Chapter 4 Environmental and Social Consideration

4-1 Environmental Legislation

4-1-1 Legislative Framework

Two legislations (the Waste Management Act No. 16 of 2001 and the Physical Planning and Development Control Act No. 25 of 2002) include provisions for environmental impact assessment (EIA) in Grenada.

It is important to note here that according to both acts, the legal responsibility for environmental impact assessments and development control in general is shared between none other than the current Planning and Development Authority (PDA) and the minister responsible for planning (Act 16:15-17 and Act 25:25 and 28). The minister is responsible for making regulations and appeals, while the PPDA is responsible for everything else with the support of the Physical Planning Unit functioning as its staff.

Table 4-1 EIA Legislations

No.	Legislation	Description
1	Physical Planning and Development Control Act No. 25 of 2002	To make provision for the control of physical development, require the preparation of physical plans for Grenada, protect the natural and cultural heritage, and for related matters.
2	Waste Management Act No. 16 of 2001	To provide for the management of waste in conformity with best environmental practices and related matters
3	(Draft) Physical Planning and Development Control Bill, 2015	To make provision for orderly and progressive development of land and to preserve and improve the amenities thereof; for the grant of permission to develop land and for other powers of control over the use of the land; for the regulation of the construction of buildings and other related matters; to confer additional powers in respect of the acquisition and development of land for planning; to protect the natural and cultural heritage, to repeal and replace the Physical Planning and Development Control Act, 2002.

Source: Legislations

The following development activities are subject to EIA under the Draft Physical Planning and Development Control Bill, 2015. Geothermal development activity should be classified under No. 14 (a power plant), No. 19 (any development generating or potentially generating emissions, aqueous effluent, solid waste, noise, vibration or radioactive discharges) and No.22 (Any development in wetlands, marine parks, national parks, conservation areas, environmental protection areas or other sensitive environmental areas.), and will thus require the preparation of an environmental impact assessment report.

Table 4-2 Development Activity Requiring EIA

No.	Types of Development
1	Hotels of more than 50 rooms
2	Sub-divisions of more than 10 lots
3	Residential development of more than 25 units
4	Any industrial plant which in the opinion of the Authority is likely to cause significant adverse environmental impact
5	Drilling, quarrying, sand mining and other mining activities
6	Marinas
7	Land reclamation, dredging and filling of ponds
8	Airports, ports and harbors
9	Dams and reservoirs
10	Hydro-electric projects
11	Desalination plants
12	Water purification plants
13	Sanitary landfill operations, solid waste disposal sites, toxic waste disposal sites and other similar sites
14	A power plant
15	An incinerator, sanitary landfill operation, solid waste disposal site, sludge disposal site or other similar site
16	Gas pipeline installations
17	Wind turbines
18	Communication towers
19	Any development projects generating or potentially generating emissions, aqueous effluent, solid waste, noise, vibration or radioactive discharges
20	Any development involving the storage and use of hazardous materials
21	Any coastal zone development
22	Any development in wetlands, marine parks, national parks, conservation areas, environmental protection areas or other sensitive environmental areas.

Source: (Draft) Physical Planning and Development Control Bill, 2015

4-1-2 Terms of Reference of EIA

The EIA for the project should provide the information in Table 4.3.

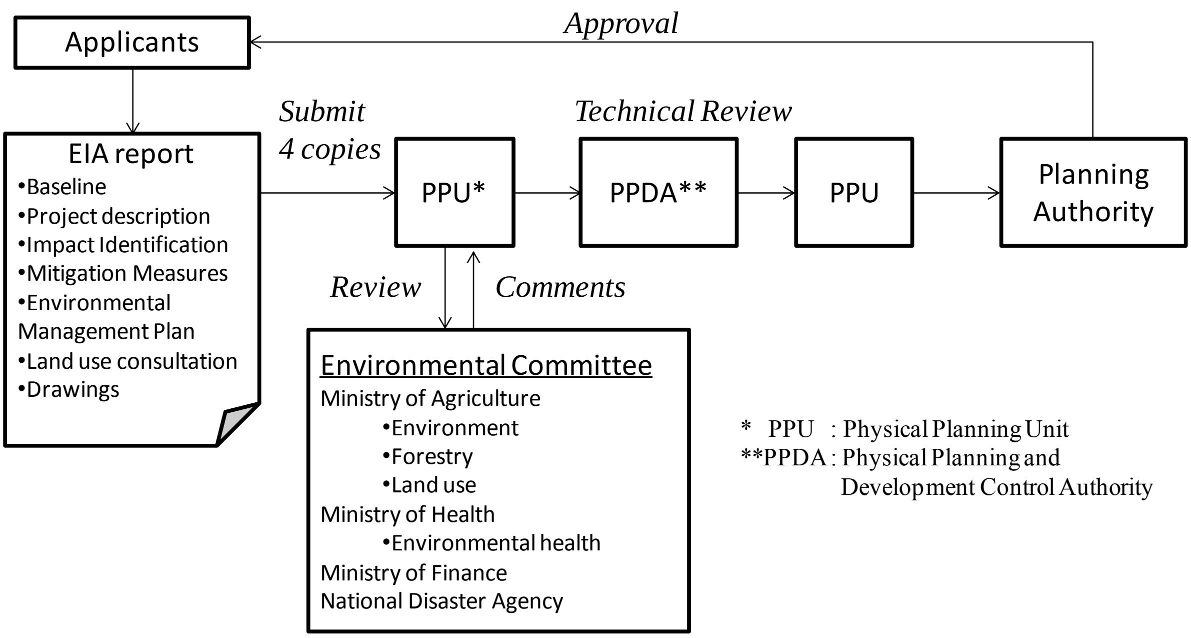
Table 4-3 TOR of EIA

No.	Terms of Reference
1	The background and objectives of the project
2	Specification of the binaries of the EIA study area
3	A description of the project from inception to operational phases
4	A description of the physical, chemical, biological, socioeconomic, and cultural characteristics of the existing environment of the study area
5	Legislative and regulatory requirements
6	Description and quantification of potential environmental effects of the project
7	Assessment of alternatives
8	Mitigation plan
9	Management and monitoring plan
10	A list of references, data sources, etc.

Source: Physical Planning Unit

4-1-3 EIA Process

The process of preparation and audit of EIA in Grenada is shown in the following Figure 4-1. After submission of the EIA report to the Physical Planning Unit, it normally takes about six weeks for the report to be approved.



Source: JICA Survey Team

Figure 4-1 EIA Process in Grenada

4-1-4 Relevant Environmental Legislation and Regulation

Since the 1940s, several pieces of legislation and regulation, including the Public Health Ordinance, have been enacted and amended with the view of providing the necessary legislative framework for the many different agencies dealing with environmental management matters. Recent legislations and regulations are listed in the following Table 4-4.

Table 4-4 Relevant Environmental Legislations and Regulations

No.	Legislation	Description
1	The Beach Protection Amendment Act of 2009	To prohibit sand mining in Grenada.
2	Litter Abatement Act of 1973	It has been supplemented by the passage of the Waste Management Act of 2001 addressing pollution control and abatement of litter.
3	Solid Waste Management Act No. 11 of 1995	It has established the Solid Waste Management Authority charged with the duty of developing solid waste management facilities and improving the coverage and effectiveness of solid waste storage, collection, and disposal facilities of Grenada.
4	National Parks and Protected Areas Act of 1991	To designate and maintain national parks and protected areas.
5	Environmental Levy Act No. 5 of 1997	To impose and collect environmental levy on certain goods and services.
6	Fisheries Act of 1986	To provide for the protection of the marine resources in Grenada; amended in 1999.
7	Forest, Soil, and Water Conservation Act, 1949	To make provision for the conservation of the forest, soil, water, and other natural resources of Grenada; amended in 1984.

Source: Legislations

4-2 Institutional Framework of Environmental Management

4-2-1 Environmental Institutions

There are several different agencies involved in activities that impact on the environment; however, eight institutions, i.e, five government departments and three statutory bodies, are directly involved in environmental management activities.

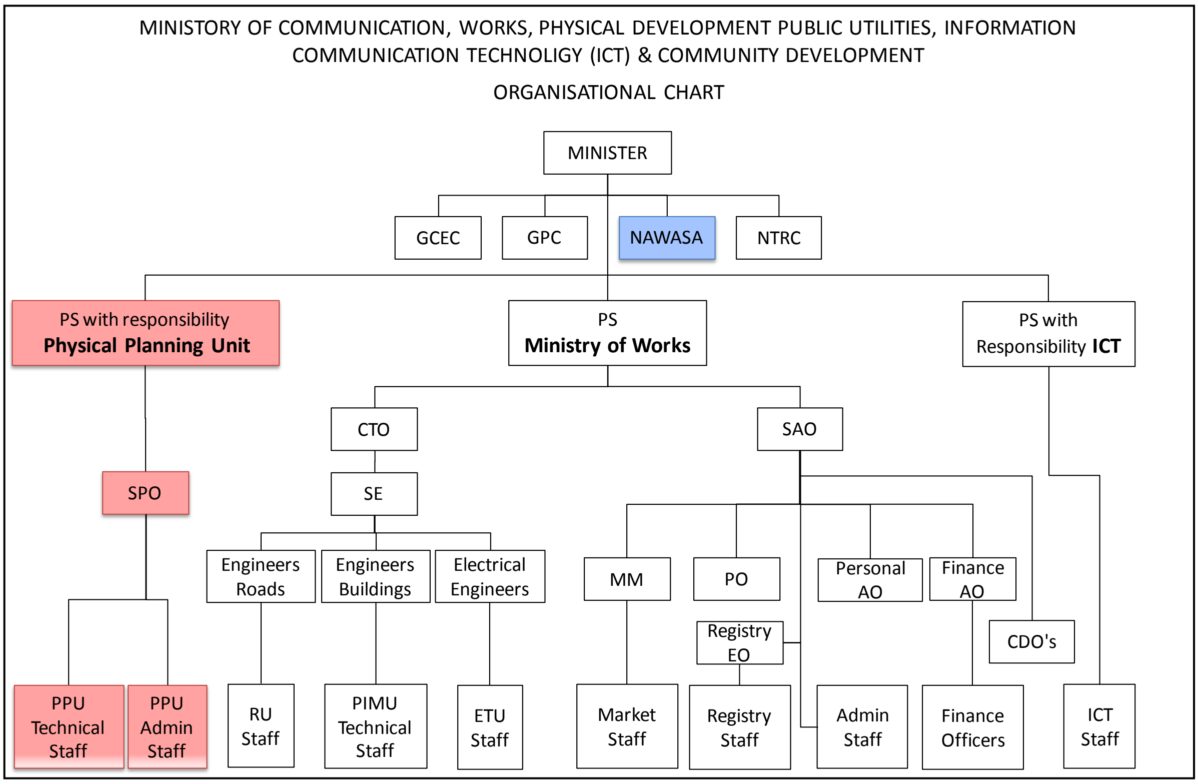
Table 4-5 Environmental Institutions in Grenada

No.	Institutions
1	Physical Planning Unit, Ministry of Communication, Works and Physical Planning
2	The Ministry of Communication, Works and Physical Planning
3	Forestry Department, Ministry of Agriculture Forestry and Fisheries, Public Utilities, Marketing Board and Energy
4	Land Use Department, Ministry of Agriculture, Forestry, Fisheries, and Marketing Board
5	Environmental Health Department, Ministry of Health and the Environment
6	Physical Planning and Development Control Authority
7	Solid Waste Management Authority
8	National Water and Sewage Authority (NAWASA)

Source: Government of Grenada, 2010

4-2-2 Physical Planning Unit

The Physical Planning Unit (PPU) has the legal responsibility to deal with EIA in Grenada. PPU is under the Ministry of Communication, Works, Physical Development, Public Utilities, Information and Communications Technology (ICT) and Community Development (as of 2015; please see Figure 4-2). NAWASA, which deals with water resource management, is also in this chart.



PS: Permanent Secretary, CTO: Chief Technical Officer, SE: Senior Engineer,
SAO: Senior Administrative Office, SPO: Senior Planning Office

Source: Physical Planning Unit

Figure 4-2 Organizational Framework of Physical Planning Unit

4-2-3 Physical Planning and Development Control Authority (PPDA)

PPDA is the authority which deals with the identification, protection, conservation, and rehabilitation of the natural and cultural heritage in Grenada. The authority consists of the following members based on the *Physical Planning and Development Control Act No. 25*:

(a) A chairperson (who may be a public officer) appointed by the minister;
(b) An executive secretary (who may be a public officer) appointed by the minister;
(c) Three other members appointed by the minister from the private sector;
(d) The following public officers as ex officio members:
  (i) The head of the Physical Planning Unit;
  (ii) Environmental Protection Officer;
  (iii) Director of Housing;
(e) Two senior public officers dealing with the following matters and nominated by the respective ministers:
  (i) Agriculture
  (ii) Public works

as ex officio members; and

(f) The manager of NAWASA as an ex officio member.

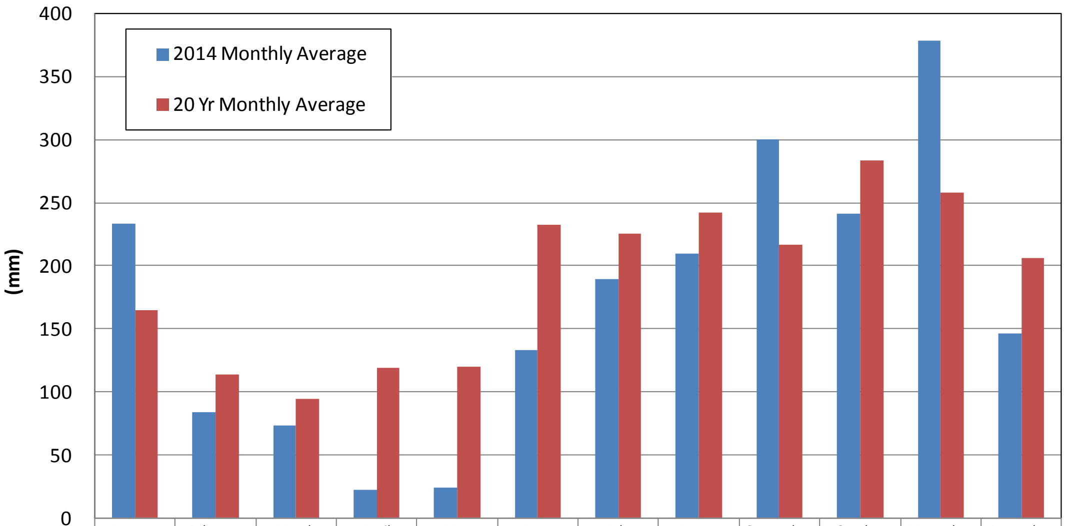
4-3 Environmental and Social Conditions

In this section, the current environmental and social conditions of Grenada, especially around Mt. St. Catherine, are analyzed using existing information in order to identify the items to be considered at the geothermal drilling stage.

4-3-1 Analysis of Environmental and Social Conditions

(1) Meteoric and Hydrological Environment

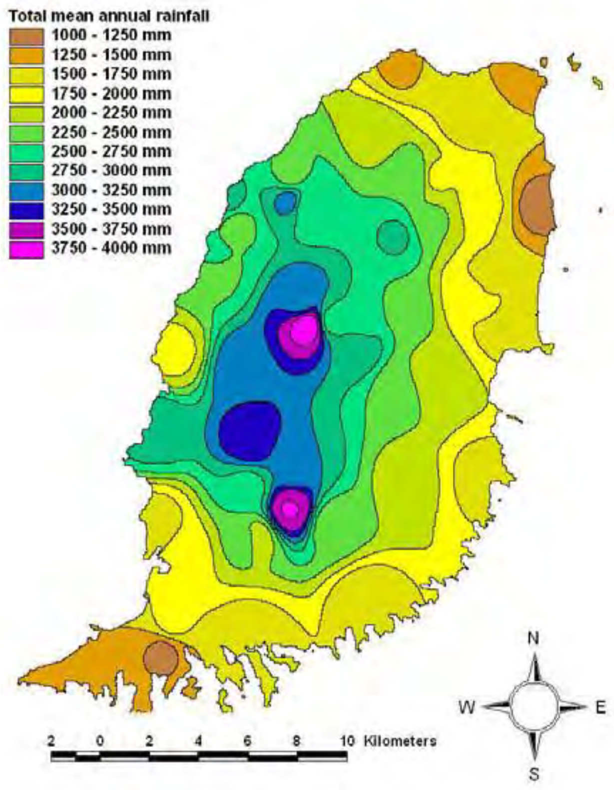
Grenada lies in the humid tropical zone within the Atlantic northeast trade wind belt and the seasonal shift in these winds give rise to the wet season (June to December) and dry season (January to May) as shown in Figure 4-3. The average annual rainfall for mainland Grenada is about 2,000 mm and it ranges from between 1,000 mm and 1,500 mm along the coastal zone to approximately 4,000 mm in the interior. It also supports surface stream flow and recharge of sub-surface aquifers (Figure 4-4). Annual average sea surface temperatures range between 28.3°C and 33.3°C; however, temperatures in the mountainous interior can dip to as low as 20°C during the winter months.



	January	February	March	April	May	June	July	August	September	October	November	December
2014 Monthly Average	233.68	84.07	73.66	22.35	24.13	132.84	189.23	209.80	300.23	241.55	378.71	146.05
20 Yr Monthly Average	165.10	113.54	94.23	119.38	120.14	232.16	225.30	241.81	216.66	283.21	258.32	206.50

Source: Ministry of Agriculture, Land Use Division

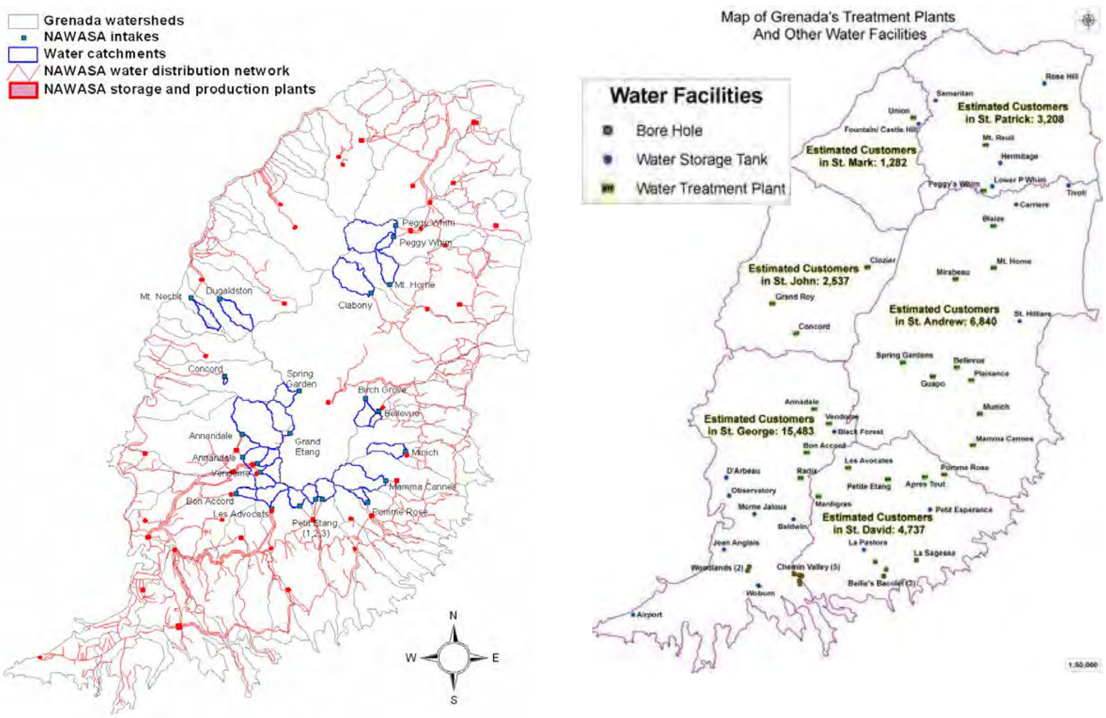
Figure 4-3 Monthly Precipitation



Source: IWRM Planning Road Map, 2007

Figure 4-4 Mean Annual Precipitation

Grenada is segregated into 71 watershed areas (Figure 4-5). There are 11 boreholes, 17 water storage tanks, and 24 water treatment tanks that serve as potable supply sources in mainland Grenada, which yield some 54,600 m^3/day (12 mgd) in the rainy season and a maximum of 31,800 m^3/day (7 mgd) in the dry season. The water demand in the rainy season is 45,500 m^3/day (10 mgd) and in the dry season, 54,600 m^3/day (12 mgd)（IWRM Planning Road Map, 2007）. NAWASA is in-charge of water resource management in Grenada.



Source: NAWASA

Figure 4-5 Watershed and Water Supply System

(2) Natural and Cultural Heritage[2]

Grenada currently has seven protected areas designated by legislation, as follows:

(1) Grand Etang Forest Reserve
(2) Annandale Forest Reserve
(3) High North Forest Reserve
(4) Perseverance Protected Area
(5) Woburn/Clarks Court Bay Marine Protected Area
(6) Moliniere/Beausejour Marine Protected Area
(7) Unspecified crown lands at Pearls are designated as a protected area

The Organization of Eastern Caribbean States (OECS) has prepared the “Systems Plans for the Protected Areas in the OECS” in 2009 in Grenada. This system plan evaluated the present situation of natural and cultural heritages in Grenada and identified the sites that government should consider for designation as protected area.

Figure 4-6 shows the zones of designated protected area and proposed area in the system plans. Protected areas are categorized into four groups as follows:

[2] OECS Protected Areas and Associated Livelihoods (OPAAL), Grenada Protected Area System Plan, 2009 (Funded by the Global Environmental Facility (GEF) through the World Bank, and the Fonds Français pour l’Environnement Mondial (FFEM))

The areas around Mt. St. Catherine are proposed for immediate designation and forest reserve and local area planning and prepared to be designated by the Government of Grenada.

The position of the proposed designation area around Mt. St. Catherine and the geothermal development areas are shown in Section 3.2.2.

Table 4-6 Types of Protected Area

Category	Feature	Area (Selected)	Designation
Designated Protected Area	Already designated by the government (7 areas)	Grand Etang	Forest Reserve
Local Area Planning	Areas that should be reviewed in the context of best land use and the local area planning process. (14 areas)	Mt. St. Catherine Addition	Mt. St. Catherine Forest Reserve Addition
Priority Area of Interest	Existing land use pressures from residential, tourism, and industrial development have the potential to threaten future protected area. (8 areas)	South Carriacou Islands	Marine Protected Area
Immediate Designation	Areas which should be designated immediately due to the importance to Grenada's endangered species and habitats. (16 areas)	Mount Hartman	National Park
		Mt. St. Catherine	Forest Reserve

Source: OPAAL. 2009

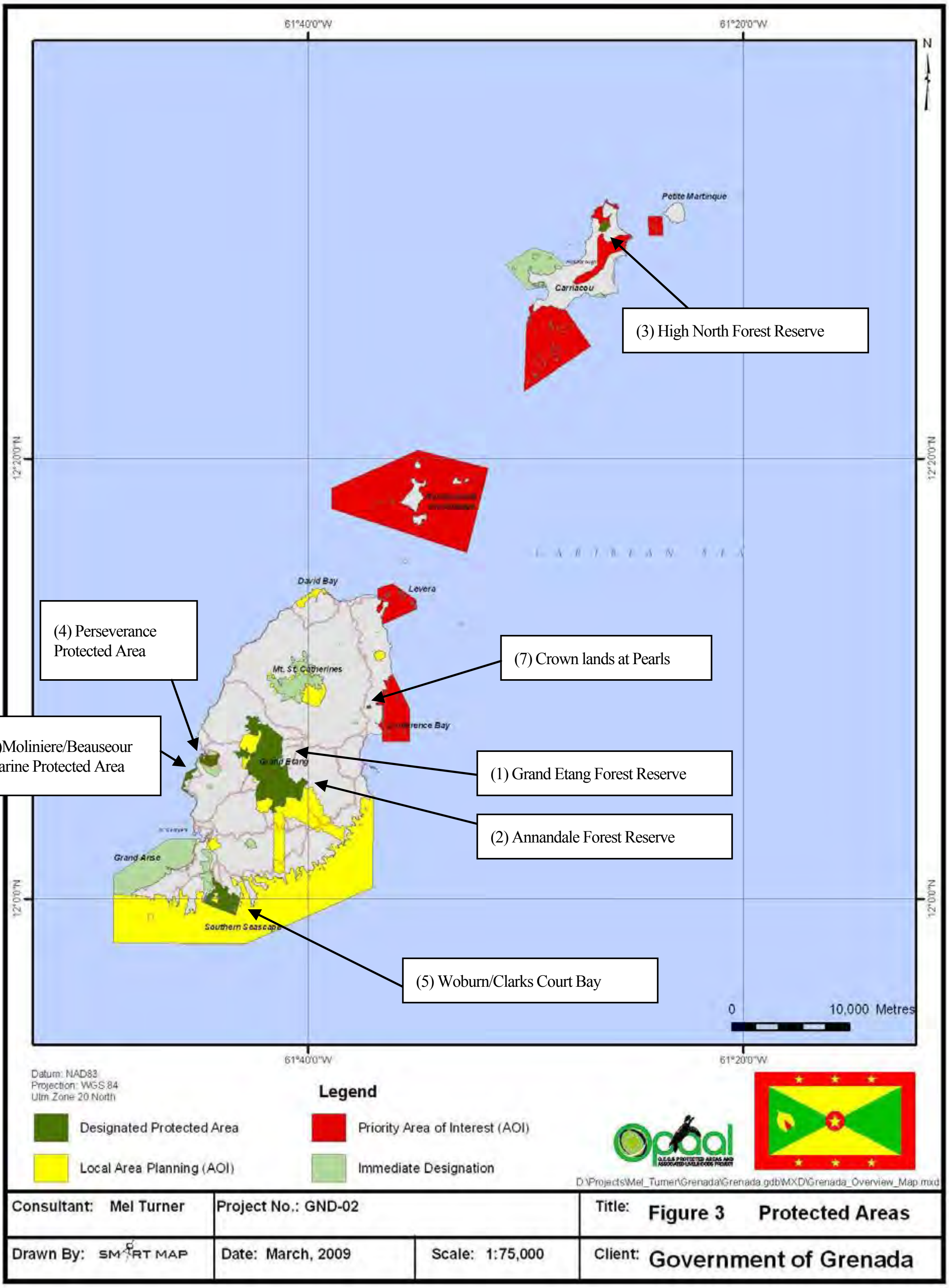


Figure 4-6 Existing and Proposed Protected Areas

(3) Flora[3]

There is little formal documentation available on the composition and status of Grenada's forests. Although some research has been conducted on a few species of trees, very little attention has been given to herbaceous and nonvascular plants. There is no information available on threatened or endangered plant species.

However, the following three endemic species of plants are known:

- Grand Etang Fern (*Danaea sp.*);
- Cabbage Palm (*Oxeodoxa oleracea*); and
- Endemic tree species (*Maythenus grenadensis*).

(4) Fauna

There is little hard data about faunal species numbers, distribution, and their current status. Grenada's terrestrial wildlife is thought to consist of four amphibian species, eight species of lizards, five species of snakes, and 150 species of birds (Groome, 1970), of which, 18 species are thought to be threatened or endangered, i.e., four native species of terrestrial mammals and 11 native species of bats (Groome, 1970). One of the most important fauna is the Grenada Dove and its habitat. It is the national bird of Grenada and considered to be an endangered species located at Mt. Hartman, in the southern part of the island.

Endemic species

- Cabbage Palm (Oxeodoxa oleracea)
- Endemic tree species (Maythenus grenadensis)
- Grenada Dove (Leptotila wellsi)
- Grenada Hook-billed Kite (Chondrohierax uncinatusmurus)
- Grenada flycatcher (Myiarchus nugator)
- Scaly-breasted thrasher (Margarops fuscus)
- Lesser Antillian bullfinch (Loxigilla noctis)
- Lesser Antillian tanager (Tangara cucullata).

Several species have become extinct in Grenada since the arrival of the Europeans (CCA/GOG/USAID, 1991), such as the following:

- Manatee (Trichecusmanatus)
- Grenada parrot (Amazona sp.)
- Agouti (Dasyprocta albida)
- Neuweid's Moon Snake (Pseudoboaneuweidi)
- Shaw's Racer (Liophis melanotus)
- Morocoy Tortoise (Geochelone carbonaria)

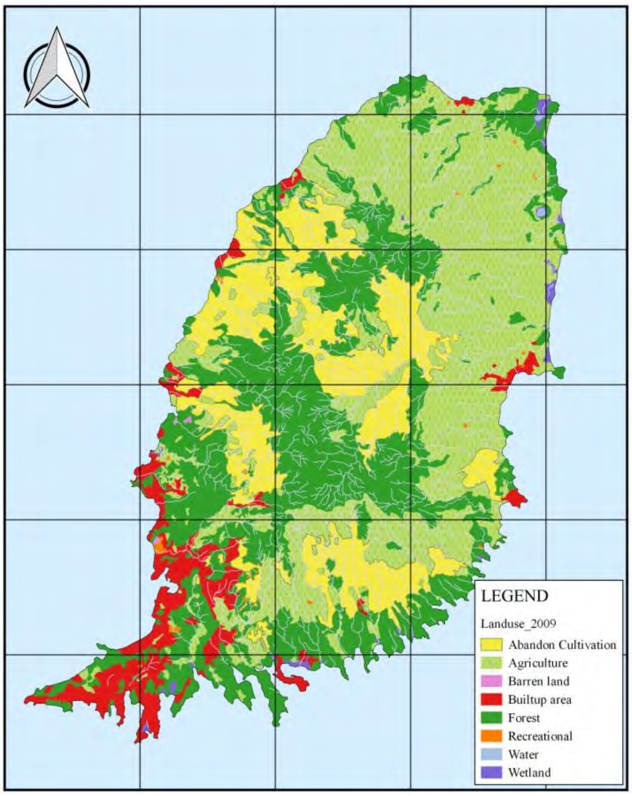
[3] The Convention on Biological Diversity in Grenada, Biodiversity Strategy and Action Plan, 2011

(5) Land Use

The land use map in Figure 4-7 shows that most of the island is used for "Agriculture", "Abandoned Cultivation", and "Forest". "Buildup area" is distributed mainly in the southwest region and some town areas around the island.

Main crops are nutmeg, cocoa, banana, sugar cane, and variety of fruits.

The frank area of Mt. St. Catherine, where potential area for geothermal development can be found, is widely used for agriculture, while some areas are privately owned.



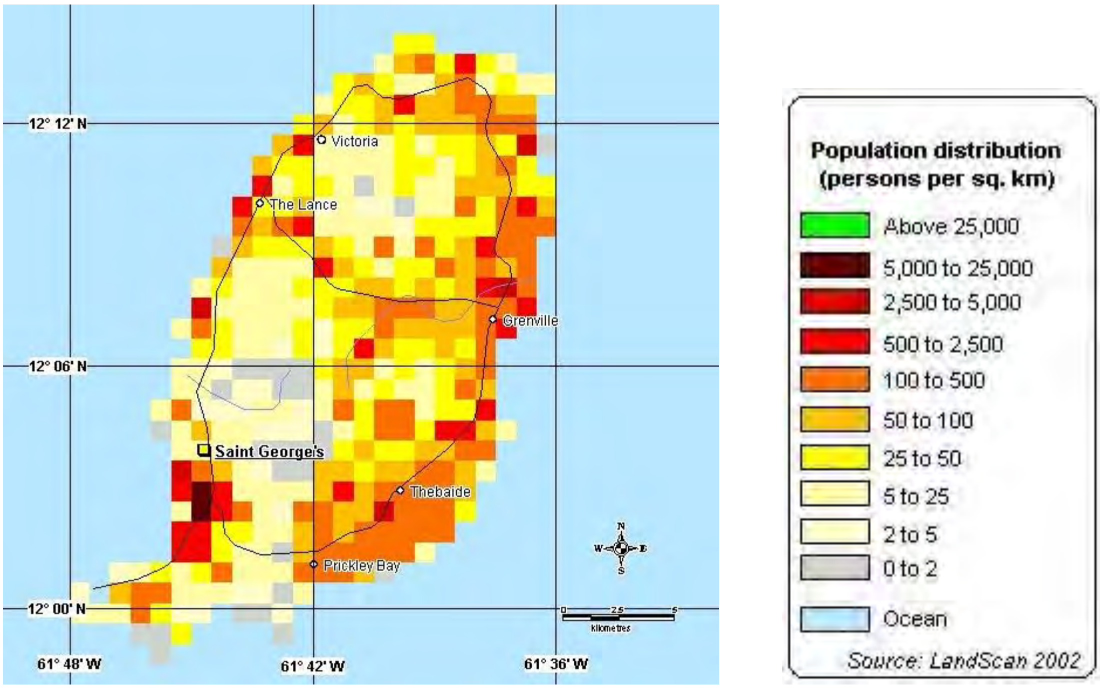
Source: Ministry of Agriculture

Figure 4-7 Land Use

(6) Residents

The population of Grenada is 105,000 (2013, World Bank) and most of the people are living in the southwest of St. George's (5,000-25,000/km^2) and along the main roads (500-5,000/km^2) (Figure 4-8).

Some resettlement should be implemented for geothermal development project around Mt. St. Catherine.



Source: UNOSAT

Figure 4-8 Population Distribution

4-3-2 Preliminary Scoping for Environmental and Social Items

In order to identify the environmental and social consideration items for the project, preliminary scoping was conducted as shown in Table 4-7. The items analyzed in the preliminary scoping were selected based on the check items listed in the JICA Guidelines for Environmental and Social Considerations (April 2010). The degree of impacts was assessed for the preparation stage (test drilling, land acquisition), construction stage (construction of facilities), and operation stage (operation of facilities) assuming that the case cannot be avoided and mitigation measures are taken.

