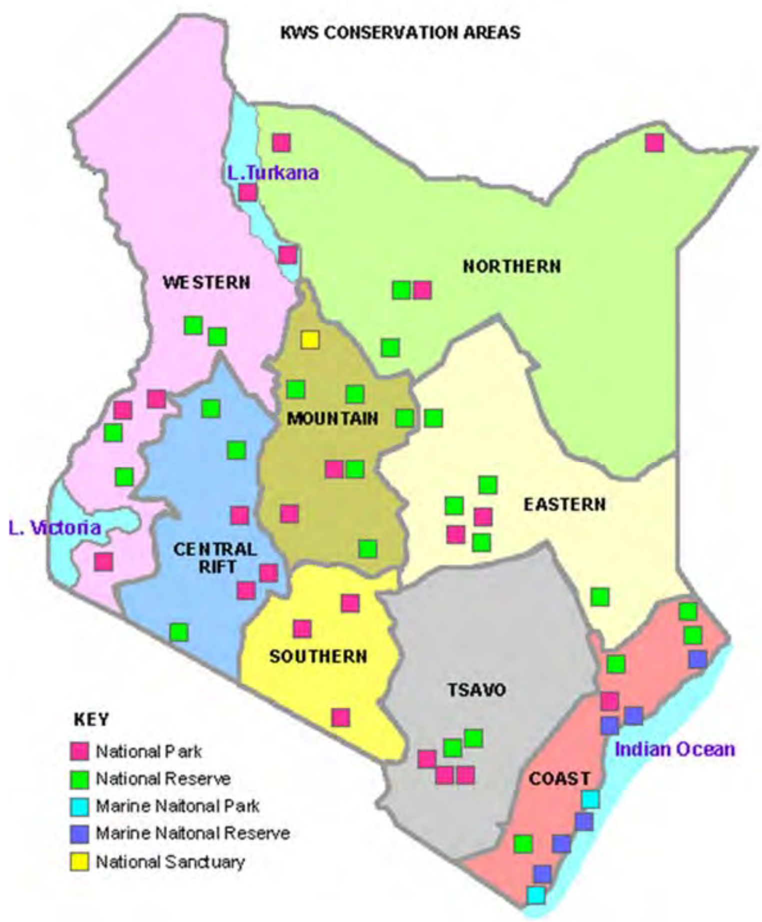


Fig. IV-1.2 Map of KWS conservation areas
Source: KWS website

c) Kenya Forest Service (KFS)

KFS is a state corporation that aims to conserve, develop and sustainably manage forest resources for Kenya's social- economic development. The KFS manages 10 conservancies that are ecologically demarcated (refer to Fig. IV-1.3) into 76 zonal forest offices, 150 forest stations and 250 divisional forest extension offices located across the country. These offices are critical in forest management and surveillance. Forest adjacent communities have formed registered groups and are currently working with KFS to sustainably manage forest resources. Currently there are 325 Community Forest Associations in Kenya. In implementing the geothermal project, it is necessary to consult KFS Eldoret Office (managing North Rift area) and the KFS Nakuru Office (managing MAU area).

Fig. IV-1.3 Map of KFS conservation areas
Source: KFS 2010/2011 Annual Report

d) Water Resources Management Authority (WRMA)

WRMA is a corporate body that was established based on the Water Act (2002) and was operationalized in 2005. It is the lead agency in the management of water resources in Kenya and its overall development objective is to ensure rational, effective management of the water resources and equitable access for the various competing groups and usage. WRMA consists of 6 regional offices and 26 sub-regional offices. Major roles and functions of WRMA are to regulate and protect water resources from adverse impact and to monitor and enforce conditions attached to water permits and water use. In implementing the geothermal project, it is essential to consult WRMA Nakuru Regional Office, which manages the Rift Valley area.

e) Northern Rangelands Trust (NRT)

NRT is an organization, established in 2004, to support each community conservancy, to raise funds for them, and to provide them with advice on how to manage their affairs. Currently, there are 27 community conservancies participating in NRT.

However, there are also many community conservancies that do not participate in NRT. Instead, they are registered in relevant local authorities of the States. In implementing this geothermal project, it is necessary to confirm the registration status of the community conservancies at Kitale office in Turukana state and Baringo office in Baringo state, and to consult concerned community conservancies.

f) National Museum of Kenya (NMK)

NMK is a state corporation whose role is to collect, preserve, study, document and present Kenya's past and present cultural and natural heritage. There are many museums and archeological sites all over the country but NMK leads management and research. Reportedly, there is no museum, archeological site and other important heritage within the target area; however, there are multiple archeological sites in progress and other potential sites which are located from southern coast of Lake Turkana to Great Rift Valley area. It will be necessary to consult NMK about the implementation of this geothermal project in the target area.

IV-1.2 Land acquisition, resettlement and poverty alleviation

a. Relevant laws, policies and procedures on land acquisition, resettlement and poverty alleviation

a) Constitution of Kenya, 2010

The Constitution of Kenya stipulates the rights related to site acquisition and resettlement. Chapter 5, article 60 (1), outlines the principles for land use and management. It stipulates land compensation and elimination of gender discrimination. Article 63 and 64 recognize the ownership of private and community land respectively. According to Article 40 (3), a just amount of compensation must be paid immediately, while in Article 40 (4), compensation is also paid to those who may not hold legal title but are occupants in good faith.

b) Land Act, 2012

This Act is for the management and usage of public land, trading of private and community land, as well as land easement. Section 111 (1) requires a just and full compensation to be paid promptly to all those affected by compulsory acquisition of land for public purposes. Also, Section 125 (1) states that full and just compensation shall be paid beforehand to obtain temporary occupation of land. Section 134 (1) requires the National Land Commission to implement settlement programs to provide access to land for shelter and livelihood, on behalf of the national and county governments.

c) The Land Registration Act, 2012

Land title registration and establishment of relevant governmental organizations will be based on this Act. The Ministry of Land is responsible for land registration.

d) The Environmental and Land Court Act, 2011

The Act enables the Parliament to hear and determine disputes relating to the environment and the use/occupation of and title to land.

e) Land Acquisition Act, 2010 (revised)

This Act provides guidelines on land expropriation by the State or Government for the general benefit of a community. The Act recognizes that the owners of the acquired land should be compensated and their grievances addressed.

f) Way Leave Act, 2011

The Act provides for certain undertakings to be constructed (e.g. transmission lines, pipelines, canals, pathways), through, over or under any land. Section 3 of the Act states that the Government may carry any works through, over or under any land whatsoever, provided it shall not interfere with any existing buildings or structures of an ongoing activity.

In accordance with the Act (Section 4), notice will be given to community members before carrying out any work and it shall provide a full description of the intended work and targeted place for inspection. Any damages caused by the works would then be compensated to the owner as per the section. The Act serves as the main legislation guiding way leaves agreements, compensation for loss or damage to assets, loss of earnings, and general inconvenience.

b. Implementing agency of site acquisition, resettlement and poverty alleviation

The Ministry of Lands delegates the District Land Boards Committee to manage district land. One of the roles of the District Land Board is to make a list of the compensation rate for loss or damage of crops, houses and other property and update this list annually.

On the other hand, the National Land Commission manages land owned by the Kenyan government. It does not generally get involved in land deals between the private sectors.

c. Land acquisition and resettlement system in Kenya

The Land Acquisition Act (Cap 295) provides for the compulsory acquisition of private land and property held under the Registered Lands Act, Cap 300 and the Land Titles Act, Cap 281. Public land administered under the Government Lands Act, Cap 280 but used for private development in leases can also be compulsorily acquired under the Land Acquisition Act. Stringent conditions have been set out under the Act in the event that compulsory acquisition must take place.

In this case compensation may take two forms. One form is cash compensation and the other is land compensation. Cash compensation is provided for under section 9 of the Act. The amount entitled to the land owner is paid directly to them but in situations of prolonged dispute, the commissioner of lands is required to deposit the money in a court of law pending resolution of the dispute. Section 12 of the Act allows the Commissioner of Lands to award land of equivalent value as compensation

d. Previous record on land acquisition, resettlement and poverty alleviation

An interview with GDC regarding its policy pertaining to land acquisition, resettlement and poverty alleviation, was conducted. The target area of the project is not owned by an individual person, rather it is owned mainly by the District Land Board in each County. Some nomadic tribes, such as Turukana and Pokot, use specific routes although at times they use other routes within the target area.

As a corporate policy, GDC started to contact existing residents, in case some residents or nomadic tribes have already lived or are using land within the target area. This is done in order to get a census of land usage for the geothermal project. As a second step, GDC has negotiated land use with the District Land Board. If there is nobody living in or using the area, GDC has to negotiate only with the District Land Board.

IV-1.3 Protected areas

a. Categories of protected areas

There are two main categories of protected areas, recognized by the government of Kenya. These are – 1) Wildlife Protected Area, which include National Parks and National Reserves; and 2) Protected Forests which include Forest Reserves, Range Forests, and Mangroves.

There are protected areas that are managed by each local community in Kenya. These areas are called "community conservancies". Each community conservancy cooperates with KWS and KFS to protect animals and nature in the conservancy.

Protected areas within the study area, which will be impacted by the project, were mapped out based from the information obtained from GDC (Fig. IV-1.4).

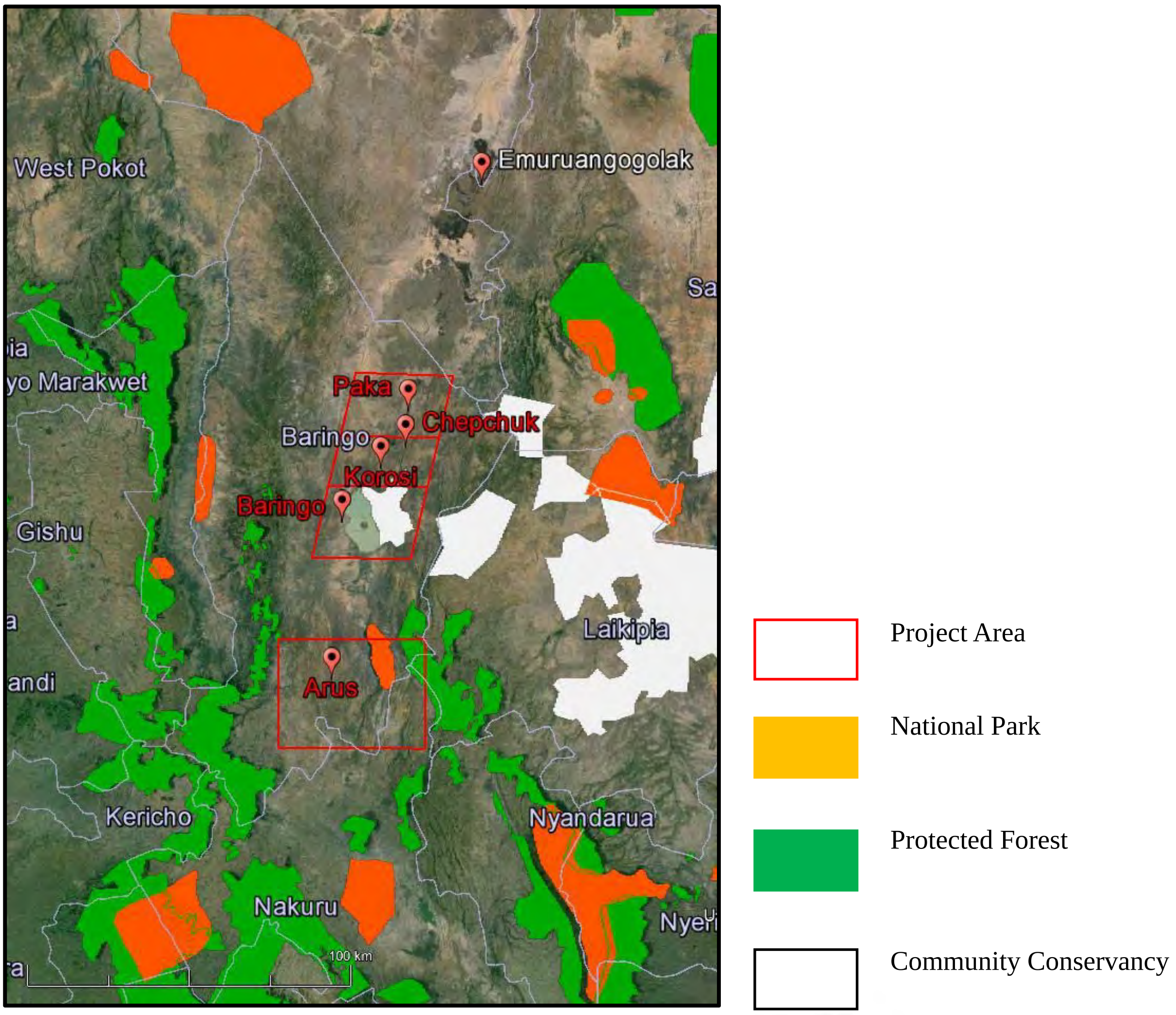


Fig. IV-1.4 Protected areas in the study area

b. Wildlife protected areas (National Parks, National Reserves)

Wildlife Protected Areas (WPAs) and Marine Protected Areas (MPAs) are defined under the Wildlife (Conservation and Management) Act CAP 376 as National Parks, National Reserves and Sanctuaries. There are also Marine Parks and Marine Reserves that serve the same function but in the aquatic environment.

The primary function of WPAs and MPAs is to conserve wildlife species and protect habitats. These areas have a significant economic value, particularly in tourism, which is a major earner for the country. Geographically, these areas are found throughout the country with 23 parks and 28 reserves and sanctuaries. There are also 10 MPAs ("parks and reserves" along the Kenyan coastline). About 8% of Kenya's land mass is protected area for wildlife conservation (kws.org). A list of registered WPAs and MPAs are listed in Table IV-1.6. Their locations are mapped out in Fig. IV-1.5.

Table IV-1.6 List of WPAs and MPAs in Kenya

National Parks (NP)		***National Reserves (NR)***	***Marine Parks (MP), Marine Reserves (MR)***
Amboseli N.P	Mt. Elgon N.P	Arawae N.R	Kuinga MR
Arabuko Sokoke N.P	Nairobi N.P	Boni N.R	Mombasa M.P
Hell's Gate N.P	Ol Donyo N.P	Buffalo Springs N.R	Kisite-Mpunguti M.P
Kora N.P	Ruma N.P	Dodori N.R	Mombasa M.R
Aberdare N.P	Kora N.P	Kakamega Forest N.R	Malindi M.P
Central Island N.P	Saiwa Swamp N.P	Kisumu Impala N.R	Mpunuguti M.R
Ruma N.P	Sibilio N.P	Masai Mara N.R	Watamu M.R
Lake Nakuru N.P	Tsavo East N.P	Arabuko N.R	Tana Delta Reserve
Marsabit N.P	Tsavo West N.P	Mwea N.R	
Meru N.P		Samburu N.R	
Mt. Kenya N.P		Shimba Hills N.R	
Chyulu Hills N.P		Marsabit N.R	
Malka Mari N.P		Tana River Primate R	
Mt. Longonot N.P		Mwalunganje N.R	
Ndere Island N.P		Witu Forest Reserve	

There also exist other sites and properties listed as Endangered Ecosystems and Areas of Environmental Significance by Kenya Wildlife Services. Relevant sites to this project include:

- Lake Turkana
- Mt. Kulal
- Mt. Nyiro
- Loima Hills
- Central Island National Park
- Southern Island National Park,
- Tana Primate National Reserve
- Marsabit Ecosystem
- Baringo Ecosystem

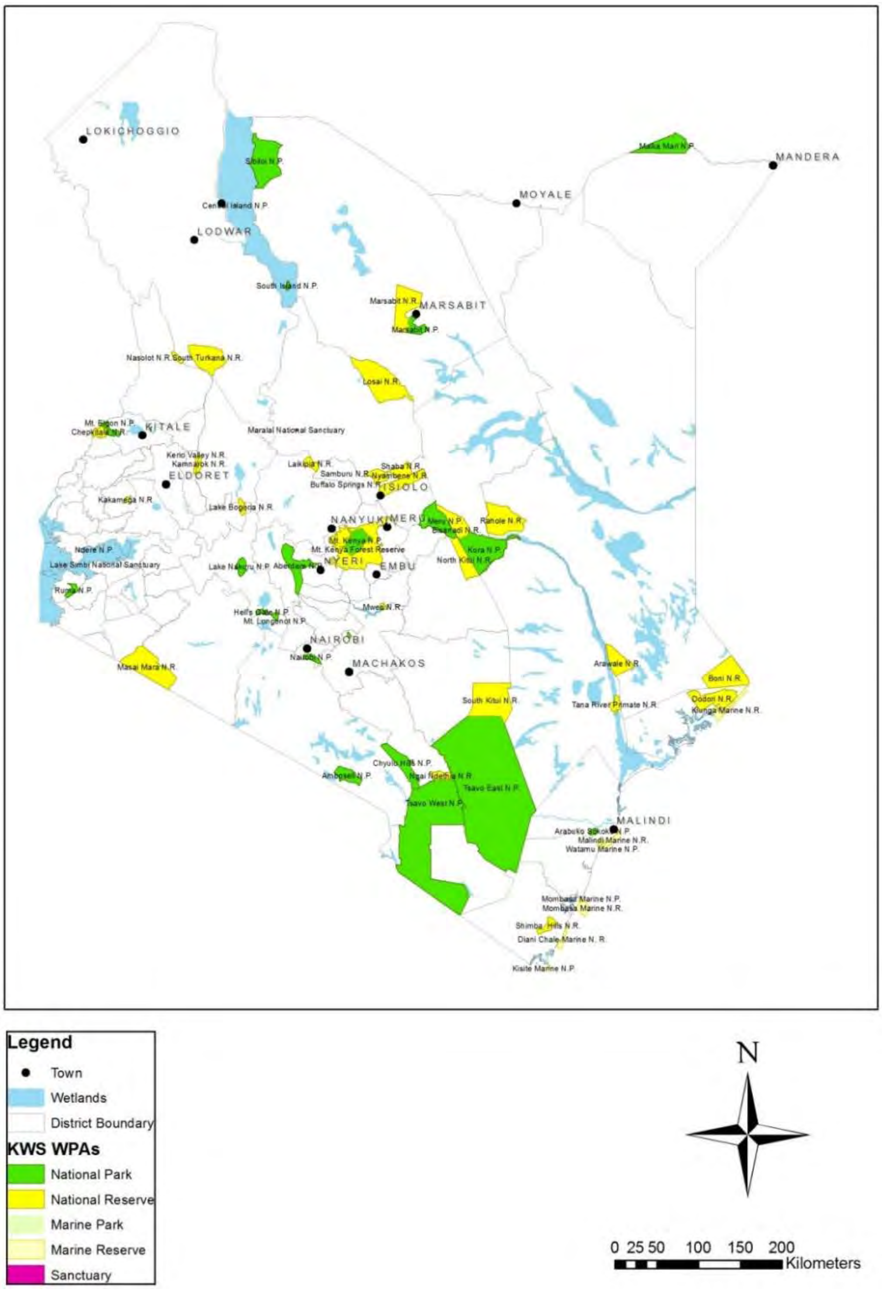


Fig. IV-1.5 Kenya's protected areas
Source: KWS

c. Protected forests (Forest Reserves, Range Forests, Mangroves)

Forests are a major resource for Kenya and have a diverse range of benefits, playing an important role on economic, environmental, social and cultural sectors. The types of forests in Kenya include rainforests, dry forests, mangroves, savannah, etc. and the current forest cover in Kenya is at 6.99% (KFS Policy 2014). Forest areas in the country are mapped in Fig. IV-1.6. Kenya's vision 2030 aims to increase the forest cover in the country by 10%.

Kenya's forests are managed by the Kenya Forestry Services (KFS). These are regulated under the Forestry Act of 2005. Major threats to Kenya's forest cover include urbanization (population pressure), deforestation, and charcoal-making.

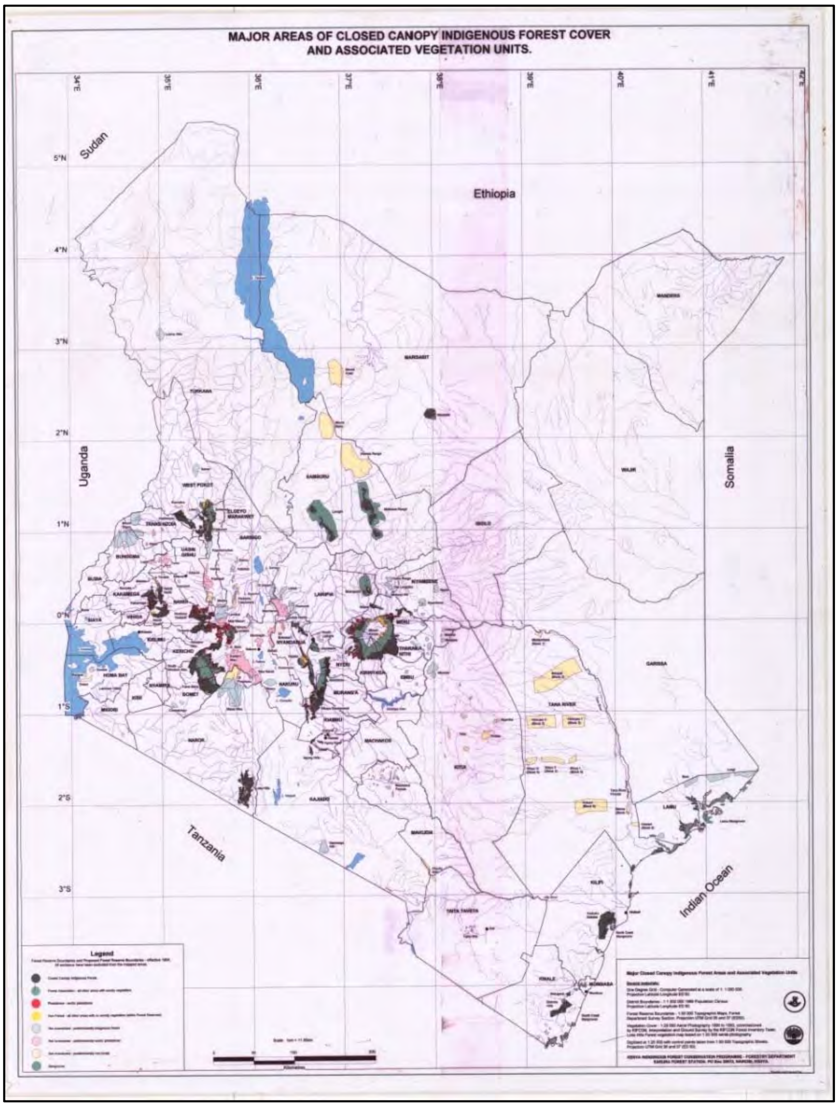


Fig. IV-1.6 Kenya's forest blocks
Source: KFS

d. Community conservancies

Community Conservancies in Kenya are a form of biodiversity conservation and wildlife management strategy. Through the Wildlife Management Act (Cap 376) and Sessional Paper No. 3 of 1976 (A Statement of Future Wildlife Management Policy in Kenya), community wildlife conservation is recognized and emphasized outside the National Park and Reserve structure of Kenya. It is estimated that approximately 70% of all Kenya's wildlife resides on community and private land which includes community conservancies. The functions of these Conservancies include:

- Breeding grounds,
- Wildlife dispersal areas and corridors,
- Protected Area buffer zones,
- Eco-tourism and recreation facilities,
- Habitats for wildlife and endemic species, and
- Education and research.

KWS, through its Director, is mandated to declare an area as a conservancy and issue a certificate of registration or license. Currently registered Kenyan Conservancies are mapped out in Fig. IV-1.7. It can be observed that conservancies are common in the country. Some have been established as early as 1995 and there has been an increase in the number of registered conservancies in the recent years. The size of the protected areas varies significantly, with the scale ranging from hundreds to as big as hundred thousands of acres. In terms of location, several conservancies are adjacent to each other and are concentrated in the central and coastal part of the country (refer to Fig. IV-1.7). It is also worth noting that most of the conservancies are owned by the communities themselves, with a couple of group ranches.

Within the target area of this study, Ruko Community Wildlife Conservancy is located in the east coast of Lake Baringo (area within red dotted circle in Fig. IV-1.7). Thus, it is essential to consult the Ruko Community Wildlife Conservancy for the implementation of this geothermal project in the target area. Moreover, it was reported to GDC that a community plans to register a community conservancy around Molo River, which is close to the proposed development area in Arus.

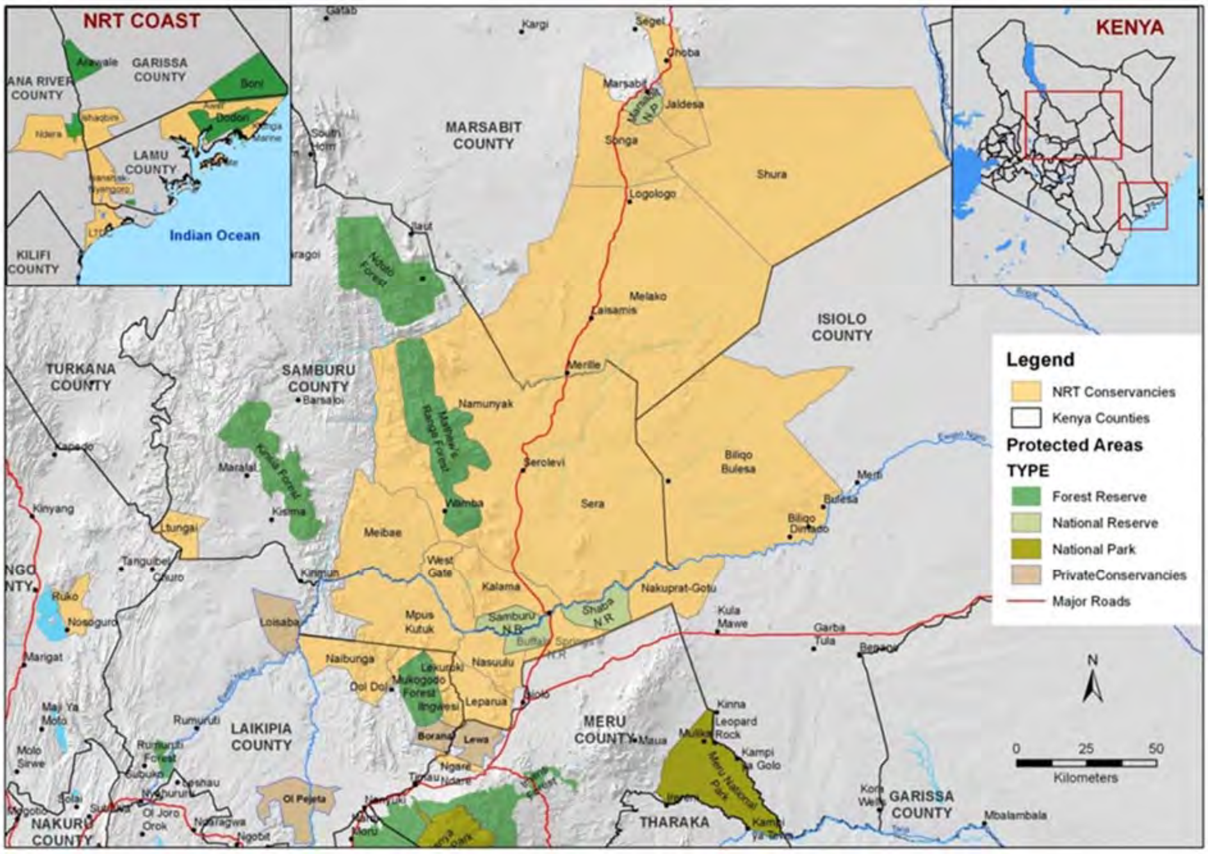


Fig. IV-1.7 Map of NRT community conservatories in Kenya
Source: NRT website

e. Ramsar sites

The Ramsar Convention is an international/intergovernmental treaty signed in February 1971 and effectuated in December 1975 aimed at the conservation and the sustainable use of wetlands. Ramsar lists 2,122 sites covering 205,366,160 ha of wetlands of International Importance. Kenya is one of the 168 member parties since October 1990. It has six Ramsar sites (Fig. IV-1.8), covering a total surface area of 265,449 ha designated as Wetlands as follows:

a) Lake Baringo

Lake Baringo (00°32'N 036°05'E) has been a designated Ramsar Site since Jan 2002. Located in the north of the Great Rift Valley, the lake covers 31,469 ha and is considered a critical habitat and refuge to approx. 500 of bird species. It is one of the two freshwater lakes in the Rift Valley. It is a habitat for freshwater fish, hippopotamuses and crocodiles.

The lake is fed by Molo, Perkerra and Ol Arabel rivers, but it has no obvious outlet. It has several small islands with the largest being Ol Kokwe Island, which is an extinct volcano. Four ethnic communities live around the lake and depend on it for resources and cultural needs. The lake also has great archeological significance.

b) Lake Bogoria

Lake Bogoria (00°15'N 036°05'E) has been a designated Ramsar Site since Aug 2001. It covers an area of 10,700ha with inflows from the Sandai and Emsos rivers. Similar to Lake Baringo, Lake Bogoria is located in the Great Rift Valley and is inhabited by a population of 1 - 1.5 million Lesser Flamingo (Phoenicopterus minor) bird species which is classified as Near Threatened (NR) by IUCN.

The lake is classified as an alkaline soda lake that supports threatened ecological species such as the Greater Kudu, which is listed as Endangered by IUCN. This animal is found on the acacia woodland on the fringe of the lake.

The catchment of Lake Bogoria is approx. 1,200 km^2 and covers the Subikia and Iguamiti shrines in Subukia Forest.

c) Lake Elementaita

Lake Elementaita (00°46'S 036°23'E) and its buffer zone covers a span of 10,880 ha. It is located in the Southern part of the Great Rift Valley and was designated as a Ramsar site in November 2005.

It is described as a shallow alkaline soda lake, which is habitat to many aquatic species like the Blue Green algae (Spirulina plantesis), a primary producer that supports the food chain for over 450 bird species. One of the species being supported by the algae is the Lesser Flamingo (Phoenicopterus minor) bird species, which is classified as Near Threatened (NR) by IUCN. Zebra, gazelle, eland, and families of warthog inhabit the shores of the lake.

d) Lake Naivasha

Lake Naivasha (00º46'S 036º22'E) is a freshwater lake in the Rift Valley province, 30,000 ha in size. The lake is home to complex vegetation of terrestrial (Acacia xanthophloea), riparian and littoral plants. The lake is supplied by the Malea and Giligil Rivers that drains from the Abadere Mountains in central Kenya.

e) Lake Nakuru

Located 160 km North of Nairobi, Lake Nakuru (00º24'S 036º05'E) was designated as a Ramsar site in June 1990 and covers an area of 18,000 ha. Seasonal rivers (Makalia, Nderit, Naishi, Njoro and Larmudiac) drain into the lake.

Lake Nakuru supports over 450 avian species and over 70 water bird species, including 1 million flamingos (Lesser and Greater) which are attracted by the algae. The lake is located within Lake Nakuru National Park which is home to a diverse range of wildlife including Black Rhino, White Rhino, Lion and Giraffe.

f) Tana river delta Ramsar site

Designated as a Ramsar Site in Sept 2012, Tana River Delta (02°27'S 040°17'E) covers 163,600 ha of a deltaic ecosystem. This site is comprised of a combination of freshwater, floodplains, estuarine and coastal plains around the outflow of River Tana. Most of the forests within this delta have been replaced by mango and cultivated land but there still exist coastal forest patches and it has approximately 4,500 ha of mangroves.

The diversity of habitats house five species of threatened marine turtles, prawns, bivalves and fish. African Elephant, Tana Mangabey, Tana River Colobus and White Collared Monkey also exist in the area. Over 600 plant species have been identified in the delta and is an Important Bird Area (IBA)

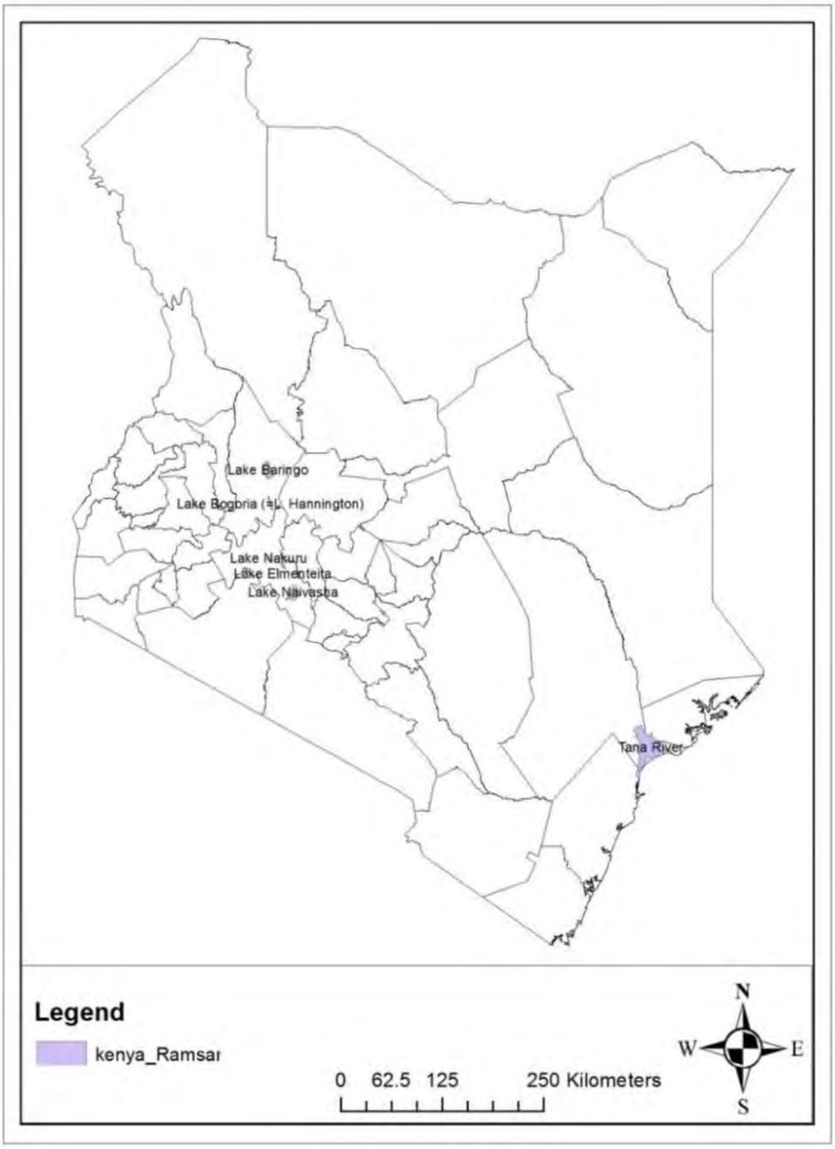


Fig. IV-1.8 Ramsar sites in Kenya
Source: IBA

IV-1.4 Protection of cultural heritage

a. World heritage sites

In Kenya, the properties inscribed on the World Heritage List are six, wherein three are cultural and three are natural sites. Details and location of these sites are shown in Table IV-1.7 and Fig. IV-1.9, respectively.

The Lake Turkana National Parks consist of three parks: Sibiloi National Park, South Island National Park and Central Island National Parks, covering a total area of about 160,000 hectares located within and near Lake Turkana.

The Kenya Lake System in the Great Rift Valley is comprised of three biologically important shallow lakes (Lake Bogoria, Lake Nakuru and Lake Elementaita). It is recognized as a major habitat for the globally threatened bird species.

Table IV-1.7 World Heritage sites in Kenya

Type	Name	Year of registration
Cultural	Lamu Old Town	2001
	Sacred Mijikenda Kaya Forests	2008
	Fort Jesus, Mombasa	2011
National	Lake Turkana National Parks	1997
	Mount Kenya National Park/Natural Forest	1997
	Kenya Lake System in the Great Rift Valley	2011

Source: UNESCO

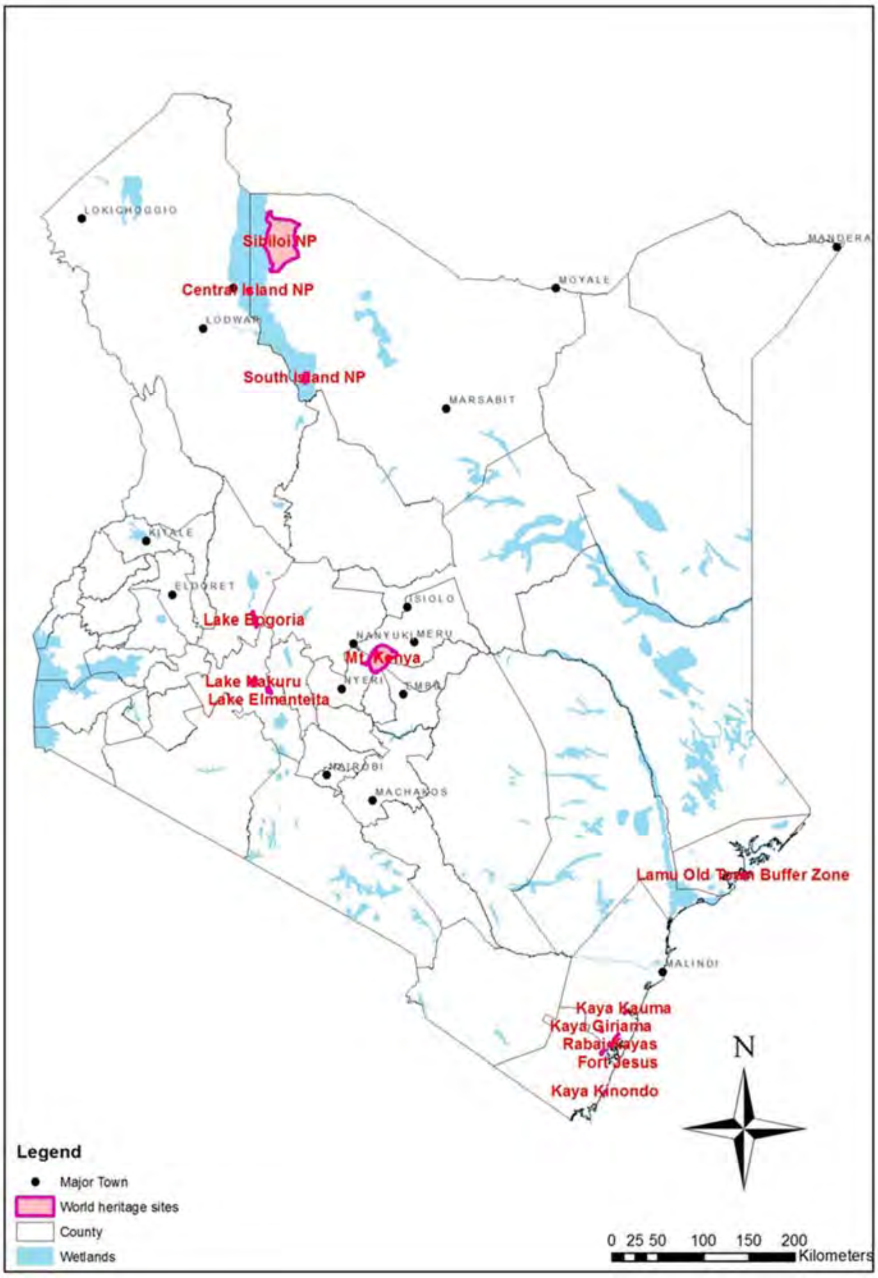


Fig. IV-1.9 World Heritage sites and wetlands in Kenya
Source: UNESCO

In addition, there are 18 properties that have been submitted and are now included in the Tentative List (see Table IV-1.8).

Table IV-1.8 List of World Heritage sites in Kenya

Name	Year of registration
Mombasa Old Town	1997
Lake Nakuru National Park	1999
Lake Naivasha	1999
Lake Bogoria National Reserve	1999
The Historic Town of Gedi	2010
The Mfangano-Rusinga Island Complex	2010
The African Great Rift Valley - The Marakwet Escarpment Furrow Irrigation System	2010
The Thimlich Ohinga Cultural Landscape	2010
The African Great Rift Valley - Olorgesailie Prehistoric Site	2010
Aberdare Mountains	2010
The Eastern Arc Coastal Forests (Arabuko-Sokoke Forest and Shimba Hills National Reserve)	2010
The Kakemega Forest	2010
The Meru Conservation Area	2010
The African Great Rift Valley - Hell's Gate National Park	2010
The African Great Rift Valley - The Maasai Mara	2010
The Tana Delta and Forests Complex	2010
Tsavo Parks and Chyulu Hills Complex	2010

Source: UNESCO

b. Historical and cultural sites

In terms of conserving historical and cultural sites in Kenya, the National Museums of Kenya (NMK) has responsibility regarding research and preservation activities. The NMK has a strong network of important regional museums and thousands of sites and monuments across the country. The current list of museums and historical sites in Kenya is shown in Table VI-1.9 and Fig. IV-1.10.

The research conducted for collating this information is currently on-going and the whole completed list has not yet been prepared.

Table IV-1.9 Museums and historical sites in Kenya

Type	**Name**
Regional Museum	Nairobi National Museum Karen Blixen Museum Fort Jesus Museum – Mombasa Lamu Museum Malindi Museum Kisumu Museum Kitale Museum Loiyangalani Museum: Gede Museum Kalenguria Museum Meru Museum Kabernet Museum Narok Museum Rabai Museum, Mombasa Tom Mboya Mausoleuma at Kisumu Hyrax Hills National Monument at Nakuru
Site Museum	Uhuru Garden at Nairobi Jumba la Mtwana at Mombasa Mnarani at Kilifi Siyu Fort Koobi Fort Songhor Takwa at Lamu: Thimlich Ohinga Olorgesailie

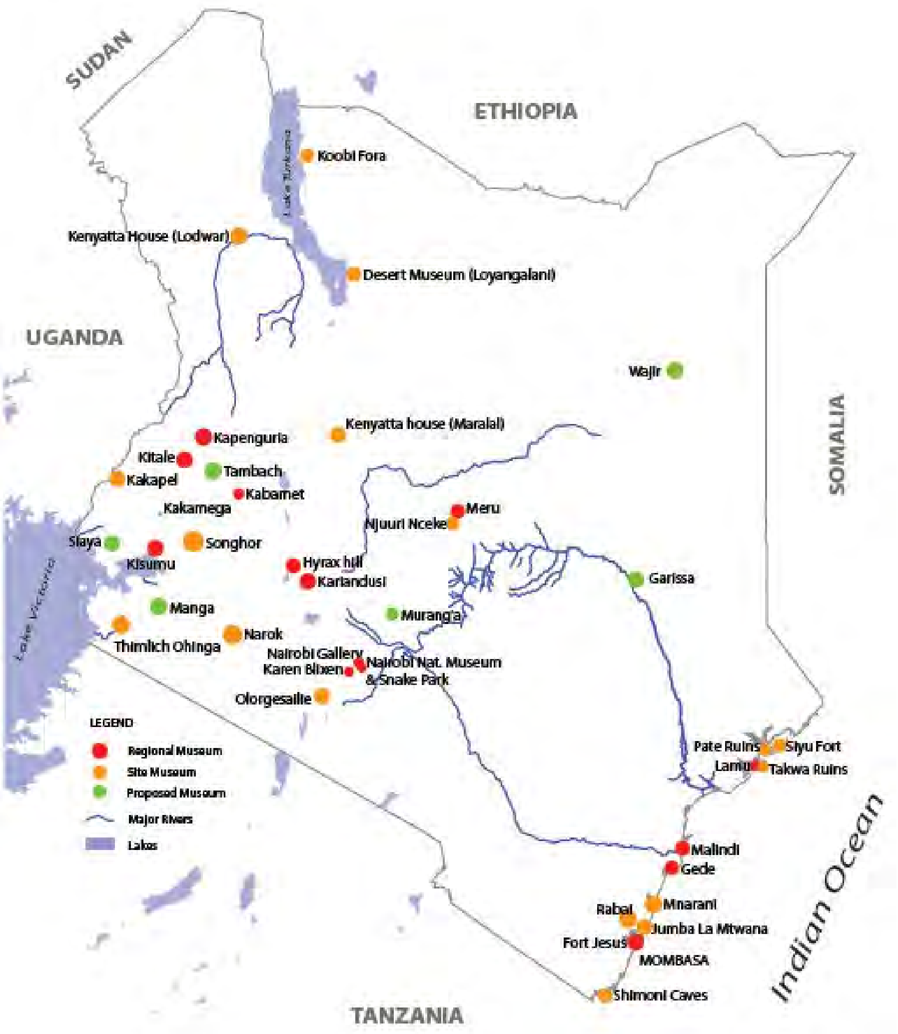


Fig. IV-1.10 Museums and historical sites
Source: NMK

As prescribed by the National Museum and Heritage Act of 2006 and the Antiquities and Monuments Act Cap 215, the National Museums of Kenya is responsible for the protection of historical sites in Kenya.

c. Tourist sites

In Kenya, there are 5 major tourist sites. Each site is described below.

a) The Great Rift Valley

The Great Rift Valley is one of the most unique geographic features in the country. The Rift Valley area also has a bountiful system of lakes and rivers. Kenya lays claim to the second largest fresh water lake in the world in Lake Victoria. Lake Bogoria is one of the most popular Kenya tourist attractions and is known for its hot springs and geysers. The valley itself is a geological phenomenon that is great for pictures and exploring.

b) African Safari & Great Migration

The African Safari is one of the most popular tourist attractions among all the activities provided in Kenya. The major target species of the activities is comprised of the Big 5 and the great migration of tens of thousands of wild animals. The major tourism location for migration is between Serengeti National Park in Tanzania and Masai Mara National Reserve in Kenya.

c) Mount Kilimanjaro & Mount Kenya

While the majority of Mount Kilimanjaro is in Tanzania, it also sits on the border between Kenya and Tanzania. Towering at over 19,000 feet Mount Kilimanjaro is the 4th largest free standing mountain in the world and the highest mountain in Africa. It provides opportunities for hiking and other outdoor activities. Mount Kenya is the second highest mountain in Africa and the highest in all of Kenya.

d) National Parks & Reserves

The vast wildlife in Kenya can be found throughout the country's wildlife parks and reserves. It enables tourists to observe exotic animals like lions, cheetahs, monkeys, and many others in their natural habitat. The income from wildlife tourism through national parks and reserves is described to occupy a large portion of the national revenue.

e) Coastal region of Kenya

Beaches are one of the main Kenyan tourist attractions. Gorgeous beaches line areas like Watamu and Tiwi beaches. They have isolated beaches like Lamu. Watamu has great coral reefs providing diving and snorkeling activities. There are also cultural and historical sites to see such as Hindu temples, Gede ruins in Malindi, and even Fort Jesus as well as entire Lamu County with several tourist sites.

IV-1.5 Environmental standards and permissible limits

a. Water quality

The Environmental Management and Coordination (Water Quality) Regulations (2006) stipulates water quality standards for various water uses (e.g. domestic, industrial, agricultural, recreational). It also specifies guidelines and standards for effluent discharge.

For steam electric power generating facilities, the effluent must be monitored according to the following parameters listed in Table IV-1.10. NEMA may prescribe additional parameters to the list depending on the case.

Table IV-1.10 Effluent standards for steam electric power generating facility

Parameters	Max Allowable (Limits)*1
Total suspended solids	30mg/L
pH	5.0-9.0 (marine) 6.5-8.5 (non-marine)
Faecal coliforms	30/100mL
Oil & grease	Nil
Temperature	±3°C
Color/pigment/dye	15HU
Total P	2mg/L *2
Flow	Not applicable *3
Chromium IV	0.05mg/L
Copper	1.0mg/L
Zinc	0.5mg/L
Residual Chlorine	0.10mg/L
Tin	Not applicable *3

Source: Water Quality Regulation (2006)

*1: The max allowable limits are applied to the daily mean value or monthly mean value
*2: The value is determined in Guidelines on drinking water quality and effluent monitoring last issued in March 2008.
*3: Flow and Tin are required to monitor for the effluent quality assessment; however, maximum allowable limits are not determined in the Law and guideline.

Table IV-1.11 shows maximum allowable values of water quality parameters for sources of domestic water in Kenya. It is important to consider this if GDC pursues the promotion of direct use of heat and other by-products from geothermal power generation, to the near-by residents.

Table IV-1.11 Standards for domestic water

Parameters	Guide Value (max allowable)
pH	6.5 - 8.5
Suspended Solids (SS)	30 mg/L
Nitrate (NO3)	10 mg/L
Ammonia (NH3)	0.5 mg/L
Nitrite(NO2)	3 mg/L
Total Dissolved Solids (TDS)	1200 mg/L
Scientific Name (E. Coli)*	Nil /100mL
Fluoride	1.5 mg/L
Phenols*	Nil mg/L
Arsenic (As)	0.1 mg/L
Cadmium (Cd)	0.1 mg/L
Lead (Pb)	0.05 mg/L
Selenium (Sn)	0.01 mg/L
Copper (Cu)	0.05 mg/L
Zinc (Zn)	1.5 mg/L
Alkyl benzul sulphonates (ABS)	0.5 mg/L
Permanganate Value (PV)	1.0 mg/L

Source: Water Quality Regulations (2006)

*Nil means less than limit of detection using prescribed sampling and analytical methods and equipment as determined by the Authority.

b. Air quality

The Environmental Management and Co-ordination (Air Quality) Regulations (2014) was issued in April 2014. It aims to prevent, mitigate, control and abate air pollution in the country. The Regulation sets guidelines for permissible levels of air pollutants from different sources – controlled areas, stationary source, mobile sources, and other sources. Other sources refer to material handling, demolition, stockpiling, waste incinerator, open burning, and cross-border air pollution.

The Regulation describes, in detail, methods of measurement, analysis, inspection, monitoring and reporting. It sets out licensing requirements and procedures. The First Schedule of the Regulation specifies ambient air quality tolerance limits (12 air pollutants) for the following areas:

- Industrial area
- Residential, rural, and other area
- Controlled area

As stipulated in the Fourth Schedule, parameters to be monitored for geothermal power plants (under stationary sources) include sulphur oxides (SOx), nitrogen oxides (NOx), hydrocarbons, and hydrogen sulphide (H_2S). Details of emission limits for geothermal power plants are listed in Table IV-1.12.

Table IV-1.12 Emission limits for geothermal power plants (under controlled facilities)

Air Pollutant	Unit (mg/Nm^3)
SOx (mg/Nm3) – non-degraded area	1.5-3.0% - only justified by project specific considerations (i.e. add secondary treatment to meet levels of 1.5% Suphur)
NOx (mg/Nm3) – non-degraded area	
Hydrogen sulphide (mg/Nm3)	

c. Noise

The Environmental Management and Co-ordination (Noise and Excessive Vibration Pollution Control) Regulations (2009) sets permissible noise levels in the country. Table IV-1.13 lists allowable noise levels for different zones – silent, places of worship, residential, mixed residential and commercial. Daytime refers to 6:00am to 8:00pm, while nighttime refers to 8:00pm to 6:00am.

Table IV-1.13 Permissible noise levels per zone

Zone		Sound Level Limits dB(A)		Noise Rating Level (NR)	
		Day	Night	Day	Night
A	Silent Zone	40	35	30	25
B	Places of Worship	40	35	30	25
C	Residential: Indoor Outdoor	 45 50	 35 35	 30 40	 25 25
D	Mixed residential (with some commercial & places of entertainment)	55	35	50	25
E	Commercial	60	35	55	25

Source: Noise and Excessive Vibration Pollution Control (2009)

For construction sites, the maximum permissible noise levels depend on the facility. Details are shown in Table IV-1.14. Measurements should be taken within the facility.

Table IV-1.14 Permissible noise levels for construction sites

Facility		Maximum Noise Level Permitted in dB(A)	
		Day	Night
(i)	Health facilities, educational institutions, homes for disabled, etc.	60	35
(ii)	Residential	60	35
(iii)	Areas other than those prescribed in (i) and (ii)	75	60

Source: Noise and Excessive Vibration Pollution Control (2009)

IV-1.6 Previous EIA studies

Previous EIA studies conducted in the target sites were collected. Details of the reports are summarized in Table IV-1.15.

Table IV-1.15 Environment and Social Impact Assessment Reports

Title of the Report	Date Implemented	Location	Implementing Agency
(1) Proposed Paka-Silale Block Geothermal Exploration Drilling Works Environmental and Social Impact Assessment	February 2012	Paka, Silale	Geothermal Development Company
(2) Arus-Korosi-Chepchuk Geothermal Drilling Project, Baringo County Environmental and Social Impact Assessment Study Report	February 2012	Arus-Bogoria area, Lake Baringo area Korosi-Chepchuk area	Geothermal Development Company
(3) Olkaria Geothermal Project Ranking of the Geothermal Prospects in the Kenya Rift Valley		Lake Magadi, Suswa Caldera, Badlands, Menengai Caldera, Arus and L. Bogoria, Korosi Volcano, Chepchuk, Paka Volcano, Silali Caldera, Emuruangogolak Caldera, Namarunu, Barrier Volcanic Complex	KenGen
(4) Project Report for the Proposed Water Abstraction for Geothermal Development at Lake Baringo, Baringo County	February 2014	Lake Baringo	Geothermal Development Company
(5) Project Report for the 20-30 MWe STEAM Gathering System and Power Plant, Baringo County Environmental and Social Impact Assessment Study Report	February 2015	North and South Districts, Baringo County	Geothermal Development Company
(6) Project Report for the 40-60MWe Korosi Gathering System and Power Plant for Geothermal Development at East Pokot District, Baringo County Environmental and Social Impact Assessment Study Report	February 2015	East Pokot District, Baringo County	Geothermal Development Company
(7) Project Report for the 60-80 mw Paka geothermal power plant project, Baringo County Environmental and Social Impact Assessment Study Report	March 2015	Paka Geothermal Area, Baringo County	Geothermal Development Company
(8) Project Report for the proposed 80-100 mw Silali geothermal power plant project, Baringo and Turkana Counties Environmental and Social Impact Assessment Study Report	March 2015	Silali Geothermal Field, Baringo and Turkana Counties	Geothermal Development Company

Brief descriptions of each report, including environmental and social impacts and the corresponding mitigation measures, are shown below.

a. Proposed Paka-Silale block geothermal exploration drilling works, environmental and social impact assessment

This EIA report details potential environmental and social impacts caused by geothermal exploration drilling works in the Paka-Silale area. Specific issues raised include H_2S/CO_2 emissions, impacts on plants, loss of cultural heritage sites and rangelands, dust emission, change in culture, and health impacts (e.g. HIV and AIDS).

On the other hand, major positive social and economic impacts are also cited. These include the following:

- providing basic infrastructure such as roads, water distribution, health facilities, and electricity,
- improving the level of education of the local community through establishment of educational facilities,
- providing employment opportunities for the local community,
- increasing the purchase and improvement of commercial machineries.

In general, the positive impacts significantly outweigh the negative ones. The report concludes that the drilling works would improve the environmental and social condition of the affected community. In order to reduce environmental impacts, it is suggested to adopt forest offsetting by planting the same forest cover that was cleared, in another area.

b. Arus-Korosi-Chepchuk geothermal drilling project, Baringo County environmental and social impact assessment study report

This EIA report investigates environmental and social impacts brought about by a geothermal drilling project in Arus-Bogoria, Baringo, and Korosi- Chepchuk areas. The study covers a wide scope. It states that special consideration should be given particularly to Lake Baringo and surrounding areas because of its rich biodiversity, and cultural significance. Also, since the study areas have scarce water resources, water to be used for the drilling project should be considered carefully.

Whilst examining several positive and negative impacts of the project, the local communities fear for changes in land/rangeland and water resources, social exclusion, and depletion of hot springs nearby Lake Bogoria. In spite this, around 95% of community members and other relevant stakeholders believe that the drilling project will bring positive impacts to the areas. They think the project can reduce the present social and economic problems in the areas.

c. Project report for the proposed water abstraction for geothermal development at Lake Baringo, Baringo County

This EIA report investigates environmental and social impacts of a geothermal development at the Lake Baringo area. Main environmental concerns raised include disturbance of the land surface, decrease in Lake Baringo water due to surface water extraction, change in the use of land and other resources, impacts on aquatic and terrestrial animals, noise, interference to social systems and communities, and health and safety of site workers.

Mitigation measures cited are: employing engineering works and pipeline installation that care for vegetation, conducting engineering works during dry season, regulating and monitoring chemical substances in effluents that are discharged to surface water, and managing waste.

Overall, the report concludes that the project is desired because the positive social and economic impacts largely outweigh the negative environmental impacts.

d. Project report for the 20-30 MWe Steam Gathering System and Power Plant in Baringo County

This EIA report details environmental and social impact assessment of a 20-30 MWe Steam Gathering System and Power Plant in Baringo County.

Specific issues raised include noise, Fuel Combustion Gases (CO_2, CO, SO_2 & NO_2), H_2S and other Non-Condensable Gases emission, impacts on global warming, dust emission, public health & visual intrusion impacts.

Besides that, social issues include impact on land, grazing grounds, water sources, and disappearance of bees.

On the other hand, major positive social and economic impacts are also cited, including:

- providing basic electric infrastructure,
- contributing great economic significance to the country,
- providing employment opportunities for the local community,
- increasing the demand for electrical power and substantial energy to the National Grid.

It is concluded that the most negative impacts can be easily mitigated.

e. Project report for the 40-60 MW Korosi Gathering System and Power Plant in Baringo County

This EIA report details environmental and social impact assessment of a 40-60 MW Korosi Gathering System and Power Plant in Baringo County.

Specific issues raised include noise, Fuel Combustion Gases (CO_2, CO, SO_2&NO_2), H_2S and other Non-Condensable Gases emission, impacts on global warming, dust emission, public health & visual intrusion impacts.

Besides that, social issues regarding the local people's resources include land, grazing grounds, water sources, and disappearance of bees.

On the other hand, major positive social and economic impacts are also cited, including:

- providing basic electric infrastructure,
- contributing great economic significance to the country,
- providing employment opportunities for the local community,
- increasing the demand for electrical power and substantial energy to the National Grid.

It is concluded that the most negative impacts can be easily mitigated.

f. Project report for the proposed 60-80 MW Paka geothermal power plant project, Baringo County environmental and social impact assessment study report

This EIA report investigates environmental and social impacts brought about by a geothermal power plant project in Paka Geothermal Area, Baringo County. The study covers a wide scope. It states that special consideration should be given particularly to volcanoes and their surroundings because of their physical, biological, socio-economic and cultural aspects of environments. Also, since H_2S would be discharged through the cooling towers emission, it would have significant impact on environment and the public in this area.

Whilst examining several potential positive and negative impacts of the project, positive impacts included:

- Improved infrastructure such as road network, water supply, health, sanitation, and Electricity ;

- Education and awareness creation amongst the community；
- Employment opportunities to the local community；
- Improved business opportunities and improved income.

The significant negative impacts are:

- Gas (H_2S and CO_2) emissions;
- Vegetation loss due clearance of project sites;
- Dust emissions;
- Health related impacts (such as HIV/AIDS);
- Erosion of cultural values

It is stated that issues pertaining to grazing grounds in the caldera should be addressed through collaboration between the Proponent, County Government and affected local communities.

g. Project report for the proposed the proposed 80-100 mw Silali geothermal power plant project, Baringo and Turkana Counties environmental and social impact assessment study report

This EIA report investigates environmental and social impacts brought about by a geothermal power plant project in Silali Geothermal Area, Baringo and Turkana Counties. The study covers a wide scope. It states that special consideration should be given particularly to volcanoes and their surroundings because of their physical, biological, socio-economic and cultural aspects of environments. Also, since H_2S would be discharged through the cooling towers emission, it would have significant impact on environment and public in this area.

Whilst examining several potential positive and negative impacts of the project, positive impacts included:

- Improved infrastructure such as road network, water supply, health, sanitation, and Electricity；
- Education and awareness creation amongst the community；
- Employment opportunities to the local community；
- Improved business opportunities and improved income.

The significant negative impacts are:

- Gas (H_2S and CO_2) emissions;
- Vegetation loss due clearance of project sites;
- Dust emissions;
- Health related impacts (such as HIV/AIDS);
- Erosion of cultural values

It is stated that issues pertaining to grazing grounds in the caldera should be addressed through collaboration between the Proponent, County Government and affected local communities.

IV-1.7 Issued permissions in the project areas

The EIA studies for geothermal well drilling projects and power plant construction projects were conducted in the target areas as summarized in the section IV-1.6 above, and licenses for the projects were issued from NEMA. GDC has a plan to take water from Lake Baringo for geothermal boring in Baringo, Paka, Korosi and Chepchuk areas. It was stated that GDC has a plan to obtain licenses for air emissions, waste water drainage and waste disposal related to geothermal well drilling before GDC commences the field work (as confirmed by the JICA team during the fourth work in Kenya in July 2016).

The volume of the Lake Baringo water reservoir is estimated to be 786,725,000 m^3 based on available information, surface area is 31,469 ha (314,690,000 m^2) and mean depth is 2.5 m. Estimated maximum pumping volume for one (1) year, 525,600 m^3, based on a daily maximum pumping rate (1,440 m^3/day) is small enough in comparison to the volume of the water reservoir. It is expected that significant negative impacts would not occur in Lake Baringo, however, the JICA team recommend monitoring the fluid level in Lake Baringo during the extraction period, since Lake Baringo is registered as a Ramsar site.

IV-2 Preliminary Study for the Direct Use of Gerothermal Energy and the Results of Interviews with Nearby Residents

A series of interviews with the surrounding residents of the five project sites were conducted to ascertain the present use of water and energy in the area and to confirm the potential of direct use of these resources. Progress and results were collected regarding a pilot test for direct use conducted by GDC in Menengai. Feasible applications of direct use for each target area were proposed below based on the information obtained during this study.

IV-2.1 Direct use

Direct use refers to the use of heat and the by-products produced during geothermal power generation. Products include thermal energy, brine, condensate, CO_2, H_2S, sulfur and precious metals.

Geothermal Development Company (GDC) is promoting the development of direct use applications, alongside power generation, in order to increase the efficiency of energy utilization. This is a relatively new concept in Kenya although it is has been practiced around the world, including Japan. Direct use can contribute to the community by providing new infrastructure; enabling opportunities for value added products; and generating employment. GDC seeks additional income by selling thermal energy – energy which would otherwise have been wasted – to industries.

In the pilot project in Menengai, GDC is implementing four demonstration projects:

1. Geothermal heating of greenhouses;
2. Geothermal heating of aquaculture ponds/tanks;
3. Geothermal milk processing; and
4. Geothermal laundry operations.

The Table IV-2.1 shows examples of direct use.

Table IV-2.1 Examples of direct use

Heat	• Agricultural uses-Raising temp in greenhouses to control humidity • Aqua cultural uses-Raising temp of ponds (fast growing and bigger organisms) • Drying – crops, fish • Heating – dairy, fermentation, honey, wood pulp • Evaporation- dairy, distillation • Refrigeration and cold storage – milk, meat • Sterilization – hospital, canning • Chemical reactions – leather treatment • Swimming and bathing • Domestic water heating
Brine	• Irrigation • Aquaculture • Swimming and bathing
Condensate	• Irrigation • Aquaculture

	• Swimming and bathing • Cement mixing • Cooling auxiliaries • Drinking water
CO_2	• Agriculture (greenhouses) • Bottling • Cold storage
H_2S	• Converted to H_2SO_4 • Counteract oxygen corrosion in pipes

IV-2.2 Direct use pilot plant in Menengai

In the pilot project in Menengai, GDC is implementing four demonstration projects:

1. Geothermal heating of greenhouses;
2. Geothermal heating of aquaculture ponds/tanks;
3. Geothermal milk processing; and
4. Geothermal laundry operations.

The JICA team visited the pilot test plants in Menengai (Figs. IV-2.1 and IV-2-2) and collected the results of the tests in July 2016. The results confirmed during the tests are summarized as follows.

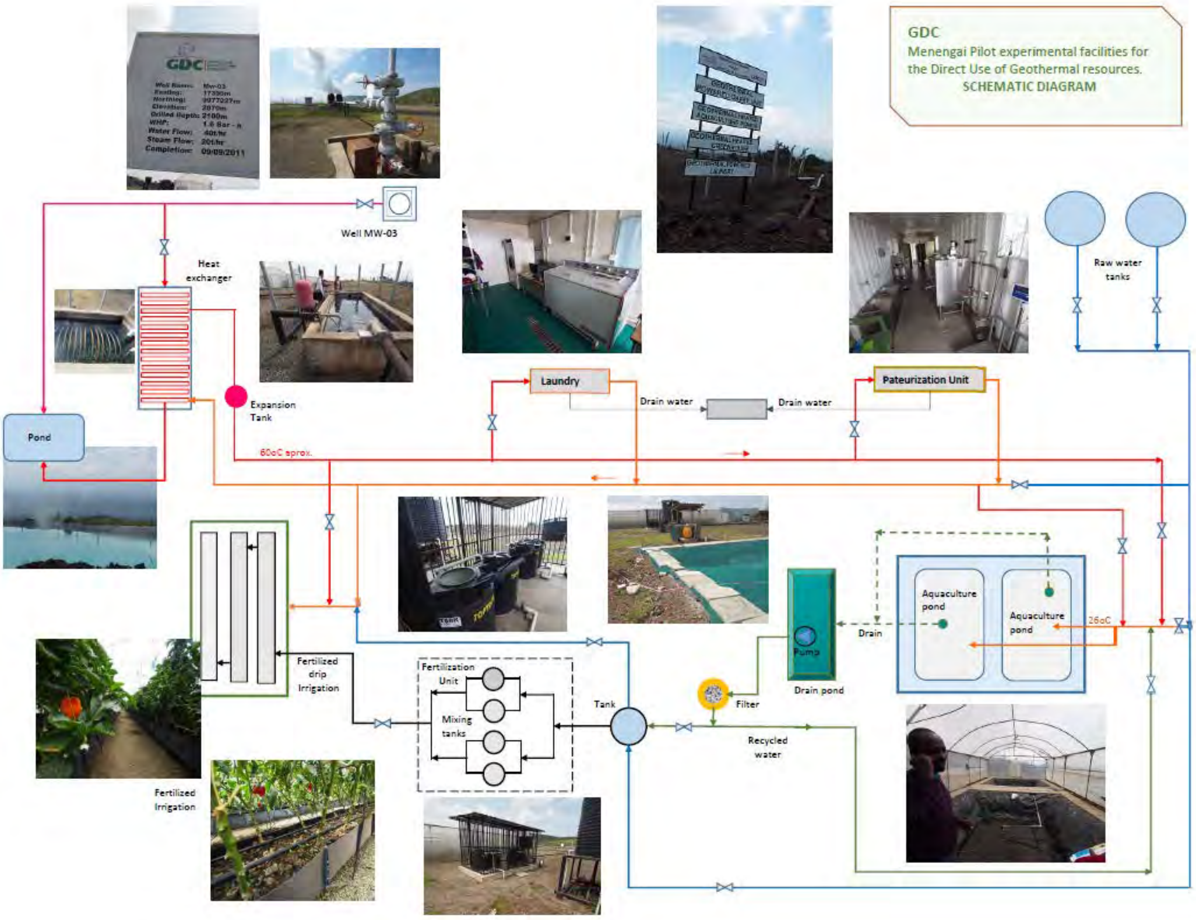


Fig. IV-2.1 Layout of direct use pilot test facilities in Menengai
Source: GDC

Direct use pilot tests were conducted at well MW-3 that does not produce enough steam to generate electricity. The depth of MW-3 is approximately 2,100 m below ground surface. MW-3 provides 40 ton/hour of hot water (brine) and 20 ton/hour of steam, and only brine is used for the direct use pilot tests. The brine was transferred to a heat exchanger through piping, groundwater taken from the shallow aquifer in Menengai site was heated up at the heat exchanger and distributed to each of the pilot test facilities. Hydrogen sulfide odor was not identified from brine and steam at MW-3 during the site walk. The brine used for exchanging heat or used by the pilot tests was drained to a pond which was constructed next to the MW-3 drilling pad. The bottom of the pond was covered by vinyl plastic sheeting to prevent infiltrating into the soil underneath the pond. Reportedly the brine was kept in the pond and most of the water was evaporated from the surface of the pond. At the time, GDC had no plan to drain the water from the pond to an area outside of the facility.

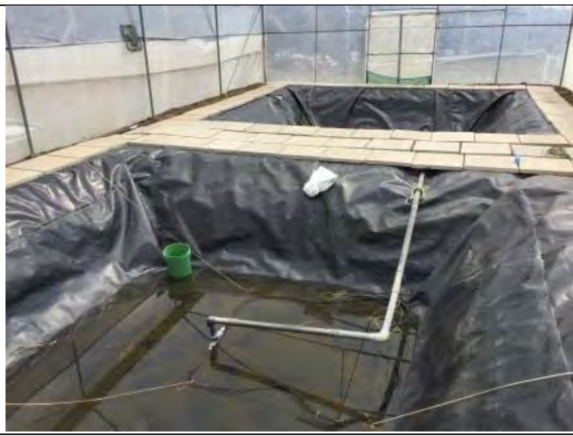
The first facility of the direct use pilot test was for agricultural use. Bell peppers were cultivated in a green house, 8 m width and 23 m length. GDC harvested bell peppers in three months through the last trial. The green house was heated by hot water pipes during the night time since the air temperature becomes low at night, but the heating system was stopped during the daytime. The temperature of the hot water was controlled to be between 60 and 75 degrees Celsius. Groundwater pumped from the shallow aquifer was used for irrigation after first using the water at aquaculture ponds. Fertilizer was added to a storage tank located between the aquaculture ponds and the green house before using the water for irrigation. It has been confirmed during the pilot tests that vegetables can be cultivated throughout the year by utilizing geothermal energy. GDC had a plan to cultivate tomatoes for the next trial.

The second facility was for aquaculture use. There were two ponds (5 m length x 5m width each, the bottom of the ponds were covered by vinyl plastic sheeting) placed in a green house. Each pond had the capacity for 500 tilapias and in total 1,000 tilapias can be bred in the facility. Average weight of a grown tilapia was 400 g to 500 g after the 1st trial of 6 months. Approximately 450 kg of tilapia was obtained during the previous trial. It was confirmed that the breeding period was shortened to 6 months by the effect of controlling the optimum temperature, 26 to 29 degrees Celsius, comparing to the general breeding period of 6 to 8 months under conditions without temperature control. GDC had a plan of conducting a 2nd trial starting from the day following the JICA team visit in July 2016.

The third facility was for milk pasteurizing. GDC used milk provided from cows in the vicinity of Menengai. The groundwater which was heated up to approximately 65 degrees Celsius at the heat exchanger was distributed to the facility and used for milk pasteurizing. Milk was pasteurized for 30 minutes and cooled down using a chiller. The treated milk was sold to GDC employees in Nakuru.

The fourth facility was for laundry. Hot water was used for laundring the work clothes of the GDC staff and drilling workers in Menengai. The heat from hot water was used for the dryer as well.

Inside green house for agricultural uses



Aquaculture ponds in a green house

Pasteurizing facility

Laundry machine

Fig. IV-2.2 Direct use pilot test facilities in Menengai

It was stated by the GDC staff that pilot tests showing the positive effects of geothermal energy had been implemented. Serious technical problem had not been identified; however, the hot water piping frequently broke, as a result of the expansion/shrinking of the piping due to operation/halting of the hot water distribution system. The leakage problem will be solved through the selection of piping materials. The first major challenge mentioned by the GDC staff for the direct use, was how to attract private companies using geothermal energy directly at an industrial zone which will be constructed at the Menengai site by presenting the result of these pilot tests. The second challenge is how to cooperate with the companies. The other technical challenges were the selection of geothermal wells for direct use, hot water distribution system & layout, the application, etc.

IV-2.3 Interview methodology and the reaction from the residents

A series of interviews with the surrounding residents for the five project sites were conducted to ascertain the life style & conditions, the present use of water and energy in the area, and the opinions regarding the potential for direct use. Whilst considering inhabited area and tribes present, two assemblies were organized for the interview. Details of each assembly (e.g. area, number of participants) are shown in Table IV-2.2. GDC presented direct and locally applicable uses of geothermal heat. Afterwards, group and personal interviews were conducted. Interviewees included not only the influential mayor but also representatives of socially vulnerable groups like women and youth. Farmers, who have a higher potential to adopt direct uses of geothermal energy, were also invited. Moreover, ways to create a conductive environment for open discussion were adopted, such as invitation of women only in some interviews.