Table 4-7 Results of Preliminary Scoping

Category	No	Items	Rating			Rating Basis
			Pre	Con	Ope	
Pollution		Air Quality	B-	B-	B-	Pre/Con: During production test, generation of gas containing hydrogen sulfide (H_2S) is expected. In addition, emission gases are discharged due to operation of heavy machines during well drilling and facility construction. Ope：H_2S is expected to be released along with steam.
		Water Quality	B-	B-	B-	Pre/Con: Mud water is expected to be generated due to well drilling. Ope: Wastewater is expected to be discharged from the facilities.
		Wastes	B-	B-	B-	Pre/Con: Drilling sludge, construction waste soil, and scrap wood are expected to be generated by well drilling activities. Ope: Wastes (sludge, waste oil) are expected to be generated in the facilities.
		Soil Pollution	D	D	D	No activities which may cause soil pollution are planned.
		Noise/ Vibration	B-	B-	B-	Pre/Con: Blowout of geothermal fluid by well drilling and noise from operation of heavy machines are expected. Ope: Noise from operation of the facilities (power generator, steam turbine, cooling tower, etc.) is expected.
		Ground Subsidence	D	D	C	Pre/Con: Collection of geothermal fluid during well drilling and facilities construction is limited. Ope: Although ground subsidence is expected due to collection of geothermal fluid, detailed examination is required.
		Offensive Odor	C	C	C	If gas contains hydrogen sulfide (H2S), odor is expected.
		Sediment Quality	D	D	D	No activities which may cause sediment quality pollution are planned.
Natural Environ-ment		Protection Area	A-	A-	A-	The project site is located close to Mt. St. Catherine Forest Reserve.
		Ecosystem/Flora and Fauna	A-	A-	A-	Some negative impacts on regional ecosystem and flora and fauna are expected due to disturbance of the land, operation, and existence of the facilities.
		Hydrology	B+	B+	D	Pre/Con: Surface water or groundwater is planned to be used for drilling. Ope: The amount of surface water or groundwater planned to be used is limited.
		Topography/ Geology	D	B-	D	Pre: Impacts are negligible as large-scale well drilling is not planned. Con: The land is expected to be disturbed due to construction of facilities (generator building, steam and hot fluid transport pipe, cooling tower, etc.). Ope: No activities which may cause impacts on topography/geology are planned.

Category	No	Items	Rating			Rating Basis
			Pre	Con	Ope	
Social Environ-ment		Involuntary Resettle-ment	C	C	C	Even though there are few residents around the project site, involuntary resettlement survey is required after the drilling plan.
		Poor People	D	B+	B+	Pre: Creation of employment opportunities from test drilling is limited. Con/Ope: Some positive impacts on regional economy are expected such as creation of employment opportunities through construction and operation of the facilities.
		Ethnic Minority/ Indigenous People	D	D	D	There are herders and nomads available in the area, but there are no ethnic minorities or indigenous people who need special consideration.
		Local Economy and Livelihood	D	B+	B+	Pre: Test drilling only creates limited employment opportunities. Con/Ope: Some positive impacts on regional economy such as creation of employment opportunities are expected by the construction and operation of the facilities.
		Land Use and Utilization of Local Resources	D	D	B+	Pre/Con: No impacts on land use and utilization of local resources are expected. Ope: Geothermal fluid could be used for other purposes in addition to geothermal generation.
		Water Use	A-	A-	D	Pre/Con: Surface water or groundwater is planned to be used for drilling. Some impacts on water resource are expected. Ope: The amount of surface water or groundwater planned to be used is limited.
		Social Infrast-ructures and Services	D	D	D	There are no sensitive social infrastructures (dwelling, school, medical facilities, etc.) located in and around the project site.
		Social Institutions and Local Decision-making Institutions	D	D	D	No impacts on social institutions and local decision-making institutions are expected.
		Misdistribu-tion of Benefits and Damages	D	D	D	No unequal distribution of benefit and damage is expected in and around the project site.
		Local Conflicts of Interest	D	D	D	No local conflict of interest is expected in and around the project site.
		Cultural and Historical Heritages	C	C	C	Although no cultural and historical heritages were considered at the project site, a detailed investigation is required.
		Landscape	D	D	A+/-	Pre/Con: Since no large-scale construction work is planned, impacts on landscape are temporal and

Category	No	Items	Rating			Rating Basis
			Pre	Con	Ope	
						limited. Ope: Some impact on landscape is expected due to the existence of plant facilities (power generator, steam turbine, cooling tower, etc.).
		Gender	D	D	D	No impact is expected.
		Children's Rights	D	D	D	No impact is expected.
		Infectious Diseases (such as HIV/AIDS)	B-	B-	D	Pre/Con: Although no large-scale construction work is planned, there is a possibility for infectious diseases to spread due to the influx of workers. Ope: Since the number of workers at the project facilities is limited, impact on infectious disease is considered to be small.
		Occupational Environment (including Occupational Safety)	B-	B-	B-	Since the project site is located at a high elevation, special considerations on occupational safety are required.
Others		Accidents	B-	B-	B-	Special considerations on accidents are required during test drilling, facility construction, and operation.
		Climate Change	D	D	A+	Pre/Con: Since no large-scale construction work is planned, impact on climate change is temporal and limited. Ope: This project could contribute to reduce greenhouse gas emission.

Note:
Pre-During preparation, Con-During construction, Ope-During operation

A+/-: Significant positive/negative impact is expected.
B+/-: Positive/negative impact is expected to some extent.
C+/-: Extent of positive/negative impact is unknown (further examination is needed, and its impact could be clarified as the study progresses)
D: No impact is expected.

Source: JICA Survey Team

As a result of preliminary scoping, environmental impacts are to be expected on air quality, water quality, waste, noise, protected area, ecosystem/flora and fauna, hydrology, topography, geology, landscape, and climate change. In addition, positive and negative social impacts are also expected on poor people, local economy and livelihood, land use and utilization of local resources, water use, infectious disease (HIV/AIDS, etc.), occupational environment (including occupational safety), and accidents. Further studies are required to assess ground subsidence and cultural and historical heritages and resettlement after drilling plan is developed.

4-3-3 Environment of Drilling Site

The detailed description about land condition and environment of three selected sites for test drilling are shown in Figure 3-14 ~ 3-20. Those three locations C, D and F are owned by private farmer and used as agricultural land. Land acquisition should be necessary but not involuntary inhabitant resettlement.

4-3-4 Comparison between Grenadian Law and JICA guidelines

Basically environmental and social impact assessment shall be conducted in accordance with laws, decrees and circulars of Grenada. The ESIA procedures for the geothermal project are summarized in the following table with relevant regulations of Grenada.

Table 4-8 Summary of ESIA Procedure according to Grenadian Law

Item	Content	Regulation
Project subject to ESIA	Defined	Bill
Timing for Execution	4 months	Not regulated
Content	TOR is prepared	PPU
Public Consultation	Needed	Act
Review Committee and Approval Authority	PPU	Act
Time Limit of Review	Up to six weeks	Not regulated
Disclosure of Information	-	Not regulated

Source: JICA Survey Team

As above mentioned, the contents to be included in an ESIA report are specified in the physical planning and development control act No.25 of 2002. They are largely in line with the requirement specified in JICA guidelines for environmental and social considerations (2010), however, Grenadian regulations do not require intensive attention on social impact assessment. In order to comply with JICA's guidelines as well as other international requirement such as IFC, it is proposed to include following studies.

- Evaluation of alternatives including zero option
- Social impact study including land acquisition and resettlement
- Public consultation

Key differences on social consideration between Grenadian and JICA policies are listed in the following table.

Table 4-9 Key Differences from JICA Policies on Social Consideration

Issues	JICA guideline	Proposed Project Policy
Land compensation	All affected persons should be compensated for land acquisition, regardless of legal status of land use	All affected persons should be compensated regardless of legal status
Compensation for houses and others	All affected structures will be compensated according to replacement cost, regardless of legal status	All affected structures will be compensated according to replacement cost
Compensation Price	Full replacement cost should be provided as much as possible since the official price	Full replacement cost at the market value should be provided as much as

	may not represent a full replacement cost	possible
Compensation for losing income or means of livelihood	All loss of income shall be compensated	All loss of income shall be compensated
Support for livelihood restoration	Support to restore at least the livelihood before the project started	Support to restore at least the livelihood before the project started

Source: JICA Survey Team

4-3-1 Capacity of Environmental Institutions

1) PPU（Physical Planning Unit）

PPU is in charge of regulate on EIA process, however not really a specialist on environmental unit, and should work together with more on the expertise of other ministries/departments.

2) Other Governmental Institutions

There are several institutions which are related to environmental issues such as Ministry of Agriculture (Environment, Forestry, and Land Use) and they have significant experience, capability, and willingness to contribute to the project, and need to date the coordination between them with the Energy Office. Solid Waste Management Authority, Environmental Health Department, Ministry of Health and the Environment, Port Authority and Airport Authority seem also willing to involve in the geothermal project.

3) Energy Office

The energy unit in general seems capable; however they may need some additional staff and training to manage a project of this nature.

4) Other Stakeholders

Stakeholder engagement is necessary based on the “Stakeholder Engagement Plan”.

Chapter 5 Pre-Feasibility Study

5-1 Project Goal and Objective

5-1-1 Goal

The National Energy Policy of Grenada – A Low Carbon Development Strategy for Grenada, Carriacou and Petite Martinique, November 2011 set up the 11 goals to be achieved. The JICA Survey Team has selected the following two goals as goals of the geothermal energy development in Grenada.

Renewable Energy Goal: Twenty percent of all domestic energy usage (electricity and transport) will originate from renewable energy sources by 2020.

Power Sector Goal: Transition to an efficient, low-carbon, national electricity generation and interconnection network that ensures safe, efficient, affordable and environmentally friendly energy services.

5-1-2 Project Objective

The immediate and direct objective of the project is to construct geothermal power stations together with related auxiliary facilities.

5-2 Outline of the Project

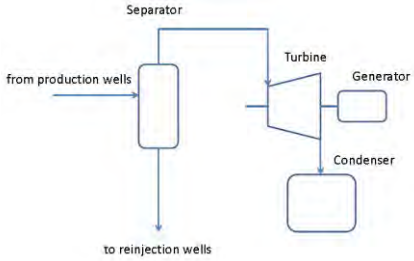
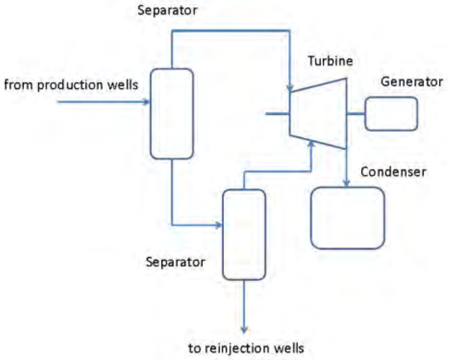
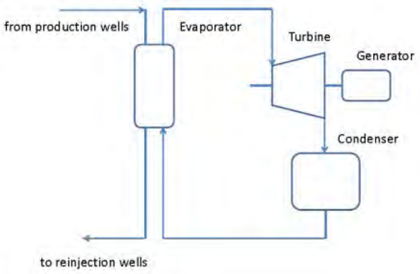
5-2-1 Geothermal Power Plant

(1) Types of Geothermal Power Plant

There are a number of power plant types that convert geothermal energy to electric energy such as single flash type, double flash type, binary type, and combined type. Each flash type may be either back pressure type or condensing type (Table 5-1).

Among these types, the JICA Survey Team recommended a single flash condensing type of power plant taking into consideration its structural simplicity and expected range of geothermal enthalpy of the reservoir.

Table 5-1 Types of Geothermal Power Plant

Type		Method
Single Flash 		Geothermal fluid produced from geothermal well shall be separated into steam and brain with the separator. The steam shall be used for turbine operation. Geothermal brine is re-injected into the ground through the re-injection well.
Double Flash 		Lower pressure steam is obtained by de- pressurization of the brine separated with the separator. Such produced steam is admitted in intermediates turbine stage for geothermal generation. 15% to 20% more power may be obtained compared with the single flash type with the same volume of the geothermal resource. Because this system utilized the lower temperature level, the silica scaling at the re-injection well would be the issue to study. It is necessary to study the anti-scaling by analysis of the composition of the geothermal steam and brine.
Binary 		Heat from the hydrothermal fluid causes the secondary fluid to vapor or flash, which then drives a turbine for geothermal generation. The working fluid of a much lower boiling point than water passes through a heat exchanger. This method is applicable for power generation to use lower temperature reservoir at 100-150 degrees Celsius. Butane, pentane, ammonia water mixture, and fluorocarbons etc. are used for the secondary fluid.
Combined		Combined type of "flash" and "binary".
Steam Turbine Type	Condensing	The unit condenses steam discharging from turbine in order to obtain higher efficiency.
	Back Pressure	This unit exhausts the incoming steam, whether dry or wet, directly to the atmosphere.

Source: JICA Survey Team

(2) Installed Capacity

The surface survey conducted by Jacobs (2016) estimated that the geothermal energy available from the reservoir could range from 20 MWe to 90 MWe. On the other hand, the Grenada Electricity Services Limited (GRENLEC) estimates the electricity base load in the Grenada Island to be about 18 MW. Although the base load is considered to be supplied from the geothermal power plant, a prudent approach is required at this stage because estimation of geothermal energy with no test wells shall be considered to be preliminary. Also, the estimated electricity base load may have seasonal or yearly fluctuations that should be adjusted by middle load power plants. Taking into consideration the above, the JICA Survey Team proposes that the installed capacity of the geothermal power station shall be 15 MW.

(3) Turbine and Generator

For continuous operation of the geothermal power station even during non-operation period for regular maintenance, multiple turbo generator units shall be installed. At the same time, capacities of the port and/or road conditions through which the units shall be transported for installation shall be taken into account. Based on the above points, the JICA Survey Team recommends three sets of 5 MW turbine generator unit to be installed (Table 5-2).

The turbine shall be the single flash condensing type and the generator will be of totally enclosed water- to air-cooled type with major specifications of 11 kV voltage, three phases, 50 Hz frequency, and 3, 000 rpm rotating speed.

Table 5-2 Assessment of Capacity of Single Unit

GRENADA

A comparison for Selection of number of turbo-generator units to be installed

Grenada		15 MW x 1 unit	10 MW x 1 unit plus 5 MW x 1 unit	7.5 MW x 2 units	5 MW x 3 units
1.	System reliability when fails Reserve margin > Largest unit capacity on the system (Data: Queen's Park P/S) - Rated installed capacity: 46 MW in 2010 - Capacity to be added: 15 MW - Rated installed capacity considered: 61 MW - Generation capacity*: 37-39 MW (tentative) - Peak demand: 31 MW in 2010 - Reserve margin (RM): 6-8 MW	Not Suitable (RM < 15 MW)	Not Suitable (RM < 10 MW)	Marginal (RM ≈ 7.5 MW)	☑ Suitable (RM > 5 MW)
2	Not greater than a 20% of the peak demand (6 MW) (DOMLEC 2015)	Not Suitable (< 15 MW)	Not Suitable (< 10 MW)	Marginal (≈ 7.5 MW)	☑ Suitable (> 5 MW)
3	Continuous operational ability of the power plant while maintenance, or when sudden shut down.	Not possible	Possible (Continuously deliverable output: 10 MW or 5 MW, variable)	Possible (Continuously deliverable output: 7.5 MW)	☑ Possible (Continuously deliverable output: 10 MW in normal case)
6	Flexibility to fluctuation in power demand due to likely unstable base load conditions	Lowest	Second highest	Second lowest	☑ Highest
7	Initial Cost, (Indicative)	☑ Lowest	Second highest	Second lowest	Highest
8	Maintenance cost	☑ Lowest	Second highest	Second lowest	Highest
9	Hand-ability - Transportation (port and inland) - Installation - Maintenance	Low	Relatively low	Medium	☑ High
10	Spare Parts compatibility between units	-	Not compatible	☑ Compatible	☑ Compatible

Generation capacity= Rated (61 MW) x Average output capacity (0.75)x Availability (0.90) x failure rate (0.90 – 0.95) - *tentative*

Source: JICA Survey Team

(4) Condensing Facility

Steam exhausted from the turbine will be condensed to liquid in the condenser to reduce the specific volume. The condenser shall have direct contact with the cooling water that will be stored in the water pool located at the cooling tower because water source (river or water stream) may not be perennial, and that will be circulated in the cooling facility consisting mainly of the condenser, cooling tower equipped with water pools, fans, and connecting pipes.

Non-condensable gas is assumed to be contained in the steam. The non-condensable gas shall be sent from the condenser to the gas extractor to be equipped near the condenser.

(5) Other Facilities in the Power Station

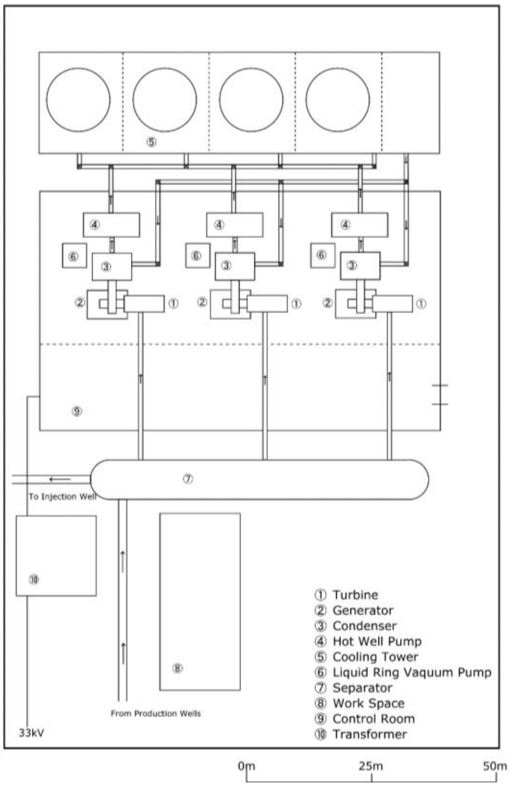
・Gas extractor and gas exhaust

The gas extractor shall be a hybrid-type of steam ejector and vacuum pump. The non-condensable gas extracted by the gas extractor will be sent to the cooling tower, where the gas will be released to the surrounding through wind-generating facilities (fans) for air cooling system.

・Transformer

Electricity of 11 kV voltage generated by the turbine-generator system will be sent to the transformer, thereby the voltage will be raised to 33 kV for transmission. While the cooling tower is located at one side of the turbine-generator building, the transformer will be located at the other side of the building because the transformer shall be as much as possible out of reach of the non-condensable gas and/or moisture exhausted from the cooling tower.

Figure 5-1 shows the schematic layout of the facility in the power station.

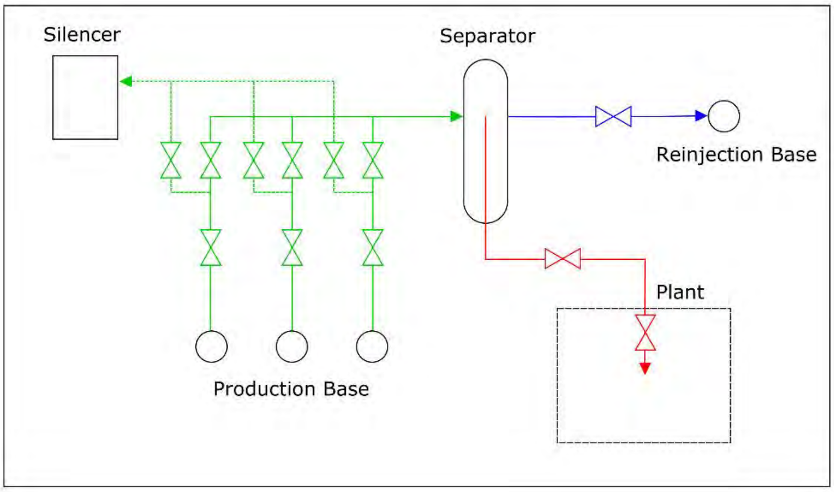


Source: JICA Survey Team

Figure 5-1 Schematic Facility Layout in the Power Plant

5-2-2 Fluid Collection and Reinjection System（FCRS）

The JICA Survey Team assumes two phases steam and liquid mixture fluid to be produced from the production wells. The fluid will be sent into the separator installed at the production base; thereafter, the steam will be sent to the power plant and the brine will be sent to the re-injection base. A schematic layout of the FCRS is shown in Figure 5-2. Explanations are presented hereunder for each facility consisting the FCRS.



Source: JICA Survey Team

Figure 5-2 FCRS Conceptual Layout

(1) Production Well and Re-injection Well

Four appraisal wells and two production wells are proposed by Jacobs (2016). The JICA Survey Team specifies the wells as full size wells of 8-1/2' inch drilling diameter at the bottom, 2,000 m length and directional. Among these, the JICA Survey Team assumes that three wells are to be converted into production wells and one into the re-injection well. 5 MW capacity per well is assumed, thereby, a total of 15 MW energy is to be exploited.

As a preliminary plan, the JICA Survey Team locates the wells in site C, D, and E among the sites identified by Jacobs (2016).

(2) Separator, Rock Muffler, Hot Water Pit

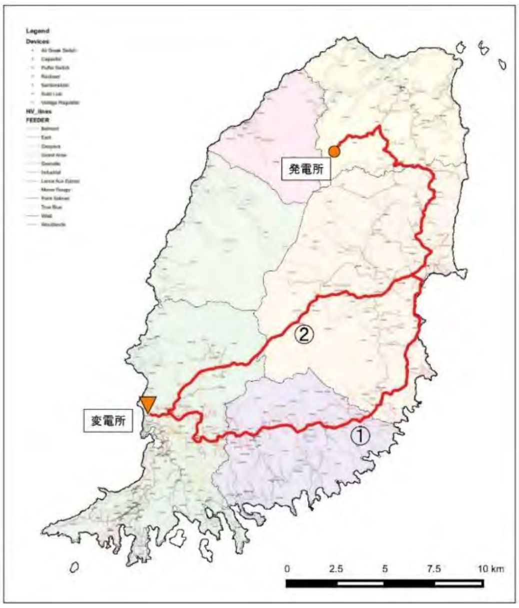
- A cyclone-type steam-water separator will be installed at each production base. Geothermal brine produced from well/s will be sent into the separator.
- A rock-muffler will be built at each production base to reduce noises generated when the steam or brine is released to the surroundings.
- Hot water pit will be constructed to temporarily store water ejected from the rock muffler.

(3) Fluid Transportation Pipeline

As the topography is intensely undulating in the target area, the lengths of the fluid transportation line may vary according to the pipeline route to be decided. Here, the JICA Survey Team assumed an average length of 3 km between the production base and the power plant, totaling to 9 km. The diameter should be 500 mm.

5-2-3 Electricity Transmission Facility

The total length of the transmission line, if placed along the road marked 2 in Figure 5-3, will be not more than 40 km. As the total installed capacity is 15 MW, the 33 kV capacity of the transmission facility will be suitable; the facility will consist of cables and concrete-made electric poles of 8.5 to 10.5 m height above the ground. Because of this reason, this transmission facility can/shall be installed along the existing road, which will contribute to easy construction and also easy maintenance during operation. The JICA Survey Team would also recommend that the facility shall have two new transmission lines, each with 100% capacity to provide full redundancy, so that reliable electric power shall be provided throughout the year. In addition, the new 11 kV line, as replacement of the existing 11 kV line, could be mounted on one new transmission line together with 33 kV line.



Source: IRENA, 2012

Figure 5-3 Transmission Line along the Existing Road

5-3 Project Cost Estimation

The project cost estimation is shown in Table 5-3.

In general, the total project cost shall include the cost of geological, geochemical, and geophysical survey. In the case of Grenada, however, the costs of the surface surveys are not included in the cost estimates because they have been completed by the JICA Survey Team and New Zealand Team (2016). The JICA Survey Team made the preliminary estimation of the costs of the activities to be conducted after the completion of the surface survey. The activities include: i) slim hole drilling, ii) appraisal well drilling, iii) production well drilling, iv) transmission facility construction, and v) power plant construction including steam field development.

The estimated cost totaled to USD 123 million.

Table 5-3 Summary of Cost Estimation

Cost Items	Cost (US$)
Civil Works & Preparation	17,700,000
Slimhole Drilling (3 Wells)	7,500,000
Appraisal Drilling (4 Wells)	20,800,000
Production Drilling (2 Wells, Production Test)	12,400,000
Field Development	6,000,000
Construction of Power Plant	35,200,000
Transmission Line (2 lines)	18,000,000
Consultancy Services (DD, SV)	5,800,000
Total	123,400,000

Source: JICA Survey Team

Assumptions made for the cost estimation are as follows:

(1) Slim Hole Drilling

- Three 1,500 m deep holes
- USD 2.5 million per hole
- Cost for preparation works (civil works, water supply and land acquisition of 40 m x 40 m each)

(2) Appraisal Well Drilling

- Four 2,000 m, full size (8-1/2" drilling diameter at the bottom) deep wells
- USD 5.2 million per well, costs for well tests are inclusive
- Cost for preparation works (Civil works, water supply and land acquisition of 100 m x 100 m each)

(3) Production Well Drilling

- Two 2,000 m, full size (8-1/2" drilling diameter at the bottom) deep wells
- USD 6.2 million per well, costs for production tests are inclusive
- Cost for preparation works (civil works, water supply and land acquisition of 100 m x 100 m each)

(4) Steam Field Development (FCRS[4] = SAGS[5])

- A steam-liquid separator, rock muffler at each of the two production bases
- An average of 3 km from each production base, totaling to 9 km of fluid transportation pipe having 500 mm diameter
- Cost for preparation works (civil works, water supply, and land acquisition)

(5) Power Plant Construction

- Three units of 5 MW turbine-generator set
- Cooling system including condensers, cooling towers, and water circulation system
- Preparation works (civil works, land acquisition of 100 m x 150 m)

(6) Transmission Facility Construction

- Two lines, 33 kV each, with full capacity for full redundancy
- Maximum 40 km for each line
- Concrete-made poles of about 10 m above ground
- USD 0. 25 million per km
- Preparation works (land acquisition)

[4] FCRS: Fluid collection and re-injection system
[5] SAGS: Steam above-ground pipeline system or steam-field above ground system

(7) Consultancy Services

- Detailed design, construction supervision
- Tendering services for procurement
- Environmental and Social Impact Assessment (ESIA) for drilling works and power plant construction works

(8) Other Cost

The JICA Survey Team anticipated that the following costs may be required; however, these are not included in this study as they are not clearly identified at this stage:

- Taxation (import tax, VAT and/or others)
- Costs for local employment for project administration by the government
- Cost for project administration by the government

5-4 Project Implementation Models

The JICA Survey Team assumed four models for the financial analysis based on variations of the cost bearing (investing) entities, i.e., Grenada government or private entity/ies, as shown in Table 5-4. For all the models, the JICA Survey Team assumed that the government will invite private entity/ies for power plant construction (including steam field development - SGAS), transmission line construction, and operation and maintenance. Also, the JICA Survey Team assumed that slim hole drilling will be conducted through grant finance to be made available to the government. Brief explanations are as follows:

Model-1: The government will undertake the works from slim hole drilling through appraisal wells drilling to the production wells. Soft loans will be made available to the government for the appraisal and production well drilling. The productive wells and reinjection well will be sold out to the private entity who will undertake the construction of SGAS and power plant, as well as the operation and maintenance.

Model-2: The government will undertake slim hole drilling through grant finance while the appraisal well drilling through soft loan. The production wells, out of the appraisal wells, will be sold out to the private firm who will undertake the production well drilling and the works thereafter, and operation and maintenance of the power station.

Model-3: The government will undertake slim hole drilling only through grant finance. The private firm will undertake the appraisal well drilling and the works thereafter, and operation and maintenance of the power station.

Model-4: There may be the case that a private firm may judge with considerable confidence that the geothermal energy could be made available based on their assessment of the available surface survey results. In this case, the private firm may undertake such slim holes that will not be converted to production wells even if they succeeded. Instead, the firm will proceed to investment directly to full-size appraisal well drilling. Model-4 assumes this type of case. This Model-4, however, will be same as Model-3 from the financial analysis point of view, because cost for slim holes (grant finance) will not be included in the calculation of the financial analysis.

Table 5-4 Implementation Models for Financial Analysis

Model	Entity	Work Allocation
Model-1	Government:	Slim holes, appraisal well, production wells, and tendering for procurement of one year
	Private:	SGAS and power plant
Model-2	Government:	Slim holes, appraisal well, and tendering for procurement of one year
	Private:	Production wells, SGAS and power plant
Model-3	Government:	Slim holes and tendering for procurement of two years (A period of two years for tendering is assumed to allocate a longer period for tender preparations because appraisal wells are not completed at this stage)
	Private:	Appraisal wells, production wells, SGAS and power plant (A period of two years for tendering is assumed to allocate a longer period for tender preparations because appraisal wells are not completed at this stage)
Model-4	Government:	Tendering for procurement of two years (A period of two years for tendering are assumed to allocate a longer period for tender preparations)
	Private:	Appraisal wells, production wells, SGAS and power plant (The JICA Survey Team assumed that a private entity will participate in the project only when he/she should be confident that geothermal energy would be available without providing slim holes or additional appraisal wells.)

Source: JICA Survey Team

5-5 Project Cost

Allocations of the project costs of each model are presented in Table 5-5.

Table 5-5 excludes the cost for slim holes, which are expected to be conducted through grant finance. Also, the costs of Model-1, -2 and Model-3, -4 are different because the assumed time period for these two groups are different as explained in Table 5-4.

5-6 Project Implementation Schedule

The timelines are presented in Table 5-6. These are the shortest cases because various uncertainties are involved in each development stage such as resources availability, finance availability, availability of private entities who are interested in the project, geological risks during drillings, and ESIA progress.

Table 5-5 Construction Allocations for Models

Model-1		
Organization in Charge	**Cost Items**	**Cost (USD)**
Public Entity (Gov)	Civil Works & Preparation	13,100,000
	Slimhole Drilling (3 Wells)	0
	Appraisal Drilling (4 Wells)	20,800,000
	Production Drilling (2 Wells, Production Test)	12,400,000
	Subtotal	***46,300,000***
	Consultancy Services (DD, SV)	1,850,000
	(ESIA)	0
	(Tender)	500,000
	Subtotal	***2,350,000***
Total		***48,650,000***
Private Entity (Sponsor)	Civil Works & Preparation	600,000
	Field Development	6,000,000
	Construction of Power Plant	35,220,000
	Transmission Line (2 lines)	18,000,000
	Subtotal	***59,820,000***
	Consultancy Services (DD, SV)	2,390,000
	(ESIA)	200,000
	(Tender)	0
	Subtotal	***2,590,000***
Total		***62,410,000***
Grand total		***111,060,000***

Model-2		
Organization in Charge	**Cost Items**	**Cost (USD)**
Public Entity (Gov)	Civil Works & Preparation	9,240,000
	Slimhole Drilling (3 Wells)	0
	Appraisal Drilling (4 Wells)	20,800,000
	Production Drilling (2 Wells, Production Test)	0
	Subtotal	***30,040,000***
	Consultancy Services (DD, SV)	1,200,000
	(ESIA)	0
	(Tender)	500,000
	Subtotal	***1,700,000***
Total		***31,740,000***
Private Entity (Sponsor)	Civil Works & Preparation	4,460,000
	Production drilling	12,400,000
	Field Development	6,000,000
	Construction of Power Plant	35,220,000
	Transmission Line (2 lines)	18,000,000
	Subtotal	***76,080,000***
	Consultancy Services (DD, SV)	3,040,000
	(ESIA)	200,000
	(Tender)	0
	Subtotal	***3,240,000***
Total		***79,320,000***
Grand total		***111,060,000***

Source: JICA Survey Team

Model-3		
Organization in Charge	**Cost Items**	**Cost (USD)**
Public Entity (Gov)	Civil Works & Preparation	0
	Slimhole Drilling (3 Wells)	0
	Appraisal Drilling (4 Wells)	0
	Production Drilling (2 Wells, Production Test)	0
	Subtotal	*0*
	Consultancy Services (DD, SV)	0
	(ESIA)	0
	(Tender)	750,000
	Subtotal	750,000
Total		***750,000***
Private Entity (Sponsor)	Civil Works & Preparation	13,700,000
	Appraisal Drilling (4 Wells)	20,800,000
	Production Drilling (2 Wells, Production Test)	12,400,000
	Field Development	6,000,000
	Construction of Power Plant	35,220,000
	Transmission Line (2 lines)	18,000,000
	Subtotal	***106,120,000***
	Consultancy Services (DD, SV)	4,240,000
	(ESIA)	200,000
	(Tender)	0
	Subtotal	***4,440,000***
Total		***110,560,000***
Grand total		***111,310,000***

Model-4		
Organization in Charge	**Cost Items**	**Cost (USD)**
Public Entity (Gov)	Civil Works & Preparation	0
	Slimhole Drilling (3 Wells)	0
	Appraisal Drilling (4 Wells)	0
	Production Drilling (2 Wells, Production Test)	0
	Subtotal	**0**
	Consultancy Services (DD, SV)	0
	(ESIA)	0
	(Tender)	750,000
	Subtotal	**750,000**
Total		**750,000**
Private Entity (Sponsor)	Civil Works & Preparation	13,700,000
	Appraisal Drilling (4 Wells)	20,800,000
	Production Drilling (2 Wells, Production Test)	12,400,000
	Field Development	6,000,000
	Construction of Power Plant	35,220,000
	Transmission Line (2 lines)	18,000,000
	Subtotal	***106,120,000***
	Consultancy Services (DD, SV)	4,240,000
	(ESIA)	200,000
	(Tender)	0
	Subtotal	***4,440,000***
Total		***110,560,000***
Grand total		***111,310,000***

Source: JICA Survey Team

Table 5-6 Project Implementation Schedule

MODEL 1		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Public Entity (Gov)	Civil Works & Preparation	■		■						
	Slimhole Drilling (3 Wells)		■							
	Appraisal Drilling (4 Wells)				■					
	Production Drilling (2 Wells)					■				
	ESIA	■				■				
	Tender						■			
Private Entity (Sponsor)	ESIA							■		
	Field Development							■	■	
	Transmission Line							■	■	
	Construction of Power Plant									■

MODEL 2		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Public Entity (Gov)	Civil Works & Preparation	■		■					
	Slimhole Drilling (3 Wells)		■						
	Appraisal Drilling (4 Wells)				■				
	ESIA	■							
	Tender					■			
Private Entity (Sponsor)	Civil Works & Preparation						■		
	Production Drilling (2 Wells)						■		
	ESIA						■		
	Field Development						■	■	
	Transmission Line						■	■	
	Construction of Power Plant								■

MODEL 3		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Public Entity (Gov)	Civil Works & Preparation	■								
	Slimhole Drilling (3 Wells)		■							
	Tender			■	■					
	ESIA	■								
Private Entity (Sponsor)	Civil Works & Preparation					■		■		
	Appraisal Drilling (4 Wells)						■			
	Production Drilling (2 Wells)							■		
	ESIA							■		
	Field Development							■	■	
	Transmission Line							■	■	
	Construction of Power Plant									■

MODEL 4		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Public Entity (Gov)	Tender	■	■					
Private Entity (Sponsor)	Civil Works & Preparation			■		■		
	Appraisal Drilling (4 Wells)				■			
	Production Drilling (2 Wells)					■		
	ESIA			■		■		
	Field Development					■	■	
	Transmission Line					■	■	
	Construction of Power Plant							■

Source: JICA Survey Team

5-7 Financial Analysis for Geothermal Development in Grenada

The financial analysis aims to examine the financial viability of the project and to compare the investment options for the government. The government is expected to take the lead in developing the geothermal resources and look for public-private-partnership (PPP) for the investment. While the specific investment partner has not been identified at the moment, it is effective to assess the possibility and bankability of the development scheme.

5-7-1 Project Scheme

It is not expected that the geothermal power development in Grenada is implemented by the government through the consolidated development method from the survey to the operation of the plant. It is envisaged in the National Energy Development Plan (2011) that the private sector would participate in the development at a certain stage. This section assumes some options for the development schemes.

The financial analysis examines the following three options for the project schemes. Models-1 to -3 are PPP options where the government and private company will demarcate the activities of the project implementation. The development of the slim hole drilling would be covered by a grant fund.

Even in the case where the grant finance would not be realized, it is expected that the private sector could participate in the development without slim hole drilling. There would also be an option (Model-4) for the traditional build-operate-transfer (BOT) scheme, which is practically similar to Model-3 if the private sector does not choose to invest in the slim hole drilling. Therefore, the financial analysis for BOT (Model-4) is studied in Model-3.

Table 5-7 Project Scheme

<table>
<tr><th colspan="3" rowspan="2">Particular</th><th>Model 1</th><th>Model 2</th><th>Model 3</th></tr>
<tr><th>(PPP Model No.1)</th><th>(PPP Model No.2)</th><th>(PPP Model No.3)</th></tr>
<tr><td rowspan="5">Development Activity & Entity</td><td>1</td><td>Exploration Slim Hole Drilling</td><td>Government (Grant Fund)</td><td>Government (Grant Fund)</td><td>Government (Grant Fund)</td></tr>
<tr><td>2</td><td>Appraisal Drilling</td><td>Government</td><td>Government</td><td>Private</td></tr>
<tr><td>3</td><td>Production Drilling</td><td>Government</td><td>Private</td><td>Private</td></tr>
<tr><td>4</td><td>Field Development and Construction of Power Plant</td><td>Private</td><td>Private</td><td>Private</td></tr>
<tr><td>5</td><td>Operation</td><td>Private</td><td>Private</td><td>Private</td></tr>
<tr><td rowspan="2">Debt Financing</td><td colspan="2">Government</td><td>Concessional Loan</td><td>Concessional Loan</td><td>Concessional Loan</td></tr>
<tr><td colspan="2">Private</td><td>Commercial Loan</td><td>Commercial Loan</td><td>Commercial Loan</td></tr>
<tr><td colspan="3">Remarks</td><td>Sales agreement of steam or sales of production wells to power producer</td><td>Transfer cost of appraisal drilling to power producer</td><td>No costs will be transferred to the private entity.</td></tr>
</table>

Source: JICA Survey Team

It is assumed that the costs of the development by the government would be recovered by the revenue of the charges from the private company that has the concession agreement with the government. The charge is one of the operating expenses of the private company. It is also assumed that the private company obtains the revenue from the power sales to GRENLEC. It is also expected that the government and GRENLEC could also be a shareholder of the generation company. However, the financial analysis does not specify the composition of the shareholders and the equity return would be an ordinary return for similar projects, which would be approximately 20%.

5-7-2 Development Plan

The overview of the development can be summarized as follows:

While the analysis examines the abovementioned three models, the major difference among them is basically the organizations that are in-charge of each activity on the project. Hence, the basic physical investment costs for each investment activity are the same. The differences in the models can be assessed by the cost of capital, project implementation schedule, corporate tax on operation, and other permission by the government.

Table 5-8 Overview of the Development Plan

1. Project Overview	
1.1 Project Description	
The project shall include the following activities: - Geothermal resources assessment - Geothermal well drilling and testing - Construction of geothermal power plant (15 MW or 10-15 MW to be examined) - Construction of transmission line (out of scope of generation development) - Operation and maintenance of the power plant	
1.2 Goal and Objectives	
- To reduce and stabilize electricity prices - To contribute in the mitigation of global warming	The ceiling price of the energy cost can be considered to be USD 0.15/kWh given the current cost of services of GRENLEC.
1.3 Decision Management	
- Currently, the assessment of the pre-feasibility of the resources is being carried out. - The procurement of funds for the exploration drilling is considered in parallel.	The development stage is generally subdivided into six steps: 1. Initiate, 2. Evaluate Resource, 3. Quantify Resource, 4. Confirm Resource, 5. Execute, 6. Operate
1.4. Project Ownership, Structure and Governance	
The formation for project development is being examined.	
1.5 Policy and Legislative Framework	
Law: - Public Utilities Regulatory Communication Bill 2015: being discussed at the Parliament - Electricity Supply Bill 2015: being discussed at the Parliament - Geothermal Development Bill: being drafted Policy The Energy Division in the Ministry of Finance, Planning, Economy, Energy and Cooperatives (Ministry of Finance) is in-charge of energy policy.	It would also be envisaged that a PPP-related regulation would be established.
2. Investment	
2.1 General Conditions	
Main procurement will be conducted through open book method in compliance with the international cooperating partners.	

2.2 Cost Estimates

Construction cost for Model-3 is as follows:

(i) Government Portion

Category	Item	Costs (USD million)	%
Well Drilling	Civil Works	0	0.0
	Slim Hole Drilling	0	0.0
	Appraisal Drilling	0	0.0
	Production Drilling	0	0.0
	Consultancy Services	0.75	100.0
Power Plant Development	Field Dev.	0	0.0
	Power Plant Dev.	0	0.0
	Transmission Line	0	0.0
	Consultancy Services	0	0.0
Total Project Cost		0.75	100.0

(ii) Private Portion

Category	Item	Costs (USD million)	%
Well Drilling	Civil Works	13.10	11.89
	Slim Hole Drilling	0.00	0.0
	Appraisal Drilling	20.80	18.87
	Production Drilling	12.40	11.25
	Consultancy Services	4.08	3.70
Power Plant Development	Field Dev.	6.60	5.90
	Power Plant Dev.	35.22	31.96
	Transmission Line	18.00	16.34
	Consultancy Services	0.00 (included in the above)	0.00
Total Project Cost		110.20	100.0

The total construction cost includes the drilling, power plant, civil works, and steam field development costs.

The cost of the transmission line is tentatively included in the project cost. This arrangement should be discussed with GRENLEC at the latter stage of the development.

The assumed figures for the other models are described in the other sections of the report.

2.3 Project Profile

The following are assumed for the base case:

- Installed capacity : 5.5 MW x 3 Units, total 16.5 MW
- In-house use : 10%
- Availability factor : 90%
- Net output : 15 MW
- Annual generation : Net 118.2 GWh/year
- Construction period : Vary by model
- Operating period : 30 years

<table>
<tr><th colspan="2">2.4 Project Schedule</th></tr>
<tr><td>Project schedule for Model-3 is estimated as follows:

<table>
<tr><th>Item</th><th>Period (year)</th><th>Remarks</th></tr>
<tr><td>Permissions & Civil Works</td><td>1.0</td><td rowspan="3">By the government (Public)</td></tr>
<tr><td>Slim Hole Drilling</td><td>1.0</td></tr>
<tr><td>Tendering</td><td>2.0</td></tr>
<tr><td>Civil Works & Preparation</td><td>1.0</td><td rowspan="5">By the private company</td></tr>
<tr><td>Appraisal Drilling</td><td>1.0</td></tr>
<tr><td>Production Drilling & Field Development</td><td>1.0</td></tr>
<tr><td>Transmission Line</td><td>1.0</td></tr>
<tr><td>Power Plant & Commissioning</td><td>1.0</td></tr>
<tr><td>Total Period</td><td>9.0</td><td></td></tr>
</table>
</td><td>The assumed figures for the other models are described in the other sections of the report.</td></tr>
</table>

Source: JICA Survey Team

5-7-3 Assumptions for the Financial Analysis

The assumptions for the financial analysis are shown in Table 5-9.

Table 5-9 Assumptions for the Financial Analysis

Item	Condition
a. Energy Generation	118.2 GWh/year (Average utilization rate: 90%)
b. Initial Investment Costs	USD 110.20 million (Model-3, private entity)
c. Total Construction Period	Vary by model
d. Project Period	Operation : 25 years from commissioning
e. Ratio of Capital Procurement (equity and debt)	Vary by model
f. Repayment of Debt	Concessional loan : 25 years (grace period: 7 years) Commercial loan : 20 years (grace period: 3 years)
g. Capital Costs	Concessional loan : 3.0% Commercial loan : 5.5%
h. Annual O&M Expenses	2.0% of total construction cost
i. WACC	Vary by model
j. Depreciation	Service life : 30 years, salvage value: 5%, Straight-line method
k. Tax and Duty	Corporate tax : 30%, VAT and import duty: exempted
l. Physical Contingency	5% of the total cost
m. Power Sales Price	Generation company to GRENLEC: US¢ 15.0/kWh
n. Charges from Public to Private (Generation Company)	Vary by model

Source: JICA Survey Team

The conditions for debt financing have been estimated based on recent trend and examples of similar projects with concessional loans of the cooperating partners and commercial loans of commercial banks. The equity return for the private company was assumed to be 20%. The depreciation of the plant is the same period as the lifetime of the power plant.

5-7-4 Results of the Financial Analysis

The results of the financial analysis are summarized in Table 5-10.

In all the models, the government is expected to recover the investment costs from the private company during the operation phase. However, the charges by the government to the private company would be kept at a minimum in order to encourage investment from the private sector.

It is assumed that the private company can sell the generated electricity at a sale price (US¢0.15/kW) acceptable to GRENLEC.

Table 5-10 Results of the Financial Analysis

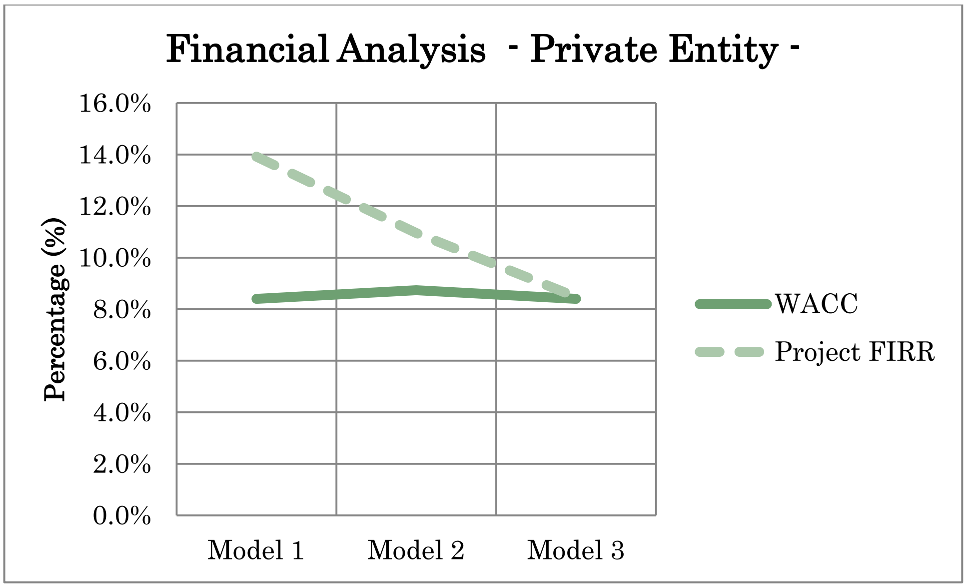
(When selling price to GRENLEC is fixed at US¢0.15/kW)

Entity	Item	Model 1	Model 2	Model 3
Public (Government)	Debt	USD 41.5 mil.	USD 27.1 mil.	USD 0.6 mil.
	Equity	USD 20.6 mil.	USD 13.8 mil.	USD 0.3 mil.
	WACC[6]	2.6%	2.6%	2.6%
	Project FIRR	3.5%	3.7%	4.3%
	Equity FIRR	- 1.1%	- 0.9%	1.7%
Private	Debt	USD 50.3 mil.	USD 66.3 mil.	USD 92.6 mil.
	Equity	USD 12.6 mil.	USD 19.1 mil.	USD 23.1 mil.
	WACC	8.4%	8.7%	8.4%
	Project FIRR	13.9%	11.0%	8.5%
	Equity FIRR	34.9%	31.8%	22.2%
Public-Private Consolidated	Project FIRR	8.2%	8.4%	8.4%

Source: JICA Survey Team

[6] WACC: Weighted Average Cost of Capital, FIRR: Financial Internal Rate of Return

The WACC and project FIRR are also compared in Figure 5-4 below.



Source: JICA Survey Team

Figure 5-4 Financial Analysis – Private Entity

The project can be assessed as viable in all the models. Since the government is in-charge of the exploration activities until the production drilling in Model-1, the investment needs of the private company is smaller than in the other models, resulting in higher rate of return. From the viewpoint of the private company, this model achieves the highest return; one of the issues would be the procurement of capital by the government.

Model-2 has higher investment costs and risks by the private company because the government invests only up to the appraisal drilling. It is however anticipated that the technical barriers would be lower for the private company since the estimation of the geothermal storage has been completed by the government.

On the other hand, in Model-3, the private company needs to invest in appraisal and production drilling. Thus, the project financial internal rate of return (FIRR) is lower than in the other models, but the return is still higher than the weighted average cost of capital (WACC). It is expected that the private company would be able to secure the expected return on investment in all the models.

The consolidated project return is around 8% in all the models. The project requires exploration activities and tender process for the private company. Therefore, the standard project period would take as long as nine years from the survey to the commissioning of the power plant.

5-7-5 Observations and Suggestions

The overall project viability can be confirmed at this point of the study phase. Some points should be noted for further consideration as follows:

(1) Government Role and Financing

The role of the government is to facilitate the project implementation by attracting private companies in the project. To achieve this, the government would need to secure the grant financing for the exploration phase of the development. It is confirmed that the exploration activities by the government will mitigate the project risks and provide a comfort to the private investors because the private company can expect a higher return at a latter phase.

The analysis assumes that the grant finance can be secured for the slim hole drilling. With respect to the appraisal drilling, the grant is not planned in the analysis. Either government or private company would need to explore the possibilities for risk mitigation schemes or concessional loans.

(2) Investment Policy of the Government

The equity return of the government portion can also be discussed. The analysis assumes that the return on investment of the government can be kept at a minimum level so that the project can attract private companies in the tendering stage. This issue can be analyzed through examining the level of charges imposed by the government to the private company because the discussion is how to allocate the profits of the project between the government and the private company.

(3) Capacity Development

The government would need to strengthen the capacity to run the project. Since the project is still at the initial stage of the development, the geothermal resources should be assessed and hence the project bankability should be analyzed. The tender and contract with the project partner should be managed by the government. These activities are the tasks of the project management office of the government in addition to funding for the project. Enhancement of scientific and engineering knowledge and techniques are not directly related to the capacity development of the government officers, in the case of Grenada.

(4) Legislation and Regulation

The project would require the streamlining and new establishment of legislation and regulation for project implementation. The establishment of the legal basis would provide comfort to the private company to invest. These rules and regulations would include the Geothermal Development Law, Public Utilities Regulatory Communication Bill 2015, Electricity Supply Bill 2015, and the PPP-related law. The technical standard for geothermal plants and monitoring of the plant operation could also be established.

(5) Improvement of the Project Survey

The project is still at the pre-feasibility study stage. Thus, it is required to examine the development plan, costs, and the feasibility of the project in due course of the additional survey and drilling works. The reviews should be made on items such as the technical design, cost estimates, financing options, construction schedule, and demarcation of the public and private entities.

In general, the more examination of the project is carried out, the lower the investment return. Therefore, careful implementation of the survey work needs to be planned through the examination of the survey items.

(6) Market Sounding

The assumptions for the financial analysis have been established based on the current best estimates; and the conditions would need to be reviewed and updated in the future planning. The private company has not been identified yet for instance. It is therefore suggested that proper exchange of information and views should be considered among the interested private companies, financial institutions, and other stakeholders. This would be a reference for future project planning.

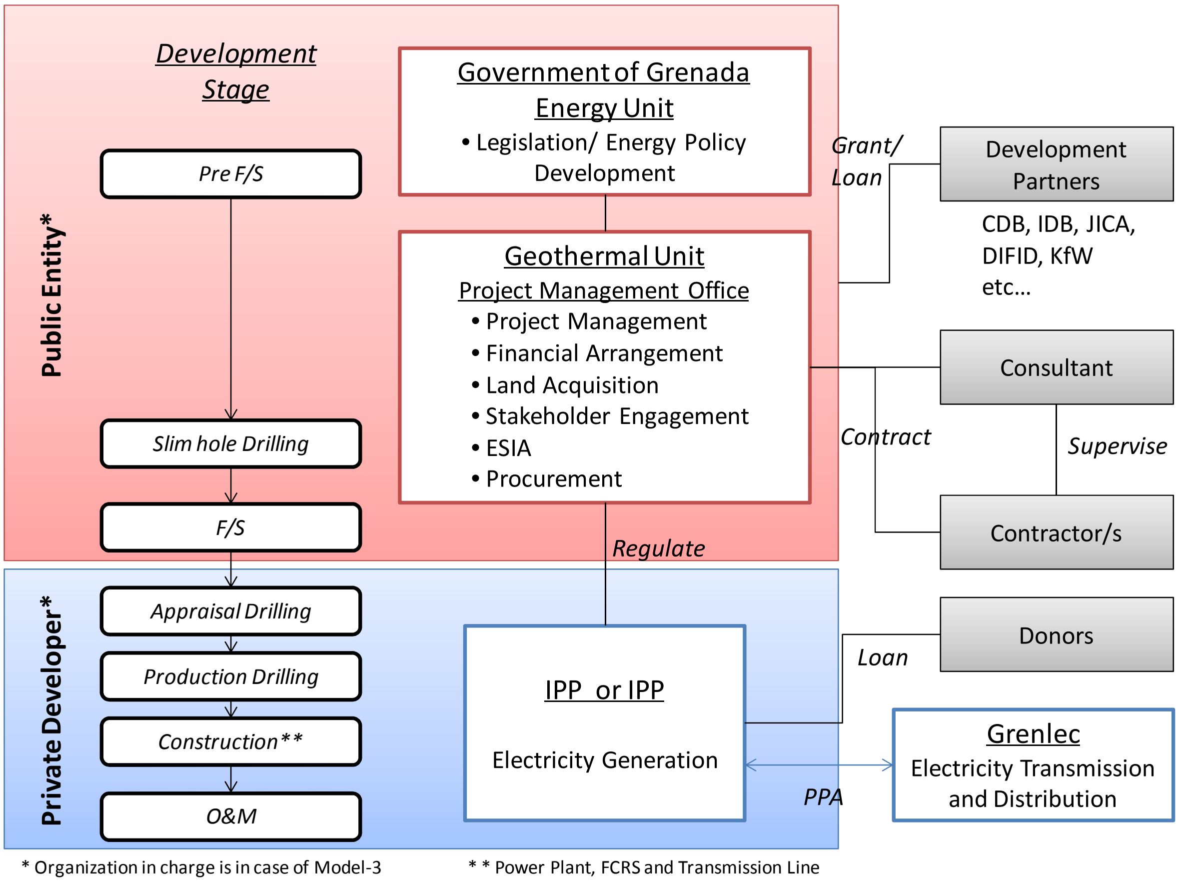
It is important to consider the trend of the market and the private company in addition to the technical and financial studies in order to examine the options of the development scheme. The expectations of the stakeholders are not always consistent with the development policy of the government. Coordination is one of the critical tasks of the government.

5-8 Project Structure

The ideal project structure for the geothermal development in Grenada is shown in the following figure. Here model case 3 is taken as a typical project scheme.

During the F/S stage, the government of Grenada is required to establish a legislation and regulation in order to promote geothermal project. Regarding a project management, it is recommended to formulate a special Geothermal Unit under the Energy Unit. Geothermal Unit. The Geothermal Unit will conduct a project management, financial arrangement for test wells, land acquisition and ESIA for test drilling as well as tender process and contract matters.

For technical management such as drilling supervise and ESIA study, consultants shall be employed by the government or other development partners.



Source: JICA Survey Team

Figure 5-5 Project Structure

5-9 Project Evaluation

5-9-1 Relevance

Relevance to the development needs: One of the National Energy Development goals is to promote renewable energy usage and transform it to low carbon-based energy generation. The geothermal development in Grenada is exactly in the same line as this national target.

Relevance to the assistance direction from international partners: International partners promote renewable energy usage to realize low carbon society in order to contribute in mitigating global warming. Therefore, geothermal development is considered to attract financial and technical cooperation from international partners.

Appropriateness as a measure for development: From the two points, the geothermal development in Grenada is considered to be appropriate for power generation in Grenada, where most of the electricity is being generated from diesel fuel engine power station.

5-9-2 Effectiveness

Project Content: Construction of geothermal power station with 3 units, each with 5 MW, totaling to an installed capacity of 15 MW, together with the transmission lines to transmit the electricity to St. George’s, the capital of Grenada. The project contents and output are clear and evident; however, to be realistically achievable, external conditions need to be satisfied.

5-9-3 Efficiency

The financial analysis of this pre-feasibility study has indicated that this project is financially feasible if external conditions are satisfied.

5-9-4 Impact

This project will develop indigenous low carbon energy for electricity power generation, which will contribute to one of the national energy policies.

【Ripple Effect】

Social Environment: The project will have positive impacts on economic boom and thereby on all the people due to its stable and cheaper electricity supply; on the other hand, it may have negative impacts on local people who may be affected by possible land acquisitions and/or resettlement.

Natural Environment: The project may have negative impacts on natural environments due to preparations for civil works, noises during construction, and/or air pollution during operations. Detailed ESIA and mitigations will have to be required.

5-9-5 Sustainability

Policies, laws, regulations, and institutions: Renewal of the relevant laws and regulations are being discussed to promote private investment in the energy sector. This reformulation is expected to make the geothermal development sustainable.

Implementation organization: The project will be implemented through independent power producer (IPP) or PPP, expecting an experienced private firm to participate in the project, which makes the project sustainable.

Financial aspect: Construction of the project will be implemented through grant aid for slim holes and soft loans for other subsequent works. Financial robustness will be sustained by setting appropriate electric tariff that is expected to be lower than the present tariff.

Technical aspects: An experienced private operator will operate and maintain the geothermal facility, which makes the project sustainable.

Environmental, social, cultural, gender and/or others: Possible impacts and their countermeasures will be identified by ESIAs including possible impact on gender, poverty, and indigenous people, if any.

5-9-6 External Conditions

Envisaged external conditions identified at this stage are as follows:

- Relevant laws and/or regulations are to be implemented.
- Grant funds, soft loans, and/or local finance for implementing the project are to be made available on time.
- Technical assistance to identify the resources and to construct the geothermal power plant is to be provided.
- Geothermal resources are to be identified and developed in economical ways.
- IPP or PPP is to be formulated through participation of private firm/s.
- Requirements relating to ESIA are to be satisfied.

5-9-7 Project Evaluation

The project, from the above assessments, is judged to be feasible if the external conditions are satisfied.

5-9-8 Funds prospect of project

Potential funds for the geothermal development projects are listed below.

Table 5-11 Potential Funds for the Project

Scheme	Fund	Activity
Grant	CDB, IDB, Bilateral donors (e.g. UK)	- Test well drilling
Loan	CDB, IDB (e.g. Clean Technology Fund), Bilateral donors (e.g. JICA), IRENA	- Appraisal well drilling - Production well drilling - Plant construction - Transmission line construction - Consultancy service
Technical Assistance	Bilateral donors (e.g.NZ, JICA), Other organizations (e.g. UN	- Project progress and capacity management

	organizations), Sustainable Energy Facility (SEF)	- ESIA - Assistance for Construction works including drilling work (Specification, Tender, Supervision, Well test, etc.)

Source: JICA Survey Team

Chapter 6 Action Plan and Issues in Project Implementation

6-1 Action Plan of the Government of Grenada and Partners

Action plans for the government, donors and IPP/PPP are shown in Figure 6-1 in case of model-3. The geothermal project in Grenada is now at the end of exploration stage and preparation for test well drilling is needed in the next stage.

In order for inviting private developers for the project investment, the government of Grenada is recommended to conduct following actions.

6-1-1 Immediate Action

a. Regulations（2016-2020）
   - Establishment of “the Geothermal Unit”
   - Improvement of Legal systems: Geothermal Law, Public Utilities Regulatory Communication Bill 2015, Electricity Supply Bill 2015 and PPP
   - Development of regulations on geothermal resource
   - Development of regulations for ESIA
   - Procurement of advisory service for development of laws and regulations

b. Technical Assistant/ Grant（2016）
   - Capacity development for staff in Geothermal Unit
   - Grant technical assistant for ESIA
     - Baseline survey and scoping for exploration
     - ESIA for test drillings including Stakeholder Engagement
   - Grant technical assistant for procurement of drilling works
     - Preparing bidding documents and other technical assistant for procurement process
   - Financial arrangement for test drilling

c. Land acquisition for test drilling（2016-）

d. Procurement of drilling contractor, and conducting test drilling (include supervise, technical assessment and planning for the next stage development)（2017-）

6-1-2 Action after Test Drilling

a. Sounding for IPP and PPP, donors and donors. Investigation on condition for loans（2016-）
b. Financial arrangement for ESIA for appraisal well drillings n including production well drillings and constructions.
c. Power Purchase Agreement

6-1-3 Action for Appraisal Well Drilling

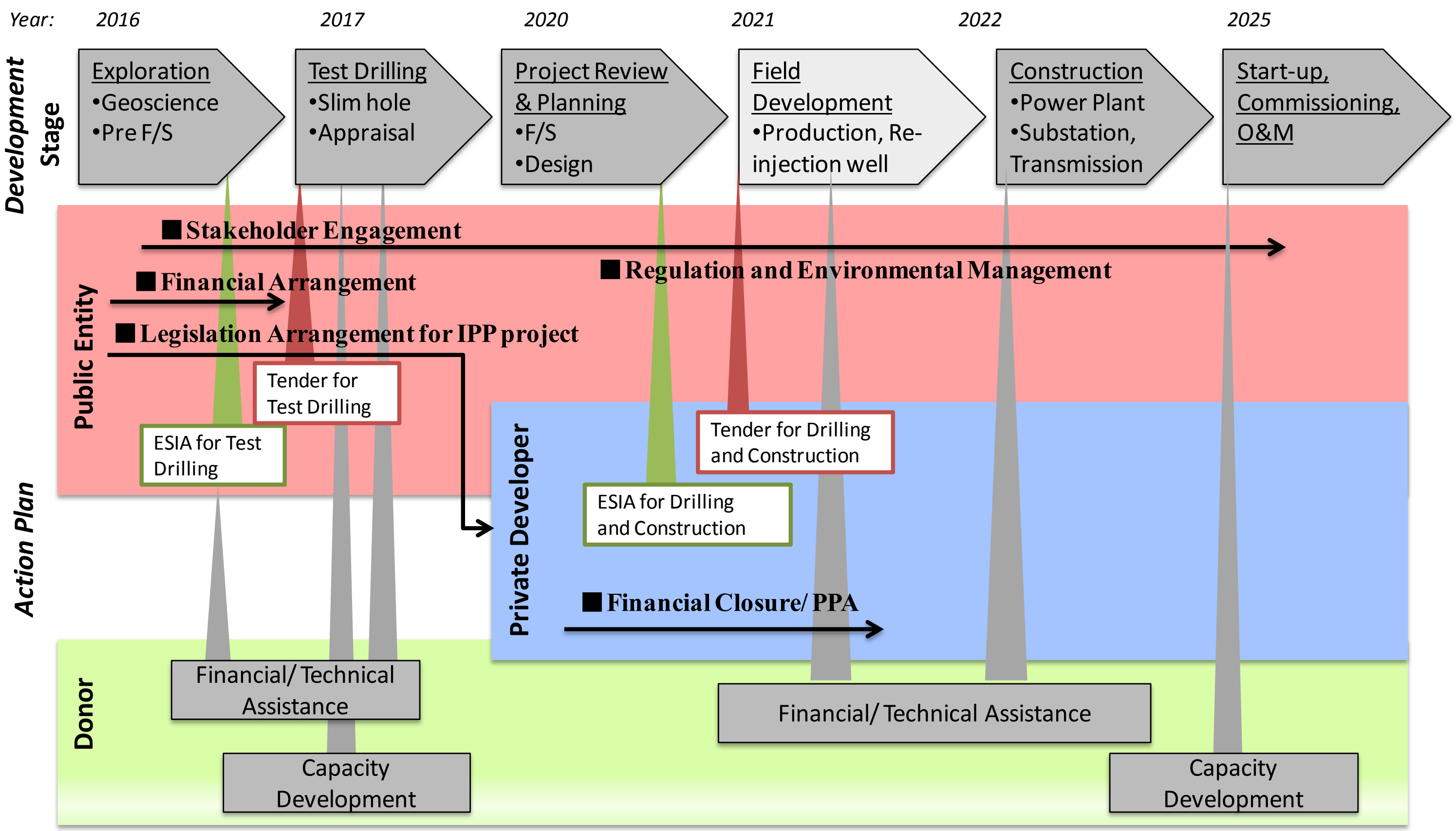
a. Selection of private developer, Business formulation either IPP or PPP
b. ESIA for appraisal (including stakeholder Engagement)
c. Financial arrangement by developer for drillings
d. Land acquisition by private firm
e. Well drilling and resource analysis
f. Feasibility Study
g. Complete PPA

6-1-4 Action for Construction

a. ESIA for drilling production wells and re-injection wells, FCRS, power plant and transmission (including Stakeholder Engagement)
b. Financial arrangement by developer
c. Land acquisition by developer
d. EPC procurement

○ Construction
a. Construction works by EPC
b. Supervise by IPP/PPP

○ Commissioning (2025)
a. Start up and Commissioning
b. O&M



Source: JICA Survey Team

Figure 6-1 Action Plan for Geothermal Development Project in Grenada

Appendixes

Appendix-1	Minutes of Meeting
Appendix-2	Photos
Appendix-3	Presentations
Appendix-4	List of data collected
Appendix-5	Volumetric method

Appendix-1 Minutes of Meeting

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

Minutes of Meeting (Memorandum within the Survey Team)

<table>
<tr><td>Meeting</td><td>Kick off meeting with Ministry of Finance and Energy</td><td>Venue</td><td>Financial Complex</td></tr>
<tr><td>Date</td><td colspan="3">2015/5/12 9:30-11:15</td></tr>
<tr><td>Participants</td><td colspan="3">[From Grenada side]
1. Mr. John Auguste (JA), Senior Energy Officer, Ministry of Finance and Energy
2. Mr. Christopher Joseph (CJ), Energy Officer, Ministry of Finance and Energy
[From Japan side]
1. YAMAGUCHI Kazutoshi (YK), Latin America and the Caribbean Department, JICA
2. TADA, IDB (through internet)
3. CDB not connected due to network problem
[JICA Survey Team]
1. TAKAHASHI Shinya (ST), Team Leader/ Geothermal Energy Development/ Reservoir Assessment
2. AKATSUKA Takashi (TA), Vice Team Leader/ Geology/ Drilling Planning
3. FUKUDA Daisuke (DF), Geochemistry
4. KAWASAKI Kiyoshi (KK), Geophysical Survey
5. KIKUKAWA Takeshi (TK), Electricity Policy/ Investment Policy
6. TERAMOTO Masako (MT), Environmental Social Consideration
7. Saul PADILLA (SP), Project coordination</td></tr>
<tr><td>Material</td><td colspan="3">1. Inception Report
2. PPT-Inception Presentation
3. PPT-Financial Aspect in Geothermal Development</td></tr>
<tr><td>Agenda</td><td colspan="3">1. Opening speech from Ministry of Finance and Energy
2. Speech from JICA and IDB
3. Introduction from JICA Survey Team
4. Presentation 1 on Inception Report from JICA Survey Team
5. Presentation 2 on Financial Aspects from JICA Survey Team
6. Discussions
7. Closing</td></tr>
<tr><td>Record of Meeting</td><td colspan="3">1. From Ministry of Energy
- Introduction by Mr. Christopher Joseph. He thanks of our visit to Grenada and they are grateful that Japan and others (IDB and CDB) are interested to contribute with assistance to Grenada to be able to develop the geothermal energy in the country.
- CJ: The information that was required previously to this office can be partially provided during the meeting and can be complemented before the team leaves the country on Saturday.
2. From IDB
- Through the phone, IDB explained the objectives of this mission and thanks for the attention to the team.
- YK: requested access to the information of the NZ Company. Mr. JA said that is not completed yet, but they expect to have it in 2 months and they are able to share it with us.
-
3. From Japan side
- ST: Introduced the team members participating in the survey during this week, including Mr. Yamagushi as the responsible of JICA for the Caribbean countries.
4. Presentation 1: <u>Inception Report</u> and its objectives of this mission are defined. Following are some comments during the presentation.
- It is confirmed that, recently a NZ company (JACOBS) has conducted some exploratory studies in Grenada.
- At moment NZ Company is still working in the final report, as soon they send it to this office, it will be shared with JICA team in order to review it and make a proper revision. From this revision it will be decide what other studies needed to additionally. The idea is not to duplicate works of both parties.
- CJ explained that the NZ company proposed to make studies 3-G including Geology, Geochemistry and Geophysics and conduct MT survey at 50 points (Actually 60 points by information from Jacobs),.
- ST asked if the scope of NZ company include environmental and social survey, in case it is not included we can assist in this matter. JA said that he is not sure but he will see.
- ST mentioned that GRENLEC owns 50% of the electricity generation company and asked for who is the responsible in the country for the geothermal development project, is it the Government or GRENLEC?
- CJ explained it is taking back under the control of the Ministry of Energy. The ides is not to own the generation company but to take the control of regulations. For this purpose, the government is redacting the Electricity Supply Act with the assistance of World Bank to make it official and it will not affect the existing installations, but, from now, every new energy project will be regulated with this Act.
- (From the comments of Mr. Christopher explained, it is understood, that in 1994 the government sold</td></tr>
</table>

the operations of the energy in the country and allow them to regulate themselves without government control, and at present the government is doing efforts to recuperate that control. But they don´t want to get control of generation only for the control through the regulations and laws. In this order, the government is defining an electricity supply Act with the collaboration of the technical assistance of the World Bank which it will have regulations for new energy development projects.)