For the local people, the concept of direct use, which is different from geothermal power generation, is new. Thus, the explanation (around 3 hours) and interviews (around 3 hours per group) took time. The local people raised several questions and seemed interested.

The local people were very glad about being able to participate in decision-making activities like this and were asking about the next visit. Also, in Menengai, some expressed the desire to personally see the practical application of direct use.

Table IV-2.2 Details of the interviews conducted

Place	Project Site	No. of Participants (including GDC)
Central Baringo Assembly	Arus、Baringo	17
Northern Baringo (Loruk) Assembly	Korosi、Chepchuk、Paka	13

IV-2.4 Present livelihood

At present, the main sources of income in the regions include grazing, agriculture, and apiculture (bee keeping) (refer to Table IV-2.3). Main products include corn, livestock (e.g. cows, goats, camels), and honey (refer to Table IV-2.4). Each region has several school teachers, other professionals, and those holding offices such as school principals.

There is a high potential to improve the livelihood of the people due to the absence of processing plants, limited access to markets and lack of water for irrigation (refer to Table IV-2.5). In the past, there was Kampi ya samaki, a fish processing factory, but it is currently not operating.

Table IV-2.3 Livelihood in the five regions

Arus	Baringo	Chepchuk	Korosi	Paka
Livestock keeping	Livestock keeping	Livestock keeping	Livestock keeping	Livestock keeping
Small scale farming	Bee keeping	Farming	Farming	Crop farming
Subsistence farming	Fishing/ fish farming	Bee keeping	Bee keeping	Bee keeping
Bee keeping	Crop farming	Trading livestock	Trading livestock	Business
	Poultry			Quarry mining

Table IV-2.4 Major products in the five regions

Arus	Baringo	Chepchuk	Korosi	Paka
Maize	Honey	Honey	Honey	Honey
Fish	Maize	Maize	Maize	Cereals
Watermelons	Livestock- cows, goats, sheep	Livestock- cows, goats, camels	Livestock-cows, goats, camels	Meat
Tomatoes	Milk			Milk
Pawpaws	Fish			
	Mellons			
	Eggs			
	Hides and skins			

Table IV-2.5 Points for improvement

Arus	Baringo	Chepchuk	Korosi	Paka
Lack of processing facilities	Lack of processing facilities Lack of water Insecurity Lack of fishing nets	Breeding Livestock disease prevention Irrigation Markets	Provision of market Irrigation Modern bee hives Capacity building	Not mentioned

IV-2.5 Present energy and water resources

The people in the regions that were interviewed depend on natural resources for their living. Firewood harvested from the mountain is the main source of energy in the regions. In the southern part, there are areas which use kerosene and charcoal. Meanwhile, from Lake Baringo to the north, only firewood is used (refer to Table IV-2.6; Fig. IV-2.4). On the other hand, for water supply, many use water pans, which collect rain water for other purposes. Communities living near Lake Baringo are fortunate to be able to use water from it (refer to Table IV-2.7 and Figs. IV-2.3 and IV-2.4). It is worth noting that communities near the lake (southern area) have more resource alternatives for both energy and water.

Table IV-2.6 Current energy resources in the five regions

Arus	Baringo	Chepchuk	Korosi	Paka
Firewood Kerosene Charcoal Solar energy	Firewood Kerosene Charcoal Solar energy Electricity	Firewood Solar energy	Firewood	Firewood

Table IV-2.7 Current water source in the five regions

Arus	Baringo	Chepchuk	Korosi	Paka
Lake Baringo River Molo River Pekkerra	Lake Baringo Pan dam Boreholes Water gutters	Pan dam	Pan dams Lake	River Nginyang Pan dam

Fig. IV-2.3 Water pan
Source: SearNet

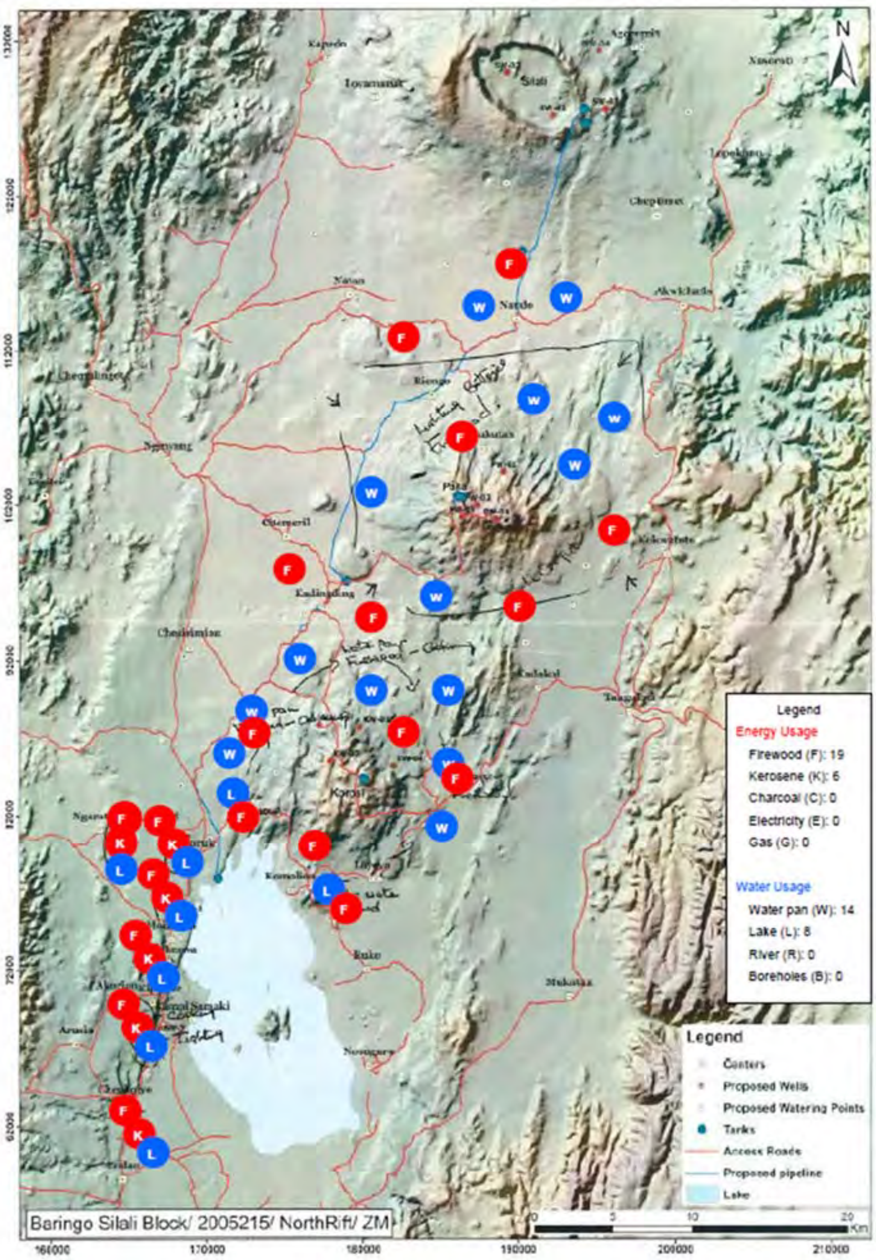


Fig. IV-2.4 Current energy resources and water sources

With regards to existing infrastructure, there are roads and electricity, particularly, at the southern side of the project site. However, there are areas like Korosi and Chepchuk, with no infrastructure (Table IV-2.8). This may be explained by the fact that kerosene and charcoal are not being used in those areas in the northern part of the project site.

Table IV-2.8 Existing infrastructure

Arus	Baringo	Chepchuk	Korosi	Paka
Roads Electricity	Road Water Electricity	None	None	Access road （Loruk to Paka)

IV-2.6 Current use of water and energy

At present, energy is used for cooking, milk processing, and electricity. Water is used for drinking, laundry and livestock.

The Tugen tribe of the north is nomadic. Nomadic tribes may change their lifestyles with the provision of alternative resources from GDC's plant operations.

IV-2.7 Prospect of direct use by the local communities

Excluding Lake Baringo, there are no major water sources in the selected regions. Also, roads have not been constructed and the lack of roads may have caused the use of firewood as the energy source in the northern part.

Thus, consistent with the interview results, the local communities are highly interested in opportunities brought by direct uses. When asked to rank possible local applications of direct uses, common priorities for the regions include irrigation, greenhouse, meat processing and fish farming (Table IV-2.9). It is worth noting that, at present, there is preference for higher priced products compared to raw materials (e.g. processed meat and leather).

Table IV-2.9 Priority list for direct use opportunities

	Arus	Baringo	Chepchuk	Korosi	Paka
1	Greenhouse, Irrigation	Greenhouse	Irrigation	Irrigation	Greenhouse
2		Meat processing	Honey processing	Greenhouse	Honey processing
3	Meat processing	Honey processing	Meat processing	Honey processing	Meat processing
3	Skin & leather processing	Fish farming	Skin & leather processing	Meat processing	Fish farming
5	Fish farming	Egg hatchery	Market	Skin & leather processing	Milk farming
6	Dairy processing	Skin & leather processing	Fish farming	Fish farming	Skin & leather processing
7	Egg hatchery	Quarry mining		Aloe vera	Egg hatchery
8		irrigation		Market	Aloe vera
9		Aloe vera			Crop drying
10		Brick making			

IV-2.8 Caution in direct use

The Rift Valley, a semi-arid region, has no seasonal water resource for most of the year. The local people have to travel long distances to get water. There are reports which show that groundwater and the water in Lake Baringo have high concentrations of Fluoride in Nakuru, Baringo districts. There is also information from GDC stating that the Fluoride concentration in Lake Baringo was high when measured during the site study.

Water with brine and steam condensate can be used for irrigation and drinking as requested by communities. However, since brine has high content of heavy metals and brine is planned to be recharged into the underground for future geothermal purposes, it is not feasible to use brine for irrigation and drinking. Since steam condensate contains less content of heavy metals, it can be used for irrigation or drinking. However, using steam condensate for drinking water is still challenging since it may contain H_2S, causing odor. Even if the concentration of H_2S is lower than the drinking criteria provide by WHO, humans have a sensitive sense of odor for H_2S. More investment for water treatment facilities will be needed to use steam condensate for drinking. There is a need to check the water quality and ensure its compliance with NEMA (refer to Table IV-1.8) and WHO standards, before using the water. According to the person responsible for GDC's Direct Use, there is a plan to conduct water quality testing in all sites to identify the most appropriate water usage.

Even according to the Direct-Use Guidebook, water quality and temperature are both important when using water directly because corrosion and scaling may have effects on the equipment. In that case, it is better not to use water with brine and steam condensate directly. It is advised to purchase a heat exchanger and use that heat to treat water.

IV-2.9 Proposed application of direct use

The five project areas are located in different environments in terms of natural environment, existing infrastructure, life culture, etc. Application of direct use must be well planned based on the characteristics in each project area. The JICA team proposes recommended applications in each project area according to the currently available information. Irrigation was not considered as a recommended application for direct use in this report since water quality has not been assessed (as mentioned in Section IV-2.8) even though most of communities requested to use the water for irrigation. Hence, the application to use it for heat was considered (Fig. IV-2.10).

Mainly Tugens settle in cities, villages and surroundings in the southern areas such as the Arus and Baringo area and Pokots live a nomadic life in the northern areas such as Paka, Korosi and Chepchuk. Livestock keeping is the main source of income in both the northern and southern areas. However, agriculture and fish farming are also common in the southern area.

Greenhouses for agriculture and fish farming are recommended as a feasible application and can contribute to the improvement of life and income in local communities in the Arus and Baringo areas. Direct use application requiring periodical and/or continuous work can be easily applied in the southern area because of their current life style and easy access from large towns or villages to the direct use facilities in Arus and Baringo areas.

It is considered that labor-intensive applications, including agriculture and fish farming in greenhouses, is not easily applicable in the northern areas such as Paka, Korosi and Chepchuk since labor-intensive applications would require the nomadic groups (including Pokot and Turkana) to change their life styles. Types of applications where direct-use facilities are used only when the nomadic people need to visit and use it are recommended. The examples are honey treatment, leather processing (dry and chemical treatment) and meat processing (dry).

Hot springs and warm water pool are applied in Olkaria area, however, these applications can provide less benefit to local communities in the five project areas, since all of the areas are not easily accessible from big towns.

Table IV-2.10 Feasible direct use applications (Heat)

Arus	Baringo	Chepchuk	Korosi	Paka
Greenhouse for agriculture	Greenhouse for agriculture	Honey processing	Honey processing	Honey processing
Fish farming	Fish farming	Leather processing (Dry and chemical treatment)	Leather processing (Dry and chemical treatment)	Leather processing (Dry and chemical treatment)
		Meat processing (Dry)	Meat processing (Dry)	Meat processing (Dry)

IV-3 Preliminary Initial Environmental Examination in Promising Geothermal Fields

IV-3.1 Initial environmental impact assessment:

For the initial environmental impact assessment, an investigation of items related to both natural and social environment in the Arus, Baringo, Korosi, Chepchuk, and Paka areas was conducted. Supplementary data collection for the Silali area was also conducted.

A summary of the results for each region are shown in Table IV-3.1 through Table IV-3.7.

a. Overall initial EIA results

Table IV-3.1 Similar characteristics among the five regions and Silali area

Items		Notes
Natural environment	Location	South of Rift Valley, found in the Western region of Kenya
	Air Quality	H_2S concentration levels were 0.0 ppm in all places where measurements were taken. The concentrations are expected to be more than 1.0 ppm H_2S during drilling, well discharge testing and project operation which is far below the WHO threshold for human exposure limit value of 10 ppm. The current H_2S background concentrations at receptor sites were 0.0 ppm (below detection limit).
	Topography and Geology	The areas possess several features of geological significance that are considered indicators of possible geothermal potential. The regions have some volcanic areas.
	Soil	For all the regions, the soil developed from volcanic rocks. Depending on the area, the soil is made up of alluvial sediments and volcanic rocks. The bedrock composition in several regions is basalt. This has weathered over time under dry climatic conditions to give rise to sandy loam soils in texture. These, however, are extremely shallow in depth. The water holding capacity is moderate to low. The soil is stony and gravelly clay loam.
	Plants	Mainly evergreen shrubland. Several areas are covered with bushes.
Social Environment	Demographic	Low human population density because there are no big cities in the region.
	Education	Education level is low especially in areas away from urban centers. Social background such as early marriage, pastoral lifestyle and high poverty levels are some of the reasons behind low rates of enrollment.
	Language	English is the official language in Kenya. Swahili is the national language. Local languages include Tugen, Pokot, and Ilchamus/Njemps.
	Religion	Christianity dominates Baringo County. However, Islam and other traditional religions are also being practiced by some people.
	Regional characteristics	Most of the community members live in traditional huts and wear traditional clothes. For instance, men wear shukas around their waists and women wear traditional beads around their necks. This traditional practice has been abandoned by most communities in Kenya. The region suffers from several social and cultural related problems. The main one being insecurity as a result of inter-ethnic conflicts. These are caused by either cattle rustling or boundary disputes among Pokots, Turkana, and Samburu (and to a smaller extent Tugen and Marakwets). Besides wealth and cultural ego, one of the main reasons that propel cattle rustling is the high bride price men have to pay the brides. Conflict over resources (pasture and water) intensifies particularly during drought periods. This is worsened by the access to light firearms by the local communities in recent times.
	Livelihood	The primary economic activities are livestock and bee farming. Some people engage in small scale farming. Urban self-employment includes small-scale business (wholesale and retail trades, hotels) and informal sector enterprises (e.g.

Items		Notes
		welding and carpentry) in urban and market centers. In general, most of the labor force within the project area is unskilled or semi-skilled.
	Poverty	More than 50％ of population in the region is below the poverty line.
	Land use	Main land uses include bush, grazing land and small scale farming.
	Land ownership	Most of the land in the proposed project area is communal land (trust lands).
	Infrastructure (Sewerage, roads, electricity, hospital)	Road connections are not good. Only a few places within the project area are connected to the electrical grid. These are mainly the trading centres located along the distribution grid. There is water scarcity in the project area.
	Cultural Heritage	There are no national cultural sites in the project area. Hot springs were considered as sacred places by the community in the past but now with Christianity they only consider it as an important place manifesting God's work on the earth's surface. It is advisable to consult the local people when the project proceeds further.
	Greenhouse Gases	No significant GHG source identified.
	Stakeholders	NEMA, KWS, KFS, Ministry of Agriculture, Ministry of Public Health, Water Resource Management Authority (WRMA), Water Resource Users Association, Representative of Education, County Government –(Governor, Representative of Youth and Women and Officials), County Commissioner, Member of County Assembly (MCA), Administrative local leaders (Chief and Assistant Chief) Local Community, Community Based Organizations (CBOs, such as women groups and youth groups), NGO, Member of Parliament, Group Ranch Official

b. Arus

Table IV-3.2 Initial EIA results for Arus

Items		Notes
Natural environment	Location	Arus-Bogoria geothermal is situated between Menengai geothermal area to the south and Lake Baringo prospect to the north.
	Water Environment and Protected Areas	Lake Bogoria and part of its catchment area is rich in fauna hence has been protected as Lake Bogoria National Reserve (LBNR) and covers an area of 107 km^2. It was gazetted in 1973 and is currently managed by Baringo and Koibatek County Councils. Recently the LBNR was designated as a third Ramsar site after Lake Nakuru and Naivasha. The lake is saline and covers an area of 34 km^2. It is rich in biodiversity, hosting about half of the world's population of lesser flamingos (*Phoeniconaias minor*). It is also a habitat to other bird species including greater flamingos (*Phoeniconaias rubber*), black-necked grebe (*Podiceps nigricollis*), ostriches, fish eagles and several migratory species. Due to its avifauna richness, it has been designated as an Important Bird Area (IBA). The mammalian fauna in LBNR include zebras, gazelles, buffaloes, several primates and the only relatively accessible population of greater kudus. In addition to its rich biodiversity, Lake Bogoria has numerous hot springs.
	Flora & fauna	**Flora:** In Arus hills the vegetation is evergreen shrubland dominated by Euclea divinorum at highest elevations which changes to bushland dominated by the Acacia species at lower elevations. The vegetation in the lower elevations is mainly thorny bushland dominated by the species of Acacia, Balanites and Commiphora with patches of riverine woodland containing Ficus capensis, Acacia xanthophloea and Acacia tortilis. In the lower slopes of the Siricho Escarpment, Combretum and Grewia thickets dominate. **Faunal Species:**

		Among the faunal species in the project area (based on local community knowledge) include gazelles, baboons, monkeys, dikdik, rabbits, hyenas, squirrels, scorpions. Avifauna such as heron birds, ostriches, doves, weaver birds and the horn bills (were identified) within the project area. Among reptiles that are likely to be found include the monitor lizards, geckos, tortoises and snakes such as Rock Pythons, Puff Adders and the Black Mamba. Several insects were also identified in the project's impact area. Among the prominent ones were dragon flies and butterflies
	Rare species	Barbus intermedius and Labeo cylindricus
Social Environment	Population distribution	In Arus' suburban area reside Emining and Mochongoi, a comparatively big community (division). According to the 2009 KNBS statistical record, there were 16,067 and 25,737 people residing in the areas, respectively.
	Landscape	Baringo and Bogoria Lake are important places for landscape
	Tribes	Tugens
	Minority groups and indigenous people	There are no minorities and marginalized people.

c. Baringo

Table IV-3.3 Initial EIA results for Baringo

Items		Notes
Natural environment	Location	Baringo County is situated in the rift valley region and borders Turkana and Samburu Counties to the North, Laikipia to the east, Nakuru to the south, Uasin Gishu to the southwest, and Elgeyo Marakwet and West Pokot to the west. It is located between longitudes 35º 30'E and 36º 30'E and between latitudes 0º 10'N and 1º 40'N
	Protected Area	Lake Bogoria was designated as a Ramsar site in January 2002. Around 500 bird species live in the area. Lake Bogoria is a freshwater lake home to freshwater fishes, hippopotamuses, and crocodiles.
	Flora & fauna	Lake Baringo is a fresh water body and is an important habitat for seven fish species. The fish species found in the lake include Tilapia Oreochromis niloticus, Protopterus aethiopicus, Clarias gariepinus, Barbus intermedius and Labeo cylindricus. The lake provides critical habitat and refuge for nearly 500 bird species, some of which are of regional and global conservation significance. The site is also a habitat for many species of animals such as *Hippopotamus amphibious* and *Crocodylus niloticus* and a wide range of mammals, amphibians, reptiles and invertebrate communities. The area around the western shore of the Lake is mainly inhabited by Acacia tortilis woodland, with small bush-covered hills, gorges and cliffs. Ficus spp. grows on the cliff faces. The north and east have denser bush, thinning out towards the south, dominated by Acacia mellifera, A. reficiens and species of Boscia coriecea, Commiphora, Terminalia and Balanites aegyptiaca.
	Rare species	*Barbus intermedius* and *Labeo cylindricus*, The tilapia *Oreochromis niloticus baringoensis* is endemic to Lake Baringo.

Social Environment	Population distribution	In 2009, the population of Baringo County was 555,561, this being 1.4% of the Kenyan population with 50.2% male and 49.8% female. It has a population density of 282 persons per square kilometers. The County has 6 constituencies namely Tiaty (East Pokot), Baringo South (Marigat), Mogotio, Eldama Ravine (Koibatek), Baringo Central and Baringo North. Kabarnet Town is the largest urban population center with a population of 5%, Eldama Ravine 3%, Marigat 1%, Maji Mazuri 1%, Mogotio 1% and Timboroa 1% of the Baringo population.
	Landscape	Baringo and Bogoria Lake are important places for landscape
	Tribes	Tugen, Pokot, Ilchamus
	Minority groups and indigenous people	Ilchamus is considered as a minority. The Constitution of Kenya recognizes the minority and marginalized groups within the country but there are no specific actions defined to be taken if they are affected by any project
	Relevant parties	Baringo Lake Management Association, Representative of the fishing industry, Parliament Member (related to the fishing industry)

d. Korosi

Table IV-3.4 Initial EIA results for Korosi

Items		Notes
Natural environment	Location	Korosi geothermal prospect is located in the northern sector of the actively faulting Kenya Rift Valley, approximately 300km from the capital, Nairobi, at approximately 0º45'N and 36º 05'E. The Korosi volcano neighbors Lake Baringo to the south and Paka volcano to the north.
	Flora & fauna	**Flora:** Away from the lake shores the terrestrial vegetation is mainly thorny bushland dominated by the species of Acacia, Balanites and Commiphora with patches of riverine woodland containing Ficus capensis, Acacia xanthophloea and Acacia tortilis. In the lower slopes of the Siricho Escarpment, Combretum and Grewia thickets dominate. **Faunal Species:** Among the faunal species in the project area (based on local community knowledge) include gazelles, baboons, monkeys, dikdik, rabbits, hyenas, squirrels, scorpions. Avifauna such as heron birds and ostriches, doves, weaver birds and the horn bills (were identified) within the project area. Among reptiles that are likely to be found include the monitor lizards, geckos, tortoises and snakes such as Rock Pythons, Puff Adders and the Black Mamba. Several insects were also identified in the project impact area. Among the prominent ones were dragon flies and butterflies
Social Environment	Tribes	Pokot

e. Chepchuk

Table IV-3.5 Initial EIA results for Chepchuk

Items		Notes
Natural environmen	Location	Chepchuk is the name given to the highest point (1380m) of a series of prominent north to south trending ridges that rise 220m above the plains to the northeast of Korosi and southeast of Paka
	Flora & fauna	In Chepchuk area, the physiognomy of vegetation is a bushland dominated by the Acacia species. The undergrowth is composed of mainly the herbaceous and

		grass species most of which are annuals. Faunal Species: Among the faunal species in the project area (based on local community knowledge) include gazelles, baboons, monkeys, dikdik, rabbits, hyenas, squirrels, scorpions. Avifauna such as heron birds and ostriches, doves, weaver birds and the horn bills (were identified) within the project area. Among reptiles that are likely to be found include the monitor lizards, geckos, tortoises and snakes such as Rock Pythons, Puff Adders and the Black Mamba. Several insects were also identified in the project impact area. Among the prominent ones were dragon flies and butterflies
Social Environment	Population distribution	In Chepchuk's suburban area resides Tangulbei, a comparatively big community (division). According to the 2009 KNBS statistical record, there were 17,251 people residing in the area.
	Tribes	Pokot

f. Paka

Table IV-3.6 Initial EIA results for Paka

Items		Notes
Natural environment	Location	Paka volcano is situated approximately 25 km north of Lake Baringo at 00° 50'N and 36° 12'E
	Protected Area	There are no protected areas within the development site.
	Flora & fauna	**Flora:** The project area has moderate plant diversity typical of semi and arid regions in Kenya. Acacia raficiens is the most abundant plant species. The most common plant species include; Acacia meliffera, Salvadora persica, and Boscia coriacea. **Fauna:** The Paka-Silale area is considered to be naturally rich in terms of animal diversity this is due to the existing natural habitats. Among the faunal species observed are termites, weaver birds, Hornbill and lizards. Goats that are the mainstay of the community livelihoods are a common sight in the project area. The wild animals in the area included dikdik.
	Rare species	Acacia species (*Acacia xanthopholea, Acacia abyssinica, Acacia drepanolobium*), white gul mohur (Delonix elata), woolly caper bush (*Capparis tomentosa*)
Social Environment	Population distribution	The demographic male-female ratio is about the same – that is 39,122 male and 39,324 female. In Paka's suburban area resides Nginyang, a comparatively big community (division). According to the 2009 KNBS statistical record, there were 20,758 people residing in the area.
	Education	The current literacy level in the area stands at less than 5%. The district has 60 ECD centers, 34 primary schools 3 secondary schools and 1 tertiary institution. Of the primary schools, the whole of Kapedo location in Turkana East district, has only 3 public primary schools.
	Tribes	Pokot

a. Silali

Table IV-3.7 Initial EIA results for Silali

Items		Notes
Natural environment	Location	Silali volcano is situated approximately 50 km north of Lake Baringo at 01° 10'N and 36° 12'E
	Protected Area	There are no protected areas within the development site.
	Flora & fauna	**Flora:** In Silali Area, a total of 115 plant species distributed in 86 genera and 39 families. The project area has moderate plant diversity typical of semi and arid regions in Kenya. The most common plant species include xerophytes, Aristidakeniensis and Digeramuricata. Three plant species were found to be endemic regionally. **Fauna:** The Paka-Silale area is considered to be naturally rich in terms of animal diversity this is due to the existing natural habitats. Among the faunal species observed are birds(total 70 in 35 families), mammals(12 mammal species), reptile (8 species). Goats and cattle are the main economic animals in this area.
	Rare species	The Somali Bee-eater bird (Meropsrevoilii), the Uniform–scaled Gecko (Hemidactylusisolepis and two migratory birds i.e. Pygmy long-tailed sunbird (Anthreptesplatura) and Beautiful sunbird (Nectariniapulchella).
Social Environment	Population distribution	The demographic male-female ratio is about the same – that is 39,122 male and 39,324 female.
	Education	The current literacy level in the area stands at less than 5%. The district has 60 ECD centers, 34 primary schools 3 secondary schools and 1 tertiary institution. Of the primary schools, the whole of Kapedo location in Turkana East district, has only 3 public primary schools.
	Tribes	Pokots Turkana, Samburu and to a smaller extent Tugens and Marakwets

IV-3.2 Selection of environmental impact assessment items

A geothermal development project may cause environmental and social impacts during its exploration, construction and operation phases. Based on the initial environmental and social impact assessment conducted for each potential geothermal site, EIA items related to potential impacts of the project have been selected in this study.

Detailed plans to construct facilities and wells have not been developed in some of the planned development sites. Thus, assumptions regarding the potential risks/impacts were made based on a worst case scenario, to be on the safe side.

Table IV-3.8 summarizes the initial assessment of potential environmental and social impacts of the project. The impact rating adopted has four levels (A, B, C, D), depending on the severity of the impact. Description of each rating is shown below:

A：Serious negative impacts are expected.

B：Some negative impacts are expected.

C：Extent of impact is unknown.

D：No significant impact. IEE/EIA is not necessary.

Assessment results are common for all the sites. For items that differed in each site, the name of the region is shown. For the detailed assessment of each region, refer to the attached file.

Table IV-3.8 Environmental and Social Impact Initial Assessment

Items		Impact Rating: Exploration/ Construction Phase	Impact Rating: Operation Phase	Explanation (scope and likelihood of potential impacts)
Social Environment	Involuntary resettlement	C	D	・In the current plan, there are few permanent residents in a significant part of the geothermal development area. Rather, surrounding nomadic people use scattered portions of land. Thus, resettlement is highly unlikely. ・Since roads have been constructed in Arus and Baringo geothermal development areas, the possibility of new relocation during exploration works is comparatively low. In other regions, access roads have not been constructed. In all the regions, population density is low and there is also a low possibility of resettlement due to the geothermal development. However, the decision on resettlement depends on the detailed plan of the proposed development, thus it remains uncertain at this stage.
	Employment, livelihood, and local economy	B	B	・There are high hopes for the positive impacts of the project to the local economy and the lives of the residents, such as increase in employment opportunities, increase in local procurement of materials and equipment, provision of infrastructure through project development, among others. ・There is a possibility of temporarily impacting the local economy and the lives of the residents due to the decrease in rangeland from land expropriation, rangeland usage restrictions (nearby the power plant's planned construction site). In such cases, the impact on residents' lives can continue even after project construction and operation.
	Land use and use of local resources	B	B	・Land and local resources will be used for the base installation needed in exploration and construction. ・Among others, the power generating facility is expected to use land and local resources.
	Social organization: social capital, local decision-making body, etc.	C	C	In the area, there are several organizations – government organizations (local government, tribal communities), social organizations (educational institutions), sectoral groups (women groups, youth groups), religious organizations (Christian groups), NGOs, community conservancies, etc. There is a need to obtain the consensus of these groups and organizations. At this stage, the impacts of each project are still unclear. However, in the interview

Items		Impact Rating		Explanation (scope and likelihood of potential impacts)
		Exploration/ Construction Phase	Operation Phase	
				regarding direct use, there were many positive opinions regarding the geothermal development in the areas. The people have high hopes of the positive impacts of the project.
	Existing social infrastructure and social services	C	D	・Improvement of social infrastructure through construction and installation of roads and water distribution facilities, during exploration and construction of the project, can be expected. On the other hand, transporting construction equipment and materials may cause stress and damage to existing roads. However, these impacts are still unclear at this stage. ・Positive impacts are also anticipated, such as construction of roads (including operation and maintenance), and electricity distribution to residents.
	Poor people, indigenous people, minority groups	C	C	・Around 50% of the population around the development area are below the poverty line. There are high hopes for positive economic impacts from the construction of the power generating facility. ・Except Baringo, there are no minority or socially marginalized groups nearby the development areas. In Baringo, Ilchamus minority group resides at the eastern area beside Lake Baringo. The distance from the project site is quite far, thus the impact may not be significant. There may be a certain level of impact on the local infrastructure,that is nomadic in nature, for most part of the prospect areas. However, these are still unclear at this stage.
	Unequal distribution of benefits and harm	C	C	・There may be concentration of pollution in a specific area or unequal damage, depending on the site location and planning of the power generating facility. There is also a possibility that certain areas and specific groups/persons will benefit from the project. ・At this stage, details of these impacts (existence and scale) are still unclear because these would depend on the detailed plan of the development.
	Cultural Heritage	C	C	・There are no cultural heritage sites within the planned development areas. On the other hand, the community used to consider hot springs as sacred places in the past and even now with Christianity they consider it as an important place manifesting God's work on the earth's surface. There is a need to consult the community and carefully consider these things during the detailed planning of the development. ・At this stage, details of these impacts (existence

Items		Impact Rating		Explanation (scope and likelihood of potential impacts)
		Exploration/ Construction Phase	Operation Phase	
				and scale) are still unclear because these would depend on the detailed plan of the development.
	Conflict of local interest	C	C	There may be conflict between groups that support and oppose the project within the area. At this stage, however, it is not clear.
	Water use, water rights, communal rights	B	B	・During exploration and construction phases, the use of surface water for well excavation works may affect amount of river flow and water level of the lake. Since the surrounding areas are arid, using water from rivers can have comparatively significant impacts depending on the season. Using a small quantity of water from the lake may have less impact. Therefore, it is necessary to confirm the quantity of water intake, usage of bodies of water, and water rights during the feasibility study. ・Regarding water withdrawal, there is a need to obtain a permit from WRMA.
	Public Health	C	D	Public health may worsen because of insufficient treatment capacity and lack/absence of health facilities, during exploration and construction phases. At this stage, details of these impacts are still unclear because these would depend on the development plan.
	Disaster (hazards), Infectious diseases like HIV/AIDS	C	D	・There is danger that HIV/AIDS may spread and worsen through the engagement of several construction workers from outside. On the other hand, since population density is low in the development areas and majority of the population are nomadic (not permanent residents), details of the impacts are unclear, at this stage. ・Impact during operation may be minimal because there is a very little possibility of engaging workers from outside and industrial workers will be limited.
Natural Environment	Topography, geology	A (Korosi, Chepchuk, Paka) B (Arus, Baringo)	D	・The topography of the area may be changed due to engineering/construction works during exploration and construction phases. There is a high possibility that construction, particularly in the Korosi, Chepchuk, Paka areas, will cover a wide area because infrastructure, such as access roads, water pipelines for construction, has to be constructed. ・There will be very minimal impact on topography and geology during operation phase.

Items		Impact Rating		Explanation (scope and likelihood of potential impacts)
		Exploration/ Construction Phase	Operation Phase	
	Soil erosion	A	D	・During exploration and construction phases, shaping of the foundation platform can expose bare land. The exposed soil is vulnerable to erosion particularly when it rains. ・There will be very minimal soil erosion during operation phase because there will be no large-scale engineering/construction work anticipated.
	Hot spring	B	A	・Drilling and exploration of geothermal wells may temporarily affect existing hot springs around the power plant sites. ・During operation, continuous extraction and reinjection of geothermal fluids from and to deep underground may also affect existing hot springs around the power plant sites.
	Groundwater	D	D	・There will be no withdrawal of groundwater. From the experience with other geothermal power plant projects, it is highly unlikely that well drilling and other activities will affect the amount and level of groundwater.
	Condition of rivers, lakes, and wetlands	B (Arus) C (Baringo, Korosi, Chepchuk, Paka)	C	・During exploration and construction phases, there will be no engineering or construction work that could significantly alter the condition of rivers, lakes and wetlands. However, in Arus region, since there are plans to withdraw water from the nearby Molo River, impacts will be anticipated depending on the plan. At this point, the scale of the impact is still unclear. There are also plans to withdraw water from Lake Baringo, but since the amount is relatively small, the impact is still unclear at this stage. ・During operation, water to be used in the power plants will be withdrawn from nearby water bodies. This can affect river flow and lake water level. However, since the amount of water that will be withdrawn is small, the impact on water quantity is anticipated to be small. In the case of discharging brine water from power generation, the salt concentration may be high. With low river flow and high discharge quantity, water quality of the river will be affected. However, since this depends on the detailed development plan, the scale of the impact is unclear at this stage.

Items			Impact Rating: Exploration/ Construction Phase	Impact Rating: Operation Phase	Explanation (scope and likelihood of potential impacts)
	Flora, fauna and biodiversity		C	C	・During exploration and construction phases, clearing of vegetation and land conversion can cause temporary impacts on flora and fauna. However, the density of vegetation is low since the area is dry, thus the scale of the impact may not be as big as expected. At this stage, it is still unclear. ・There will be minimal impacts on flora, fauna and biodiversity during operation phase. Details are still unclear at this point.
	Landscape		B	B	・Depending on the power plant site, the construction of the power plant, its surrounding facilities, and access roads can affect the view and natural landscape of the area. Lake Bogoria and Lake Baringo, near Arus region, have visual significance. ・Depending on the power plant site, existence of facilities and white smoke (steam) may affect the area's landscape.
	Global warming		D	D	・Bringing construction equipment, machinery, and materials used in exploration and construction phases, in and out of the site can emit low amounts of greenhouse gases. The anticipated impact is temporary and minor. ・CO_2 emission during operation is expected. However, GHG emissions would be less compared to alternative power generation processes as it uses a very clean technology. Thus, several positive impacts are expected.
Pollution	Air pollution	H_2S	B	A	・With the conducting of production tests to evaluate geothermal reservoirs, H_2S will be generated and would temporarily affect the surrounding areas. ・Geothermal fluid containing H_2S is used as steam for power generation. With this, H_2S with steam is emitted from the cooling tower. This can cause environmental impacts to areas surrounding the power plant.
		Dust	B	D	・Vehicles transporting equipment and materials during construction will hoist dirt and create dust clouds. However, the affected area will be limited. There will be impacts if there are residents near access roads. ・ There will be minimal impact during operation due to the limited number of passing of vehicles.

Items		Impact Rating		Explanation (scope and likelihood of potential impacts)
		Exploration/ Construction Phase	Operation Phase	
	Water Pollution	A	A	・Muddy water from drilling works and water effluent from construction can cause water pollution. Also, with exposure of bare soil during site development, rainwater with eroded soil can pollute surface water. ・During operation, effluent from the power plant may affect surrounding water bodies.
	Soil Pollution	B	C	・During exploration and construction, excavation sludge and leakage from temporary accumulation of warm water may cause pollution of surrounding soil. ・During construction of facilities on land, there will be no handling/use of soil contaminants. ・During operation, there will be no handling/use of soil contaminants. On the other hand, with direct use, steam and brine water, which contain heavy metals, will be used. This can cause soil pollution. Details of the impacts are still unclear at this stage.
	Waste	A	A	・During exploration and construction, industrial waste (excavation sludge, construction waste and debris) will be generated. ・During in-service, industrial waste (e.g. sludge and waste oil) will be generated.
	Noise and vibration	B	A	・Noise and vibration will be generated from the discharge test, operation of construction equipment, and construction works. Since these will be temporary, the anticipated environmental impact is low. ・During operation, the cooling tower, steam turbine, and generator will produce noise and vibration and these can affect the environment.
	Land subsidence	D	A	・Extraction of geothermal fluid during exploration and construction phases happens for a short period of time, thus significant impact is not foreseen. ・Extraction and injection of hot water from deep underground during operation, may cause land subsidence to the power plant's surrounding areas. Geothermal fluid will be extracted from deep underground and hot water will be returned to deep underground, is forecasted land subsidence in the area of the power plant.
	Offensive Odor	C	C	・Foul odor of H_2S from the discharge test may temporarily affect surrounding areas. Since the population density there is low, the extent of the impact is still unknown. ・Foul odor of H_2S from the power plant during operation, may temporarily affect surrounding areas. Since the population density there is low, the extent of the impact is still unknown.

Items		Impact Rating		Explanation（scope and likelihood of potential impacts）
		Exploration/ Construction Phase	Operation Phase	
	Accident	C	C	・The possibility of accidents caused by H_2S gas from the discharge test is low but not negligible. ・Accidents during construction and operation (H_2S gas leakage) are possible.

V RECOMMENDATIONS FOR REVIEWING THE GEOTHERMAL DEVELOPMENT MASTER PLAN

V-1 Study Regarding the Geothermal Development Priorities

V-1.1 Previous studies regarding geothermal development priorities

Comparative evaluations regarding the development potential for the geothermal prospects existing along the Rift Valley in Kenya had been carried out by BGS (1993) and KenGen (2002). BGS (1993) performed an evaluation based on the results of geological and geochemical surveys for nine geothermal fields in the Northern Rift Valley (Table V-1.1). KenGen (2002) evaluated twelve geothermal fields located throughout the entire Rift Valley in Kenya taking into account the results of geophysical surveys (Table V-1.2). However, Olkaria was not evaluated as part of this survey.

In the early stages of geothermal exploration, two essential factors used to evaluate resource potential are the potential and size of heat source and the estimated temperature of subsurface geothermal fluids. Therefore, the age of volcanic activity, the extension (area) of surface geothermal manifestations, geochemical temperatures and others are utilized as the primarily parameters. In the evaluation by KenGen (2002), they refer to the geochemical temperatures calculated by BGS (1993).

Table V-1.1 Geothermal resource evaluation by BGS (1993)

Locality	Relative strength and style of activity	Area of activity (km^2)	Max surface Temp (°C)	Geothermometry (°C) range	average	Age of last trachytic activity
North Is.	Vigorous fumaroles, solfataras and hot ground	0.5	96.3	241–244	243	–
Central Is.	Vigorous fumaroles, solfataras and hot springs	0.5	97.4	251–253	252	–
Kakorinya	Fumaroles of moderate strength and hot steaming ground	20	98.6	189–314	263	58 ± 4 ka
Em'gogolak	Moderately strong fumaroles and hot steaming ground	8	96.0	310–343	327	c.100 yr
Silali	Moderately strong fumaroles and hot steaming ground	20	96.8	261–335	304	4 ± 2 ka
Paka	Moderately strong fumaroles and hot steaming ground	32	97.8	256–329	303	11 ± 3 ka
Chepchuk	Weak fumaroles and hot, altered ground	2.5	96.1	202–261	231	1.13 Ma
Korosi	Weak fumaroles and hot, altered ground	33	95.7	197–203	200	104 ± 2 ka
Ol Kokwe Is.	Moderately strong fumaroles hot springs and solfataras.	<0.5	97.2	–	170	?300 ka

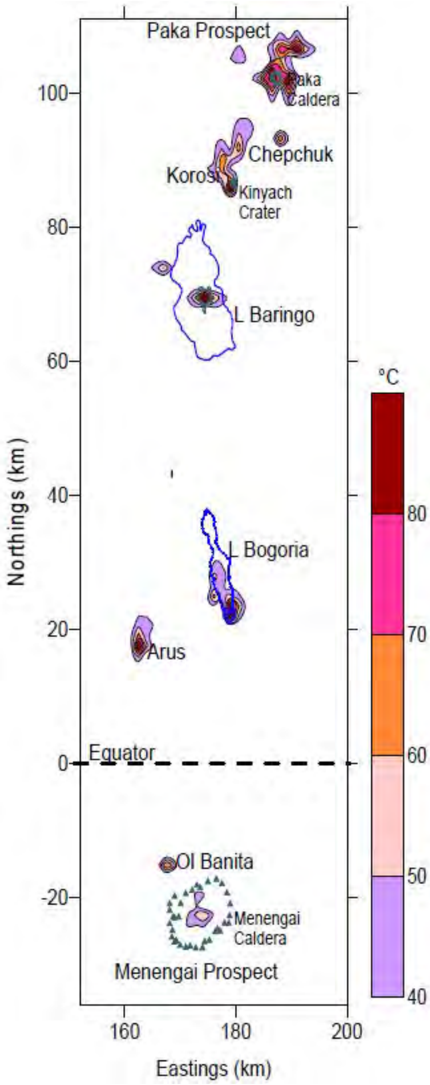
Note: Geothermometry values are for a methane/ethane gas geothermometer, except for the value for Ol Kokwe which is for a chalcedony silica geothermometer.Source: BGS (1993)

Table V-1.2 Geothermal resource evaluation by KenGen (2002)

	Name of Prospect	Geological Setting	Age of last volcanism		Nature of Geothermal Activity	Area of activity (km^2)	Max. measure surface T (°C)	Geothermometry (°C)		Heat Source	Geophysical Indications
			Bas	Trach				Range	Ave.		
3	Silali	Caldera volcano that was active between 224Ka to 200 yrs BP. NNE structures abundant and last activity was basaltic	200-300 yr BP	4±2 ka	Moderately strong fumaroles and hot steaming grounds. Large (Kapedo) spring discharge (100MW_t) to River Suguta in the west of volcano.	20	96.8	261-335	304	Large, shallow, and associated with caldera	Positive magnetic anomaly and high seismicity within the caldera. No resistivity data available.
4	Emuruangogolak	Caldera volcano that commenced activity at 900ka and continued to recent times. NNE tectonic structures dominant	250 yr BP	100 yr BP	Moderately strong fumaroles and hot steaming grounds	8	96.0	310-343	327	Large, shallow, and associated with caldera	High gravity anomaly and positive magnetic anomaly
1	Suswa	Central volcano with two calderas and N-S trending fissure zone. Volcano active between 400ka – Recent and dominated by phonolite.		0.24Ma -200 yr BP (est)	Fumaroles, steaming and altered grounds. Deposits of sulphur occur within the annular trench. Altered lithics (T>250°C) common.	3	93	230-310	265	Large magma chamber at shallow depth immediately below Caldera II.	High gravity in the south of caldera which is also the most seismically active. Strong magnetic anomaly. Reservoir is at >1000 masl -Resist
2	Menengai	Nested calderas of Menengai, Olrongai, and Olbanita. Menengai is the most prominent while the others are completely covered by younger pyroclastics from Menengai. The volcanoes have been active since 0.2 Ma to present.		1.4ka 0.7-0.3Ma	Medium strength fumaroles, steaming, and altered grounds. Scarce manifestations within Menengai caldera **Olbanita**: Boreholes in the immediate neighbourhood discharge steam and warm water.	<2	90 67	170-220 170-220	200 200	The main heat source is associated with the magma chamber under Menengai. Older heat sources are ass with Olbanita and Olrongai ring structures.	Resistivity lows occur to the NE & SW of caldera. Olbanita area has high resistivity, and may, thus, be of lower potential than Menengai caldera.
10	Badlands	Located on the low-lying grounds north of Eburru volcanic massif. Volcanoes of basalt to intermed comp occur along active NNE trending faults.	200-300 yr BP	Upper Pleist	Med strength fumaroles are associated with the volcanic centers (T=40-93°C). Boreholes having warm water (T>35°C) common.	<2	93	-	-	Heat source are possibly discrete & due to medium depth, intermed comp intrusions under the small volcanoes	Low resistivity anomalies cover 25km^2 suggesting T>200°C at 1000 masl.
9	Chepchuk	Ass with an old ring (caldera?) structure to the far southern slopes of Paka volcano. Area is intensely faulted (NNE). Activity is long lived from about 1.3Ma.	100 ka	1.13Ma	Weak fumaroles; hot, steaming, and altered grounds. Dating of silica sinter indicates that geothermal activity has been active since 430ka	2.5	96.1	202-261	231	Magmatic and associated with the inferred old caldera. Some heat could also be due to the more Recent Paka volcano just to the north.	Area located to the east boundary of the axial gravity high and within a positive magnetic anomaly. Insufficient data to rank.
8	Korosi	Multi vent complex, which has been active from about 380Ka to Recent., NNE faults abundant and along some occurs pyroclastic cones. The fault zone extends under Lake Baringo.	200-300 yr BP	104±2 ka	Weak fumaroles and hot altered grounds with T=40-95°C. Most of the manifestations are restricted along fault zones. Most active zones located in the north and NE of massif.	33	95.7	197-203	200	The heat source in the prospect is ass with magmatic body under the volcano. Satellite volcanoes that extend to island in Lake Baringo have added discrete heat sources.	Positive magnetic anomaly present. Seismic activities higher under Lake Baringo than under Korosi. No clear gravity anomaly exists.
5	Paka	Shield volcano with craters and a small caldera at the top. The volcano has been active from 390ka to Recent. Resurgence activity (trachyte) followed caldera collapse. NNE faults traverse the summit.	200-300 yr BP	10±3 ka	Moderately strong fumaroles and hot steaming grounds occur within the summit and within the craters and caldera. Most activity manifested along fault zones. Temps lower in the south.	32	97.8	256-329	303	Medium size trachytic body that is associated with the caldera. Depth to intrusion (heat source) is about 5km	Ass with high gravity and positive magnetic anomaly. High seismic activity trending NNE occurs at shallow depths (2,5-5km).
7	L. Bogoria and Arus	No clear magmatic and volcanic association noted. However, the Plio-Pleistocene lavas that cover the area are extensively faulted (NE).		<1.6Ma	Hot springs, geysers, and steamjets common and occur along fault zones. The springs discharge at low temperatures. CO_2 gas emissions common.	2	42	145-270	180	No magmatic body anticipated. Probably associated with frictional heat along the major rift faults. Dykes might inflate the local geotherm.	High gravity and positive magnetic anomaly. Intense, deep (>15km) seismicity on the east along Marmanet fault. Low resistivity occurs to the east of Lake Bogoria
11	Namarunu	Is a bas-tra volcanic complex active since about 4 Ma. The old eruptive centers are buried. There occur younger basaltic cones (1.8Ka) within the complex and within the rift trough and constrained by NNE structures.	500 ±3ka	509 ±5ka	Mostly very weak and characterized by altered grounds and hot springs in valley. Most manifestations occur along inner rift edges within fault lines.	<2	100	78-112	85	Dykes and small magmatic intrusives at shallow depth. Minor discrete heat sources ass with basaltic cones	Large positive magnetic anomaly occurs that may indicate a heat source.
6	Barrier (Kakorinya)	Consists of a volcanic complex of three major volcanoes of bas to sili comp. Kakorinya caldera is in the centre of the complex. The complex has been active since 0.7Ma to 100 yrs BP. NNE faults abundant.	100 yrs	58- 4ka	Fumaroles of moderate strength and hot steaming grounds common. Hot springs, sinters, and altered grounds occur. Sulphur deposits on Teleki's volcano.	20	98.6	189-314	263	Associated with caldera and satellite volcanoes. Heat source is shallow and is of itermed comp. Whole region has high heat flow but highest potential is associated with Kakorinya.	Prospect is within a high gravity anomaly.
12	Lake Magadi	The prospect is within a Pleistocene volcanic field that is heavily faulted by NE faults. The alkaline. Flood trachytes (faulted) dominate the area. Nearest volcanoes are the late Pleistocene Olorgesaile and Shompole. Pyroclastics in the region are highly alkaline.		Pleist	Geothermal activity is concentrated along the margins of Lake Magadi. The hottest springs are in the north adjacent to Little Magadi. Hot spring temperatures are generally low (30-60°C). Reservoir fluid is likely to have high TDS	<2	86	140	140	The heat source could be a combination of high heat flow within the rift and dyke intrusions along the rift floor faults. Shallow magma bodies are unlikely.	Positive magnetic anomaly and large low resistivity (MT) anomaly present. High seismic activity to the NE of Little Magadi.

Source: KenGen (2002)

In a recent survey by GDC which used the temperature measurement data of 1m deep surveys and shallow boreholes, the areas of high temperature anomaly and the heat loss in each geothermal field were assessed. The temperature distribution and the amount of heat loss at the surface in a study by Mwawongo (2013) are shown in Fig. V-1.1. The study results indicate that the order of ranking for the target fields of this project based on the total heat loss are Paka, Korosi, Baringo, Chepchuk and Arus.



Prospect	Heat loss		Total heat loss (MWt)
	Conductive (MWt)	Convective (MWt)	
Menengai	1095	2440	3536
Paka	2845	10	2855
Korosi	2135	0.4	2135
Bogoria	762	437	1199
Baringo	941	108	1049
Chepchuk	546	Negligible	546
Arus	467	.03	467
Olkaria			400
Domes			187

Source: Mwawongo (2013)

Fig. V-1.1 Temperature distribution and heat loss at the surface at geothermal prospects

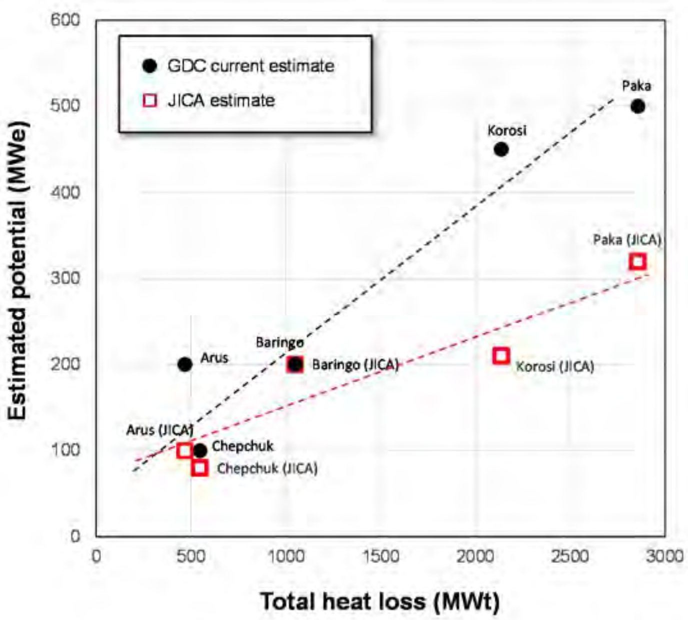
V-1.2 Results of this project regarding geothermal development priorities

Table V-1.3 shows the results regarding the estimation of the resource potential for each of the target geothermal prospects of this project. Excluding Baringo (total of South and North), the estimated potential of four geothermal prospects is lower than that estimated by GDC in 2013. However, as described in II-5, the method of resource estimation used for this project was more elaborate than that used by GDC, so the accuracy of the estimation is considered to be improved. Note that the estimated resource potentials in this project are proportional to the total heat loss at each prospect, indicating that the estimation is highly reliable (Fig. V-1.2).

Table V-1.3 Summary of current estimate of geothermal resource potential

Field		GDC (April 2013)			JICA Team (WJEC-MMTEC: 2016)				Proposed Development Plan		
		Field Capacity	Power Generation		Field Capacity						
		Current Estimate (MW)	Early Generation	Large Scale Power (MW)	Power Densitty (MW)	Heat in Place (P90) (MW)	Heat in Place (P50) (MW)	Heat in Place (P10) (MW)	Initial (MW-gross)	Additional (MW-gross)	Total (MW-gross)
Arus		200	Yes	2 X 100?	94 - 360	57.5	121.1	236.6	50	50	100
Baringo	South	200	Yes	2 X 100?	105 - 408	48.4	103.4	204.1	50	50	100
	North				99 - 334	39.0	90.9	197.7	-	2 x 50	100
	Total				204 - 742	87.4	194.3	401.8	50	3 x 50	200
Korosi		450	Yes (A few 5-10MW units)	3 X 150	161 - 686	134.4	227.2	364.6	70	2 x 70	210
Chepchuk		100	Yes (A few 5-10MW units)	1 X 100	68 - 287	46.0	86.9	155.8	40	40	80
Paka		500	Yes (A few 5-10MW units)	5 X 100	203 - 979	185.6	327.7	556.1	70	3 x 70 + 40	320
Silali		800	Yes (10 units 5-10MW each)	8 X 100							

Prepared by JICA study team



Prepared by JICA study team

Fig. V-1.2 Plot of estimated resource potential vs. total heat loss in each geothermal prospect

Table V-1.4 summarizes the estimated development cost and the results of the economic evaluation regarding the target geothermal prospects of this project. The comparison of the unit cost of power plant construction and the comparison of unit generation cost are shown in Fig. V-1.3 and Fig. V-1.4, respectively.

Based on these comparisons, the unit cost for power generation from lowest to highest is as follows: Korosi, Paka, Arus, Baringo North, Baringo South, and Chepchuk.

Table V-1.4 Summary of estimated development cost and results of economic evaluation for the geothermal power project in the five target prospects

Fields	Arus	S_Baringo	N_Baringo	Korosi	Chepchuk	Paka
Development						
Output [MW]	100	100	100	210	80	320
Unit-1 [MW]	50	50	50	70	40	70
Development period [years]	7	7	7	7	8	7
Unit-2 [MW]	50	50	50	140	40	250
Dev. period after Unit-1 [years]	+2	+2	+2	+3	+2	+3
Construction cost						
Construction cost (with IDC) [M$]	368	437	376	602	317	918
Unit const. cost (with IDC) [M$]	3,670	4,370	3,760	2,870	3,970	2,870
Generation cost (IPP model)						
Steam cost [US¢/kWh]	4.7	5.9	4.8	3.2	5.1	3.0
Conversion cost [US¢/kWh]	5.7	5.7	5.8	5.5	7.3	5.8
Generation cost (total) [US¢/kWh]	10.3	11.5	10.5	8.7	12.4	8.8
Economic IRR						
EIRR (against Coal-fired PP)	15.6%	12.0%	15.1%	22.7%	12.2%	23.5%
EIRR (against LNG-fired PP)	18.8%	16.2%	18.4%	23.3%	15.7%	23.8%
EIRR (against Diesel PP)	31.6%	29.1%	31.2%	36.7%	26.4%	37.5%

(Generation cost includes all the development costs involving drilling costs of reinjection wells.)

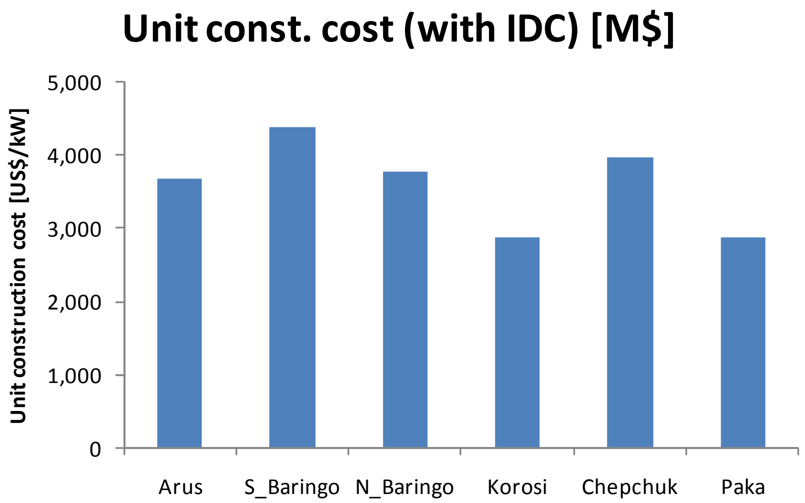


Fig. V-1.3 Comparison of estimated unit construction cost in each geothermal prospect

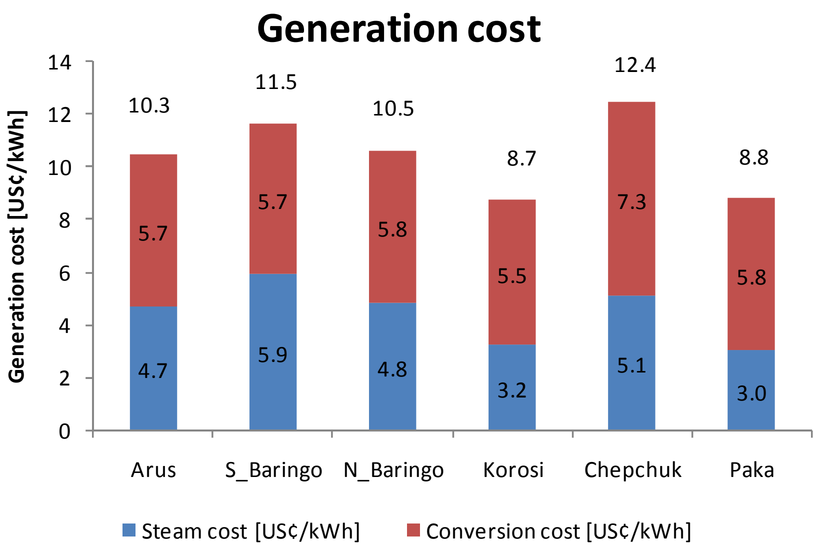


Fig. V-1.4 Comparison of estimated unit generation cost in each geothermal prospect

In order to evaluate the development priorities of the five target prospects, a scoring method was adopted to comprehensively consider the factors related to the geothermal power development, including not only the estimated resource potential and development cost but also various other factors. Factors involved in the evaluation regarding the scoring method and their weights are as follows.

- Resource Probability (progress of resource assessment): 10%
- Resource Temperature (estimated reservoir temperature): 15%
- Resource Potential (proposed development scale): 20%
- Infrastructure/Accessibility: 5%
- Topography (ease of field development): 5%
- Natural/Social Environment: 10%
- Direct Use: 5%
- Power Generation Cost 30%

The evaluation criteria of the respective factors are shown in TableV-1.5 and the results of the evaluation based on the criteria in Table V-1.6.

Table V-1.5 Evaluation criteria of factors used in the scoring method

Resource Probability (progress of resource assessment) (weight: 10%)

point	class	criteria
100	proven	exploitable reservoir confirmed by well drilling (including borehole)
75	highly probable	reservoir infered by geology, geochemistry and detailed geophysical survey
50	probable	reservoir infered by geology, geochemistry and regional geophysical survey
25	possible	reservoir infered by geology and geochemistry

Resource Temperature (estimated reservoir temperature) (weight: 15%)

point	class	criteria
100	very high	estimated average reservoir temperature >=300°C
75	high	estimated average reservoir temperature 270-300°C
50	moderate	estimated average reservoir temperature 240-270°C
25	rather low	estimated average reservoir temperature <240°C

Resource Potential (proposed development scale) (weight: 20%)

point	class	criteria
100	very large	Power output of proposed development >=300MW
75	large	Power output of proposed development 200-300MW
50	moderate	Power output of proposed development 100-200MW
25	small	Power output of proposed development <100MW

Infrastructure/Accessibility (Weight: 5%)

point	class	criteria
100	very good	Distance from existing major arterial road and water intake point to the site < a few km
75	good	Distance from existing feeder arterial road and water intake point to the site < a few km
50	fair	Distance from existing feeder arterial road or water intake point to the site > a few km
25	poor	Distance from existing feeder arterial road and water intake point to the site > a few km

Topography (ease of field development) (Weight: 5%)

point	class	criteria
100	very good	Gentle slope <5°
75	good	Relatively gentle slope <10°
50	fair	Relatively gentle slope >10°
25	poor	Steep slope >15°

Natural/Social Environment (Weight: 10%)

point	class	criteria
100	no serious negative impact	No serious negative impact is expected for all assessment items.
75	some negative impact	No serious negative impact is expected for major assessment items such as involuntary resettlement, cultural heritage and biodiversity (i.e. National park, protected area), but some negative impacts are expected, and less serurity issue is expected.
50	some negative impact with security issue	No serious negative impact is expected for major assessment items such as involuntary resettlement, cultural heritage and biodiversity (i.e. National park, protected area) but some negative impacts are expected, more serurity issue is expected.
25	serious negative impact is expected	Serious negative impact is expected for major assessment items such as involuntary resettlement, cultural heritage and biodiversity (i.e. National park, protected area)

Direct Use (Weight: 5%)

point	class	criteria
100	highly feasible	Direct use facilities can be placed at the location easily accessible from a city or large village. High use and more application of direct use are expected.
75	feasible	Direct use facilities can be placed at the location comparatively accessible from a city or large village. A medium level regarding the frequency of use and feasible applications for direct use are expected.
50	challenging	Direct use facilities will be placed far from a city or large village, however, feasible application of direct use are expected.
25	limited	Access to direct use facilities for people would be limited. Few fieasible applications are expected.

Power Generation Cost (Weight: 30%)

point	class	criteria
100	-	< 8 US-cent/kWh
75	-	8-9 US-cent/kWh
50	-	9-11 US-cent/kWh
25	-	> 11 US-cent/kWh

Table V-1.6 Results of evaluation of development priority for five target prospects using the scoring method

Parameter	Weight	Arus	S-Baringo	N-Baringo	Korosi	Chepchuk	Paka
Resource Probability (progress of resource assessment)	10%	50	100	50	75	75	75
Resource Temperature (estimated reservoir temperature)	15%	50	25	50	75	50	100
Resource Potential (proposed development scale)	20%	50	50	50	75	25	100
Infrastructure/Accessibility	5%	75	100	100	50	25	50
Topography (ease of field development)	5%	75	100	100	50	50	25
Natural/Social Environment	10%	75	75	75	50	50	50
Direct Use	5%	75	75	75	50	50	50
Power Generation Cost	30%	50	25	50	75	25	75
Total Score	100%	**56.3**	**52.5**	**58.8**	**68.8**	**38.8**	**76.3**
Rank		**4**	**5**	**3**	**2**	**6**	**1**

As a result of the evaluation, Paka and Korosi were ranked first and second respectively in regards to development priority. Since geothermal well drilling pads (three in each prospect) have already been constructed by GDC and the expected development scale is large in these two prospects, it is desirable to drill the exploratory wells as soon as possible.

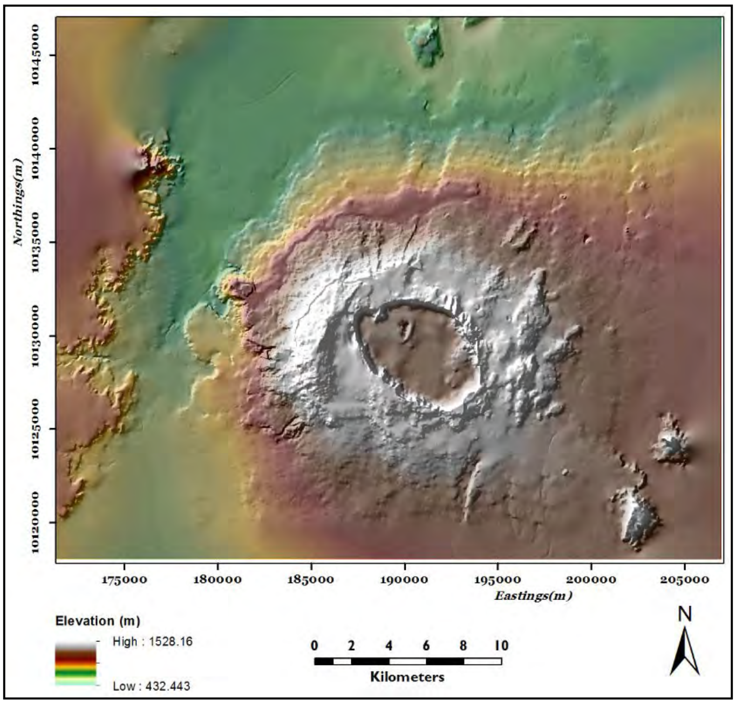
The development priority of North Baringo and South Baringo was ranked third and fifth respectively. In addition to the advantages regarding accessibility and water supply at both of these prospects, the existence of a high-temperature aquifer layer has been confirmed by a borehole and a drilling pad has already been constructed by GDC in South Baringo. It is therefore desirable for the exploratory wells to be drilled as soon as possible. However, since detailed geophysical surveys have not yet been conducted at Baringo, it is advisable to conduct surveys in order to site the detailed location of wells to be drilled.

For the vicinity of the Steam Jets in the Arus prospect, the priority was ranked fourth. Although large-scale development may not be expected, the presence of promising geothermal resources is presumed, so detailed resource evaluation by detailed geophysical surveys should be conducted promptly. The Arus prospect has good accessibility and is located at the farthest south of the five prospects, so it is advantageous from the viewpoint of the construction of a transmission line planned to extend from the south. If the existence of an exploitable geothermal reservoir is confirmed by geophysical surveys and well drilling, an early development would be possible in this prospect.

The Chepchuk prospect is ranked sixth. The expected development scale is relatively small and accessibility is also not good at present. Therefore, it is desirable to wait until the exploitation is advanced at the neighboring prospects, Korosi and Paka, before confirming the exploitable geothermal reservoir by well drilling at Chepchuk.

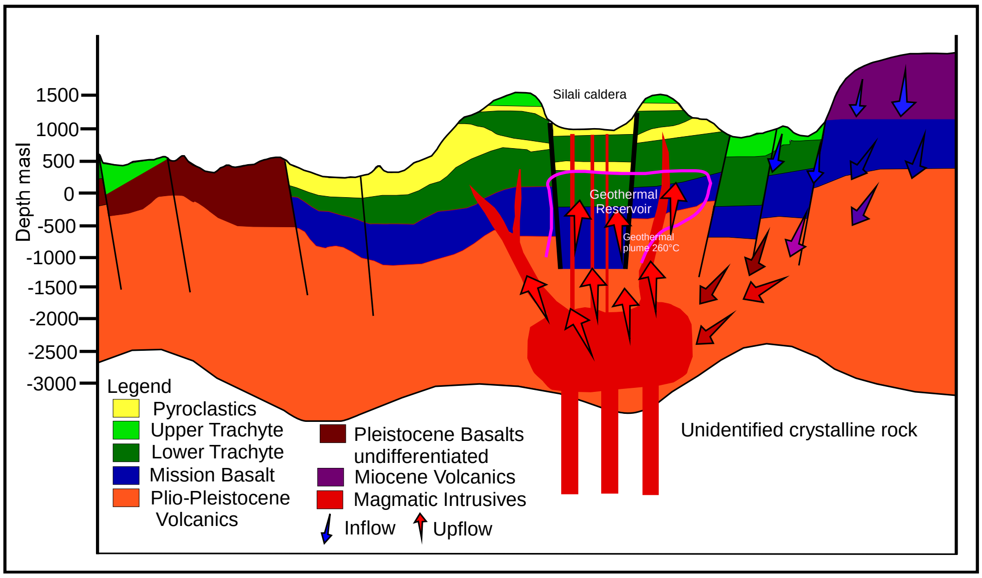
Regarding the development priorities of the five target prospects mentioned above, since they are preliminary (in the surface survey stage) it is desirable that the priorities be reviewed and updated as needed based on the results of exploratory well drilling and other exploration to be performed at the respective prospects in future.

Meanwhile, in regards to the Silali prospect, which is located further north than the target five prospects, the existence of promising geothermal resources is presumed. In the course of installing roads and water supply systems to the geothermal prospects north of Lake Baringo, GDC is also considering the Silali prospect. In addition, resource assessment has also been conducted by GDC and the German government (through BGR) jointly in recent years. According to the Silali resource assessment report (2011) prepared by GDC, several surface surveys including MT/TEM surveys have already been carried out. Figures V-1.5 and V-1.6 show a topographic map and the geothermal conceptual model of the Silali prospect.



Source: GDC Internal Report (2011)

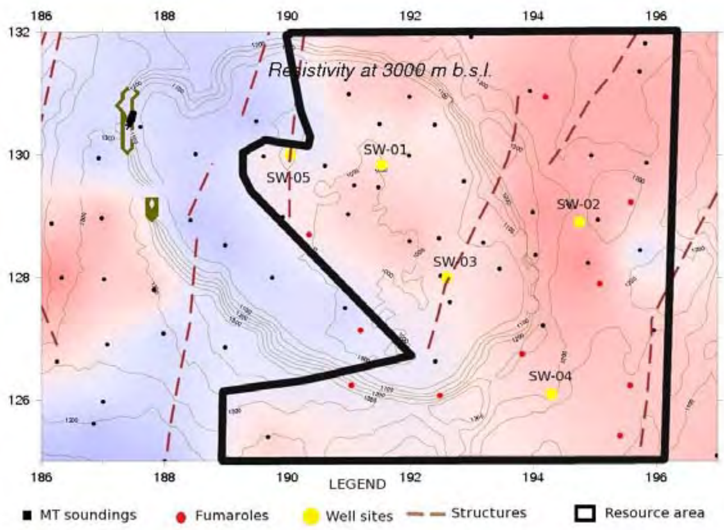
Fig. V-1.5 Topographic map of the Silali prospect



Source: GDC Internal Report (2011)

Fig. V-1.6 Conceptual model of Silali geothermal system (E-W cross section)

There is a huge caldera at the Silali prospect, and promising geothermal resources are presumed to exist near the eastern part of the caldera. From gas geothermometry temperatures, the subsurface temperature is estimated to be over 260ºC. The area of exploitable reservoir, which is based on physical survey results, is presumed to be about 54 km^2 (Fig. V-1.7). A resource potential of 810MW is estimated by utilizing a conversion rate of 15MW/km^2 (by the power density method).



Source: GDC Internal Report (2011)

Fig. V-1.7 Estimated area of exploitable geothermal reservoir in Silali

In terms of the natural environment at the Silali prospect, it is classified as a dry/semi-arid area largely similar to the other five target prospects, and protected areas and rare species have not been confirmed in this prospect. Regarding the local society, it is confirmed that the tribes rely mainly on grazing (similar to those in Korosi, Chepchuk, and Paka), and the possibility of encountering problems of resettlement relating to geothermal development is considered to be low. The main tribes living in the Silali area are the Pokot, Turkana and Samburu, but many conflicts between Pokot and Turkana have been reported.

After further resource assessment and evaluation, it will be desirable to evaluate the relationship between the development priority of Silali versus the five target prospects of this project. In addition to installing access roads and water supply systems at Silali, well drilling pads are also being constructed. Therefore, the evaluation of development priorities based on the results of drilling should also be considered. However, conditions other than the geothermal resources related to power generation development at the Silali prospect should be considered and it is desirable to carefully consider the following.

- Since it is located 30km north of Paka, extra costs and difficulties regarding access, water supply, and power transmission are expected.
- Since it is located near the boundary between Baringo county and Turkana county and conflicts between the tribes are occurring frequently, difficulties are expected regarding maintaining security for the development work and gaining the understanding of the local residents regarding the power plant project.

Another promising prospect for geothermal development is Suswa, which is located about 50km northwest of Nairobi and already has an estimated resource potential of about 750MW from the results of detailed surface exploration. Regarding resource development at this prospect, a joint implementation with the private sector had been temporarily planned, however due to several different circumstances, the present plan is for development solely by GDC. Although it is not possible to determine the relative development priorities for the five prospects and the Suswa prospect in relation to this project, it is desirable to confirm the existence of exploitable geothermal resource in Suswa by well drilling as soon as possible.

V-2 Characteristics of Geothermal Development Business and Importance of GDC's Role

The geothermal development business has two big barriers; resource risks and large up-front investment without cash-inflows during a long development period. These barriers hinder the ability of private companies to take part in the geothermal business. This chapter first discusses the effect of up-front investment on the energy price or the steam price of a geothermal project, and secondly discusses the importance of the role of GDC as a state-owned enterprise.

V-2.1 Economics of geothermal business

a. Assumptions of model geothermal business

A geothermal power plant harnesses steam heated and stored in a reservoir underground. Therefore, the generation capacity has to be consistent with the size of the geothermal reservoir. Also, its economics are site-specific. However, for simplicity purposes, this section assumes a model geothermal project for which the capacity is 70 MW, the standard capacity of a newly developed geothermal power plant in Kenya. Based on data acquired by GDC in Menengai field, the assumptions of the main parameters for a calculation of a model geothermal power plant (Model GPP) economics are as shown in Table V-2.1.

Table V-2.1 Assumptions of steam field parameters

Item	Value
Output	70 MW
Average production per well	8.75 MW/well
Water/Steam ratio	0.357
Average capacity of reinjection wells	200 (ton/h)/well
Turbine specific consumption	7.0 (ton/h)/MW
Plant capacity factor	90%
Steam declining rate	3%/year
Reinjection capacity declining rate	3%/year

b. Geothermal development procedure

Here, it is assumed that the Model GPP will be developed in the following stages:

(a) Surface survey

Geological survey from ground surface is done in the 7th year prior to the operation (-7 yr). The drilling sites are decided and the access road construction is done in the second half of the year.

(b) Resource confirmation survey:

Exploratory wells will be drilled to confirm the existence of the resource. This Model assumed one (1) well is successful out of two (2) exploratory drills. It is assumed that the well will confirm the existence of a resource, which could produce 10% of the steam necessary for 70 MW generation. The well could be used as a production well during the operation stage. This stage is assumed to be carried out in the 6th year and 5th year prior to the operation (-6 yr ~ -5 yr).

(c) Development（Resource capacity evaluation survey）

In this stage, further exploratory wells are drilled to evaluate the capacity of the resource. This Model assumes three (3) successful exploratory drills out of five (5). Together with the successful production well developed during the resource confirmation stage, the four (4) successful wells provide enough data for the resource capacity estimation and the feasibility study. This process is done in the 5th and 4th year prior to the operation (-5 yr ~ -4 yr).

(d) Construction

Once the feasibility study for the Model GPP is completed, a construction plan for the power plant will be produced and the project will be ready for financial close. The construction will be conducted with 30% equity and 70% loan from commercial banks. The Model assumes that five

(5) further drillings will yield four (4) more production wells. Steam pipelines, power plant and other equipment will also be constructed concurrently. The construction period is assumed to be 3 years (-3 yr ~ -1 yr).

(e) Operation

The Model GPP is operated for 30 years.

As a result, it is assumed that seven (7) years are required to develop the Model GPP (Table V-2.2, and Fig. V-2.2).

Table V-2.2 Steam field development activities

Item	Reconnaissance	Exploration	Confirmation	Construction	Total
Activity years	-7 yr	-7 ~ -6 yr	-5~ -4 yr	-3~ -1yr	7 years
Target steam amount	-	10%	40%	50%	100%
Production wells drilled (wells)	-	2	5	5	12
Successful wells (wells)	-	1	3	4	8
Success rate	-	67%	67%	80%	-
Reinjection wells drilled (wells)	-	-	-	3	3
Successful wells (wells)	-	-	-	2	2
Success rate	-	-	-	90%	-

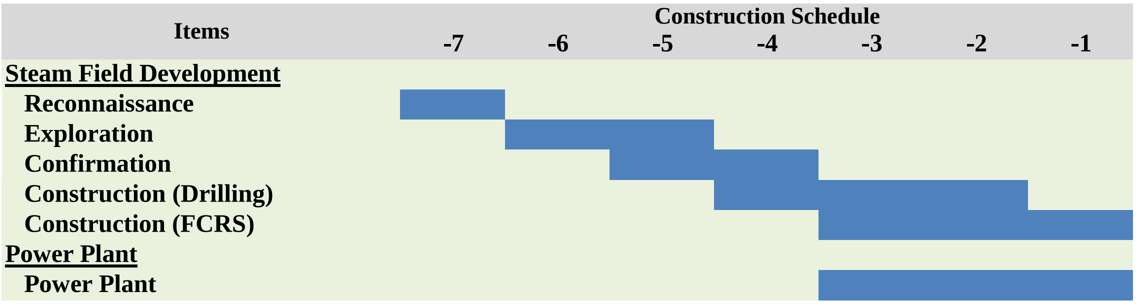


Fig. V-2.1 Assumption of development schedule

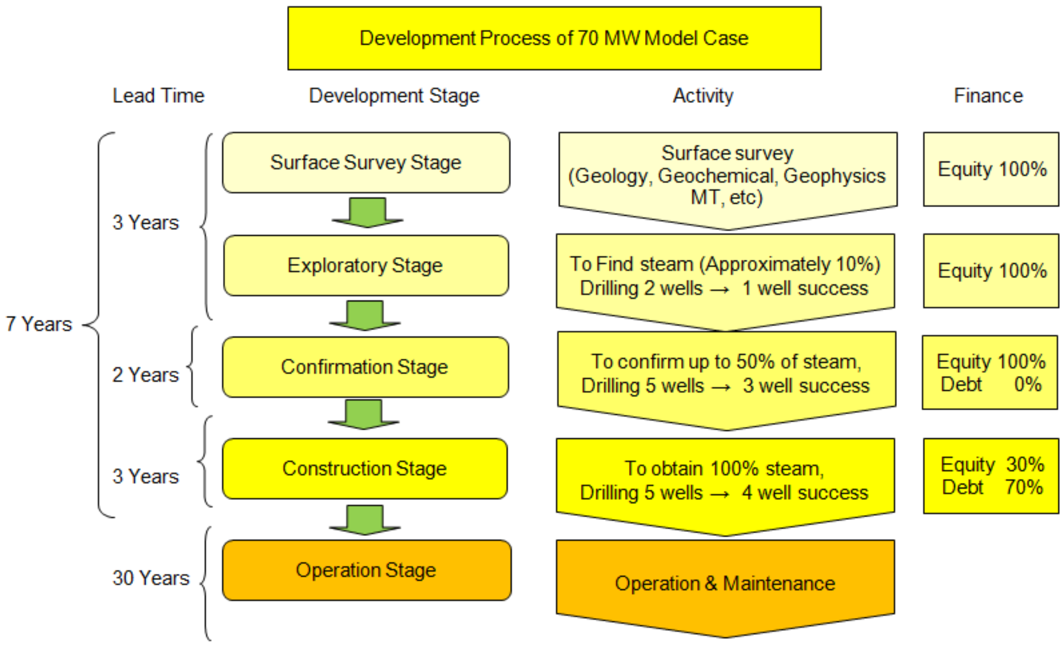


Fig. V-2.2 Assumption of development stages

c. Finance procurement assumptions

Geothermal energy development entails significant risks during the surface survey, the resource confirmation survey and the development stages. Since a project has little chance of obtaining financial support in the early stages, its early stage activities are conducted by the steam developer's equity alone. After the feasibility study confirms the feasibility of the project, it can acquire funding from commercial banks, leveraged with a ratio of 70% debt to 30% equity.

The interest rate is assumed to be 8.0%. The loan period is 10 years with a 3 year grace period for a commercial loan. The tax rate is assumed as 30% and a 1.0% royalty is assumed on the annual steam sales. The depreciation period is 25 years and the depreciation method is straight line. The evaluation is performed using 2015 US$ price without considering price inflation.

Table V-2.3 Financial arrangement

Item	Reconnaissance	Exploration	Confirmation	Field Const.	Plant Const.
Equity	100%	100%	100%	30%	30%
Borrowings	-	-	-	70%	70%
Equity expected return	GDC 10% IPP 20%	GDC 10% IPP 20%	GDC 10% IPP 20%	GDC 10% IPP 20%	GDC 10% IPP 20%
Borrowings					
Interest rate	-	-	-	8%	8%
Grace period (years)	-	-	-	3	3
Repayment period (years)	-	-	-	10	10
Operation years	30 years				
Corporate income tax rate	30%				
Loyalty	1.0% of sales				
Depreciation period	25 years				
Depreciation method	Straight line				

d. Construction costs estimation

The construction costs estimation of the 70 MW Model GPP is shown in Table V-2.4. The depth of exploration and production wells is assumed to be 2,000 meters and the drilling cost is assumed to be US$ 4 million per well. This cost is estimated from the current drilling ability of GDC. The drilling cost of reinjection wells is assumed to be 80% of that of production wells. The unit construction cost of the power plant is estimated at US$ 1,550/kW, which corresponds to US$ 1,600/kW at a 60 MW plant.

Based on these estimations, the total construction costs become US$ 254 million without interest during construction (IDC), and the unit construction cost becomes US$ 3,630/kW. The construction costs of the steam field section are US$ 135 million, and that of the power plant section is US$ 118 million. The cost ratio between the steam field section and the power plant section is 53%:47%. The drilling cost of exploration, production and reinjection wells in total is US$ 58 million and accounts for 22% of the total costs (Fig. V-2.3).

The total IDC in three construction years is US$ 27 million and the construction costs with IDC become US$ 280 million. The unit construction cost is US$ 4,000/kW.

Table V-2.4 Construction costs estimation of the Model 70 MW GPP

Stage	Content	Cost (m$)
1. Surface Survey	Wide-area surface survey	2
2. Exploratory	2 Exploratory wells (success rate 67%) etc.	10
3. Confirmation	5 Confirmation wells (success rate 67%) etc.	26
4. Construction		
4.1 Steam Field	5 Production wells (success rate 80%), pipelines etc.	98
4.2 Power Plant	Power plant, Switch yard, etc.	118
Total		254
IDC	8.00%	27
Total		280
	Unit construction cost (without IDC)	3,630 ($/kW)
	Unit construction cost (with IDC)	4,000 ($/kW)

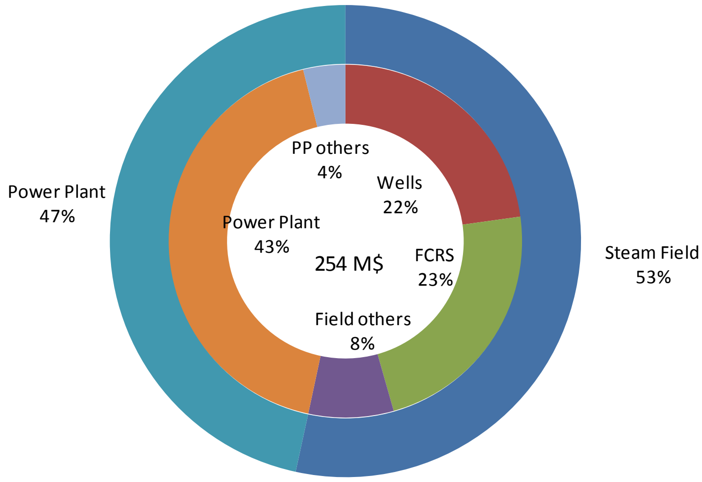


Fig. V-2.3 Breakdown of construction costs of the 70 MW Model GPP

e. Steam price and energy price

How much are the steam cost (levelized steam cost of plant life time; LSC) and the energy cost (levelized energy cost of plant life time; LEC) of the 70 MW Model GPP when the construction cost estimation is the above-mentioned? The steam cost or the energy cost is not an absolute single number but a variable number according to how much the project owner expects as a return from his project, even though the project construction cost is same. The more return the project owner expects from the project, the higher the steam/energy cost will need to be.

The expected rate of return from the project differs according to whether the project owner is a private company or a public one. A state-owned enterprise (SOE) such as GDC or KenGen is likely to require lower return than that of a private company. Here, first, let us suppose the Model GPP is constructed as a total project of GDC. Also, let us assume the expected rate of return of GDC is 10%. When the Model GPP of which construction costs are US$ 254 million is operated for 30 years, the energy price which obtains 10% of equity internal rate of return (Eq-IRR) is calculated as 9.2 US¢/kWh. This energy cost includes a 5.3 US¢/kWh steam cost. The breakdown of the cost is as follows: the capital costs (the construction cost depreciation expense and the investment return in total) are 5.9 US¢/kWh, the depreciation costs of make-up wells are 0.3 US¢/kWh, the maintenance and operation costs (O&M) are

1.1 US¢/kWh, the royalty costs are 0.1 US¢/kWh and the corporate income tax costs are 1.8 US¢/kWh (Fig. V-2.4 and Table V-2.5).

Table V-2.5 Breakdown of energy cost of the Model GPP (Total project by SOE)

Item	Cost (US¢/kWh)	(%)
Initial investment	5.9	64.3%
Makeup wells	0.3	3.5%
O&M costs	1.1	11.6%
Royalty	0.1	0.9%
Corp. income tax	1.8	19.7%
Total	9.2	100%

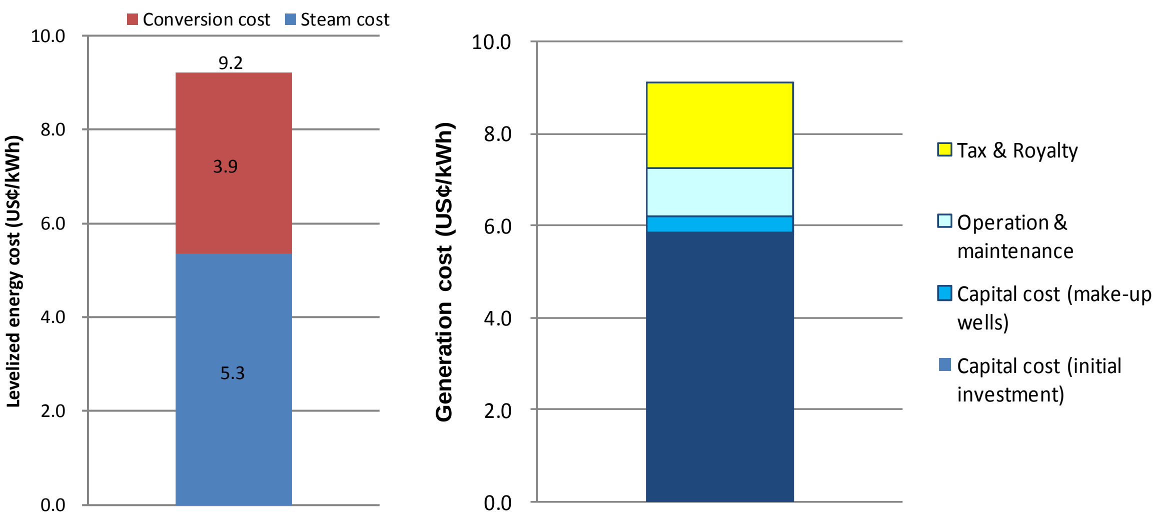


Fig. V-2.4 Energy cost and steam cost of the Model GPP (Total project by SOE)

Next, let us see how the energy cost and steam cost change when the expected rate of return of the project owner changes. The relationship between the project owner's expected rate of return and the energy/steam cost is shown in a graph with x-axis as the expected rate of return and with y-axis as the energy/steam cost. This can be referred to as the "characteristic curve" of the expected rate of return and the energy/steam cost. The characteristic curve of the 70 MW Model GPP is shown in Fig. V-2.5. Similarly the characteristic curve of a coal-fired power plant and a natural gas-fired combined cycle power plant, for which the specifications are shown in Table V-2.6, are shown in Fig. V-2.6 and compared with that of the Model GPP.

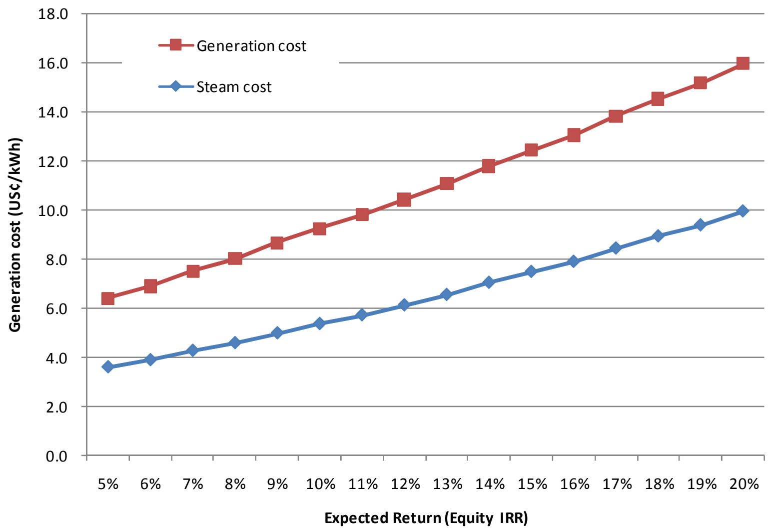


Fig. V-2.5 Characteristic curve of the expected rate of return and the energy/steam cost (70 MW Model GPP)

Table V-2.6 Specifications of a coal-fired plant and a natural gas-fired combined cycle plant

Item	Coal-fired plant	Natural gas-fired combined cycle plant
Power output	300 MW	300 MW
Unit construction costs (without IDC)	2,000 US$/kW	2,160 US$/kW
Construction period	4 years	3 years
Fuel	Coal	Liquefied natural gas
Heat value of fuel	6,000 kcal/kg	1,027 BTU/CF
Fuel price	115 US$/ton	12 US$/MMBTU
Efficiency of power plant	35%	45%

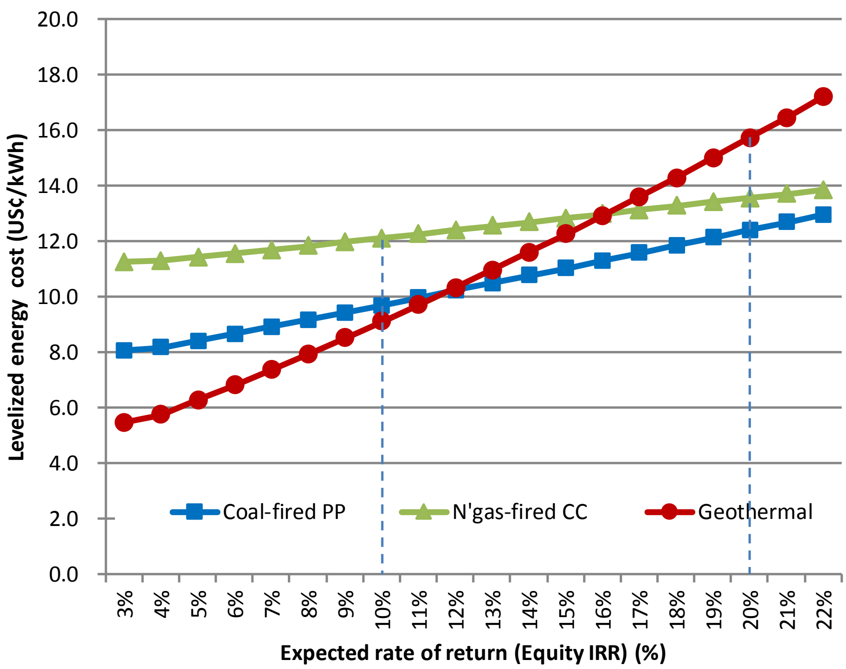


Fig. V-2.6 Comparison of characteristic curves between Model GPP and thermal power plants

Table V-2.7 Energy cost under different expected rate of return by plant type (US¢/kWh)

Expected rate of return	Model GPP	Coal-fired plant	Natural gas-fired combined cycle plant
10%	9.2	9.7	12.1
20%	15.9	12.4	13.6

In any power plant business, the characteristic curve is an upward-sloping curve because as the expected rate of return becomes higher, the energy price becomes higher. The remarkably distinctive point of the characteristic curve of a geothermal plant is a steep angle, while other fuel-fired thermal plants have a gentle slope curve, as shown in Fig. V-2.6. The reason for the steep slope curve of a geothermal plant is that the amount of up-front investment is large and therefore, in the geothermal business, in order to obtain a high rate of return on the investment there must be a high sales price. Therefore, geothermal 'energy cost' becomes high. On the contrary, fuel-fired thermal plants do not require a large up-front investment, but instead require fuel expenditures every year. Therefore, the relationship between the expected rate of return from the investment and the energy cost becomes weak, and the slope of the curve becomes gentle.

This fact is of great importance when designing an electric power development plan or considering policies promoting geothermal energy. There are many players in the power sector, including public companies, private companies, and the combination of public and private companies. Each player's expected rate of return from the investment is different, and as a result, the energy price is accordingly different, even if they build a power plant with the same technical specifications. For instance, it is likely safe to consider the expected rate of return of Kenyan SOEs such as GDC to be about 10%. This means that the energy cost from a geothermal power plant built by a Kenyan SOE becomes 9.2 US ¢/kWh. When an SOE builds a coal-fired plant, the energy cost is 9.7 US¢/kWh, and when it builds a natural gas-fired combined plant, the energy cost is 12.1 US¢/kWh. In this case, the cost of geothermal energy is lower than that of a coal-fired or natural gas-fired combined plant.

On the other hand, private companies, especially foreign private companies, demand 20% or more for their expected return when they invest in the Kenyan power market. Therefore, when a foreign private company builds a coal-fired power plant in Kenya, the energy cost might be 12.4 US¢/kWh and for a gas-fired combined cycle plant, the energy cost might be 13.6 US¢/kWh. When a private company builds a geothermal power plant, the energy cost might rise to 15.9 US¢/kWh, to satisfy the company's required return (Fig. V-2.6, Table V-2.7). Unlike the SOE example, for private companies the geothermal energy cost becomes the highest among the three types of power plants.

Fig. V-2.6 indicates that geothermal energy is cost competitive with other fuel-fired energy from the viewpoint of SOEs, but that geothermal energy is no more competitive than other energy from the viewpoint of private companies. This corresponds with experiences of the JICA study team. Fig. V-2.7 shows the change in the power supply composition in the 1990s and 2000s for six countries in Central America (Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama). In all of these countries except Costa Rica, privatization policies were adopted in the 1990s, which unbundled and privatized the state-owned electric power companies and invited private independent power producers (IPPs) into the power generation business. The result of these policies was that afterwards mainly thermal power plants were built and within approximately ten years the energy mix rapidly became dependent on thermal power, as shown in Fig. V-2.7

This change is attributed to the fact that thermal plants are profitable for private companies as seen in Fig. V-2.6. Geothermal power plants or hydro power plants need a large amount of up-front investment and a long development period. Because of this characteristic, private companies are unlikely to choose these plants and are willing to build fuel-fired thermal plants for which the initial investment is lower. As a result, thermal power generation has expanded greatly in these five countries.

By contrast, Costa Rica maintained the system of a vertically integrated state-owned electric power company, Instituto Costarricense de Electricidad (ICE). As a result, power source diversification is advancing with steady development of hydro power, geothermal power and wind power in Costa Rica.

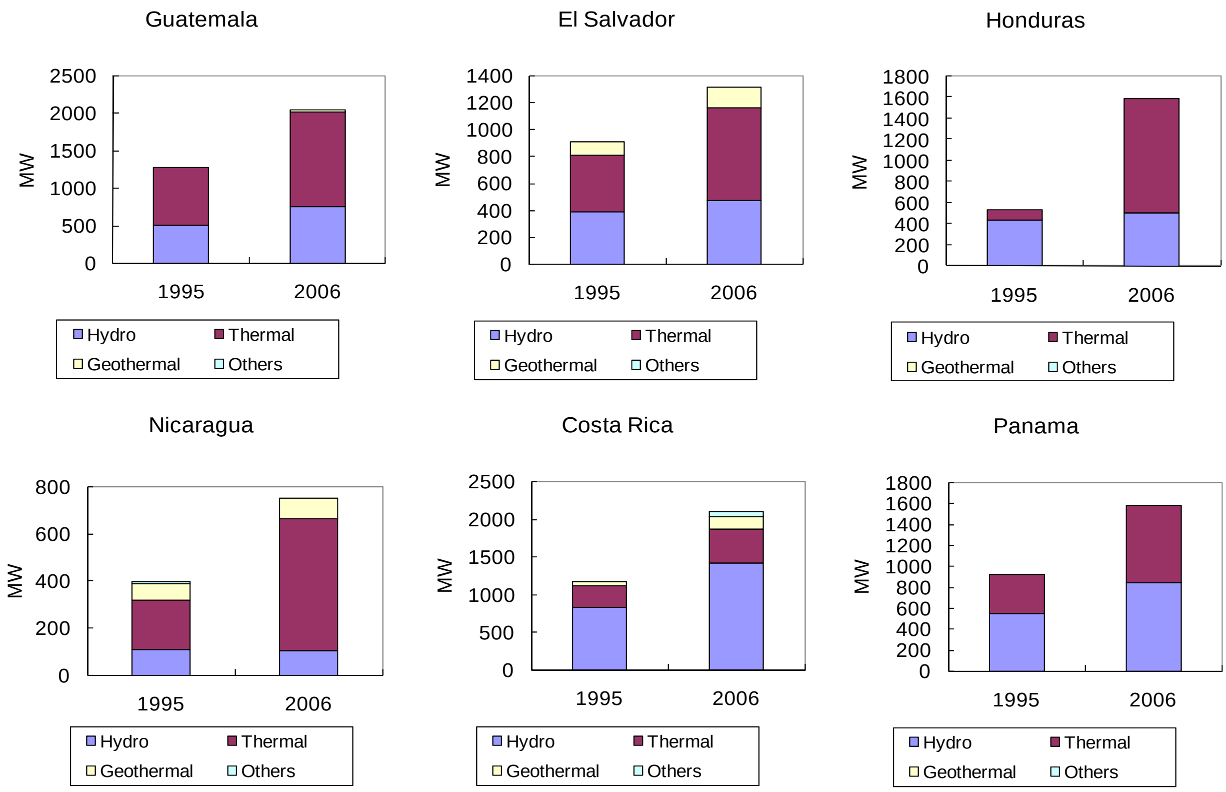


Fig. V-2.7 Change of power plant mix after power sector unbundling in six Central American countries (by author from JEPIC(2000) and JEPIC(2010))

Thus, it is understandable that geothermal energy development has difficulty making significant progress when it is left to private companies' discretion. Fig. V-2.8 shows the difference in the energy cost and the steam cost of a Model GPP when it is carried out by a state-owned enterprise (10% expected return), by a private company (20% expected return), and by a public/private joint scheme (10% for SOE's steam development and 20% for private company's power plant construction). If the Model GPP is developed by GDC (state-owned enterprise) as a total project, the energy price is 9.2 US¢/kWh, which includes a 5.3 US¢/kWh steam cost. When the Model GPP is developed by a private company as a total project, the energy cost jumps to 15.9 US¢/kWh, which includes a 10.0 US¢/kWh steam cost. As a case in between, when it is jointly developed by GDC's steam development and a private company's power plant construction, the energy cost is 11.4 US¢/kWh, which includes a 5.4 US¢/kWh steam cost. There are big differences in the energy cost and the steam cost with respect to who implements the project. Currently the Kenyan government faces two different propositions with a mutual trade-off; one is to promote geothermal energy development aimed at the diversification of power sources, and another is to supply an affordable price for electric power. It is necessary to recognize the importance of a state-owned company's role to satisfy both propositions at the same time.

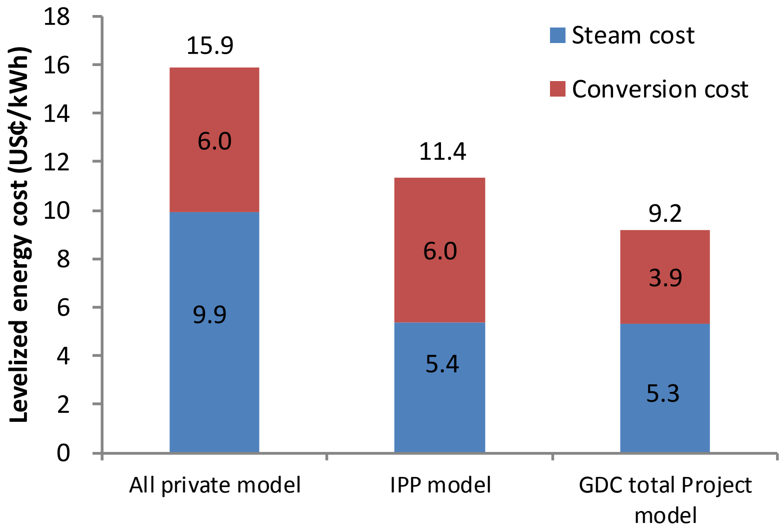


Fig. V-2.8 Energy/steam cost of Model GPP by different project style

The fact that the capital cost accounts for a major part of geothermal energy cost causes another strong relationship between the energy/steam cost and the financing cost. Figure V-2.9 shows the relationship between the energy/steam cost of the model geothermal power plant of 70 MW and the interest rate of borrowings at the construction stage. The figure shows the three cases of (i) a total project by a state-owned company, (ii) a joint project between a state-own steam developer and a private IPP company (IPP model), and (iii) a total project by a private company. In all cases, it is understood that the high interest rate of the borrowings increases the energy/steam cost while the low interest rate decreases it.

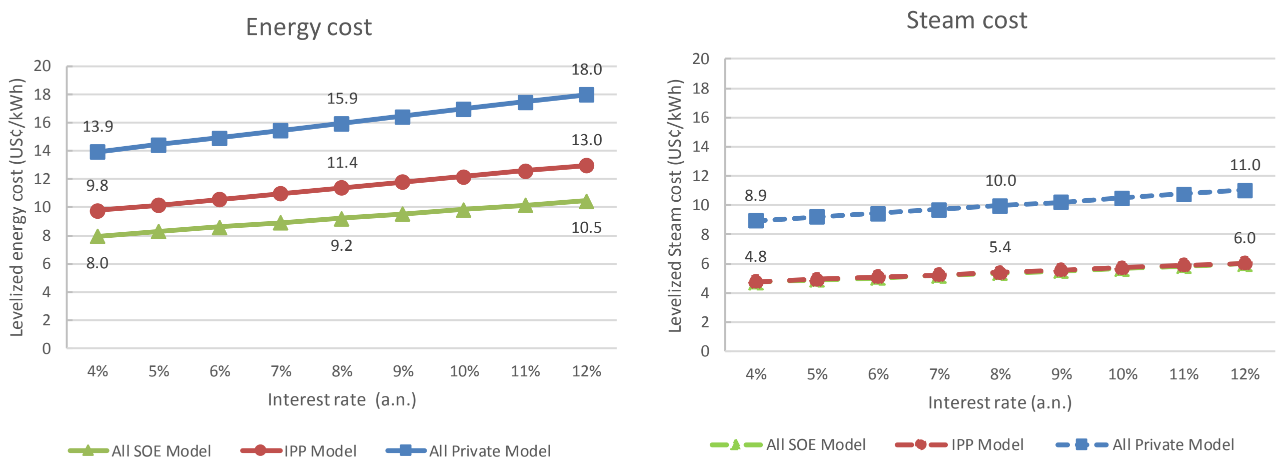


Fig. V-2.9 The effect of interest rate of borrowings on energy/steam cost of Model GPP

V-2.2 Importance of a state-owned company which has drilling ability

The previous section demonstrated the importance of state-owned enterprises (SOE) regarding two different requirements; the promotion of geothermal energy development and the supply of an affordable price for electric power. The importance of an SOE is attributed to the fact that the enterprise could procure low cost funding and could reduce the energy/steam cost. This section discusses another important aspect of the SOE, as an entity that has drilling ability.

At present, the only entity that has the ability to drill geothermal wells in Kenya is KenGen. This capacity, however, is not enough to respond the drilling demands of the Kenyan geothermal development plan. Therefore, thus far KenGen and GDC have been procuring drilling services from overseas companies. The procurement cost of drilling services for geothermal wells in Kenya is rising and has reached about US$ 6 million for a 2,000-meter class well. The drilling costs account for a large portion of the total construction costs in the 70 MW Model GPP as shown in Fig.-2.3. Therefore, the energy/steam cost of the geothermal plant will decrease significantly if the drilling costs can be reduced. The most effective way to reduce drilling costs is for the entity to acquire its own drilling ability and save the outsourced drilling costs. Therefore, GDC has procured several drilling rigs through the use of Kenyan government and external assistance funds. In addition, GDC is carrying out a technical cooperation program of drilling ability enhancement with the Japanese Government. Through these activities, GDC aims to develop into an entity that has adequate drilling abilities to drill geothermal wells in Kenya, and aims to achieve a great decrease of the drilling costs.

The number of wells that GDC has drilled in Menengai has reached 20 (as of December, 2014) (Table V-2.8). The current speed of GDC's drilling of wells is in the range of between 13 meters per day and 28 meters per day (13-28 m/day), and is around 20 meters per day (20 m/day) on average, as shown in Fig. V-2.10. This speed is approximately equivalent to drilling a 2,000-meter well in 100 days. GDC is aiming to enhance its drilling ability in order to drill the same well in 70 days. As Table V-2.9 shows, if GDC drills a 2,000-meter well in 100 days using its own drilling rig, the drilling cost is estimated at US$ 4 million per well. When GDC acquires the target ability to drill a well in 70 days, the drilling cost will be reduced to US$ 3.5 million. When GDC acquires the ability to drill a well in 60 days, the cost will be further reduced to US$ 3.4 million. Such drilling cost is very low when compared to the drilling service outsourcing cost of US$ 6 million. Therefore, if GDC enhances the ability to drill wells by itself, GDC could drill wells at a much low cost (Table V-2.9).

Table V-2.8 GDC's wells in Menengai

No.	WELL	FIELD	ELEVATION (Masl)	TARGET	DRILLING DAYS	DEPTH (M)	RIG	Average drilling speed (m/day)	FINANCIAL YEAR
1	MW-01	Menengai	2,064	Vertical	79	2,206	RIG1	27.9	2011-2012
2	MW-02	Menengai	1,898	Vertical	125	3,200	RIG2	25.6	
3	MW-03	Menengai	2,032	Vertical	100	2,117	RIG1	21.2	
4	MW-04	Menengai	2,085	Vertical	83	2,096	RIG2	25.3	
5	MW-06	Menengai	2,095	Vertical	96	2,203	RIG2	22.9	
6	MW-07	Menengai	1,942	Vertical	120	2,118	RIG1	17.7	
7	MW-08	Menengai	2,015	Vertical	126	2,355	RIG2	18.7	
8	MW-09	Menengai	2,105	Vertical	90	2,088	RIG2	23.2	2012-2013
9	MW-10	Menengai	2,085	Vertical			RIG1		
10	MW-12	Menengai	2,106	Vertical	93	2,054	RIG4	22.1	
11	MW-11	Menengai	1,993	Vertical	135	1,842	RIG3	13.6	
12	MW-05A	Menengai	2,052	Vertical	105	2,096	RIG2	20.0	
13	MW-15	Menengai	1,959	Vertical	80	1,680	RIG3	21.0	
14	MW-13	Menengai	2,081	Vertical	159	2,012	RIG1	12.7	
15	MW-14	Menengai	2,007	Vertical			RIG4		
16	MW-16	Menengai	1,965	Vertical	142	2,414	RIG2	17.0	2013-2014
17	MW-17	Menengai	2,060	Vertical	121	2,218	RIG3	18.3	
18	MW-19	Menengai	2,085	Vertical	102	2,501	RIG4	24.5	
19	MW-18	Menengai	1,859	Vertical			RIG1		
20	MW-20	Menengai	2,105	Vertical	119	2,461	RIG2	20.7	
21	MW-21	Menengai	2,131	Vertical	Drilling Ongoing		RIG1		
22	MW-22	Menengai	2,055	Vertical	Drilling Ongoing		RIG4		
23	MW-10A	Menengai	2,085	Vertical	Drilling Ongoing		RIG3		

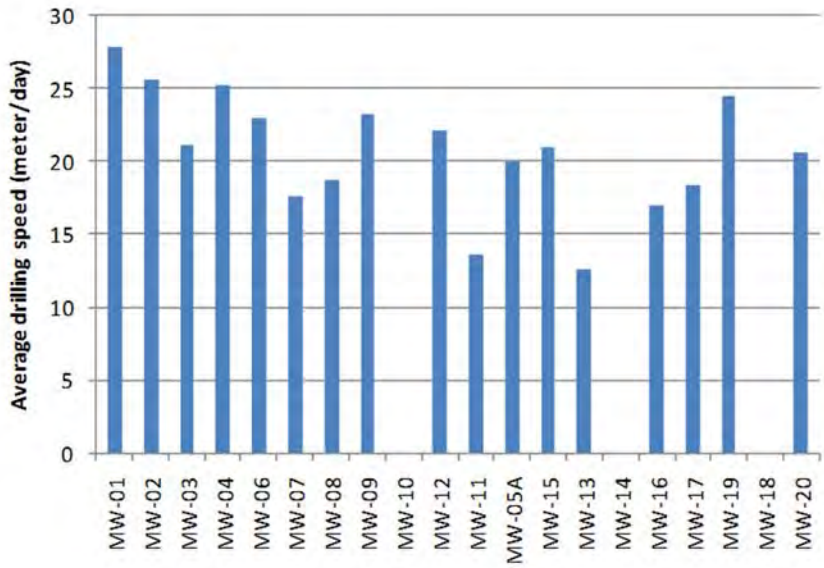


Fig. V-2.10 Drilling speed of GDC

Table V-2.9 GDC's drilling costs estimation by drilling ability

Cases	Outsourcing		GDC [100 drilling days]		GDC [70 drilling days]		GDC [60 drilling days]	
Cost items	mil US$	(%)	mil US$	(%)	mil US$	(%)	mil US$	(%)
1 Drilling cost	3.4	(56.3%)	3.0	(74.5%)	2.8	(79.5%)	2.8	(82.4%)
2 Overseas mibilization	1.2	(19.9%)	-	(-)	-	(-)	-	(-)
3 Rig cost	1.4	(23.8%)	1.0	(25.5%)	0.7	(20.5%)	0.6	(17.6%)
Total	6.0	(100.0%)	4.0	(100.0%)	3.5	(100.0%)	3.4	(100.0%)
Note: Rig costs estimation	Drilling company: Cost Recovery Factor (20%, 10 yrs) = 0.24 30 M$ x 0.24 = 7.2 M$/yr							
Rig cost : 30 M$	GDC: Cost Recovery Factor (8%, 15 yrs) = 0.12 30 M$ x 0.12 = 3.6 M$/yr							
Rig cost	5 wells/yr 1.4 M$/yr		3.5 wells/yr 1.0 M$/yr		5 wells/yr 0.7 M$/yr		6 wells/yr 0.6 M$/yr	

This drilling cost reduction leads to a big reduction of geothermal energy cost. As shown in Table V-2.10 and Fig. V-2.11, if GDC obtains the target ability to drill a 2,000-meter well in 70 days, the construction costs of the 70 MW Model GPP will be reduced to US$ 246 million. These construction costs are cheaper than the construction costs of US$ 284 million when GDC procures foreign drilling services at a cost of US$ 6 million per well. Also the construction costs are cheaper than that of US$ 254 million under the current GDC drilling ability of US$ 4 million per well.

Table V-2.10 Effect of drilling cost reduction on the construction costs of Model GPP

70 MW GPP		Drilling costs (M$/well)			
Construction costs (M$)		6.0	4.0	3.5	3.4
	Remarks	Outsourcing	100 drilling days	70 drilling days	60 drilling days
Steam Field	Wells	87	58	51	48
	FCRS	58	58	58	58
	Field others	21	20	19	19
Power Plant	Power Plant	109	109	109	109
	PP others	10	10	10	10
Total		284	254	246	244
Unit construction costs ($/kW)		4,060	3,630	3,520	3,480

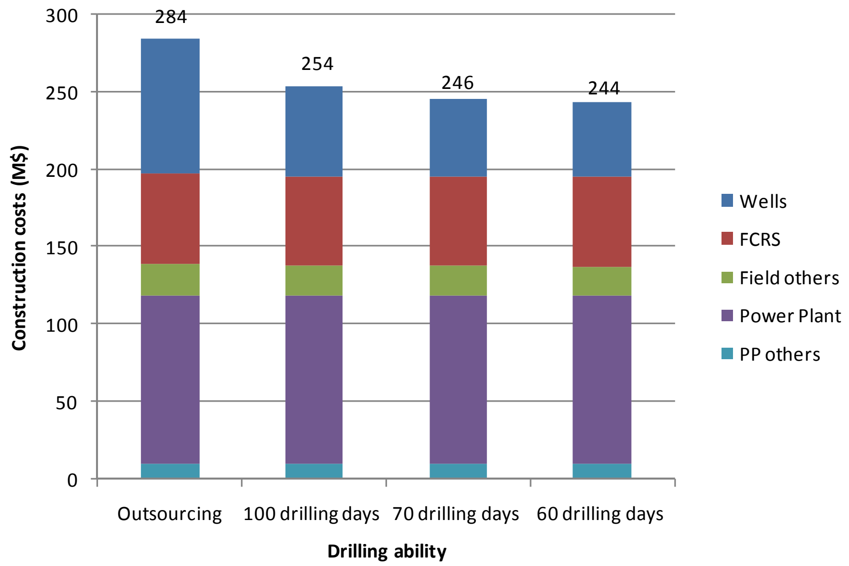


Fig. V-2.11 Effect of drilling cost reduction on the construction costs of Model GPP

Fig. V-2.12 shows how the drilling ability affects the energy/steam cost in the example of a Model GPP that is implemented as a joint project by the partnership of GDC's steam development and a private company's power plant construction. When GDC procures drilling services at US$ 6 million per well, the energy cost is estimated as 12.6 US¢/kWh. When GDC drills a well in 70 days with its own rigs, the energy cost is reduced to 11.1 US¢/kWh. If GDC could drill a well in 60 days, the energy cost will become 11.0 US¢/kWh. Thus, the effect of GDC acquiring its own drilling ability is significant regarding the supply of affordably-priced geothermal energy.

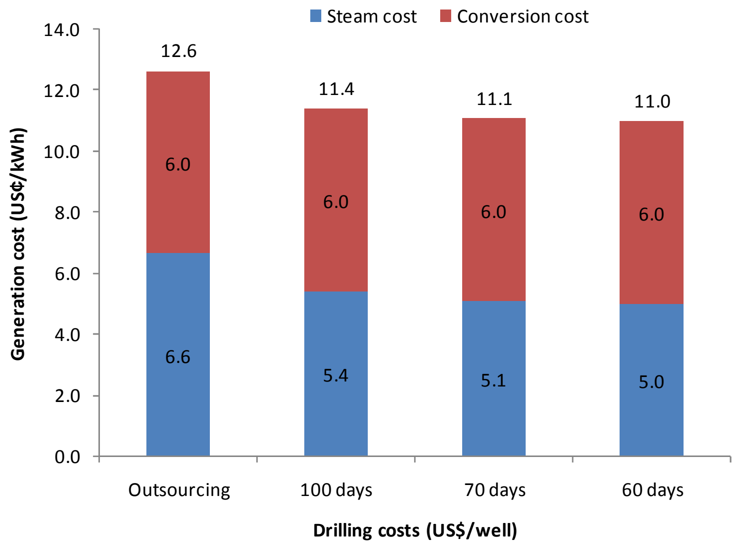


Fig. V-2.12 Effect of drilling costs on energy/steam cost (in the case of Model GPP as a joint project utilizing GDC's steam supply and IPP's energy conversion)

V-2.3 Business model of GDC

a. Several kinds of public-private-partnership models

In the previous sections, the following three cases were considered: (i) a total project by a private developer, (ii) a joint project with a state-owned enterprise responsible for steam supply and a private IPP responsible for generation, (iii) a total project by a state-owned enterprise. These models show that once the state-owned enterprise (GDC) takes part in the project, the energy/steam cost is remarkably reduced because the state-owned enterprise's expected return rate is lower. In addition, if the enterprise acquires a higher drilling ability, the drilling cost becomes lower and the energy/steam cost is greatly reduced.

However, as the participation of GDC expands, the amount of development funds expended by GDC will also increase. Since the funding of GDC's activities comes mainly from the government coffer, there is a possibility that the demand of GDC's development fund will exceed the limit of the government allowance. Therefore it is necessary to work out some kind of mechanism that introduces private capital into the geothermal developments in order to make up for the shortage of governmental funds. The scheme is the public-private partnership (PPP) for geothermal development. This section discusses several different kinds of PPP models which could be used as GDC's business model.

Several kinds of PPP models could be designed for a geothermal development project. They are arranged below from the one with the smallest participation of GDC to the one with the largest participation of GDC:

(i) All private model (reference model)
In this model, a private developer carries out all development stages ranging from the surface survey, the resource exploration, the resource confirmation, the drilling of the production wells, the construction of the field facility, the construction of the power plant, to the operation of power generation. In this model, there is no GDC participation. This is an extreme reference model with no participation by GDC.

(ii) Initial exploration model
In this model, GDC carries out the exloration stage from the surface survey to the resource confirmation. A private developer then continues the development from the drilling of the production wells stage, through the construction of the field facility, the construction of the power plant, to the operation of power generation. GDC's participation in this model is limited to the initial exploration, and this is similar to the model that New Energy and Industrial Technology Development Organization (NEDO) used in Japan.

(iii) Joint SPC model
In this model, GDC carries out the exploration stage from the surface survey to the resource confirmation. After that, GDC and a private the developer jointly establish a special purpose company (SPC) to continue the development from the drilling of the production/reinjection wells stage, through the construction of the field facilities, the construction of the power plant, and the operation of power generation units. GDC transfers the exploration results to the SPC adding a sur-charge. This is a new conceptual model that has not yet been used anywhere in the world.

(iv) IPP model
In this model, GDC carries out steam development and supplies steam to a private independent power producer (IPP) for generation. GDC carries out all stages of steam development from the surface survey to the construction of the field facility. A private IPP constructs the power plant, buys steam and generates power. This is the model that GDC is using in the Menengai 3x35 MW project, and is considered to be the main business model of GDC.

(v) Build-Operate-Transfer (BOT) model
This is a model that is similar to the IPP model, but is different in regards to the limited operation period of the IPP. In this model, the IPP's operation period is limited to a certain number of years, for example 10 years, and at the end of the BOT period, the IPP transfers the power plant to GDC without

any charge. The IPP's role is to build a power plant, operate it and transfer it (BOT). During the operation, the IPP is supplied steam without charge, but the IPP is obliged to transfer the power plant free of charge at the end of the BOT period. The IPP obtains its investment return in the BOT period and GDC obtains its investment return from the power plant operation after the BOT period. This is a model that was designed in the Philippines in the 1990s.

(vi) All public model (Total project of GDC)

In this model, GDC carries out all development stages ranging from the surface survey, the resource exploration, the resource confirmation, the drilling of the production wells, the construction of the field facility, the construction of the power plant, to the operation of power generation. KenGen used this model in Olkaria I, II, and IV. This is a model of full GDC participation, and is another extreme reference model of a total project by public enterprise.

b. Examples of various public-private-partnerships

Several kinds of public-private–partnerships can be observed in geothermal projects around the world. Examples of each PPP model are as follows (Note: Capacity and operation year refers to each country's Country Update Report in the World Geothermal Conference 2015).

(i) All private model (reference model)

In this model, a private company takes all the resource risks and develops the whole process of the geothermal project; from the surface survey, exploration in green-field, and confirmation of the resource, to the construction of the steam field facilities and power plant. Although some examples can be seen in Japan and Indonesia, there are few examples of the use of this model. This is because private companies hardly ever take the resource risks of a green-field, unless there are conditions (either in the market or in relation to incentives), which can offset this risk.

In the Japanese examples, the driving force was the price jump of imported oil after the two oil crisis in the 1970s. The development of indigenous energy was highly promoted by the Japanese government in those days, and some private companies started geothermal energy development in green-fields. (However, the boom stagnated afterwards in the 1990s when imported oil prices dropped.) In the Indonesian examples, the promotion factor was favorable purchase prices of geothermal energy by utilities in the early 1990s. Some foreign companies were attracted by the prices and invested in green-field geothermal prospects in Indonesia. (However, the boom stopped suddenly due to price cuts after the Asian finance crisis in 1997.)

Country	Japan
Power plant	Hacchoubaru
Capacity	Unit-1 55 MW Unit-2 55 MW
Operation	1977~
Developer	Total project by Kyushu Electric Power Co.

Country	Indonesia
Power plant	Salak
Capacity	Unit-4~6 66.7 MW x 3 (*1)
Operation	Unit-4~6 1997 ~ (*2)
Developer	Total project by Union Oil Company of California Ltd. (UNOCAL) (*3)
Remarks	*1: Unit-1～3（60MWx3) are joint projects by UNOCA (steam) and PLN（National Power Company）(generation) *2: Unit-1~3 started in 1994. *3: Currently Chevron Geothermal of Indonesia Ltd.

Country	Indonesia
Power plant	Wayang-Windu
Capacity	Unit-1 110 MW, Uni-2 117 MW
Operation	Unit-1 2000~, Unit-2 2009~
Developer	Total project by Magma Nusantara Ltd. Union Oil Company of California (*1)
Remarks	*1: Currently Star Energy Ltd.

The following are all private model examples as a joint development by two private companies.

Country	Japan
Power plant	Takigami
Capacity	27.5 MW
Operation	1996~
Developer	Joint project by Idemitsu Ohita Geothermal Co.(steam) and Kyushu Electric Power Co. (generation)

Country	Japan
Power plant	Kakkonda
Capacity	Unit-1 50 MW, Unit-2 30 MW
Operation	Unit-1 1978~, Unit-2 1996~
Developer	Joint project by Japan Metals & Chemicals Co. (*1) (steam) and Tohoku Electric Power Co. (generation)
Remarks	*1: Currently Tohoku Natural Energy Co.

(ii) Initial exploration model

This is a model where a government agency carries out the surface survey and exploration drillings to reduce the resource risks, and a private company takes over the development from the government agency afterwards. This PPP model can frequently be seen in many countries where geothermal development is advanced mainly by private companies. In this model, the government provides its geological survey with strong budget measures as seen in the U.S.A., Turkey and New Zealand. In Japan, New Energy and Industrial Technology Development Organization (NEDO), a governmental agency, executed the initial survey and several exploration drillings to clarify the resource potential in many geothermal prospects. The examples of this model are as follows.

Country	U.S.A.
Power plant	Almost all power plants
Capacity	3,477 MW in whole country
Operation	1960～
Developer	Almost all geothermal power plants are developed by private companies in U.S.A. However, the development environment was created by government-funded surface survey and exploration by the U.S. Geological Survey (USGS) to cope with the oil crisis in the 1970s. The results were disclosed in USGS Circular 790 (1978). Although some plants had been developed in the Geysers already, other geothermal developments afterwards were advanced based on this governmental information (GEA (2014)).

Country	Japan
Power plant	Yanaizu Nishiyama
Capacity	65 MW
Operation	1995~
Developer	Surface survey and exploration was carried out by New Energy and Industrial Technology Development Organization (NEDO). Based on the results, Okuaizu Geothermal Co. developed the field and Tohoku Electric Power Co. built the power station (Joint project).

Country	Turkey
Power plant	Kizlidere-2 (*1)
Capacity	60 MW
Operation	2013~
Developer	National Geological Survey (MTA) carried out the surface survey and exploration. Based on the results, Zorlu Co. developed the steam field and power plant (Total project).
Remarks	*1: Kizlidere-1 (15 MW) was developed as a joint project by MTA (steam) and Turkish Electricity Establishment (TEK) (generation). *2: Most geothermal power plants except Kizlidere-1 are developed based on the MTA's exploration work in Turkey. *3: Since 1962, MTA has clarified 227 geothermal prospects in Turkey (Dagistan (2015)). MTA has drilled 578 exploratory wells. The total depth of the wells is over 450 km (MTA (2015)).

Country	New Zealand
Power plant	Wairakei
Capacity	157 MW
Operation	1958-1963 ~
Developer	Surface survey and exploration was carried out by the Department of Science & Industrial Research (DSIR). Based on the results, Electricity Corporation of New Zealand (ECNZ), a state-owned enterprise, developed the steam field and power plant (Total project) (*1).
Remarks	*1: ECNZ was divided into ECNZ and Contact Energy Co. in 1996, and Contact Energy Co. was privatized. Afterwards, what remained of ECNZ was divided into three companies (Genesis Power Co., Meridian Energy Co., and Mighty River Co.). Contact Energy Co. succeeded at the Wairakei plant and is operating it. *2: Proactive exploration work was done by the Government (DSIR) in New Zealand in the 1960-1970's. As a result, all high temperature geothermal prospects were discovered by the governmental exploration by 1980 (NZGA (2015)). Therefore, most geothermal power plants are developed based on the results of the initial exploration of DSIR.

Country	Kenya
Power plant	Olkaria-III
Capacity	100 MW
Operation	2000-2014 ~
Developer	KenGen, a state-owned generation company, surveyed and explored the Olkaria field. Ormat Co., a private company, obtained concession of Olkaria-III section through international bidding in 1998. Ormat Co. established OrPower-4 Inc. and advanced the steam field development

	and power plant construction.
Remarks	*1: Unit-1 is 52 MW and started in 2000. Unit-2 is 40 MW and started in 2008. Unit-3 is 18 MW and started in 2014.

Country	Guatemala
Power plant	Amatitlan
Capacity	24 MW
Operation	2007~
Developer	INDE (Instituto Nacional de Electrification), a state-owned power company, drilled four (4) exploratory wells supported by JICA. Afterwards, INDE bestowed concession to Ormat Co. in 2000, and Ormat Co. succeeded the development (Asturias (2008)).

Country	Indonesia
Power plant	-
Capacity	-
Operation	Fund was established in 2012, however has not yet commenced.
Developer	The Government of Indonesia, which plans to promote geothermal development mainly by private companies, recognized the importance of government-funded initial exploration and established the Geothermal Fund to carry out governmental exploration in 2012. The current Fund amount is US$ 300 million. The details of the Fund are currently being designed. The Fund will be used for exploration, and afterwards, tenders of concession will be done based on the exploration results.

(iii) Joint SPC model

This is a model which GDC is considering the possibility of using as the PPP model in Silali. In this model, a government agency takes responsibility of the development stages from the surface survey to the resource confirmation through the resource exploration. After that, the government agency and a private developer jointly establish a special purpose company (SPC) to continue the development from the drilling of the production wells stage. The SPC also constructs the field facility and power plant, and afterwards generates power. The government agency transfers the exploration results to the SPC adding some surcharge. This is a new idea for a PPP model, and this study could not yet find examples elsewhere in the world.

However, one example that is close to this model was found; Berlin unit-3 (44 MW) developed by LaGeo in El Salvador. LaGeo had been a 100% state-owned enterprise specializing in geothermal energy in El Salvador, but ENEL, an Italian electric power company, obtained 36% of LaGeo's stock in 2002. While in this half-public and half-private status, LaGeo developed Berlin Unit-3 in 2006 (Prevost, 2004). However, this is a case where a private company obtained stock of an existing state-owned enterprise, and it is not a case where a private company and a government agency jointly establish a new SPC as GDC envisages. In addition, discord between the El Salvador side and the ENEL side came to light, and the El Salvador side bought all of the stock back from ENEL in 2014. LaGeo is no longer in the status of half-public and half-private (ENEL (2014)).

(iv) IPP model

In this model, a government agency carries out the steam development and supplies steam to a private independent power producer (IPP) for generation. This is the model that GDC is planning to use in Menengai, and is the main business model that GDC intends to adopt. However, there are few examples of this the application of this model in the world. One example existed until recently in Guatemala; Zunil-1.

Country	Guatemala
Power plant	Zunil-1
Capacity	28 MW
Operation	1999~
Developer	INDE (Instituto Nacional de Electrification), a state-owned power company, has developed the field and supplies steam to Ormat Co. (ORZUNIL-I de Electricidad Co.) to generate power. Ormat concluded a 25 year-PPP contract with INDE (Lima (2003)).

Although it is a small-scale project, the following example also exists in Japan.

Country	Japan
Power plant	Sugawara
Capacity	5 MW
Operation	2015~
Developer	The steam development was executed by New Energy and Industrial Technology Development Organization (NEDO), and the wells were transferred to Kokonoe town, a host local municipality. Kokonoe town supplies steam to Kyuden Mirai Energy, a subsidiary of Kyushu Electric Power Co., which built and operates the power plant.

(v) BOT model

The BOT model, in which an IPP builds and operates the power plant and transfers it to the steam supplier after the 10-year BOT period passes, was created in the Philippines in the early 1990s. This method became a driving force behind the Philippines development of geothermal energy in the 1990s, as described later. Afterwards, Costa Rica also adopted a BOT model of 15 years for Miravalles-III.

Country	Philippines
Power plant	Tongonan-II, Tongonan-III (*1)
Capacity	Tongonan-II 220 MW, Tongonan-III 391 MW
Operation	Tongonan-II 1997~, Tongonan-III 1997~
Developer	Steam development was done by Philippine National Oil Company-Energy Development Corporation (PNOC-EDC), a state-owned enterprise. Power plant was built and operated by California Energy Co., a private company under a 10 year BOT contract.
Remarks	*1: Tongonan-I (113 MW) was jointly developed by PNOC-EDC and NPC (National power company) in 1983 (Joint project). *2: The power plant was transferred to PNOC-EDC after the 10 year BOT period passed.

Country	Philippines
Power plant	Mindanao
Capacity	54 MW × 2 unit
Operation	Unit 1 1997~ Unit-2 1999~
Developer	Steam development was done by Philippine National Oil Company-Energy Development Corporation (PNOC-EDC), a state-owned enterprise. Power plant was built and operated by Oxbow Co. and Marubeni Co., a U.S. private company and a Japanese private company respectively, under a 10 year BOT contract.
Remarks	*1: The power plant was transferred to PNOC-EDC after the 10 year BOT period passed.

Country	Costa Rica
Power plant	Miravalles-III
Capacity	27.5 MW
Operation	2000~
Developer	Steam development was done by Instituto Costarricense de Electricidad (ICE), a state-owned enterprise. Power plant was built and operated by GeoEnergia of Guanacaste Ltd., which was established by Oxbow Co. and Marubeni Co., a U.S. private company and a Japanese private company respectively. The BOT period was 14 years (Laprensalibre (2015)).
Remarks	*1: This is the first BOT model in Latin America. *2: The power plant was transferred to ICE in March 2015 after the 15 year BOT period passed (Laprensalibre (2015)).

(vi) All public model

In this model, a government-owned enterprise carries out all of the development stages by itself. This model is seen in many countries where geothermal energy is well developed, such as Kenya, Italy, Mexico, Costa Rica, Iceland, El Salvador and so on. The fact that this model is frequently seen in many countries is good evidence that SOEs play an important role in developing geothermal energy, where resource development risks are too high for private companies to bear. Examples of this model are as follows.

Country	Kenya
Power plant	Olkaria-I, Olkaria-II, Olkaria-IV
Capacity	Olkaria-I 185 MW, Olkaria-II 105 MW, Olkaria-IV 140 MW
Operation	Olkaria-I 1981-2014 ~, Olkaria-II 2003-2010~, Olkaria-IV 2014~
Developer	Total project by KenGen, a state-owned power generation enterprise (state 70%: private 30%)

Country	Italy
Power plant	Larderello, Travale-Radicondoli, Mt. Amiata
Capacity	Larderello (595 MW), Travale-Radicondoli (200 MW), Mt. Amiata (81 MW)
Operation	Larderello (1991-2009 ~), Travale-Radicondoli (1986-2010 ~), Mt. Amiata (1991-2013 ~)
Developer	Total project by ENEL (Ente Nazionale per l' Energia Eletterica), a state-owned power company
Remarks	*1: Operation years are that of existing units. *2: ENEL was established as a state-owned power company in 1962. It was transformed to a company with 100% of the stock held by the government in 1992. Since 1999, the stock began to be sold to the private sector. The government's stock share became 21% in 2005 (JEPIC (2010)). *3: All the geothermal power plants were transferred to ENEL Green Power Co., which was established in 2008 as a subsidiary of ENEL in the process of electric power industry liberalization. Therefore, although the current status of power plants' owner is a private company, the historical development was categorized into the SOE total project.

Country	Mexico
Power plant	Cerro Prieto, Los Azfures etc.
Capacity	Cerro Prieto 720 MW, Los Azfures 188 MW
Operation	Cerro Prieto 1973-2000~, Los Azfures 1982~
Developer	Total project by CFE (Commission Federal of Electricity), a state-owned power company.

Country	Cost Rica
Power plant	Miravalles, Las Pailas
Capacity	Miravalles 136 MW, Las Pailas 43 MW
Operation	Miravalles 1994～, Las Pailas 2011～
Developer	Total project of Instituto Costarricense de Electricidad (ICE), a state-owned power company

Country	Iceland
Power plant	Krafla, Bjarnarflag
Capacity	Krafla 30 MW x 2 unit, Bjarnarflag 3 MW
Operation	Krafla unit-1:1978 ~, unit-2: 1998 ~, Bjarnarflag 1969 ~
Developer	Total project by Landsvirkjun, a state-owned electric power company

Country	Iceland
Power plant	Nesjavellir, Hellisheiði
Capacity	Nesjavellir 30 MW x 3 unit, Hellisheiði 45 MW x 3 unit, 33 MW x 1 unit
Operation	Nesjavellir 1998-2005~, Hellisheiði Krafla 2006-2010~
Developer	Total project by Reykjavik Energy Co., a company where all the stock is held by the government

Country	El Salvador
Power plant	Ahuachapan, Berlin (Unit-1&2)
Capacity	Ahuachapan 95 MW, Berlin (Unit-1&2) 56 MW
Operation	Ahuachapan 1975-1981~, Berlin (Unit-1&2) 1999~
Developer	Comisión Ejecutiva Hidroeléctrica del Río Lempa (CEL), a state-owned electric power company, developed the field and the power plant with the assistance of the World Bank (Prevost (2004)). LaGeo, which was established by National Energy company (INE) in 1999, succeeded the ownership of two power plants and is operating and developing the fields currently.
Remarks	ENEL (Italian electric power company) participated in the management of LaGeo while holding 36% of LaGeo's stock since 2002. LaGeo returned to a 100% state-owned enterprise in 2014.

Country	Japan
Power plant	Onikobe
Capacity	15 MW
Operation	1975~
Developer	Total project by J-Power, a state-owned power generation company (fully privatized in 2004)

In addition, there are examples where two SOEs, one as the steam developer and another as the power producer, have jointly developed geothermal energy.

Country	Philippines
Power plant	Palenpinon, Bac-Man
Capacity	Palenpinon 193 MW, Bac-Man 150 MW
Operation	Palenpinon 1983-1995 ~, Bac-Man 1993-1995 ~
Developer	Steam development was done by Philippine National Oil Company-Energy Development Corporation (PNOC-EDC), a state-owned enterprise. Power plant was built and operated by National Power Company (NPC), a state-owned electric power company (*1).
Remarks	*1: Power plants were sold to Green Core Geothermal Inc. (GCGI), which is a subsidiary of PNOC-EDC, during the process of NPC's privatization in 2009.

Country	Indonesia
Power plant	Kamojang (unit-1~unit-3), Lahendong
Capacity	Kamojang (unit-1~unit-3) 140 MW, Lahendong 60 MW
Operation	Kamojang (unit-1~unit-3) 1983-1988 ~, Lahendong 2001-2009 ~
Developer	Steam development was done by PT. Pertamina Geothermal Energy (PGE) which is a subsidiary of Pertamina, an SOE of Indonesia. Power plant is operated by PT. PLN, a state-owned electric power company.

These examples are shown in Fig. V-2.14.

c. Energy/steam price in different PPP models

This section calculates the energy/steam price of the 70 MW Model GPP if it is developed in each PPP model and compares them. In the calculation of the energy/steam prices, the following assumptions were adopted:

<Expected rate of return>

10% for GDC, 20% for private developer/private IPP, and 15% for SPC jointly established by GDC and a private developer.

<Drilling cost>

Drilling cost was assumed to be US$ 3.5 million per well, regardless of who drills, i.e. GDC, private developer or SPC.

<Sales price of exploration results>

In the calculation of the Initial exploration model (model-(ii)) and of the Joint SPC model (model-(iii)), GDC's exploration results are supposed to be transferred to a private developer or SPC at a price of US$ 42 million. This price includes 10% interest and the original survey/exploration cost (Table V-2.11). This transfer is supposed to be done at the end of exploration (i.e. -4 yr), and the payment is done in a lump sum.

Table V-2.11 Transfer price of GDC's exploration results

(in the cases of the Initial exploration model and the Joint SPC model)

Stage	Contents	Cost (m$)	Time of execution
1. Surface survey	Wide survey, Detailed survey	2	-7 yr
2. Exploration	2 exploratory wells	10	-6 yr ～-5 yr
3. Resource confirmation	5 exploratory wells	23	-5 yr ～-4 yr
	Well test, etc.	3	-4 yr
Sub total		38	
Margin	10% of interest	4	
Total		42	At the end of -4 yr

GDC's business model explanation chart and assumptions are shown in Table V-2.12 and Fig. V-2.13.

Table V-2.12 GDC's business model and assumptions of energy/steam price calculation

GDC's business model	Explanation	Assumptions
All private model	Total project by a private developer （No participation of GDC）	Expected return rate of private developer : 20% Drilling cost of private developer: 3.5 M$/well
Initial exploration model	GDC carries out development until confirmation stage (drills 7 wells), sells the results at US$ 42 million to a private developer. The private developer continues the development.	Expected return rate of GDC: 10% Drilling cost of GDC: 3.5 M$/well Expected return rate of private developer : 20% Drilling cost of private developer: 3.5 M$/well
Joint SPC model	GDC carries out development until confirmation stage (drills 7 wells), establishes SPC with a private developer, and then sells the results at US$ 42 million to SPC. The SPC continues the development.	Expected return rate of GDC: 10% Drilling cost of GDC: 3.5 M$/well Expected return rate of SPC: 15% Drilling cost of SPC: 3.5 M$/well
IPP model	GDC develops steam and sells it to a private IPP. The IPP constructs the power plant and generates power.	Expected return rate of GDC: 10% Drilling cost of GDC: 3.5 M$/well Expected return rate of private IPP: 20%
BOT (10years) model	GDC develops steam and sells it to a private IPP. The IPP constructs the power plant and generates power for 10 years. Ten years later, the IPP transfers the plant to GDC. GDC continues generation afterwards. The steam price to IPP and the power plant price to GDC are free of charge.	Expected return rate of GDC: 10% Drilling cost of GDC: 3.5 M$/well Expected return rate of private IPP: 20%
GDC total project model (All public model)	Total project by GDC （Full participation of GDC）	Expected return rate of GDC: 10% Drilling cost of GDC: 3.5 M$/well

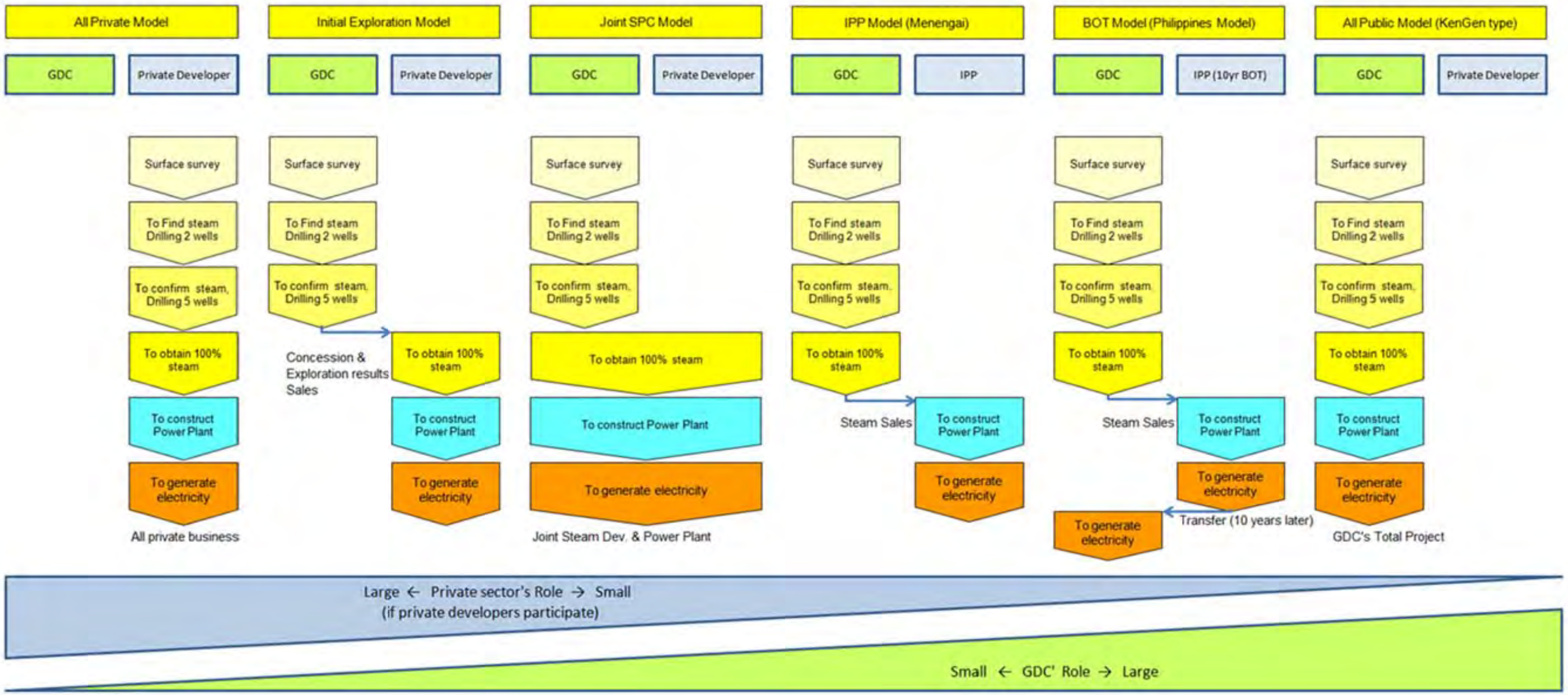
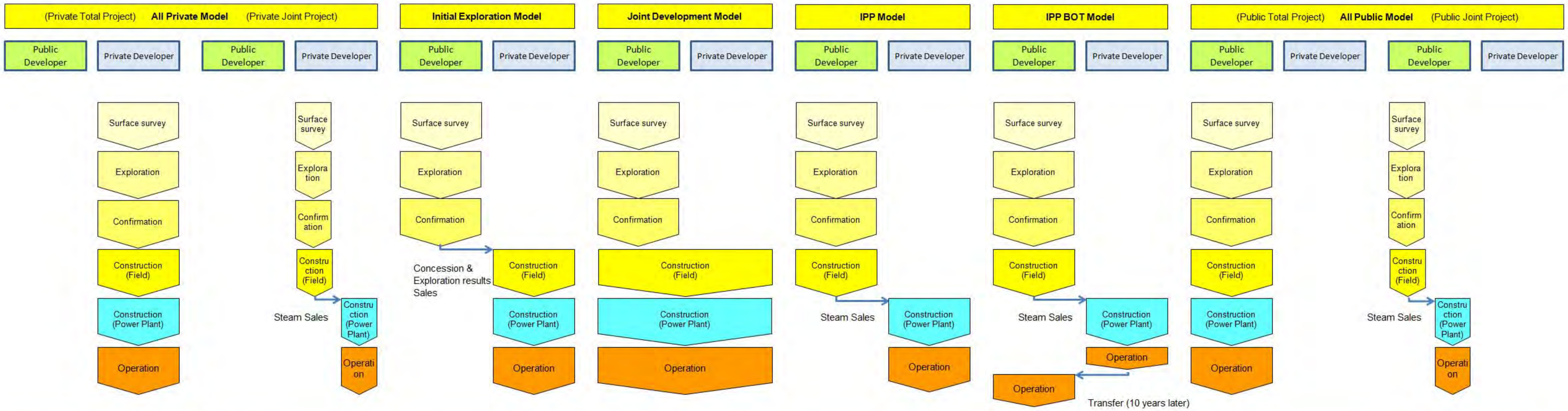


Fig. V-2.13 GDC's PPP model spectrum



All Private Model (Private Total Project)

Country	Japan
Project	Hacchoubaru
Public	-
Private	Kyushu Electric Power Co.