- YK: requested access to the information of the NZ Company. JA answered that is not completed yet, but they expect to have it in 2 months and they are able to share it with us. The terms of reference will be shared.
- JA confirmed that NZ study is not including financial issues in this time.
- JA explained that for the 2nd survey program, JICA team has to take into account that rainy/hurricane season is from middle of May until November.

5. Presentation 2: **Financial Aspects in Geothermal Development** is presented and discussed . Following are some comments during the presentation.
   - Geothermal development could take up to 6 years or more, and this in the case that everything is moving in the good way.
   - Testing wells drilling has the highest risk in the project, and the investors are not willing to get involved in this stage of the project.
   - TK explained that, some years ago, GRENLEC presented a plan to install a 20 MW power plant for geothermal resource.
   - JA explained that the government plans to use geothermal electricity as a base load since the peak demand is 30MW.
6. Other discussions

Site Investigation

- ST asked if there is no problem to visit geothermal manifestations.
- CJ answered that JICA survey team may visit geothermal manifestations, however need to submit the work plan (sampling and shipping program) in ahead for permission from relevant departments such as Forest department. The work plan will be sent by JICA survey team later.
- CJ provided the information of a guide who has visited sites with the last JICA mission on November 2014 (guide: Mr. Telfor Bedeau, Hiking Guide, Tel. (473) 442 6200).

Information to be collected

- Information of Laws & Regulation can be obtained from web page of the government.
- TK asked if the existing two Acts (still in draft version) are enough for geothermal developments project by a PPP company. JA said that there is nothing approved to allow a PPP company to make investment on geothermal development projects.
- MT would like to have contacts with departments of environmental, forest, etc. in order to contact them directly. CJ promised to send her this information by e-mail.
- ST asked if we can contact the person in charge of the team from Jacobs (NZ Company)- JA said that there is no problem at all for that, and explained that this company is based in Saint Lucia island.
- CJ said that Ministry of Energy will not join the following meeting with GRENLEC in order not to disturb free discussion with them.

Wrap up Meeting

- Wrap-up meeting is set on 15 May at 13:00 with Ministry of Energy. Followed by the meeting with Permanent Secretary is set from 14:00


Mr. John Auguste


Mr.Kris

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

Minutes of Meeting (Memorandum within the JICA Team only)

Meeting	Grenada Electricity Services Limited (GRENLEC)	Venue	GRENLEC
Date	2015/5/12 11:45-12:30		
Participants	[From Grenada side] 1. Mr. Murray Skeete (MS), Vice President- Engineering and Regulation, WRB (parent company of GRENLEC) 2. Mr. Collin Cover (CC), General manager and Chief Executive Office, GRENLEC 3. Mr. Clive Hosten (CH), Chief Engineer, GRENLEC 4. Mr. Ahmin Z. Baksh (AB), Planning and Engineering Manager, GRENLEC 5. Mr. Stanley Barreto (SB), Renewable Energy Developer, WRB [From Japan side] 1. YAMAGUCHI Kazutoshi (YK), Latin America and the Caribbean Department, JICA [JICA Survey Team] 1. TAKAHASHI Shinya (ST), Team Leader/ Geothermal Energy Development/ Reservoir Assessment 2. AKATSUKA Takashi (TA), Vice Team Leader/ Geology/ Drilling Planning 3. FUKUDA Daisuke (DF), Geochemistry 4. KAWASAKI Kiyoshi (KK), Geophysical Survey 5. KIKUKAWA Takeshi (TK), Electricity Policy/ Investment Policy 6. TERAMOTO Masako (MT), Environmental Social Consideration 7. Saul PADILLA (SP), Project coordination		
Material	No material used		
Agenda	1. Introduction of JICA survey team, purpose of survey 2. Interview and discussions on geothermal development status by GRENLEC		
Discussions and Conclusions	1. From Japan side - YK introduced about JICA survey. - ST explained the purpose of JICA survey as to examine the present situation of geothermal development in Grenada in order to propose the possible cooperation from Japan 2. From GRENLEC: MS from WRB, the parent company of GRENLEC, explained current situation most of the time during the meeting as follows. [Policy for geothermal power generation] - GRENLEC is interested in geothermal development at the stage of Power plant and Operation. Exploration and drilling in not within GRENLEC's normal risk profile but it could potentially find joint venture partners to do this if necessary. - Present maximum geothermal development is up to 10 - 15MW. Present minimum load is 17MW and the peak demand is 29MW. - The financial source of the test drilling has not been decided. Resource exploration could be a task of the government. - If the resource is proved, GRENLEC is ready to start business of geothermal with training for their staffs working for the diesel power plant now and hire new workers if needed. - Regarding renewable energy, GRENLEC plans to introduce re-newables (wind, solar, geothermal or other) for 20% of their power generation by 2020. [Organization and business] - In Grenada, GRENLEC is the only power company who can be a power operator by law. - WRB has 50% of share, while the government has 10%, citizens and employees have ~29% and the National Insurance Scheme has the rest ~11% - Tariff is also registered in the law. 3. Others - Next meeting is set on 13 May at 14:30. Several options on geothermal business model and financial scheme would be proposed by JICA Survey Team for further discussion.		
Photo	 From L to R: CH, AB, CC	 From L to R: SB, MS	

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

Minutes of Meeting (Memorandum within the JICA Team)

<table>
<tr><td>Meeting</td><td>Grenada Electricity Services Limited (GRENLEC)</td><td>Venue</td><td>GRENLEC</td></tr>
<tr><td>Date</td><td colspan="3">2015/5/13 14:30-15:30</td></tr>
<tr><td>Participants</td><td colspan="3">[From Grenada side]
1. Mr. Murray Skeete (MS), Vice President- Engineering and Regulation, WRB (parent company of GRENLEC)
2. Mr. Robert Blanchard, Jr. (RB1), President, WRB
3. Mr. Robert Blenker (RB2), Vice President –Renewable Energy, WRB
4. Mr. Collin Cover (CC), General manager and Chief Executive Office, GRENLEC
5. Mr. Clive Hosten (CH), Chief Engineer, GRENLEC
6. Mr. Ahmin Z. Baksh (AB), Planning and Engineering Manager, GRENLEC
[From Japan side]
1. YAMAGUCHI Kazutoshi (YK), Latin America and the Caribbean Department, JICA
[JICA Survey Team]
1. TAKAHASHI Shinya (ST), Team Leader/ Geothermal Energy Development/ Reservoir Assessment
2. KIKUKAWA Takeshi (TK), Electricity Policy/ Investment Policy</td></tr>
<tr><td>Material</td><td colspan="3">No material used</td></tr>
<tr><td>Agenda</td><td colspan="3">1. Interview and discussions on geothermal development status by GRENLEC
2. Interview and discussions on draft electricity supply bill</td></tr>
<tr><td>Discussions and Conclusions</td><td colspan="3">1. From Japan side
- TK asked the readiness of the draft geothermal development bill and the GRENLEC's position for risk/profit sharing with the steam production.
- TK also asked the prospect of the possible agreement on the different views on the draft electricity supply bill between GRENLEC and the government.

2. From GRENLEC: MS and RB2 explained the current situation on the draft bills.
[Draft geothermal development bill]
- GRENLEC collaborated with the government in drafting the bill. The draft bill took into considerations the good practice in other countries and the local context of Grenada. Hence the bill has been well drafted.
- However due to the election and the change of the ruling party, the bill has not been approved in the Parliament.
- One of the major topics is the issue of the property right of geothermal resources. The draft bill stipulates the resources belongs to the State. The government will then give approval for the use of the resources to the operator.
- Geothermal plants could be developed by GRENLEC with the current legal and legislation if the property rights issue is resolved among the stakeholders.

[Draft electricity supply bill]
- Grenlec hopes to find the mutual agreements on the argument points. Grenlec believes it achieves high efficiency of the management and operation of the company, providing a competitive electricity price.
- There are a few countries in the Caribbean region where IPPs operate such as Jamaica, Trinidad, and Antigua.
- The new electricity bill has no impacts on the geothermal development. Even if the discussions on the draft bill are not settled, the current legal framework would support the investment activities.

[Geothermal development]
- Grenlec wishes to collaborate with potential partners (steam provider) in geothermal development.

3. Others
- n/a</td></tr>
<tr><td>Photo</td><td colspan="2">n/a</td><td></td></tr>
</table>

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

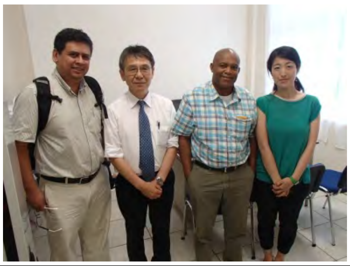
Minutes of Meeting

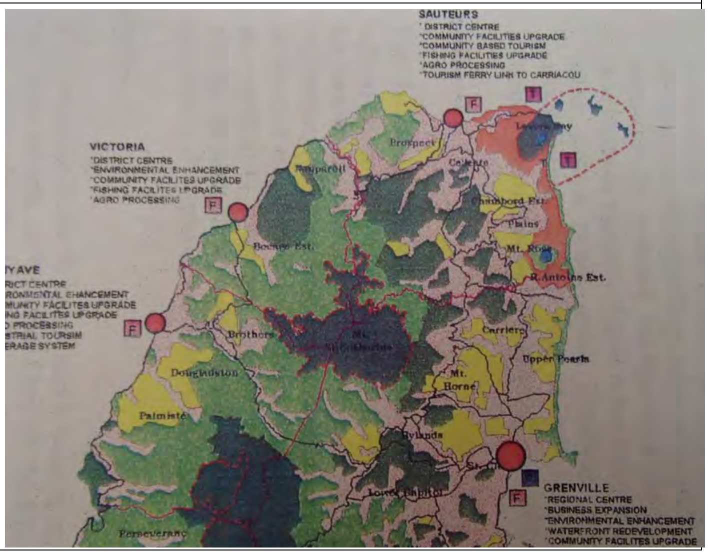
<table>
<tr><td>Meeting</td><td>Meeting with Ministry of Finance and Energy, Office of Permanent Secretary</td><td>Venue</td><td>Financial Complex</td></tr>
<tr><td>Date</td><td colspan="3">2015/5/15 9:15-10:00</td></tr>
<tr><td>Participants</td><td colspan="3">[From Grenada side]
1. Timothy N. J. Antoine (TA), Permanent Secretary
2. Mr. John Auguste (JA), Senior Energy Officer, Ministry of Finance and Energy
3. Mr. Christopher Joseph (CJ), Energy Officer, Ministry of Finance and Energy
[From Japan side]
1. YAMAGUCHI Kazutoshi (YK), Latin America and the Caribbean Department, JICA
[JICA Survey Team]
1. TAKAHASHI Shinya (ST), Team Leader/ Geothermal Energy Development/ Reservoir Assessment
2. AKATSUKA Takashi (TA), Vice Team Leader/ Geology/ Drilling Planning
3. FUKUDA Daisuke (DF), Geochemistry
4. KAWASAKI Kiyoshi (KK), Geophysical Survey
5. KIKUKAWA Takeshi (TK), Electricity Policy/ Investment Policy
6. TERAMOTO Masako (MT), Environmental Social Consideration
7. Saul PADILLA (SP), Project coordination</td></tr>
<tr><td>Material</td><td colspan="3">1. Inception Report
2. PPT presentation on Overview of Geothermal Development and Queries</td></tr>
<tr><td>Agenda</td><td colspan="3">1. Opening speech from Mr. Yamaguchi
2. Welcome from Permanent Secretary
3. Explanation of JICA survey from Mr. Takahashi</td></tr>
<tr><td>Record of Meeting</td><td colspan="3">1. From Permanent Secretary
- TA: welcome the JICA survey team and thanks for the interest to help to Grenada to develop the geothermal resource.
2. From JICA
- YK: Thanks to the Permanent Secretary for the time and allow us to explain the objectives of the mission. And explained that this mission is in coordination with IDB and CDB.
3. From Japan side
- ST: Introduced the team members participating in the survey during this week, including Mr. Yamaguchi as the responsible of JICA for the Caribbean countries.
- ST: gave an inception report to TA which was presented to JA and CJ at kick-off on 12 May.
- ST: explained the objective of JICA Survey as to collect and review existing data and information regarding geothermal development in Grenada, to conduct field surface survey if necessary, and to identify geothermal development project/s which JICA could extend its assistance through the international partnership.
Things to be clarified in the 1st survey are:
(1) What kind of cooperation could be implemented by JICA without duplication between NZ's study?
(2) To whom JICA would assist regarding technical and financial cooperation, GRENLEC or Ministry?
(3) Implementation framework of geothermal project is not yet clearly identified.
- TA: clarified that GRENLEC is not a leader of future geothermal development in Grenada the government of Grenada is the one. Only after the potential is demonstrated, GRENLEC can be one of the potential investors that could be interested in the development. It is not appropriate to lead the discussion with GRENLEC.
- TA: explained that they are working for drafting legal framework and <u>legislation for geothermal development</u> with GRENLEC as a key partner. Not yet received it but will be ready in the later this year. This is potentially one of the areas that Japan can help Grenada to finalize geothermal legislation. Draft of geothermal legislation will be shared with JICA team. And you are welcome to comment on it.
- TA: explained that the Government of Grenada wants the shortest possible period of development and followings actions are to be done for it.
(1) Establish liability.
(2) Prepare Electricity Supply Act.</td></tr>
</table>

	(3) Prepare Geothermal Development Act. (4) Convene the partners. (5) Fund to prove geothermal resource to call investors. - ST: asked what is following with the NZ Company. Because this is not clear at moment. - TA: answered that it is not clear about NZ further study, probably no other participation to continue with the project. It is an opportunity for Japan to take us forward by examining the possible test drilling sites. - TA: Mentioned that he consider that Japan can collaborate with the government of Grenada to establishment of Laws and Regulations of geothermal developments in Grenada as well as technical assistance and human resource development. - TK: asked about financial and business matter. What would be the government's role? - TA: explained that government's role is establishing legal framework. Once resource is proven by grant, private partners involve in project. - MT: For next stage of test drilling, necessary EIA study should be prepared. If NZ's study doesn't include EISA, JICA study could assist it. End of discussion.
Photo	

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

Minutes of Meeting(Internal use only within the JICA Team)

<table>
<tr><td>Meeting</td><td>Meeting with Physical Planning Unit,</td><td>Venue</td><td>GCNA Complex Building</td></tr>
<tr><td>Date</td><td colspan="3">2015/5/15 14:30-15:30</td></tr>
<tr><td>Participants</td><td colspan="3">[From Grenada side]
1. Mr. Fabian Purcell (FP), Head{Ag}, Physical Planning Unit, Ministry of Works, Physical Development and Public Utilities
[JICA Survey Team]
1. TAKAHASHI Shinya (ST), Team Leader/ Geothermal Energy Development/ Reservoir Assessment
2. TERAMOTO Masako (MT), Environmental Social Consideration
3. Saul PADILLA (SP), Project coordination</td></tr>
<tr><td>Material</td><td colspan="3">N/A</td></tr>
<tr><td>Agenda</td><td colspan="3">1. Interview on EIA in Grenada</td></tr>
<tr><td>Record of Meeting</td><td colspan="3">1. JICA survey team explained about JICA study and status of our cooperation on geothermal development in Grenada
2. FP asked about the geothermal power plant facilities and possible environmental influence by geothermal development. Impacts on water and plants should be carefully determined because agriculture is important industry in Grenada.
3. Following information was given to JICA study team.
- There is no regulation or guideline about EIA in Grenada. Need to refer to best practices of other countries or international agencies.
- The water and sewage company is the only responsible to drill water wells for human consumption. To do it, they are required to present the project to this office and they can proceed to drill.
- Mitigation measures should be prepared for both preparatory works and drilling works.
- The team explained that the required area for a drilling site is like a yard for football, approximately.
- The potential sites around Mt. St. Catherine are possibly inside "Conservation Area".
⇒Necessary to check the position of potential sites with the map below
- However, FP talked that the development might be possible because renewable energy is a policy of government of Grenada.
⇒Need to be clarified with relevant organizations (Ministry of forestry)</td></tr>
<tr><td>Photo</td><td>

</td><td colspan="2">
</td></tr>
</table>

Comments of JICA study team:

During 2nd survey, it might be a good idea to have a workshop for relevant organizations to deepen their understandings of geothermal development project.
Possible stakeholders are Ministry of energy, Ministry of Forestry, Ministry of physical planning and Ministry of tourism.

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

Geothermal Forum

Day one：Ministerial Forum

Date: 21st June 2016 (Tuesday) 9:00-15:00

Participants Invited：Relevant officials of Grenada government, approximately 20 officers from Physical Planning Unit, Min. of Agriculture, Works Finance, and others

Energy Unit: Two (Mr. J Auguste, Mr, C Joseph.)

NZ(Jacobs)：Mr. Alastair

JICA Team: Mr. Akatsuka, Dr. Kikukawa, Dr. Tearamoto

Major questions risen:

Will the electric prices become lower? How lower will it become?

- How could the government be involved in PPA comprising GRENLEC and/or electric company?
- Should the grant financing be included in the cost of the government？
- Does the financial analyses not include the case of Contingent Grant？
- What would the institutional arrangement be？
  - "Geothermal Unit" needs to be established for various tasks including coordination with other relevant government offices (Energy Unit
- How will impacts on the water quality of the water sources？
  - Impacts shall be assessed by ESIA and measures shall have to be taken by the project owner to prevent or mitigate any adverse impacts.
  - A water-intake plan has to be proposed through close commutation with Nawasa, Ministry of Forestry and/or relevant organizations including users (JICA Team).

Major Comments：

- Mt. St. Catherine is known as a habitat zone of various fauna and flora.
  - A survey for biodiversity shall be included in ESIA (JICA Team)

Notes of the JICA Team

- No specific comments related to geothermal were risen.
- Dissemination of information on major characteristics of geothermal generation is felt necessary.

End of Documents

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

Day Two: <u>Stakeholders' Meeting</u>

Date: 23rd June 2016 (Thursday), 9:00-12:00

Participants Invited: Stakeholders (local communities, NGO, IPP)

Energy Unit: Kris J.

NZ(Jacobs) : Alastair

JICA Dominican republic office: Mr. Morita

JICA Team: Takahashi, Akatsuka, Kikkawa, Teramotno

Major questions risen:

- Mt. St. Catherine is the valuable forestry felt as a consecrated place by the people of Grenada. The project shall take care of water, forest, flora and fauna as well as local inhabitants.
- Consensus has to be reached through public meeting involving various range of people.
- Were alternatives examined such as solar, wind, tidal and so on? Does the government consider energy mix strategy?
- Affordability of geothermal power plant has to be examined?
- How long will it be operated in plan? Could the cost level of 15 US-cent/kWh be maintained?
- Does the estimated cost 15 US-cent/kWh include the loyalty to the government?
- What is the timing of ESIA in relation with the drilling?
  - Two times of ESIA are usually required, one before the test well drilling and the other before the production well drilling and plant construction (JICA Team)

Notes of the JICA Team

- Participants were interested in possible impacts on the natural conditions.
- Some were interested in other renewable energies in addition to geothermal.
- A participant from GRENLEC was interested in energy prices.

End of documents

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

Day Three : Partners' Forum

Date : 24^{th} June 2016 (Friday) 8:30-15:00

Participants invited : Development partners: High commissioner of New Zealand, CDB, DFID, US embassy, EU representative, CARICOM secretariat

Government of Grenada: Prime-minister (Opening address), Ministry of Finance

Energy Unit: J. Auguste, C Joseph

NZ(Jacobs) : Alastair

JICA Dominican republic office: Mr. Morita

JICA Team: Takahashi, Akatsuka, Kikkawa, Teramotno

Major statements presented :

1. ESIA will be very important for the smooth promotion of the project; an assessment will be essential on water for the works, waist and others.
2. CDB handles SEF (sustainable energy fund) total 71.5 million USD provided by IDB
   ① Global Credit Loan (GCL): 20 million
   ② Clean Technology Fund (Grant): 19 million
   ③ Global Environment Facility Trust Fund (Grant): 3 million
   ④ Counterpart contribution: 29.4 million
   There is an grant allocation for Grenada, which may be made available for the proposed test well drilling.
3. NZ is prepared for continuation of the technical assistance (T/A) to Grenada. Various training courses such as project management, technical management as well as scholar ship for master course in NZ.
4. DFID provides CDB with UK Caribbean Infrastructure Fund (23 Million GBP) . Financial assistance for geothermal development is available for four Caricom countries. His fund may be made available for test well drilling. In fact, SVG has been given a grant aid for the well drilling though it is not test drilling.
5. IDB financial assistance may not be suitable for test well drilling with grant finance. Contingent-recovery resources, GeoSmart Facility may be made available from the next stage of development (soft loan schemes).
6. JICA is now under negotiation with CDB regarding financing to renewable energy development in Caricom countries through CDB. This will not be grant financing schemes but soft loan schemes.
7. Caricom secretariat: Other funding facilities such as Abu Dhabi found are available. Information sharing will be important among parties concerned.

Major questions risen :

- Water for work in Florida may not be sufficient for drilling.
  - The JICA Team selected a water intake point downstream side of a NAWASA intake facility not to disturb the water right. Towards the materialization of the project, a detailed planning shall be needed.
- How is the mud water treated?
  - Sludge and cuttings are usually dried and wasted to designated areas according to regulations in the country. Inclusion of harmful materials or minerals will have to be examined before wasted.
- What is the position of the geothermal power generation amongst other options. Is the possibility of solar generation not examined?

Notes of the JICA Team

- The project shall be aware that not many people of Grenada have much knowledge on geothermal power generation.
- Thus, strategic explanations will be necessary on why geothermal would be superior to the other renewable energy in terms of base load energy.

End of the document

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

Day Four: <u>Additional Stakeholders' Meeting</u>

Date : 28th June 2016 (Tuesday) 9:00-12:00

The additional stakeholder meeting was organized after the Day Two meeting, because some of key expected participants were not present at the Day two meeting.

Participants invited: NGOs, local developers (9 people)

Energy Unit: C Joseph

NZ: Alastair

JICA Team : Takahashi

Major questions and comments were as follows:

- Will Mt. St. Catherine possibly erupt near future ? (this is a general question, irrelevant to geothermal development)
- Possible impacts of natural environment and local society have to be examined.
- Local people and local knowledge shall be involved and utilized, such as employment.
- Geothermal development is a new subject to Grenada. It is sensitive to eco-system and water systems.
- Mt. St. Catherine is the important water source and consecrated forestry of Grenada. Water dried up in 2010 due to unknown reasons. At-most attentions shall be given. Biodiversity shall also be considered. In any case, farmers and local inhabitants will be the key stakeholders.
- Land-use, employment and education/training shall be examined.
- Has a cost comparison been made among the other renewable energy such as wind, solar? Why now is geothermal proposed? Alternatives shall be examined.
- Assessment by a third party will be needed to assess the results conducted by the present consultants, such as the validity of the zoning maps presented.

Notes of the JICA Team

- Subjects were concentrated on natural and social environment. Such responses were given to the participants as:-

- The key tasks were to given to resource assessment. Only preliminary scoping were conducted for ESIA this time.
- One the drilling locations are decided, an ESIA will have to be conducted in accordance to internationally accepted guideline. Stakeholder meetings shall be programmed.
- The results of ESIA will be made open to public for comments from public.

End of document

Appendix-2 Photos

Appendix-2 Record Photographs

	
Hot Spring and Alteration (Hapsack)	Hot Spring (Chambord, Sulfur Springs)
	
Hot Spring (Peggy’s Whim)	Hot Spring (Clabony)
	
Hot spring (Castle Hill South)	Travertine consist of Carbonate Mineral (Castle Hill South)

Main Road in the City of Grenville

Main Road in the Gouyabe

Eastern Coastal Road

Access Road on the vicinity of the Drilling Site

Paradise Bridge

Belmont Blidge

Overview of Grand Etang Lake

Antonie Crater

Transmission Line

St. Georges Port

Queen’s Park Power Station

Small Power Station in Grenada University

Meeting with Ministry of Finance, Energy Unit

Meeting with Grenlec

Overview of St. George's Town

Building of Ministry of Finance, Energy Unit

Old Airport

Gravity Survey (Gravimeter and GPS)

Appendix-3 Presentations

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

INCEPTION PRESENTATION

MAY 2015
In St. Georges

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CONSULTANTS;
NIPPON KOEI CO., LTD.
JMC GEOTHERMAL ENGINEERING CO., LTD
SUMIKO RESOURCE EXPLORATION AND DEVELOPMENT CO., LTD

OUR TEAM

TAKAHASHI Shinya	Team Leader/ Geothermal Energy Development/ Reservoir Assessment
AKATSUKA Takashi	Vice Team Leader/ Geology/ Drilling Planning
FUKUDA Daisuke	Geochemistry
KAWASAKI Kiyoshi	Geophysical Survey
TERAMOTO Masako	Environmental Social Consideration
KIKUKAWA Takeshi	Electricity Policy/ Investment Policy
MOMOSE Yasushi/ YOSHIDA Satoshi	Civil Engineering Planning

NK: Nippon Koei Co., Ltd.

Geo-E: JMC Goethermal Engineering Co., Ltd.

SRED: Sumiko Resource Exploration and Development Co., Ltd.,

BACKGROUND: International Partnership

1. IDB and JICA entered in the agreement on "Cofinancing for Renewable Energy and Energy Efficiency (CORE scheme)" in 2013,
2. IDB, JICA and CDB entered in the Memorandum aiming at building a new partnership to promote renewable energy and energy efficiency in Eastern Caribbean Region in 2014.

BACKGROUND: Project Identification by JICA

1. JICA conducted a preliminary survey in 12 CARICOM countries to identify projects regarding renewable energy and energy conservation in 2014;
2. Grenada has been identified as one of the potential countries for geothermal development.

OBJECTIVES

1. To collect and review existing data and information regarding geothermal development;
2. To conduct field surface survey if necessary;
3. Thereby, to identify geothermal development project/s which JICA could extend its assistance through the international partnership;

➔ Based on the above, another JICA Survey may be implemented to formulate specific cooperation programs for geothermal development.

PRESENT SITUATIONS - OUR UNDERSTANDINGS

1. Six geothermal prospects have been identified in early 1990's.
2. Geothermal Support Partnership Framework Agreement between the government of Grenada and New Zealand was agreed in 2014.
3. Geological, geochemical and geophysical survey is being conducted by an eminent New Zealand Consultants.
4. GRENLEC (a private owns 50% stocks) is only operator of electric sector.
5. Implementation framework is yet to be decided (i.e. implementation organization, financial arrangement and etc)

OUR ACTIVITIES (for 1st visit)

1. To collect relevant data and information; a questionnaire has already been sent to the Energy Office;
   the information includes the survey plan and results of the NZ consultants;
2. To conduct field survey if judged necessary and approved;
3. To discuss implementation framework, financial arrangement and others as necessary for geothermal development ;
4. To have a wrap up meeting on 15th May 2015.

Schedule for the 1st Visit

May, 2015		Team Leader	Development/Investment	Geology/Drilling	Geo-chemist	Environment	Geo-physics	Coordination	Civil Eng.
9	Sat		Arriving						
10	Sun	Arr.	Preparation						
11	Mon	Kick-off meeting							
12	Tue	Discussions with relevant organization							
13	Wed	Data Collection							
14	Thu	Data Collection							
15	Fri	Wrap-up Meeting							
16	Sat	Moving							

Surveys to be conducted for the 2nd visit, if judged necessary

1. Analysis of remote sensing data,
2. Geological field survey and laboratory analysis,
3. Geochemical field survey and laboratory analysis,
4. Geophysical field survey and/or 2-D inversion analysis,
5. Scoping for Environmental and Social Impact Assessment (ESIA), Gap analysis of guidelines for ESIA
6. Survey and analysis on electricity policy and investment policy
7. Others as necessary

Overall schedule

No.	Position	Name	2015										2016		
			3	4	5	6	7	8	9	10	11	12	1	2	3
1	Team Leader/Geothermal Development Plan/Reservoir	Shinya TAKAHASHI													
2	Sub-Team Leader/Geology/Drilling Engineer	Takashi AKATSUKA													
3	Geochemistry	Daisuke FUKUDA													
4	Geophysics	Kiyoshi KAWASAKI													
5	Environmental and Social Considerations Evaluation	Masako TERAMOTO													
6	Energy Policy Analysis/Project Finance Policy Analysis	Takeshi KIKUKAWA													
7	Civil Engineering Planning	Yasushi MOMOSE/ Satoshi YOSHIDA													
Report				△ IC/R			△ PR						△ DF/R		△ F/R

*Intermittent: Detailed survey plan will be made after the discussion.
IC/R: Inception Report, P/R: Progress Report, DF/R: Draft Final Report, F/R: Final Report

Deliverables

1. Inception Report: May, 2015
2. Progress Report: August 2015
3. Draft Final Report: February 2016
4. Final Report: March 2016

Remarks

- This JICA survey will be conducted in close communication with IDB and CDB, for possible cooperation in geothermal energy development in Grenada.

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

We appreciate
your understanding and cooperation

Thank you
Arigatou

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT

Financial Aspect in Geothermal Development

GRENADA

MAY 2015

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CONSULTANTS;
NIPPON KOEI CO., LTD.
JMC GEOTHERMAL ENGINEERING CO., LTD
SUMIKO RESOURCE EXPLORATION AND DEVELOPMENT CO., LTD

Today's Presentation

Part-I: Overview of Geothermal Project Risk

Part-II: Finance Options for Geothermal Development

Information provided in the presentation is not confidential but quoted from the public domain in order to provide related references for the counterpart organizations.
In addition, the presentation by the JICA Survey Team does not represent nor endorse the policy and viewpoints by the donor agencies.

PART-I

- Overview of Geothermal Project Risk

1. Geothermal Project Development Schedule
2. Geothermal Project Risk Identification
3. Project stage and Project Risks
4. Experiences in the World

Geothermal Project Development

(for a Unit of Approximately 50 MW)

	1st	2nd	3rd	4th	5th	6th	7th	lifetime
1. Pre-Survey (Geological, Geochemical)	■							
2. Exploration (MT/TEM survey)	■	■						
3. Test Drilling			■	■				
4. Project Review and Planing		■	■	■				
5. Field Development				■	■			
6. Construction					■	■	■	
7.Start up and commissioning							■	
8.Operation and Maintenance								■
	1st	2nd	3rd	4th	5th	6th	7th	lifetime

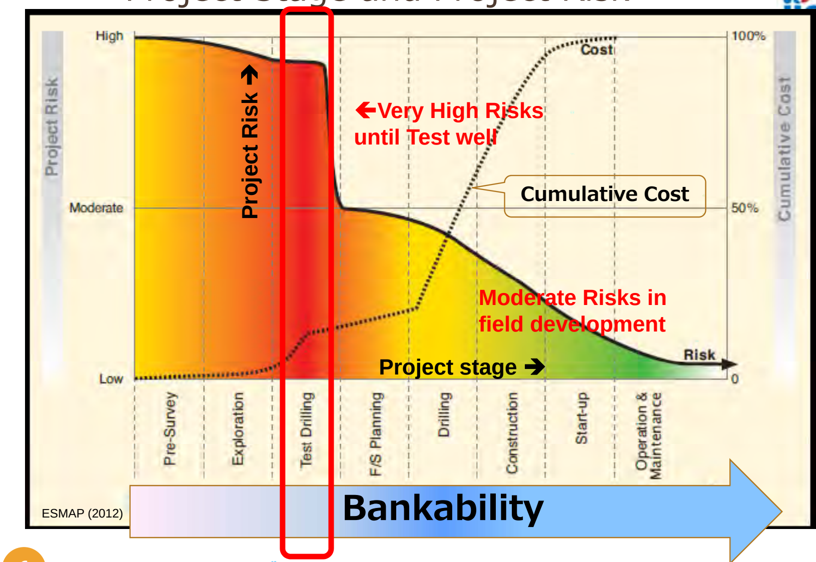
ESMAP 2012

It needs approximately six years to a start up and commissioning.