Country	Indonesia
Project	Salak
Public	-
Private	Union Oil Company of California

Country	Indonesia
Project	Wayang Windu
Public	-
Private	Mandala Nusantara Ltd.

All Private Model (Private Joint Project)

Country	Japan
Project	Takigami
Public	-
Private-1	Idemitsu Geothermal Co.
Private-2	Kyushu Electric Power Co.

Initial Exploration Model

Country	U.S.A.
Project	almost all proojects
Public	USGS
Private	Private developers

Country	Japan
Project	Yanaizu Nishiyama
Public	NEDO
Private	Okuaizu Geothermal Co.

Country	Turkey
Project	Kizildere-2, etc.
Public	MTA
Private	Zorlu, etc.

Country	New Zealand
Project	Wairakei, Reporoa, etc.
Public	Department of Scientific & Industrial Research
Private	Contact Energy, Mighty River, etc.

Country	Kenya
Project	Olkaria -III
Public	KneGen
Private	Ormat

Country	Guatemala
Project	Amatitlan
Public	INDE (National Power Co.)
Private	Ormat

Country	Indonesia
Project	(under designing)
Public	Geothermal Fund (MOF)
Private	(under designing)

Joint Development Model

No Example

IPP Model

Country	Guatemala
Project	Zunil
Public	INDE (National Power Co.)
Private	Ormat

Country	Japan
Project	Sugawara Binary
Public	NEDO / Kokonoe town
Private	Kyuden Mirai Energy Co.

IPP BOT Model

Country	Philippines
Project	Tongonan
Public	PNOC-EDC
Private	California Energy Co.

Country	Philippines
Project	Mindanao
Public	PNOC-EDC
Private	Oxbow/Marubeni

Country	Costa Rica
Project	Miravalles-III
Public	ICE (National Power Co.)
Private	Oxbow/Marubeni

(15 years-BOT)

All Public Model (Public Total Project)

Country	Kenya
Project	Olkaria
Public	KenGen
Private	-

Country	Italy
Project	Larderello, etc.
Public	ENEL (National Power Co.)
Private	-

Country	Mexico
Project	Cerro Prieto, Los Azufres, etc.
Public	CFE (National Power Co.)
Private	-

Country	Costa Rica
Project	Miravalles, Las Pailas, etc.
Public	ICE (National Power Co.)
Private	

Country	Iceland
Project	Krafla, Bjarnarflag
Public	National Power Co.
Private	-

Country	Iceland
Project	Nesjavellir, Hellisheiði
Public	Reykjavik Energy Co.
Private	-

Country	El Sarvador
Project	Ahuachapan
Public	CEL (LaGeo)
Private	-

Country	Japan
Project	Onikohbe
Public	EPDC (National Gen. Co.)
Private	-

All Public Model (Public Joint Project)

Country	Philippines
Project	Palinpinon, Bac-Man, etc.
Public-1	PNOC-EDC
Public-2	NPC (National Power Co.)
Private	-

Country	Indonesia
Project	Kamojang, Lahendong, etc.
Public-1	Pertamina
Public-2	PLN (National Power Co.)
Private	-

Fig. V-2.14 Examples of PPP model

The result of the energy/steam cost for the 70 MW Model GPP in each GDC PPP model is shown in Fig. V-2.15. It is understood that the energy/steam price decreases as the participation of GDC increases. The main role of GDC in a PPP scheme is to bear the high resource risks that private companies have difficulty bearing. There is however another benefit, that the energy/steam cost is expected to be reduced as GDC's participation becomes greater. This confirms the significance of GDC's role in the development and supply of affordably priced geothermal energy.

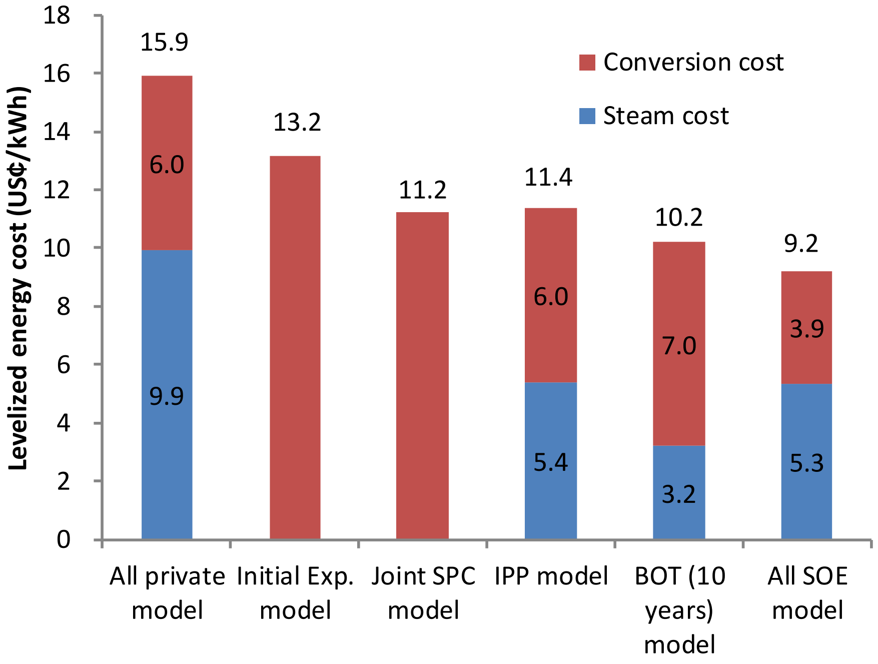


Fig. V-2.15 Energy cost and steam cost by GDC's PPP model

d. BOT Model

This section adds some more explanation and discussion regarding the BOT model. In the BOT model, GDC develops steam and sells the steam to a private IPP. The private IPP builds a power plant, purchases steam from GDC, generates electricity, and then sells it to the electric power company (Kenya Power). Up to this point it is the same as the IPP model, but in the BOT model the power generation period by the IPP is limited (for example, 10 years) and after a predetermined period the power plant will be transferred to GDC free of charge. After receiving the plant, GDC will conduct steam production and power generation from the 11th year onward and will sell electricity to Kenya Power. In this case, GDC acquires the power plant free of charge, but at the same time it also owes an obligation to repay the remaining loan held by the IPP. It is called "BOT" because the power plant is Built, Operated and then Transferred by the IPP. For the IPP, the project participation period is limited to 10 years, but the IPP can enter the geothermal project without the burden of the resource risks. If the IPP can obtain a certain return on investment in the 10 year period, the BOT model provides benefits to both the IPP and GDC. The model forms a win-win relationship between GDC and the IPP. Therefore, GDC can expect many companies to desire to participate in this model as an IPP.

As explained in the previous section, the BOT model was designed in the Philippines in the 1990's. The Philippines suffered from serious power shortages from the second half of the 1980's to the first half of the 1990's. To cope with this power crisis, the Philippines government allowed private companies to participate in the power generation business under the BOT scheme by the BOT Law (Law No 6957/1989) and the Expanded BOT Law (Law No. 7718/1993). Under these new rules, private companies started to build gas turbine power plants, which could be built in a short period, under the BOT scheme. These laws also paved the way for private companies to participate in constructing geothermal power plants in place of National Power Company (NPC) under the BOT scheme. Geothermal development in the Philippines in the 1990's has advanced dramatically by introducing this BOT scheme as Fig. V-2.16 clearly shows.

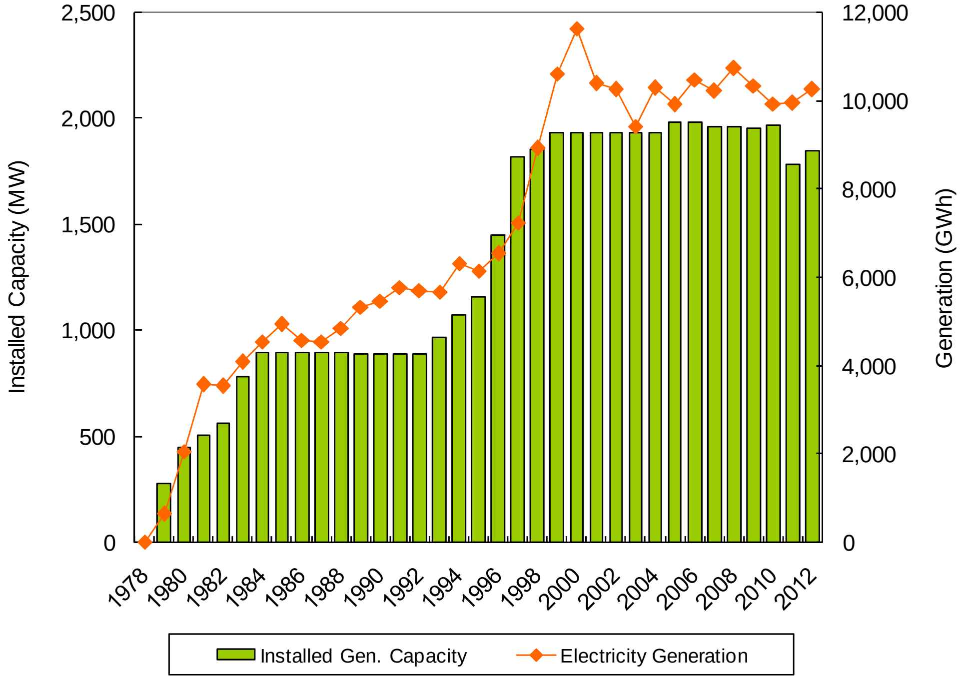


Fig. V-2.16 Growth of geothermal power plant capacity and generation in the Philippines

Thus the introduction of the BOT scheme was effective in assisting to resolve the power crisis. At the same time, however, it had the unfavorable side effect of creating a dependency on gas turbine plants, which require smaller initial capital expenses, but largeer fuel expenditures. As a result, the consumer's electric tariff increased sharply and the financial situation of NPC deteriorated. Therefore, the government enacted the Electric Power Industry Reform Act (EPIRA) in 2001 and unbundled and privatized NPC. In this process, PNOC-EDC was also privatized. In this environment, private companies greatly reduced investiments in new geothermal development.In such a movement, new investment to geothermal development by private companies stopped. Here again, is another example that shows geothermal development has difficulty proceeding if it is entrusted to private companies alone.

The BOT model could be designed with various different terms. Some examples of this variability include whether the operation period of IPP is 10 years or 15 years, whether the IPP sells power to Kenya Power or sells it to GDC, whether the electricity sales price to Kenya Power is constant or changeable in multi-steps, and so on. As for the BOT period, 10 years was used in the Philippines in the 1990s (for example, Tongonan, Mindanao, etc.). However, 15 years was used in the case of Miravalles-III in Costa Rica which started operation in 2000. The JICA team recommends a 10-year BOT period in this study report. The reason is that in the case of a 15-year BOT period, there is a concern regarding deterioration of the plant at the time of transfer. For this reason, the following sections calculate generation cost of the 10-year BOT model.

As for the sales of electricity, two types of BOT schemes could be designed; one is a scheme in which an IPP buys geothermal steam from GDC and generates electricity and sells it to Kenya Power (option-1). Another scheme is that an IPP buys geothermal steam from GDC and generates electricity and sells the electricity back to GDC. GDC then sells the electricity to Kenya Power (option-2) (Fig. V-2.17). In the comparison of the two options, Option-2 is superior to Option-1. It is because the number of contracting partners for the IPP is only one (i.e. GDC) in Option-2. In the case of Option-1, it is necessary for the IPP to simultaneously negotiate both the electricity sales conditions with Kenya Power and the steam purchase conditions with GDC. In the case of Option-2, the IPP receives steam from GDC, generates electricity and sells the electricity to GDC. The steam is supplied free of charge from GDC, and the electricity will be purchased by GDC at a certain price. GDC sells the electricity to Kenya Power at a certain price which includes the cost of both the steam GDC generated and the electricity purchased from the IPP. At a quick glance, GDC seems a one-sided loser because it supplies steam free of charge and takes back electricity at a high price. However, after ten years GDC will take over the power plant free of charge and undertake power generation. GDC will then reap the benefits of this arrangement over a long-term period. On the other hand, although the generation period is limited to only a 10-year period, the IPP can obtain a profit by selling power for 10 years with a guaranteed steam supply by GDC. The purchase of electricity is also guaranteed by GDC. In this model, the IPP is escaping the fuel supply risk and the off-taker's risk. Therefore, this mechanism is a win-win scheme for both parties.

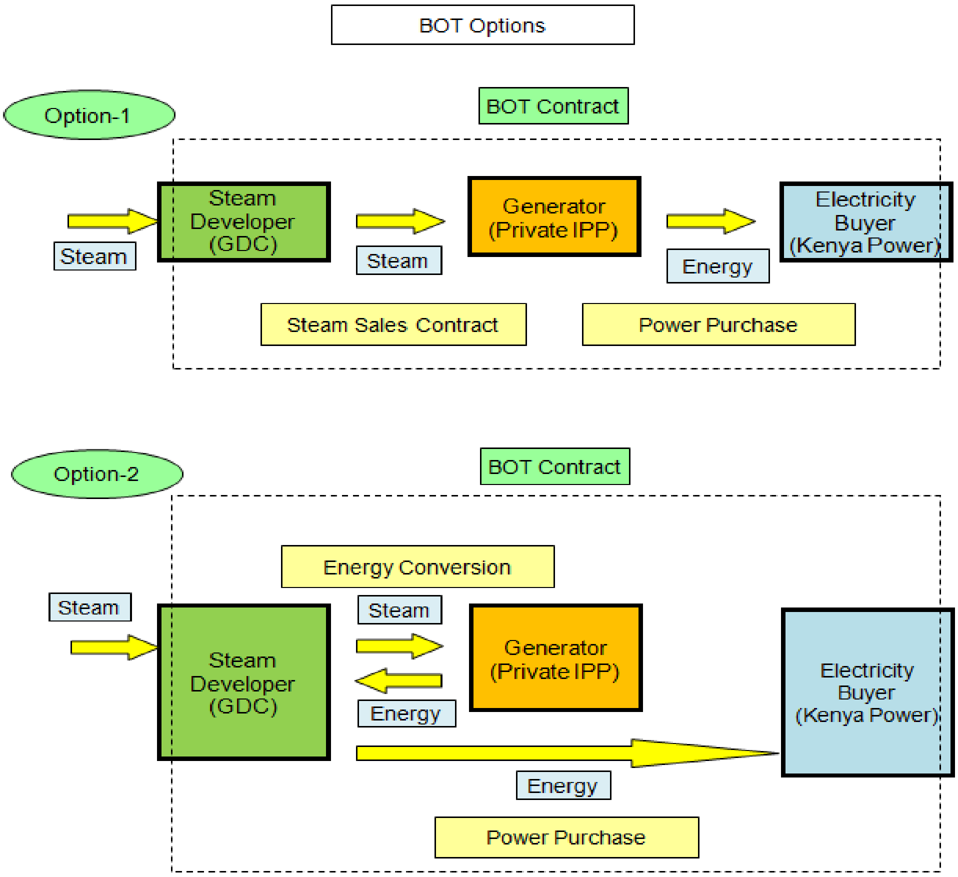


Fig. V-2.17 Two types of BOT schemes

Regarding the sales price of electricity, for the purposes of this analysis, the scheme in which the electricity sales price remains at the same level even after the plant is transferred to GDC will be known as BOT-1. The scheme in which the electricity sales price is different after the plant is transferred to GDC will be known as BOT-2. Figure V-2.18 shows a conceptual diagram of the electricity sales price (or the generation cost of energy) and the steam price (or the steam cost) of the IPP model, of the BOT-1 model and of the BOT-2 model respectively. In the case of the IPP model, it is necessary for GDC to sell steam at 5.4 US¢/kWh to secure the expected return rate of 10% in 30 years (the steam cost is 5.4 US¢/kWh). For the IPP, it is necessary to set the energy conversion price at 6.0 US¢/kWh to secure the expected return rate of 20% in 30 years (the conversion cost is 6.0 US¢/kWh). As a result, the electricity sales price becomes 11.4 US¢/kWh in the IPP model (the generation cost is 11.4 US¢/kWh. Hereinafter the word "price" is the same meaning as the word "cost"). In the case of the BOT-1 model, the IPP needs to raise its energy conversion price to 7.0 US¢/kWh in order to secure the expected rate of return of 20% in

10 years. As for GDC, the steam price can be lowered to 3.2 US¢/kWh for the first 10-year period, since GDC will acquire the power plant and will sell electricity at 10.2 US¢/kWh for the period from the 11th year to the 30th year. These sales prices will bring about 10% of return to GDC in the 30-year period. As a result, the electricity sales price of the BOT-1 model is 10.2 US¢/kWh, which is 1.2 US¢/kWh lower than the IPP model. As the involvement of GDC in the BOT-1 model is larger than the IPP model, the sales price of the BOT-1 model is lower than that of the IPP model. Figure V-2.19 shows the impact on the sales price of the BOT period in the BOT-1 model. As the involvement of GDC decreases, the electricity sales price increases.

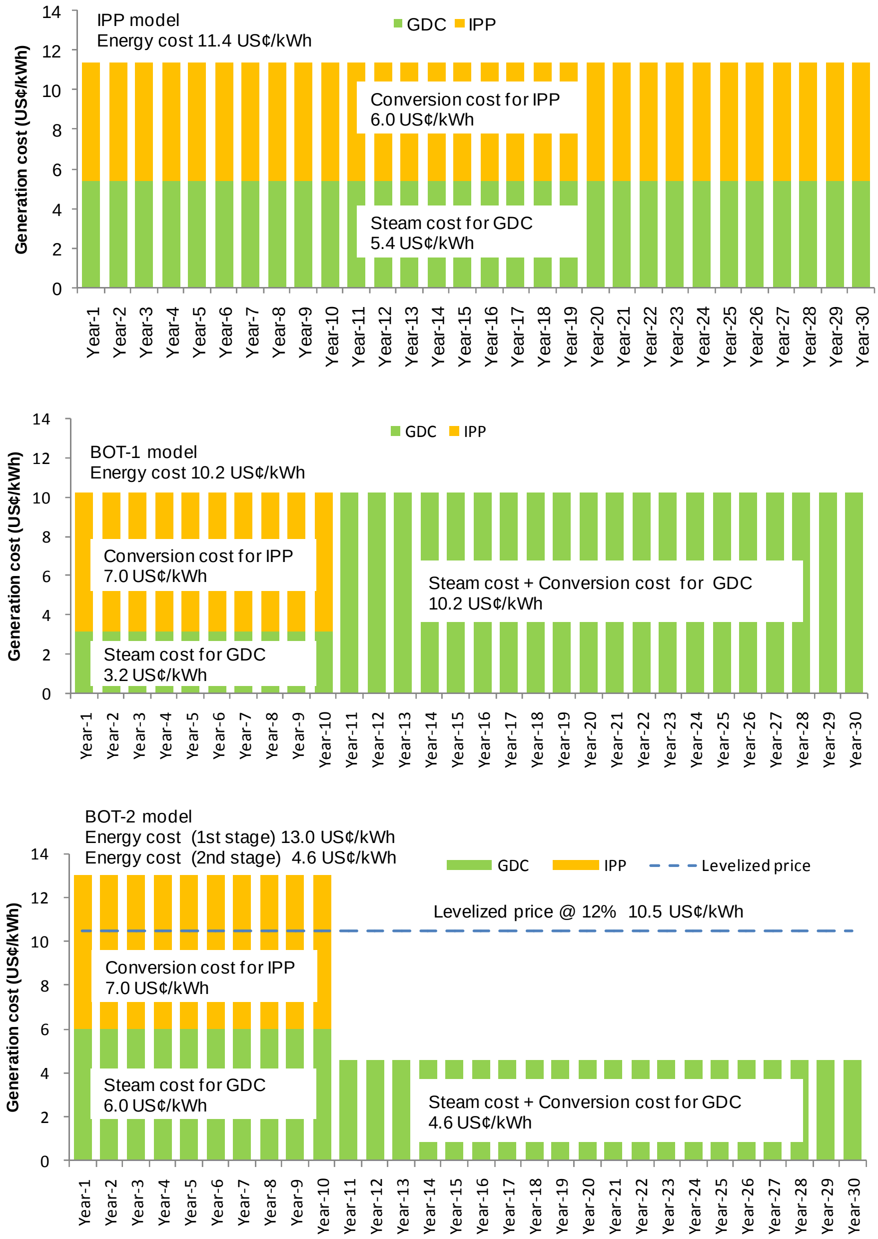


Fig. V-2.18 Concept chart of energy cost and steam cost between IPP model (top) and BOT models (bottoms)

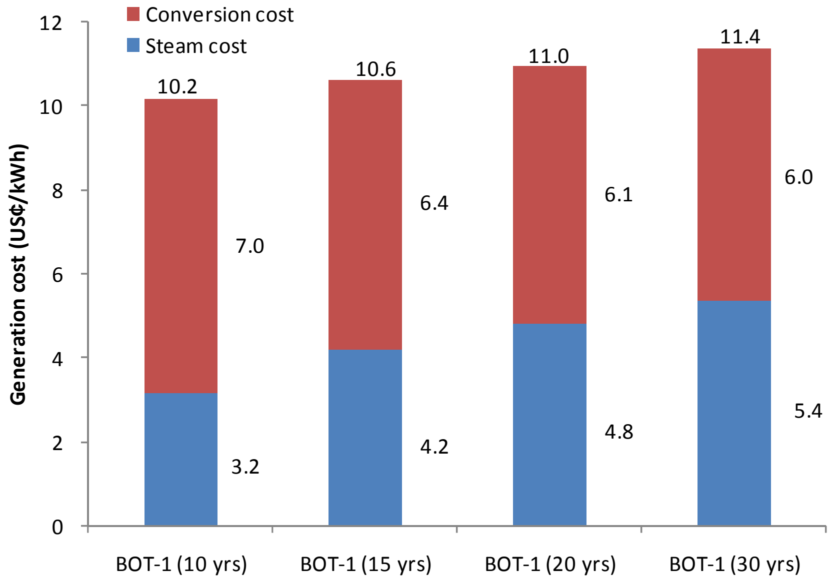


Fig. V-2.19 Effect of BOT period on energy cost and steam cost in the BOT model

The BOT-2 model is an improved model to increase the income of GDC in the first 10-year period. If the steam price of GDC in the first 10 years is 6.0 US¢/kWh, the electricity sales price will be 13.0 US¢/kWh, taking into account the IPP's share of 7.0 US¢/kWh. GDC can sell electricity at 4.6 US¢/kWh from the 11th year to secure the 10% expected return in 30 years. In other words, the electricity sales price to Kenya Power becomes two (2) stages, 13.0 US¢/kWh and 4.6 US¢/kWh. If this two-tier rate is levelized at a discount rate of 12% for 30 years, it will be 10.5 US¢/kWh, which is slightly higher than the Option-1 model but lower than the IPP model.

It might be difficult for GDC to collect the huge amount of funding that is necessary to develop all the geothermal fields. Therefore, GDC needs to make the best use of the investments of private companies in the geothermal business. In such a situation, it is worthwhile to pay attention to how the BOT method can utilize private participation and lower geothermal energy prices.

e. Discussion regarding an appropriate PPP model for GDC

This chapter further discusses an appropriate PPP model for GDC based on the results of the survey of examples in the world and the energy/steam cost calculation in each PPP model.

(i) Determining whether a total project or a joint project is more advantageous

This section will first consider whether a total project or a joint project is more advantagous. The previous section, provided examples of joint projects by private companies (Takigami and Kakkonda in Japan) and by public companies (Palinpinon and Bac-Man in the Philippines, and Kamojang and Lahendong in Indonesia). Although it is true that there are these examples, these joint projects may be remnants of the past when power generation was not permitted by private companies. Since generation was only permitted by electric power companies in many countries, the steam developers were forced to enter into a joint project with an electric power company. However, the number of projects using this development style has decreased recently as private companies are now allowed to generate power as a result of the movement towards the liberalization of the electric power industry. Today in Japan, private developers are exploring geothermal prospects with the intention of operating geothermal power plants by themselves. Also in Indonesia, the number of examples where Pertamina Geothermal Energy handles the entire process from the steam development to the power generation is increasing.

When we compare the "steam development section" and "energy conversion section," the energy conversion section can obtain a cash flow stream with less resource risks. Therefore, it is indeed an unwise choice to cut off this "cash cow" section from the steam development component, which bears large resource risks. It is wise to integrate the two sections as much as possible.

Joint projects are likely to evolve into a system where one of the joint companies tend to force the risks of a project to the other company. Therefore, joint projects are likely to take a long time to conclude a joint development agreement. The history of the development of geothermal projects in Japan shows that joint projects required an average of 22 years from the start of the surveys until commissioning. This is 8 years longer than total projects, which required an average of 14 years to complete (Fig. V-2.20). The measures used to cope with resource risks is a question of managerial judgment. It is thought that geothermal energy development is preferable to be done in a system where one manager can make prompt judgments.

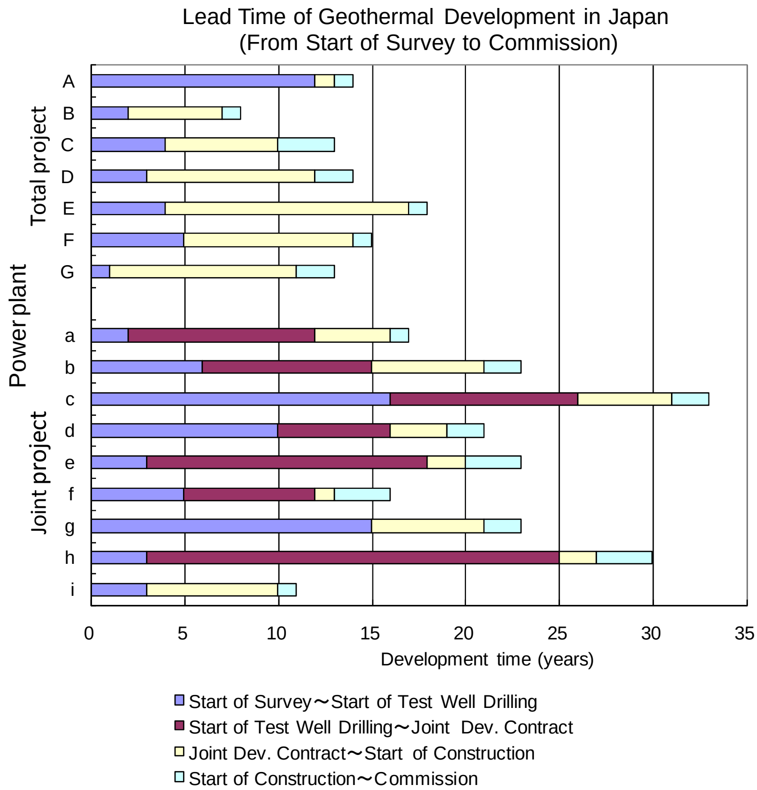


Fig. V-2.20 Comparison of incubation time between total projects and joint projects in Japan (modified from JGIA (2000))

(ii) Determining whether an initial exploration model or a complete development model is more advantagous

The survey of examples, showed that the governmental role is ambivalent. One is a model where a government agency undertakes only the initial survey and exploration (resource confirmation). The results of this survey and exploration are then transferred to private developers which may be interesting in attempting to develop any possible geothermal potential which is found. Another is a model where a state-owned enterprise executes the complete development from the initial survey to the power generation.

The former model might be effective in industrialized countries where private companies have enough technology and capital power and the investment environment of the market is stable. The former model allows the government to develop geothermal resources at a lower cost with the assistance of the private sector's power. This model, however, is ineffective in developing countries where the investment environment of the market is not well developed. An example is Olkaria-III in Kenya. Although the concession of Olkaria-III was granted to a private company in 1998, it took until 2014 for a 100 MW development to be achieved. Meanwhile, KenGen has developed 468 MW of geothermal plants at Olkaria during the same period, which is 4 times more than the private company.

The reason why GDC was established as a state-owned enterprise is that it seemed difficult for private companies to enter into the geothermal development of green-fields in Kenya. If returning to this original intention, it could be said that the model Kenya should use is a complete development model, from exploration to power generation, by the state-owned enterprise.

(iii) Determining whether the IPP model or the BOT model is more advantagous?

The example survey, found only two examples of the IPP model; one is in Guatemala and another small one is in Japan. The number is less than initially expected. The reason for this is attributed to the disadvantage of cutting off the "cash cow" section, as already described above.

To cope with this disadvantage, the Philippines worked out the BOT model. Because PNOC-EDC is a steam development company, the company neither possesses the technology/expertise nor experience concerning power generation. Moreover, the capital power of the company to construct power plants is also insufficient. In such a situation, however, PNOC-EDC was able to acquire the power plant free of charge after the 10 year BOT period by adopting the BOT method. On the other hand, the BOT model was also profitable for the private side. Private companies could enter into the geothermal power business without bearing large resource risks and an expected investment return was obtained during the 10 year BOT period. Thus, the BOT became a win-win method for both parties, and the geothermal development of the Philippines has advanced rapidly. Of course, extensive discussions and legal arrangements would be necessary within the Kenyan government to allow GDC to enter into the power generation business. However, the success of the Philippines BOT case seems to suggest one intriguing path for Kenya.

V-2.4 Role as a receiver of ODA

This section points out the third important role of a state-owned enterprise in geothermal energy development. That role is to function as a receiver of ODAs. The strong relationship between the expected return rate of the project owner and the energy/steam price of a geothermal project is demonstrated in Fig.V-2.6. Therefore, if the expected return rate of the project owner can be lowered, the energy/steam price can be lowered accordingly. If the project owner could procure finance with a lower interest rate, then the expected return rate could fall. Therefore, ODA financing (which has extremely low interest rates) is very effective in lowering the geothermal energy price.

As an example, the following is a calculation of the generation/steam cost of the 70 MW Model GPP when the project receives an ODA loan instead of commercial loan. In this calculation, the ODA loan condition is represented by that of Yen Loan as shown in Table V-2-13. Only GDC is able to receive ODA financing while a private IPP receives a commercial loan. As Fig. V-2.21 shows, the steam cost of GDC decreases as a result of the ODA's low interest rate, and the generation cost is reduced to 9.4 US¢/kWh in the IPP model. In the BOT model, the steam cost reduction lowers the generation cost to 9.2 US¢/kWh (BOT-2 model) and 8.8 US¢/kWh (BOT-1 model). In this manner, GDC could lower the geothermal generation cost by using ODA financing. This is the third important role of GDC to be the receiver of ODA financing, in order to supply affordably priced geothermal energy to consumers.

Table V-2.13 Conditions of commercial loan and ODA loan

Loan	Commercial loan (assumption)	ODA loan (Yen Loan)
Interest rate	8%	0.2%
Grace period	3 years	10 years
Repayment period	10 years	20 years

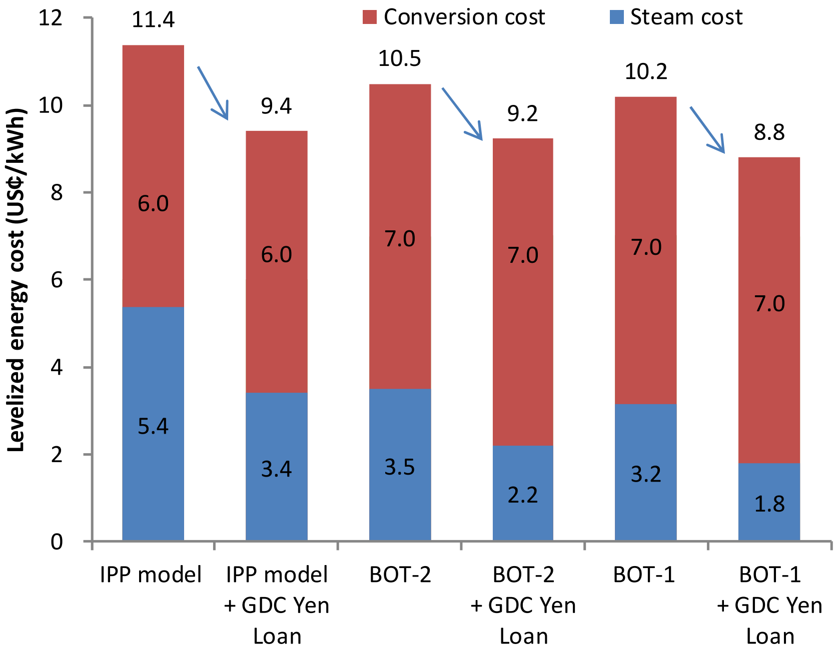


Fig. V-2.21 Cost reduction effect of ODA loan

V-2.5 Expectations regarding GDC

Geothermal energy brings great value to society when it is developed properly. However, the large resource risks and up-front investment sometimes hinders smooth geothermal development. The existence of geothermal resources is insufficient to ensure their successful development. There are additional essential factors, so that society can enjoy the benefits of geothermal energy.

The factors that are given special emphasis in this report are shown in Fig. V-2.22. They are; (a) Technology, (b) Development financing, and (c) Commitment of the government (the will of the government). The existence of geothermal resources is merely one of the preconditions of success. In order to develop geothermal resources, technology and development financing are necessary. In addition, another important factor is a strong will or commitment of the government to exploit geothermal energy.

This section will first consider the technology factor. Geothermal development requires various kinds of technology; exploration technology, steam development technology, power generation technology, and operation and maintenance technology. Exploration technology consists of technologies such as those enabling geological surveys, geophysical surveys, geochemical surveys, and so on. Steam development technology involves various technologies associated with well drilling, reservoir evaluation, the design and construction engineering of steam production facilities, and so on. Power generation technology includes engineering technology for the design, manufacture and construction of power plants. Furthermore, the operation and maintenance technology for power plants is also critical. Although heavy electric machinery such as steam turbines and generators can be imported, exploration technology and development technology should be available within the country.

A country that desires geothermal development should have a certain level of these technologies readily available within the country. In this respect, one important factor to consider is whether or not there is a core geothermal development organization that acts as an incubator for local expertise and technology. Such a core organization functions as the recipient of technology that is introduced from more advanced countries during the initial stage. In the second stage, the introduced technology is digested, accumulated and localized within the core organization. Through repetitions of this assimilation process, the core organization finally acquires enough technology to compete with the more advanced countries at least in regards to the development of its domestic resources. This is a common development pattern that can be seen in several countries that have succeeded in acquiring advanced technology. In addition, these acquired technologies spill over from the core geothermal organization into the local industry to form a geothermal-support industry within the country. Such a core organization exists in some countries where geothermal development is very active. The key factor in the success of geothermal development is ultimately whether or not a country can establish a core organization within the country that will grow as development progresses. GDC aspires to play this important role in Kenya.

Regarding the second factor of financing, GDC is in the position to receive ODA financing from various countries or agencies. Although GDC cannot rely on ODA indefinitely, it can absorb technology and concessional financing while receiving ODA. Taking advantage of ODA, GDC could accumulate experience and knowledge.

PNOC-EDC of the Philippines had neither sufficient technology nor a sound financial base immediately after its establishment. However, with ODA support from the World Bank, New Zealand and Japan, PNOC-EDC accumulated experience. In this process, the lessons learnt worked and a geothermal supporting industry was promoted in the country. As a result, geothermal energy became the least cost energy in the 1990's. Today, PNOC-EDC has developed into a geothermal consulting and investment company participating in the international market. This is a successful pattern that many ODA countries/agencies expect GDC to follow. It is hoped that GDC becomes into a "Center of Excellence" for geothermal energy development in Eastern Africa.

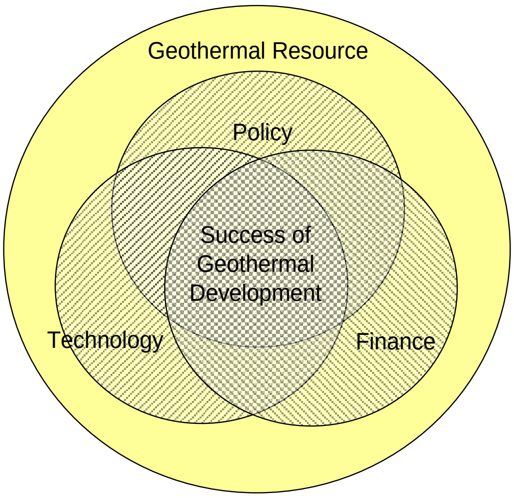


Fig. V-2.22 Key success factors of geothermal development

V-2.6 Conclusions

This section discussed the economics of geothermal projects and the importance of a state-owned enterprise in developing geothermal energy. The summary is as follows:

a) As opposed to fossil fuel-fired thermal power plants, geothermal plants require an extremely large proportion of the capital expense in its energy/steam price.
b) As a result, there is a strong relationship between the energy/steam cost and the project owner's expected rate of return. When a private company with a high expected rate of return develops geothermal energy, the energy/steam cost becomes high. On the other hand, when a state-owned enterprise with a low expected rate of return develops it, the energy/steam cost becomes lower.
c) One of the SOE's roles is to utilize this advantage in order to supply geothermal energy at a low cost.
d) By owning its own drilling rigs and by enhancing its drilling ability, GDC can reduce drilling costs. The reduction of the cost of drilling leads to the reduction of the geothermal energy/steam cost.

e) There are several kinds of public-private-partnerships that can be applied in the development of geothermal energy. Although the PPP that GDC envisages is an IPP model, there are very few examples of the IPP model in the world. The model that is frequently observed is an SOE's total project model. Although GDC is an SOE established to work in an IPP model, JICA strudy team would like to propose the introduction of BOT model which is located in-between the IPP model and the SOE's total project model.
f) The BOT model can make the energy/steam price lower than that of the IPP model. The model is regarded as a model which favors the consumer.
g) GDC has the other advantage of being eligible for ODA financing. The energy/steam cost could be lowered further by using ODA financing.
h) It is necessary for successful geothermal development to foster a strong central organization in a country. GDC is expected to become a "Center of Excellence" for geothermal energy development in Eastern Africa through accumulating the experience, taking advantage of the "lessons learnt", and localizing the technology and expertise.

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V-3 Suggestions to Review GDC's Business Plan[1]

V-3.1 GDC corporate financial model

When designing GDC's future geothermal development plans, it is necessary to consider not only the economic aspect of each project, but also the whole financial situation of GDC as a company. From the standpoint of Kenya's national perspective, it is preferable that an aggressive geothermal development plan be established which expedites the development of as many fields as possible. However, geothermal development requires significant initial investment for resource exploration and facility construction. Consequently, an unreasonably aggressive development plan may place a heavy burden on the financial situation of GDC. Therefore, an appropriate development plan for the geothermal resources should be determined that can be implemented within the financial capacity of GDC. For this purpose, the JICA team created a corporate financial model of GDC (GDC Corporate Financial Model) and examined the maximum development plan which GDC's financial capacity allows.

(1) Assumptions of GDC's financial situation

The financial situation of GDC from the financial year 2009/2010 to the financial year 2013/2014 is shown in Table V-3.1. The revenue in FY 2013/2014 was Ksh 680 million (US$ 7.8 million at the rate of 87.6 Ksh/US$ at that time) and expenditure was Ksh 788 million (US$ 9.0 million). The comprehensive loss for the year was Ksh 116 million (US$ 1.3 million). In addition, the total assets of GDC as of the end of FY 2013/2014 (June 2014) was Ksh 52,183 million (US$ 596 million), which consisted of Ksh 27,706 million (US$ 316 million) of Exploration assets, Ksh 16,124 million (US$ 184 million) of Equipment, Ksh 3,912 million (US$ 45 million) of Inventories, Ksh 4,315 million (US$ 49 million) of Cash and Receivables, and so on. Most of these assets were funded by the Kenyan government and donor agencies.

Based on these figures, it was assumed that GDC's assets at the end of the calendar year 2014 consisted of three sections: Head Office, Olkaria and Menengai, and simplified the situation as follows (Table V-3.2).

<Head Office>

The Head Office holds US$ 190 million of equipment. For the purposes of simplification, the equipment is mainly considered to be drilling rigs, and the rigs will be amortized over 15 years starting from 2015. In addition, the Head Office holds US$ 50 million of cash and receivables at the end of the calendar year 2014. In regards to cash flow, the Head Office expends US$ 10 million of administrative expenses and this expenditure continues every year at the same amount for 30 years in the future. On the other hand, the government subsidizes approximately US$ 10 million for GDC's operation every year. However, it is assumed that this subsidy will be abolished since the steam sales income from Menengai is expected from 2015.

<Olkaria>

Olkaria field holds a total of 60 production/reinjection wells as of the end of 2014, of which the asset value is US$ 250 million. Steam produced from these wells will be supplied to KenGen at the steam unit price of 3.0US¢/kWh from the beginning of 2015. This revenue is one of the main cash flow sources of GDC, and it will continue until 2045. These wells will be amortized over 25 years from 2015. It is assumed that KenGen, not GDC, will drill make-up wells to cope with steam decline. For this reason, it is assumed that the income from the existing wells of GDC will decrease by 3% each year as the steam amount declines.

<Menengai>

As of the end of 2014, Menengai field was still under construction. The value of total assets was US$ 110 million as of the end of 2014. Additional investment of US$ 145 million had been scheduled in 2015 and

[1] For the convenience of explanation, the terms of "energy sales price", "steam sales price" and "conversion fee" are used in this section V-3. They are the same meaning of "generation cost", "steam cost" and "conversion cost" in section V-2. These costs in section V-2 include returns from the investment and taxes and, therefore, the project owner can sell energy/steam at these costs to the market.

2016. Thirty-three (33) production/reinjection wells and pipelines were planned to be developed by the end of 2016. However, due to the delay of power plant construction by IPPs, the income from steam sales (unit price is 3.5US¢/kWh) will be obtained only starting at the beginning of 2018, which is one year behind schedule. The total investment amount of US$ 255 million shall be amortized over 25 years from 2018. Make-up wells will be drilled by GDC to keep the steam sales income at a constant level every year. On the other hand, investment expenditures for drilling make-up wells will be needed in the year prior to the year when the steam amount shortage occurs.

Table V-3.1 Financial situation of GDC

GDC Financial Record (KSH) <'000 Ksh>

Ending June 30th of Year

Profits and Losses	2010	2011	2012	2013	2014
Revenue	265,041	703,329	762,237	930,459	680,084
Revenue grants	256,000	700,000	711,727	917,635	578,750
Other income	9,041	3,329	50,510	12,824	101,334
Administrative expenses	774,387	1,152,617	1,006,224	1,249,452	787,551
Operation Profit (Loss)	-509,346	-449,288	-243,987	-318,993	-107,467
Financial income	31,367	61,743	35,997	21,442	-5,416
Profit (Loss) before income tax	-477,979	-387,545	-207,990	-297,551	-112,883
Income tax expense					2,618
Profit (Loss) for the year	-477,979	-387,545	-207,990	-297,551	-115,501
Other comprehensive income					
Total comprehensive profit (loss) for the yea	-477,979	-387,545	-207,990	-297,551	-115,501

Balance Sheet	2010	2011	2012	2013	2014
Asset					
Non-current Assets	4,547,409	12,152,734	31,040,795	36,795,126	43,955,135
Property, Plant and equipment	2,613,005	6,941,555	12,944,459	14,538,777	16,123,703
Exploration and evaluation asset	1,934,404	5,211,179	17,901,458	22,088,897	27,706,413
Intangible assets			194,878	167,452	125,019
Current assets	1,148,563	1,031,475	2,724,815	5,807,228	8,227,706
Inventories		44,582	651314	3,827,218	3,912,051
Receivables and prepayments	367,372	533,298	800,959	1,498,557	4,314,160
Cash and bank balances	781,191	453,595	1,272,542	481,453	1,495
Total Assets	5,695,972	13,184,209	33,765,610	42,602,354	52,182,841
Equity and Liabilities					
Equity attributable to owners					
Share capital	2,000	2,000	2,000	2,000	2,000
Accumulated loss	-477,979	-865,525	-1,073,514	-1,371,065	-1,486,566
Total Equity	-475,979	-863,525	-1,071,514	-1,369,065	-1,484,566
Non-current liabilities	5,675,817	11,760,497	32,727,578	40,125,461	50,367,119
Grants	5,675,817	11,760,497	32,727,578	40,125,461	50,367,119
Current liabilities	496,134	2,287,236	2,109,546	3,845,958	3,300,288
Borrowings	69,701	1,062,422	0	736,110	2,155,288
Trade and other payables	426,433	1,224,814	2,109,546	3,109,848	1,145,000
Total liabilities	6,171,951	14,047,733	34,837,124	43,971,419	53,667,407
Total Equity and Liabilities	5,695,972	13,184,208	33,765,610	42,602,354	52,182,841

(Source) GDC's annual report

Table V-3.2 Assumption of GDC's assets for the three sections in GDC Corporate Financial Model

(As of the end of 2014) [M$]

Section	Head Office	Olkaria	Menengai	Total
Exploration Assets		250	110	360
Equipment	190			190
Inventories			50	50
Cash & Receivables	50			50
Total	240	250	160	650

(Source) Assumptions by JICA study team

(2) Concept of GDC Corporate Financial Model

GDC can earn income from the steam sales in Olkaria starting from 2015 and in Menengai starting from 2018. On the other hand, GDC will continue to expend the administrative expenses for the Head Office, the operation and maintenance (O&M) expenditures for the facilities in Olkaria and Menengai, and the expenditures for drilling necessary make-up wells in Menengai. The remaining cash amount are the financial resources for investments in new projects. The GDC Corporate Financial Model calculates how many new projects can be implemented within the limitations of these financial resources (Table V-3.3, Fig. V-3.1 and Fig. V-3.2).

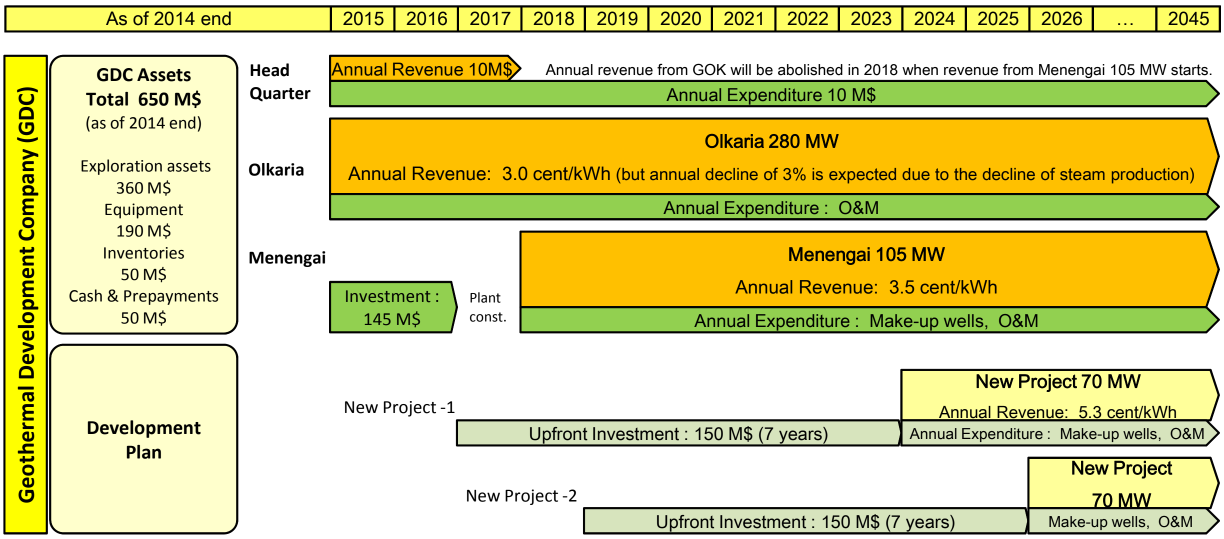


Fig. V-3.1 Concept of GDC Corporate Financial Model

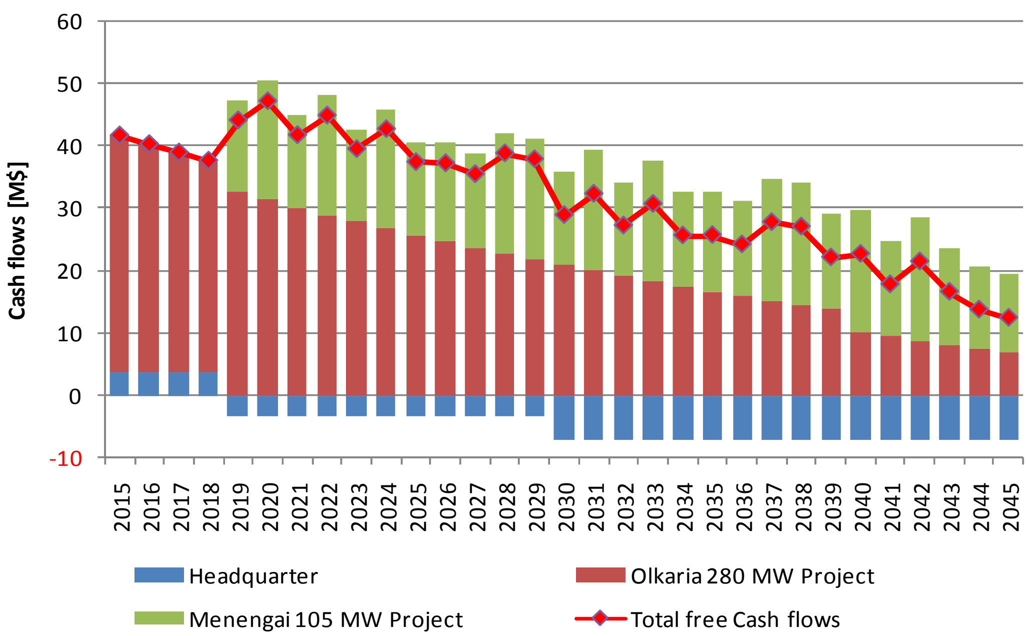


Fig. V-3.2 Cash flows of Head Office, Olkaria and Menengai

Table V-3.3 Cash flows of Head Office, Olkaria and Menengai

[M$]	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Headquarter															
Operation Costs	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Depreciation	12.67	12.67	12.67	12.67	12.67	12.67	12.67	12.67	12.67	12.67	12.67	12.67	12.67	12.67	12.67
Tax	(3.80)	(3.80)	(3.80)	(6.28)	(6.80)	(6.80)	(6.80)	(6.80)	(6.80)	(15.80)	(6.80)	(15.80)	(6.80)	(15.80)	(6.80)
Free Cash Flows	3.80	3.80	3.80	3.80	(3.20)	(3.20)	(3.20)	(3.20)	(3.20)	(24.20)	(3.20)	(24.20)	(3.20)	(24.20)	(3.20)
Olkaria 280 MW Project															
Revenue	66.23	64.24	62.31	60.44	58.63	56.87	55.16	53.51	51.90	50.35	48.84	47.37	45.95	44.57	43.23
Operation Costs	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56
Depreciation	10.19	10.19	10.19	10.19	10.19	10.19	10.19	10.19	10.19	10.19	10.19	10.19	10.19	10.19	10.19
Tax	11.85	11.25	10.67	10.11	9.57	9.04	8.53	8.03	7.55	7.08	6.63	6.19	5.76	5.35	4.95
Free Cash Flows	37.82	36.43	35.08	33.78	32.51	31.28	30.08	28.92	27.80	26.71	25.65	24.63	23.63	22.67	21.73
Menengai 105 MW Project															
Revenue					28.97	28.97	28.97	28.97	28.97	28.97	28.97	28.97	28.97	28.97	28.97
Operation Costs					6.21	6.21	6.21	6.21	6.21	6.21	6.21	6.21	6.21	6.21	6.21
Depreciation (*)					10.34	10.34	10.51	10.51	10.69	10.69	10.86	11.00	11.17	11.17	11.17
Make-up wells					4.30		4.30		4.30		4.30	3.50	4.30		
Tax					3.73	3.73	3.68	3.68	3.62	3.62	3.57	3.53	3.48	3.48	3.48

[M$]	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Headquarter														
Operation Costs	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Depreciation														
Tax	(12.00)	(3.00)	(3.00)	(3.00)	(3.00)	(3.00)	(3.00)	(3.00)	(3.00)	(3.00)	(3.00)	(3.00)	(3.00)	(3.00)
Free Cash Flows	(28.00)	(7.00)	(7.00)	(7.00)	(7.00)	(7.00)	(7.00)	(7.00)	(7.00)	(7.00)	(7.00)	(7.00)	(7.00)	(7.00)
Olkaria 280 MW Project														
Revenue	41.94	40.68	39.46	38.28	37.13	36.01	34.93	33.88	32.87	31.88	30.93	30.00	29.10	28.23
Operation Costs	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56	16.56
Depreciation	10.19	10.19	10.19	10.19	10.19	10.19	10.19	10.19	10.19	10.19				
Tax	4.56	4.18	3.82	3.46	3.12	2.78	2.46	2.14	1.84	1.54	4.31	4.03	3.76	3.50
Free Cash Flows	20.82	19.94	19.09	18.26	17.45	16.68	15.92	15.19	14.47	13.78	10.06	9.41	8.78	8.17
Menengai 105 MW Project														
Revenue	28.97	28.97	28.97	28.97	28.97	28.97	28.97	28.97	28.97	28.97	28.97	28.97	28.97	28.97
Operation Costs	6.21	6.21	6.21	6.21	6.21	6.21	6.21	6.21	6.21	6.21	6.21	6.21	6.21	6.21
Depreciation (*)	11.34	11.34	11.51	11.51	11.69	11.83	12.00	12.00	12.00	12.17	12.17	12.34	12.34	12.51
Make-up wells	4.30		4.30		4.30	3.50	4.30			4.30		4.30		4.30
Tax	3.43	3.43	3.38	3.38	3.32	3.28	3.23	3.23	3.23	3.18	3.18	3.13	3.13	3.08

(3) Assumptions for new projects

It is assumed that all new projects are 70 MW in scale with reservoir characteristics of 8.6 MW average output per production well and 0.36 of steam/water ratio. Under these conditions, a total of 15 wells are needed for production and reinjection wells. In order to drill these wells, one (1) rig is required at each stage of reconnaissance, exploration, resource confirmation and construction. The funds required for these activities are self-funded at the stages of reconnaissance, exploration and resource confirmation (which are carried out from the 7th to the 4th year prior to the operation.) In the construction stage, which is carried out from the 3rd year to the 1st year prior to the operation, 30% is self-funded and 70% is funded by external loans. The annual interest rate of the loans is 8% with a three-year-grace period and a 10-year-repayment period after the grace period (Table V-3.4).

The steam development cost of GDC is assumed to be US$ 145 million and the construction cost of the power plant by the IPP is assumed to be US$ 129 million. It takes seven years for development, and the expenditure of the development cost over seven years is simply assumed as shown in Table V-3.5. When this project starts operation, GDC sells steam to the IPP and the IPP generates electricity and sells it to an electric power company ("IPP model"). In this business model, GDC sells steam at the unit price of 5.3 US¢/kWh and earns US$ 42 million annually. From these sales, GDC gains a net cash flow of approximately US$ 20-40 million per year even after the expenditure of the operation and maintenance costs, the drilling cost of make-up wells, and so on (Fig. V-3.3). This cash flow will be added to the cash flow from Olkaria and Menengai and will be the financial resource for investment in subsequent new projects. In this way, it was simulated how many new projects could be implemented within the limitations of the financial resources of GDC (Fig. V-3.4).

Table V-3.4 Outline of a new project (70 MW)

Category	Item	Value
Steam field condition	Capacity	70 MW
	Average output of production well	8.6 MW per well
	Water/steam ratio	0.36
	Capacity of reinjection well	200 (ton/h)/well
	Turbine efficiency	7.0 (ton/h)/MW
	Plant factor	90%
	Decline rate of steam production	3% an.
	Decline rate of reinjection capacity	3% an.
	Drilling speed	70 days per well
	Number of wells drilled in a year	4 wells
Financial condition	Borrowing ratio of construction cost	70%
	Interest rate	8% an.
	Grace period	3 years
	Repayment period (after grace period)	10 years

Table V-3.5 Assumptions regarding drilling activity and disbursement schedule of construction cost of a new project (70 MW)

Item		Total	Disbursement schedule in the year prior to operation						
			-7	-6	-5	-4	-3	-2	-1
Steam development	Number of wells to be drilled	15 wells	2.3	2.3	2.3	0	2.7	2.7	2.7
	Number of rigs required	-	1	1	1	0	1	1	1
GDC	Exploration & confirmation	40 M$	10	10	10	10			
	Construction of field facilities	89 M$					30	30	30
	Administration cost and IDC	16 M$	1	1	1	1	2	4	6
	Steam field development total	145 M$	11	11	11	11	32	34	36
IPP	Power plant construction (with administration cost and IDC)	129 M$					41	43	45

(Note) Assumes a drilling speed of 70 days for each well, drilling ability of four (4) wells per rig in a year, and US$ 3.5 million of drilling cost per well.

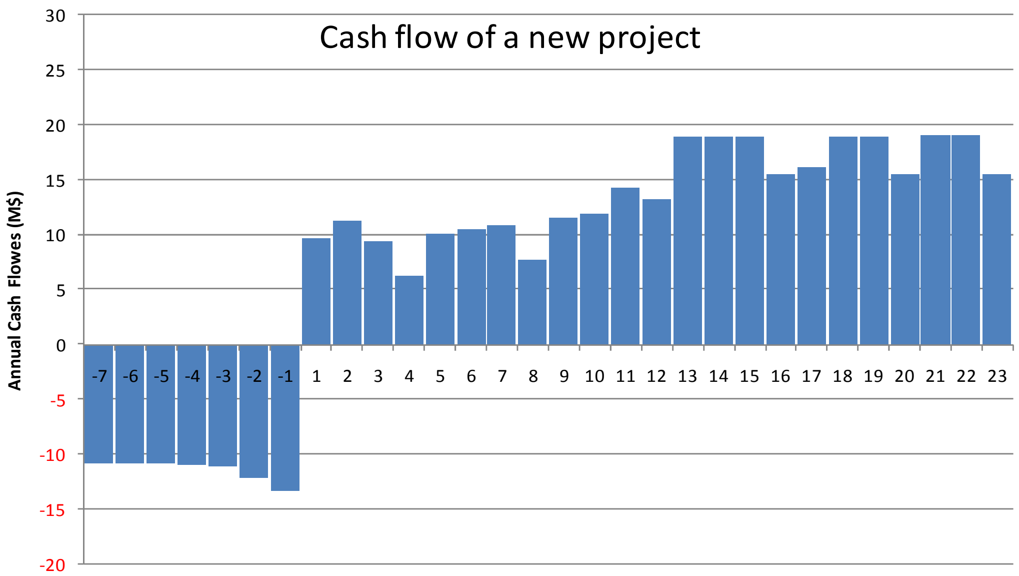


Fig. V-3.3 Cash flow of a new project (70 MW) in the IPP model case

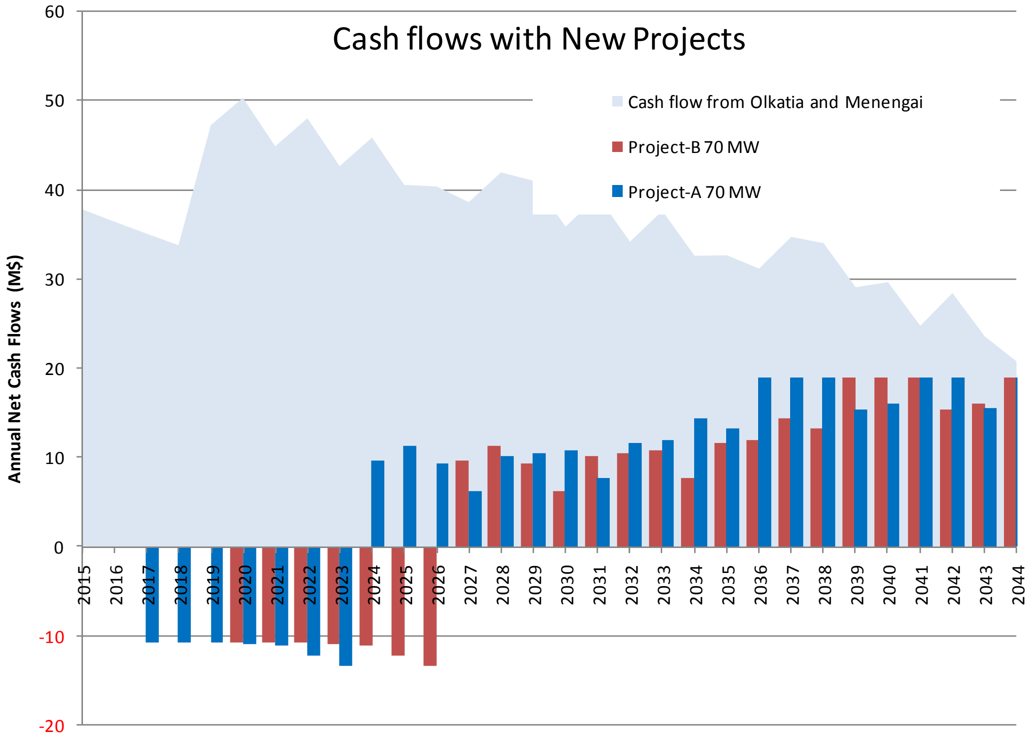


Fig. V-3.4 Concept chart of new projects which are allowed under the limitation of GDC's financial resources

(4) Constraints considered

The following two constraints were considered in the simulation.

a. Cash balance of GDC

The balance of cash (including receivables) of GDC at the end of each year shall not be negative.

b. Rigs availability

The number of rigs available was assumed as shown in Table V-3.6. Although GDC currently owns seven (7) rigs, only four (4) rigs are operational due to a lack of operators and related equipment. Table V-3.7 assumes that this shortage of operators and equipment will be gradually resolved over the years and by 2020, all seven (7) rigs will be operational. Table V-3.6 also assumes that GDC will purchase five (5) additional rigs (in 2021, 2024, 2026, 2028 and 2030.) The constraint concerning the rigs is no longer considered after 2031, due to the assumption that GDC's financial base will become strong enough to purchase as many rigs as it needs.

Table V-3.6 Number of rigs available

Year	2017	2018	2019	2020	2021	2024	2026	2028	2030	2031-
Number of rigs	4	5	6	7	8	9	10	11	12	No limit

(5) Other assumptions of the GDC Corporate Financial Model

The GDC Corporate Financial Model is a multi-spread-sheet model using Excel. For a detailed explanation of the Model, please refer to "GDC Corporate Financial Model Users' Manual" in APPENDIX. In the simulation, the Model does not consider items such as price inflation, increases in the cost of personnel expenses, and so on. Also the Model does not consider increases in the steam sales price. In other words, the simulation is performed on the basis of 2015 real prices. This is due to the difficulty of assuming the future inflation/cost-up rate over 30 years. There may be insignificant between simulations using real price and using nominal price, if the steam price is raised timely and appropriately so as to offset the effect of price increases.

V-3.2 Simulation of development potential under various business models

The JICA study team carried out several simulations of development potential under various different business models. These simulations will be discussed below:

(1) Simulation of development potential under IPP model (Business as Usual)

The first model which will be discussed is the IPP model. The result of the simulation is shown in Fig. V-3.5. Five (5) new projects (cumulative total of 735 MW) can be developed by 2030, 22 new projects (1,925 MW) by 2040, and 30 new projects (2,480 MW) by 2045[2]. This case under IPP model will be considered the basic case, and called the "Business as Usual (BAU) case". The forecast of the average sales price of geothermal energy from these projects is shown in Fig. V-3.6. Although the sales price of geothermal energy is set at 8.5 US¢/kWh in the project of Menengai 105 MW, the energy sales price for a new project is set at 11.8 US¢/kWh in this financial model. This is a sales price that allows IPPs to obtain a 20% return on equity (ROE) from their investment. For this reason, it is expected that the average sales price will gradually increase in the future.

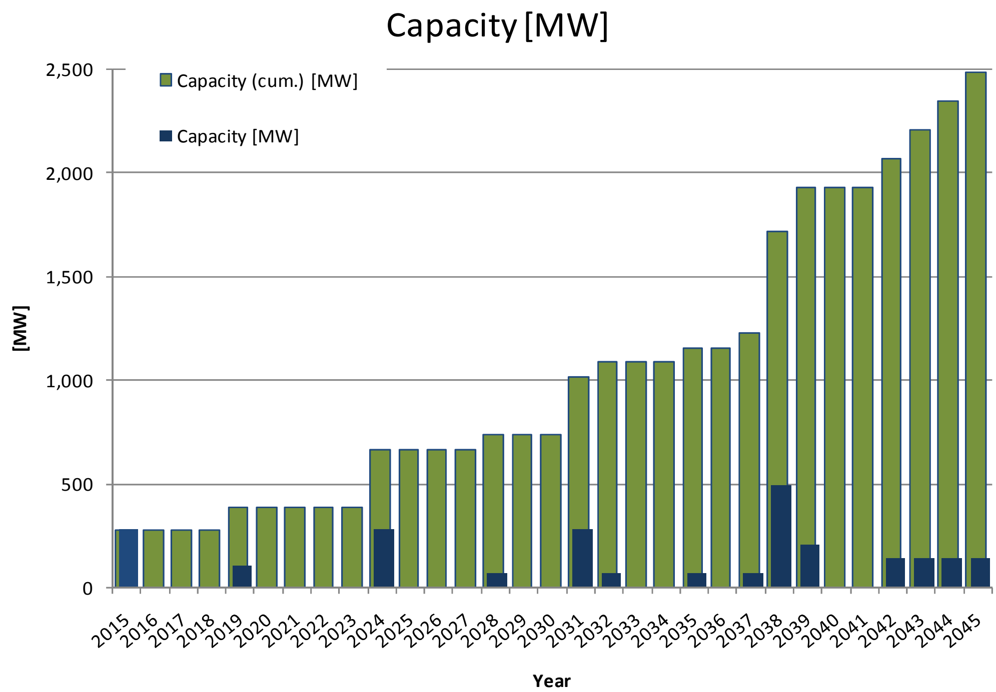


Fig. V-3.5 Forecast of development in IPP model (BAU case)

2 The GDC Corporate Finance Model can only handle up to 30 new projects. As a result of this limitation, the maximum development capacity of this model is 2,485 MW. This report forecasts the development potential of GDC when 30 new projects are implemented.

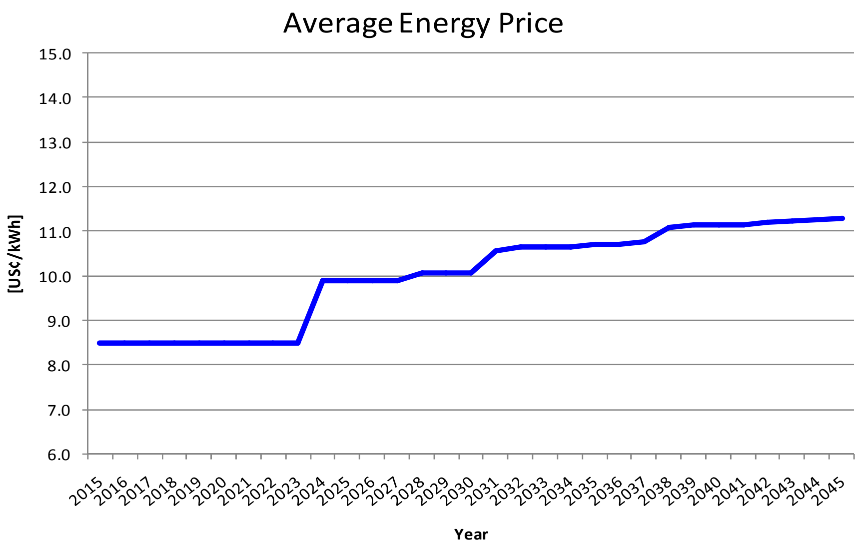


Fig. V-3.6 Forecast of the average sales price of geothermal energy in IPP model (BAU case)

Table V-3.7 Summary of development potential in IPP model (BAU case)

Item	Unit	2030	2035	2040	2045
Development potential	MW	735	1,115	1,925	2,485
Number of projects	-	5	11	22	30
Number of rigs required	-	8	18	11	12
Cash balance at year end	M$	3	10	502	1,965
Average price of geothermal energy	US¢/kWh	10.1	10.7	11.2	11.3

(2) Effect of drilling ability

The simulation of the BAU case in the previous section was performed under the assumptions that GDC can drill a 2,000-meter class well in 70 days; it can drill four (4) wells in a year; and it can drill a well at a drilling cost of US$ 3.5 million. For reference, other cases using different drilling abilities were simulated; (i) a case in which GDC outsources the drilling services (drilling cost is US$ 6.0 million, annual drillable wells is 5), (ii) a case in which GDC can drill a well in 100 days (drilling cost is US$ 4.0 million, annual drillable wells is 3), and (iii) a case in which GDC can drill a well in 60 days (drilling cost is US$ 3.4 million, annual drillable wells is 5). The results are shown in Table V-3.8 and Fig. V-3.7. If GDC does not hold any rigs of its own and continues to outsource the drilling services; the amount of development in 2045 would be only 1,505 MW. Also, if there is no improvement in the drilling speed from the current level of 100-day drilling, only 1,925 MW can be developed by 2045. These results show the importance of enhancing GDC's drilling ability in relation to raising the development potential, as well as the importance of GDC possessing its own rigs.

Table V-3.8 Effect of drilling ability on the development potential (in IPP model case)

Drilling ability	Drilling cost [M$]	Drillable wells per year	2030 [MW]	2035 [MW]	2040 [MW]	2044(*) [MW]
Outsourcing	6.0	5	665	875	1,155	1,505
100-day drilling	4.0	3	735	1,085	1,715	1,925
70-day drilling	3.5	4	735	1,155	1,925	2,205
60-day drilling	3.4	5	945	1,225	1,855	2,485

(*) Since the development potential in 2045 reaches the calculation limitation of 2,485 MW for all cases of 100-day drilling, 70-day drilling and 60-day drilling, the results of 2044 are shown in this table.

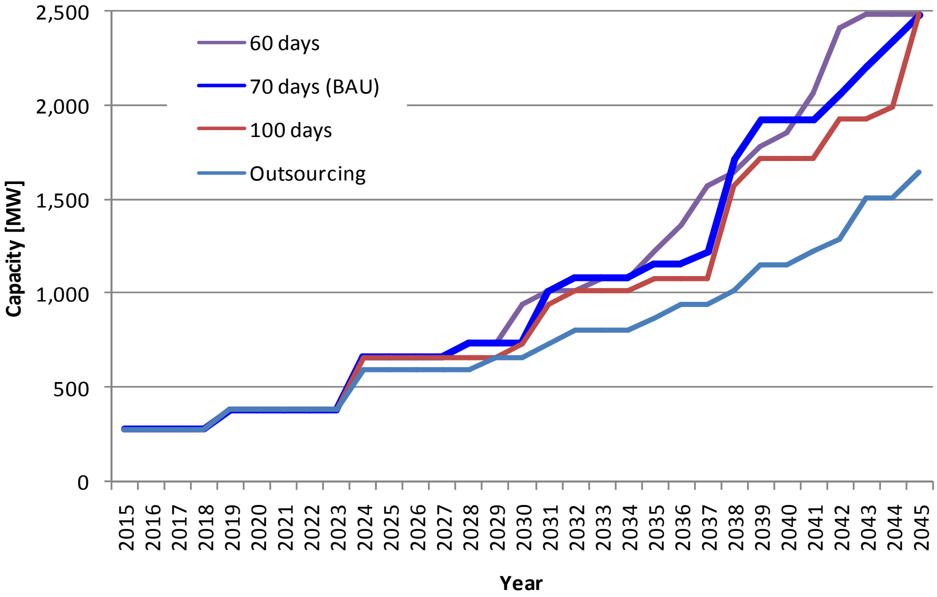


Fig. V-3.7 Forecast of development by different drilling ability (IPP model)

(3) Simulation of development potential under the Exploration model and Joint Steam Development model

The main business model of GDC is an IPP model in which GDC develops steam and sells it to IPPs. Currently GDC is studying the possibility of implementing other business models such as the (i) Exploration model and (ii) Joint Steam Development model. The Exploration model is a model in which GDC conducts only the reconnaissance and the exploration stage. The results of the exploration are sold to a private company. The private company carries out subsequent steam development, constructs a power plant, and operates it. The sales price of the exploration results is the total of the exploration cost plus an interest rate which is applied for the period of the exploration. The payment is made either as a lump sum at the end of exploration stage or by installments over the power plant's operation period. In this simulation, the latter method is adopted for the convenience of the Corporate Financial Model. The installments are done as the name of the steam charge. The Joint Steam Development model is a model in which GDC conducts the reconnaissance and the exploration stage. After the exploration stage, GDC and a private company jointly establish a joint special purpose company (SPC) which carries out subsequent steam development. The private company constructs a power plant. The steam SPC sells steam to the private company and the private company generates power. GDC receives its share of steam sales income from the steam SPC.

In this section, both business models are simulated. Table V-3.9 shows assumptions regarding the allocation of development costs of a new project (70 MW) between GDC and a private company. In the Exploration model, GDC only performs the reconnaissance and the exploration stages. In such a case, GDC's expenditure becomes US$ 42 million, which is 29% of the US$ 145 million of the IPP model. On the other hand, the private company undertakes steam development and builds a power plant. The expenditure of the private company becomes US$ 232 million. When the power plant starts operation, GDC obtains its share of the steam charge in accordance with the development cost allocation. Given the expected return on investment (ROE) of GDC as 10%, the steam charge that earns the return is estimated to be 1.6 US¢/kWh. GDC's cash inflow from these sales becomes the source of the next investment.

In the Joint Steam Development model, GDC is responsible for the reconnaissance and the exploration, until the confirmation of the resource. After the confirmation stage, GDC and a private company establish a joint SPC for steam development. In such a case, GDC's expenditure becomes US$ 93 million, which is 64% of the US$ 145 million of the IPP model. On the other hand, the private company's expenditure becomes US$ 181 million. When the power plant starts operation, GDC obtains its share of the steam charge in accordance with the development cost allocation. Given the expected return on investment (ROE) of GDC as 10%, the steam charge that earns the return is estimated to be 3.4 US¢/kWh.

Considering these cash outflows in the development stage and cash inflows in the operation stage, the Exploration model forecasts nine (9) new projects (cumulative total of 1,015 MW) by 2030, and 30 new projects (2,485 MW) by 2040 and 2045. In the case of the Joint Steam Development model, it forecasts seven (7) new projects (875 MW) by 2030, 26 new projects (2,205 MW) by 2040, and 30 new projects (2,485 MW) by 2045 (Fig. V-3.8). Figure V-3.9 shows the forecast of the average sales price of geothermal energy in the both business models.

According to Fig. V-3.8, both the Exploration model and Joint Steam Development model forecast more development than the IPP model. This is because the development cost of GDC in both models is less than that of the IPP model and, therefore, GDC can handle more projects. However, in the case of these two models, as a practical matter, how many private companies will appear who are willing to bear the steam development risks in Kenya's geothermal development market? Even if some companies appear, can they develop as many as 30 projects of 2,485 MW by 2045? The JICA study team is very pessimistic regarding these points and believe that the effect of these two models will be much more limited. Furthermore, as shown in Fig. V-3.9, the average geothermal energy sales price will become higher in these two models than in the case of the IPP model. In consideration of such circumstances, the JICA study team does not recommend the use of either of these business models as a future business model of GDC.

Table V-3.9 Development cost allocation in the Exploration model and Joint Steam Development model

Item		IPP model [M$]		Exploration model [M$]		Joint Steam Dev. model [M$]	
		GDC	Private	GDC	Private	GDC	Private
GDC	Exploration & confirmation	40		40		40	
	Construction of field facilities	89			89	45	45
	Administration cost and IDC	16		2	14	9	7
	Steam field development total	145 (100)		42 (29.0)	103 (71.0)	93 (64.1)	52 (35.9)
Private	Power plant construction (with administration cost and IDC)		129		129		129
Reference	Total	145	129	42	232	93	181

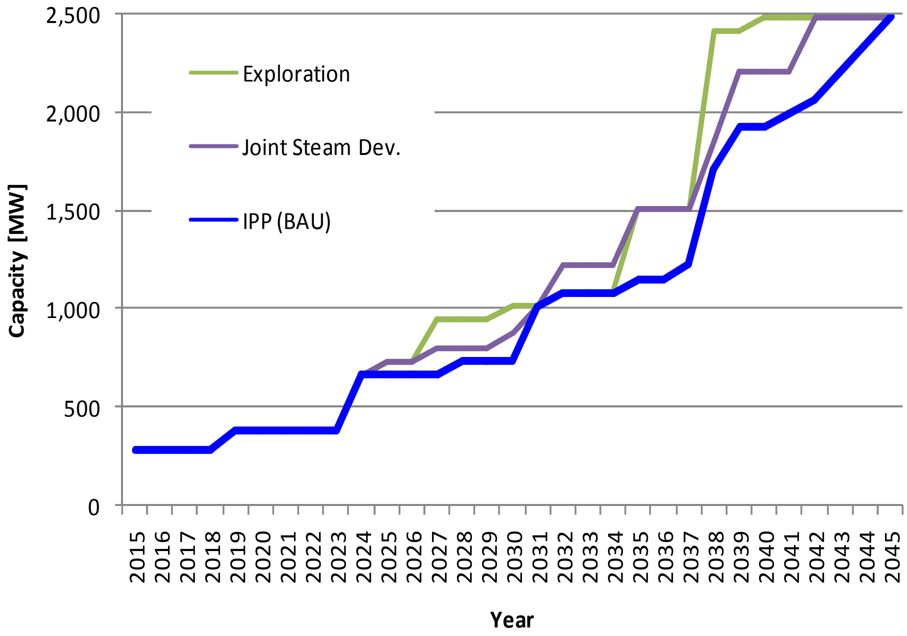


Fig. V-3.8 Forecast of development in the Exploration model and Joint Steam Development model

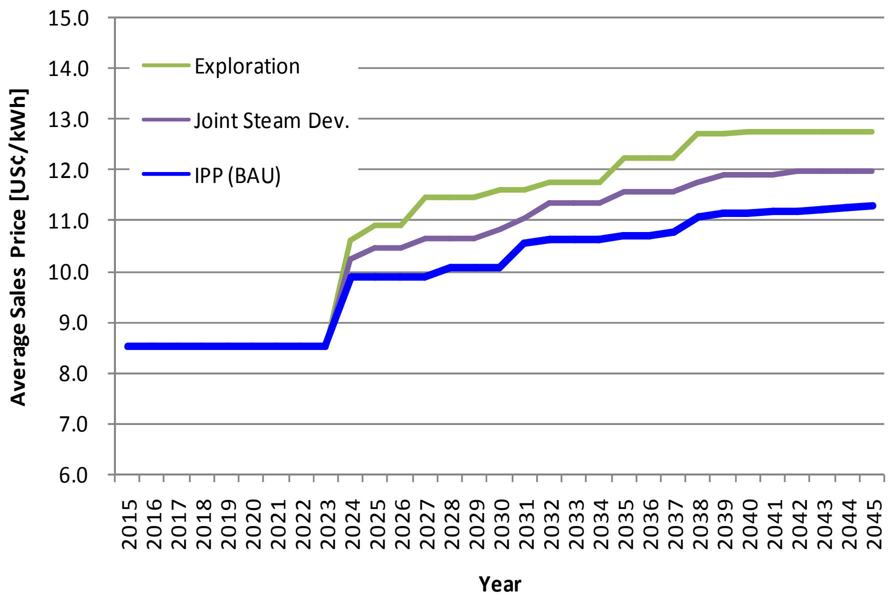


Fig. V-3.9 Forecast of the average sales price of geothermal energy in the Exploration model and Joint Steam Development model

Table V-3.10 Summary of development potential in the Exploration model

Item	Unit	2030	2035	2040	2045
Development potential	MW	1,015	1,505	2,485	2,485
Number of projects	-	9	16	30	30
Number of rigs required	-	12	26	6	15
Cash balance at year end	M$	245	125	1,033	2,118
Average price of geothermal energy	US¢/kWh	11.6	12.2	12.7	12.7

Table V-3.11 Summary of development potential in the Joint Steam Development model

Item	Unit	2030	2035	2040	2045
Development potential	MW	875	1,505	2,205	2,485
Number of projects	-	7	16	26	30
Number of rigs required	-	12	21	9	11
Cash balance at year end	M$	14	48	827	2,300
Average price of geothermal energy	US¢/kWh	10.8	11.6	11.9	12.0

(4) Simulation of development potential in the BOT model

As already described in section V- 2.3 (4), there is another business model in geothermal development, called the BOT model. In this section, two BOT models, one is called the BOT-1 model (one-step sales price) and another is called the BOT-2 model (two-step sales price), are simulated. The BOT period is 10 years in both models.

The development forecast of both BOT models is shown in Fig. V-3.10. The forecast of the average sales price of geothermal energy is shown in Fig. V-3.11. Although the development potential in the BOT-1 model does not reach that of the case of the IPP model, the BOT-1 model has the effect of making the geothermal sales price less expensive than the IPP model. The BOT-2 model results in a development forecast at the almost same level as the IPP case, while the BOT-2 model also makes the long-term sales price a little cheaper. Adopting the BOT-1 model is an option if the aim is to reduce the future sales price of geothermal energy, however it would sacrifice some development volume. The BOT-2 model could be adopted if the aim is to increase the development volume, even if we sacrifice the sales price to some extent. These BOT models are worthwhile for consideration as GDC's business model.

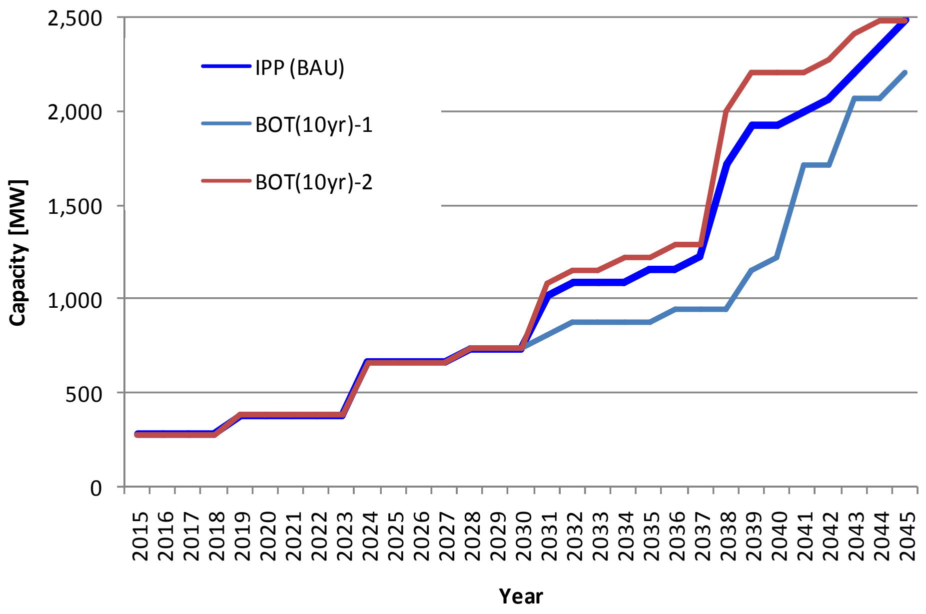


Fig. V-3.10 Forecast of development under the BOT models

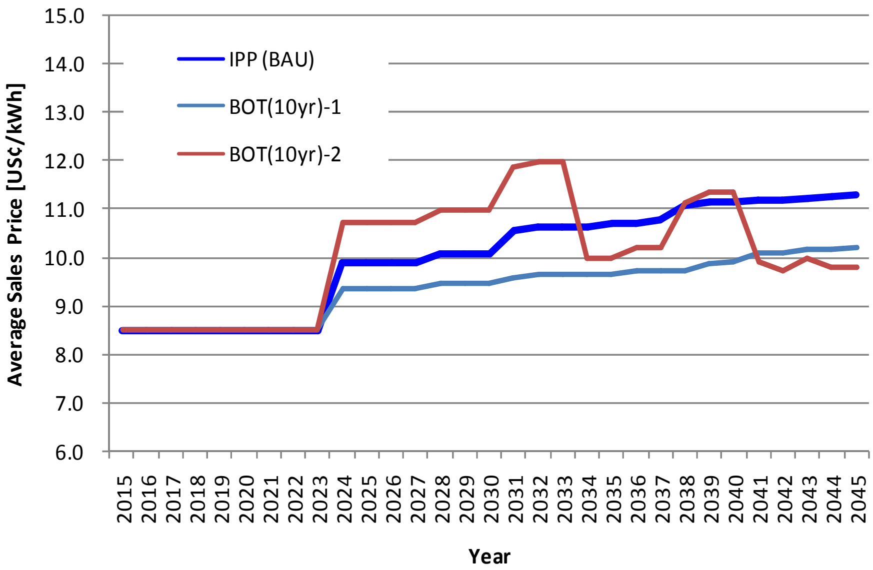


Fig. V-3.11 Forecast of the average sales price of geothermal energy under the BOT models

Table V-3.12 Summary of development potential in the BOT-1 model

Item	Unit	2030	2035	2040	2045
Development potential	MW	735	875	1,225	2,205
Number of projects	-	5	7	12	26
Number of rigs required	-	4	16	22	7
Cash balance at year end	M$	3	5	6	893
Average price of geothermal energy	US¢/kWh	9.5	9.6	9.9	10.2

Table V-3.13 Summary of development potential in the BOT-2 model

Item	Unit	2030	2035	2040	2045
Development potential	MW	735	1,225	2,205	2,485
Number of projects	-	5	12	26	30
Number of rigs required	-	8	19	7	13
Cash balance at year end	M$	1	1	872	2,561
Average price of geothermal energy	US¢/kWh	11.0	10.0	11.4	9.8

(5) Simulation of development potential when ODA financing is used

One of the factors which will determine the development pace is GDC's financial constraints. Therefore, if external funds are provided for new projects, the development pace can be accelerated. One of the funds which is effective for this purpose is ODA financing. In the simulations of the previous sections, it was assumed that new projects would be funded by GDC's self-resource in the stages from reconnaissance to confirmation. Thereafter, they will be funded by commercial banks when they reach the construction stage. This is because commercial banks do not finance new projects at the early stages where resource risks are very high. However, ODA agencies such as the World Bank, AfDB and JICA are providing financing to support GDC's new projects from the early stage. This section simulated a case where new projects of IPP models will receive ODA financing from the reconnaissance stage. For this example, Yen loan conditions are taken as an ODA loan, the loan coverage ratio is 85%, the interest rate is 0.2%, and a grace period of 10 years and a repayment term of 20 years after the grace period is applied.

If all new projects using an IPP model are funded by ODA financing, the development forecast is greatly enhanced; the result is shown in Fig. V-3.12. As shown, ODA financing has a strong power to expedite geothermal projects. ODA financing has another important effect of greatly reducing the sales price of the energy produced (Fig. V-3.13). The JICA study team would like to emphasize again that ODA financing is a powerful promotional tool for developing geothermal projects.

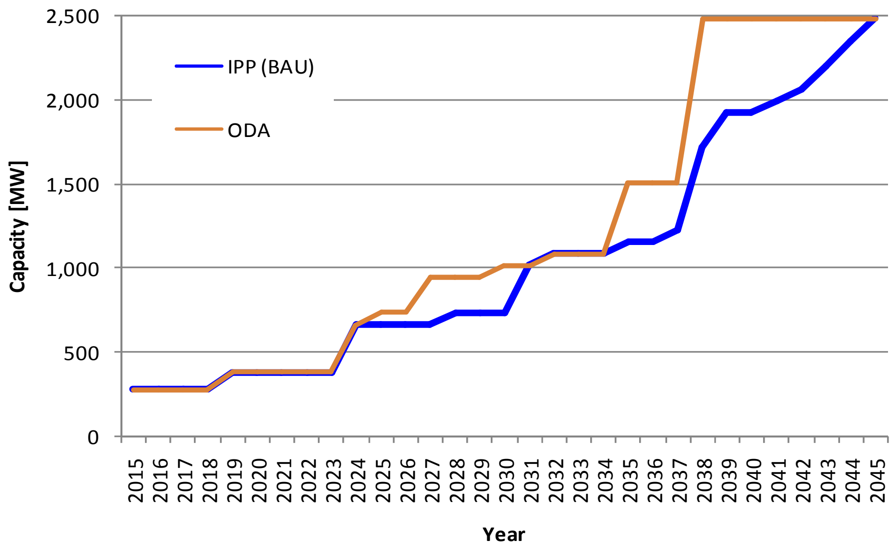


Fig. V-3.12 Forecast of development in the ODA-funded IPP model

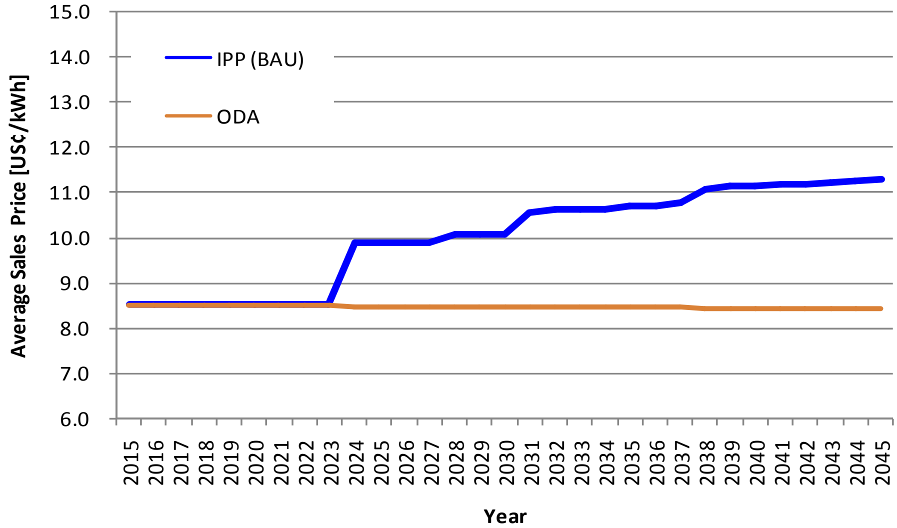


Fig. V-3.13 Forecast of the average sales price of geothermal energy in the ODA-funded IPP model

Table V-3.14 Summary of development potential in the ODA-funded IPP model

Item	Unit	2030	2035	2040	2045
Development potential	MW	1,015	1,505	2,485	2,485
Number of projects	-	9	16	30	30
Number of rigs required	-	12	26	5	16
Cash balance at year end	M$	524	542	946	1,347
Average price of geothermal energy	US¢/kWh	8.5	8.4	8.4	8.4

(6) Promotion method for geothermal projects

As previously described in Section (3), the Exploration model and Joint Steam Development model are based on the assumption that many private companies will participate in Kenya's geothermal development. However, this may be an unrealistic expectation. Also, as seen in Fig. V-3.10, an increase of the average sales price of energy is forecasted in these two models where the role of GDC is small. On the other hand, the BOT model in Section (4) and the ODA-funded model in Section (5) need only GDC as a main player. Therefore these models are considered as very realistic models. In addition, by using these models GDC can accumulate valuable experience and technology for future use by GDC. It is expected that this accumulated experience and technology will exert learning effects and work to lower the cost of future development. It is extremely important to consolidate the experiences of development into one institution in a country and foster the institution as the Center of Excellence (COE) for geothermal energy, in order toobtain long-term sustainable geothermal development.

In addition, business models with a high involvement of GDC can lower the geothermal energy sales price. Therefore, by using GDC as the center of geothermal development and further utilizing ODA funds and adopting the BOT model, a more advantageous development scenario may be achieved than the current IPP model (BAU). The JICA study team is hoping that Kenya will design a geothermal development framework that places GDC in the center position, and then will consider utilizing ODA funds and the BOT model to support GDC's activities.

V-3.3 Optimized development plan reflecting the resource evaluation of five fields

In the previous section, this report discussed the business models of GDC using simulations which were limited to 30 standard projects (70 MW). In this section, the JICA study team proposes an optimized development plan for GDC which reflects the resource evaluation of the five (5) fields reported in Chapter III. In the plan, the IPP model is used as the business model of GDC.

(1) Optimized development plan

As discussed in Chapter V-1, the development priorities of the five (5) surveyed fields are as shown in Table V-3.15. The development of these five fields can be broken down into 16 projects as shown in the same table. Therefore, the simulation performed for this section used the individual data of these 16 projects, such as the capacity of the project, the flow rate of the production wells, the number of necessary wells, the necessary development period, the estimated development cost, and so on. The development order for the projects follows the development priorities of the 5 fields, but each project of phase-2 shall be developed one by one in every year, after a certain period passed, after phase-1 of the project is completed. For the remaining 14 projects, the standard data of a 70 MW project was used and they were named Project-X (70MW). Under these conditions, the maximum development plan was simulated using the GDC Corporate Financial Model.

Table V-3.15 Development priority of five fields and the breakdown of development

Priority	Field	Development capacity (MW)	Phase-1 development		Phase-2 development	
			Capacity (MW)	Dev. period (years)	Capacity ((MW)	Dev. period after Phase-1 (years)
1	Paka	320	70	7	70×3, 40×1	+3
2	Korosi	210	70	7	70×2	+3
3	N-Baringo	100	50	7	50	+2
4	Arus	100	50	7	50	+2
5	S-Baringo	100	50	7	50	+2
6	Chepchuk	80	40	8	40	+2
Total		910	230	-	16 projects	-

Figure V-3.14 shows the development plan of these projects, and Fig. V-3.15 shows the rig placement and drilling plan for these projects. In the development plan, the first and the second projects are assumed to be Menengai-2 and Menengai-3. This is because some rigs are currently working in the Menengai field to expand development. In consideration of this situation, the development of these two projects in Menengai are implemented as the first priority, and as a result, two 70 MW units of development will be completed. Thereafter, the development of the five fields will follow. Under this assumption, an optimal development plan was worked out under the following three constraints; (i) GDC cash balance at each year end, (ii) number of rigs, (iii) development priority and necessary development period shown in Table V-3.15. The forecast of development obtained is shown in Fig. V-3.17.

According to the simulation, projects could be developed under the following schedule; five (5) projects (cumulative total of 565 MW) by 2025, 11 projects (985 MW) by 2030, 15 projects (1,205 MW) by 2035, 25 projects by 2040 (1,815 MW), and 31 projects (2,205 MW) by 2045. The specific projects which are expected to be developed by each year are listed in Table V-3.16.

The GDC's cash balance at the end of each year and the number of necessary rigs in each year are shown in Fig. V-3.17. As can be seen, the factor that restricts this development plan is not GDC's year-end cash balance but the number of rigs. The year-end cash balance seems to have a sufficient margin until 2033. However, the number of necessary rigs is projected to be 8 in 2023, 9 in 2024 and 2025, 10 in 2027, and 12 in 2030. Since GDC only currently has 7 available rigs, the number of rigs that GDC will have available by each year will be the limiting factor After 2030, the GDC Corporate Financial Model removes the constraint regarding the number of rigs, because GDC will hold a sufficient cash balance to purchase drilling rigs.

Following the removal of the rig number ceiling, the necessary number of rigs from 2030 onwards is between 10 and 21. The development pace is then regulated by GDC's year-end cash balance. When the development is performed according to this plan, the average sales price of geothermal energy and average steam price for GDC is forecast as shown in Fig. V-3.18. Since the development of the five fields would be carried out roughly in ascending order of generation costs, the rise of the overall average sales price of energy/steam is somewhat suppressed.

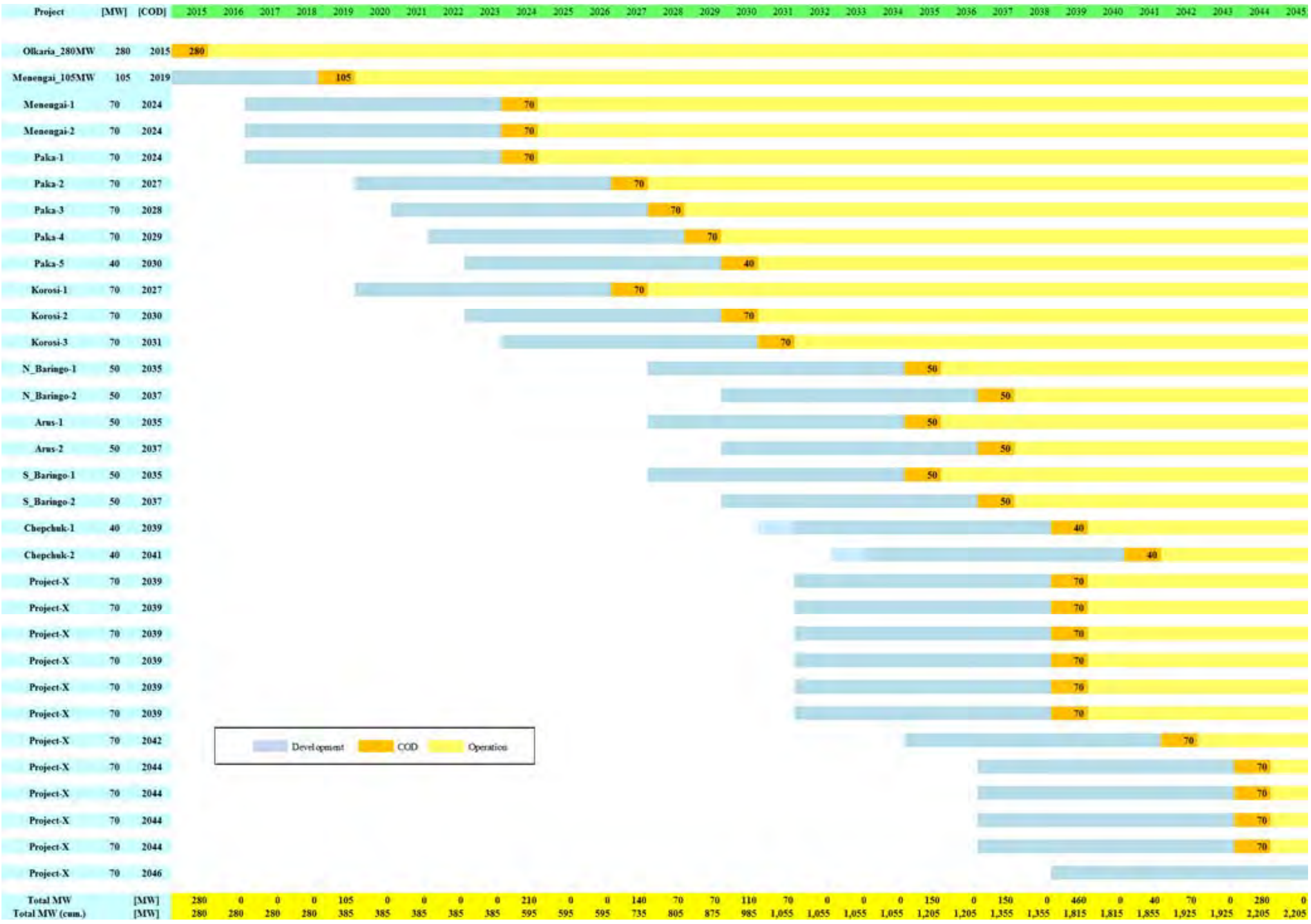


Fig. V-3.14 Optimized development plan reflecting the resource evaluation of five fields

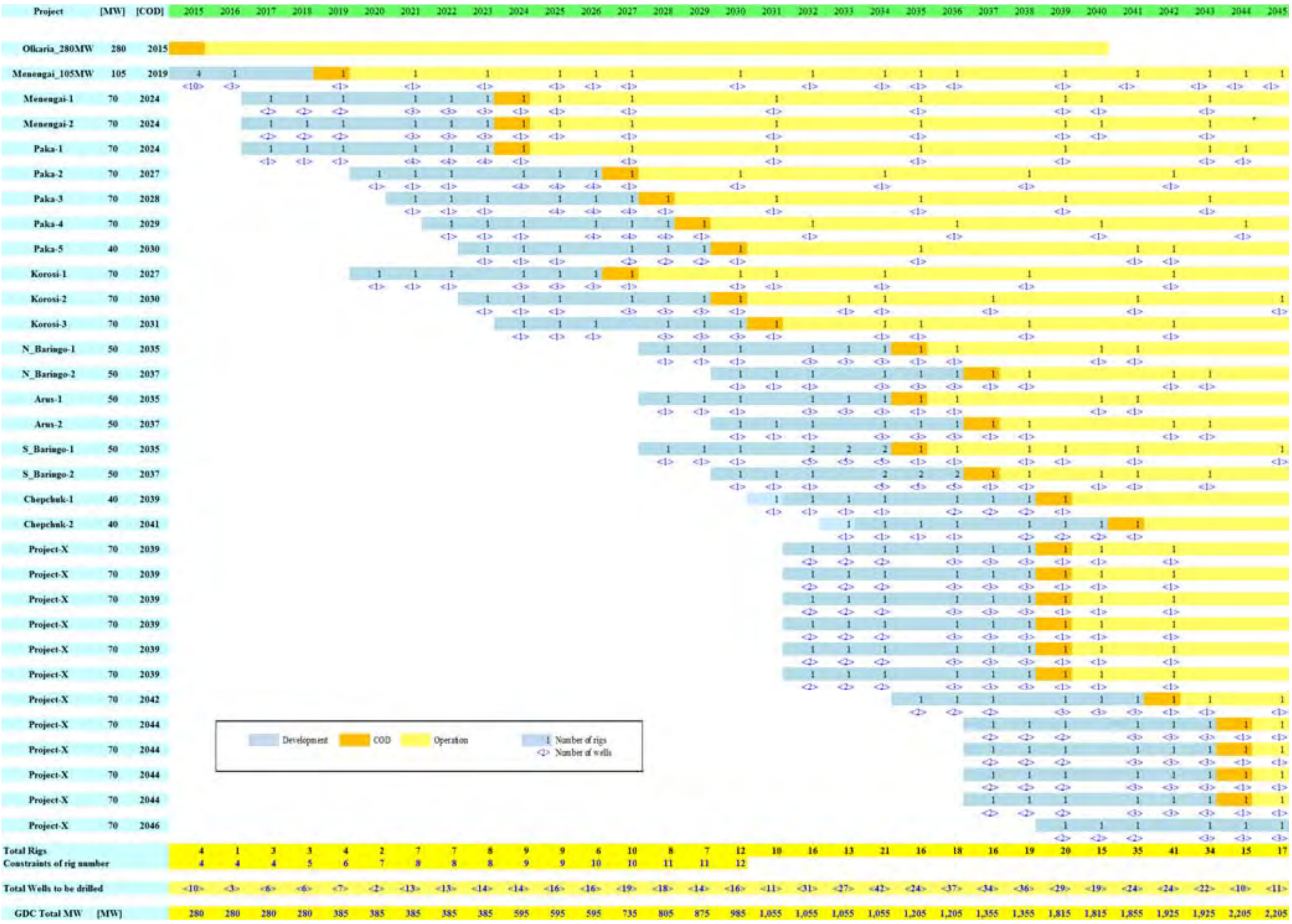


Fig. V-3.15 Rig placement and drilling plan in the optimized development plan reflecting the resource evaluation of five fields

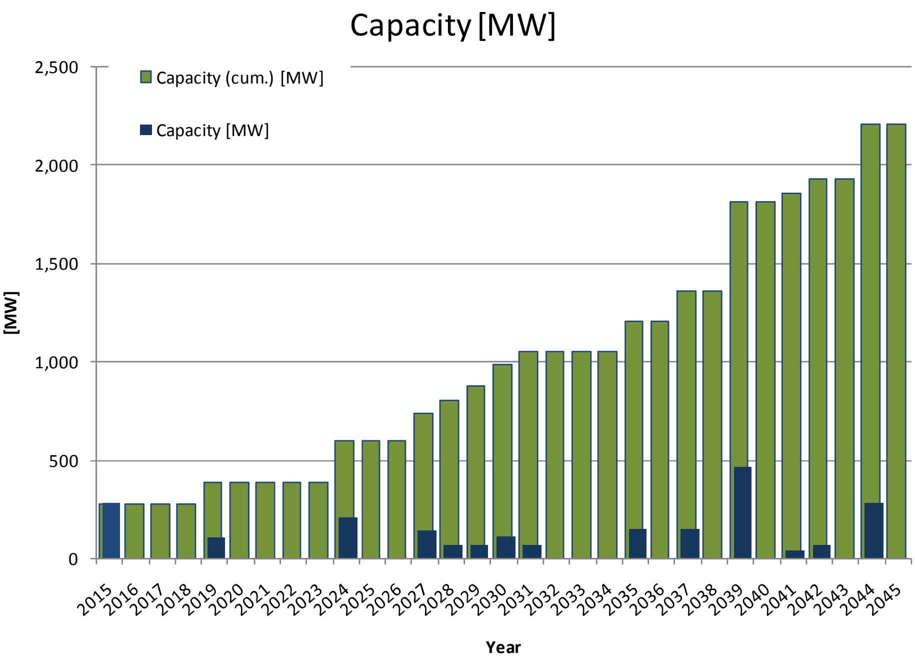


Fig. V-3.16 Development forecast in the optimized development plan reflecting the resource evaluation of five fields

Table V-3.16 Forecast of development

Year	Number of projects		Capacity (MW)		Project developed
	Total	Cum.	Total	Cum.	
2025	5	5	595	595	Olkaria 280 MW Menengai 105 MW Menengai-1 70 MW Menengai-2 70 MW Paka-1 70 MW
2030	6	11	390	985	Paka-2 70MW Paka-3 70MW Paka-4 70 MW Paka-5 40 MW Korosi-1 70 MW Korosi-2 70 MW
2035	4	15	220	1,205	Korosi-3 70 MW North-Baringo-1 50 MW Arus-1 50 MW South-Baringo-1 50 MW
2040	10	25	610	1,815	North-Baringo-2 50 MW Arus-2 50 MW South-Baringo-2 50 MW Chepchuk-1 40 MW Project-X 70 MW 6 units
2045	6	31	390	2,205	Chepchuk-2 40 MW Project-X 70 MW 5 units

Table V-3.17 Summary of the optimized development plan reflecting the resource evaluation of five fields

Item	Unit	2025	2030	2035	2040	2045
Development potential	MW	595	985	1,205	1,815	2,205
Number of projects	-	5	11	15	25	31
Number of rigs required	-	9	12	16	15	9
Cash balance at year end	M$	16	16	24	19	11
Average price of geothermal energy	US¢/kWh	9.3	9.1	9.3	10.1	10.4
GDC's average price of geothermal steam	US¢/kWh	3.6	3.4	3.6	4.1	4.6

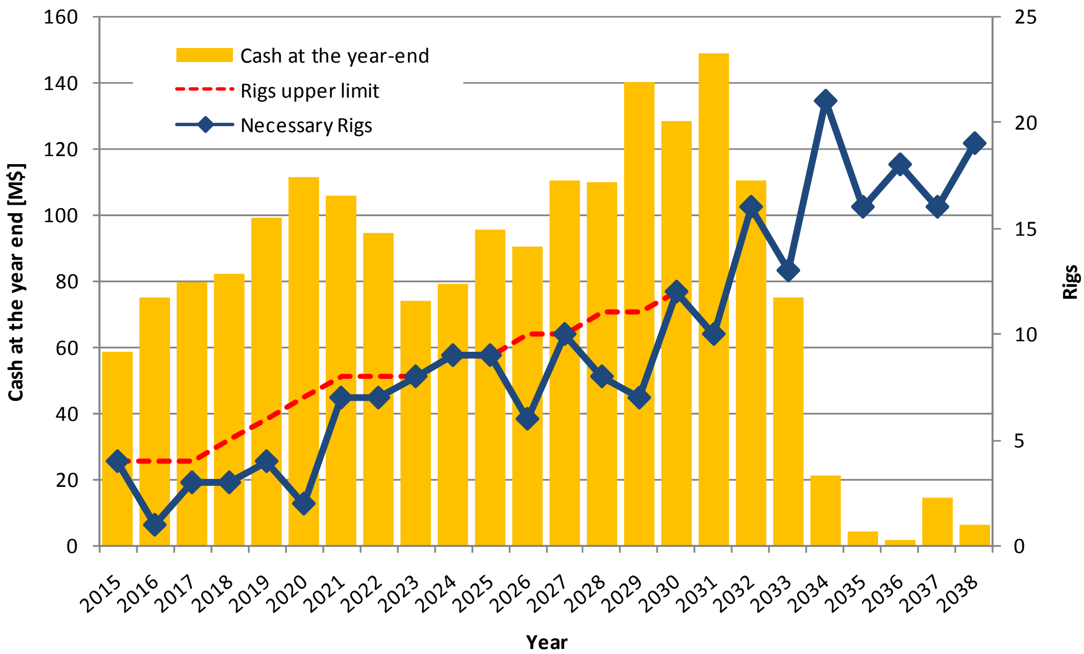


Fig. V-3.17 GDC's year-end cash balance and the number of required rigs in the optimized development plan reflecting the resource evaluation of five fields

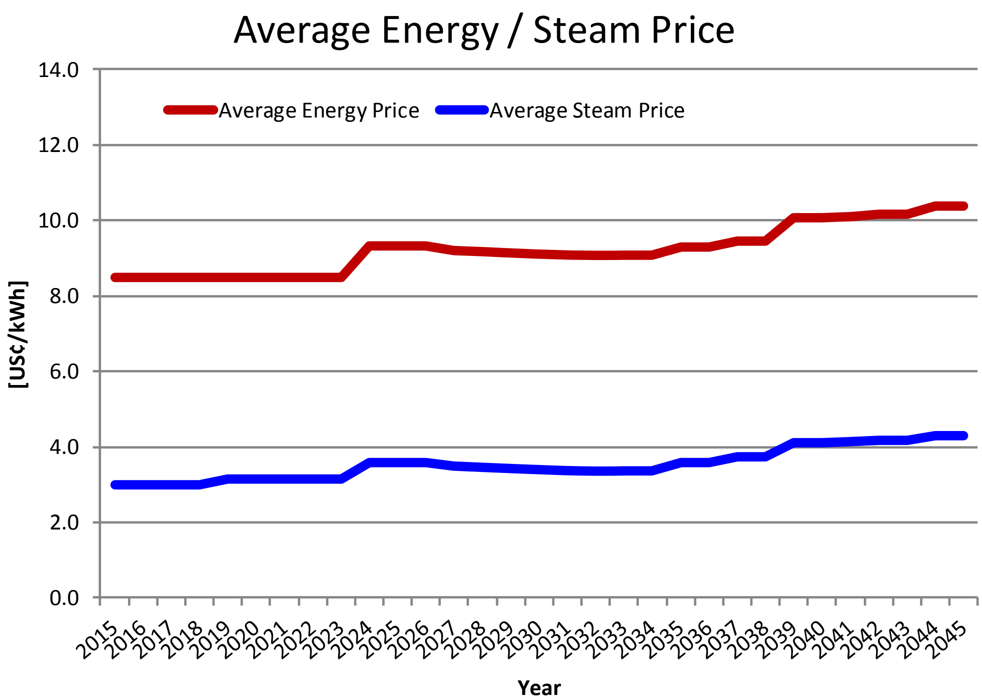


Fig. V-3.18 Forecast of the average sales price of geothermal energy/ GDC's steam in the optimized development plan reflecting the resource evaluation of five fields

(2) Outlook regarding GDC's financial situation

The long-term financial outlook of GDC, when the development is done in accordance with the optimized plan, is shown in Table V-3.18, and the excerpt table is shown in Table V-3.19. Figure V-3.19 shows GDC's profits/loss outlook, Fig. V-3.20 shows the cash flow outlook, and Fig. V-3.21 shows the outlook of GDC's total asset amount. The gross steam sales of GDC will be US$ 151 million from 5 projects in 2025, US$ 209 million from 11 projects in 2030, US$ 311 million from 15 projects in 2035, and US$ 553 million from 25 projects in 2040. The total assets at the end of the year will be US$ 1,096 million (among which US$ 96 million is cash balance) in 2025, 1,313 million (128 million cash balance) in 2030, US$ 1,675 million (4 million cash balance) in 2035, and US$ 2,595 million (278 million cash balance) in 2040. New debt outstanding of GDC will be US$ 221 million (with a debt/assets ratio of 20%) in 2025, US$ 302 million (23%) in 2030, US$ 308 million (18%) in 2035, and US$ 583 million (22%) in 2040. However, since the debt-service-coverage-ratio (DSCR) of the respective years are 4.6, 2.2, 3.6 and 3.4, the financial situation can be evaluated as healthy and steady. The return on asset (ROA) of 2025 and 2030 is around 3%, but is expected to increase to 5-7% in 2035, 2040 and 2045. Thus, in accordance with this optimized development plan, GDC is expected to grow steadily.

(3) Government's tax revenue

When GDC advances geothermal development according to this plan, the government can collect corporate income tax from GDC and IPPs respectively. The outlook of the government's tax revenue is shown in Fig. V-3-22. The tax revenue is about US$ 30 million per year in the first half of the 2020's, but it will exceed US$ 100 million per year after 2030. This is a direct benefit that the government obtains from geothermal development.

Table V-3.18 GDC's long-term financial outlook

Output (MW)					0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
No.		Field	COD	[MW]	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
		GDC Total Capacity [MW]			0	280	280	280	280	385	385	385	385	385	595	595	595	735	805	875	985	1,055	1,055	1,055	1,055	1,205	1,205	1,355	1,355	1,815	1,815	1,855	1,925	1,925	2,205	2,205
		GDC capacity added [MW]			0	280	0	0	0	105	0	0	0	0	210	0	0	140	70	70	110	70	0	0	0	150	0	150	0	460	0	40	70	0	280	0
Rigs needed and Wells to be drilled				[count]	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
		RIGs needed			9	4	1	3	3	4	2	7	7	8	9	9	6	10	8	7	12	10	16	13	21	16	18	16	19	20	15	14	17	14	8	9
		Wells to be Drilled			24	10	3	6	6	7	2	13	13	14	14	16	16	19	18	14	16	11	31	27	42	24	37	34	36	29	19	24	24	22	10	11
Profits and Losses of GDC Total				[M$]	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
1		**Revenue**			0	155	119	64	62	88	86	84	82	81	123	151	120	183	168	213	209	255	254	253	252	311	310	369	368	554	553	568	596	595	708	708
2		**OPEX**			0	27	27	27	27	33	33	33	33	33	45	45	45	53	58	62	68	72	72	72	72	81	81	90	90	117	117	120	124	124	140	140
3		**Depreciation**			0	23	23	23	23	33	33	33	33	34	48	49	49	56	60	63	56	60	61	61	62	74	75	87	88	125	116	120	128	129	141	142
4		**EBIT**			0	106	70	15	13	22	20	18	16	15	30	58	26	73	51	88	84	123	121	120	118	155	153	192	190	312	319	328	345	342	427	425
5		**Interest Payment**			0	0	0	0	0	0	0	4	9	13	16	19	22	25	27	28	27	24	24	24	27	28	39	46	54	53	52	55	56	59	55	50
6		**Tax**			0	32	21	4	4	6	6	4	2	0	4	12	1	15	7	18	17	30	29	29	27	38	34	44	41	77	80	82	87	85	112	113
7		**Net Income (after Tax)**			0	74	49	10	9	15	14	9	5	1	10	27	3	34	16	42	40	69	68	67	63	89	80	102	95	181	188	191	202	199	261	263
8		**Net Income (after Tax) (Cum.)**			0	74	123	133	142	157	171	181	186	187	196	224	227	261	277	319	359	428	496	563	626	715	796	897	992	1,172	1,360	1,551	1,753	1,952	2,213	2,475
Cash flows of GDC Total				[M$]	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
1		**Cash Inflows**			0	97	72	33	32	48	47	99	95	90	85	118	108	141	126	140	110	129	170	170	209	206	330	322	324	335	333	416	413	431	423	426
2		**Net Income (after Tax & Interest)**			0	74	49	10	9	15	14	9	5	1	10	27	3	34	16	42	40	69	68	67	63	89	80	102	95	181	188	191	202	199	261	263
3		**Borrowing for Construction**			0	0	0	0	0	0	0	56	56	56	28	42	56	51	50	35	13	0	42	42	84	42	175	133	142	29	29	104	83	104	21	21
4		**Depreciation**			0	23	23	23	23	33	33	33	33	34	48	49	49	56	60	63	56	60	61	61	62	74	75	87	88	125	116	120	128	129	141	142
5		**Cash Outflows**			110	89	55	29	29	31	35	104	106	111	81	101	113	121	126	110	122	109	209	205	262	223	333	309	332	199	198	267	252	259	138	144
6		**CAPEX**			110	89	55	29	29	31	35	104	106	111	75	90	96	101	102	80	87	70	166	161	224	185	297	268	291	145	137	196	182	187	56	58
7		**Loan Repayment (Principal)**			0	0	0	0	0	0	0	0	0	0	6	11	17	20	24	29	34	39	43	44	39	37	36	41	41	53	62	71	70	72	82	86
8		**Net Cash Flows**			-110	8	17	4	3	17	12	-6	-11	-21	5	17	-5	20	-0	30	-12	20	-38	-36	-53	-17	-2	13	-8	136	135	149	161	172	284	282
9		**Net Cash Flows (cum.)**	Seed cash	**160**	50	58	75	79	82	99	111	106	94	74	79	96	90	110	110	140	128	149	110	75	21	4	2	15	6	143	278	426	587	759	1,044	1,325
Balance Sheet of GDC Total				[M$]	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
1		**Asset Total**			652	726	775	785	794	809	823	888	950	1,006	1,038	1,096	1,138	1,204	1,246	1,294	1,313	1,342	1,409	1,473	1,581	1,675	1,895	2,088	2,283	2,439	2,595	2,819	3,034	3,265	3,465	3,662
2		**Cash**			50	58	75	79	82	99	111	106	94	74	79	96	90	110	110	140	128	149	110	75	21	4	2	15	6	143	278	426	587	759	1,044	1,325
3		**Inventory**			50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
4		**Fixed Asset**			551	617	650	656	662	660	662	733	805	883	909	951	999	1,044	1,086	1,104	1,135	1,144	1,249	1,349	1,510	1,621	1,843	2,024	2,227	2,247	2,267	2,343	2,398	2,456	2,371	2,287
5		**Debt & Equity Total**			652	726	775	785	794	809	823	888	950	1,006	1,038	1,096	1,138	1,204	1,246	1,294	1,313	1,342	1,409	1,473	1,581	1,675	1,895	2,088	2,283	2,439	2,595	2,819	3,034	3,265	3,465	3,662
6		**Debt**			0	0	0	0	0	0	0	56	112	168	190	221	260	291	317	323	302	262	261	259	304	308	448	539	639	615	583	616	629	662	600	535
7		**Equity**			652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652	652
8		**Earned Reserve**			0	74	123	133	142	157	171	181	186	187	196	224	227	261	277	319	359	428	496	563	626	715	796	897	992	1,172	1,360	1,551	1,753	1,952	2,213	2,475
Financial Analysis					2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
1		Return on Sales (ROS)			0%	48%	41%	16%	14%	17%	16%	11%	6%	1%	8%	18%	2%	19%	10%	20%	19%	27%	27%	26%	25%	29%	26%	28%	26%	33%	34%	34%	34%	33%	37%	37%
2		Return on Asset (ROA)			0%	10%	6%	1%	1%	2%	2%	1%	1%	0%	1%	3%	0%	3%	1%	3%	3%	5%	5%	5%	4%	5%	4%	5%	4%	7%	7%	7%	7%	6%	8%	7%
3		Return on Equity (ROE)			0%	10%	6%	1%	1%	2%	2%	1%	1%	0%	1%	3%	0%	4%	2%	4%	4%	6%	6%	6%	5%	7%	6%	7%	6%	10%	9%	9%	8%	8%	9%	8%
4		Debt to Capital [D/(D+E)]			0%	0%	0%	0%	0%	0%	0%	6%	12%	17%	18%	20%	23%	24%	25%	25%	23%	20%	19%	18%	19%	18%	24%	26%	28%	25%	22%	22%	21%	20%	17%	15%
5		Debt Service Coverage Ratio			0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.1	11.6	7.7	4.8	4.6	3.3	3.7	3.0	2.9	2.2	2.4	2.9	2.8	3.6	3.6	5.0	4.2	3.9	3.6	3.4	3.7	3.7	3.8	3.5	3.5
<Break down of Net Cash Flows by Project>				[M$]	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
1		Headquarter	2015	[MW]	0	59	35	-2	-2	-3	-3	-3	-3	-3	-24	-3	-24	-3	-24	-3	-28	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7
2		Olkaria_280MW	2015	280	-74	38	36	35	34	33	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	17	16	15	14	14	10	9	9	8	8	7
3		Menengai_105MW	2019	105	-36	-89	-55	-2	-2	15	19	15	19	15	19	15	16	15	19	19	15	19	15	19	15	16	15	20	20	15	20	15	20	15	13	12
4	1	Menengai-1	2024	70	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8	9	6	10	10	11	8	12	12	14	13	19	19	19	15	16	19	19	16	19	19
5	2	Menengai-2	2024	70	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8	9	6	10	10	11	8	12	12	14	13	19	19	19	15	16	19	19	16	19	19
6	3	Paka-1	2024	70	0	0	0	-6	-6	-6	-1	-8	-9	-10	2	5	3	-0	4	4	4	1	5	5	7	4	10	10	10	6	10	10	10	6	6	10
7	4	Paka-2	2027	70	0	0	0	0	0	0	-6	-6	-6	-1	-8	-9	-10	2	5	3	-0	4	4	4	1	5	5	7	4	10	10	10	6	10	10	10
8	5	Paka-3	2028	70	0	0	0	0	0	0	0	-6	-6	-6	-1	-8	-9	-10	2	5	3	-0	4	4	4	1	5	5	7	4	10	10	10	6	10	10
9	6	Paka-4	2029	70	0	0	0	0	0	0	0	0	-6	-6	-6	-1	-8	-9	-10	2	5	3	-0	4	4	4	1	5	5	7	4	10	10	10	6	10
10	7	Paka-5	2030	40	0	0	0	0	0	0	0	0	0	-4	-4	-4	-1	-5	-5	-6	-1	2	2	2	2	-2	2	2	3	3	4	1	2	6	6	6
11	8	Korosi-1	2027	70	0	0	0	0	0	0	-6	-6	-6	-1	-7	-8	-9	3	6	5	1	1	5	6	2	6	6	8	5	11	11	11	7	11	11	11
12	9	Korosi-2	2030	70	0	0	0	0	0	0	0	0	0	-6	-6	-6	-1	-7	-8	-9	3	6	5	1	1	5	6	2	6	6	8	5	11	11	11	7
13	10	Korosi-3	2031	70	0	0	0	0	0	0	0	0	0	0	-6	-6	-6	-1	-7	-8	-9	3	6	5	1	1	5	6	2	6	6	8	5	11	11	11
14	11	N_Baringo-1	2035	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-8	-8	-8	-4	-8	-8	-9	5	3	6	6	7	3	3	7	8	8	9
15	12	N_Baringo-2	2037	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-8	-8	-8	-4	-8	-8	-9	5	3	6	6	7	3	3	7	8
16	13	Arus-1	2035	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-8	-8	-8	-9	-6	-7	-7	5	4	7	7	7	4	4	8	8	8	10
17	14	Arus-2	2037	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-8	-8	-8	-9	-6	-7	-7	5	4	7	7	7	4	4	8	8
18	15	S_Baringo-1	2035	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-8	-8	-8	-4	-10	-11	-12	7	5	7	4	4	8	5	9	9	10	8
19	16	S_Baringo-2	2037	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-8	-8	-8	-4	-10	-11	-12	7	5	7	4	4	8	5	9	9
20	17	Chepchuk-1	2039	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-6	-6	-6	-6	-1	-5	-5	-6	4	7	7	7	7	7	7
21	18	Chepchuk-2	2041	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-6	-6	-6	-6	-1	-5	-5	-6	4	7	7	7	7
22	19	Project-X	2039	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8	9	6	10	10	11
23	20	Project-X	2039	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8	9	6	10	10	11
24	21	Project-X	2039	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8	9	6	10	10	11
25	22	Project-X	2039	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8	9	6	10	10	11
26	23	Project-X	2039	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8	9	6	10	10	11
27	24	Project-X	2039	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8	9	6	10	10	11
28	25	Project-X	2042	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8	9	6
29	26	Project-X	2044	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8
30	27	Project-X	2044	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8
31	28	Project-X	2044	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8
32	29	Project-X	2044	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-11	-11	-11	-11	-11	-12	-13	10	8
33	30	Project-X	2046	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-11	-11	-11	-11	-11	-12	-13
		Net Cash Flows			-110	8	17	4	3	17	12	-6	-11	-21	5	17	-5	20	-0	30	-12	20	-38	-36	-53	-17	-2	13	-8	136	135	149	161	172	284	282
		Net Cash Flows (Cum.)	Seed cash	**160**	50	58	75	79	82	99	111	106	94	74	79	96	90	110	110	140	128	149	110	75	21	4	2	15	6	143	278	426	587	759	1,044	1,325
		Average Energy Price		[UScent/kW	0.00	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	9.32	9.32	9.32	9.21	9.17	9.14	9.10	9.07	9.07	9.07	9.07	9.28	9.28	9.45	9.45	10.06	10.06	10.11	10.17	10.17	10.38	10.38
		Average Steam Price		[UScent/kW	0.00	3.00	3.00	3.00	3.00	3.14	3.14	3.14	3.14	3.14	3.60	3.60	3.60	3.50	3.46	3.42	3.39	3.38	3.38	3.38	3.38	3.59	3.59	3.75	3.75	4.11	4.11	4.13	4.17	4.17	4.30	3.92

Table V-3.19 Long-term financial outlook of GDC (Excerpt)

Item	unit	2014	2020	2025	2030	2035	2040
Development	MW	-	385	595	985	1,205	1,815
Gross sales of steam	M$	-	86	151	209	311	553
Net income (aft. tax)	M$	-	14	27	40	89	188
Cash inflow	M$	-	47	118	110	206	333
Cash outflow	M$	-	35	101	122	223	198
Cash balance	M$	-	12	17	-12	-17	135
Year-end cash balance (*)	M$	50	111	96	128	4	278
Total assets	M$	650	823	1,096	1,313	1,675	2,595
Debt outstanding of new loans	M$	-	0	221	302	308	583
Debt/assets ratio	-	-	0%	20%	23%	18%	22%
Debt service coverage ratio	DSCR	-	-	4.6	2.2	3.6	3.4
Income/sales ratio	ROS	-	16%	18%	19%	29%	34%
Return on assets	ROA	-	2%	3%	3%	5%	7%
Return on equity	ROE	-	2%	3%	4%	7%	9%

(*) including receivables

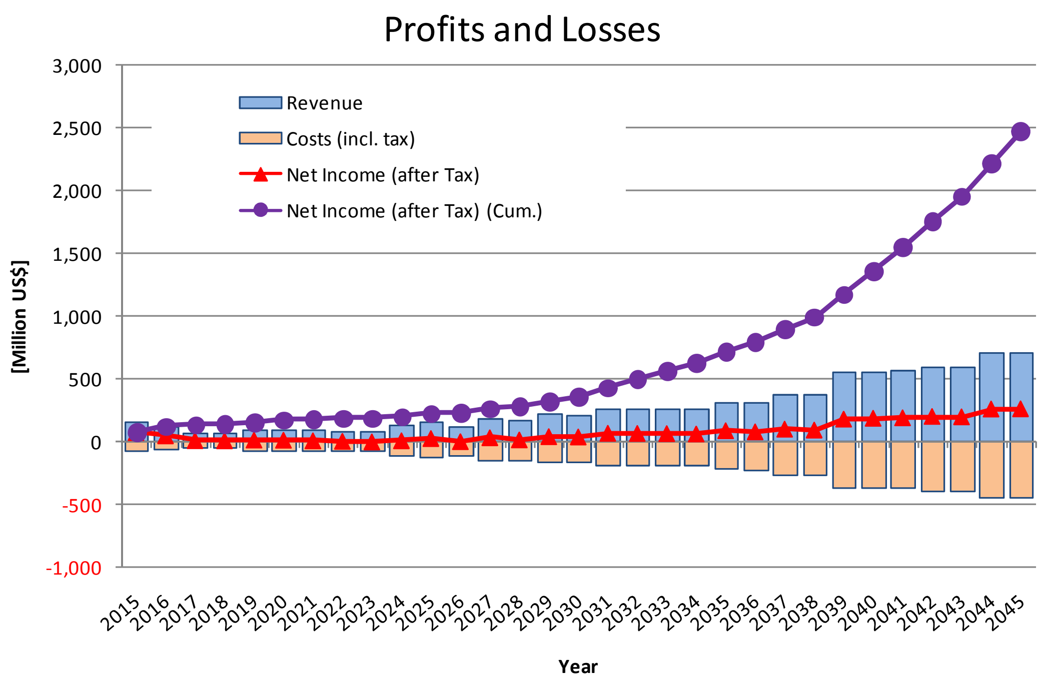


Fig. V-3.19 Profits/loss outlook for the optimized development plan reflecting the resource evaluation of five fields

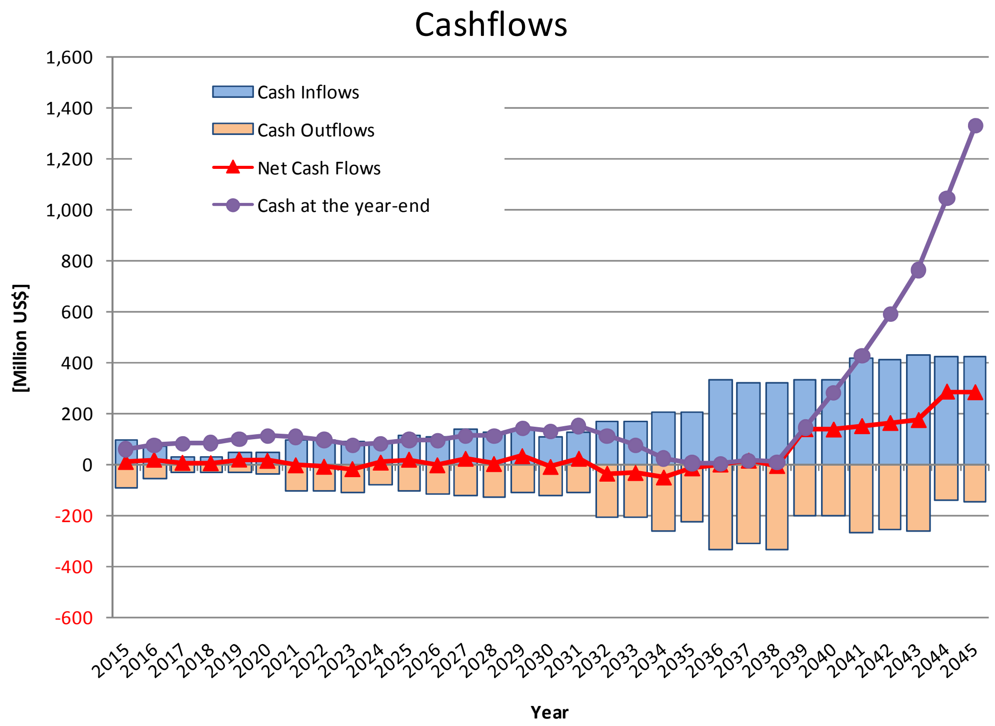


Fig. V-3.20 Cash flow outlook for the optimized development plan reflecting resource the evaluation of five fields

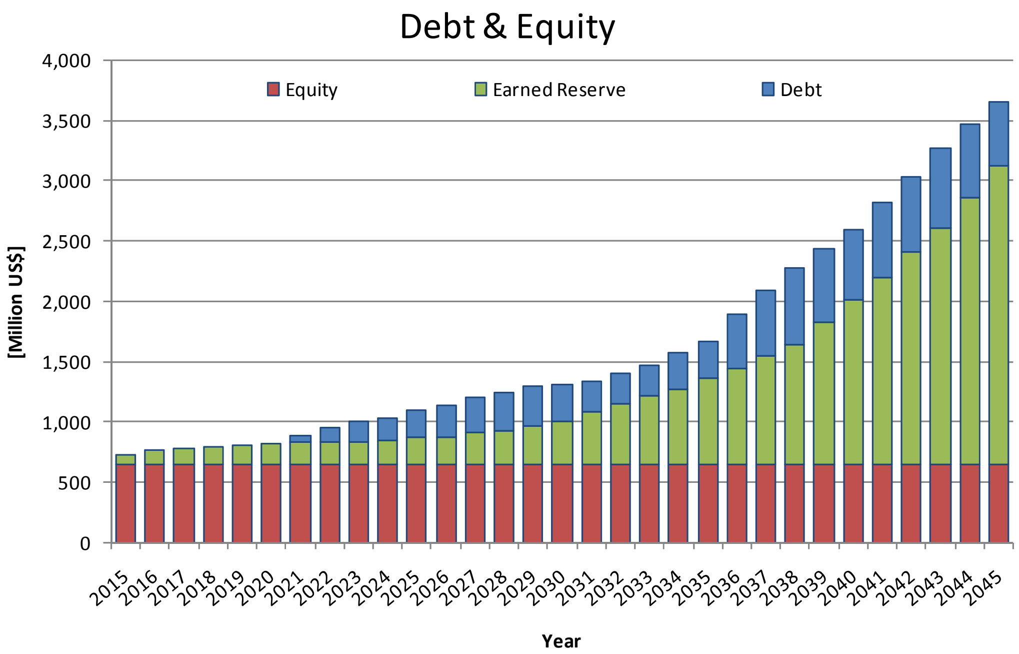


Fig. V-3.21 Total assets outlook for the optimized development plan reflecting the resource evaluation of five fields

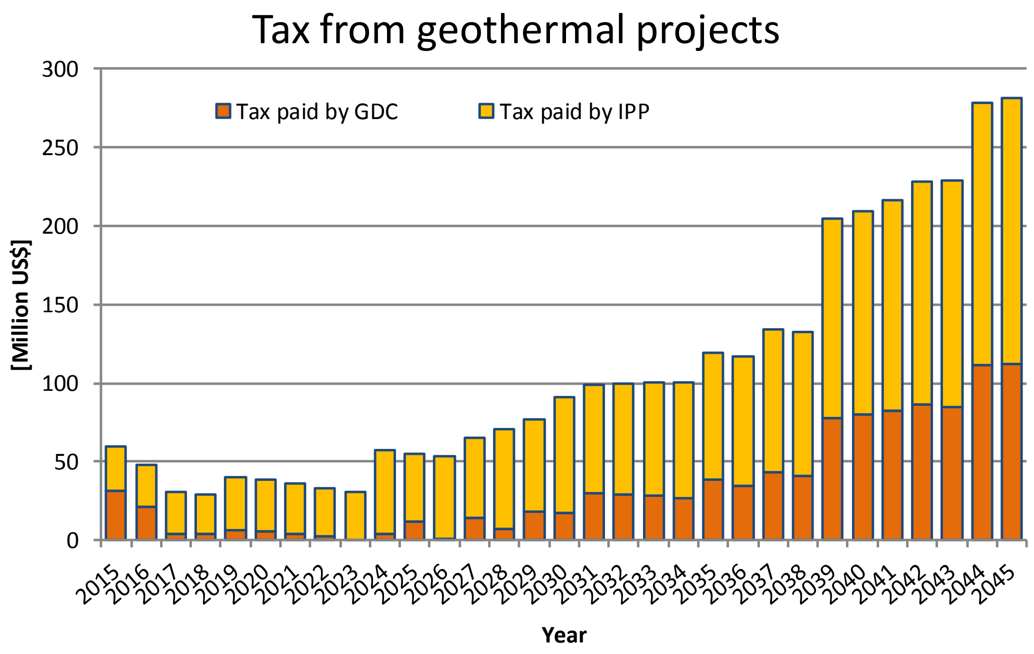


Fig. V-3.22 Tax revenue outlook of Kenya government from geothermal projects according to the optimized development plan reflecting resource evaluation of five fields

V-4 Recommendations Regarding Governmental Policy for Geothermal Development

In this section, recommendations are made regarding several policies that the Kenyan Government should promote for the future geothermal development by GDC, taking into consideration the current situation.

(1) Continuing promotion of geothermal development (primarily by GDC)

Since the enactment of the Geothermal Resource Act No. 12 in 1982, the Kenyan Government has been promoting geothermal power generation development. Until now, power generation development in the Olkaria field has been proceeding vigorously, and the capacity of the geothermal power plant has reached approximately 600 MW. As of FY 2014/15, the generated power by geothermal has covered over 40% of the domestic demand in Kenya (Table V-4.1). In addition, the establishment of GDC was an important part of the policy of geothermal development promotion.

Table V-4.1 Electric power generation sources and energy generated in Kenya (2014-2015)

Sources of Electric Power Generation		Installed Capacity (December 2014)		Annual Generation (FY 2014/15)	
		(MW)	Percentage	(GWHrs)	Percentage
Renewable Energy	Hydro	821	37.8	3,466	36.8
	Geothermal	593.5	27.3	4,060	43.1
	Wind	25	1.2	37	0.4
	Cogeneration	38	1.7	14	0.2
	Imports	-	-	79	0.8
	Total	**1477.5**	**68.0**	**7,657**	**81.3**
Fossil Fuels	MSD	579.5	26.7	1,643	17.4
	Gas Turbines	60	2.8	4	0.0
	HSD (Isolated Stations)	25.8	1.2	36	0.4
	Emergency Power Plant	30	1.4	84	0.9
	Total	**695.3**	**32.0**	**1,767**	**18.7**
Installed Capacity and Units Generated		**2,173MW**		**9,424GWhrs**	

Source: MOEP（2015）: Draft National Energy and Petroleum Policy

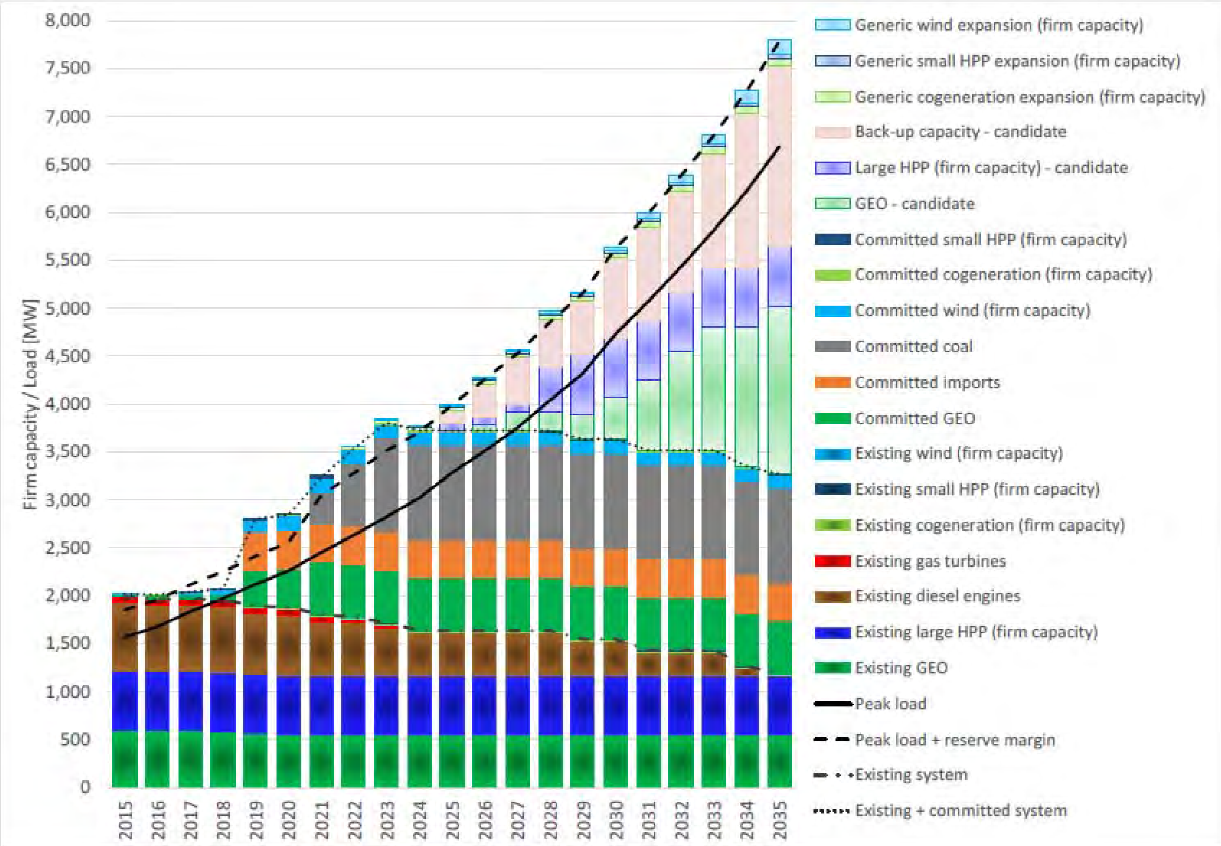
Such policies for promoting geothermal heat are based on the following advantages related to geothermal power generation in Kenya.

- Abundant geothermal resources existing along the Rift Valley (and few other energy indigenous resources)
- Stable base load power supply (hydropower is significantly affected by precipitation)
- Renewable energy
- Low environmental impact

According to the Draft National Energy and Petroleum Policy (DNEPP) created by MOEP in 2015, support for resource assessment and development, and streamlined licensing procedures by the government are necessary as part of a long-term geothermal development policy (up to 2030).

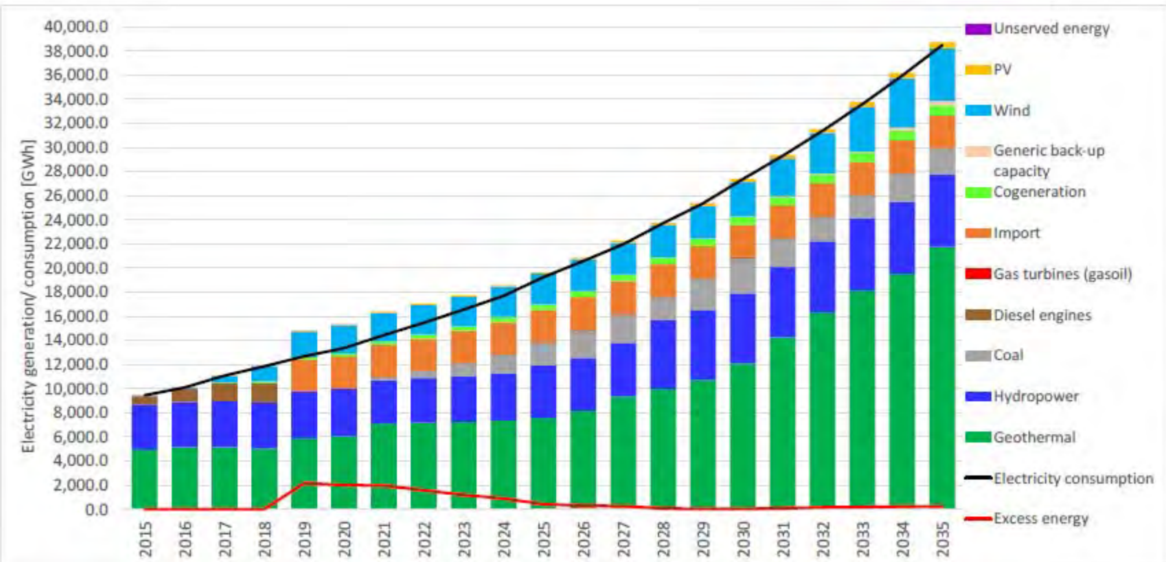
Moreover, in consideration of the importance of geothermal energy and the policy proposals as described above, a report entitled the Development of a Power Generation and Transmission Master Plan, Kenya (Long-term Plan of 2015-2035) was prepared by MOEP through an entrusted consultant (Lahmeyer

International). The report describes that geothermal is expected to play an important role in the future power supply (Fig. V-4.1 and Fig. V-4.2).