Geothermal Project Risk Identification

1. **Financing Risks**, due to a High Upfront Cost and a Long Lead Time
2. Resource or Exploration Risks
3. Completion or Delay Risks (due to difficult geology)
4. Risk of Over-sizing the Power Plant (due to resource over estimation),
5. Operation Risks (due to steam field operation and maintenance)
6. Off-take Risk and Price Risk
7. Regulatory Risk

Project Stage and Project Risk



Experiences in the World

Project stages

	1 Preliminary Survey (Early Stage)	2 Surface Exploration (Early Stage)	3 Test Drilling, F/S (Early Stage)	4 Field Development (Middle Stage)	5 Power Plant Construction (Late Stage)	6 O&M (Late Stage)	Note
1	A Fully integrated single national public entity			Public Entities			Kenya (Olkaria), Costa Rica, Indonesia (before), NZ
2	Multi national public entities (Early stage by one entity and subsequent stage by other/s for an example)						
2'	Public entity (CFE)				Private Contractor	CFE	Mexico (OPF model)
3	National and municipal public entities						**Iceland (before)**
4	Fully integrated JV partially owned by the government						El Salvador (LaGeo + Enel Green Power), Japan(recent)
5	Public entities			Private Developers			**Japan (before)**
5'	Public entity (PNOC EDC)				Private Developer	NPC	Philippines BOT model;
5"	Public entities (GDC in Kenya, Purutamina in Indonesia)				Public entities (Steam production) / Private Developers (power generation)		**Kenya (KenGen + GDC), Indonesia (before), Philippines (before)**
6	Public entities			Private Developers			**US, Turkey, NZ, Guatemala, others**
7	Public entities		Private Developers				**US, Nicaragua, new Chile**
8	Private Developers			Private Developers			**New Philippines, New Indonesia, Italy, others**

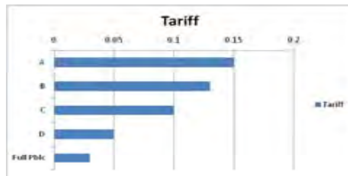
ICE: Instituto Costarricense de Electricidad, Costa Rica; CFE: Federal Commission for Energy, Mexico; PNOC EDC: Philippines National Oil Co.,-Energy Development Corporation, Philippines; NPC: National Power Corporation, Philippines; GDC: Geothermal Development Company, Kenya;

(Original Source: ESMAP 2012, modified by JICA Team)

Business model & Tariff Level (an example)

Business Model	Preliminary Survey	Exploration	Test drilling	F/S & planning	Field development	Plant construction	Operation: Field	Operation: Plant	Tariff ($/kWh)	Remarks
A	Public	Private							0.15	
B	Public		Private						0.13	
C	Public			Private					0.10	
D	Public					Private	Public	Private	0.05	
Full Public	Public								0.03	

(Source: JICA Team)



PART-II

Financial Options for Geothermal Development

1. Options for Financial Arrangement
2. Capital Structure vs. Success of Project
3. JICA Projects
   in Indonesia, in Bolivia, in Costa Rica
4. IDB Facility for Geothermal Development
5. Loan Guarantee by IFC
6. Geothermal Development Facility (GDF)

Options for Financial Arrangement

Arrangement for Implementing Organization -Options from viewpoints of financial arrangement-

Possible Options	Development Stage					
	Preliminary Survey	Surface Exploration	Test Drilling	Field Development	Power Plant Construction	O&M
Option-1	PPP	PPP	PPP	PPP	PPP	PPP
Option-2	GRENLEC	PPP	PPP	PPP	PPP	PPP
Option-3	GRENLEC	GRENLEC	PPP	PPP	PPP	PPP
Option-4	GRENLEC	GRENLEC	GRENLEC	PPP	PPP	PPP
Option-4	GRENLEC	GRENLEC	GRENLEC	GRENLEC	PPP	PPP
Option-5	GRENLEC	GRENLEC	GRENLEC	GRENLEC	GRENLEC	PPP
Option-7	GRENLEC	GRENLEC	GRENLEC	GRENLEC	GRENLEC	GRENLEC

note) PPP: Public Private Partnership

Possible Financing Sources for Development

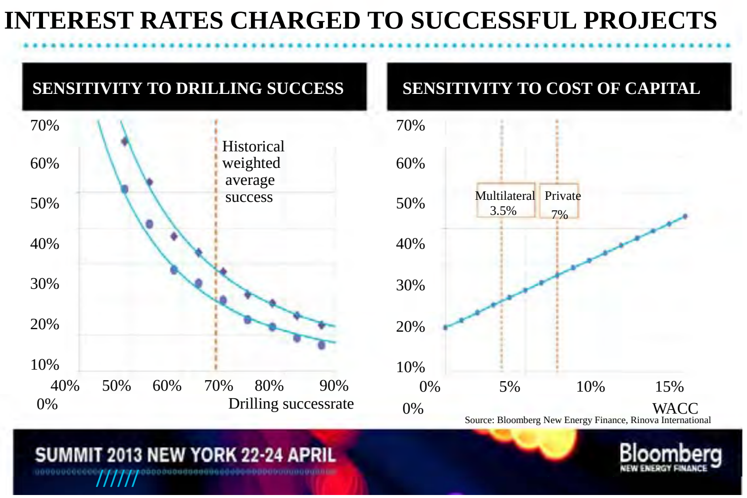
Possible Financing Sources	Development Stage					
	Preliminary Survey	Surface Exploration	Test Drilling	Field Development	Power Plant Construction	O&M
Government Budget	To be discussed in the Study. Depending on (i) project characteristics, (ii) government policy, (iii) organizational arrangement, and (iv) availabilityand condition of finance.					
Guarantee Scheme (e.g. IDB Facility)						
Concessional Loan (e.g. ODA)						
Commercial Loan						

Risk Management and Financial Facility

	Iceland	Indonesia	Japan	Mexico	New Zealand	Philippines	Turkey	USA
Drilling Failure Insurance							X	
Government-led Exploration	X	X	X	X	X	X	X	
Cooperative Agreements								X
Grants	X		X					
Lending Support Mechanism		X						X
Loan Guarantees								X

Source) Geothermal Development Workshop, IFC (2014)

Capital Structure vs. Success of Project



Source) Bloomberg New Energy Finance

JICA Project in Indonesia

Engineering Services for Kamojang Geothermal Power Plant Extension Project

1. Overview

The Project aims to develop the geothermal power plant (60MW). The loan is allocated for the engineering services for design and the test drilling.

2. Loan

Amount;	JPY 995 mil.
Interest Rate;	1.5%
Amortization;	30 years
Grace Period;	10 years

3. Implementing Agency

PT PLN (Persero) (state-owned power utility)

JICA Project in Bolivia

Laguna Colorada Geothermal Power Plant Project (1st Phase)

1. Overview

The Project aims to develop the geothermal power plant (50MW), the transmission line and the substation . The loan is allocated for the engineering services for design and the field development.

2. Loan

Amount;	JPY 2,495 mil.
Interest Rate;	Main Work 0.65%, Engineering Services; 0.01%
Amortization;	40 years
Grace Period;	10 years

3. Implementing Agency

Empresa Nacional de Electricidad (state-owned power utility)

JICA Project In Costa Rica

Guana Caste Geothermal Development Sector Loan

1. Overview

The Project aims to develop the multiple geothermal power plants. The loan is allocated for the engineering services for design, the field development, and the civil works for power plants.

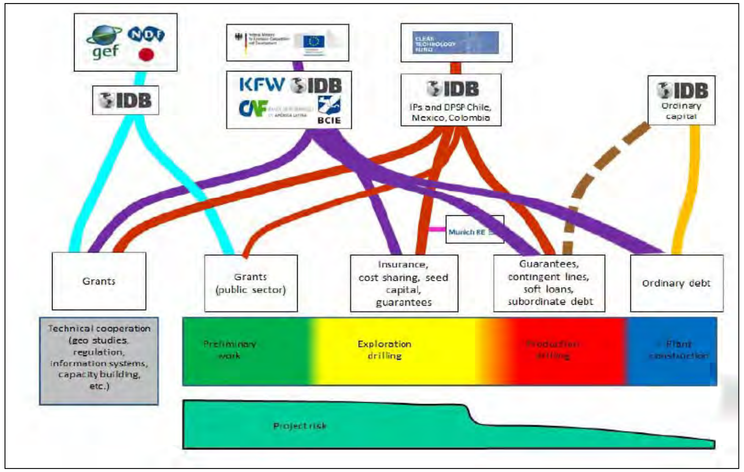
2. Loan

Amount;	JPY 16,810 mil.
Interest Rate;	Main Work 0.60%, Engineering Services; 0.01%
Amortization;	40 years
Grace Period;	10 years

3. Implementing Agency

Instituto Costarricense de Electricidad (state-owned power utility)

IDB Facility for Geothermal Development



Source) IDB Web Data

IDB Facility for Geothermal Development

1. Grants to finance technical assistance

   (e.g. Prefeasibility studies, such as surface studies, hydro-chemical and hydrogeological studies, electromagnetic studies, modeling , Design of Public Private Partnership (PPP) schemes)

2. Direct loans to governments of the Region

   (for developing geothermal projects, through public utilities or private players)

3. Corporate or project finance to private developers

   (For projects in advanced phases, IDB can provide a range of financial instruments for late stage exploration, production wells and cost overruns.)

4. Lines of credit to development banks to provide geothermal financing to developers

   (During each and every stage of a geothermal project, the IDB facilitates the provision of structured finance tailored to each project, seeking to provide flexible financing terms aligned to the expected cash flow of the project.)

5. Access to international concessional finance

(Opportunity to offer risk mitigation instruments such as loans convertible to grants, insured loans, cost-sharing schemes for the early exploration phase, loan guarantees, or insurance premiums.)

Loan Guarantee by IFC

<Overview>

- National government underwrites loan taken on by developer
- Allows developer to access debt
- Government repays to bank in case of failure
- Developer pays fee for guarantee
- Impact on tariff

<Pros>

- Simple to structure/ administer through national development bank
- Project risk lower
- Can be a self-sustained fund

<Cons>

- Impact on government balance sheet
- Possible limits for guarantee

Geothermal Development Facility (GDF)

The GDF constitutes the first multi-donor initiative to promote geothermal energy on a continental scale. It will provide at least USD 75 million in grant-based risk mitigation instruments and USD 1 billion in tailored financing to geothermal projects in a range of Latin American countries

- The GDF seeks to incentivize at least 350 MW of geothermal generation capacity.
- Under the Risk Mitigation Fund public and private developers will be able to apply from early 2016 onwards for a Contingency Grant that will cover up to 40% of the cost of up to three early exploration wells.
- Grants received will only have to be repaid in case of a successful exploration.
- Developers will further be able to refinance grant repayments through the provided Bridge and Investment Financing Lines for geothermal power plants.

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN

Thank you
Arigatou

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

Overview of Geothermal Development

MAY 2015

In St. Georges

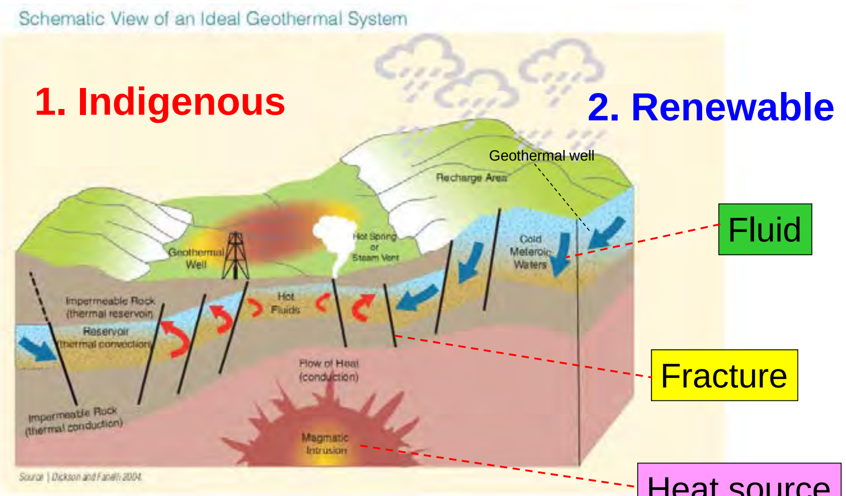
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CONSULTANTS;
NIPPON KOEI CO., LTD.
JMC GEOTHERMAL ENGINEERING CO., LTD
SUMIKO RESOURCE EXPLORATION AND DEVELOPMENT CO., LTD

Introduction of Geothermal Power Generation

Superiority of Geothermal Power Generation

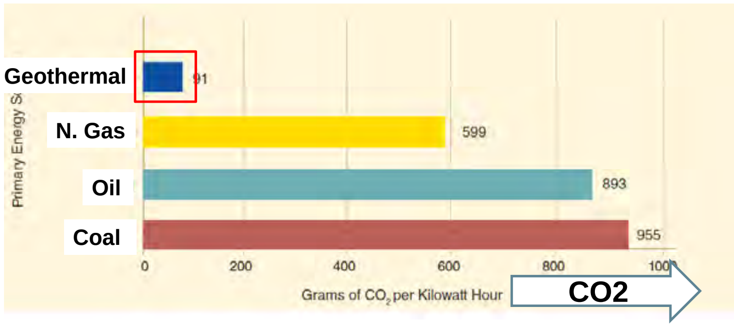
Two Key Characteristics



- USGS on www.cnsm.csulb.edu
- Industry professionals often use the terms "high-enthalpy" and "high-temperature" as synonyms when describing geothermal resources (Eliasson 2001). Enthalpy is a measure of the total energy of a thermodynamic system including the latent heat of vaporation/condensation. As such, it more accurately describes the energy production potential of a geothermal system that includes both hot water and steam.

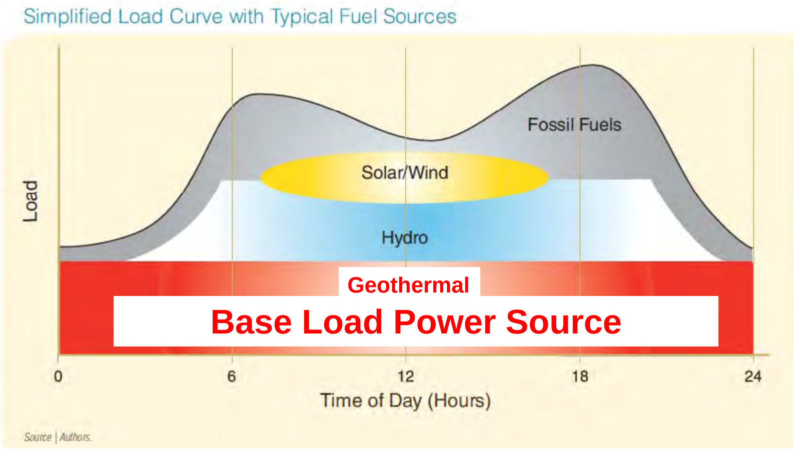
Other Salient Characteristics

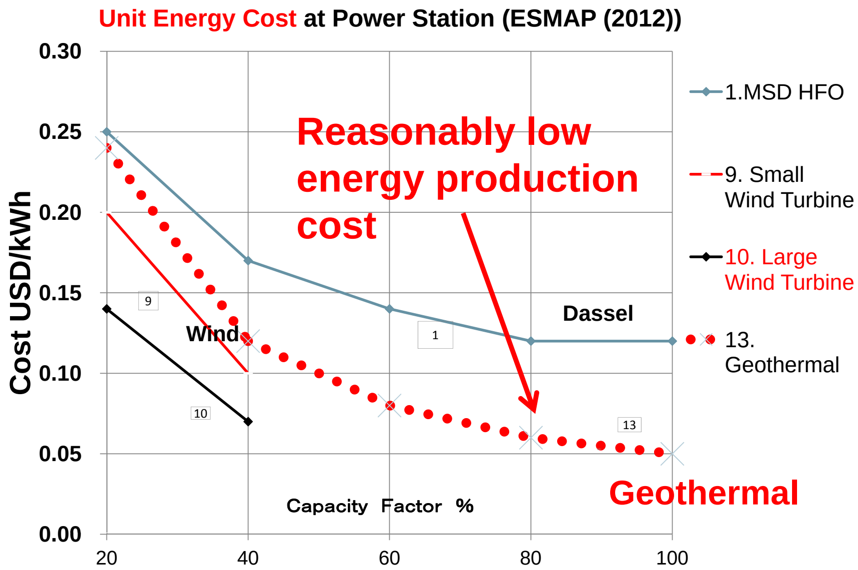
1. Low CO_2 Emission



2. High capacity factor : more than 70%
(Compare with Wind: 20%, Solar: 12%)

Contribution to the power supply as:

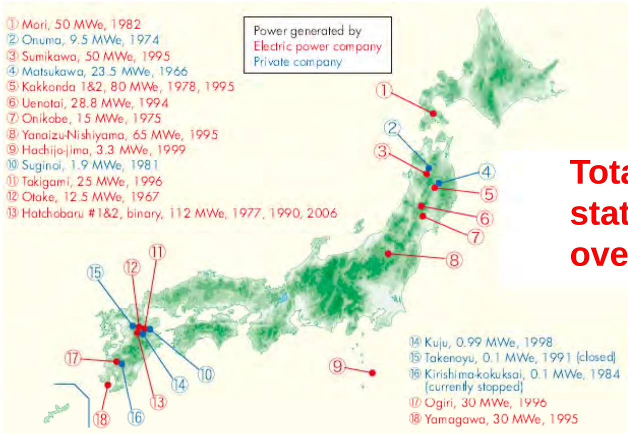




Geothermal Power Plant in Japan

Geothermal Power Plants in Japan

The first installation at Matsukawa in 1966, being operational for 50 years.



Total 18 power stations, over 500 MWe

Geothermal Turbine:

The most important facility for Geothermal power generation

Geothermal turbine manufacturer

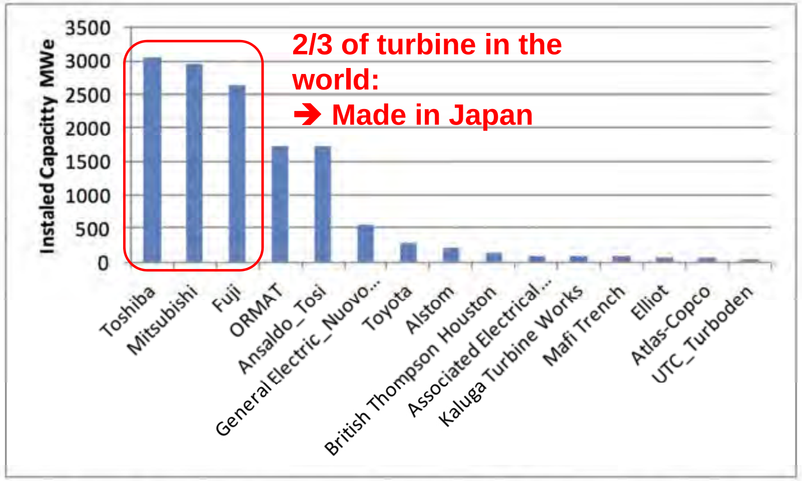
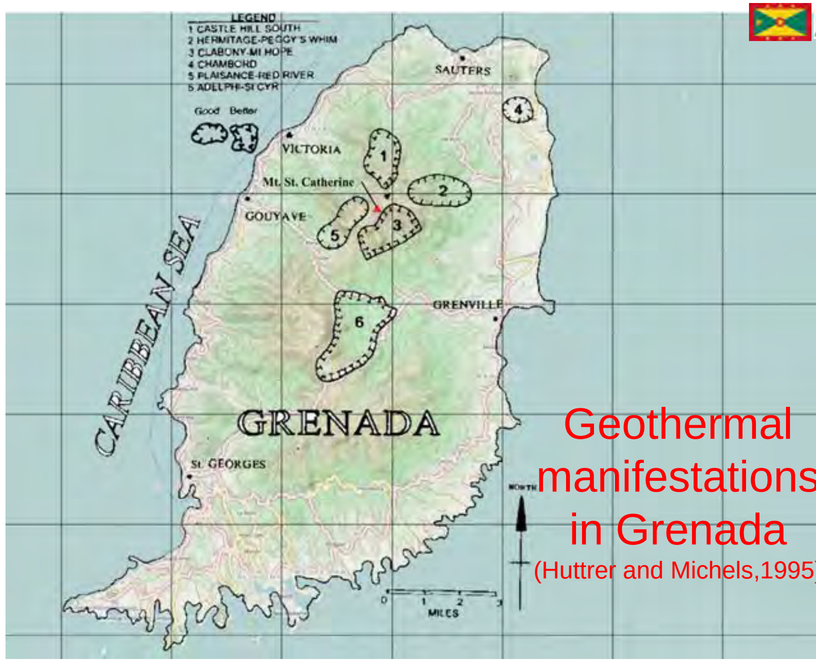


Figure 7: The most important geothermal Turbine manufacturer.

Geothermal potential of Grenada and Assistance from Japan

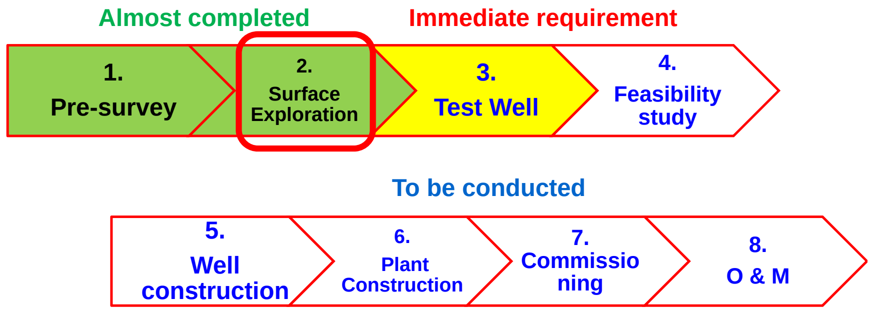


Geothermal manifestations in Grenada
(Huttrer and Michels,1995)

Present Situation in Grenada
- Our Understandings -

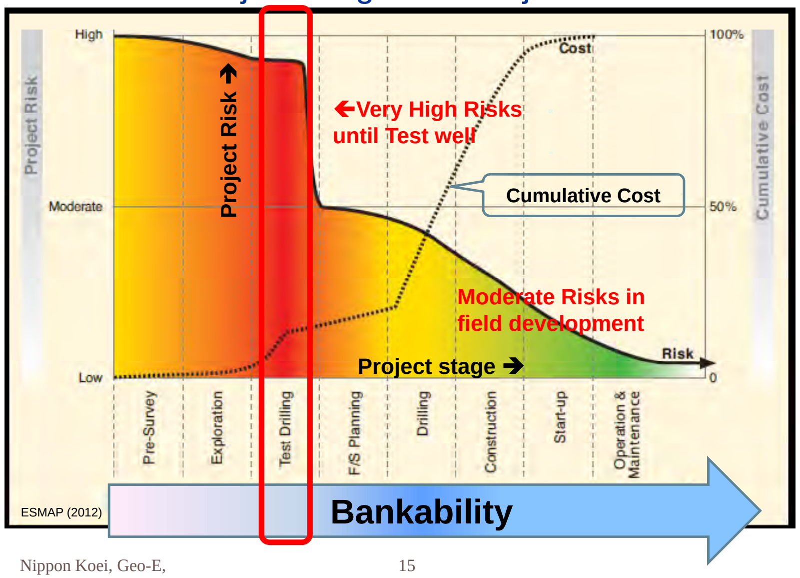
1. Geothermal Support Partnership Framework Agreement between the government of Grenada and New Zealand was agreed in 2014.
2. Geological, geochemical and geophysical survey is being conducted by an eminent New Zealand Consultant.
3. GRENLEC (a private owns 50% stocks) is only operator of electric sector.
4. Implementation framework is yet to be decided (i.e. implementation organization, financial arrangement and etc)

Present development stage



This needs:
- **At least six years or more for completion.**
- **Persistent effort and consistent technical and financial support**

Project Stage and Project Risk



Possible cooperation from Japan
- *Consistent and Seamless Assistance* -

Scientific research and development
- To provide advanced scientific research for exploration and experienced skilful services for development,

Human resources development
- To contribute to human resource development with various programs,

Development policy and plan
- To propose practical development policy and to promote optimal development plan from technical and economical point of view,

ODA loan – CORE Scheme (IDB, CDB involvement)
- To finance the geothermal development with concessional loans

JICA Team's Queries and Views

JICA Team's Query and Views

I. Coordination with NZ assistance

1. To avoid duplications with NZ study, the government is kindly requested to provide the JICA Team with the reports and data of the NZ study, as soon as possible.
2. Please let us know what assistance NZ will provide after this surface survey.
3. Please let us know what assistance the government expects from NZ and Japan for geothermal development, a matter of demarcation.
4. We also would like to be informed how it is coordinated between NZ and Japan.

JICA Team's Query and Views

I. Development policy and priority

1. We understand the geothermal development has long been an issue for development. How is the priority ranking of the geothermal development in the National Development plan.

JICA Team's Query and Views

I. Legal matters

1. Regarding Electricity Supply Act (Draft) and Geothermal Development Act (Draft), we are aware that there are controversial points among parties concerned.
2. What are impacts on geothermal development from the two acts?
   - What are the processes for obtaining the test drilling license by whom ?
   - What would the government think the roles of GRENLEC in the geothermal development?

JICA Team's Query and Views

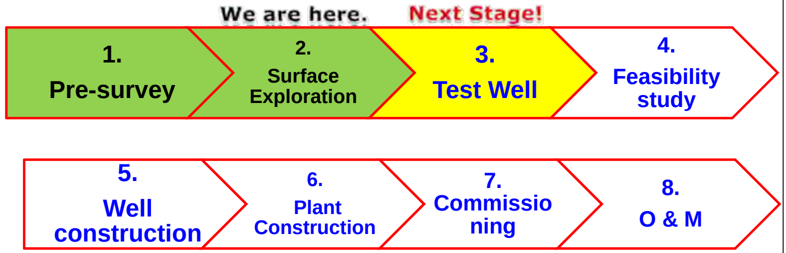
I. **Financial and Business Matter**

1. The public financing for geothermal development will significantly reduce the cost of capital. How would the government financially contribute to the geothermal development, for in particular test drilling? (e.g. debt guarantee, equity participation, other capital from government general budget, etc.)

JICA Team's Query and Views

I. **Environmental Social Impact Assessment (ESIA)**

1. Next stage is drilling test wells (approx.1,000-2,500m). What kind of ESIA is expected to be required ?



DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

Overview of JICA's Contribution To Grenada Geothermal Development

June 2016
By Shinya TAKAHASHI

JAPAN INTERNATIONAL COOPERATION AGENCY (**JICA**)

CONSULTANTS;
NIPPON KOEI CO., LTD.
JMC GEOTHERMAL ENGINEERING CO., LTD
SUMIKO RESOURCE EXPLORATION AND DEVELOPMENT CO., LTD

Outline of JICA's Work

- Background
- Objectives
- Our Professionals

BACKGROUND (1/2): International Partnership

1. IDB and JICA entered in the agreement in 2013, on "**Cofinancing for Renewable Energy** and Energy Efficiency (CORE scheme)",
2. IDB, JICA and CDB entered in the Memorandum in 2014, aiming at building a new partnership to promote **renewable energy** and energy efficiency **in Eastern Caribbean Region**.

BACKGROUND (2/2): Project Identification by JICA

1. JICA conducted a preliminary survey in 12 CARICOM countries in 2014, to identify potential countries for renewable energy and energy conservation projects;
2. **Grenada** has been identified as one of the potential countries for geothermal development.

Objectives

1. To collect and review the existing data and information,
2. To conduct additional field surface surveys,
3. Thereby, to identify geothermal development project/s which JICA could extend its assistance,

➔ Through above activities, to promote a geothermal development project in Grenada.

JICA Team Nine (9) Professionals

Name	Responsible for	Firm
TAKAHASHI Shinya	Team Leader/ Geothermal Energy Development/ Reservoir Assessment	NK
AKATSUKA Takashi	Vice Team Leader/ Geology/ Drilling Planning	Geo-E
FUKUDA Daisuke	Geochemistry	Geo-E
KAWASAKI Kiyoshi/ TAKEDA Masahiro	Geophysical Survey	SRED
TERAMOTO Masako	Environmental Social Consideration	NK
KIKUKAWA Takeshi	Electricity Policy/ Investment Policy	(NK)
MOMOSE Yasushi/ YOSHIDA Satoshi	Civil Engineering Planning	NK

NK: Nippon Koei Co., Ltd.
Geo-E: JMC Goethermal Engineering Co., Ltd.
SRED: Sumiko Resource Exploration and Development Co., Ltd.,

Overview of JICA's Work

1. 3G surveys → 2. Integrated Reservoir Analysis → 3. Well targeting → 4. Test Well drilling design → 5. Scoping for ESIA → 6. Pre-F/S

In Collaboration with Japan and New Zealand

Works by NZ and Japan

1. 3G surveys → 2. Integrated Reservoir Analysis → 3. Well targeting → 4. Test drilling design → 5. Scoping for ESIA → 6. Pre-F/S

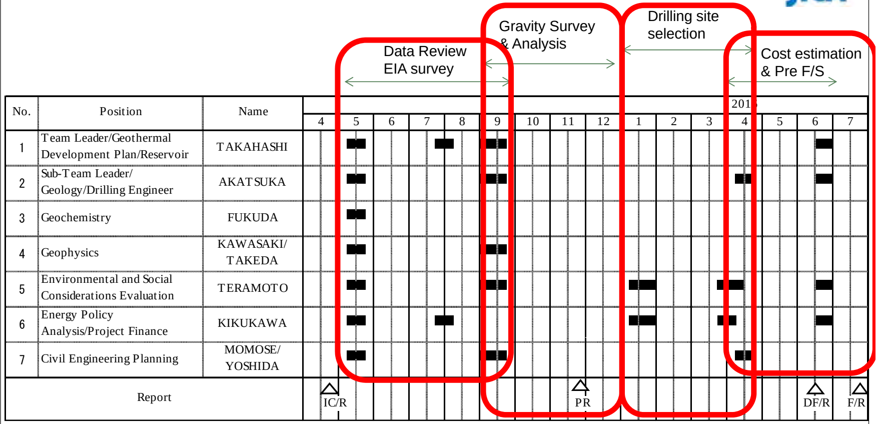
	Item	Sub-item	NZ	JAPAN	Delivery
Surface Surveys & Interpretation	1.	The 3-G surveys			
	1.1	Geology	☒	☒	
	1.2	Geochemistry	☒	☒	
	1.3	MT-survey	☒	-	
	1.4	Additional MT survey	☒		
	1.5	Gravity survey	-	☒	December
	1.6	MT 3-D analysis	☒	-	March
	1.7	Additional MT 3-D analysis	☒	-	March
	2.	Integrated Reservoir Analysis			
	2.1	Reservoir conceptual model	☒	-	March
	2.2	Reservoir assessment (MWe)	☒		March
Planning	3.	Well targeting			
		Proposal of well target	☒	☒	March

1. 3G surveys → 2. Integrated Reservoir Analysis → 3. Well targeting → 4. Test drilling design → 5. Scoping for ESIA → 6. Pre-F/S

	Item	Sub-item	NZ	JAPAN	Delivery
T-Well Planning	1.	Planning of test drilling works			
	4.1	Drilling program(preliminary)		☒	June
	4.2	Assessment of port of unloading, land transportation		☒	June
	4.3	Civil work plan (including site access road)		☒	April
	4.4	Water supply plan		☒	June
	4.5	Other planning		☒	June
	4.5	Cost estimation(preliminary)		☒	June
ESIA	2.	ESIA for drilling works			
	5.1	Baseline survey (secondary information survey)		☒	March
	5.2	Scoping		☒	March
	5.3	ESIA		◆	Next phase
Pre-FS	3.	Pre-Basic design and Feasibility Study			
	6.1	Power plant		☒	June
	6.2	FCRS		☒	June
	6.3	Project cost		☒	June
	6.4	Project viability assessment		☒	June

☒:Completed, ◆: proposed to be conducted by additional funding

JICA survey schedule



*Intermittent: Detailed survey plan will be made after the discussion.
IC/R: Inception Report, P/R: Progress Report, DF/R: Draft Final Report, F/R: Final Report

Today's Presentation by JICA team

1. **Drilling Plan** presented by **Akatsuka**
2. **Environmental and Social Consideration**, presented by **Dr.Teramoto**
3. **Financial Analysis and Feasibility Study**, presented by **Dr. Kikukawa**



Matsukawa Geothermal Power Generation, Japan


Continuous 50 years operation since 1966

Nippon Koei, Geo-E, SRED

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT

Delivering the drilling plan

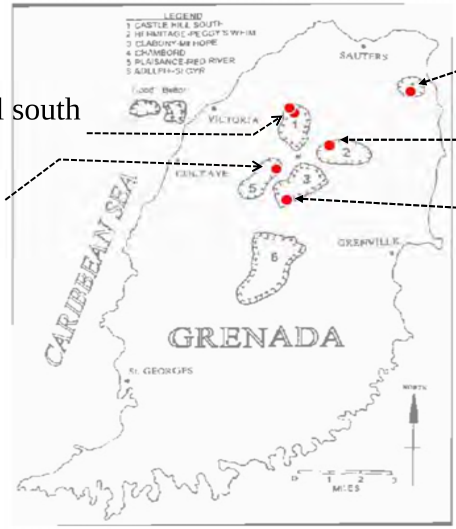
June 23, 2016

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CONSULTANTS;
NIPPON KOEI CO., LTD.
JMC GEOTHERMAL ENGINEERING CO., LTD
SUMIKO RESOURCE EXPLORATION AND DEVELOPMENT CO., LTD

Contents

Geothermal manifestations in Grenada



Castle Hill south

Hapsack

Chambord

Peggy's Whim

Clabony
Mt. Hope

Source:Huttrer & Michels (1995)

Geothermal manifestations in Grenada

You will have soft skin like baby's ….