Source: MOEP-Lahmeyer (2016) Development of a Power Generation and Transmission Master Plan, Kenya – Long Term Plan 2015-2035

Fig. V-4.1 Reference expansion scenario – firm capacity versus peak demand



Source: MOEP-Lahmeyer (2016) Development of a Power Generation and Transmission Master Plan, Kenya – Long Term Plan 2015-2035

Fig. V-4.2 Reference expansion scenario – electricity generation versus electricity consumption

From the above, it is considered that the policy of promoting geothermal power generation in Kenya should be continued. In recent years, the Kenyan Government is also promoting geothermal development from resource exploration by private enterprises such as the Akiira project, but no project has yet reached the stage of commencing the construction of a power plant. As described in section V-2, integrated development by the private sector (all private model) is likely to increase the power selling price, and as the involvement of state-run organizations in development increases, the selling price can be expected to be kept lower. Therefore, this JICA study recommends that the Kenyan Government focus on supporting 100% state-owned GDC regarding policies promoting geothermal development.

Recommendations

- ✧ The implementation of policies promoting geothermal power generation in Kenya should continue to be continued over the long term.
- ✧ The main target for geothermal development support should be state-owned GDC, and it is desirable to consider development support including integrated development until power generation (total project) and development using the BOT model.

(2) Support for financing

As described in the previous sections, regarding the funding of geothermal power generation projects, steam cost/power generation cost can be lowered by applying the low-interest financing (soft loan) available from ODA. In fact, low-interest loans are actually being provided by donors such as JICA and the World Bank to KenGen's power generation projects at the Olkaria field.. For example, Table V-4.2 shows the financing sources for the 280 MW expansion project in Olkaria.

Table V-4.2 Financing sources for the Olkaria IV and Olkaria I expansion projects (280MW)

	Financier (Million USD)							
Project Component	GOK	KenGen	JICA	WB	AfD	EIB	KfW	**Total**
Drilling Costs	313						15	328
Steamfield Development		7		107			54	168
Power Plants		35	323		210	135		703
Transmission	3.4					32		35.4
Consultancy Services							30	30
Admin & Local Infr.		29		12				41
RAP		10						10
BoC				1				1
IDC		57						57
Total	316.4	138	323	120	210	167	99	**1,373**

Source: Saitet and Muchemi (2015)

In order to obtain the low-interest financing of ODA, it is necessary for government agencies to coordinate with donors and related domestic organizations. In future geothermal development projects carried out by 100% state-owned GDC, it is hoped that the government will cooperate to obtain financing through low-interest ODA loans.

Recommendations

- ✧ In geothermal development projects conducted by GDC, in order to reduce the development cost as much as possible, it is hoped that the government will cooperate to obtain financing through low-interest ODA loans.

(3) Support for project site preparation

In regards to geothermal development, it is necessary to acquire permission for land acquisitions, road establishment, water rights, etc. and to coordinate with land owners. If these procedures are delayed, the schedule of the entire power generation project may be greatly affected. GDC is obviously primarily responsible for these arrangements, but smooth procedures and support by the government are desirable in order to promote geothermal development.

Electricity from the geothermal power plant constructed by GDC (and IPP) is transmitted to the nearest substation under the responsibility of the power generation company, but power transmission/connection to the electricity grid thereafter is the responsibility of KETRACO. Regarding the five target fields of this project, construction of a 400 kV transmission line from Rongai to Silali is planned. To avoid delay, the construction of the transmission line must be coordinated with the construction of the power plant at each field. Since multiple parties are involved, in order for that coordination to occur it will be necessary for the government to properly supervise the development of the power supply and the development of the power transmission facilities.

In the development of geothermal resources and the construction of power plants, natural and social environmental assessment and the formulation of conservation plans are conducted, and the relevant approval of the government is required. It is important that these procedures and approvals will be properly conducted by the relevant government agencies, without delay.

Recommendations

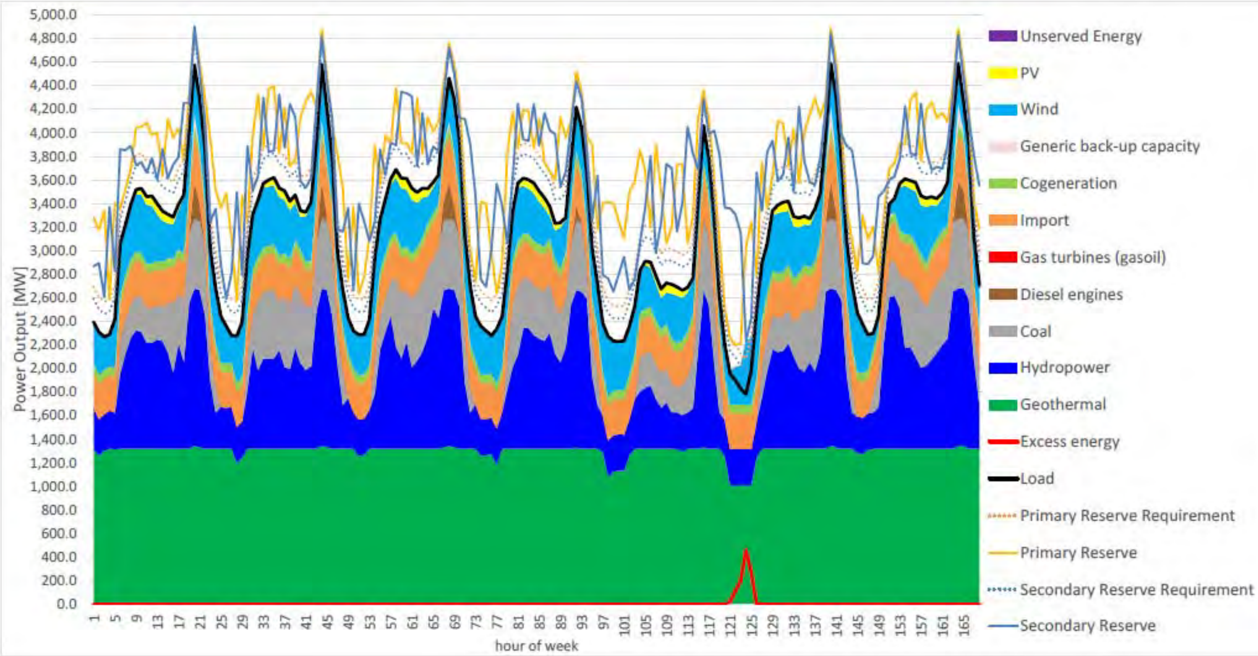
- ✧ In geothermal development projects conducted by GDC, it is important that the procedures for the permission of land acquisition, road establishment, water rights etc. will be smoothly carried out without delay.
- ✧ It is necessary for the government to properly supervise the development of the power transmission facilities in coordination with the geothermal power development carried out by GDC.
- ✧ It is important that government organizations will efficiently carry out the procedures and provide the approvals for natural and social environmental assessment and preservation plans in order to avoid delay of geothermal power development conducted by GDC.

(4) Support for selling steam and electricity

If the development of geothermal power is further promoted in Kenya, it is expected that the proportion of geothermal power to domestic demand will exceed 50% of the total. Geothermal power should be used as a base load, but surplus electricity may be generated depending on the situation of demand fluctuation in a day or a year (Fig. V-4.3). One way to avoid this situation is the export of electricity to neighboring countries (Uganda, Tanzania, etc.). Kenya is a member of the Eastern African Power Pool (EAPP), in which ten countries in East Africa participate, and the power grid of Kenya has been already connected with those of Uganda and Tanzania. Also, a connecting transmission line with Ethiopia is under construction (DNEPP, 2016). Based on these circumstances, it is hoped that government organizations will consider exporting power for long-term market development.

Recommendations

- ✧ In order to effectively maximize the utilization of power from the abundant geothermal resources in Kenya, it is desirable for government organizations to consider the export of power for long-term market development.



Source: MOEP-Lahmeyer (2016) Development of a Power Generation and Transmission Master Plan, Kenya – Long Term Plan 2015-2035

Fig. V-4.3 Reference expansion scenario – sample dispatch in 21-27 June 2030

(5) Support for development of human resources

In regards to future geothermal development in Kenya, which is expected to be further expanded mainly by GDC, demand for geothermal related engineers and technicians is anticipated to increase. In order to contend with this issue, it is desirable to train engineers and others concerning geothermal development, not only at GDC, but also at universities and other educational institutions. It is desirable to implement policies to support the training of technicians by establishing and expanding professional education departments related to geothermal energy at universities and assisting students to study abroad or participate in training courses in other countries.

Recommendations

- ✧ In order to respond to the growing demand for geothermal related human resources in Kenya, it is desirable to implement policies to support the training of engineers and technicians at universities and other educational institutions.

V-5 Summary of Recommendations

The various recommendations described in the previous section of this chapter (V-1 to V-4) are summarized as follows.

(1) Recommendations for reviewing GDC's geothermal development master plan

Priority of geothermal development (field rating)

- According to the results of a comprehensive evaluation of the elements, including geothermal resource characteristics, infrastructure/accessibility, topography, natural and social environment and the possibility of geothermal direct use, the fundamental priority of development for the five fields assessed in this project at the present are as follows.

  1. Paka (320MW)
  2. Korosi (210MW)
  3. Baringo North (100MW)
  4. Arus (around Steam Jets) (100MW)
  5. Baringo South (100MW)
  6. Chepchuk (80MW)

  However, since this development priority is preliminary (at the surface survey stage), it is desirable to review and update it from time to time based on the future results of exploration by well drilling and other surveys at each field.

- As for the relative priority between the above five fields and Silali, it is desirable to evaluate the situation based on the more detailed future resource assessments, including the drilling of exploratory wells in those fields. Additionally, it is also necessary to take into consideration that Silali is located further north than Paka, and is located in a region where conflict among ethnic groups occurs frequently.

Role, business model and development plan of GDC

- Compared with private companies, state-owned enterprises are able to procure low-cost funding against the background of the creditworthiness of the country, and as a result, it is possible to suppress the expected rate of return. Therefore, if state-owned enterprises develop geothermal resources, it becomes possible to lower the power generation cost. This is an important role of a state-run geothermal development enterprise (GDC) in geothermal development.

- The possession of drilling rigs and increase in the drilling ability by GDC will lead to a drastic reduction in drilling expenses and speed up the development. This has the effect of reducing power generation cost and, at the same time, expanding future development capacity. This is the second role, that state-run geothermal development companies are expected to own drilling rigs and exist as institutions which possess drilling ability in their own country.

- It is meaningful to consider public-private partnerships between GDC and private companies in order to utilize private financial capital for geothermal development. Various models are conceivable for public-private partnerships, but from the case study of other countries, it is necessary to take into consideration that the IPP model that is currently GDC's standard model (steam supply by GDC and power generation by IPP), have unexpectedly few examples in the world.

- The geothermal development model that Kenya should orient is the integrated development model (total project model) by a state-owned enterprise (GDC). If it is difficult, it is desirable to instead aim for the BOT model, located in the middle of the IPP model and the GDC's total project model. With the appropriate institutional design, the BOT model can make the power generation cost less expensive than the IPP model, and is possible to achieve a development volume comparable to the IPP model.

- As another important role of state-run geothermal development enterprises, GDC has the advantage that it is eligible for ODA. By using ODA funds, it is possible to further lower power generation costs and expand development volume, without burdening GDC's finances.

- In the estimation of the maximum development plan considering the resource characteristics of the five (5) surveyed fields and financial soundness of the GDC, it is found that five (5) projects (cumulative total of 565 MW) by 2025, 11 projects (985 MW) by 2030, 15 projects (1,205 MW) by 2035, and 25 projects by 2040 (1,815 MW), and 31 projects (2,205 MW) by 2045 could be developed. The factors that determine the development speed of this plan are the number of GDC's own rigs in the 2020's and the GDC's year-end cash balance in the 2030's. However, in accordance with this development plan, GDC is expected to grow steadily and soundly as a state-run geothermal development company.

- Three elements: "Commitment of the government (the will of the government)", "Technology" and "Development financing" are required in order to sustain successful geothermal development. With respect to the commitment of the government of Kenya, the JICA team recognizes the significant achievements of the government thus far and hopes that this support will continue in the future. Regarding technology, it is expected that GDC will become the core institution of geothermal development and grow as a Center of Excellence for geothermal development through the accumulation of development experience. Moreover, the technology will then penetrate into other Kenya domains by the spillover effect, and a geothermal support industry will be formed further enhancing the efficiency of development. Regarding development financing, it is most practical to utilize ODA funds, and further consideration of the BOT model is appropriate if private funds are needed.

(2) Recommendations for governmental policy regarding geothermal development

- The implementation of policies promoting geothermal power generation in Kenya should continue to be continued over the long term.

- The main target for geothermal development support should be state-owned GDC, and it is desirable to consider development support including integrated development until power generation (total project) and development using the BOT model.

- The main target for geothermal development support should be state-owned GDC, and it is desirable to consider development support, including integrated development until power generation (GDC's total project) and development using the BOT model.

- In geothermal development projects conducted by GDC, in order to reduce the development cost as much as possible, it is hoped that the government will cooperate to obtain financing through low-interest ODA loans.

- In geothermal development projects conducted by GDC, it is important that the procedures for the permission of land acquisition, road establishment, water rights etc. will be smoothly carried out without delay.

- It is necessary for the government to properly supervise the development of the power transmission facilities in coordination with the geothermal power development carried out by GDC.

- It is important that government organizations will efficiently carry out the procedures and provide the approvals for natural and social environmental assessment and preservation plans in order to avoid delay of geothermal power development conducted by GDC.

- In order to effectively maximize the utilization of power from the abundant geothermal resources in Kenya, it is desirable for government organizations to consider the export of power for long-term market development.

- In order to respond to the growing demand for geothermal related human resources in Kenya, it is desirable to implement policies to support the training of engineers and technicians at universities and other educational institutions.

APPENDIX

1. Methodology of Remote Sensing
2. Polarizing Microscope Images of Petrographic Thin Section
3. X-ray Diffraction Chart
4. Spectral Reflectance
5. Geochemical Diagrams for Each Geothermal Fields
6. Methodology of MT Data Analysis and Results
7. Methodology of MT Data Analysis and Results
8. Results of the Supplementary Study on Environmental and Social Considerations
9. Economic Evaluation of Wellhead Generator
10. GDC Corporate Financial Model (2015US$) – User's Manual

APPENDIX

1. Methodology of Remote Sensing

Methodology of Remote Sensing

Base map preparation

As an example of base map, a TERRA/ASTER false color image of Paka area is shown in Fig. 1.

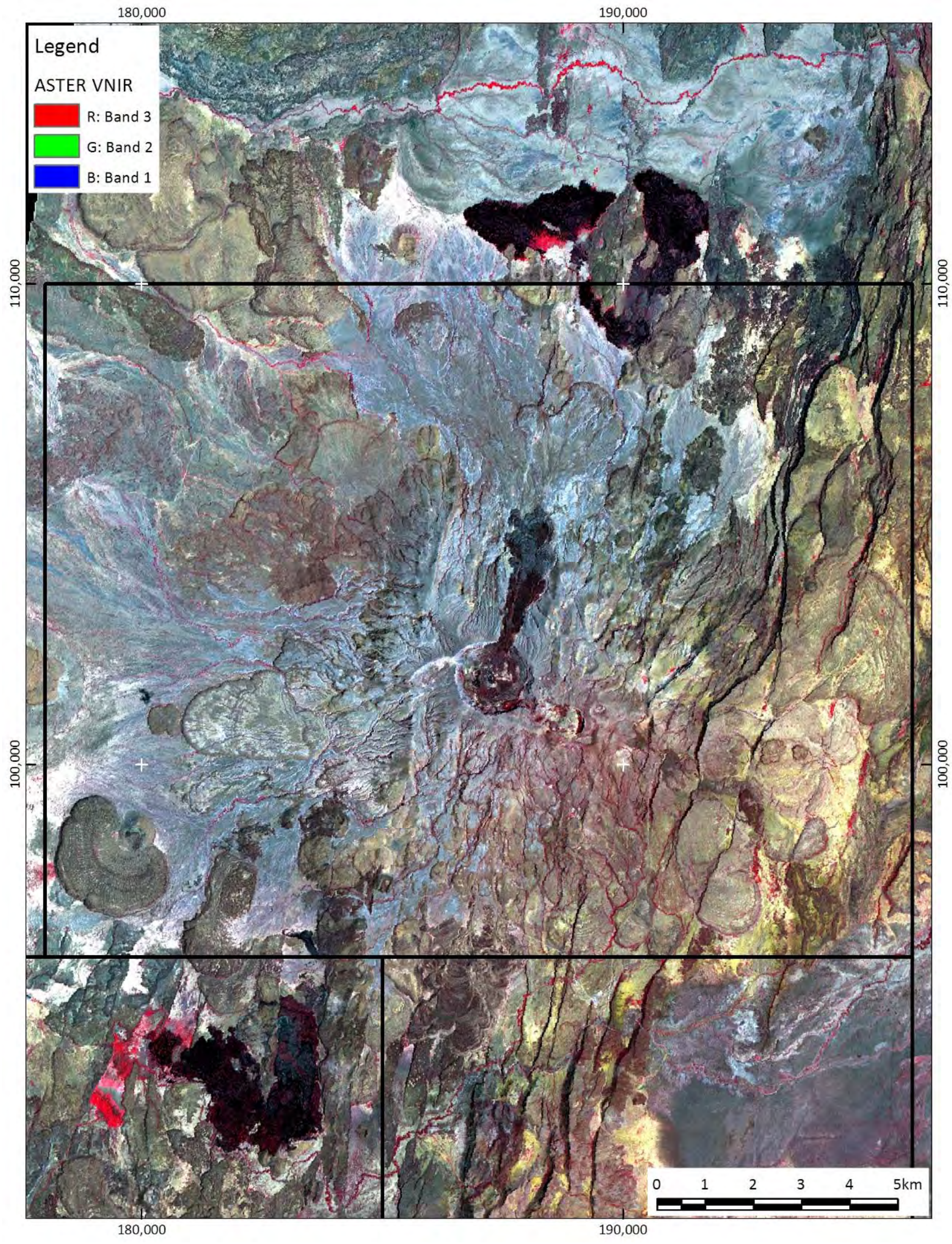
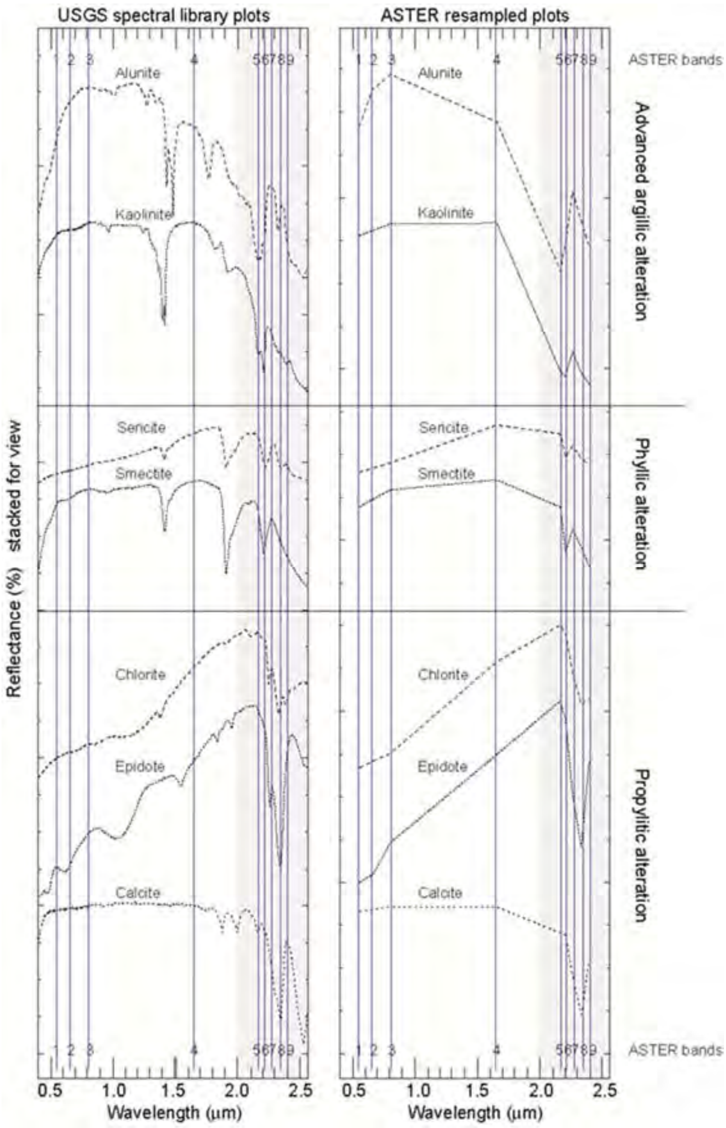


Fig. 1 ASTER VNIR false color image of Paka area

False color image preparation

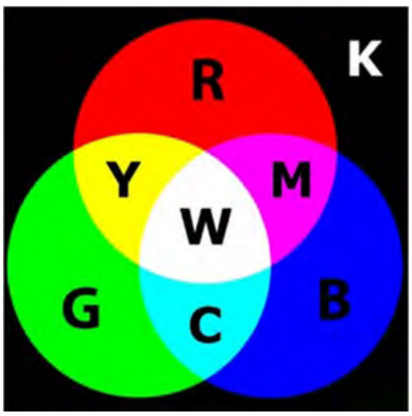
The false color images of TERRA/ASTER VNIR (visible and near infrared radiometer) mentioned previously, were made by assigning the reflection intensity of electromagnetic wave in the observational wavelength range of Band 3 (0.76 to 0.86 micrometers), Band 2 (0.63 to 0.69 micrometers) and Band 1 (0.52 to 0.60 micrometers) to the three primary colors of light (Red, Green and Blue, hereafter RGB) on the images. In the ASTER VNIR false color images, the pixels covered by vegetation appear bright red color since the reflection from vegetation becomes very strong in Band 3 assigning red color on the images. Similarly, the pixels corresponding to exposed rocks and soils appear various color depend on their lithology or component mineral, dark brown (especially lava flow) – brown – light blue – light green to white color, and the waters appear light blue – dark blue – black color.

In addition, the ASTER SWIR (short wavelength infrared radiometer) false color images were created by assigning the reflection intensity of Band 8 (2.295 to 2.365 micrometers), Band 6 (2.185 to 2.285 micrometers) and Band 4 (1.600 to 1.700 micrometers) to RGB on the images to extract alteration zones constituted of clay minerals. It is known that this color composite image is useful for identification of hydrothermal alteration, i.e. advanced argillic alteration (alunite, kaolinite), phyllic alteration (sericite, smectite) and prophylitic alteration (chlorite, epidote). And their component minerals of advanced argillic and phyllic alteration are characterized by strong absorption near 2.2 to 2.3 micrometers corresponding to Band 5 (2.145 to 2.185 micrometers) and Band 6 of ASTER SWIR data (Fig. 2). In the false color images, the pixels corresponding to advanced argillic and phyllic alteration have absorption, or low reflectance intensity at Band 6 assigning green color and high reflectance intensity at Band 4 and Band 8 assigning red and blue color, and appear magenta color produced by additive color mixing of red and blue on the composite image (Fig. 3).



Source: Yajima et al. (2007)

Fig. 2 Spectral reflectance and ASTER simulated spectral patterns of alteration minerals



R: red, G: green, B: blue, Y: yellow, C: cyan, M: magenta and K: black

Fig. 3 Additive color mixing

Relative absorption band-depth image

A conceptual diagram of RBD is shown in Fig. 4. In the diagram, the RBD of targeted absorption band can be calculated by summing up the reflectance of two bands located at both shoulders of the absorption band and then dividing it by the reflectance of absorption band. The equations calculating RBD of each component mineral related to alteration zones are shown as below.

$$RBD_{Alunite} = \frac{Ref_4 + Ref_6}{Ref_5}$$

$$RBD_{Kaolinite} = \frac{Ref_4 \times Ref_6}{Ref_5 \times Ref_6}$$

$$RBD_{Sericite} = \frac{Ref_5 + Ref_7}{Ref_6}$$

$$RBD_{Chlorite} = \frac{Ref_7 + Ref_9}{Ref_8}$$

Where; Ref# is reflectance of Band #.

The result of kaolinite mapping by the RBD methods in Paka area is shown in Fig. 5. In a RBD image, the pixel with higher value showing warm color indicates that its absorption in the band corresponding to the fraction of equation is lager and the existence probability of targeted mineral becomes higher in the pixel.

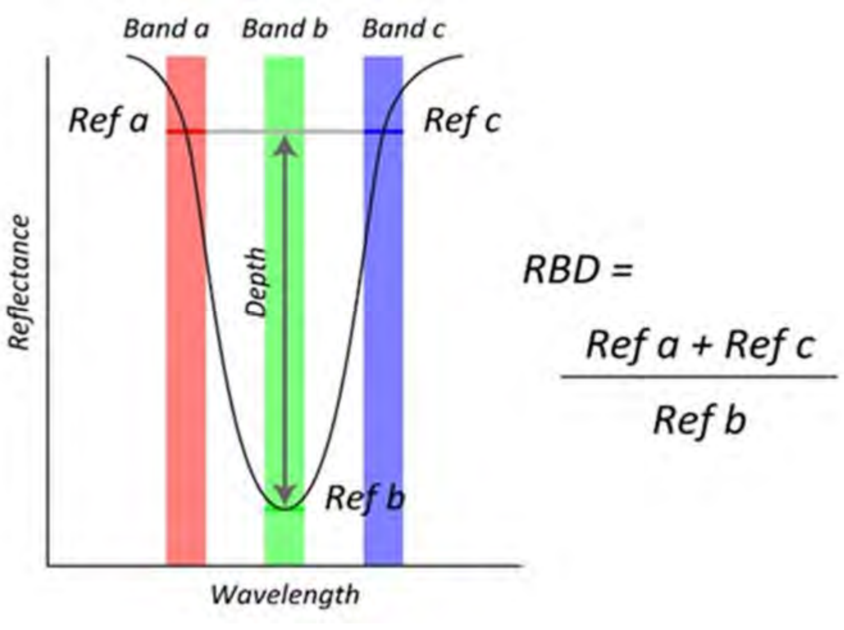


Fig. 4 Conceptual model of RBD

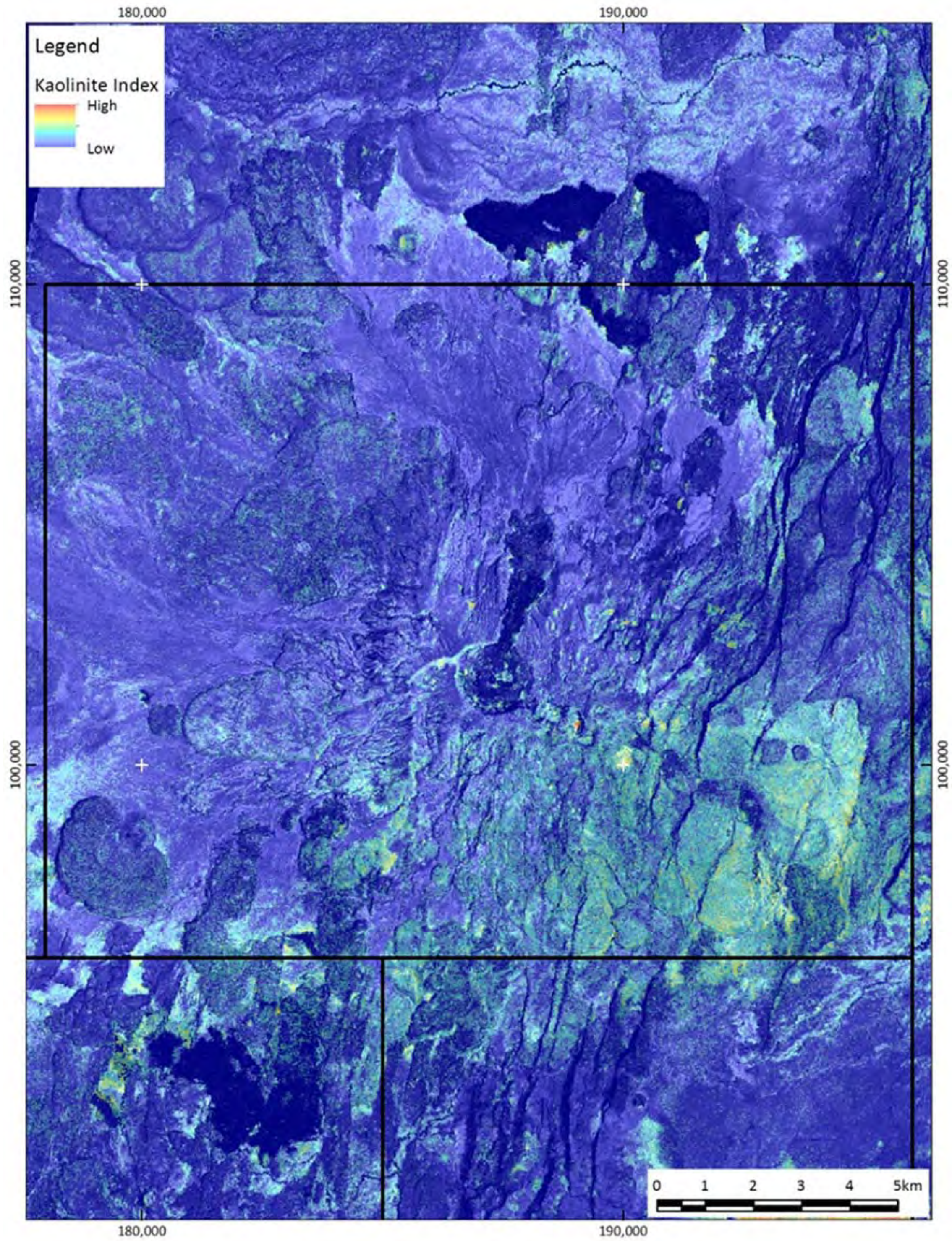


Fig. 5 ASTER SWIR RBD image (kaolinite) of Paka area

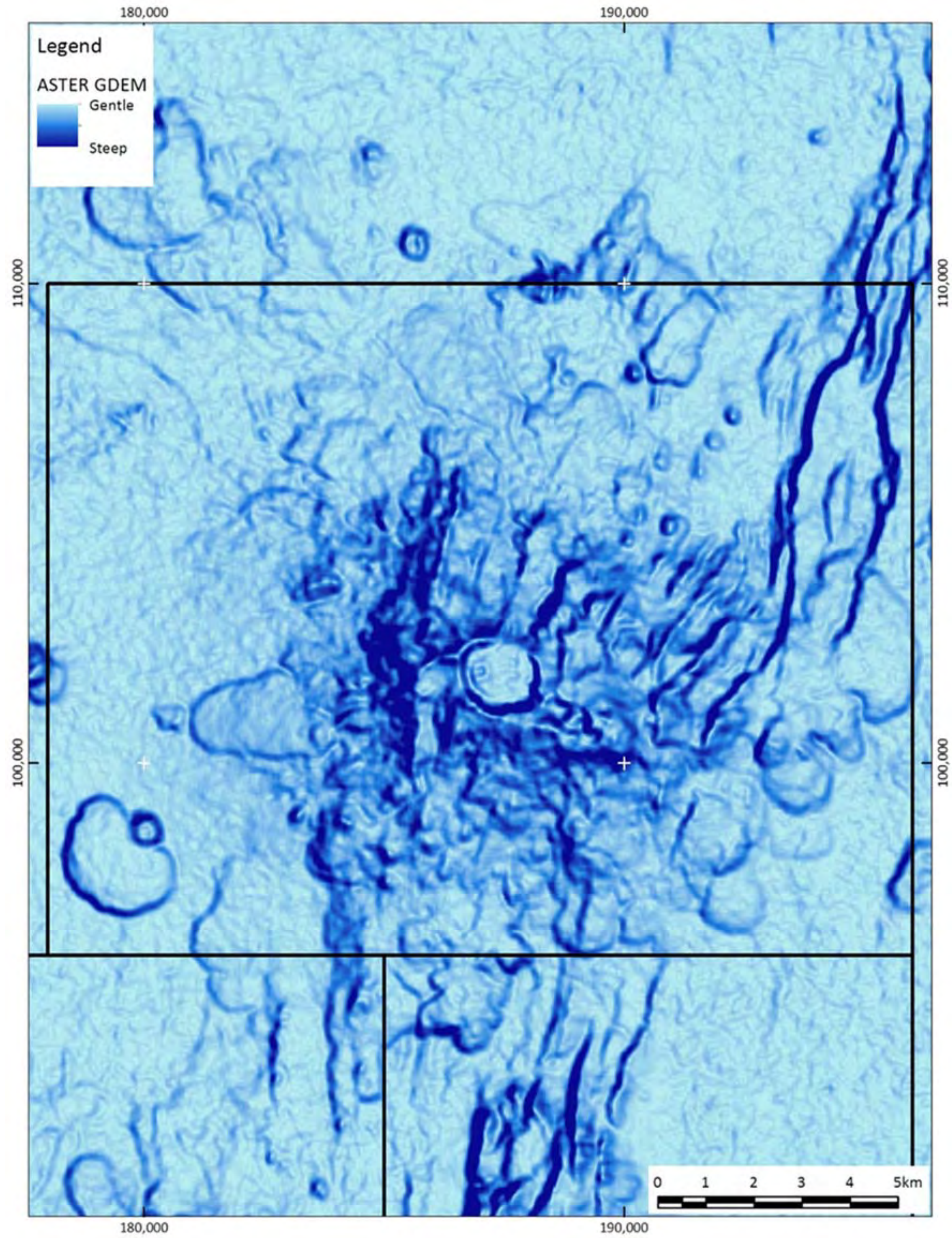


Fig. 6 ASTER GDEM Composite image of slope analysis and shaded relief in Paka area

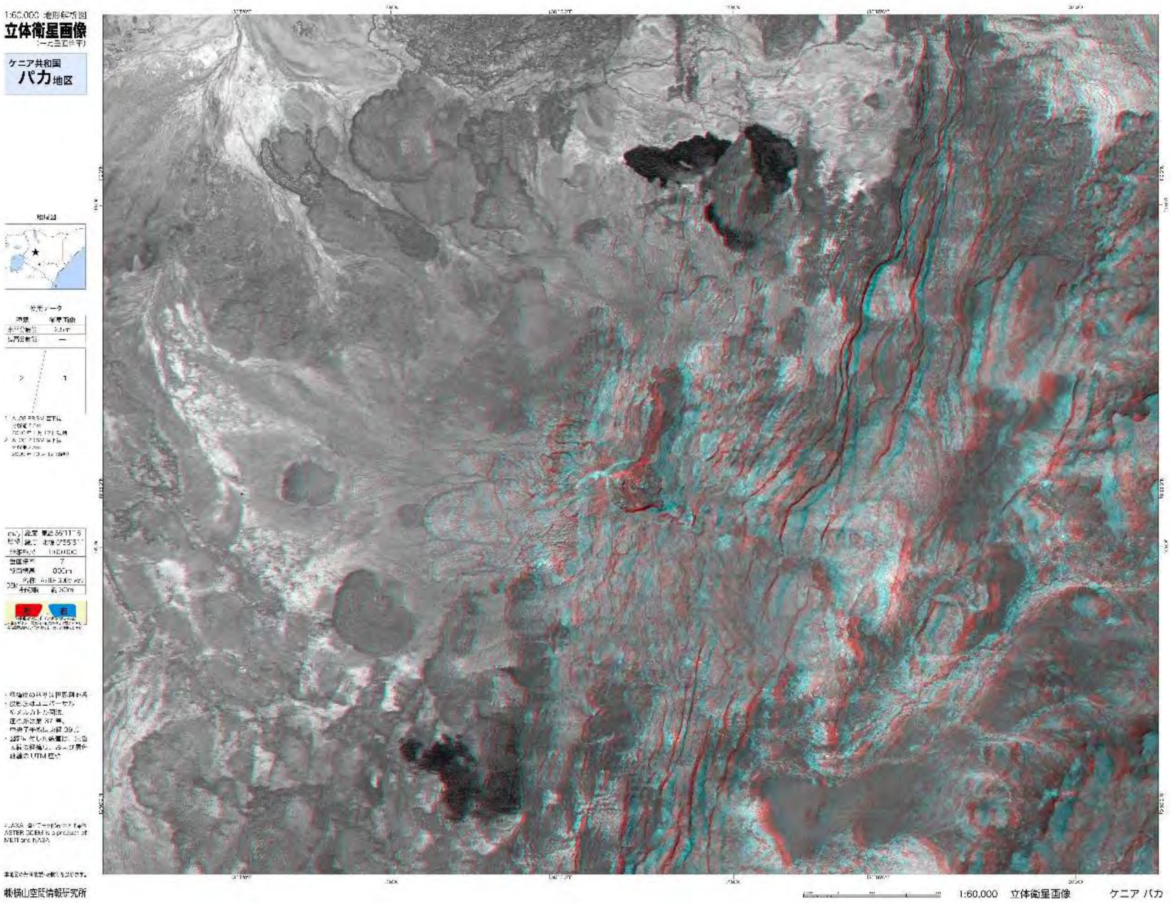
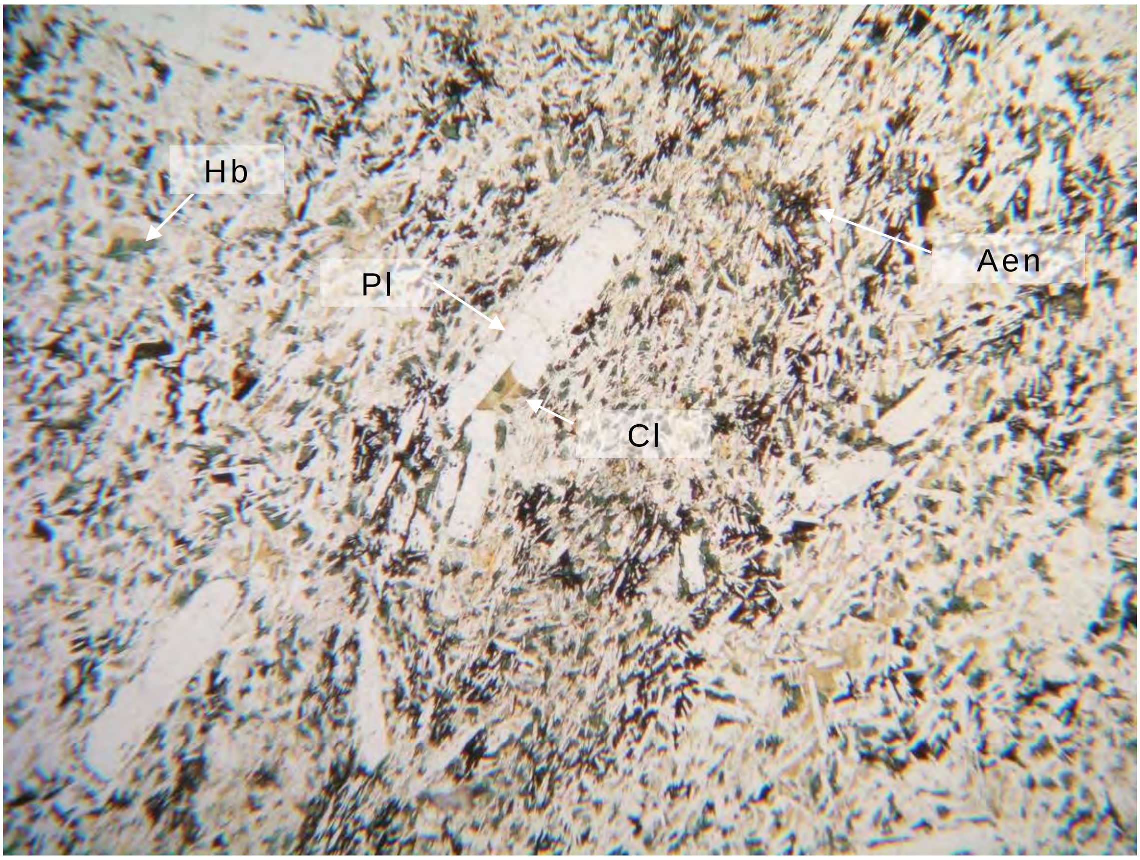


Fig. 7　ALOS PRISM stereo image of Paka area

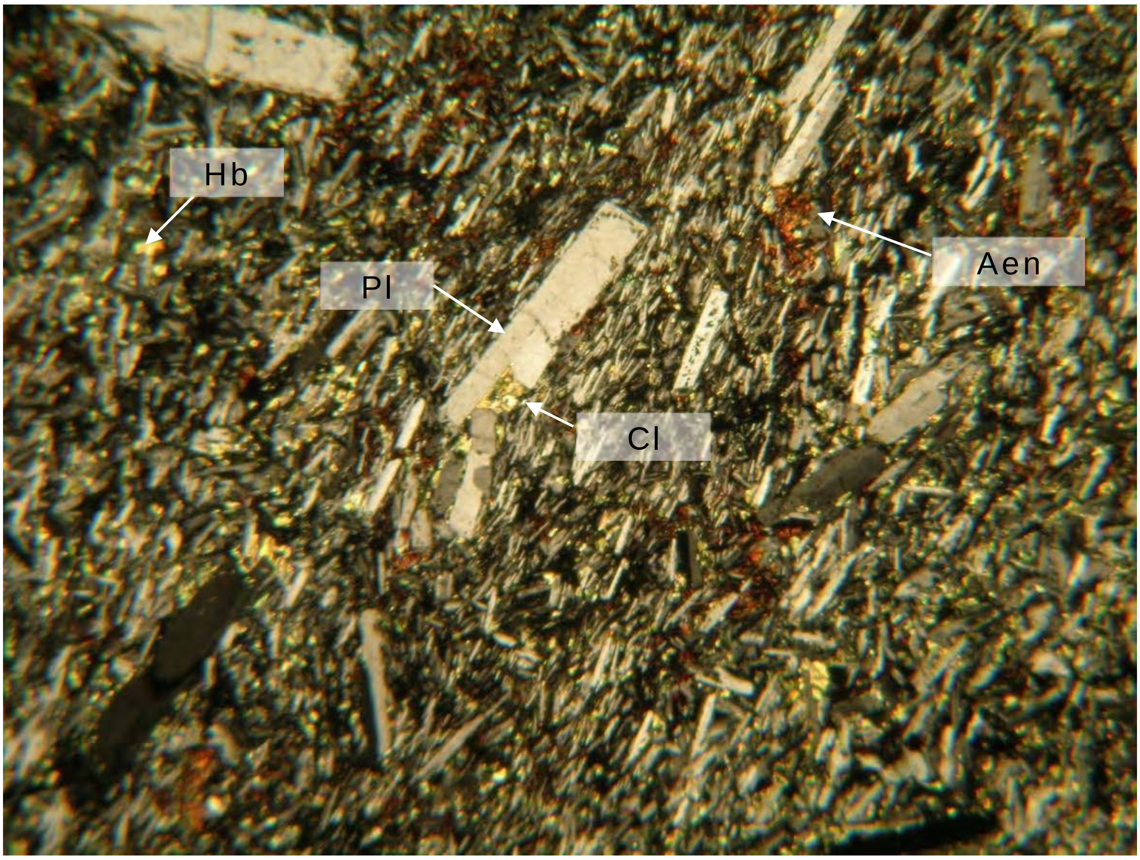
APPENDIX

2. Polarizing Microscope Images of Petrographic Thin Section

2015052704-T



0.5mm Plane-Polarized



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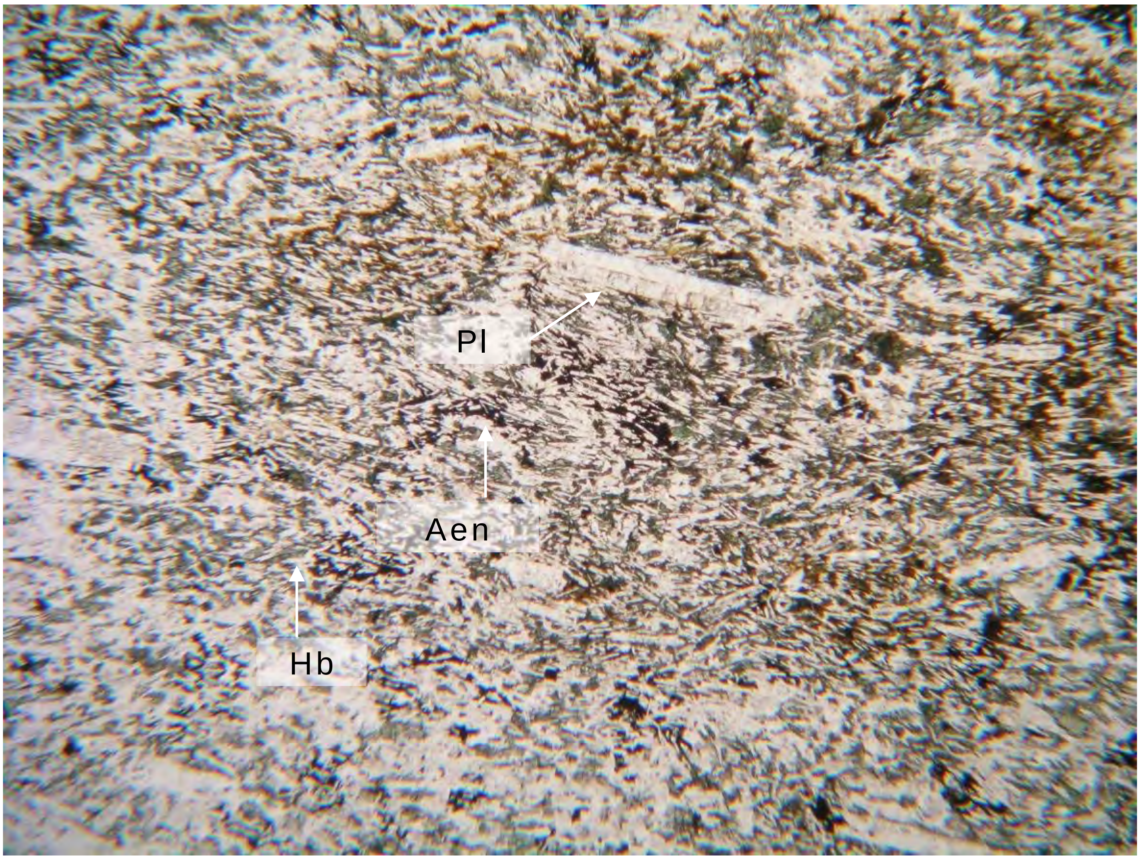

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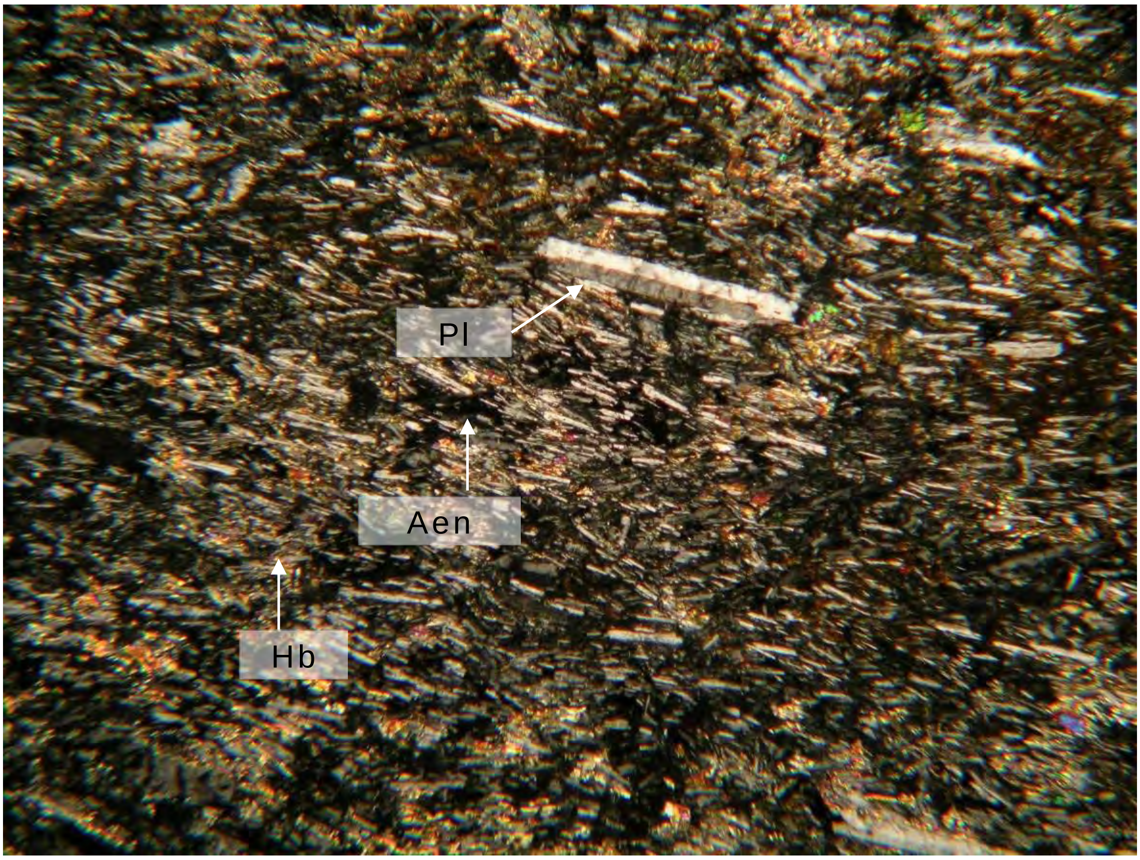

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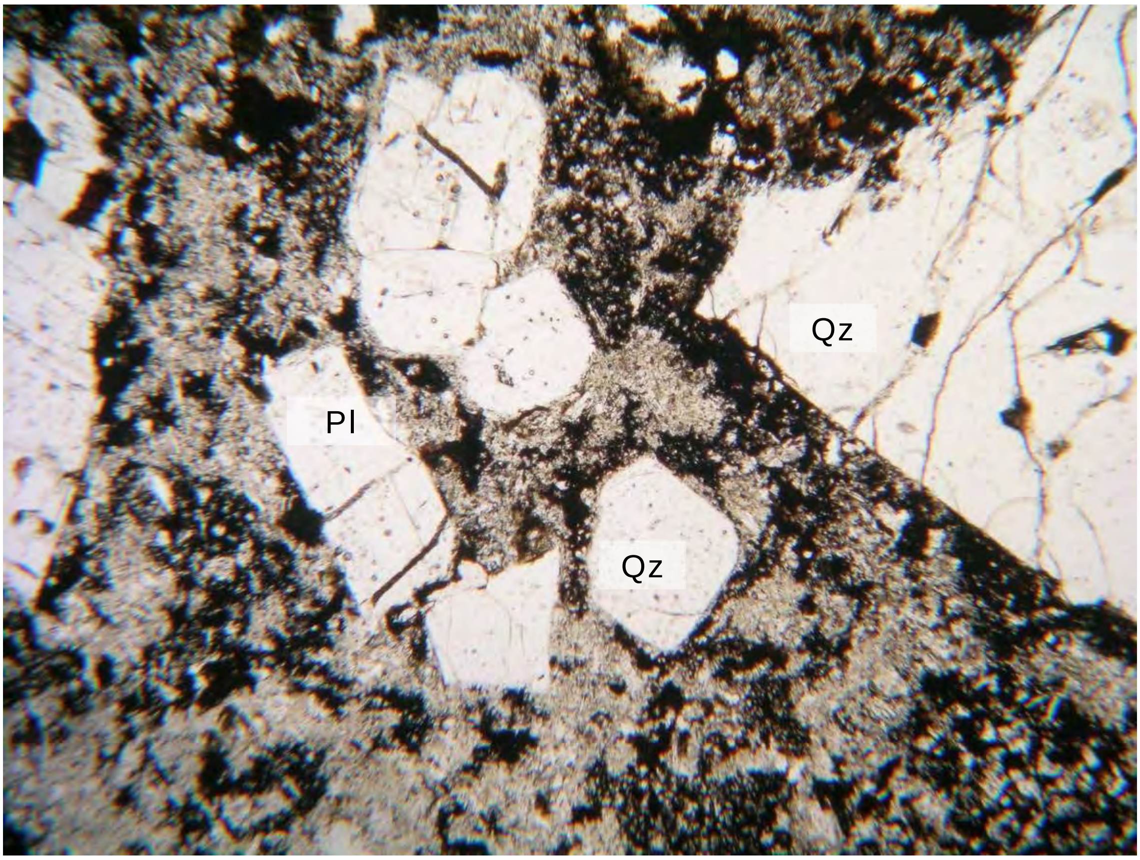

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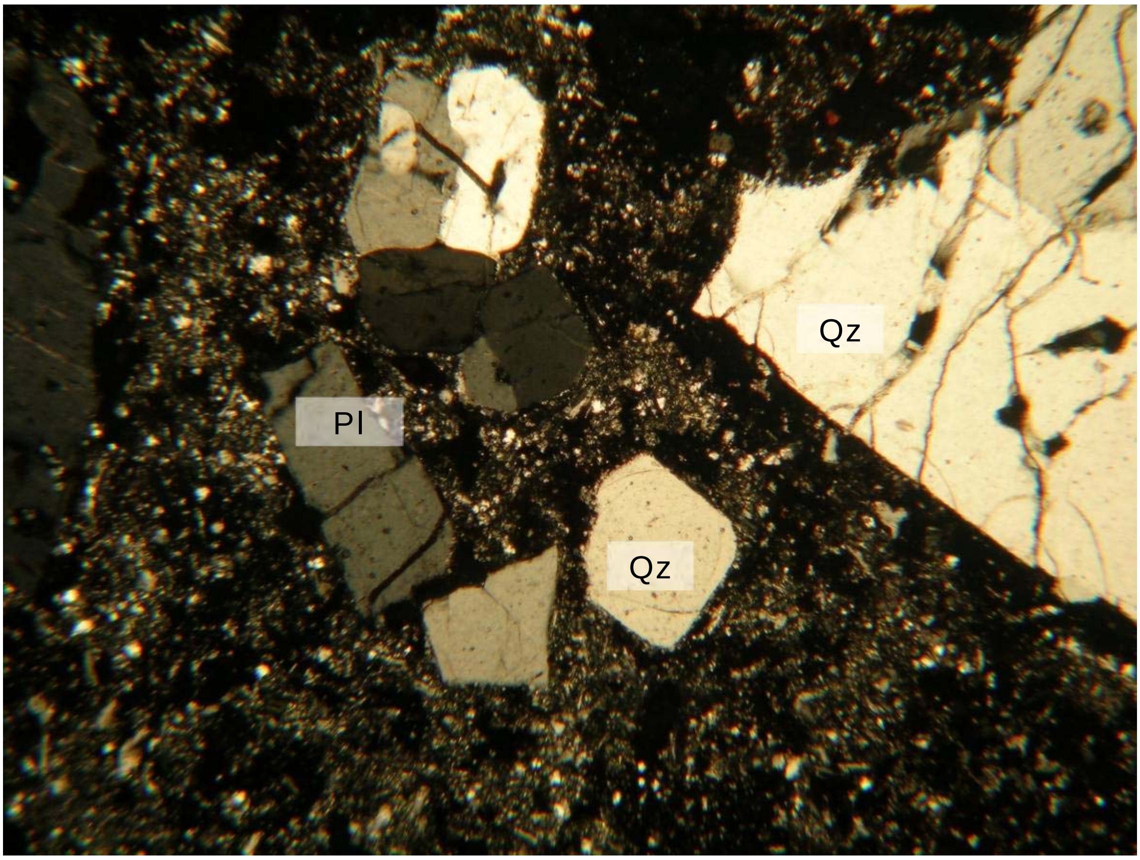

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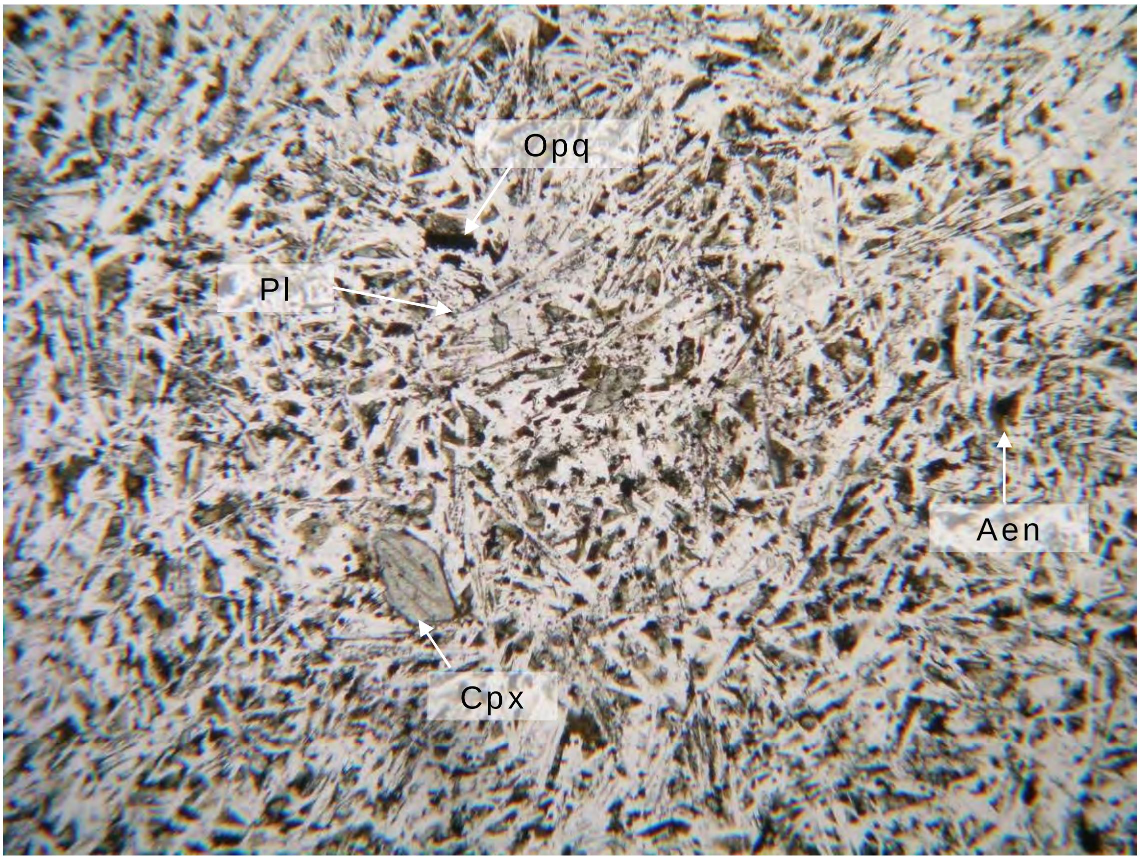

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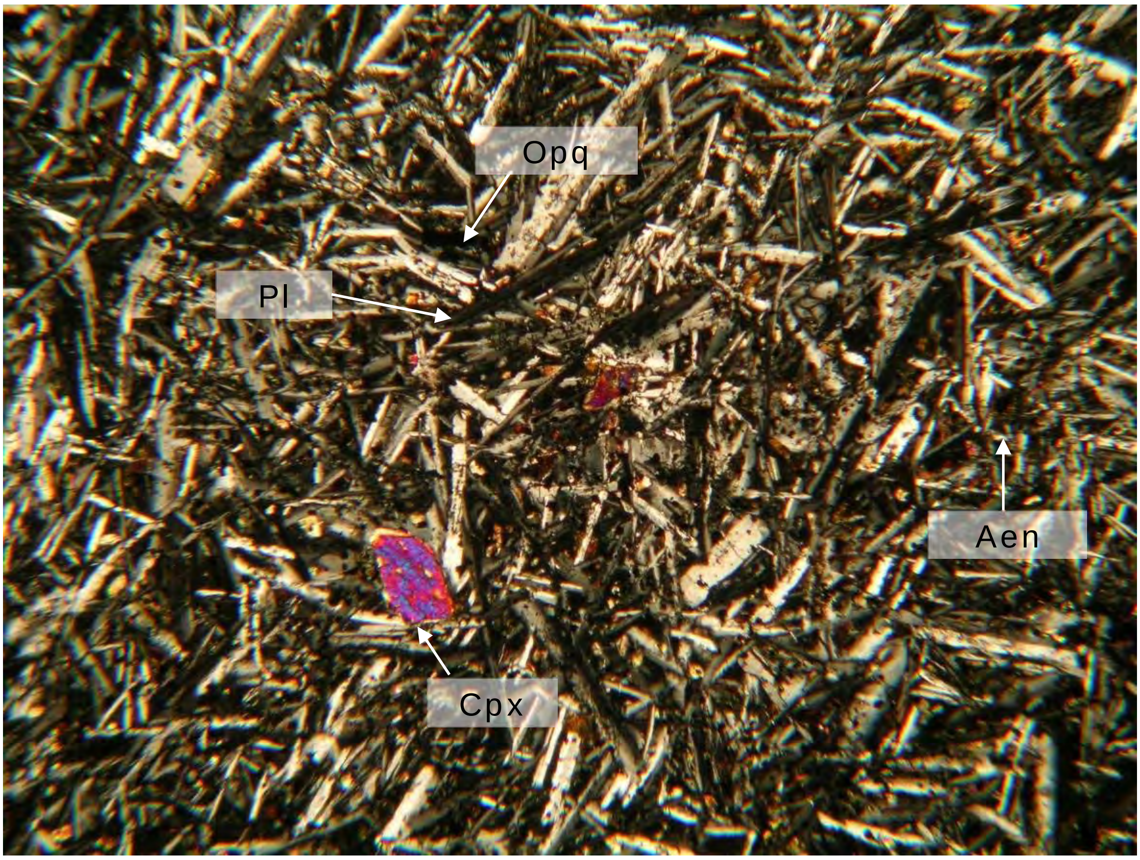

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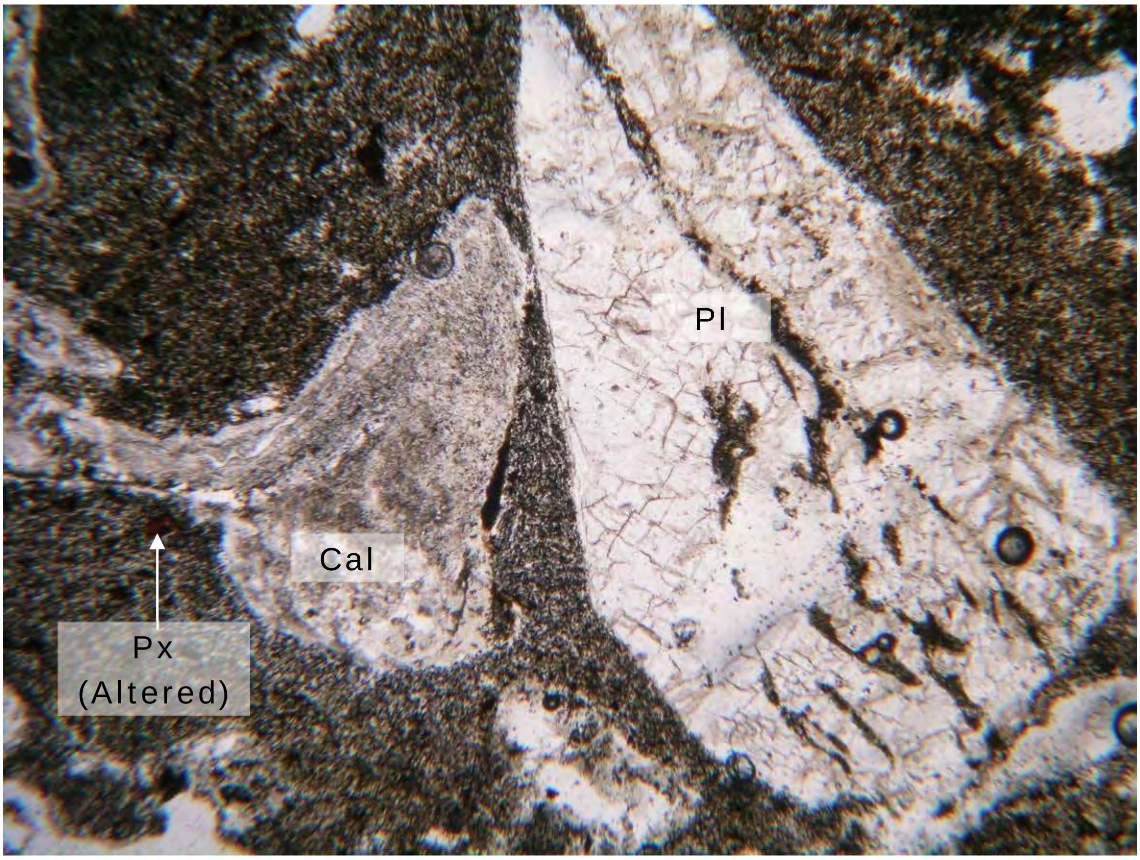

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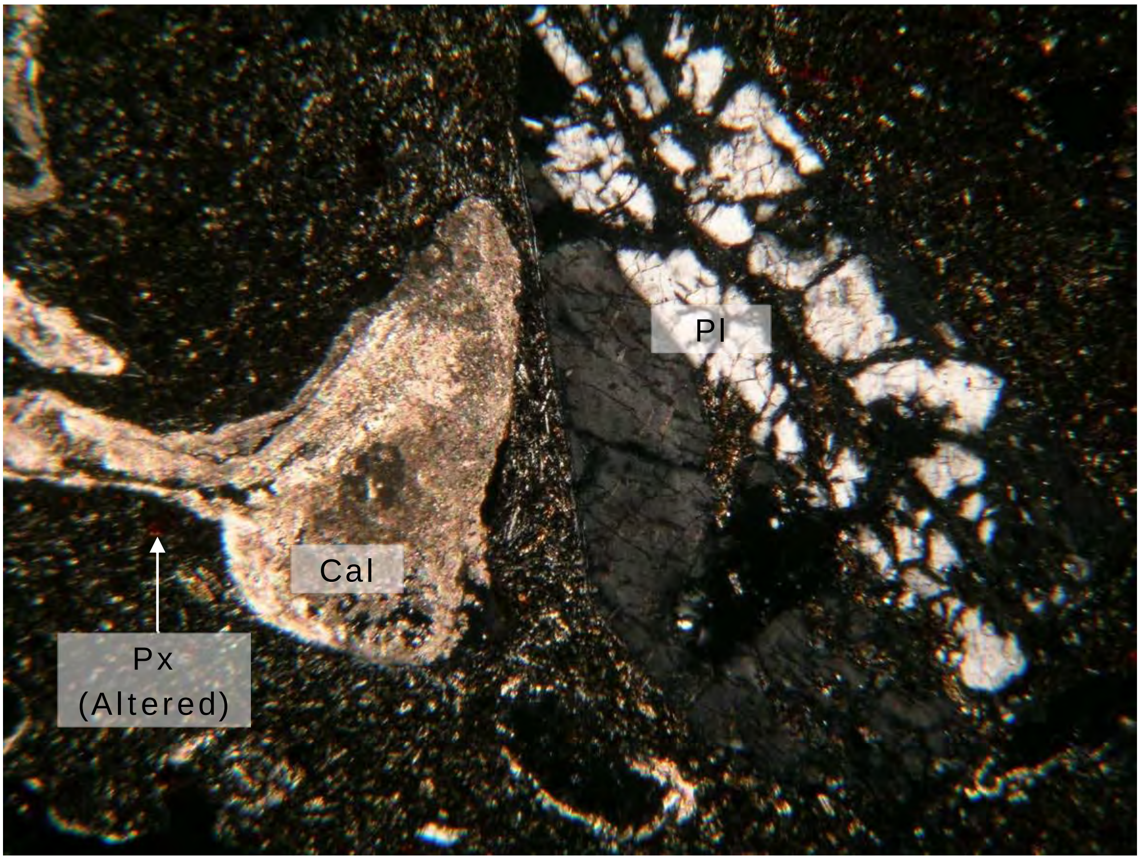

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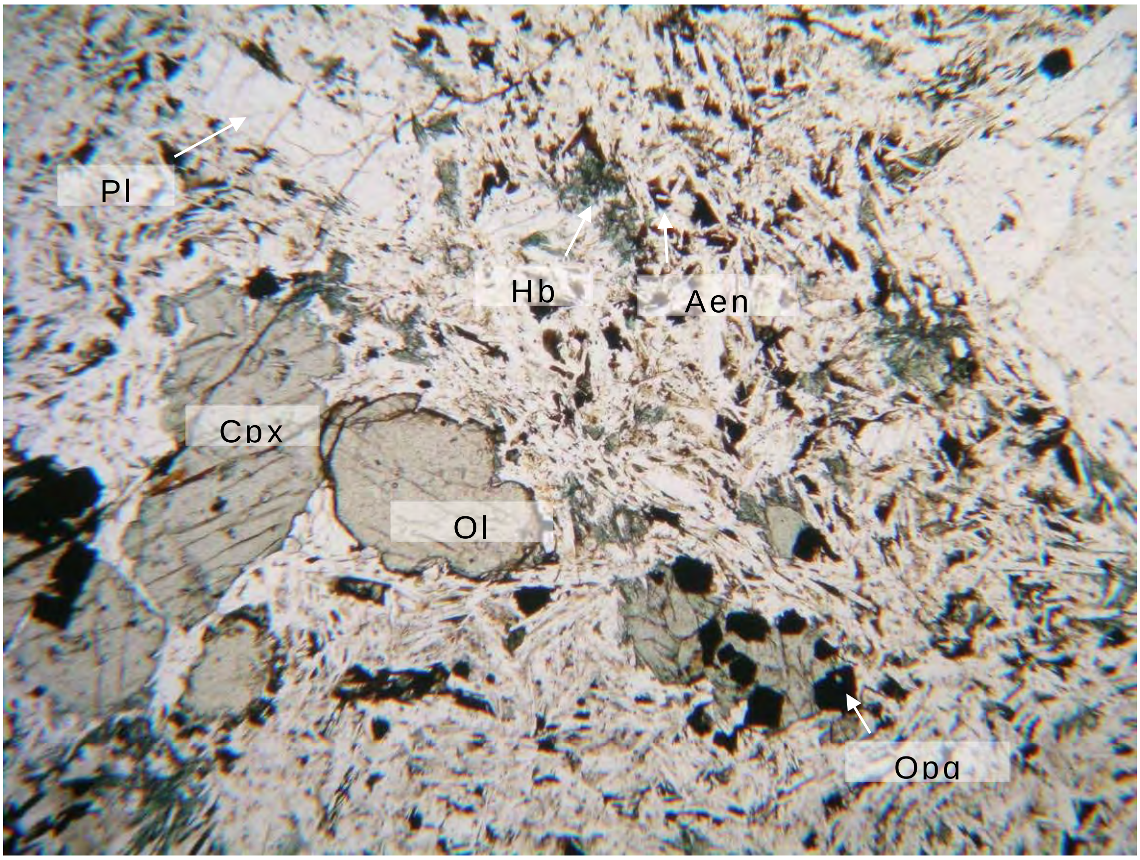

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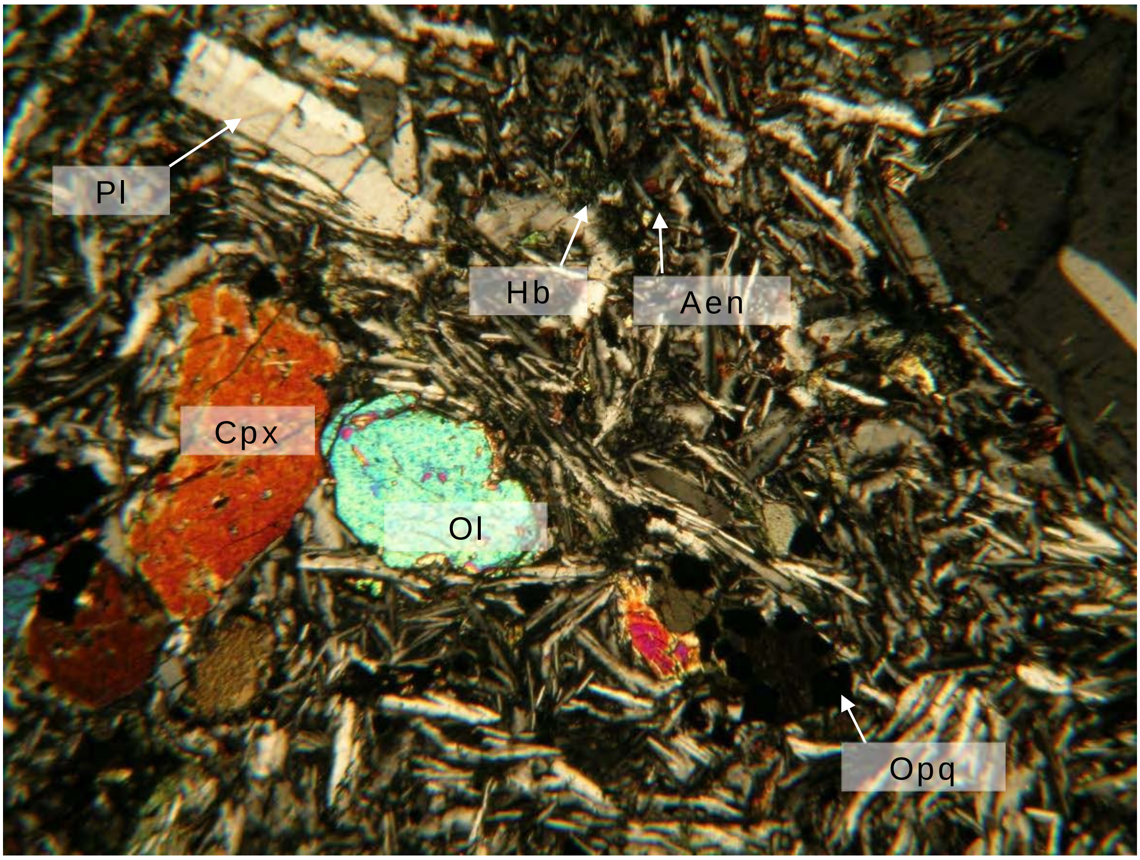

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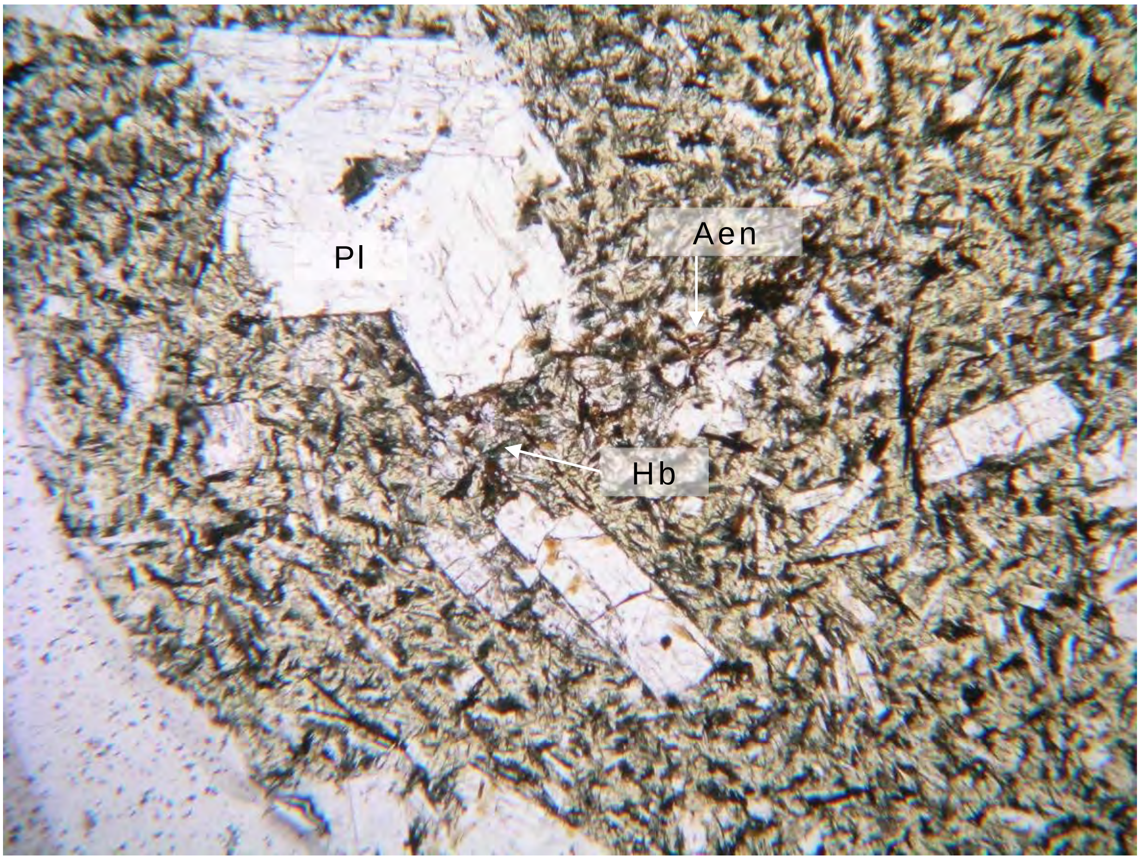

0.5mm Plane-Polarized

0.5mm Cross-Polarized

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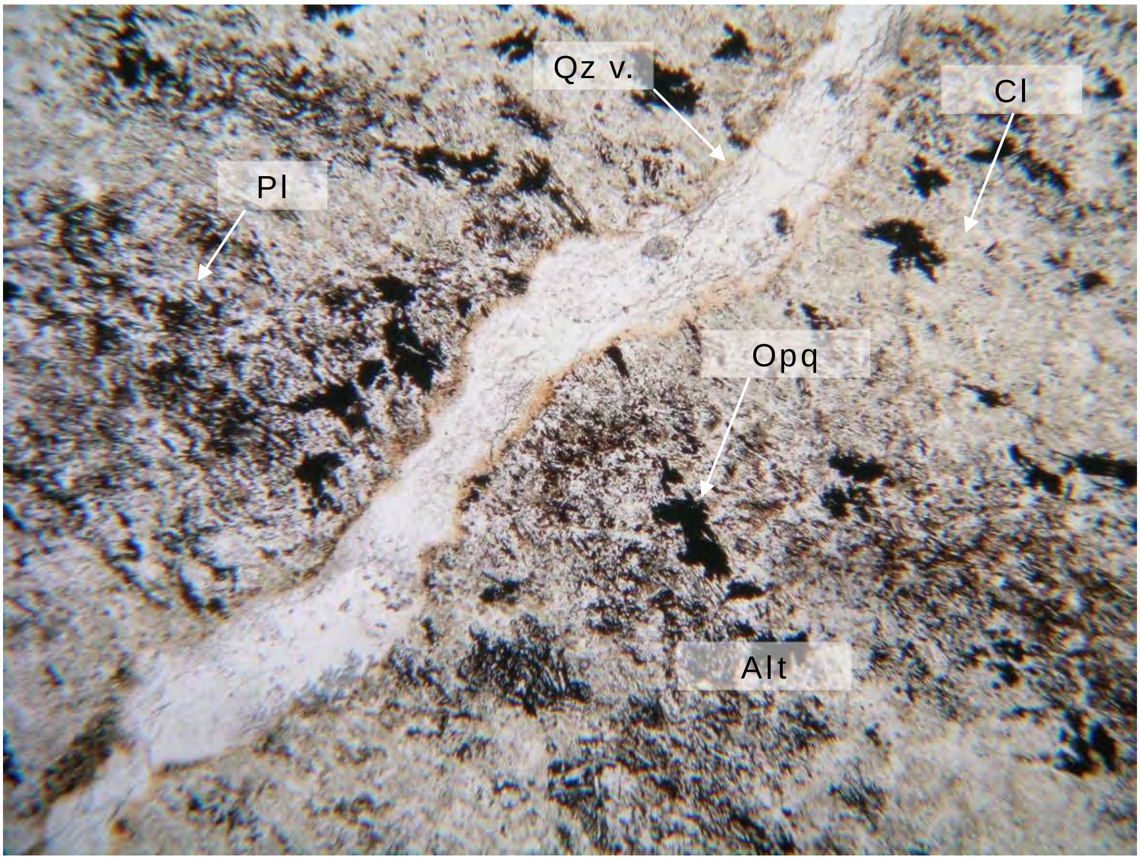

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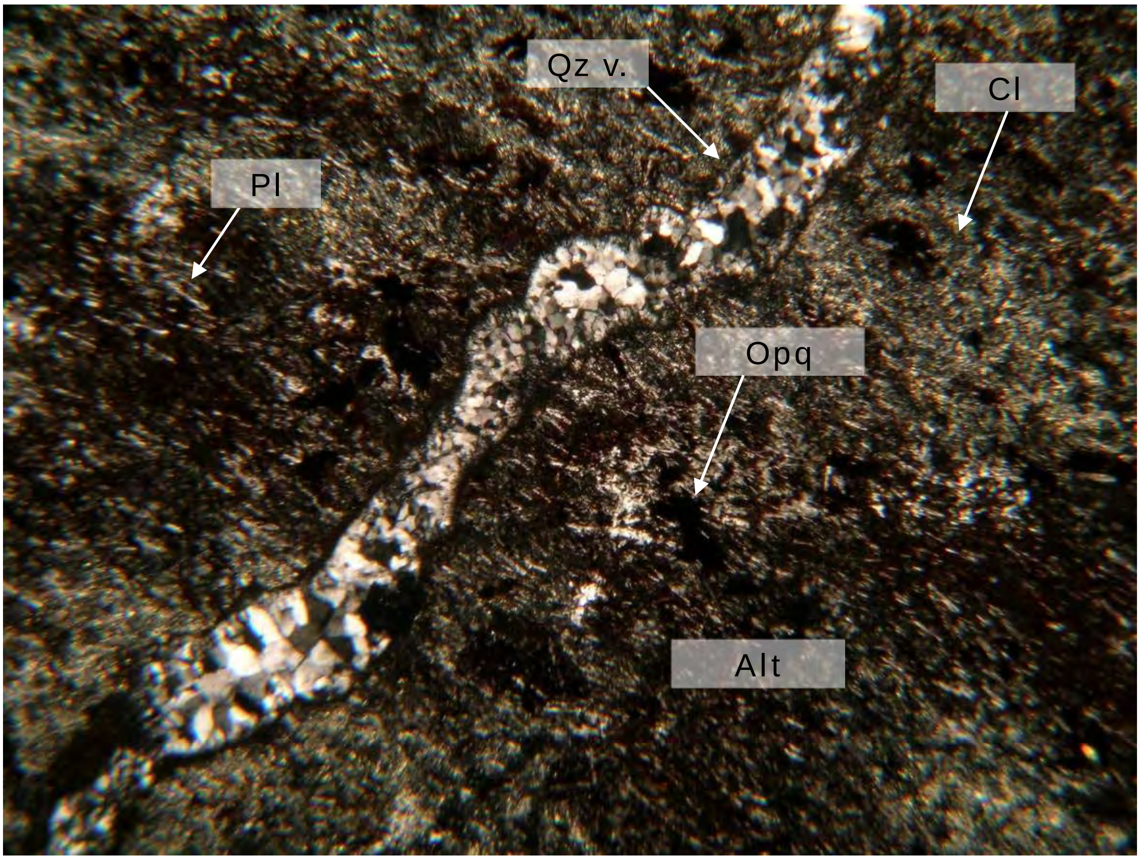

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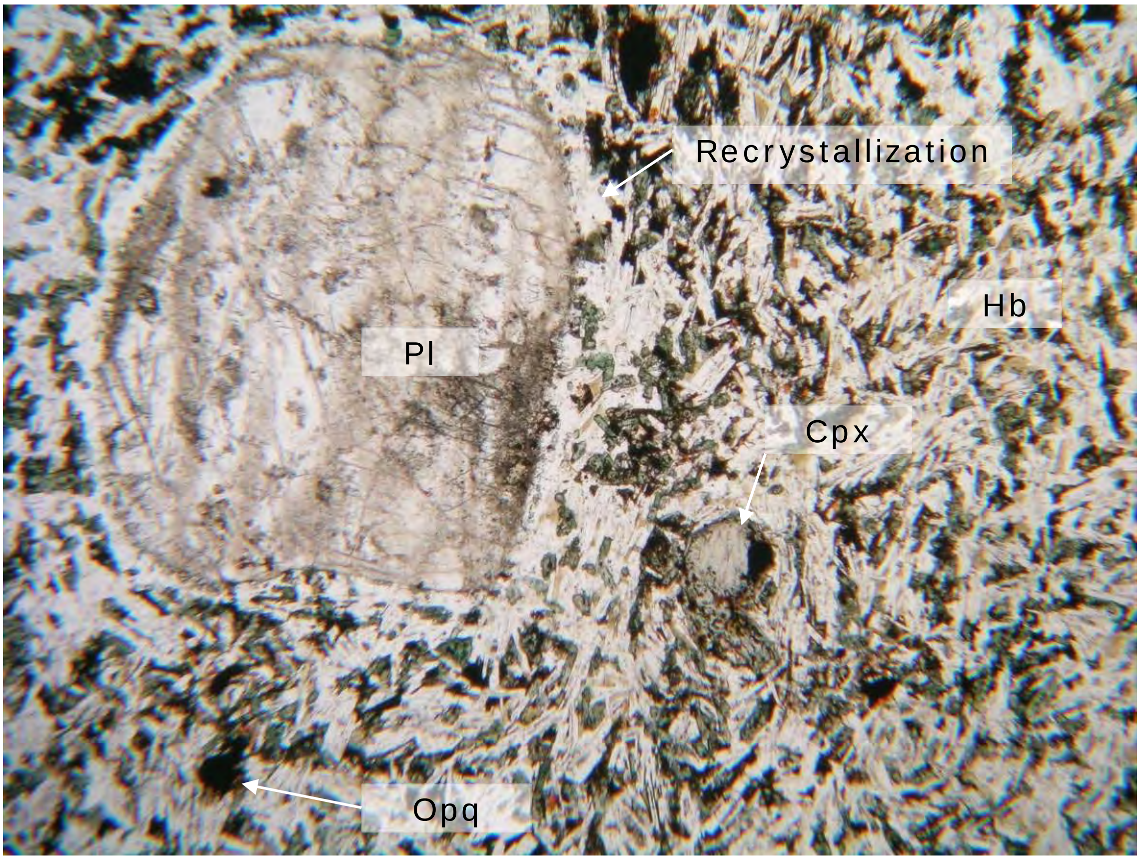

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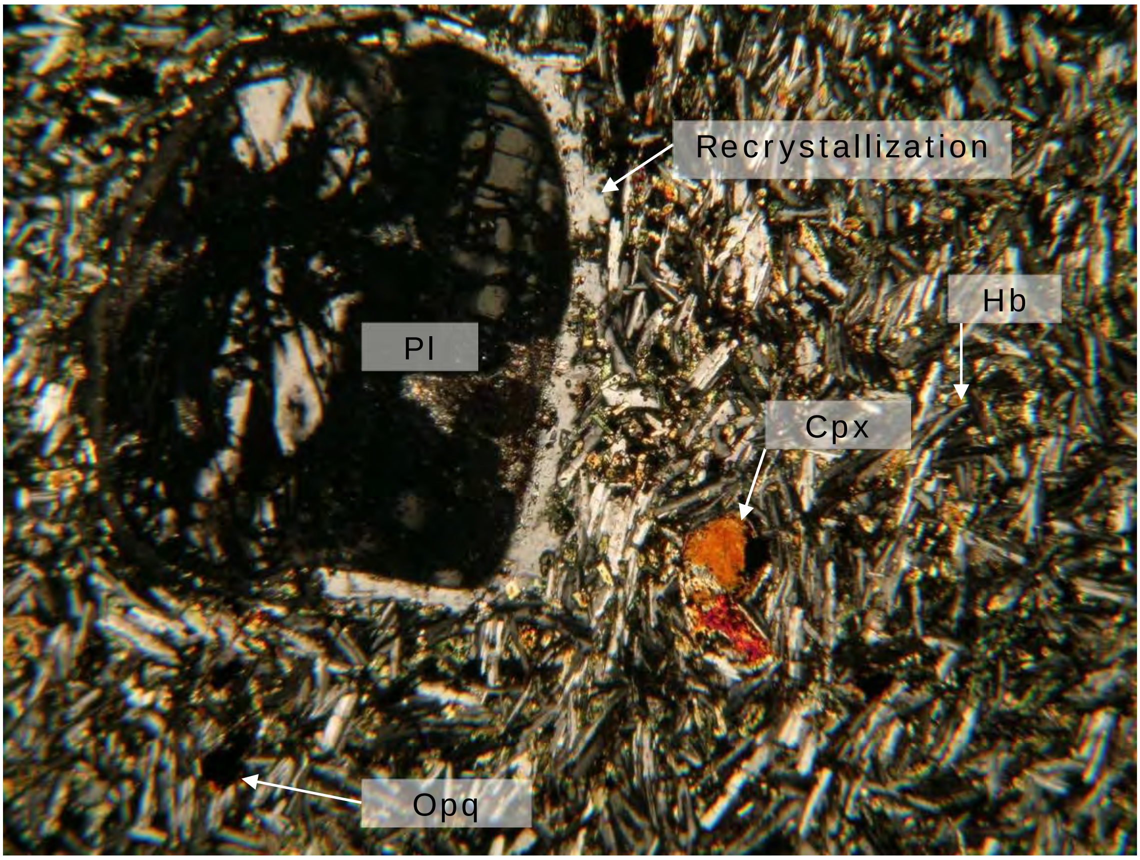

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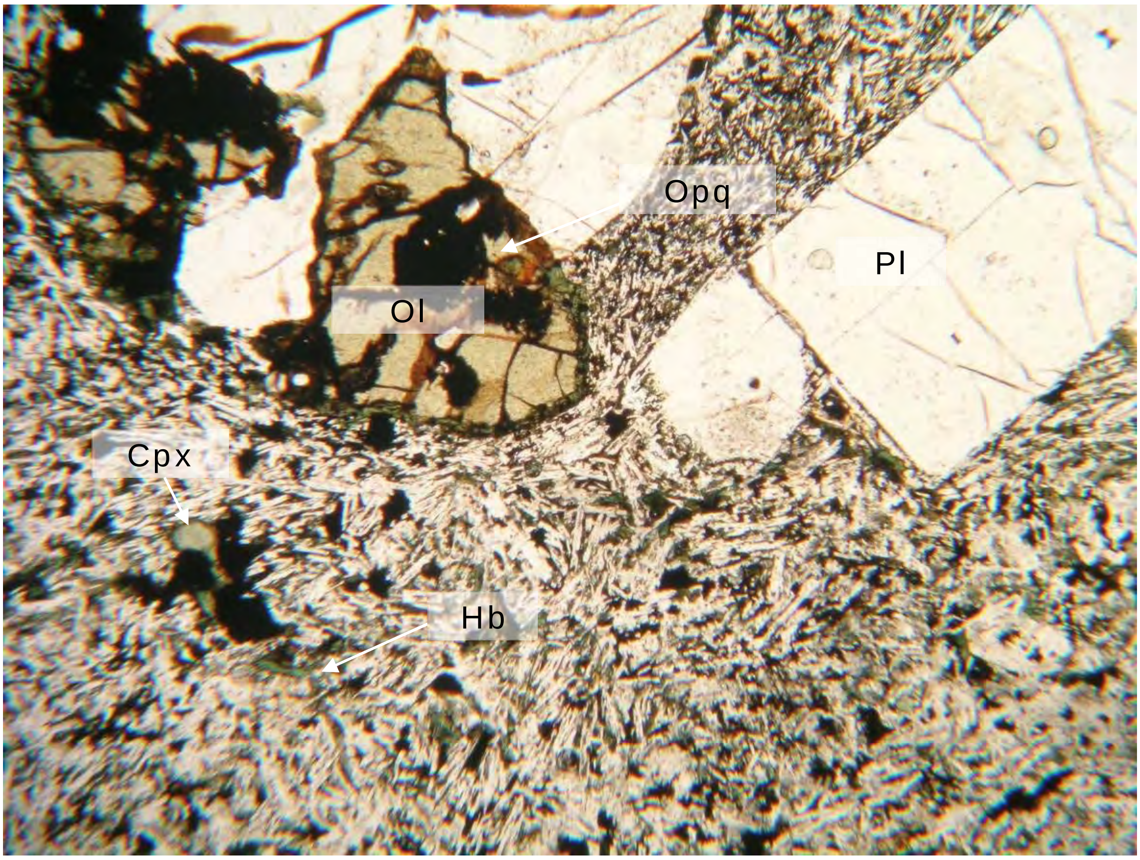

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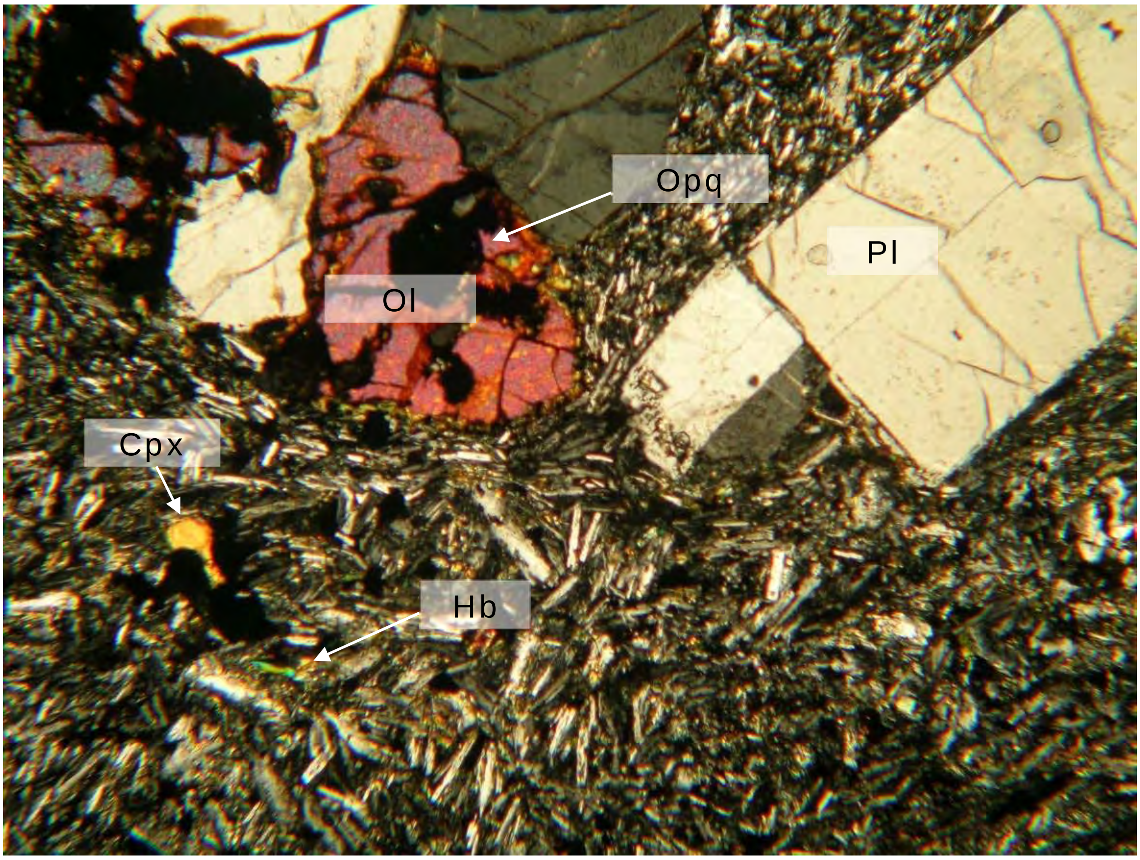
Plane-Polarized



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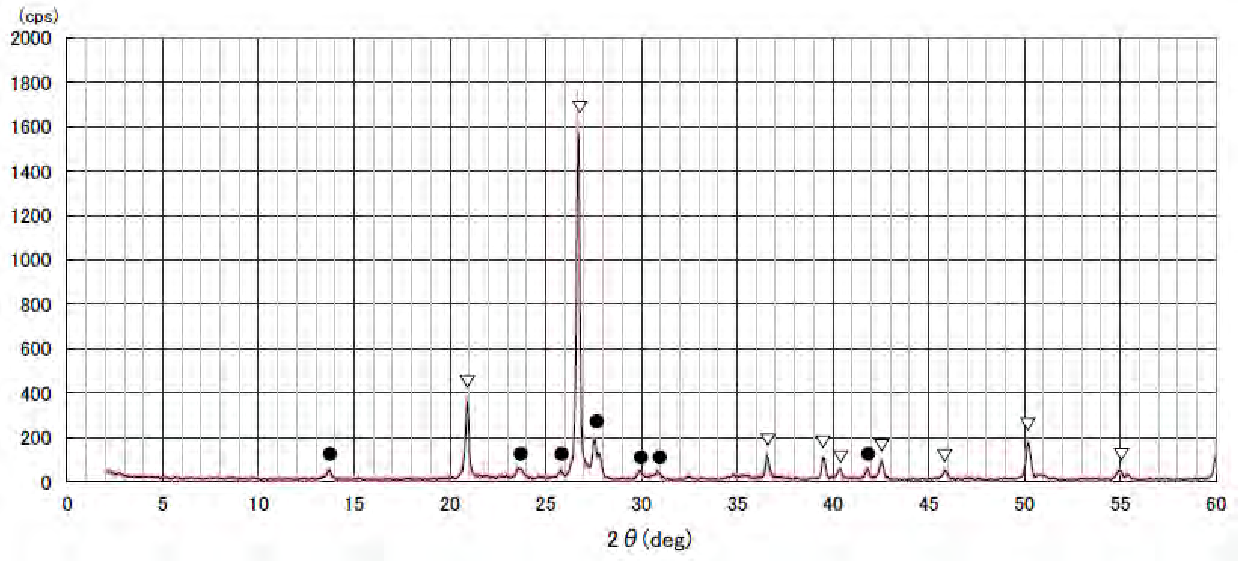
Cross-Polarized

APPENDIX

3. X-ray Diffraction Chart

2015052701-X

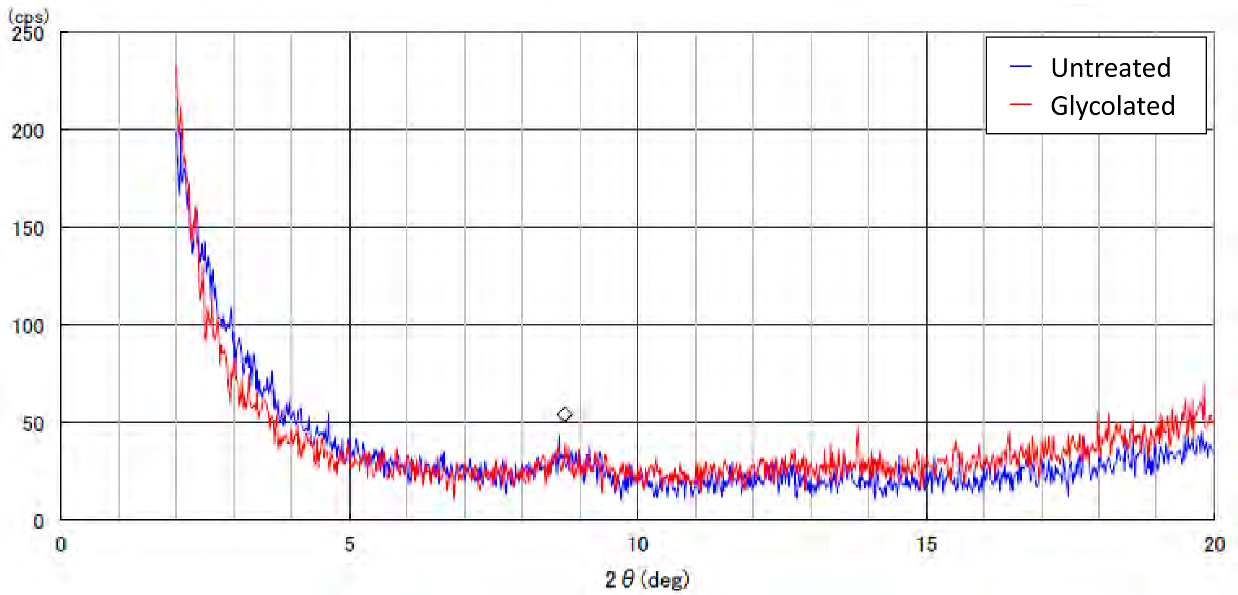
[Whole Rock]



Measurement data	: 2015/8/13	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

▽: Quartz ●: Feldspar

[Oriented]

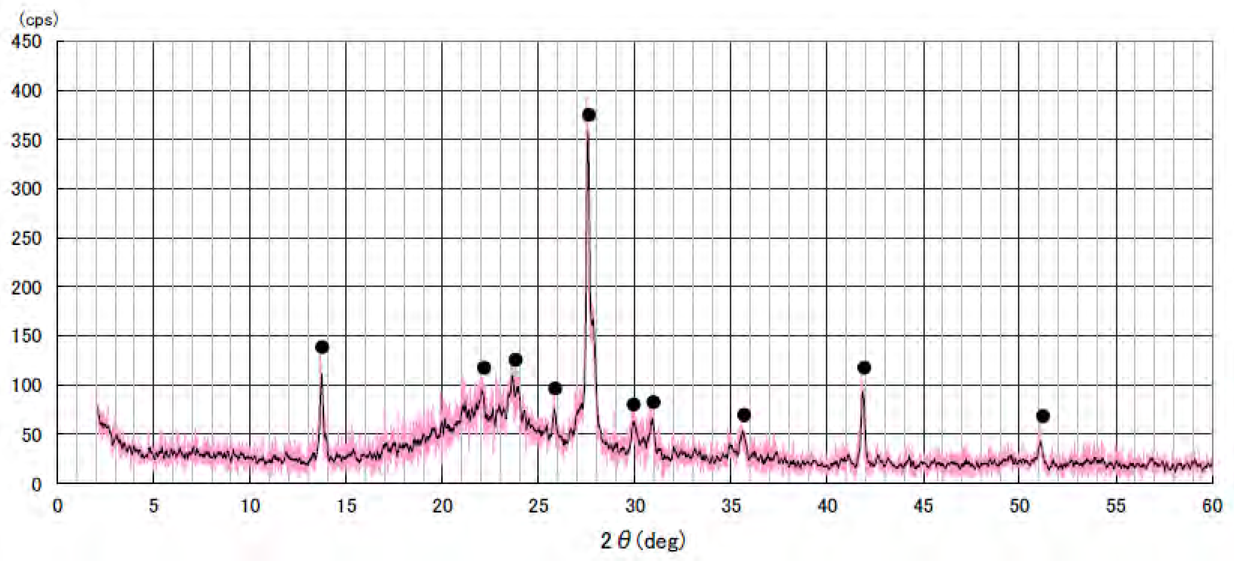


Measurement data	: 2015/8/13	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◇: Illite

2015052703-X

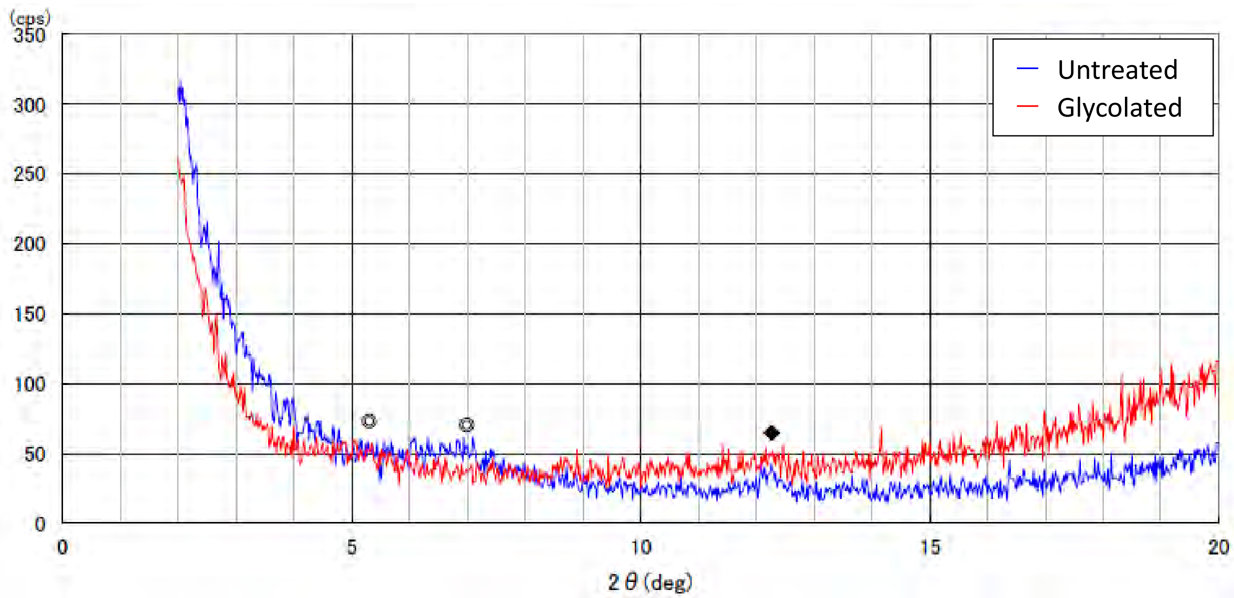
[Whole Rock]



Measurement data	: 2015/8/13	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar

[Oriented]

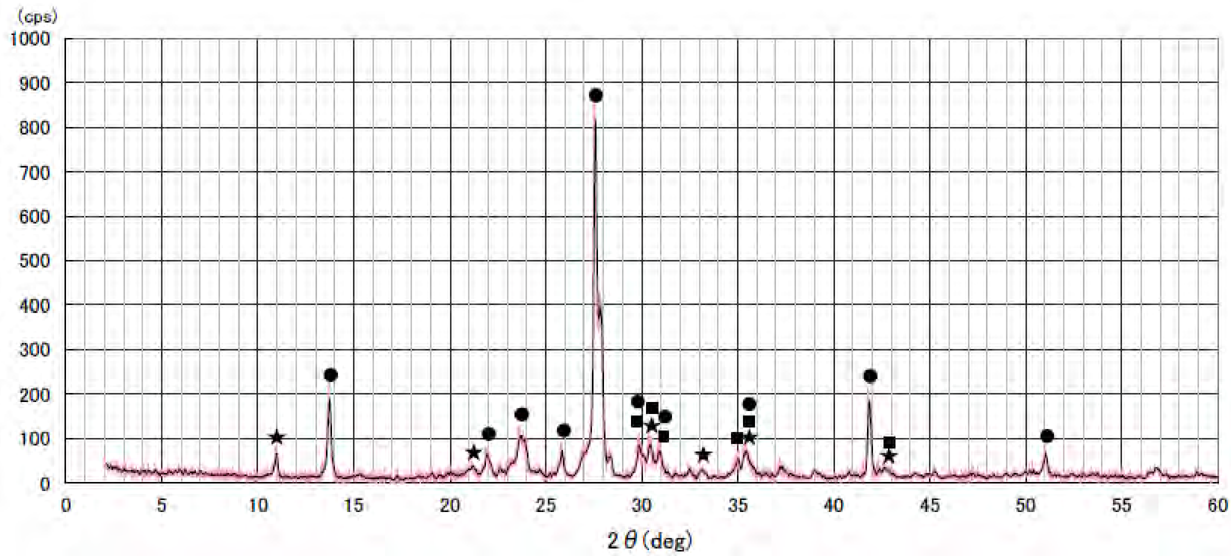


Measurement data	: 2015/8/13	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, ◎: Smectite

2015052704-X

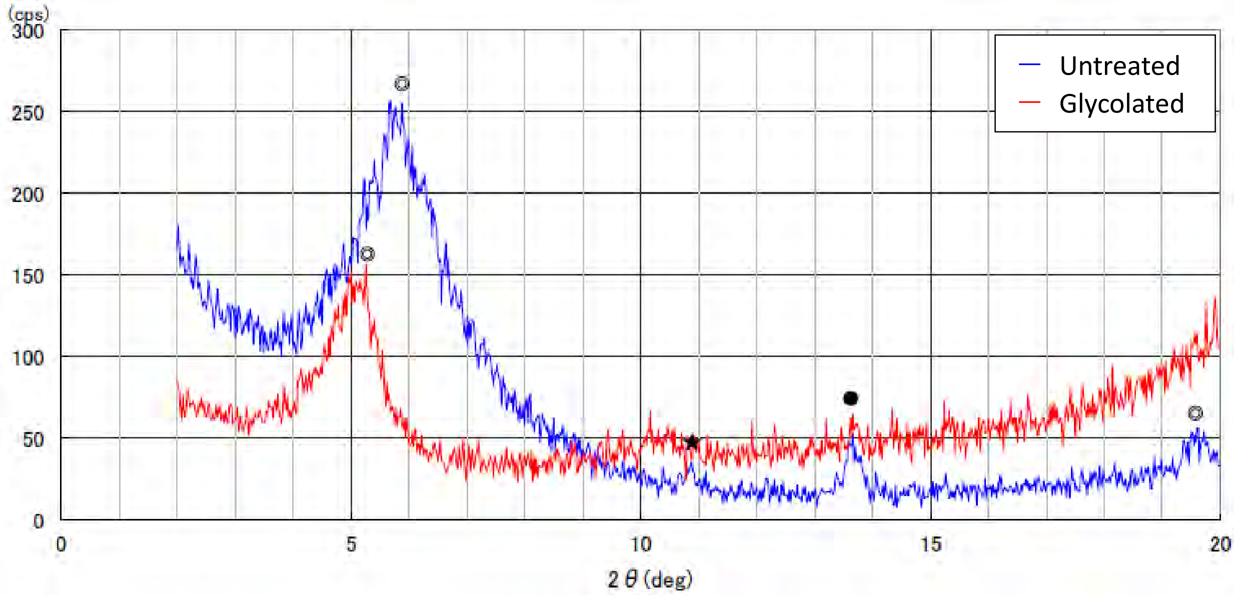
[Whole Rock]



Measurement data	: 2015/8/13	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2θ/θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ■: Clinopyroxene, ★: Aenigmite

[Oriented]

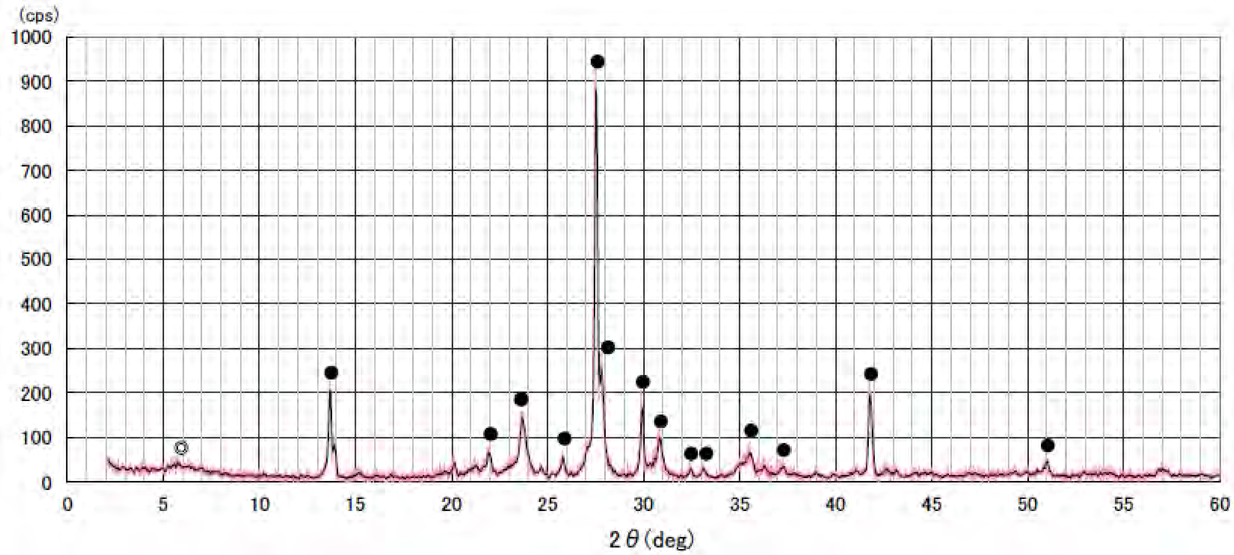


Measurement data	: 2015/8/13	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2θ/θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ◎: Smectite, ★: Aenigmite

2015052705-X

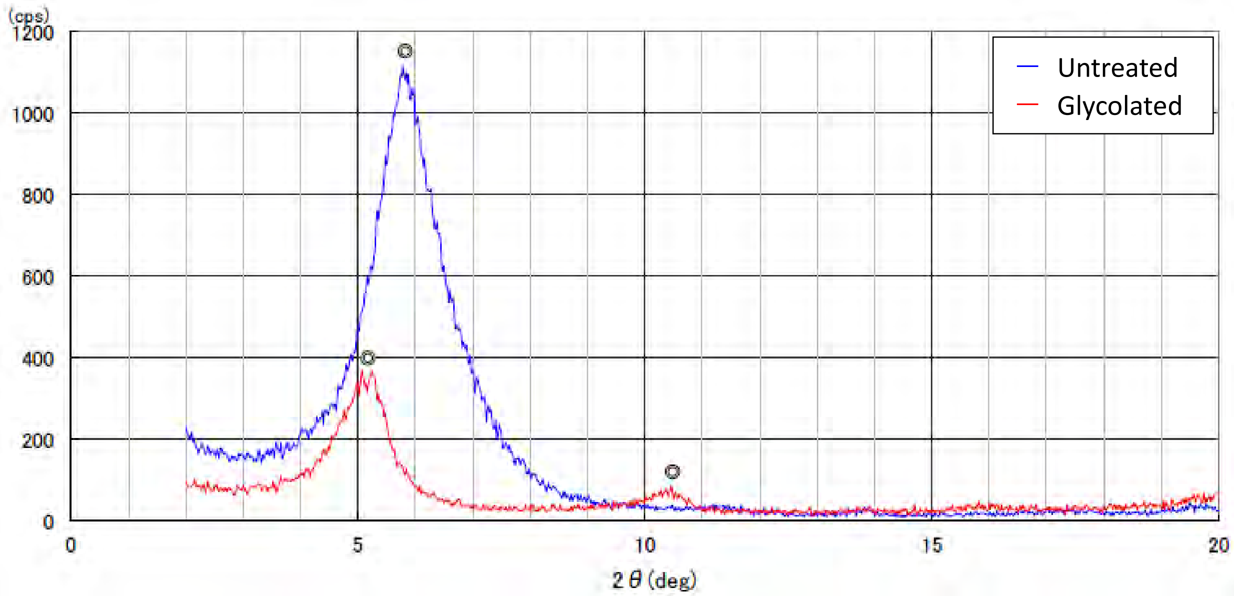
[Whole Rock]



Measurement data : 2015/8/13
Incident X-ray : CuK α /30kV/15mA
Divergence slit : 5/8°
Emission slit : 0.3mm
Scattering slit : 5/4°
●: Feldspar, ◎: Smectite

Scan speed : 2.0° /min
Sampling width : 0.01°
Scan axis : 2θ / θ
Scanning range :2.00～40.00°

[Oriented]

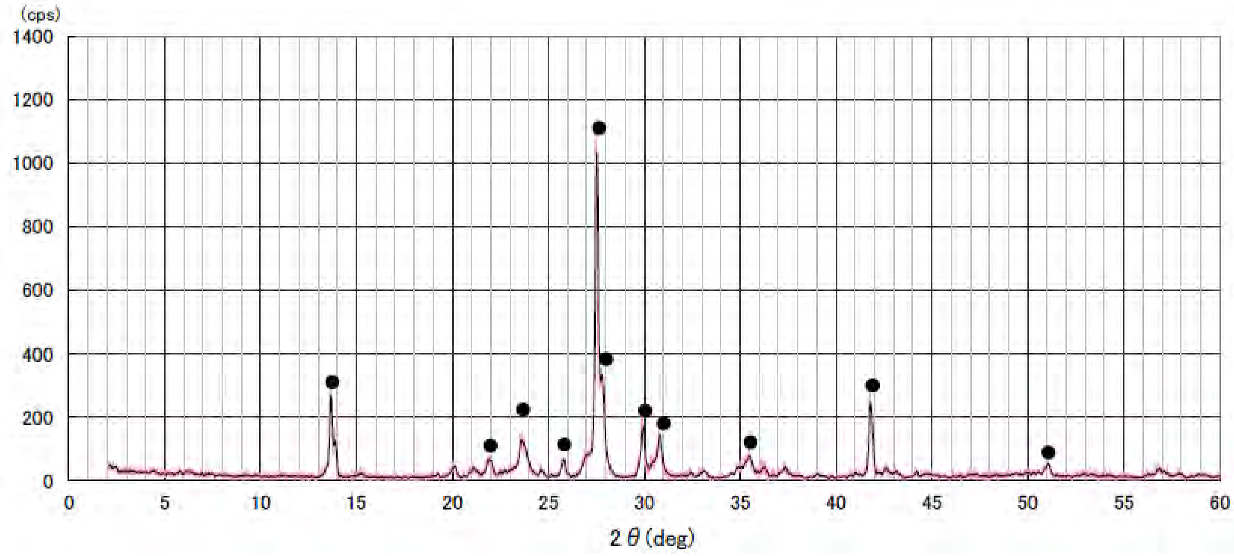


Measurement data : 2015/8/13
Incident X-ray : CuK α /30kV/15mA
Divergence slit : 5/8°
Emission slit : 0.3mm
Scattering slit : 5/4°
◎: Smectite

Scan speed : 2.0° /min
Sampling width : 0.01°
Scan axis : 2θ / θ
Scanning range :2.00～40.00°

2015052706-X

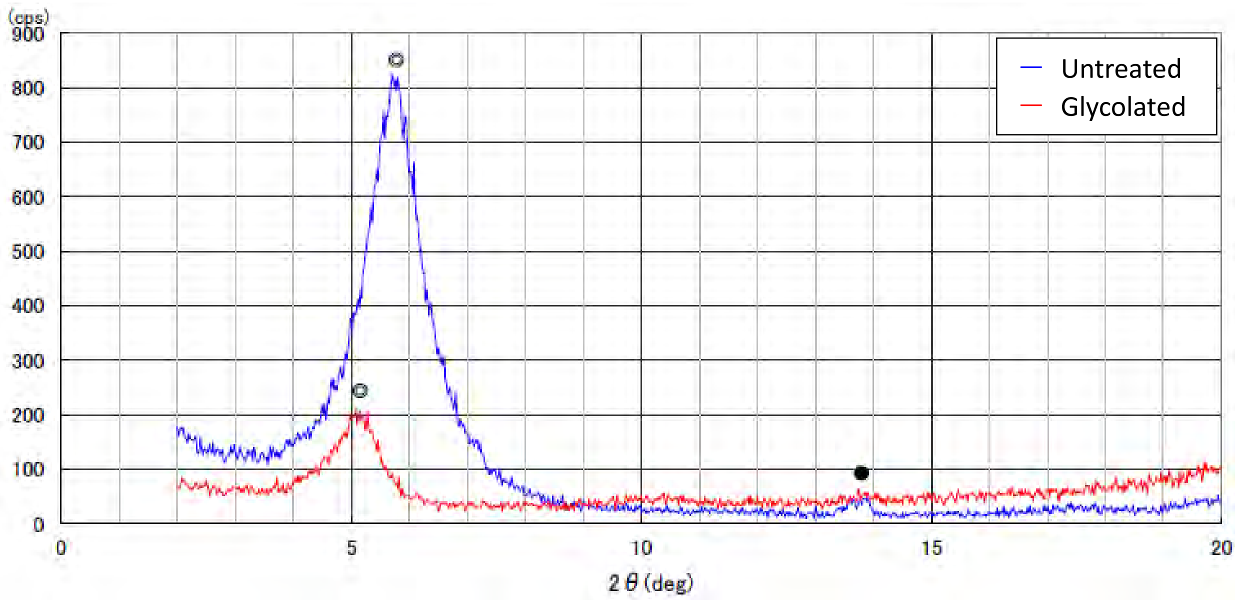
[Whole Rock]



Measurement data	: 2015/8/14	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar

[Oriented]

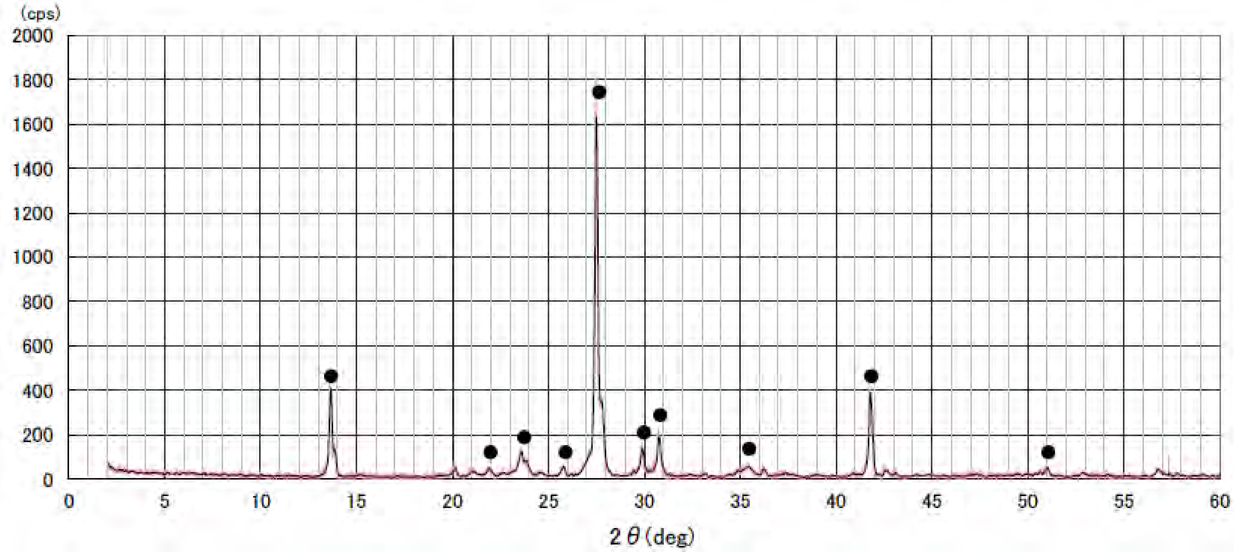


Measurement data	: 2015/8/14	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ◎: Smectite

2015052707-X

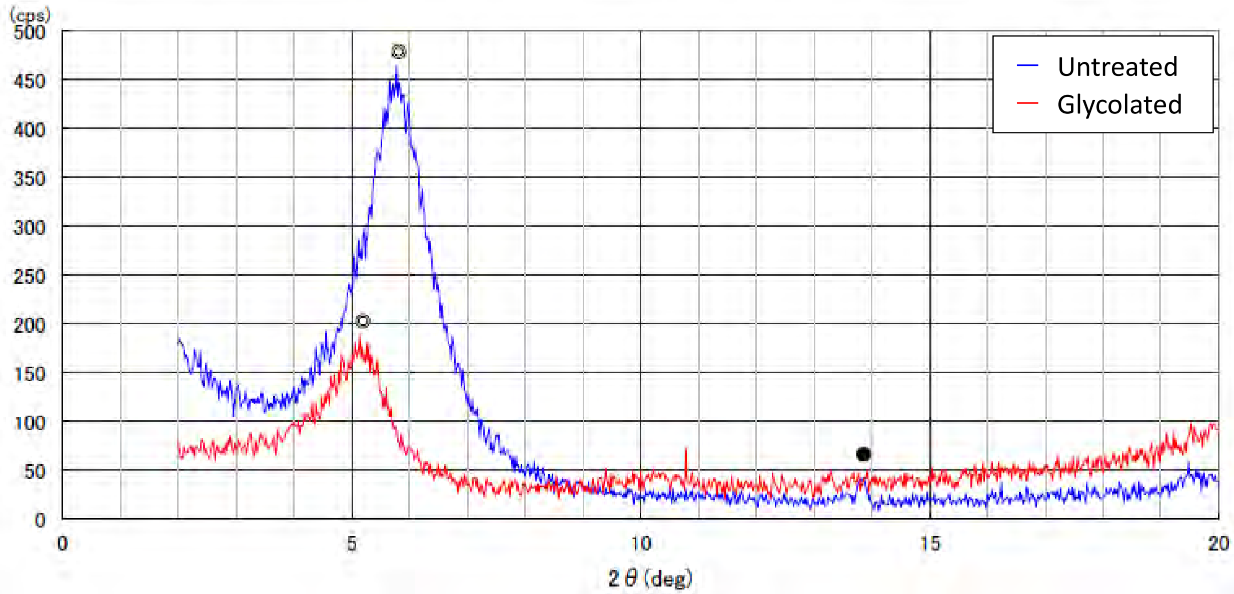
[Whole Rock]



Measurement data	: 2015/8/14	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar

[Oriented]

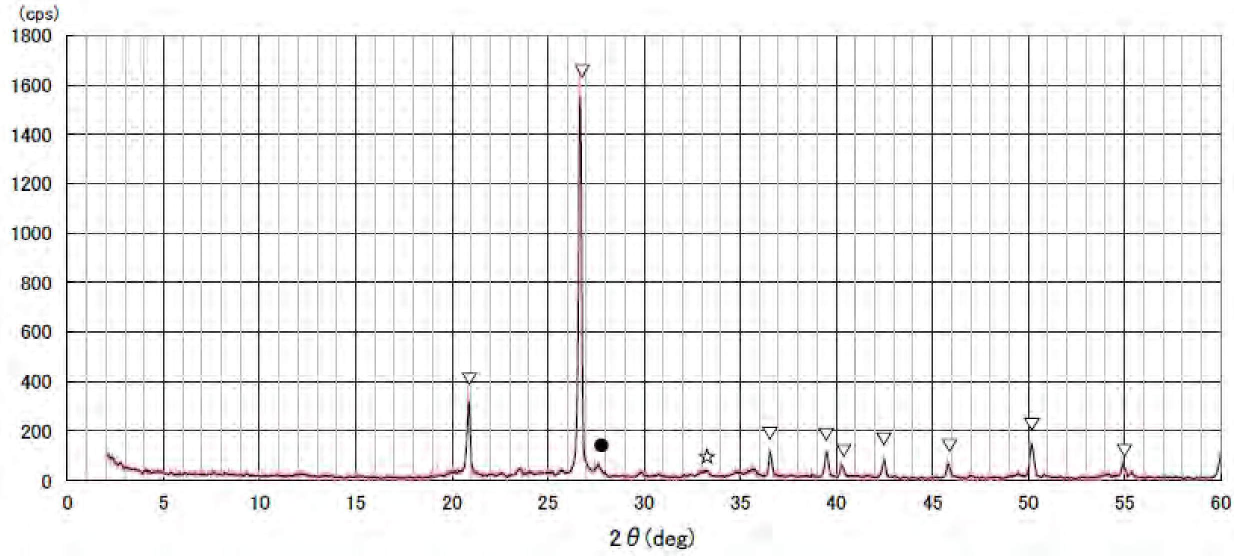


Measurement data	: 2015/8/14	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ◎: Smectite

2015052801-X

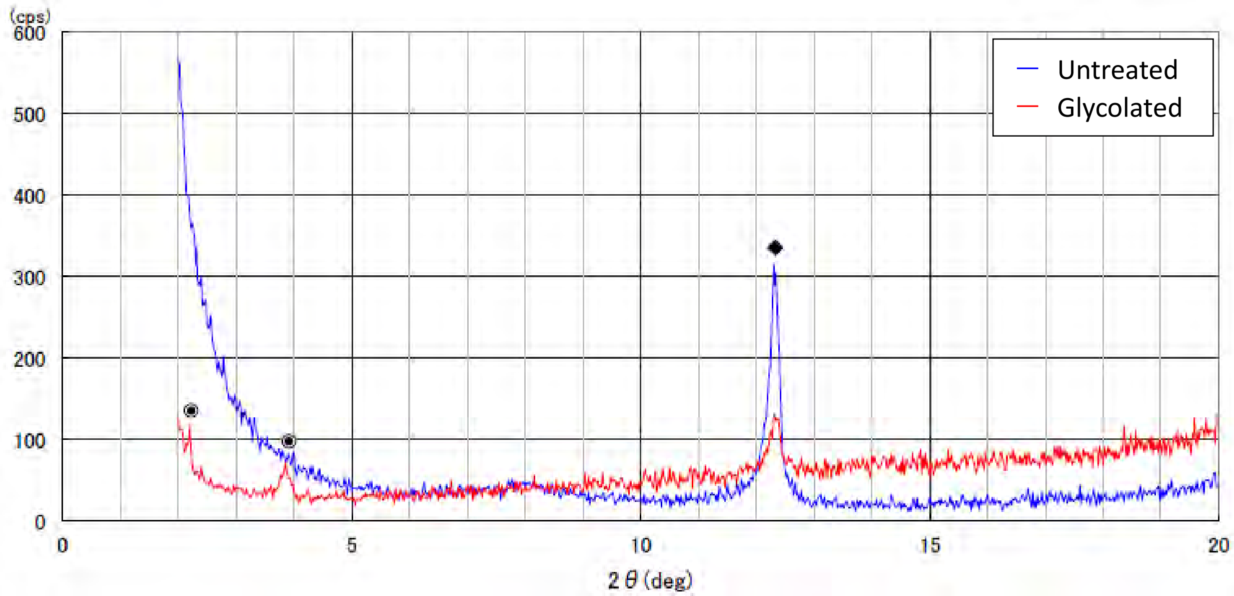
[Whole Rock]



Measurement data	: 2015/8/14	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2θ/θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

▽: Quartz, ●: Feldspar, ☆: Pyrite

[Oriented]

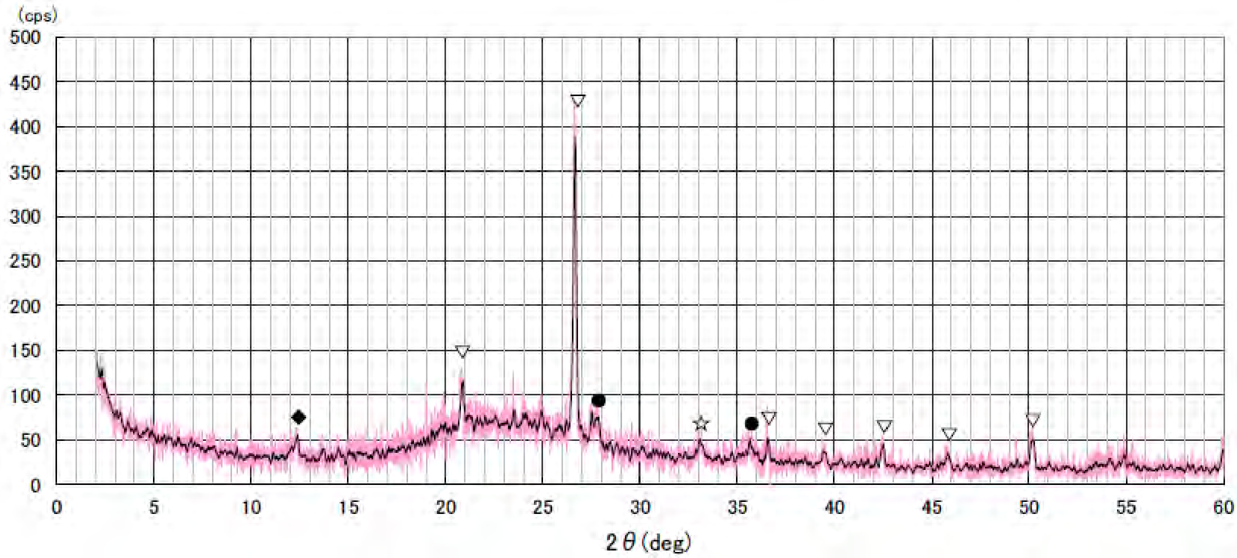


Measurement data	: 2015/8/14	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2θ/θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, ◎: Mixed Layer

2015052802-X

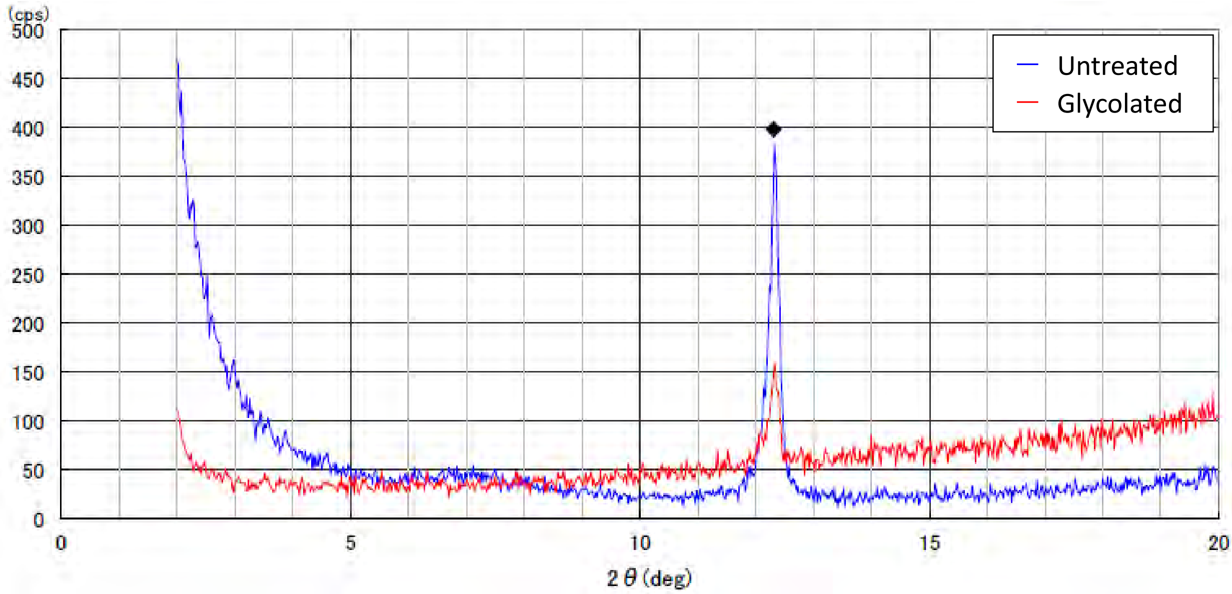
[Whole Rock]



Measurement data	: 2015/8/14	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

▽: Quartz, ●: Feldspar, ◆: Kaolinite, ☆: Pyrite

[Oriented]

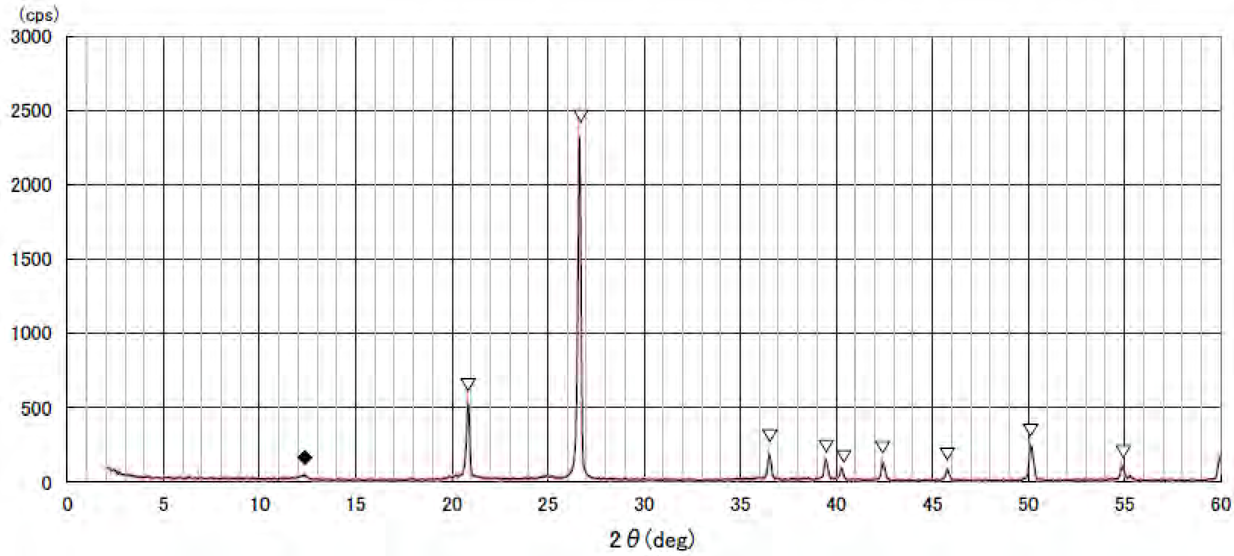


Measurement data	: 2015/8/14	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite

2015052803-X

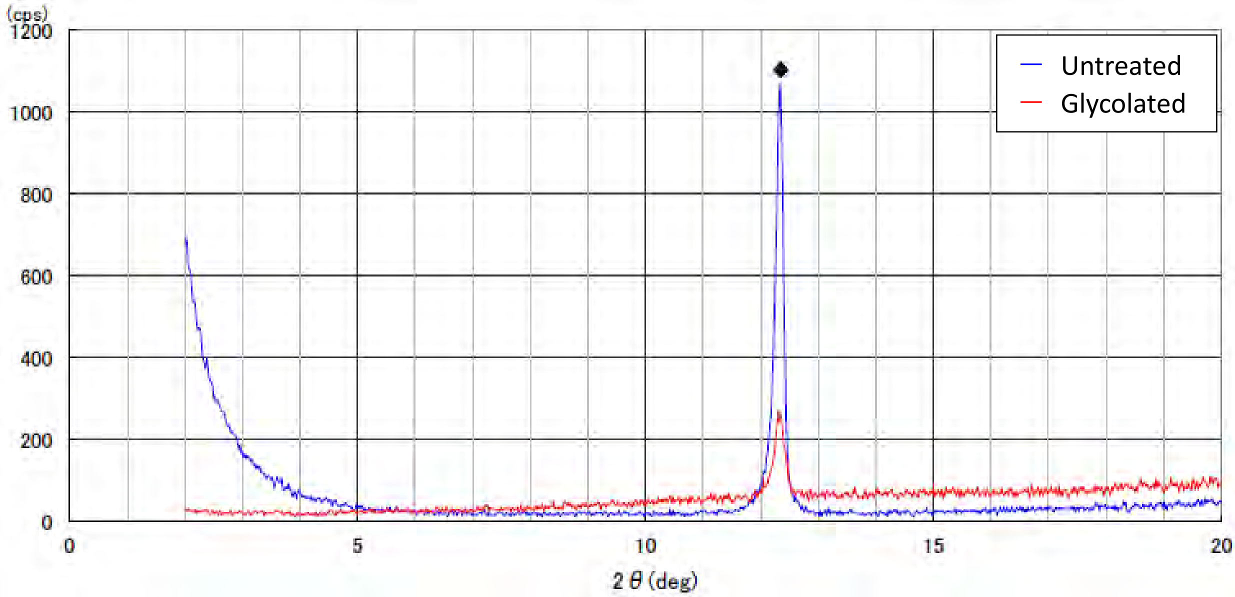
[Whole Rock]



Measurement data	: 2015/8/14	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

▽: Quartz, ◆: Kaolinite

[Oriented]

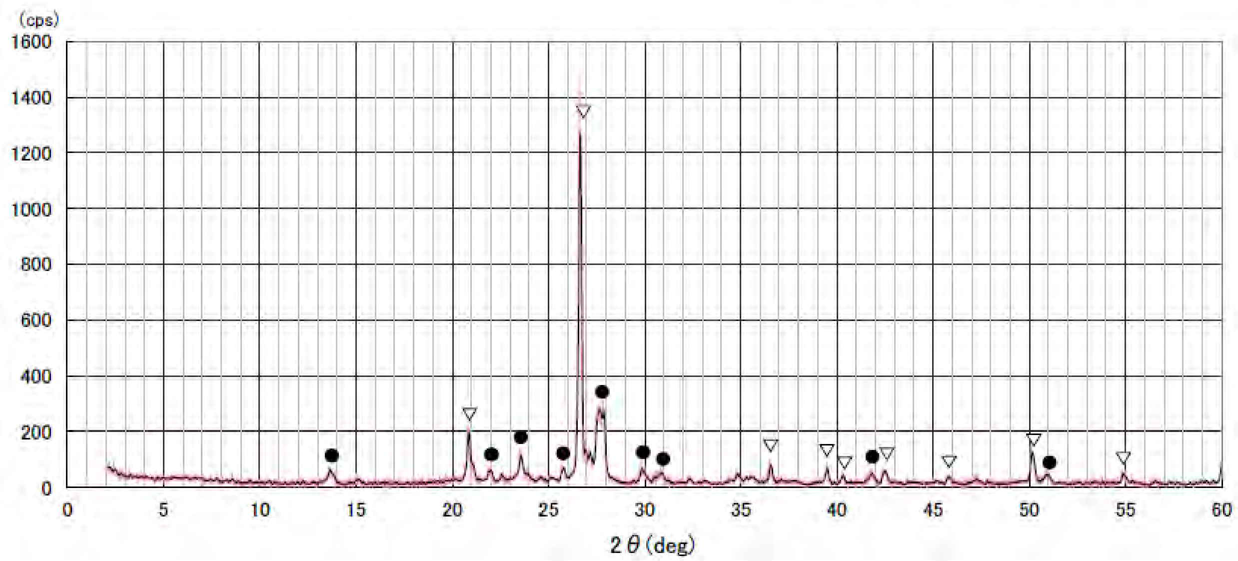


Measurement data	: 2015/8/14	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite

2015052804-X

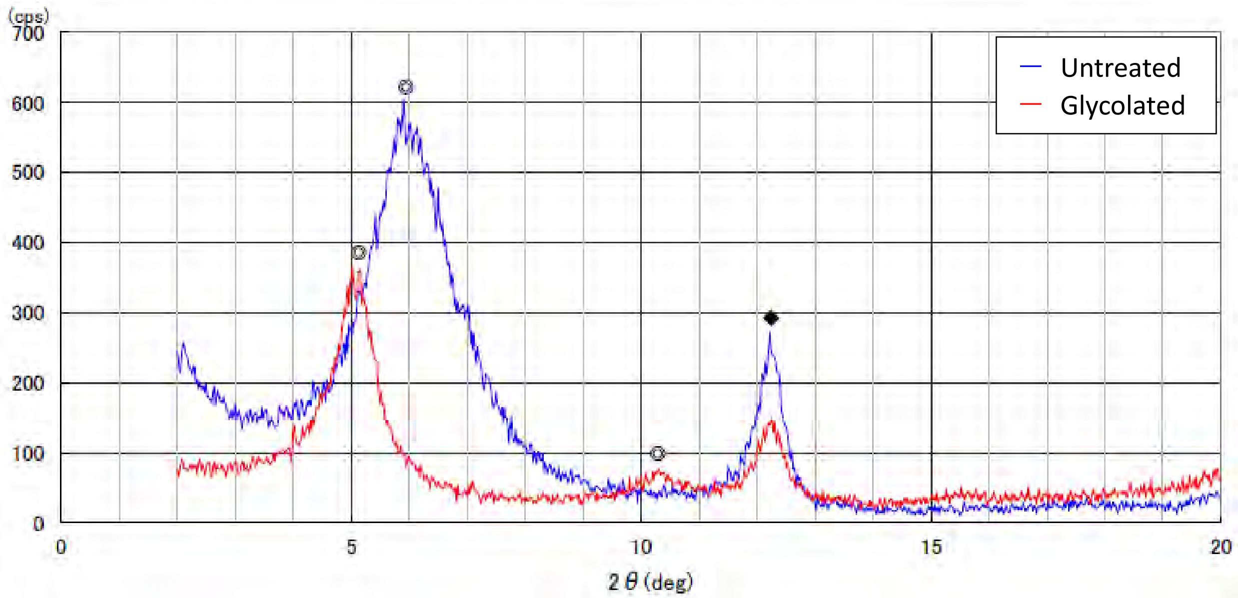
[Whole Rock]



Measurement data	: 2015/8/14	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

▽: Quartz, ◆: Kaolinite

[Oriented]