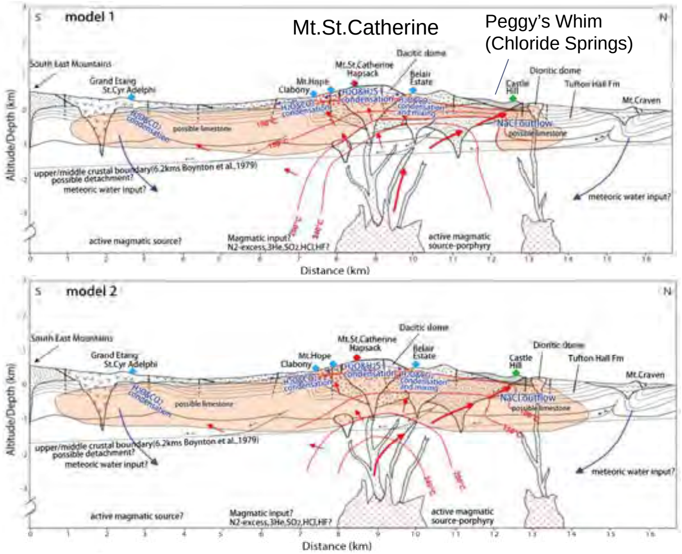
Mudpaste for beauty?

Hot !!!! Good for Bath

Chambord
Temp32.7 degrees C (field)
Salty, Travertine (Calcite)

Peggy's Whim
Temp 38.7 degrees C (field)
Geothermal alteration

2 models of geothermal in Grenada



Cap rock
thin or thick ?

Upper & Outflow zone
Good permeability
200-220 degrees C
Or
Outflow zone
less permeability
100-160 ℃

Deep reservoir
Shallow and wide
Or
Deep and narrow

Source:Jacobs(2016)

3G(Geology, Geochemistry and Geophysics) surface surveys reveal the potential and possible location of geothermal resource in GRENADA. But,

Main Risks before drilling full-size well are in below

1) Reservoir Temperature

Boiling thermal features are common in many geothermal fields. But,….

2) Permeability

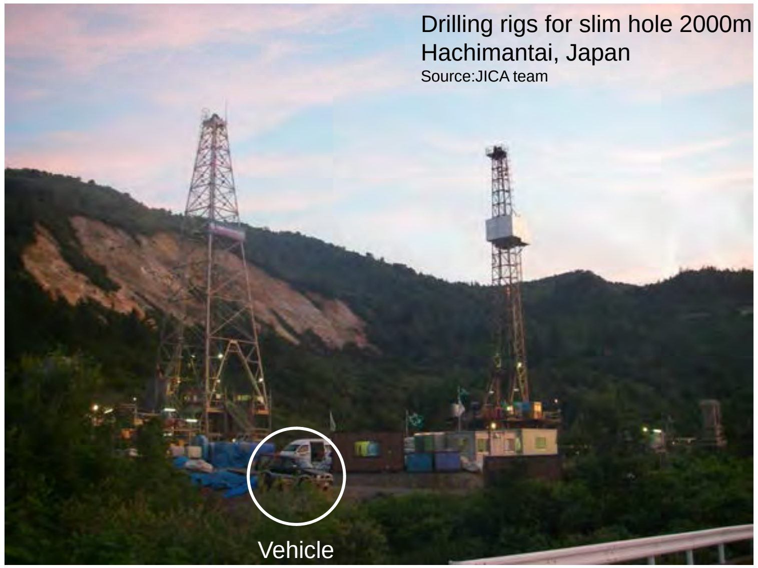
Many volcanic geothermal field are hosted in volcanic deposits.
Geothermal Reservoir under Mt. St. Catherine would correspond to sedimentary deposits.

3) Size of the reservoir

Hydrothermal and native smectite may cause over estimating the size of reservoir.

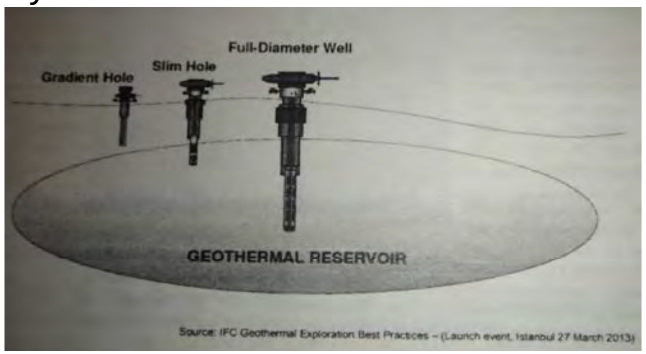
>>SLIM HOLE is best on next stage.

1. SLIM HOLE



CONCEPT OF SLIM HOLE

- Smaller diameter than full-size wells
- Normally drilled into the reservoir



- Drilled using BOP(Blow Out Preventer) equipment with light-medium range oilfield Rigs.

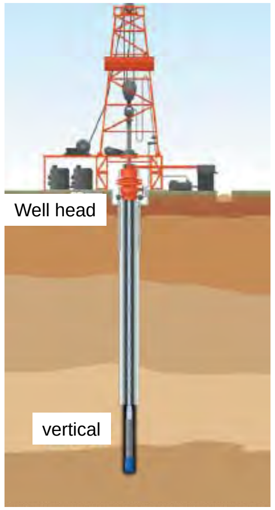
Purpose OF SLIM HOLE

- Collection of underground date
  - Reservoir temperature
  - Pressure
  - Geology
  - Permeability (fractured or not)
  - Hydrothermal alteration

- Improvement of geothermal model
- Evaluation of geothermal potential

- Revealing the promising area for APPRAISAL WELLs

>>Contribution to be more successful.



Source: JOGMEC

Advantages OF SLIM HOLE

- Cost
- Time to start
- Small space (approximately 2000m^2)

Drilling rig for slim hole 2000m
Hachimantai, Japan
Source:JICA team

Procedure of SLIM HOLE drilling

1. Planning
2. Site Preparation (< a few month)
3. Rig up & installation of water supply line(<1month)
4. Drilling (several month)
5. Rig down(<1month)
6. Vegetational reclamation
7. Data analysis

Procedure of SLIM HOLE drilling

1. Planning

- Drilling depth
- Target
- Casing program
- Drilling equipment (rig, pump etc)

- Time schedule
- Licensing Procedure
  Negotiation with related government agencies, landowners
  Permission
- Cost

Procedure of SLIM HOLE drilling

2. Site Preparation (< a few month)

- Tree trimming and change in geometry (making flat space)
  >>for drilling pad, temporary equipment space..
- Setting the temporary road

Tree trimming

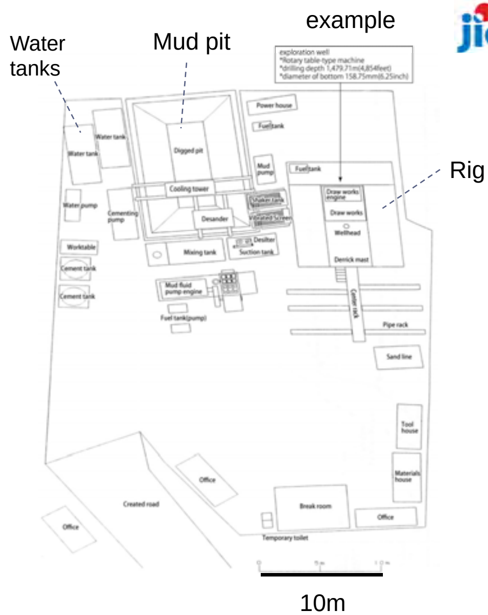
Vegetation on digged slop

Source: JOGMEC

Drilling pad

- Approximately 2000m^2
  =40m*50m is needed for drilling equipment.

- water supply pit
- space for temporary construction material



Procedure of SLIM HOLE drilling

3. Rig up & installation of water supply line(<1month)

Conveyance of drilling equipments.
>>Assembling rig, water supply line, mudfluid circulation sustem etc…(Rig up)

Source:JICA team

Rig of SLIM HOLE

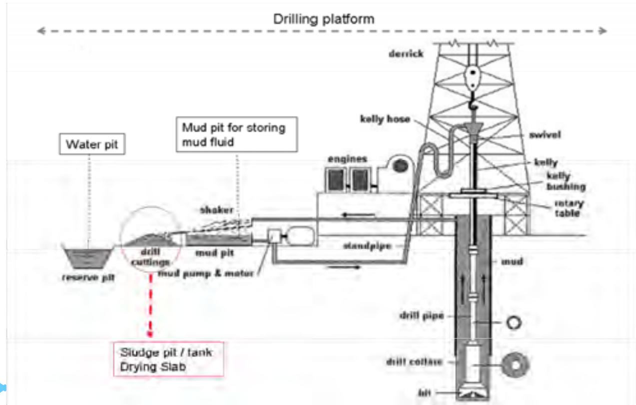
1.Rotary table-type Truck-mounted rig
Source:
http://www.esmap.org/sites/esmap.org/files/Bailey_Exploration(Day1)_0.pdf

2. Spindle-type boring machine
Source: http://toa-tone.jp/manufacture/m03.html#m03

Water is important role for Drilling

- Drilling fluid (water + clay + polymer)
  Cooling bit, Removing cuttings, covering wall.

- Injection water into well to prevent blowout.



Amount used of Water for Drilling

- Drilling without loss circulation
  A small amount of water (approximately a few ton per minute)
  >>Mainly resupply amount of evaporated water

- Drilling with loss circulation, cementing
  Large amount of water (approximately 2-3 ton per minute)
  >>In case of water flowing out well by way of several fractures.

Water Supply Pit

- water supply pit (about 12m × 12m × 1m ≈ 150m^3 is needed, equivalent 5 times volume of the slim hole.

Source:JICA team

Source:JICA team

Procedure of SLIM HOLE drilling

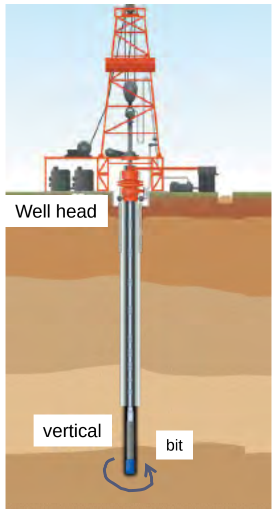
4. Drilling (< several month)

Spindle-type machine

Core bit

Collecting core sample

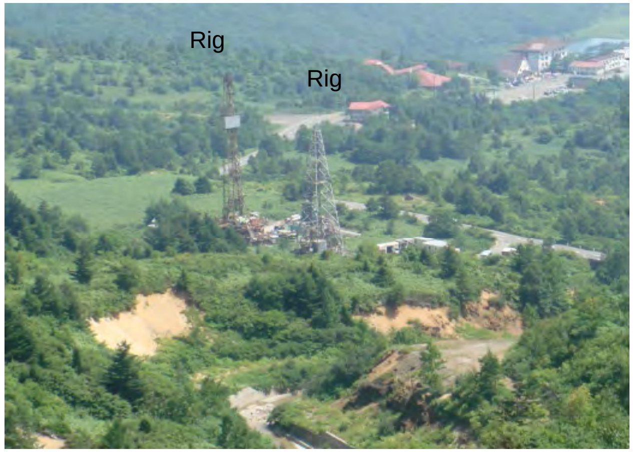
analysis core sample



Source: JOGMEC

Procedure of SLIM HOLE drilling

Drillings on going…..



Source: JOGMEC

Procedure of SLIM HOLE drilling

5. Rig down (< 1 month)

6. Vegetational reclamation
7. Data analysis

- Geology, physical properties (temperature, pressure etc.) in drilled well
- Improvement of geothermal model
- Planning of appraisal well (target, drilling procedure etc.)

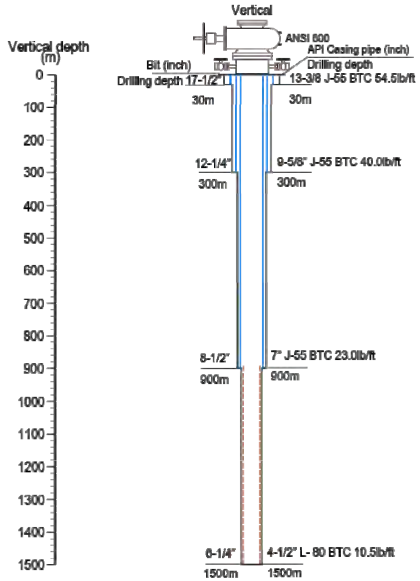
GO on to NEXT STAGE

Source: JOGMEC

2. Recommendation

- Rig
- Drilling depth and Casing program
- Intake water
- Location and access

Well program drilled by rotary-table



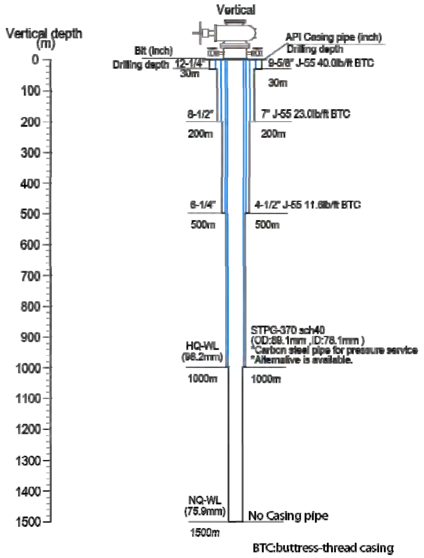
BTC:buttress-thread casing

Drilling Rig:Rotary table-type Truck-mounted rig

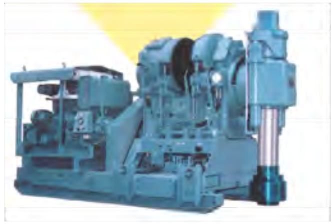
Casing pipe: API (American Petroleum Institute) Standard
*Insert casing pipe into bottom of well.

Logging Items
Pressure-Temperature logging
Wellsite Geology
description of lithology (cuttings, core sample)

Well program (drilled by Spindle-type)



Drilling Rig:Spindle-type boring machine

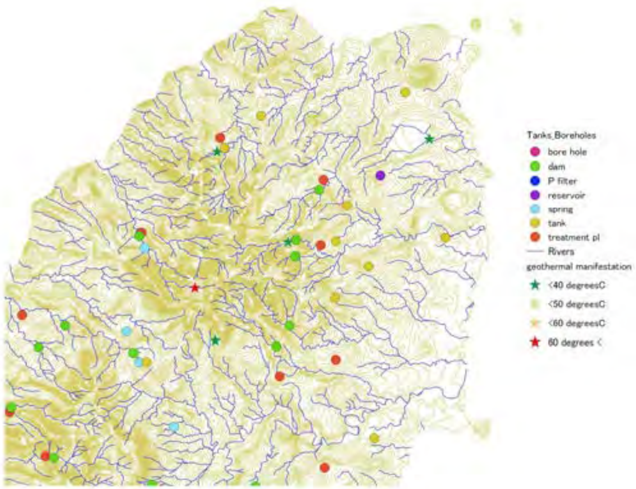


Casing pipe: API (American Petroleum Institute) Standard
*Insert casing pipe into bottom of well.

Logging Items
Pressure-Temperature logging
Wellsite Geology
description of lithology (cuttings, core sample)

Water intake

Intake are recommended to locate the down the stream of NAWASA's facility.
Negotiation and agreement from NAWASA are needed to use river water for drilling.

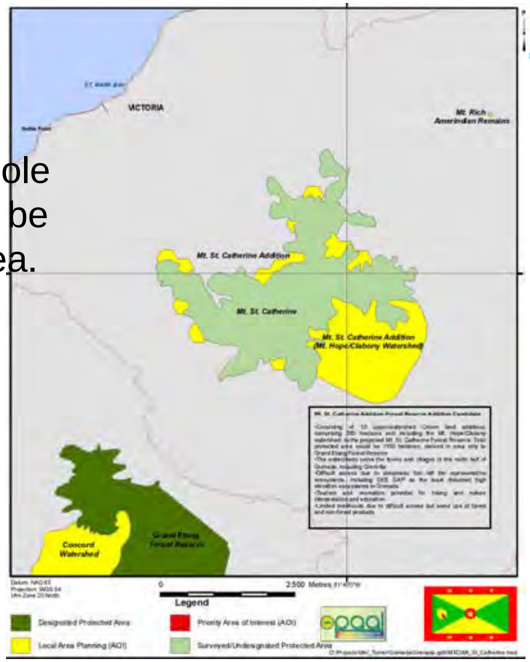


Location of drilling pad

Drilling pad for slim hole are recommended to be accessible.

Location of drilling pad

Drilling pad for slim hole are recommended to be out of the reserve area.



Conclusion

- SLIM HOLE is best choice for the geothermal development in Grenada.
- It is possible to obtain the data of pressure-temperature distribution, geology and fracture information, and reservoir pressure to evaluate geothermal reservoir.
- SLIM HOLE is designed as vertical, 1,500 meters in depth.
- Agreement of Landowners are needed to proceed slim hole drilling.
- Negotiation and agreement from NAWASA are needed to use river water for drilling.

Thank you

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT IN GRENADA

Environmental and Social Considerations for Geothermal Project

Partners' Forum

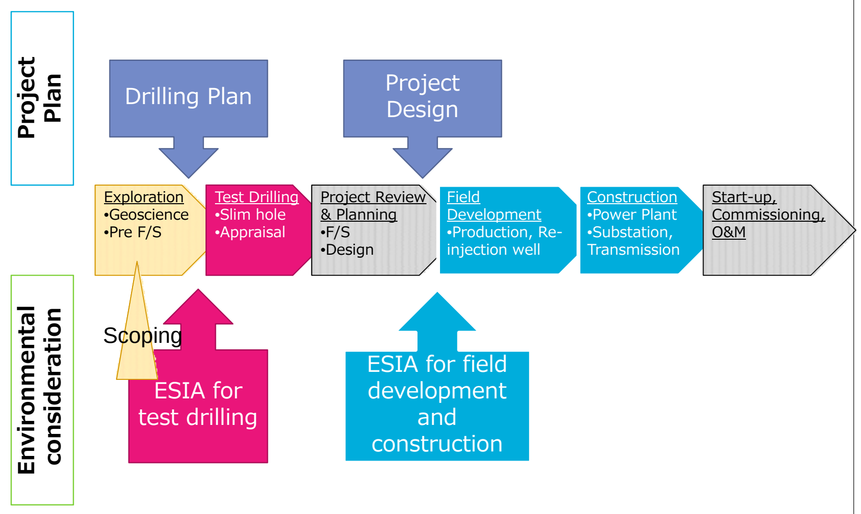
24th June 2016

Masako TERAMOTO

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CONSULTANTS;
NIPPON KOEI CO., LTD.
JMC GEOTHERMAL ENGINEERING CO., LTD
SUMIKO RESOURCE EXPLORATION AND DEVELOPMENT CO., LTD

Geothermal Development Stage and ESIA



Legal Framework of Environment

for geothermal development in Grenada

EIA Legislation

◆Two legislations include provisions for environmental impact assessment (EIA) in Grenada.
◆Physical Planning Development Authority (PDA) and the minister responsible for environmental planning.

No.	Legislation	Description
1	Physical Planning and Development Control Act No. 25 of 2002 Physical Planning and Development Control Bill, 2015 (Draft)	To make provision for the control of physical development, require the preparation of physical plans for Grenada, protect the natural and cultural heritage, and for related matters.
2	Waste Management Act No. 16 of 2001	To provide for the management of waste in conformity with best environmental practices and related matters

Development Activity Requiring EIA

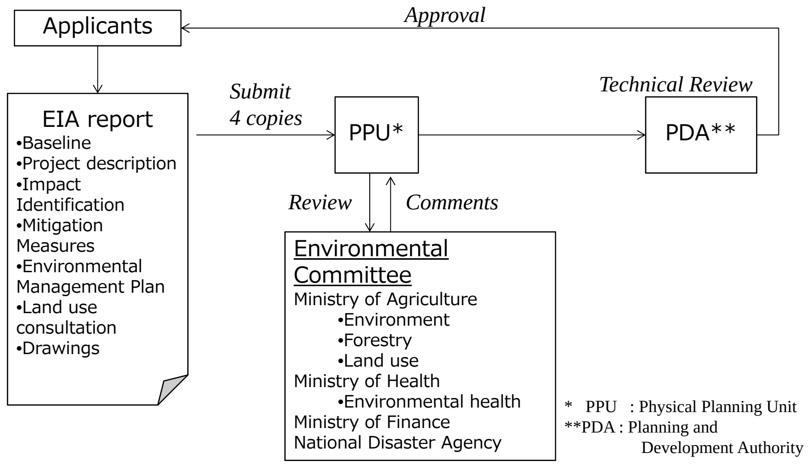
- 18 development activities listed below are subject to EIA.
- Geothermal development activities are classified in No.10, No.15 and No.18.

No.	Types of Development
1	Hotels of more than 50 rooms
2	Subdivisions of more than ten lots
3	Residential development of more than 25 units
4	Any industrial plant which in the opinion of the authority is likely to cause significant adverse environmental impact
5	Quarrying and other mining activities
6	Marinas
7	Land reclamation, dredging, and filling of ponds
8	Airports, ports, and harbors
9	Dams and reservoirs
10	Hydroelectric projects and power plants

Development Activity Requiring EIA

No.	Types of Development
11	Desalination plants
12	Water purification plants
13	Sanitary landfill operations, solid waste disposal sites, toxic waste disposal sites, and other similar sites
14	Gas pipeline installations
15	Any development generating or potentially generating emissions, aqueous effluent, solid waste, noise, vibration, or radioactive discharges
16	Any development involving the storage and use of hazardous materials
17	Any coastal zone development
18	Any development in wetlands, marine parks conservation areas, environmental protection areas, or other sensitive environmental areas.

EIA Process in Grenada



* PPU : Physical Planning Unit
**PDA : Planning and Development Authority

- After submission of the EIA report to the Physical Planning Unit, it normally takes about six weeks for the report to be approved.

Relevant Environmental Legislations and Regulations

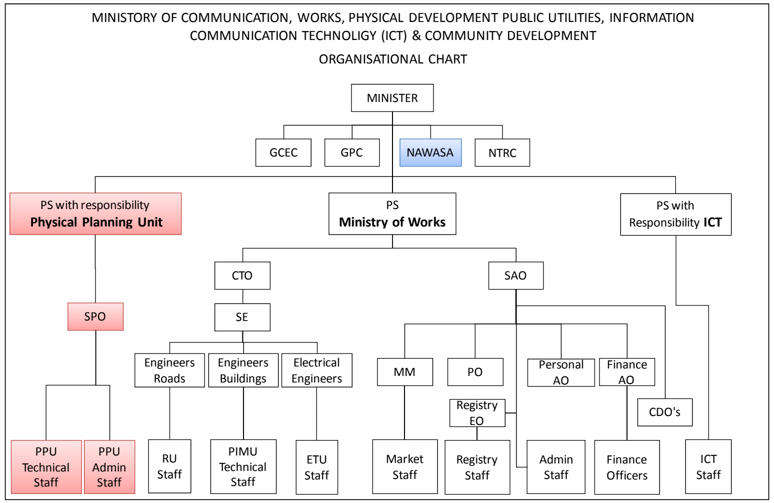
No.	Legislation	Description
1	The Beach Protection Amendment Act of 2009	To prohibit sand mining in Grenada.
2	Litter Abatement Act of 1973	It has been supplemented by the passage of the Waste Management Act of 2001 addressing pollution control and abatement of litter.
3	Solid Waste Management Act No. 11 of 1995	It has established the Solid Waste Management Authority charged with the duty of developing solid waste management facilities and improving the coverage and effectiveness of solid waste storage, collection, and disposal facilities of Grenada.
4	National Parks and Protected Areas Act of 1991	To designate and maintain national parks and protected areas.
5	Environmental Levy Act No. 5 of 1997	To impose and collect environmental levy on certain goods and services.
6	Fisheries Act of 1986	To provide for the protection of the marine resources in Grenada; amended in 1999.
7	Forest, Soil, and Water Conservation Act, 1949	To make provision for the conservation of the forest, soil, water, and other natural resources of Grenada; amended in 1984.

Institutional Framework

◆Currently following institutions are directly involved in environmental management activities in Grenada.

No.	Institutions
1	Physical Planning Unit, Ministry of Communication, Works and Physical Planning
2	Forestry Department, Ministry of Agriculture Forestry and Fisheries, Public Utilities, Marketing Board and Energy
3	Department of Environment, Ministry of Agriculture Forestry and Fisheries, Public Utilities, Marketing Board and Energy
4	Land Use Department, Ministry of Agriculture, Forestry, Fisheries, and Marketing Board
5	Environmental Health Department, Ministry of Health and the Environment
6	Solid Waste Management Authority
7	National Water and Sewage Authority (NAWASA)
8	Port Authority
9	Airport Authority

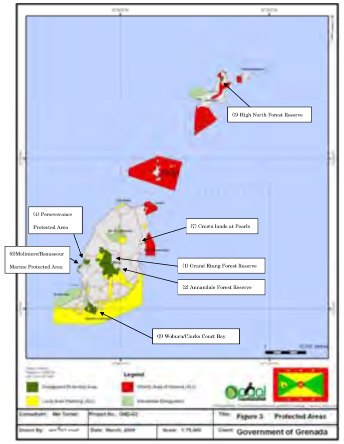
Organizational Structure



Environmental and Social Conditions

of geothermal development project in Grenada

Natural and Cultural Heritage



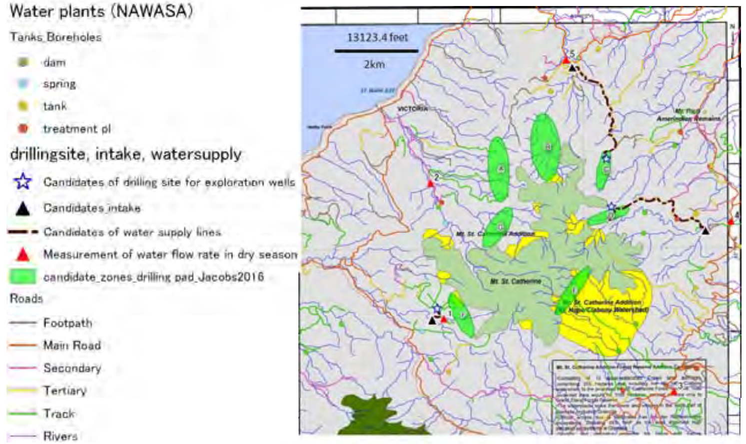
1. Grand Etang Forest Reserve
2. Annandale Forest Reserve
3. High North Forest Reserve
4. Perseverance Protected Area
5. Woburn/Clarks Court Bay Marine Protected Area
6. Moliniere/Beausejour Marine Protected Area
7. Unspecified crown lands at Pearls are designated as a protected area

Types of Protected Area

Category	Feature	Area (Selected)	Designation
Designated Protected Area	Already designated by the government (7 areas)	Grand Etang	Forest Reserve
Local Area Planning	Areas that should be reviewed in the context of best land use and the local area planning process. (14 areas)	Mt. St. Catherine Addition	Mt. St. Catherine Forest Reserve Addition
Priority Area of Interest	Existing land use pressures from residential, tourism, and industrial development have the potential to threaten future protected area. (8 areas)	South Carriacou Islands	Marine Protected Area
Immediate Designation	Areas which should be designated immediately due to the importance to Grenada's endangered species and habitats. (16 areas)	Mount Hartman	National Park
		Mt. St. Catherine	Forest Reserve

- In Grenada, there are several endemic species of flora and fauna.
- Need to be assess environmental impact from the project.

Location of Protected Area and Drilling Candidate Areas



- In Grenada, the center part of Mount St. Catherine and parts of coast area are designated as protected areas. All the drilling candidate zones is outside these protected zones.

Hydrological Environment

- 71 watershed areas (left).
- There are 11 boreholes, 17 water storage tanks, and 24 water treatment tanks (right)

- Need to avoid negative impact on water resource by drilling activities regarding both quantity and quality.

Social Environment

- Land Use:
  - Agriculture (light green)
  - Abandoned cultivation(yellow)
  - Forest (green)
- Local Economy:
  - Most of residents around Mr.St.Catherine make a living by agriculture.
    - Nutmeg, cocoa, banana, sugarcane and other fruits.

- There might be some land acquisition and replacement needed for geothermal project.

NIPPON KOEI Geo-E

Results of Preliminary Scoping

for geothermal development
in Grenada

Results of Preliminary Scoping

◆In order to identify items for ESIA for the geothermal project in Grenada, preliminary scoping was conducted.
◆Check items listed below are selected based on the JICA Guidelines for Environmental and Social Considerations (April 2010)

RATING

- A+/-: Significant positive/negative impact is expected.
- B+/-: Positive/negative impact is expected to some extent.
- C+/-: Extent of positive/negative impact is unknown (further examination is needed, and its impact could be clarified as the study progresses)
- D: No impact is expected.

Results of Preliminary Scoping

Category: "Pollution(1/2)"

No.	Items	Rating			Rating Basis
		Pre	Con	O&M	
1	Air Quality	B-	B-	B-	Pre・Con : During production test, generation of gas containing hydrogen sulfide (H2S) is expected. In addition, emission gases are discharged due to operation of heavy machines during well drilling and facility construction. Ope : H2S is expected to be released along with steam.
2	Water Quality	B-	B-	B-	Pre・Con : Mud water is expected to be generated due to well drilling. Ope : Wastewater is expected to be discharged from the facilities.
3	Wastes	B-	B-	B-	Pre・Con : Drilling sludge, construction waste soil, and scrap wood are expected to be generated by well drilling activities. Ope : Wastes (sludge, waste oil) are expected to be generated in the facilities.
4	Soil Pollution	D	D	D	No activities which may cause soil pollution are planned.

Results of Preliminary Scoping

Category: "Pollution(2/2)"

No.	Items	Rating			Rating Basis
		Pre	Con	O&M	
5	Noise/ Vibration	B-	B-	B-	Pre・Con : Blowout of geothermal fluid by well drilling and noise from operation of heavy machines are expected. Ope : Noise from operation of the facilities (power generator, steam turbine, cooling tower, etc.) is expected.
6	Ground Subsidence	D	D	C	Pre・Con: Collection of geothermal fluid during well drilling and facilities construction is limited. Ope : Although ground subsidence is expected due to collection of geothermal fluid, detailed examination is required.
7	Offensive Odor	C	C	C	If gas contains hydrogen sulfide (H2S), odor is expected.
8	Sediment Quality	D	D	D	No activities which may cause sediment quality pollution are planned.

Results of Preliminary Scoping

Category: “Natural Environment”

No.	Items	Rating			Rating Basis
		Pre	Con	O&M	
9	Protection Area	A-	A-	A-	The project site is located close to Mt. St. Catherine Forest Reserve.
10	Ecosystem /Flora and Fauna	A-	A-	A-	Some negative impacts on regional ecosystem and flora and fauna are expected due to disturbance of the land, operation, and existence of the facilities.
11	Hydrology	B-	B-	D	Pre・Con : Surface water or groundwater is planned to be used for drilling. Ope : The amount of surface water or groundwater planned to be used is limited.
12	Topograph y/ Geology	D	B-	D	Pre : Impacts are negligible as large-scale well drilling is not planned. Con : The land is expected to be disturbed due to construction of facilities (generator building, steam and hot fluid transport pipe, cooling tower, etc.). Ope : No activities which may cause impacts on topography/geology are planned.

Results of Preliminary Scoping

Category: “Social Environment(1/4)”

No.	Items	Rating			Rating Basis
		Pre	Con	O&M	
13	Involuntary Resettlement	C	C	C	Even though there are few residents around the project site, involuntary resettlement survey is required after the drilling plan.
14	Poor People	D	B+	B+	Pre : Creation of employment opportunities from test drilling is limited. Con・Ope : Some positive impacts on regional economy are expected such as creation of employment opportunities through construction and operation of the facilities.
15	Ethnic Minority/ Indigenous People	D	D	D	There are herders and nomads available in the area, but there are no ethnic minorities or indigenous people who need special consideration.
16	Local Economy and Livelihood	D	B+	B+	Pre : Test drilling only creates limited employment opportunities. Con・Ope : Some positive impacts on regional economy such as creation of employment opportunities are expected by the construction and operation of the facilities.

Results of Preliminary Scoping

Category: “Social Environment(2/4)”

No.	Items	Rating			Rating Basis
		Pre	Con	O&M	
17	Land Use and Utilization of Local Resources	D	D	B+	Pre・Con : No impacts on land use and utilization of local resources are expected. Ope : Geothermal fluid could be used for other purposes in addition to geothermal generation.
18	Water Use	A-	A-	D	Pre・Con : Surface water or groundwater is planned to be used for drilling. Some impacts on water resource are expected.. Ope : The amount of surface water or groundwater planned to be used is limited.
19	Social Infrastructures and Services	D	D	D	There are no sensitive social infrastructures (dwelling, school, medical facilities, etc.) located in and around the project site.
20	Social Institutions and Local Decision-making Institutions	D	D	D	No impacts on social institutions and local decision-making institutions are expected.

Results of Preliminary Scoping

Category: “Social Environment(3/4)”

No.	Items	Rating			Rating Basis
		Pre	Con	O&M	
21	Misdistribution of Benefits and Damages	D	D	D	No unequal distribution of benefit and damage is expected in and around the project site.
22	Local Conflicts of Interest	D	D	D	No local conflict of interest is expected in and around the project site.
23	Cultural and Historical Heritages	C	C	C	Although no cultural and historical heritages were considered at the project site, a detailed investigation is required.
24	Landscape	D	D	A+/-	Pre・Con : Since no large-scale construction work is planned, impacts on landscape are temporal and limited. Ope : Some impact on landscape is expected due to the existence of plant facilities (power generator, steam turbine, cooling tower, etc.).

Results of Preliminary Scoping

Category: "Social Environment(4/4)"

No.	Items	Rating			Rating Basis
		Pre	Con	O&M	
25	Gender	D	D	D	No impact is expected.
26	Children's Rights	D	D	D	No impact is expected.
27	Infectious Diseases (such as HIV/AIDS)	B-	B-	D	Pre・Con : Although no large-scale construction work is planned, there is a possibility for infectious diseases to spread due to the influx of workers. Ope : Since the number of workers at the project facilities is limited, impact on infectious disease is considered to be small.
28	Occupational Environment (including Occupational Safety)	C-	C-	C-	Although the project site is located at not special area, some sort of considerations on occupational safety are required.

Results of Preliminary Scoping

Category: "Others"

No.	Items	Rating			Rating Basis
		Pre	Con	O&M	
29	Accidents	B-	B-	B-	Special considerations on accidents are required during test drilling, facility construction, and operation.
30	Climate Change	D	D	A+	Pre・Con : Since no large-scale construction work is planned, impact on climate change is temporal and limited. Ope : This project could contribute to reduce greenhouse gas emission.

Compliance with International Requirement

- ToR to be included in an ESIA are specified in the physical planning and development control act No.25 of 2002.
- They are largely in line with the requirement specified in JICA guidelines for environmental and social considerations (2010), however, Grenadian regulations do not require intensive attention on social impact assessment.
- In order to comply with JICA's guidelines as well as other international requirement such as IFC, it is proposed to include following studies.
  1. Evaluation of alternatives including zero option
  2. Social impact study including land acquisition and resettlement
  3. Public consultation

Proposed ToR for ESIA for Next Phase

1. Baseline survey
2. Stakeholder Engagement Plan (SEP)
3. Environmental and Social Studies
   - Biodiversity
   - Water
   - Noise
   - Air quality
   - Socoi-Enocomics and Cultural Heritage
   - Involuntary Resettlement (physical and economic displacement)
4. Impact Assessment
5. Environmental and Social Management Plan (ESMP)
6. Environmental and Social Management System (ESMS)
7. Consultation and Disclosure

Thank you very much
for your attention

DATA COLLECTION SURVEY FOR GEOTHERMAL DEVELOPMENT

Financial Analysis for Geothermal Project

June 2016

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CONSULTANTS;
NIPPON KOEI CO., LTD.
JMC GEOTHERMAL ENGINEERING CO., LTD
SUMIKO RESOURCE EXPLORATION AND DEVELOPMENT CO., LTD

Project Design Summary

Project Overview (1/3)

1. Project Overview	
1.1 Project Description	
The project shall include the following activities. - Geothermal resources assessment, - Geothermal well drilling and testing - Construction of Geothermal Power Plant (15MW or 10-15 MW to be examined.) - Construction of Transmission Line (out of scope of development of generation) - Operation and Maintenance of the Power Plant	
1.2 Goal and Objectives	
- To reduce and stabilize electricity prices - To contribute to the mitigation of the global warming	The ceiling price of the energy cost can be considered to be 0.15 USD/kWh given the current cost of services of GRENLEC.
1.3 Decision Management	
- Currently the assessment of the pre-feasibility of the resources is being carried out. - The procurement of fund for the exploration drilling is considered in parallel.	The development stage is generally subdivided into six steps. 1. Initiate, 2. Evaluate Resource , 3. Quantify Resource, 4. Confirm Resource, 5. Execute, 6. Operate
1.4. Project Ownership, Structure and Governance	
The formation for project development is being examined.	
1.5 Policy and Legislative Framework	
Law: - Public Utilities Regulatory Communication Bill 2015: being discussed at Parliament - Electricity Supply Bill 2015: being discussed at Parliament - Geothermal Development Bill: being drafted. Policy The Energy Division in the Ministry of Finance, Planning, Economy, Energy & Cooperatives (Ministry of Finance) is in charge of energy policy.	It would also be envisages that a PPP-related regulations would be established.

Project Overview (2/3)

2. Investment

2.1 General Conditions

Main procurement will be conducted through open book method in compliance with the international cooperating partners.

2.2 Cost Estimates

Construction costs for Model 3 are as follows.

(i) Government Portion

Category	Item	Costs (USD mil.)	%
Well Drilling	Civil Works	0	0.0
	Slimhole Drilling	0	0.0
	Appraisal Drilling	0	0.0
	Production Drilling	0	0.0
	Consultancy Services	0.75	100.0
Power Plant Development	Field Dev.	0	0.0
	Power Plant Dev.	0	0.0
	Transmission Line	0	0.0
	Consultancy Services	0	0.0
Total Project Costs		0.75	100.0

(ii) Private Portion

Category	Item	Costs (USD mil.)	%
Well Drilling	Civil Works	13.10	11.89
	Slimhole Drilling	0.00	0.0
	Appraisal Drilling	20.80	18.87
	Production Drilling	12.40	11.25
	Consultancy Services	4.08	3.70
Power Plant Development	Field Dev.	6.60	5.90
	Power Plant Dev.	35.22	31.96
	Transmission Line	18.00	16.34
	Consultancy Services	0.00 (included in the above)	0.00
Total Project Costs		110.20	100.0

Project Overview (3/3)

2.3 Project Profile	
The followings are assumed for the base case - Installed Capacity : 5.5 MW x 3 Unit, total 16.5 MW - In house use : 10% - Availability factor : 90% - Net output : 15 MW - Annual generation : Net 118.2 GWh/year - Construction period: Vary by model - Operating period : 30 years	

2.4 Project Schedule

Project Schedule for Model 3 is estimated as follows.

Item	Period (year)	Remarks
Permissions & Civil Works	1.0	By Government (Public)
Slimhole Drilling	1.0	
Tendering	2.0	
Civil Works & Preparation	1.0	By Private
Appraisal Drilling	1.0	
Production Drilling & Field Development	1.0	
Transmission Line	1.0	
Power Plant & Commissioning	1.0	
Total Period	9.0	

The assumption figures for the other models are as described in the other sections of the report.

Project Costs

The activities after the surface survey include;
i) slimhole drilling,
ii) appraisal well drilling,
iii) production well drilling,
iv) transmission facility construction, and
v) power plant construction including steam field development.
The estimation cost totaled to 123 million USD.

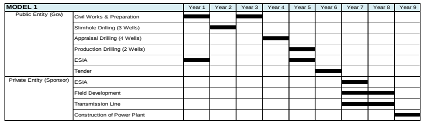
Cost Items	Cost (US$)
Civil Works & Preparation	17,700,000
Slimhole Drilling (3 Wells)	7,500,000
Appraisal Drilling (4 Wells)	20,800,000
Production Drilling (2 Wells, Production Test)	12,400,000
Field Development	6,000,000
Construction of Power Plant	35,200,000
Transmission Line (2 lines)	18,000,000
Consultancy Services (DD, SV)	5,800,000
Total	123,400,000

Project Scheme

Model #	Slimholes	Appraisal Drilling	Production Drilling	Field Dev & Power Plant
Model 1	Gov	Gov	Gov	Private
Model 2	Gov	Gov	Private	Private
Model 3	Gov	Private	Private	Private
Model 4	n/a	Private	Private	Private

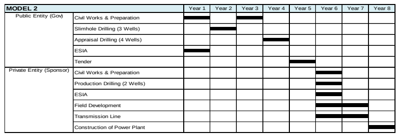
Project Schedule

Model 1



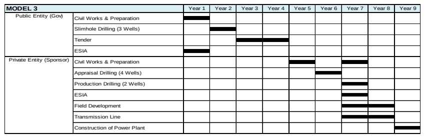
9 Years

Model 2



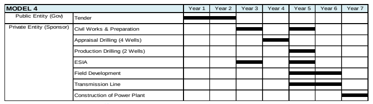
8 Years

Model 3



9 Years

Model 4



7 Years

Financial Analysis

Sample Development Phase

1. Phase I : Preparation (Indicative Duration: 2015 - 2016)
1) Surface Exploration
2) Conceptualization

2. Phase II : Exploration (2017 - 2019)
1) Slimhole Drilling
2) Confirmation of Resources
3) Concession Award

3. Phase III : Appraisal (2019 – 2020)
1) Appraisal Drilling
2) Feasibility Study/ Arrangement of Debt Financing

4. Phase IV : Production Drilling/ Construction (2021 – 2024)
1) Production Drilling/ Field Development
2) Construction of Power Plant
3) Substation & Transmission Line

5. Phase V : Operation and Maintenance (Commissioning in 2025 – 2026)
1) Operation and Maintenance of Power Plant
2) Management of Geothermal Reservoir

Project Scheme

Particular		Model 1 Separation of Power Plant (PPP Model no.1)	Model 2 Separation of Production Drilling (PPP Model no.2)	Model 3 Separation of Appraisal Drilling (PPP Model no.3)
Development Activity & Entity	1. Exploration Slimhole Drilling	Government (Grant Fund)	Government (Grant Fund)	Government (Grant Fund)
	2. Appraisal Drilling	Government	Government	Private
	3. Production Drilling	Government	Private	Private
	4. Field Development & Construction of Power Plant	Private	Private	Private
	5. Operation	Private	Private	Private
Debt Financing	Government	Concessional Loan	Concessional Loan	Concessional Loan
	Private	Commercial Loan	Commercial Loan	Commercial Loan
Remarks		Sales agreement of steam OR Sales of production wells to power producer	Transfer cost of appraisal drilling to power producer	No costs will be transferred to private entity.

Source: JICA Survey Team (2016)

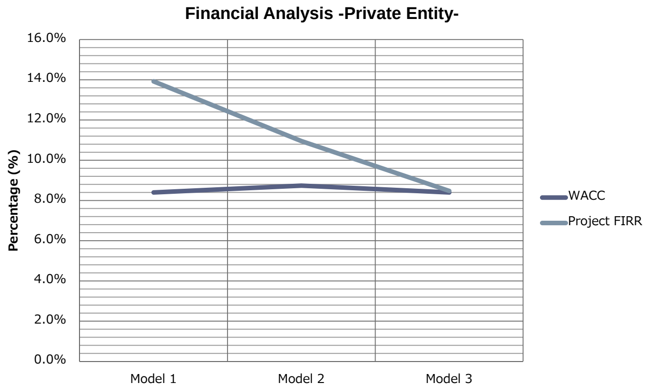
Assumptions for Analysis

Item	Condition
a. Energy Generation	118.2 GWh/year (Average utilization rate; 90%)
b. Initial Investment Costs	110.20 USD mil. (model 3, private entity)
c. Total Construction Period	Vary by model
d. Project Period	Operation; 25 years from commissioning
e. Ratio of capital procurement (equity & debt)	Vary by model
f. Repayment of Debt	Concessional loan[?] 25 years (grace period; 7 years) Commercial loan; 20 years (grace period; 3 years)
g. Capital Costs	Concessional loan[?] 3.0% Commercial loan; 5.5%
h. Annual O&M Expenses	2.0% of total construction cost
i. WACC	Vary by model
j. Depreciation	Service life: 30 years, Salvage value: 5%, Straight-line method
k. Tax &Duty	Corporate tax[?] 30%, VAT & Import Duty: exempted.
l. Physical Contingency	5% of total costs
m. Power Sales Price	Generation Company to GRENLEC; US 15.0 cents/kWh
n. Charges from Public to Private (Generation Company)	Vary by model

(1/2)

Entity	Item	Model 1	Model 2	Model 3
Public (Government)	Debt	US$ 41.5 mil.	US$ 27.1 mil.	US$ 0.6 mil.
	Equity	US$ 20.6 mil.	US$ 13.8 mil.	US$ 0.3 mil.
	WACC[1]	2.6□	2.6□	2.6□
	Project FIRR	3.5%	3.7%	4.3%
	Equity FIRR	-1.1%	-0.9%	1.7%
Private	Debt	US$ 50.3 mil.	US$ 66.3 mil.	US$ 92.6 mil.
	Equity	US$ 12.6 mil.	US$ 19.1 mil.	US$ 23.1 mil.
	WACC	8.4□	8.7□	8.4□
	Project FIRR	13.9%	11.0%	8.5%
	Equity FIRR	34.9%	31.8%	22.2%
Public-Private Consolidated	Project FIRR	8.2%	8.4%	8.4%

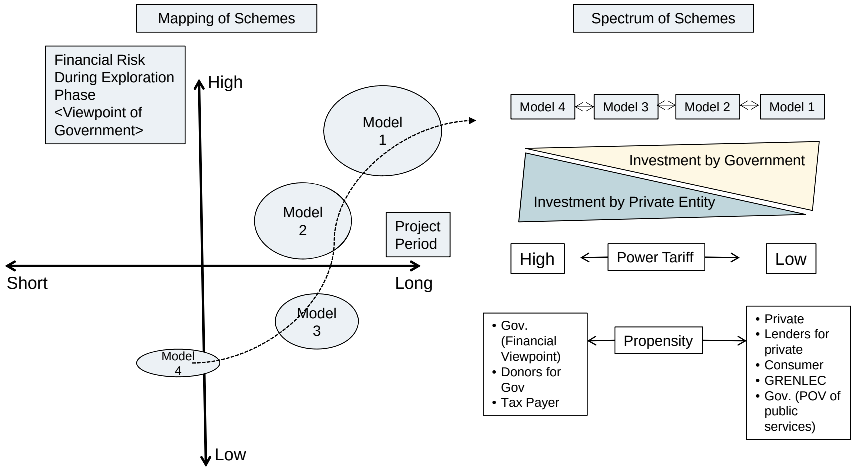
(2/2)



Implication for Power Tariff

#	Assumption	Indicator		Model 1	Model 2	Model 3
1.	Power Sales Tariff to Off-taker (15.0 US cents/kWh)	Equity FIRR	%	34.9%	31.8%	22.2%
2.	Equity Return (Target: 20%)	Power Sales Tariff	c/kWh	12.1	12.9	14.3

Scheme



Recommendations

1. Government Role and Financing
2. Investment Policy of Government
3. Capacity Development
4. Legislation and Regulation
5. Improvement of Project Survey
6. Market Sounding

Roles of Government

Government Policy
(1) Sector Development Policy
(2) Legal Framework/ Regulations
(3) Commitments
(4) Support to Private Sector
(5) Collaboration with Partners

Finance
(1) Public Support to Initial Investment
(2) Grant/ Loan Guarantees
(3) Equity Participation to PPP
(4) Development Lending
(5) Tax and Fiscal Incentives

Focal Point for Integration

Institution
(1) Development Body
(2) Inter-ministerial Arrangement
(3) Government Staff
(4) Outside Resources
(5) Capable Regulator

Expertise/Information
(1) Technical Study
(2) Resource Survey/ Investigation
(3) Environment and Social
(4) Power Demand and Supply
(5) Industry Trend /Latest Technology

Elements of Roadmap for Geothermal Development

Phase	Phase I Preparation	Phase II Exploration	Phase III Appraisal	Phase IV Production/ Construction	Phase V O & M
Activity/ Analysis	(1)Ongoing pre-feasibility study (2)Pre-scoping for environmental and social considerations (3)Preparation of Action Plan	(1)Infrastructure procurement (2)Bidding for exploration drilling (e.g. slimholes) (3)Supervision of drilling (4)Updating pre-feasibility study	(1)Concession Tender (2)Executing of appraisal drilling (3)Confirmation of final feasibility (4)Debt financing arrangement (5)Financial closure for construction	(1)Procurement of production drilling, field development and power plant (2)Construction supervision (3)Inspection before use (4)Transmission Line dev.	(1)Monitoring of operation (2)Market regulation (3)Monitoring of power supply and demand
Decision Making/ Action Plan	(1)Phase II Planning (Technical, Financial, Legal, Environmental) (2)Fund-arrangement for Slimhole Drilling	(1)Phase III Planning (2)Marketing sounding for private sector participation (3)MOU	(1)Phase IV Planning (2)Government Participation (3)Selection of Developer (4)Various Contracts	(1)Phase V Planning (2)Preparation for Commissioning	(1)Review of Development (2)Consideration of Future Development

Appendix-4　List of data collected

Appendix-4 Collected Data

Arclus, 1976. Geology and Geochemistry of the alkali basalt – andesite association of Grenada, Lesser Antilles island arc

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Appendix-5 Volumetric method

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Improvement of Calculating Formulas for Volumetric Resource Assessment

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ABSTRACT

The USGS volumetric method is used for assessing the electrical capacity of a geothermal reservoir. The calculation formulas include both underground related parameters and above-ground related parameters. While primary variability and uncertainty in this method lay in the underground related parameters, electric capacity calculated is also a function of the above-ground related parameters. Among those parameters, the fluid temperature of the reservoir will be the key parameter for the volumetric method calculation when used with Monte Carlo method, because this temperature is the variable (uncertain) underground related parameter which affects the steam-liquid separation process in the separator - an above-ground related parameter. Conventional calculation methods do not deal with the steam-liquid separation process being affected by fluid temperature as a random variable when used together with Monte Carlo method. In order to fix up this issue, we have derived calculation formulas by introducing “Available Exergy Function”, thereby, the fluid-temperature-dependant separation process can be included in the equations together with the fluid temperature as a random variable. This paper presents the electricity capacity calculations formulas that can be used for the volumetric method together with Monte Carlo method. In addition, a comparison is also made between the proposed method and the USGS method. The theoretical background of the proposed formula has eventually proved to be as same as USGS method except for a few parameters adopted.

Keywords: triple point temperature; single flash power plant; steam-liquid separation process at separator; available exergy function; adiabatic heat drop at turbine

1. INTRODUCTION - ISSUES OF THE CALCULATION METHODS BEING AVAILABLE

The USGS (1978) defines the reservoir thermal energy available under a reference temperature by the following equation.

$$q_r = \rho C V (T_r - T_{ref}) \quad \text{[kJ]} \qquad \text{(Eq. 1)}$$

Where q_r is geothermal energy that is stored in geothermal reservoir and is able to be used under reference temperature conditions, ρC is volumetric specific heat, V is reservoir volume, T_r is reservoir temperature and T_{ref} is reference temperature. It describes that the reference temperature (15 ℃) is the mean annual surface temperature and for simplicity is assumed to be constant for the entire United States. A set of calculation equations are presented, on the basis of the second law of thermodynamics, to estimate electric energy to be converted from geothermal energy available under the reference temperature. Parameters required for the calculation of the electric generation capacity by using the USGS method are summarized below.

Table 1 Classification of Parameters for USGS Method (1978)

A. Underground related parameters	**B.** Above-ground related parameters
a-1. Reservoir volume: V [m^3]	b-1. Reference temperature: T_{ref} [°C]
a-2. Reservoir temperature: T_r [°C]	b-2. Utilization factor: η_u[-]
a-3. Volumetric specific heat: ρC [$kJ/m^3 - K$]	b-3. Plant life: L [sec]
a-4. Recovery factor: R_g [-]	b-4. Plant factor: F [-]

While primary variability and uncertainty in this method lay in the underground related parameters, considerations have also been directed to above-ground related parameters. The USGS method defines ‘utilization factor’ to convert heat energy to electric energy, giving 0.4 (USGS 1978). It was updated to 0.45 by USGS (2008). USGS (1978) states the given utilization factor is applicable only for the case that the reference temperature is 15 ℃ (the average ambient temperature in the United State) and the condenser temperature is 40 ℃. On the other hand, S. K. Garg and J. Combs (2011) pointed out that the utilization factor depends on both power cycle and the reference temperature; the available work (calculated electric energy) is a strong function of the reference temperature. This suggests that type of power cycle has to be defined to obtain valid results when practicing the volumetric method.

We consider here a single flash condensing power cycle as a typical plant. Electric energy to be generated is calculated by well established calculation processes for turbine-separator-condenser performance in accordance to thermodynamics; the electric energy generated is principally dependent on fluid temperature sent to separator together with separator temperature and condenser temperature; a set of each fixed temperature may be given into the calculation process. However, these conventional calculation methods are not applicable when practicing the volumetric method together with Monte Carlo method because the fluid temperature shall be dealt as a random variable due to its uncertainty and the steam-liquid separation process is a fluid-temperature-dependant process. Calculation equations for the volumetric method need to satisfy those two requirements when used with Monte Carlo method. In order to provide this issue with a solution, we have derived calculation formulas by introducing “Available Exergy Function”, thereby, fluid-temperature-dependant separation process can be included in a equation together with the fluid temperature as a random variable for the use with Monte Carlo method.

With the concept above, Takahashi and Yoshida (2015 a, 2015 b) proposed a simplified calculation formula, assuming a single flash condensing power cycle of the separator temperature 151.8 ℃ and condenser temperature 40 ℃; the formula includes fluid temperature as a random variable and the function that reflects the fluid-temperature-dependant steam-liquid separation process;

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that can be used with Monte Carlo method. We herein refined the proposed method and expand its application to various combinations of separator and condenser temperatures assuming a single flash condensing power cycle.

Discussions on other important subjects of the underground related parameters are out of the scope of this paper. We believe the proposed equations will provide clearer ideas on the reservoir potential once the underground related parameters are properly defined.

2. SUMMARY OF THE PROPOSED CALCULATION EQUATIONS

The key points of the proposal are described below. A detailed explanation on how the equations have been derived are presented in Chapter 3 for verifications by readers.

1. We placed the "triple point temperature" in the equation-2 for the place of the reference temperature of the equation-1 of USGS (1978). The equation-2 represents the heat energy potentially stored in the geothermal reservoir, whereas the equation-1 defines the heat energy available in the reference temperature condition out of the heat energy potentially stored in a geothermal reservoir. This is because the fluid recovered at well head is sent to the power plant before exposed to any of reference conditions.

2. We adopted the concept of the "exergy" at a single flash condensing cycle by the equation-5 or -6 (adiabatic heat drop) in accordance to thermodynamics. This equation is eventually proved to be the same as the one given by USGS (1978) as the "Available Work" (Chapter-11).

3. We defined the "Available Exergy Function" by the equation-7. This represents the ratio of the exergy at a turbine-generation system against the total heat energy recovered at well head. Inclusion of the function in the calculation formula is the key idea of this paper.

4. By using the Available Exergy Function, the electricity to be generated is given by the equation-10. "Exergy efficiency", instead of "utilization factor", is included in the equation to tie up with the "exergy" adopted. This is the base equation from which approximation equations for application are derived.

5. For the separator temperature of 151.8 ℃ and the condenser temperature of 40 ℃ as an example; an approximation of the Available Exergy Function is given first as cubic polynomial as in the equation-21; this polynomial approximation is further simplified by the equation-23 for practical uses; Exergy efficiency is approximated in the equation-25, -26 based on 189 actual performance data; Electricity to be generated is given by the equation-27.

6. A comparison with USGS method is discussed in Chapter 8 and Chapter 11 for further reference. A discussion on the utilization factor defined by USGS is also given in Chapter-11

2.1 Application

We will first present the sets of equations in Table-2. Thereafter, the explanation is given on how those equations have been derived.

2.1.1 Underground Related Conditions

The underground related parameters listed in Table 1 shall be determined first. We referred to the USGS method (1978) for the definitions and applications of those parameters. For the proposed calculation method, those parameters can be random variables for Monte Carlo method as has been practiced in the past. Much attention and examination shall be directed to the determination of those parameters because primary variability and uncertainty lay in the underground related parameters. Discussions on how to determine those parameters are out of scope of this paper.

2.1.2 Geothermal Fluid Conditions for the Proposed Method

We assume the geothermal fluid is the single phase liquid conditions in the reservoir. This is because "a fluid that is all liquid has a smaller entropy value than a two phase fluid with same enthalpy; thus, the available work (exergy) value assuming liquid water is greater than any two-phase mixture of the same enthalpy and is an appropriate reference condition" (USGS 1978). The enthalpy of the fluid in the reservoir usually decreases when it comes up to the wellhead due to the partial or entire flashing, frictions, gravitational forces and/or others. We, however, assume the fluid enthalpy available at the wellhead should correspond to the enthalpy of the single phase liquid in the reservoir. The loss of enthalpy while the fluid comes up to the well head could be included in the recovery factor when practicing the volumetric method.

2.1.3 Above-Ground Conditions for the Proposed Method

A single flash condensing system is assumed, where separator temperature and condenser temperature shall be pre-determined. The combination of separator temperature and the condenser temperature will be the index for selection of the simplified calculation equation presented in Table 2. Discussions on how to determine the separator temperature and the condenser temperature in relation to geothermal fluid characteristics are out of the scope of this paper. The following presentation however may be helpful.

Figure 1 shows the relative power output to be generated by a power plant with the separator pressures ranging from 2 bar-a to 10 bar-a, with two cases of condenser temperatures of T_{cd} =40℃ or T_{cd} =50℃, for the geothermal fluid temperature raging from 200 ℃ to 350 ℃, (assuming $R_g \rho CV$=1 for the calculations of relative outputs). Power output may be maximum when the separator pressure of 5 or 6 bar-a for the fluid temperature of 250 ℃ - 275 ℃. These separator pressures may be recommended for an initial stage of resource evaluation if other conditions should allow to do so. Note that power output will be about 88 % when condenser temperature increases from 40 ℃ to 50 ℃ with the separator pressure of 5 bar-a just for a reference.

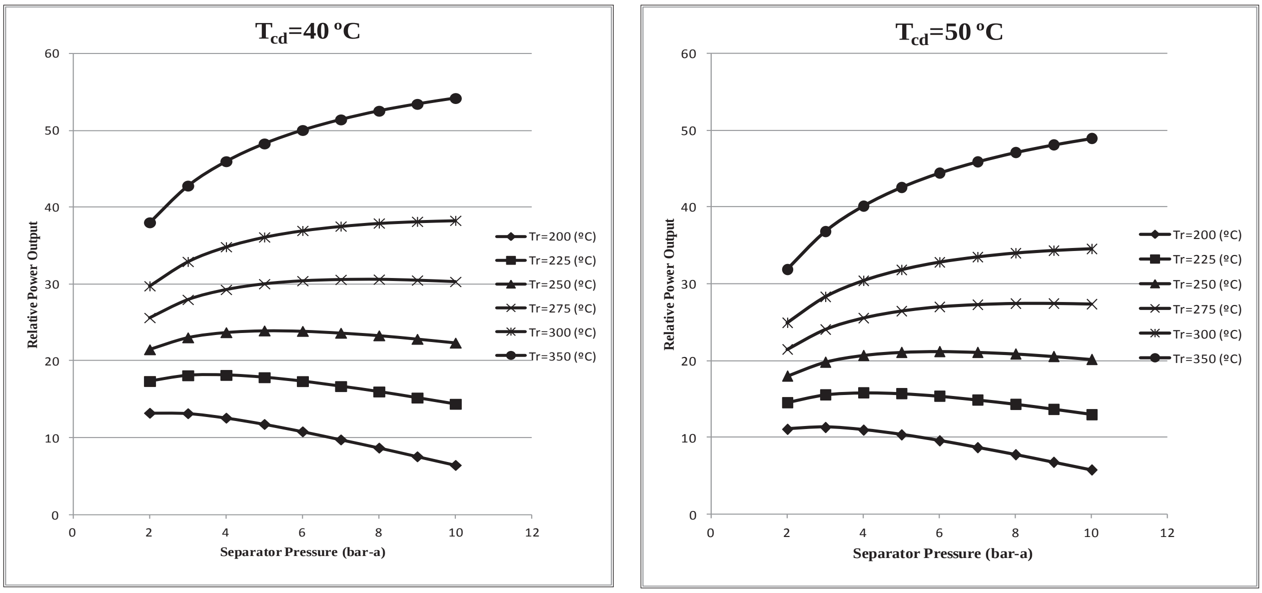


Figure 1 Relative Power Output for Various T_{sp} with T_{cd} =40 ℃ (Left) or T_{cd} =50 ℃ (Right)

2.1.4 A Note on "Reference Temperature" and "Utilization Factor"

For the proposed calculation method, we do not use such generalized temperature names as "reference temperature", "abandonment temperature" or "rejection temperature". Instead, specified temperatures as "triple point temperature", "separator temperature" and "condenser temperature" are used to avoid possible misunderstandings. We do not use 'utilization factor' either, because it is originally defined for the use exclusively in the United State. It is a rather region specific factor. Instead of the "utilization factor", we use plant specific "exergy efficiency" (defined by Equation-24) together with plant specific "exergy" (defined by Equation-5 or -6) at a turbine-generator. A brief observation on the "utilization factor" is given in Chapter 11.1 of this paper for further observation.

2.2 Calculation Equations

The sets of the calculation equations are presented in Table-2. Abbreviations appeared in the table are shown below.

E : Electric energy $[kJ]$
R_g : Recovery factor [-]
V : Reservoir volume$[m^3]$
T_r : Average reservoir temperature [℃]

$\rho C = (1-\varphi)C_r\rho_r + \varphi C_f\rho_f$: Reservoir volumetric specific heat $[\mathrm{kJ}/m^3 - \mathrm{K}]$
φ : Porosity [-]
C_r : Specific heat of rock $[kJ/kg]$
ρ_r : Rock density $[kg/m^3]$
C_f: Specific heat of fluid $[kJ/kg]$
ρ_f: Fluid density $[kg/m^3]$

A calculation equation is uniquely given by selecting a combination of the temperatures of the separator and the condenser. Numerical constants in the equations in Table-2 shall not be modified or changed in any case. These are the products from a series of approximation processes. Coefficients of the turbine-generator efficiency are included in the numerical terms in the equations based on information of actual power plants all over the world.

The average output capacity of the power plant in a designed plant life period is given as follows.

$$W_e = \mathrm{E}/(\mathrm{FL}) \qquad [kJ] \text{ or } [kW]$$

Where; "We" is the average output capacity of the power plant, "F" is the plant utilization factor, "L" is the plant life period (sec).

Table 2 Proposed Calculation Equations for Volumetric Method

Eq.-ID	Conditions				Electric Energy (kJ) Linear Approximation
	Separator		Condenser		
	P (bar-a)	T (℃)	P (bar-a)	T(℃)	
230	2	120.2	0.04	30	(0.19 ± 0.01) * $R_g \rho CV$ * (T_r - 120.2)
240	2	120.2	0.07	40	(0.17 ± 0.01) * $R_g \rho CV$ * (T_r - 120.2)
250	2	120.2	0.12	50	(0.14 ± 0.01) * $R_g \rho CV$ * (T_r - 120.2)
260	2	120.2	0.20	60	(0.11 ± 0.01) * $R_g \rho CV$ * (T_r - 120.2)
370	2	120.2	0.31	70	(0.09 ± 0.01) * $R_g \rho CV$ * (T_r - 120.2)
330	3	133.5	0.04	30	(0.23 ± 0.01) * $R_g \rho CV$ * (T_r - 133.5)
340	3	133.5	0.07	40	(0.20 ± 0.01) * $R_g \rho CV$ * (T_r - 133.5)
350	3	133.5	0.12	50	(0.17 ± 0.01) * $R_g \rho CV$ * (T_r - 133.5)
360	3	133.5	0.20	60	(0.14 ± 0.01) * $R_g \rho CV$ * (T_r - 133.5)
370	3	133.5	0.31	70	(0.12 ± 0.01) * $R_g \rho CV$ * (T_r - 133.5)
430	4	143.6	0.04	30	(0.25 ± 0.02) * $R_g \rho CV$ * (T_r - 143.6)
440	4	143.6	0.07	40	(0.22 ± 0.01) * $R_g \rho CV$ * (T_r - 143.6)
450	4	143.6	0.12	50	(0.19 ± 0.01) * $R_g \rho CV$ * (T_r - 143.6)
460	4	143.6	0.20	60	(0.17 ± 0.01) * $R_g \rho CV$ * (T_r - 143.6)
470	4	143.6	0.31	70	(0.14 ± 0.01) * $R_g \rho CV$ * (T_r - 143.6)
530	5	151.8	0.04	30	(0.27 ± 0.02) * $R_g \rho CV$ * (T_r - 151.8)
540	5	151.8	0.07	40	(0.24 ± 0.02) * $R_g \rho CV$ * (T_r - 151.8)
550	5	151.8	0.12	50	(0.21 ± 0.01) * $R_g \rho CV$ * (T_r - 151.8)
560	5	151.8	0.20	60	(0.19 ± 0.01) * $R_g \rho CV$ * (T_r - 151.8)
570	5	151.8	0.31	70	(0.16 ± 0.01) * $R_g \rho CV$ * (T_r - 151.8)
630	6	158.8	0.04	30	(0.29 ± 0.02) * $R_g \rho CV$ * (T_r - 158.8)
640	6	158.8	0.07	40	(0.26 ± 0.02) * $R_g \rho CV$ * (T_r - 158.8)
650	6	158.8	0.12	50	(0.23 ± 0.02) * $R_g \rho CV$ * (T_r - 158.8)
660	6	158.8	0.20	60	(0.20 ± 0.01) * $R_g \rho CV$ * (T_r - 158.8)
670	6	158.8	0.31	70	(0.18 ± 0.01) * $R_g \rho CV$ * (T_r - 158.8)
730	7	165.0	0.04	30	(0.31 ± 0.02) * $R_g \rho CV$ * (T_r - 165.0)
740	7	165.0	0.07	40	(0.28 ± 0.02) * $R_g \rho CV$ * (T_r - 165.0)
750	7	165.0	0.12	50	(0.25 ± 0.02) * $R_g \rho CV$ * (T_r - 165.0)
760	7	165.0	0.20	60	(0.22 ± 0.01) * $R_g \rho CV$ * (T_r - 165.0)
770	7	165.0	0.31	70	(0.19 ± 0.01) * $R_g \rho CV$ * (T_r - 165.0)
830	8	170.4	0.04	30	(0.32 ± 0.02) * $R_g \rho CV$ * (T_r - 170.4)
840	8	170.4	0.07	40	(0.29 ± 0.02) * $R_g \rho CV$ * (T_r - 170.4)
850	8	170.4	0.12	50	(0.26 ± 0.02) * $R_g \rho CV$ * (T_r - 170.4)
860	8	170.4	0.20	60	(0.23 ± 0.02) * $R_g \rho CV$ * (T_r - 170.4)
870	8	170.4	0.31	70	(0.21 ± 0.01) * $R_g \rho CV$ * (T_r - 170.4)
930	9	175.4	0.04	30	(0.34 ± 0.02) * $R_g \rho CV$ * (T_r - 175.4)
940	9	175.4	0.07	40	(0.31 ± 0.02) * $R_g \rho CV$ * (T_r - 175.4)
950	9	175.4	0.12	50	(0.28 ± 0.02) * $R_g \rho CV$ * (T_r - 175.4)
960	9	175.4	0.20	60	(0.25 ± 0.02) * $R_g \rho CV$ * (T_r - 175.4)
970	9	175.4	0.31	70	(0.22 ± 0.01) * $R_g \rho CV$ * (T_r - 175.4)
1030	10	179.9	0.04	30	(0.35 ± 0.02) * $R_g \rho CV$ * (T_r - 179.9)
1040	10	179.9	0.07	40	(0.32 ± 0.02) * $R_g \rho CV$ * (T_r - 179.9)
1050	10	179.9	0.12	50	(0.29 ± 0.02) * $R_g \rho CV$ * (T_r - 179.9)
1060	10	179.9	0.20	60	(0.26 ± 0.02) * $R_g \rho CV$ * (T_r - 179.9)
1070	10	179.9	0.31	70	(0.23 ± 0.01) * $R_g \rho CV$ * (T_r - 179.9)

3. DERIVING THE PROPOSED EQUATIONS

We will describe hereunder how the proposed calculation equations have been derived. The key abbreviations used correspond to those in Figure 2.