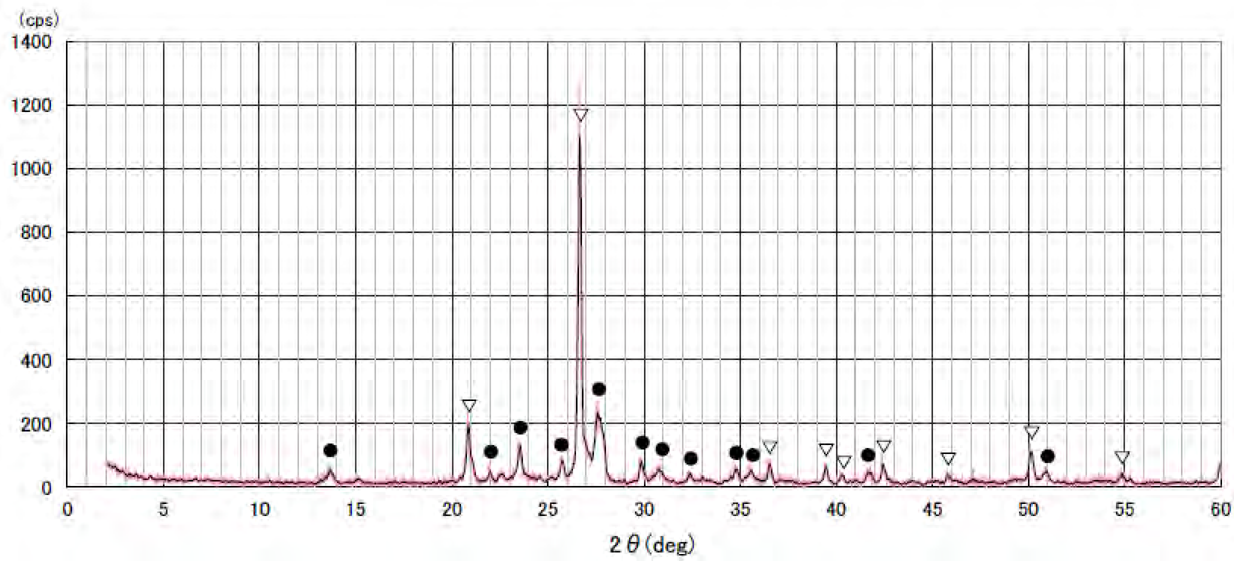


Measurement data	: 2015/8/14	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, ◎: Smectite

2015052805-X

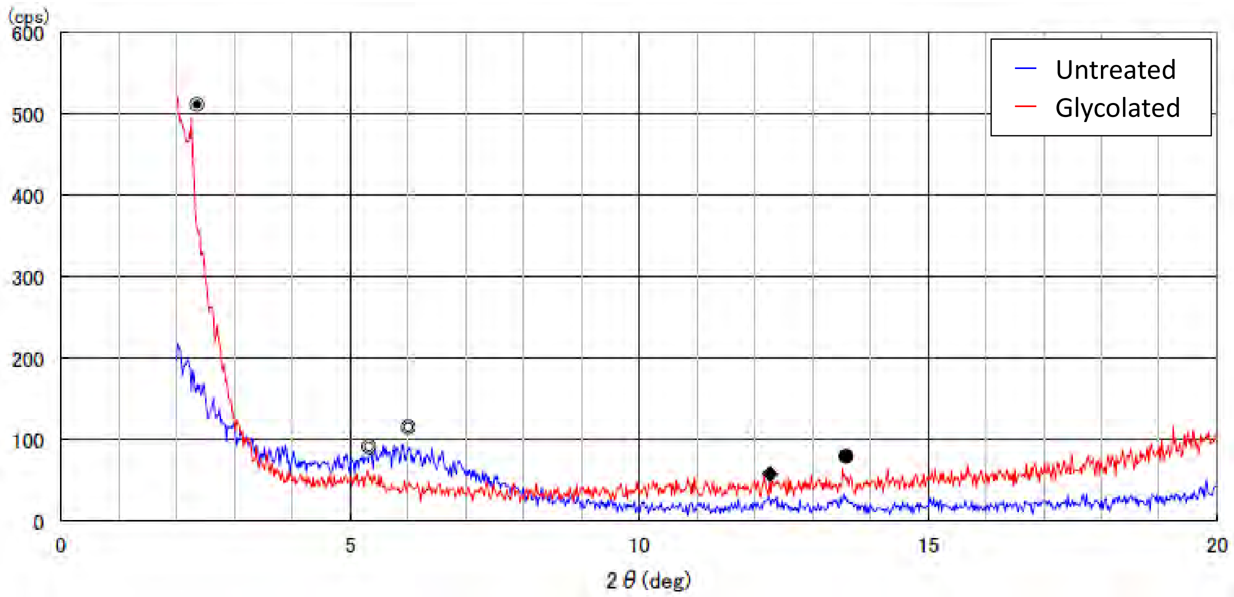
[Whole Rock]



Measurement data	: 2015/8/17	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

▽: Quartz, ●: Feldspar

[Oriented]

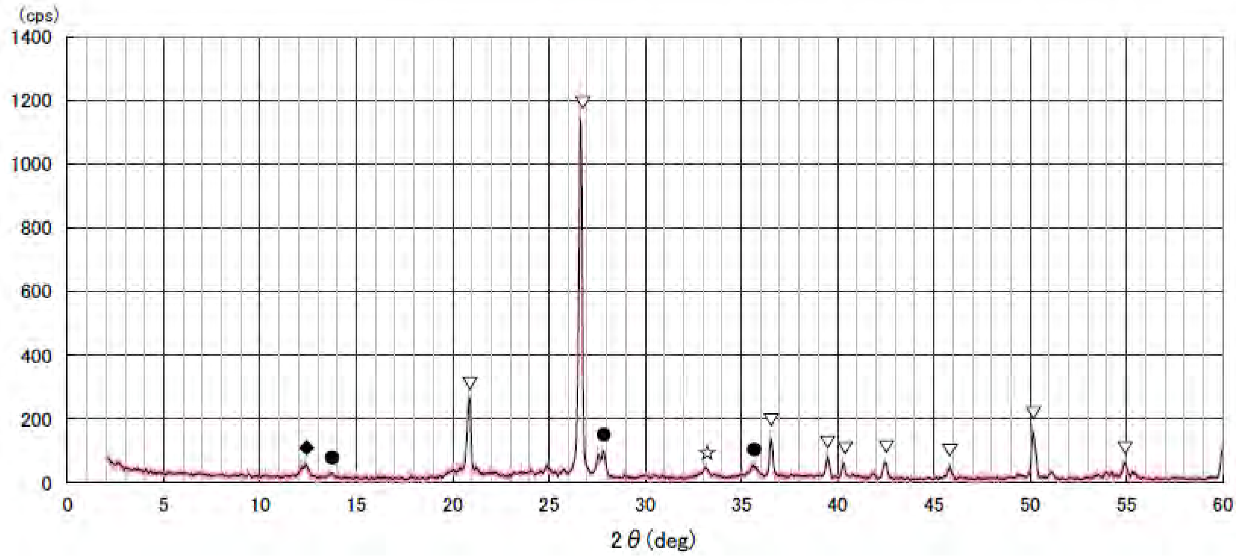


Measurement data	: 2015/8/17	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ◆: Kaolinite, ◎: Smectite, ◎: Mixed Layer

2015052806-X

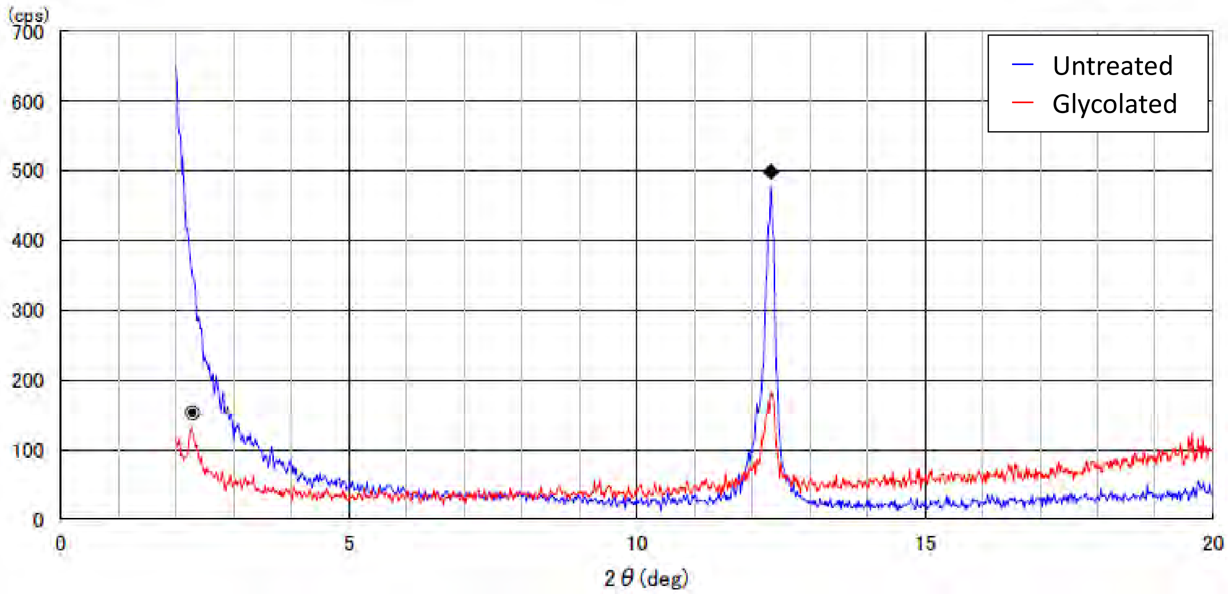
[Whole Rock]



Measurement data	: 2015/8/17	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

▽: Quartz, ●: Feldspar, ◆: Kaolinite, ☆: Pyrite

[Oriented]

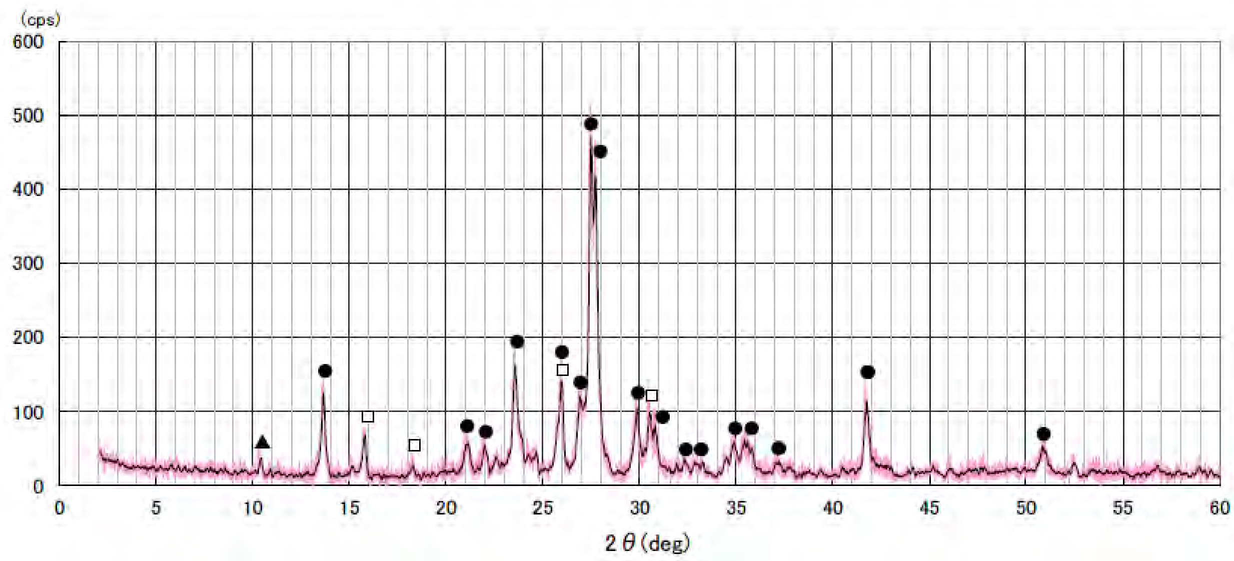


Measurement data	: 2015/8/17	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, ◎: Mixed Layer

2015052807-X

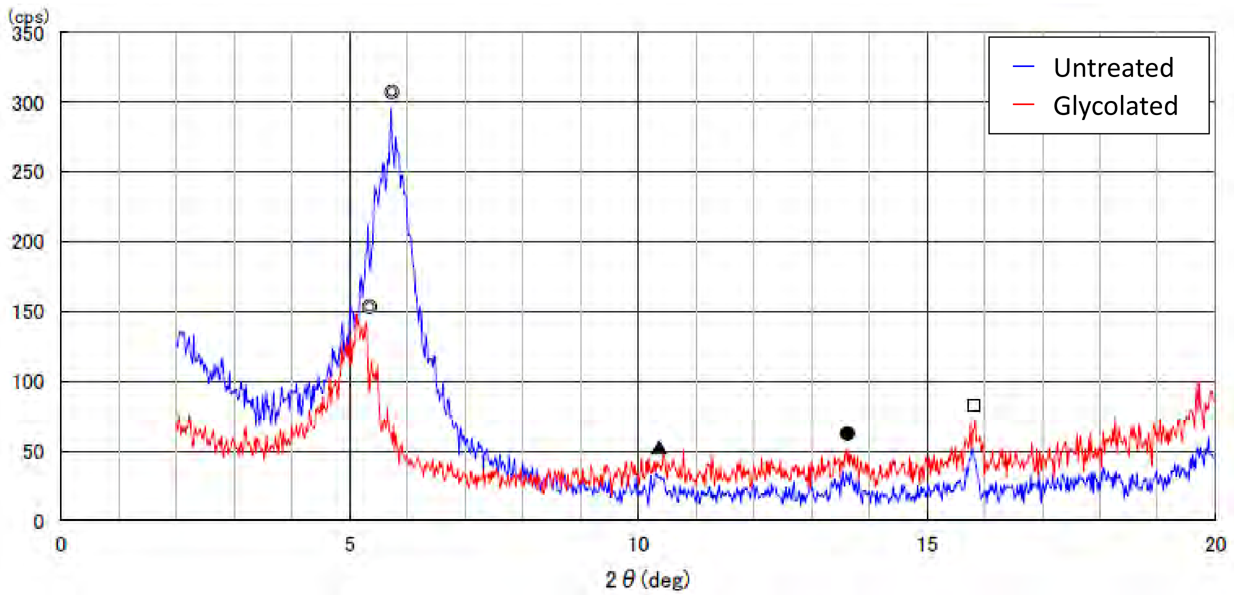
[Whole Rock]



Measurement data	: 2015/8/17	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ▲: Hornblende, □: Analcime

[Oriented]

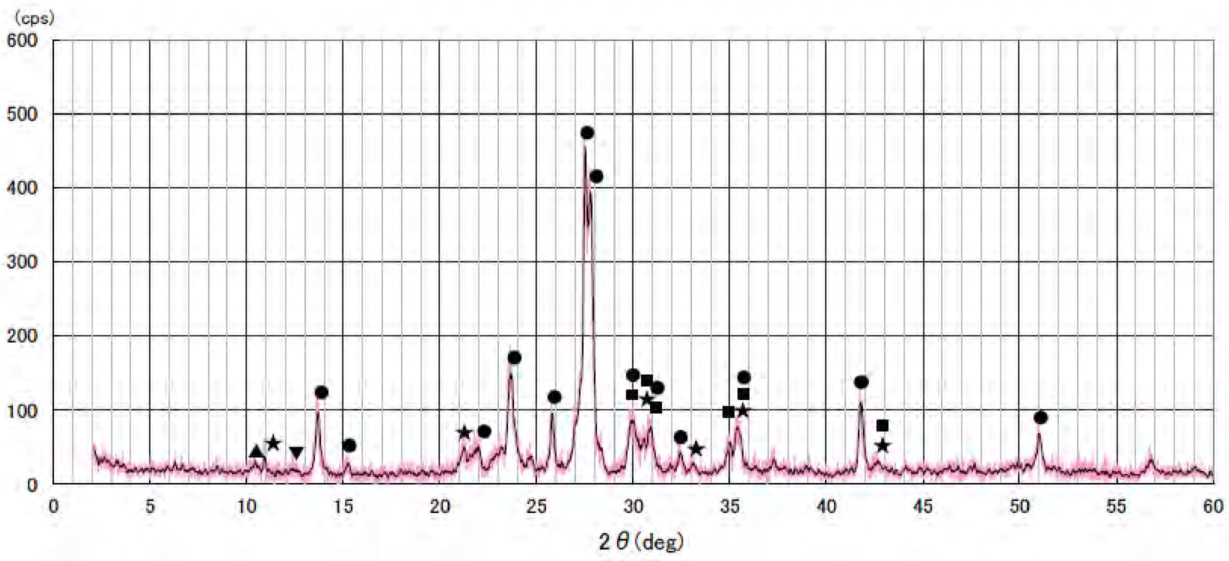


Measurement data	: 2015/8/17	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ▲: Hornblende, □: Analcime, ◎: Smectite

2015052901-X

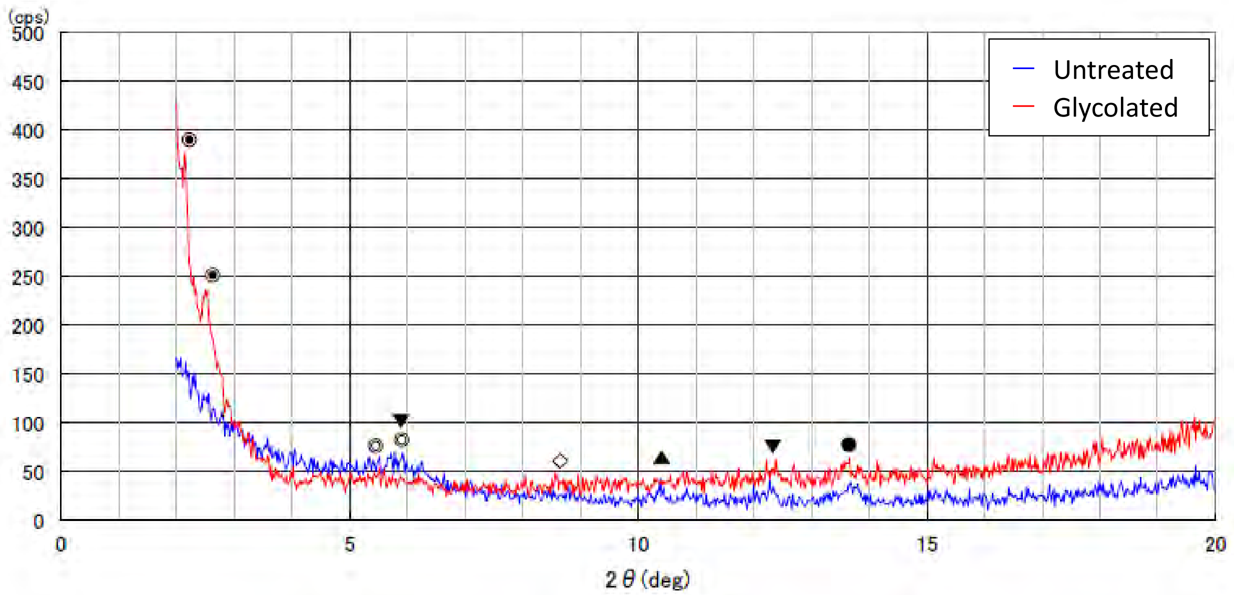
[Whole Rock]



Measurement data	: 2015/8/17	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ▲: Hornblende, ■: Clinopyroxene, ★: Aenigmite, ▼: Chlorite

[Oriented]

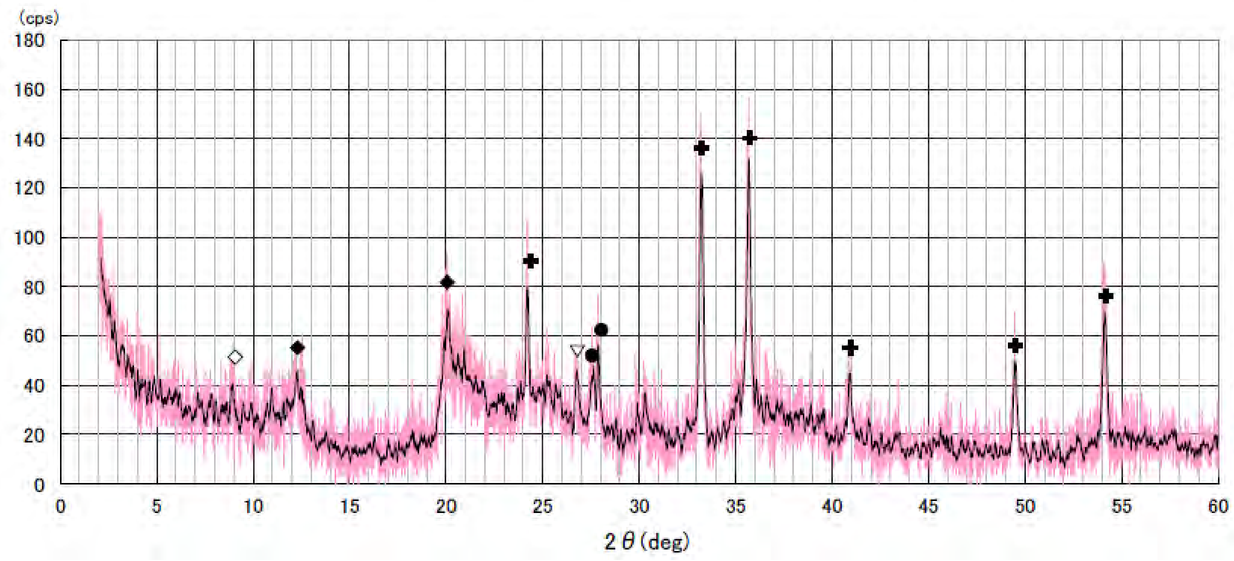


Measurement data	: 2015/8/17	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ▲: Hornblende, ◇: Illite, ▼: Chlorite, ◎: Smectite, ◎: Mix Layer

2015053001-X

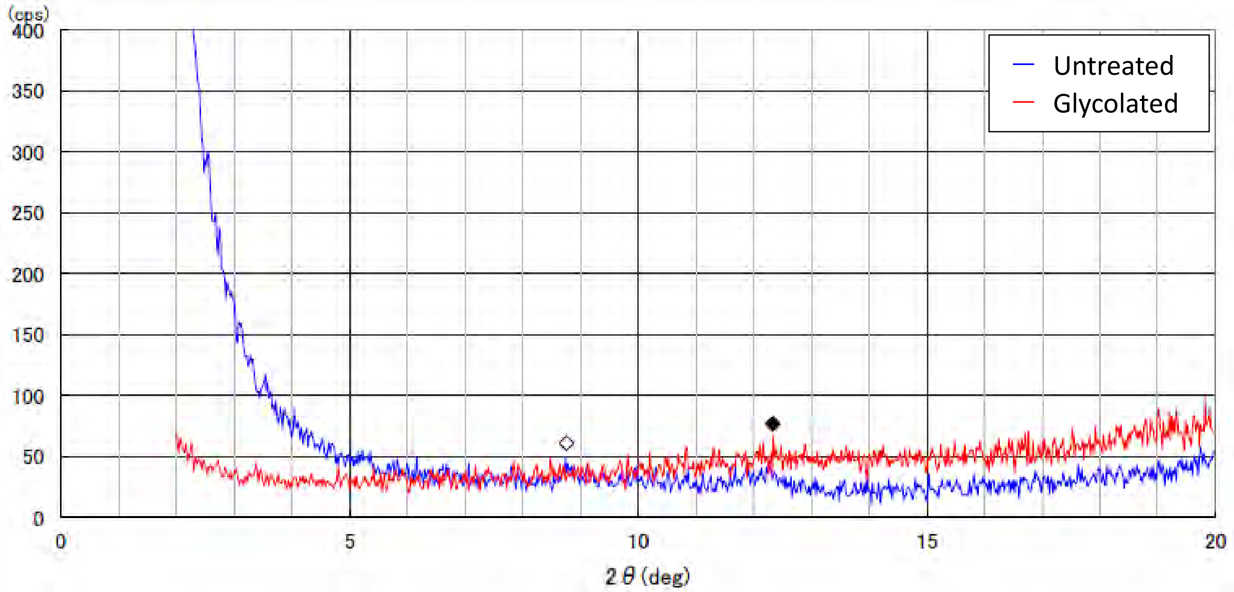
[Whole Rock]



Measurement data	: 2015/8/17	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2θ/θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

▽: Quartz, ●: Feldspar, ◇: Mica, ◆: Kaolinite, ＋: Ilmenite

[Oriented]

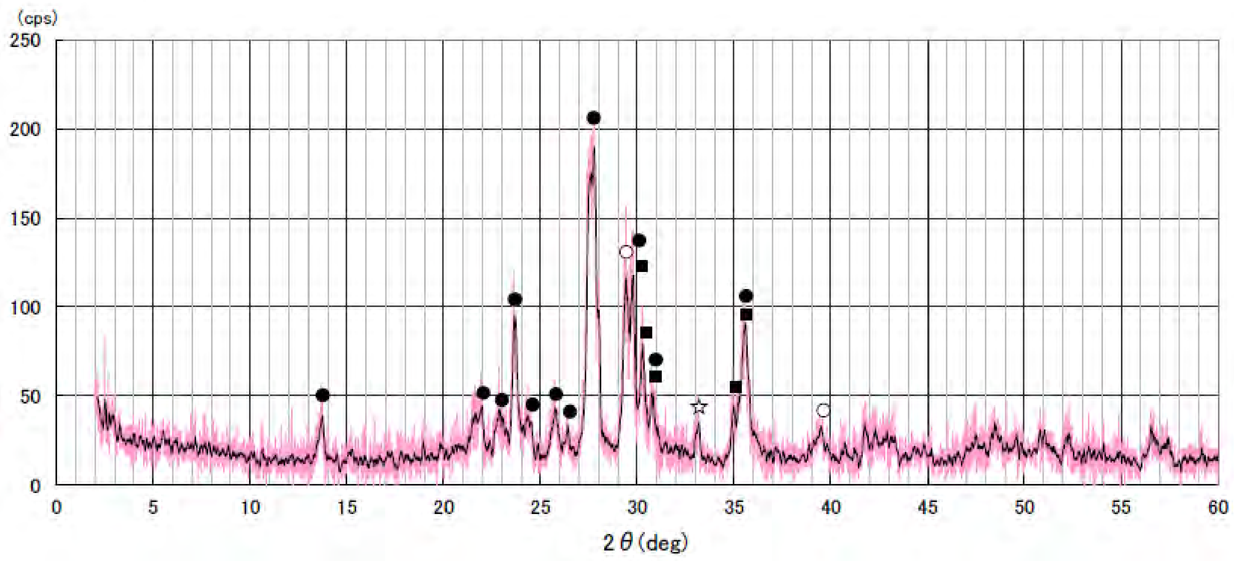


Measurement data	: 2015/8/17	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2θ/θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◇: Illite, ◆: Kaolinite

2015053003-X

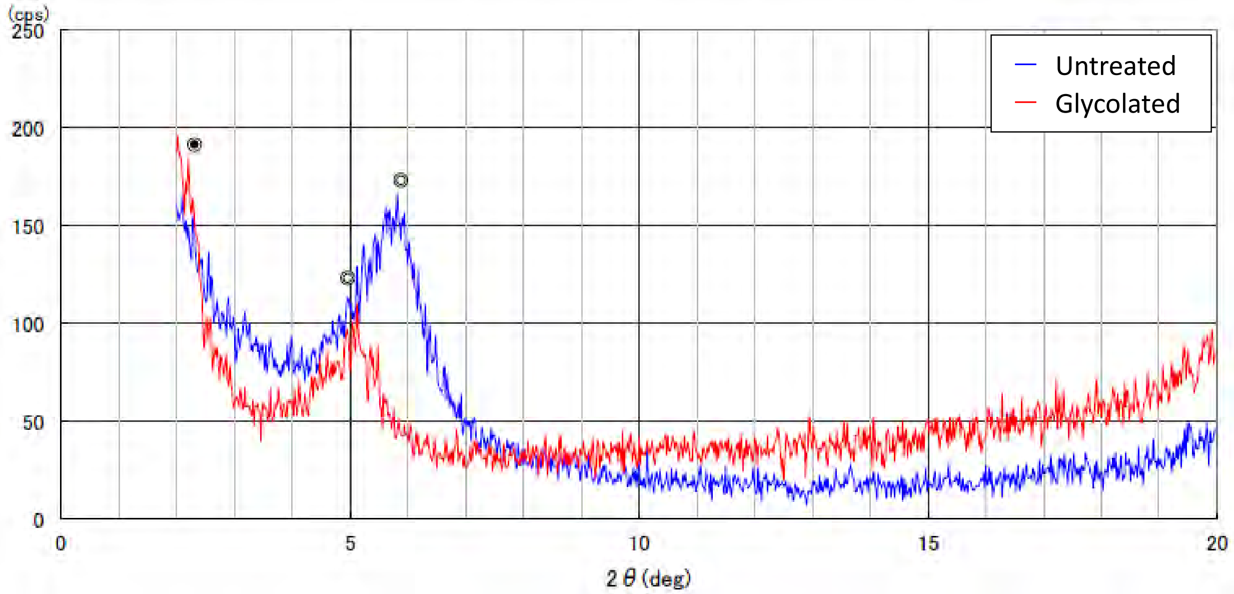
[Whole Rock]



Measurement data	: 2015/8/17	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ■: Clinopyroxene, ○: Calcite, ☆: Pyrite

[Oriented]

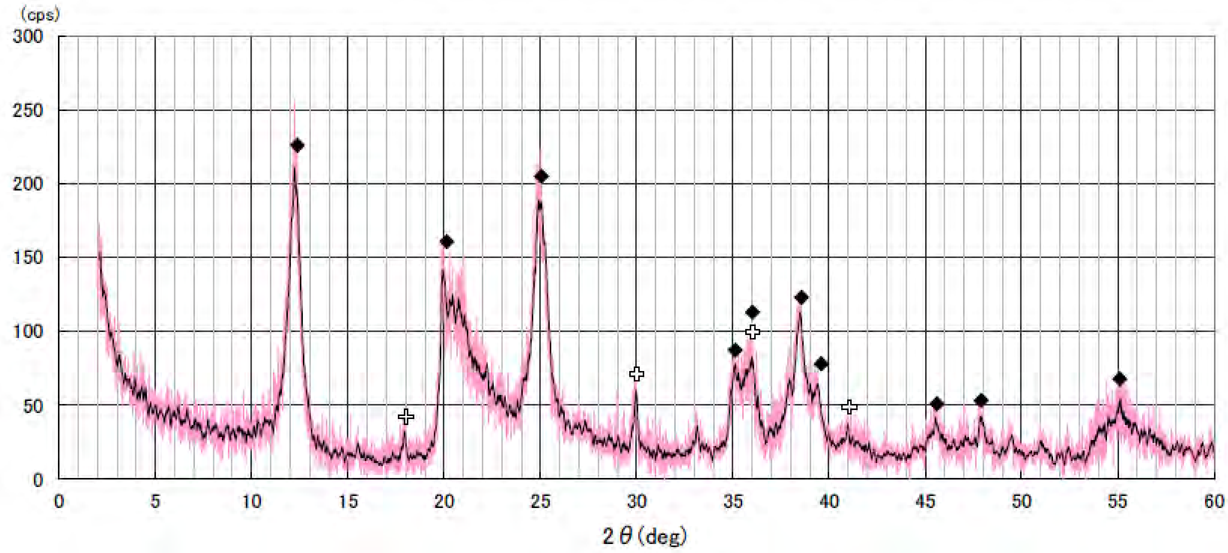


Measurement data	: 2015/8/17	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◎: Smectite, ◎: Mix Layer

2015053004-X

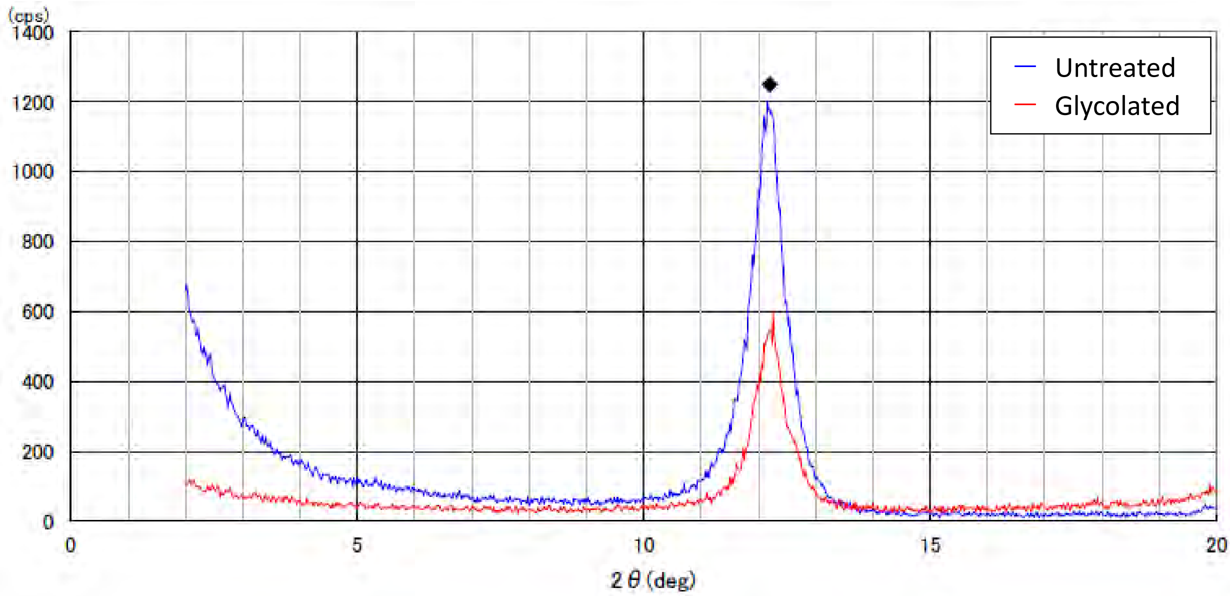
[Whole Rock]



Measurement data	: 2015/8/18	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, ＋: Heterosite

[Oriented]

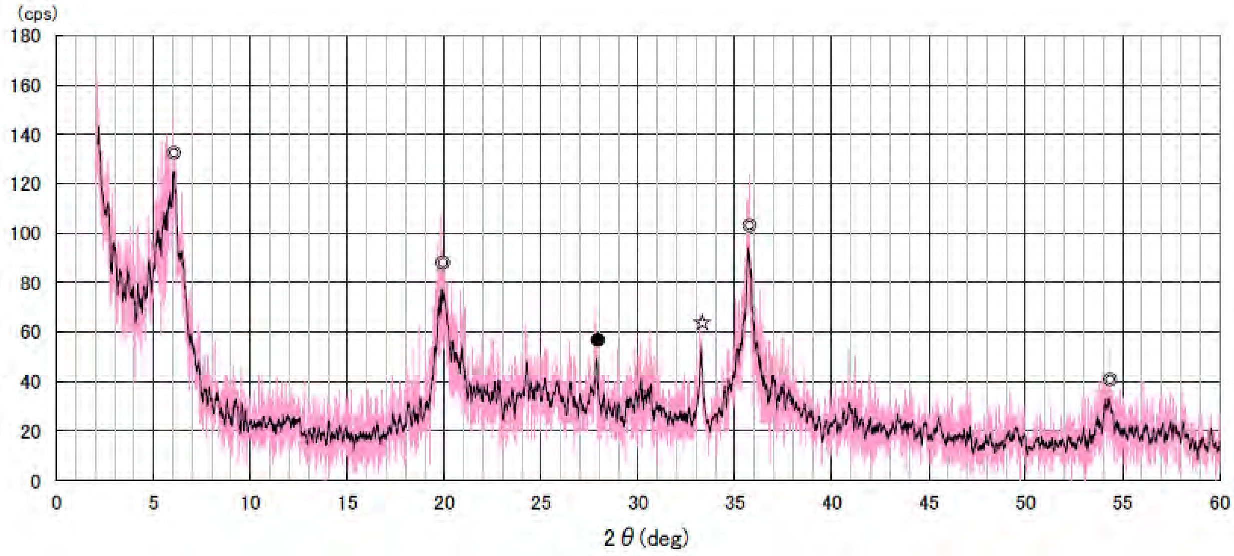


Measurement data	: 2015/8/18	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite

2015053005-X

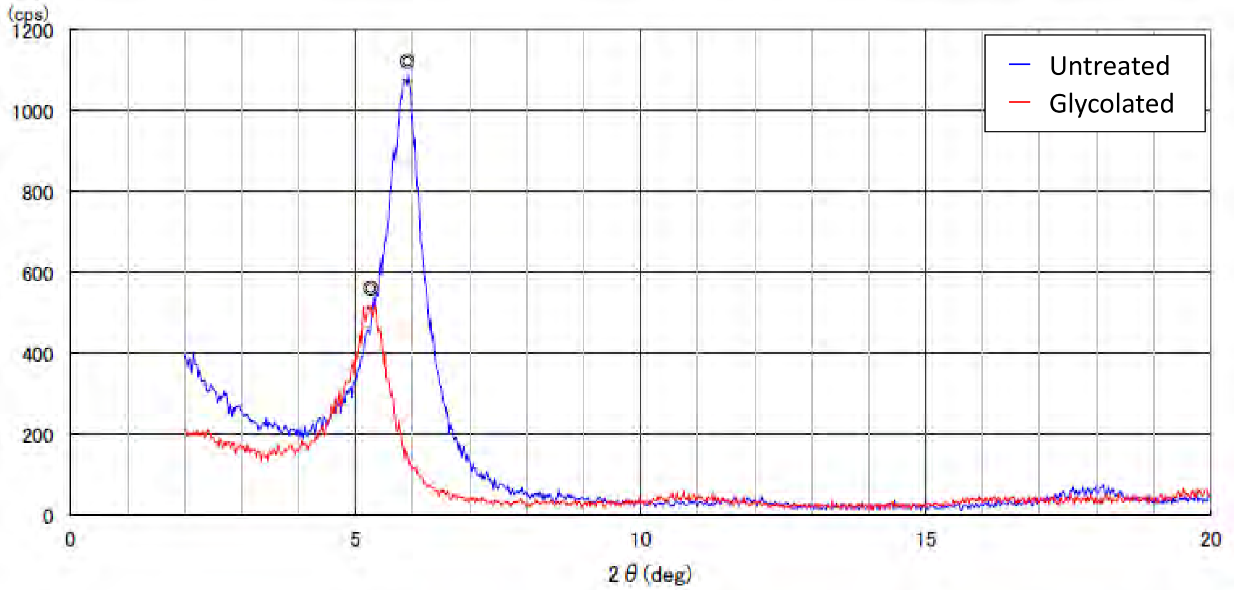
[Whole Rock]



Measurement data	: 2015/8/18	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ◎: Smectite, ☆: Pyrite

[Oriented]

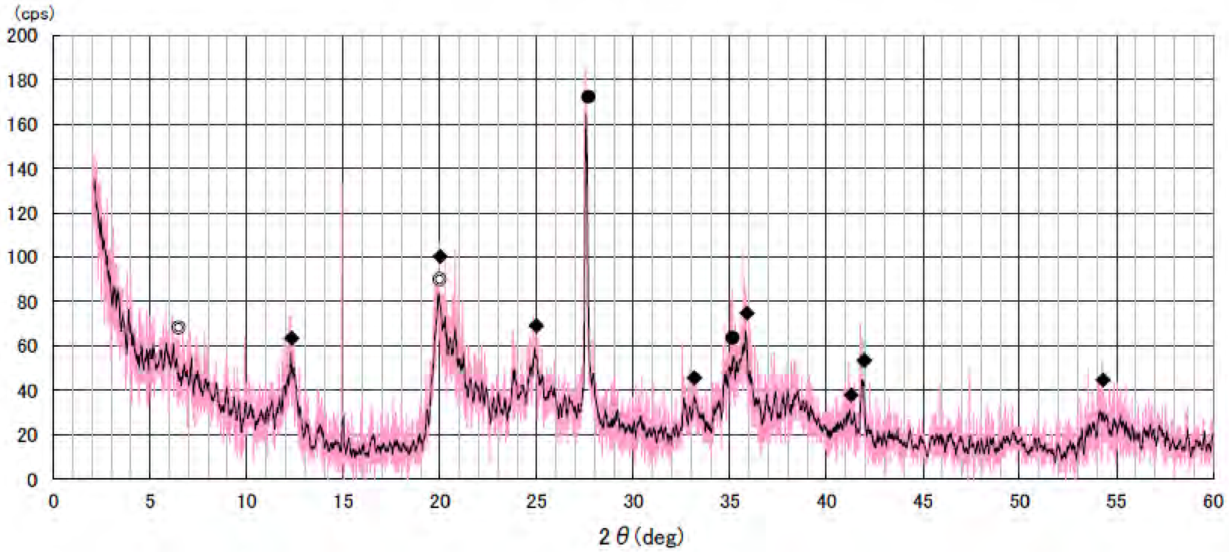


Measurement data	: 2015/8/18	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◎: Smectite

2015060102-X

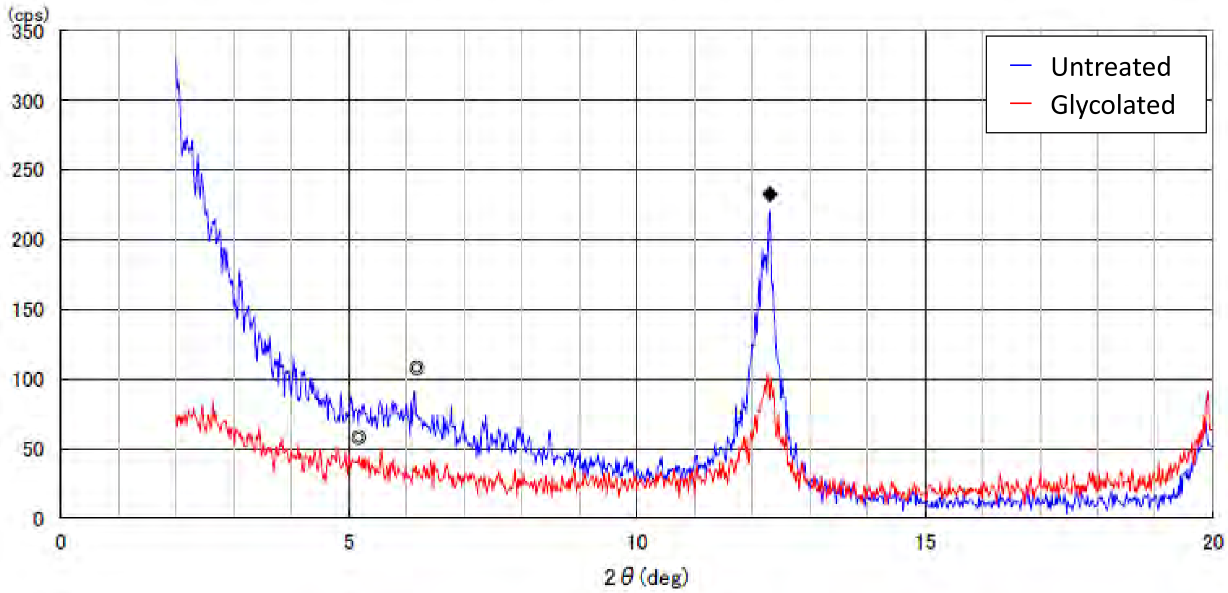
[Whole Rock]



Measurement data	: 2015/8/18	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ◆: Kaolinite, ◎: Smectite

[Oriented]

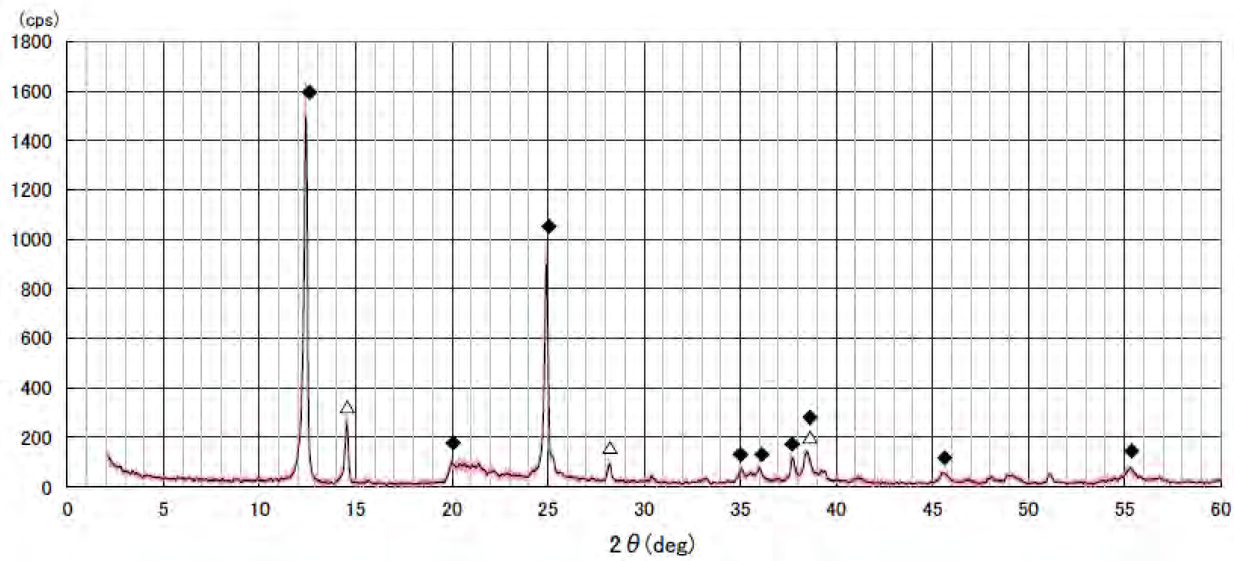


Measurement data	: 2015/8/18	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, ◎: Smectite

2015060103-X1

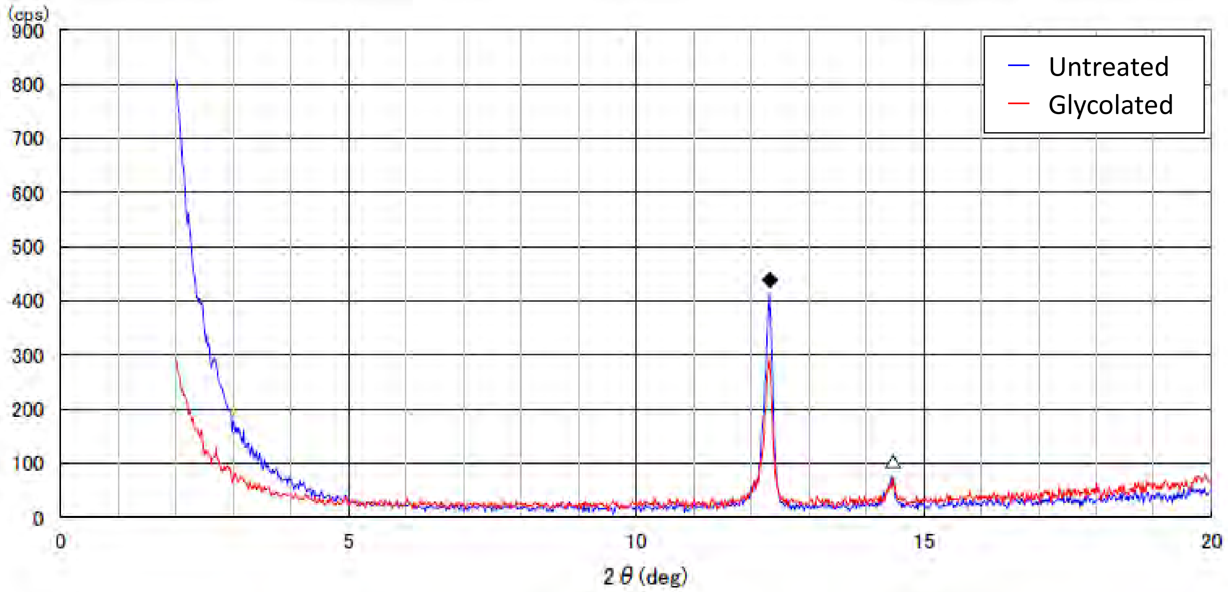
[Whole Rock]



Measurement data	: 2015/8/18	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, △: Boehmite

[Oriented]

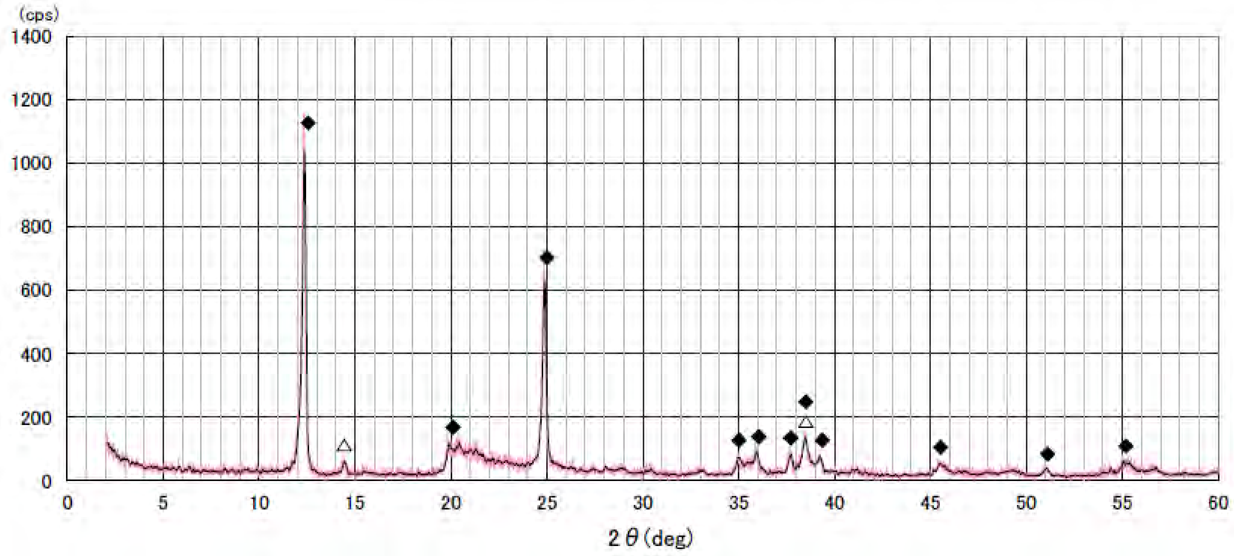


Measurement data	: 2015/8/18	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, △: Boehmite

2015060103-X2

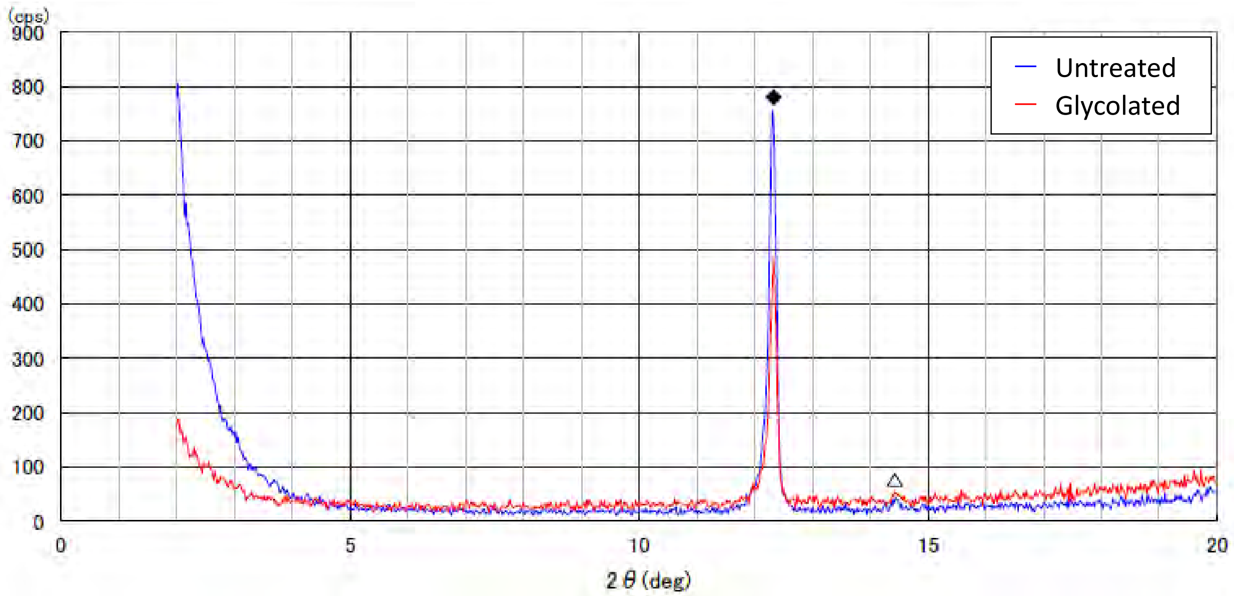
[Whole Rock]



Measurement data	: 2015/8/18	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, △: Boehmite

[Oriented]

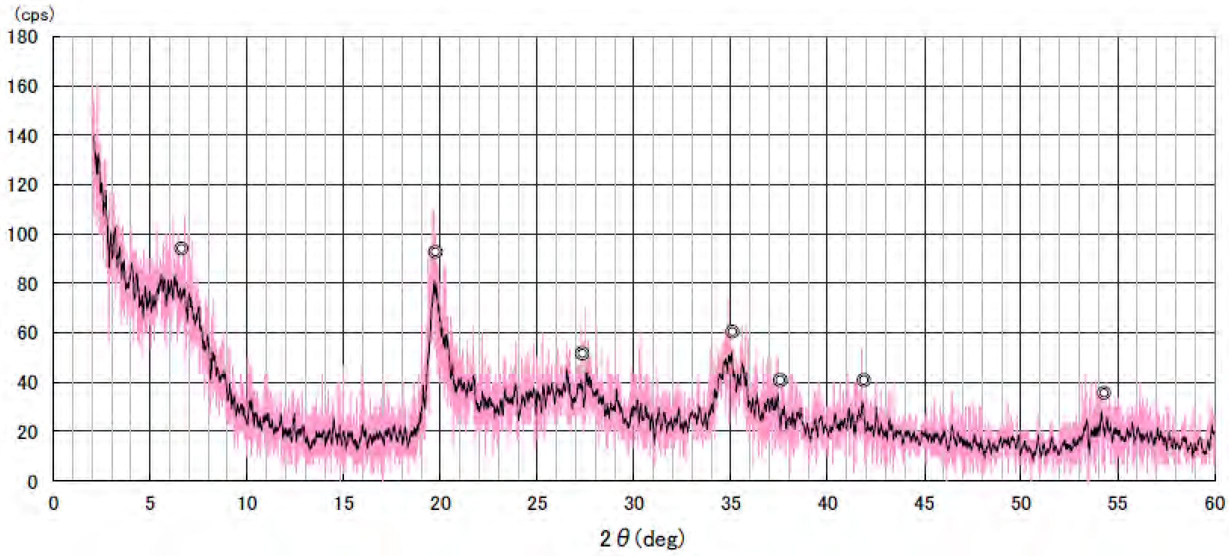


Measurement data	: 2015/8/18	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, △: Boehmite

2015060105-X

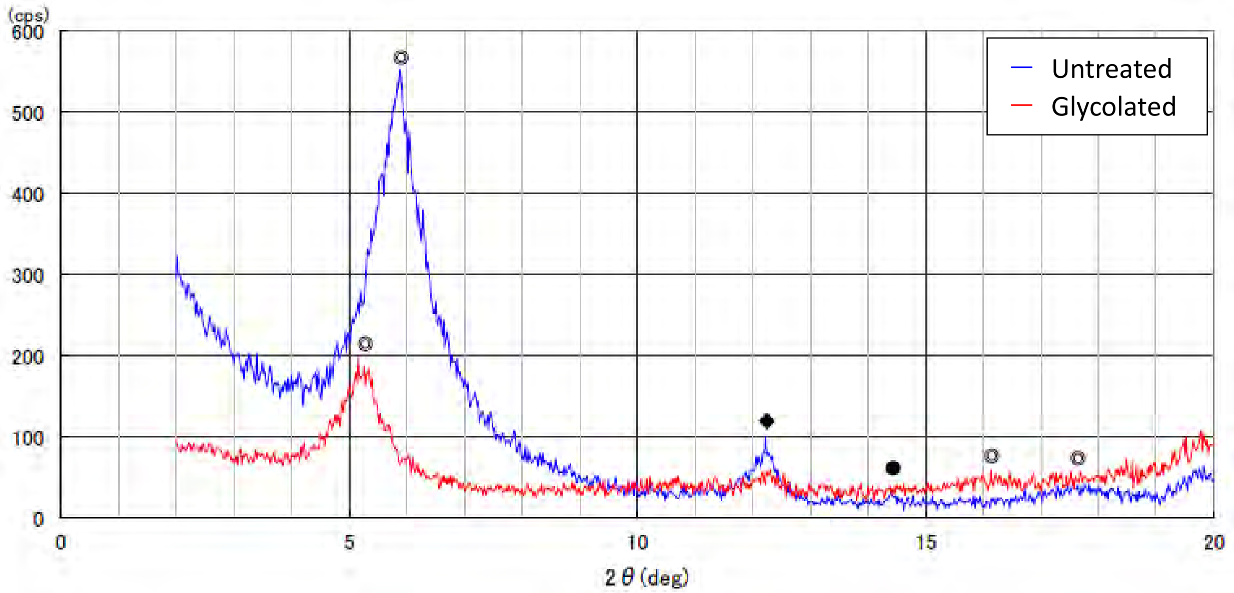
[Whole Rock]



Measurement data	: 2015/8/18	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◎: Smectite

[Oriented]

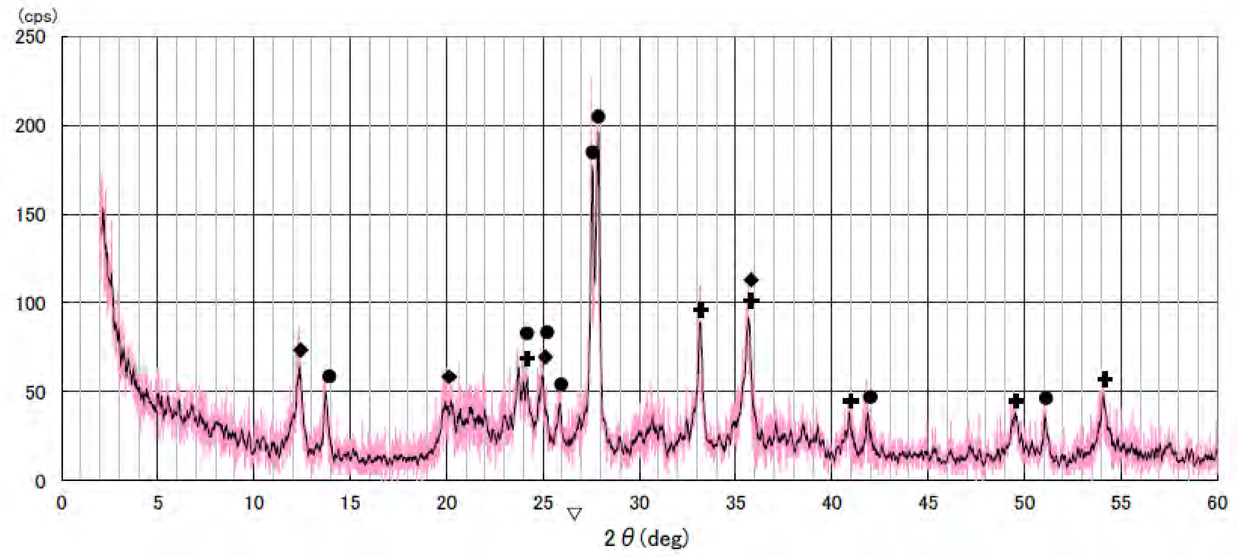


Measurement data	: 2015/8/18	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ◆: Kaolinite, ◎: Smectite

2015060201-X

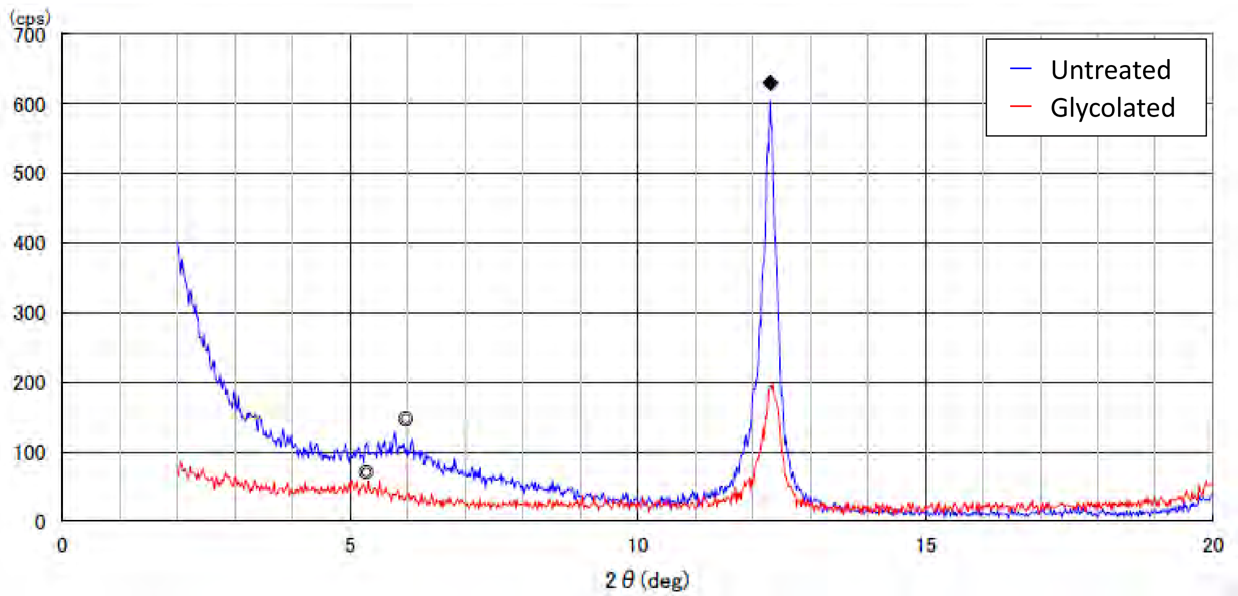
[Whole Rock]



Measurement data	: 2015/8/19	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2θ/θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

●: Feldspar, ◆: Kaolinite, ＋: Ilmenite

[Oriented]

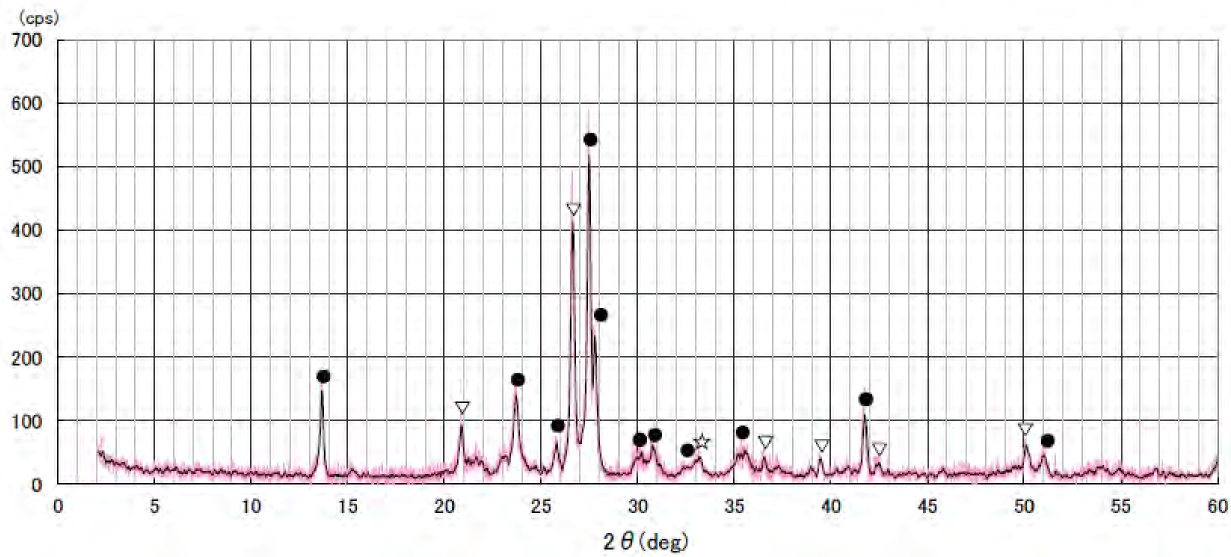


Measurement data	: 2015/8/19	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2θ/θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, ◎: Smectite

2015060203-S2

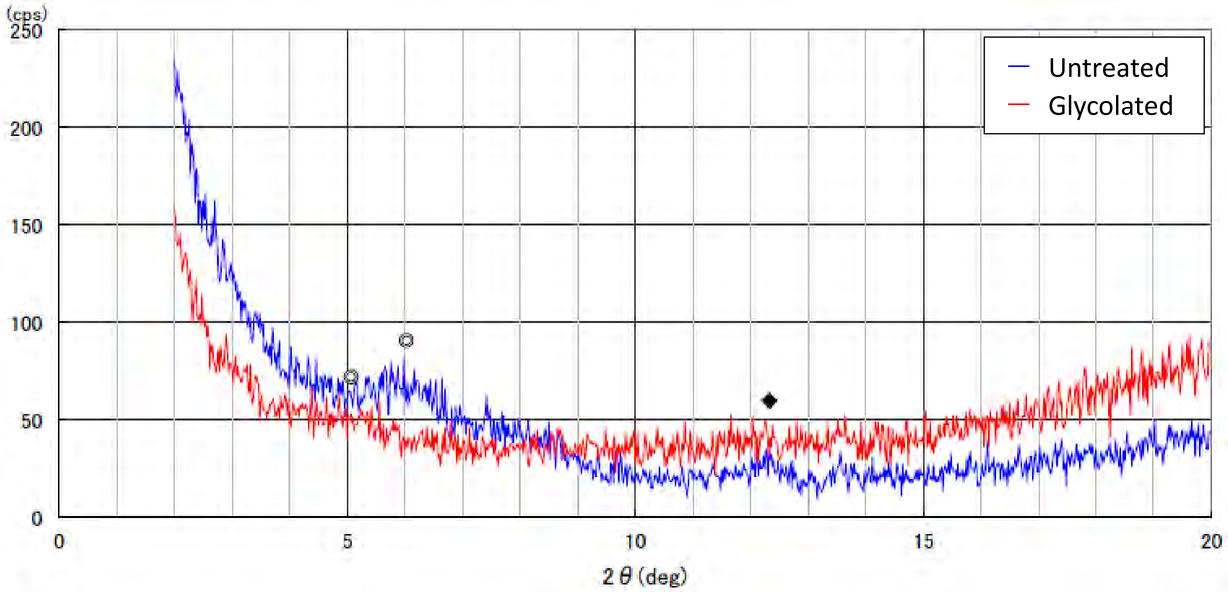
[Whole Rock]



Measurement data	: 2015/8/19	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

▽: Quartz, ●: Feldspar, ☆: Pyrite

[Oriented]

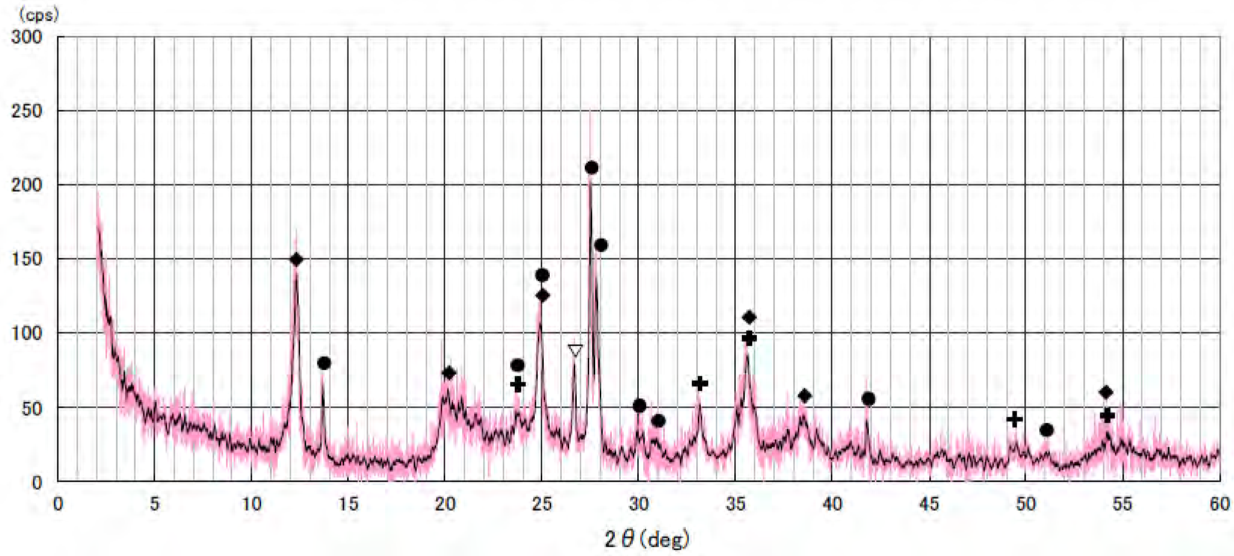


Measurement data	: 2015/8/19	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, ◎: Smectite

2015060203-S2

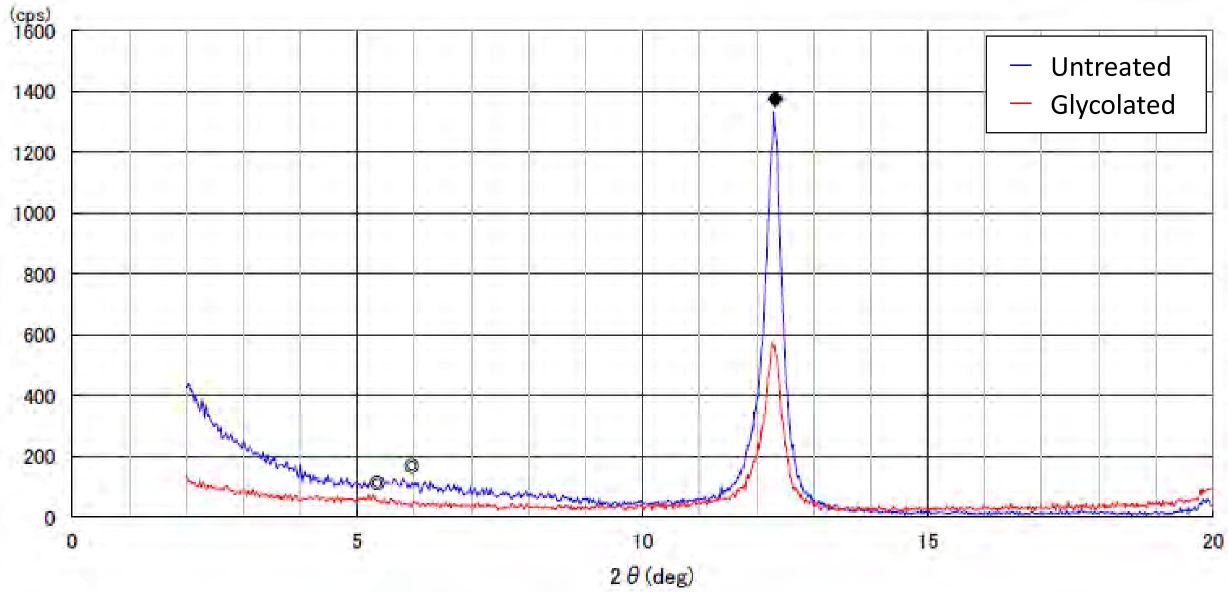
[Whole Rock]



Measurement data	: 2015/8/19	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

▽: Quartz, ●: Feldspar, ◆: Kaolinite, ＋: Ilmenite

[Oriented]



Measurement data	: 2015/8/19	Scan speed	: 2.0° /min
Incident X-ray	: CuK α /30kV/15mA	Sampling width	: 0.01°
Divergence slit	: 5/8°	Scan axis	: 2 θ / θ
Emission slit	: 0.3mm	Scanning range	:2.00～40.00°
Scattering slit	: 5/4°		

◆: Kaolinite, ◎: Smectite