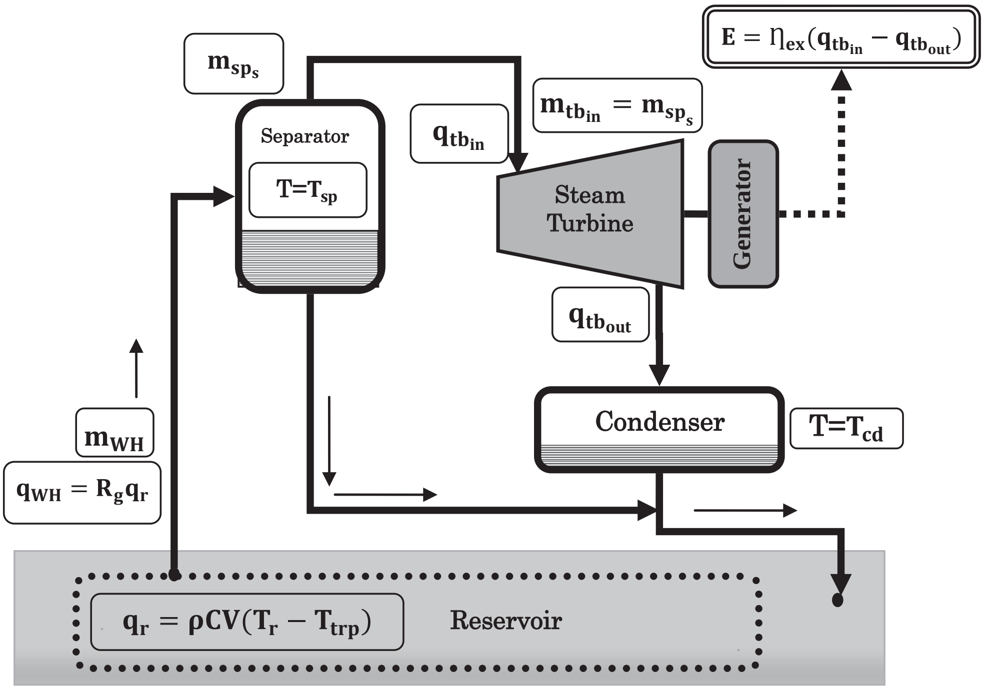


Figure 2 Simplified Single Flash Power Plant Schematic.

3.1 Thermal Energy Potentially Stored in Geothermal Reservoir

The thermal energy potentially stored in a geothermal reservoir is given as follows.

$$q_r = \rho CV(T_r - T_{trp}) \quad \text{[kJ]} \quad \text{(Eq. 2)}$$

Where T_{trp} is triple point temperature (T_{trp}=0.01℃ for pure water).

Note that we placed T_{trp} (triple point temperature) in the equation Eq. 2 for the position of T_{ref} (reference temperature) of the equation Eq. 1 given by USGS (1978). The equation-2 represents the heat energy potentially stored in the geothermal reservoir, whereas the equation-1 defines the heat energy available in the reference temperature condition out of the heat energy potentially stored in a geothermal reservoir. The process of utilization of the geothermal fluid stored in a reservoir is made through three steps; (i) First, the geothermal fluid having the heat energy potentially stored in the reservoir is recovered at the well head (with recovery factor to be considered. See section 3.2); (ii) Second, the recovered fluid is sent into a energy utilization system before exposed to any of ambient conditions; (iii) Third, the heat energy, after utilized, decreases down to the final state condition. The equation Eq. 1 represents the heat energy made available through these three steps. Here, we consider the heat energy of the geothermal fluid at the first step only, where the fluid is not yet exposed to any of reference conditions such as the ambient temperature; the geothermal fluid retains potentially available heat energy at this step. In accordance to thermodynamics, potentially available heat energy of geothermal fluid of temperature $\boldsymbol{T_r}$ ºC is given by the equation Eq. 2 using the triple point temperature. The triple point temperature is the extreme minimum temperature for the reference temperature in thermodynamic. The potentially available heat energy is sent into the geothermal power plant.

3.2 Thermal Energy in the Reservoir, Recovery Factor

Since not all heat energy is recovered, the recovery factor is defined by USGS (1978) as follows.

$$R_g = q_{WH}/q_r \quad \text{[-]} \quad \text{(Eq. 3)}$$

Where R_g is the recovery factor, and q_{WH} is the heat energy recovered at the well head.

From the equations Eq. 2 and Eq. 3, the heat energy recovered at the well head is expressed by the following equation.

$$q_{WH} = R_g \rho CV(T_r - T_{trp}) \quad \text{[kJ]} \quad \text{(Eq. 4)}$$

This recovered heat energy is sent into separator through a adiabatic treated fluid transport pipe system without losing its energy to the ambient.

3.3 Electric Power Output from Turbine-generator

Electric power output generated by a steam turbine-generator system is expressed by the following equation using "adiabatic heat drop" between the heats at the turbine entrance and at the turbine exit (DiPippo 2008 or Hirata, et al 2008 or other references on thermodynamics).

$$E = \eta_{ex}\, m_{tb_{in}} (h_{tb_{in}} - h_{tb_{out}}) \quad [\text{kJ}] \quad (\text{Eq. 5})$$

or

$$E = \eta_{ex} (q_{tb_{in}} - q_{tb_{out}}) \quad [\text{kJ}] \quad (\text{Eq. 6})$$

Where η_{ex} is the turbine-generator efficiency (exergy efficiency), $m_{tb_{in}}$ is the mass of the steam at turbine entrance, $h_{tb_{in}}$ is the specific enthalpy at the turbine entrance, $h_{tb_{out}}$ is the specific enthalpy at the turbine exit, $q_{tb_{in}}$ is the thermal energy of the turbine entrance, $q_{tb_{out}}$ is the thermal energy of the turbine exit.

Note that the $h_{tb_{out}}$ is the heat energy at turbine exit under the condition when the heat at turbine entrance and heat at condenser (final state) are given, the explanation for this will be given in section 4.2.2; that the η_{ex} defined as the turbine-generator efficiency (exergy efficiency) is different from the 'utilization factor' defined by the USGS (1978). Also note that E defined by Eq. 5 is eventually proved to be the exergy energy (Available work) defined by USGS (1978) in Section 11 of the paper.

3.4 Definition of Available Exergy Function

We herein define the following equation. We name it "Available Exergy Function"

$$\zeta = (q_{tb_{in}} - q_{tb_{out}})/q_{WH} \quad [\text{-}] \quad (\text{Eq. 7})$$

Where ζ is the Available Exergy Function.

This is the ratio of the heat energy that contributes to electric power generation (i.e. exergy) at the turbine-generator against the whole thermal energy recovered at the well head.

3.5 Deriving the Rational Calculation Equation

We reform the equation Eq. 7 to the following equation.

$$(q_{tb_{in}} - q_{tb_{out}}) = \zeta\, q_{WH} \quad [\text{kJ}] \quad (\text{Eq. 8})$$

Combination of the equation Eq. 6 and Eq. 8 gives the following equation.

$$E = \eta_{ex}\, \zeta\, q_{WH} \quad [\text{kJ}] \quad (\text{Eq. 9})$$

Further, q_{WH} in the equation Eq. 9 is replaced with the equation Eq. 4, resulting in the following equation.

$$E = \eta_{ex}\, \zeta\, \rho C V (T_r - T_{trp}) \quad [\text{kJ}] \quad (\text{Eq. 10})$$

The equation Eq. 10 expresses the electric energy generated at a turbine-generator; the electric energy converted from the thermal energy sent into the turbine-generator of the efficiency η_{ex} (exergy efficiency).

4 CALCULATION OF THE AVAILABLE EXERGY FUNCTION

Although the equation Eq. 10 gives the electric energy to be converted from the thermal energy recovered at the well head, the equation is not ready for a practical calculation in field. This has to be expressed as an equation that shall be practically and user-friendlily used.

4.1 Assumptions

In order to convert the equation Eq. 10 to a calculable equation, we assume the following three conditions.

a. Geothermal fluid recovered at well head is assumed to have the enthalpy that corresponds to the enthalpy of the single phase liquid stored in the reservoir (as stated in 2.1),
b. Single flash condensing geothermal power plant is assumed for resource evaluation (as stated in 2.1),,
c. Dry steam sent into the turbine and wet steam exhausted from the turbine is assumed.

4.2 Deriving the Calculable Equation of "Available Exergy Function ζ"

The Available Exergy Function consists of thermal energies (i) at the well head, (ii) at the turbine entrance and (iii) at the turbine exit. Calculation processes of these three thermal energies are explained hereunder step by step.

4.2.1 Geothermal energy recovered at the wellhead (q_{WH})

The geothermal energy at the well head is expressed by the following equation[1].

$$q_{WH_L} = m_{WH_L}\, h_{WH_L} \quad [\text{kJ}] \quad (\text{Eq. 11})$$

[1] Note that the equation $m_{WH} = q_{WH}/(h_{WH} - h_{ref})$ given by USGS(1978) is valid only when $h_{ref} = 0$.

Where q_{WH_L} is the geothermal energy recovered at the wellhead, m_{WH_L} is the mass of the liquid recovered at the wellhead, h_{WH_L} is the specific enthalpy of the fluid recovered at the wellhead.

4.2.2 Thermal energy at turbine entrance ($q_{tb_{in}}$)

The geothermal fluid recovered at the well head is sent into the separator, separated into steam fraction and liquid fraction; and the steam fraction (dry steam) only is sent into the turbine. The thermal energy of the dry steam sent into the turbine is first given by the equation Eq. 12 and Eq. 13; the Equations Eq. 12 and Eq. 13 are re-written using water/steam separation ratio (Eq. 14), as the equation Eq. 15 below.

$$q_{tb_{in}} = m_{sp_s} h_{sp_s} \quad \text{[kJ]} \quad \text{(Eq. 12)}$$

$$m_{sp_s} = \alpha_{sp_s} m_{WH_L} \quad \text{[kg]} \quad \text{(Eq. 13)}$$

$$\alpha_{sp_s} = (h_{WH_L} - h_{sp_L})/(h_{sp_s} - h_{sp_L}) \quad \text{[-]} \quad \text{(Eq. 14)}$$

$$q_{tb_{in}} = \alpha_{sp_s} m_{WH_L} h_{sp_s} \quad \text{[kJ]} \quad \text{(Eq. 15)}$$

Where $q_{tb_{in}}$ is the thermal energy sent into the turbine, m_{sp_s} is the mass of the steam fraction separated at the separator and sent into the turbine, h_{sp_s} is the specific enthalpy of the steam fraction separated at the separator and sent in to the turbine, α_{sp_s} is the ratio of the steam mass fraction separated at the separator, h_{sp_L} is the specific enthalpy of the liquid fraction separated at the separator.

4.2.3 Thermal energy at turbine exit ($q_{tb_{out}}$)

The dry steam sent into the turbine is losing its thermal energy being converted into electric energy. At the same time the dry steam is becoming to be wet steam. The thermal energy of the wet steam exhausted at the turbine exit is given in the following equation. Note the mass of the steam fraction at the turbine entrance is preserved at the turbine exit.

$$q_{tb_{out}} = m_{sp_s} h_{tb_{out_{SL}}} \quad \text{[kJ]} \quad \text{(Eq. 16)}$$

Where $q_{tb_{out}}$ is the thermal energy at the turbine exit, $h_{tb_{out_{SL}}}$ is the specific enthalpy of the wet steam fraction at the turbine exit.

Dryness of the steam exhausted at the turbine exit is given by the following equation (DiPippo 2008 and/or Hirata et. al 2008).

$$\chi = (s_{sp_s} - s_{cd_L})/(s_{cd_s} - s_{cd_L}) \quad \text{[-]} \quad \text{(Eq. 17)}$$

Where χ is the quality of steam (dryness of steam), s_{sp_s} is the entropy of the steam at the separator, s_{cd_L} is the entropy of the liquid at the condenser and s_{cd_s} is the entropy of the steam at the condenser. Using the equation E. 17, the specific enthalpy of the wet steam fraction exhausted at the turbine exit is given by the following equation.

$$h_{tb_{out_{SL}}} = h_{cd_L} + (h_{cd_s} - h_{cd_L})\chi \quad \text{[kJ/kg]} \quad \text{(Eq. 18)}$$

Where h_{cd_L} is the specific enthalpy of the liquid at the condenser and h_{cd_s} is the specific enthalpy of the steam at the condenser.

Combination of the equations Eq. 16, Eq. 17 and Eq. 18 gives the following equation.

$$q_{tb_{out}} = \alpha_{sp_s} m_{WH_L} h_{tb_{out_{SL}}} \quad \text{[kJ]} \quad \text{(Eq. 19)}$$

4.2.4 The Available Exergy Function (ζ)

Replacing the terms in the equation Eq. 7 (Available Exergy Function) with the equations Eq. 11, Eq. 15 and Eq. 19 gives the following equation.

$$\zeta = \alpha_{sp_s}(h_{sp_s} - h_{tb_{out_{SL}}})/h_{WH_L} \quad \text{[-]} \quad \text{(Eq. 20)}$$

An approximation equation of the Available Exergy Function will be derived by the equation Eq. 20 through specifying the combination of a separator temperature and a condenser temperature.

5 APPROXIMATION EQUATION (AN EXAMPLE) OF AVAILABLE EXERGY FUNCTION

5.1 Step One Approximation to Cubic Polynomial

In order to convert "Available Exergy Function" into a calculable equation, a set of a separator temperature and a condenser temperature has to be selected first. There are a number of combinations of the temperatures; among those one sample approximation equation is derived assuming a typical temperature combination.

a. Separator temperature : 151.8℃ (0.5 MPa)
b. Condenser temperature : 40.0℃ (0.007 MPa)

The correlation between the geothermal fluid temperature and the Available Exergy Function is presented in Figure 3 for this example. Figure 3 shows that the thermal energy contributing to electricity power generation in the turbine ranges from 8% to 16 % for the geothermal fluid temperature ranging from 200 ℃ to 300 ℃.

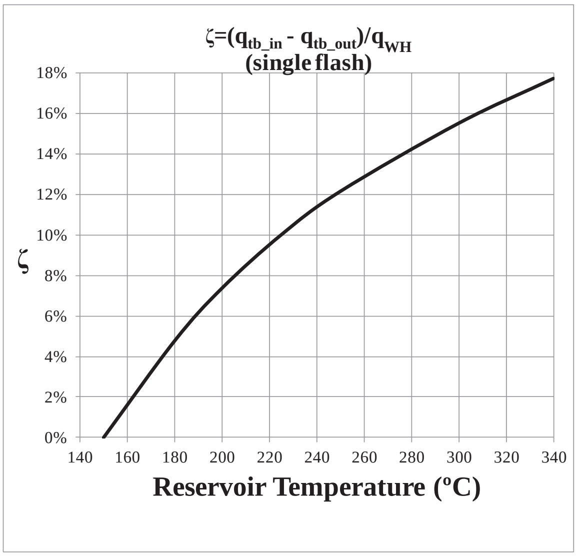


Figure 3 Available Exergy Ratio vs. Fluid Temperature
(for T_{sp}=151.8 °C, T_{cd}=40.0 °C)

The approximation equation of the correlation is given by the following cubic polynomial.

$$\zeta = 0.0000000127\, T_r^3 - 0.0000124900\, T_r^2 + 0.0046543806 T_r - 0.4591082158 \qquad \text{(Eq. 21)}$$

Note that the Available Exergy Function shall be zero ($\zeta = 0$) when the fluid temperature equals to the separator temperature according to the definition of the equation (see Eq. 7). For this example of the separator temperature T_{sp}=151.8 ℃ , ζ shall theoretically be zero ($\zeta = 0$). (However, this is not necessarily attained by the approximation although we specified ten digits after the decimal point for the coefficients.)

5.2 Step Two Appropriation to a Practical Equation for the Available Exergy Function

The equation Eq.21 as an approximation equation of the Available Exergy Function, is still somewhat too large to be used as a user-friendly calculation equation. Thus, a simpler and more user-friendly approximation equation is hereunder derived.

Figure 4 shows a lenear correlation between $\zeta(T_r - T_{trp})$ in the equation Eq. 10 on the vertical axis and $(T_r - T_{sp})$ on the horizontal axis. Since when $T_r = T_{sp}$, $\zeta = 0$, the correlation between $\zeta(T_r - T_{trp})$ and $(T_r - T_{sp})$ is expressed by the following equation.

$$\zeta(T_r - T_{trp}) = A(T_r - T_{sp}) \qquad [\,-\,] \qquad \text{(Eq. 22)}$$

Where A is a constant.

For this example of T_{sp}= 151.8 ℃ and T_{cd} =40 ℃ the equation Eq. 22 shall be as follows (Figure 4).

$$\zeta(T_r - T_{trp}) = 0.3155(T_r - 151.8) \qquad [\,-\,] \qquad \text{(Eq. 23)}$$

(For T_{sp}= 151.8 ℃ and T_{cd}=40 ℃ only)

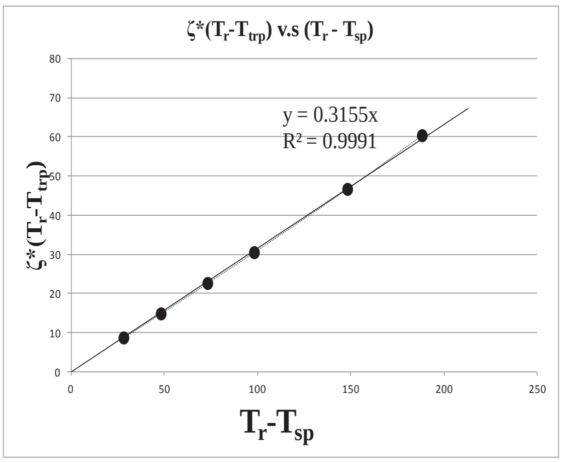


Figure 4 Linear Approximation $\zeta(T_r - T_{trp})$ and $(T_r - T_{sp})$
(for T_{sp}=151.8 °C, T_{cd}=40.0 °C)

6 TURBINE-GENERATOR EFFICIENCY (η_{ex})

The equation Eq. 5 defines the electric energy converted from the thermal energy, using the adiabatic heat-drop concept at a turbine. The equation includes the turbine-generator efficiency (exergy efficiency). The equation Eq. 5 is reformed to the following equation.

$$\eta_{ex} = E/\{m_{tb_{in}}(h_{tb_{in}} - h_{tb_{out}})\} \qquad [\text{-}] \qquad (\text{Eq. 24})$$

We analyzed the correlation between turbine-generator efficiencies (η_{ex}), and temperature drops ($T_{tb_{in}} - T_{cd}$) of turbine entrance and condenser. We used 189 data of geothermal power plants all over the world (listed in ENAA 2013 in Japanese) resulting in the following correlation.

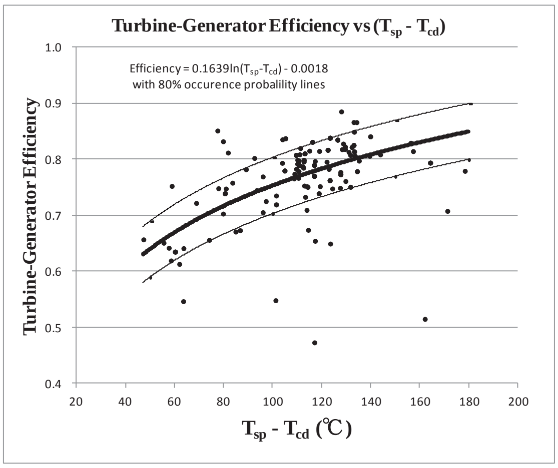


Figure 5 Turbine-Generator Efficiency from 189 data

$$\eta_{ex} = 0.164\ \ln(T_{tb_{in}} - T_{cd}) - 0.002 \pm 0.05 \qquad [\text{-}] \qquad (\text{Eq. 25})$$

Where $T_{tb_{in}}$ is the temperature of the turbine entrance and T_{cd} is the temperature of the condenser.

The actual efficiency of a turbine-generator system depends on many factors that include the efficiency of basic power plant design, resource temperature, concentrations of dissolved gases in the reservoir fluid, the condition of plant maintenance and so on. For this reason, we included an range of ± 0.05 in the approximation equation Eq. 25, which encompasses 153 data among the 189 data (approximately 80% occurrence probability).

For this example of T_{sp}= 151.8 ℃ and T_{cd}=40 ℃, the equation Eq. 25 is as follows.

$$\eta_{ex} = 0.77 \pm 0.05 \qquad [\text{-}] \qquad (\text{Eq. 26})$$

(For the case of T_{sp}= 151.8 ℃ and T_{cd}=40 ℃ only)

7. A RATIONAL, PRACTICAL AND USER-FRIENDLY EQUATION FOR VOLUMETRIC METHOD

7.1 Approximation For the Example of T_{sp}= 151.8 ℃ and T_{cd}=40 ℃

Replacing $\zeta(T_r - T_{trp})$ and η_{ex} in the equation Eq. 10 with the equations Eq. 23 and Eq. 26 gives the following equation.

$$E = (0.24 \pm 0.02) R_g \rho C V (T_r - 151.8) \qquad [\text{kJ}] \qquad (\text{Eq. 27})$$

(For the case of T_{sp}= 151.8 ℃ and T_{cd}=40 ℃ only)

The equation Eq. 27 above gives the electric energy converted in the geothermal power plant with separator of T_{sp}= 151.8 ℃ and condenser of T_{cd}=40 ℃. The other factors, i.e. recovery factor (R_g), Volumetric specific heat of the reservoir (ρC), reservoir volume (V) and average reservoir temperature (T_r) have to be given by the practitioners in charge.

7.2 Approximation Equations for Various Sets of Separator Temperatures and Condenser Temperatures

We have derived approximation equations for various sets of separator temperatures and condenser temperatures, so that practitioners may select one or some of those that may suite to their site conditions. The equations are presented in Table-2.
.

8. A COMPARISON WITH THE USGS METHOD

A comparison is made between the proposed method and the USGS method.

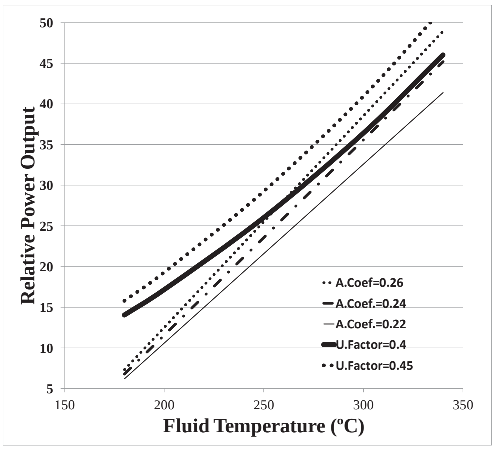
In theory, T_{ref} should be T_{trp} in USGS method when fluid is sent into a geothermal power plant directly. But, here T_{ref} = 15 ℃ is assumed because the utilization factors (0.4 and 0.45) might have been given with the assumption that the T_{ref} is the average ambient temperature of the USGS[2]. The conditions for the comparison is summarized in Table 3.

Table 3 Calculation Conditions for Comparison between USGS method and the Proposed method

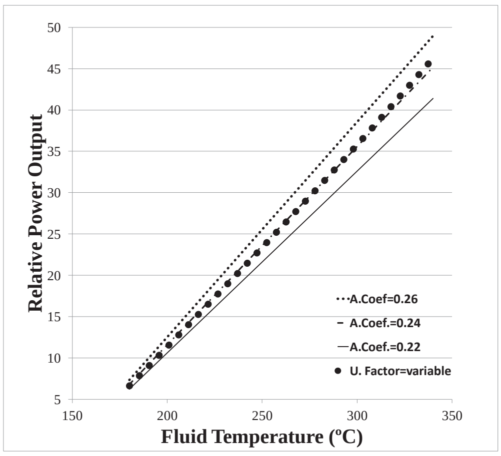
	USGS method	Proposed method (for T_{sp} = 151.8 ℃ and T_{cd} = 40 ℃)
Reference Temperature	Ambient temperature (15 ℃)	Triple point temperature for potential heat stored in reservoir (0.01℃)
Separator temperature	Not given	151.8 ℃
Condenser temperature	40 ℃	40 ℃
Factor in equation	Utilization factor (η_u) 0.40, 0.45	Approximation value of Exergy efficiency (η_{ex}) x Available exergy function (ζ) 0.22 (minimum), 0.24 (central value), 0.26 (maximum)
Reservoir related factors	($R_g \rho CV$) = 1 is assumed for this comparison	

Figure 6 (Left) shows that the USGS method gives slightly larger values than those of the proposed method; the USGS method with the utilization factor of 0.4 is in good agreement with the proposed method when fluid temperature is over 250 ℃ approximately.

While the USGS method treated the utilization factor as constant possibly for a practical reason, it shall be variable in theory. The utilization factors as variable is calculated in Section 11.1. We calculated the relative power output using “utilization factors as variable”. The relative power output of the USGS method with variable utilization factor is shown in Figure 6 (Right). It demonstrates that the result of the USGS method is on the line of the proposed method with the approximation coefficient of 0.24.



Proposed Method (for T_{sp}=151.8 ℃, T_{cd}=40 °℃) and USGS method (fixed Utilization factor of 0.40 and 0.45, T_{ref}=15 ℃ and T_{cd}=40 ℃)



Proposed Method and USGS method with variable utilization factor (for both T_{sp} =151.8 ℃, T_{cd}=40 ℃; only for USGS T_{ref}=15 ℃)

Notes: A. Coef.: Approximation Coefficient of the proposed method, U. Factor: Utilization Factor of the USGS method

Figure 6 A Comparison of the Proposed Method with USGS Method

It has become evident that both of the USGS method and the proposed method are on the same theoretical basis (see the section 11.2). The major difference is that the USGS method defines the Utilization factor as a constant, whereas the proposed method deals all factors as dynamic variable factors. Thus, the proposed method is more ‘accurate’ than the USGS method although the method is expressed by approximation equations. Moreover, the proposed method is much simpler and therefore much more user-friendly, particularly when practiced with Monte Carlo Simulation.

9. NOTES AND DISCUSSIONS

It has been pointed out that the USGS method may have given larger resource estimations than that of reservoir resources actually available on site. Thus, the proposed method may also give excessive resource estimation than actual. In connection with this issue, one may be tempted to calibrate the equations by changing the constants in the equations of the proposed method. However, any of the constants shall not be changed, because the equations in Table-2 do not represent any of thermodynamic implications directly; the separator temperature in the second brackets acts only for zero-point adjustment; the constants in the first brackets are only the resultants of the approximations.

If the calculation results should not agree to the reservoir resource actually available, such reservoir related factors have to be reviewed as recovery factor (R_g), volumetric specific heat of the reservoir (ρC), reservoir volume (V) and average reservoir temperature (T_r). In particular, recovery factor (R_g) and reservoir volume (V) shall have to be examined prudently, because the two factors will give significant impacts on the resource assessment.

10. CONCLUSIONS

The USGS method is widely used for assessing the electrical capacity of a geothermal reservoir. While the under-ground related parameters will have significant impacts on the resource assessment, the electric capacity calculated is a strong function of the above-ground related conditions. The fluid temperature recovered at well head will be the key parameter for the volumetric method calculation when used with Monte Carlo method, because this temperature is the variable (uncertain) underground related parameter which affects the steam-liquid separation process in the separator - an above-ground related parameter. We have derived calculation formulas by introducing "Available Exergy Function", thereby, fluid-temperature-dependant separation process can be included in the equations together with the fluid temperature as a random variable for the Monte Carlo method. It is expected that this calculation method may provide clearer ideas on geothermal resources assessment because the above-ground related parameters are separately defined from the much uncertain underground related parameters. The proposed calculation formulas is proved to be on the same theoretical base of the USGS method (1978). They may thus give larger resource estimation than actually monitored on site if conventional underground related parameters should be selected. However, any of coefficients in the equations of the proposed method must not be changed or adjusted or calibrated. It is the underground related factors that shall be reviewed. In particular, recovery factor and/or reservoir volume have to be reviewed.

11. ADDITIONAL NOTES

11.1 About Utilization Factor of the USGS Method

The utilization factor defined by the USGS (1978) is as follows.

$$\eta_u = E'/W_A \quad [-] \quad \text{(Eq. 28)}$$

Where η_u is the utilization factor; W_A is the thermodynamically available energy produced at a thermo-engine, into which all energy of the recovered fluid at well head (originally under the ambient condition in the United State) is assumed to be sent in. E′ is the electric power generated at the thermo-engine, into which only the steam fraction separated at the separator is assumed to be sent in.

The USGS has given the constants of 0.40 (USGS 1978) or 0.45 (USGS 2008) to the utilization factor as an empirical factor. However, the factor shall be a variable because W_A and E′are given by the following exergy equations, based on the USGS theoretical concept.

$$W_A = m_{WH_L}\{h_{WH_L} - h_{ref_L} - T^K_{ref_L}(s_{WH_L} - s_{ref_L})\} \quad [kJ] \quad \text{(Eq. 29)}$$

$$E' = \eta_{ex} m_{sp_s}\{h_{sp_s} - h_{cd_L} - T^K_{cd_L}(s_{sp_s} - s_{cd_L})\} \quad [kJ] \quad \text{(Eq. 30)}$$

Where $T^K_{ref_L}$, $T^K_{cd_L}$ are temperature of liquid in reference (i.e. ambient) condition and the condenser in K (absolute temperature) respectively; h_{ref_L}, h_{cd_L} are specific enthalpy of liquid in reference (i.e. ambient) condition and in the condenser respectively; s_{WH_L}, s_{ref_L} , s_{cd_L} are specific entropy of the liquid at the well head, in reference (i.e. ambient) condition and in the condenser respectively. The numerical utilization factors calculated by the equation Eq. 28, Eq. 29 and Eq. 30 for the case of T_{sp}=151.8 ℃, T_{cd}=40.0 ℃ and η_{ex}=0.77 are as shown in the table below.

Table 4 Utilization Factors as Variable (for T_{sp}=151.8 ℃, T_{cd}=40.0 ℃, η_{ex}=0.77)

Fluid temperature at Well head (℃)	Utilization factor (variable)
200	0.27
250	0.36
300	0.39
340	0.40

The utilization factor ranges from 0.27 to 0.40 in accordance to the temperatures of the fluid recovered at the well head. If the exergy efficiency η_{ex} could be larger than 0.77, the utilization factor would be larger than those calculated above.

11.2 Theoretical Background of the Proposed method

We presented first the adiabatic heat drop concept for the proposed method in the equation Eq. 5. The specific enthalpy of the turbine exit was expressed by the equations Eq. 16, Eq. 17 and Eq. 18. Among those, combination of the equations Eq. 17 and Eq. 18 gives the following equation.

$$h_{tbout_{SL}} = h_{cd_L} + (h_{cd_s} - h_{cd_L})\{(s_{sp_s} - s_{cd_L})/(s_{cd_s} - s_{cd_L})\}$$

$$= h_{cd_L} + T^K_{cd_L}(s_{cd_s} - s_{cd_L})\{(s_{sp_s} - s_{cd_L})/(s_{cd_s} - s_{cd_L})\}$$

$$= h_{cd_L} + T^K_{cd_L}(s_{sp_s} - s_{cd_L}) \quad [kJ/kg] \quad \text{(Eq. 31)}$$

Further combination of the equation Eq. 5 and Eq. 31 gives:

$$\mathbf{E = \eta_{ex} m_{tb_{in}} \{ h_{tb_{in}} - h_{cd_L} - T^{K}_{cd_L} \left(s_{sp_s} - s_{cd_L} \right) \}} \qquad \textbf{[kJ]} \qquad \textbf{(Eq. 32)}$$

Where m_{sp_s}=$m_{tb_{in}}$, h_{sp_s}=$h_{tb_{in}}$

The equation Eq. 32 has been derived from the concept of the proposed method (adiabatic heat-drop at turbine), whereas the equation Eq. 30 from the USGS method (exergy exergy). The electric energy outputs of the two methods have become eventually to be expressed by the same equation. Thus, the two methods have been proved to be on the same theoretical basis

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