MOEJ/GEC JCM Project Feasibility Study (FS) 2014
Summary of the Final Report

“（20-MW Geothermal Power Generation）”

(Implementing Entity: Mizuho Information and Research Institute, Inc.)

1. Overview of the Proposed JCM Project

<table>
<tr><td rowspan="5">Study partners</td><td>Country</td><td>Participating group name</td><td>Relationship with the trustee</td><td>Details implemented</td></tr>
<tr><td>Japan</td><td>(Manufacturer)</td><td>Subcontractor</td><td>Outline of the development of the project plan, etc.</td></tr>
<tr><td>Japan</td><td>(Geothermal consultant)</td><td>Subcontractor</td><td>Analysis of technical feasibility of wellhead power generation from a geothermal resources perspective, etc.</td></tr>
<tr><td>Japan</td><td>(Financial institution)</td><td>Subcontractor</td><td>Analysis of profitability, etc. of wellhead power generation project</td></tr>
<tr><td>Host country</td><td>(Geothermal power generation company)</td><td>Project implementer</td><td>Local study arrangement, etc.</td></tr>
<tr><td>Project site</td><td colspan="4">A geothermal field around the Great Rift Valley, Federal Democratic Republic of Ethiopia</td></tr>
<tr><td>Category of project</td><td colspan="4"><u>Renewable Energy</u></td></tr>
<tr><td>Description of project</td><td colspan="4">This potential JCM project is a wellhead geothermal power generation project implemented by a foreign-capital special-purpose corporation to be proposed to utilize geothermal power generation facilities manufactured by a Japanese manufacturer. GHG emissions reduction is expected to be achieved by feeding electricity into the grid in the Federal Democratic Republic of Ethiopia (hereinafter “Ethiopia”).</td></tr>
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Expected project implementer	Japan	(A manufacturer)		
	Host country	(A geothermal power generating company)		
Initial investment	4,065,600,000 yen	**Date of groundbreaking**	March, 2015	
Annual maintenance cost	114,204,000 yen	**Construction period**	24 months	
Willingness to invest	Yes	**Date of project commencement**	September, 2016	
Financial plan of project	The project implementer plans to cover the initial investment costs through capital investment and to cover maintenance and management costs by the income from the sale of electricity based on the power purchase agreement (PPA) with the off taker. The PPA negotiation is currently in the final stage.			
GHG emission Reductions	49,012 (tCO2/year)			

2. Study Contents

(1) Project development and implementation

1) Project planning

○ Project implementation structure

The following figure outlines the prospected implementation structure of this project.

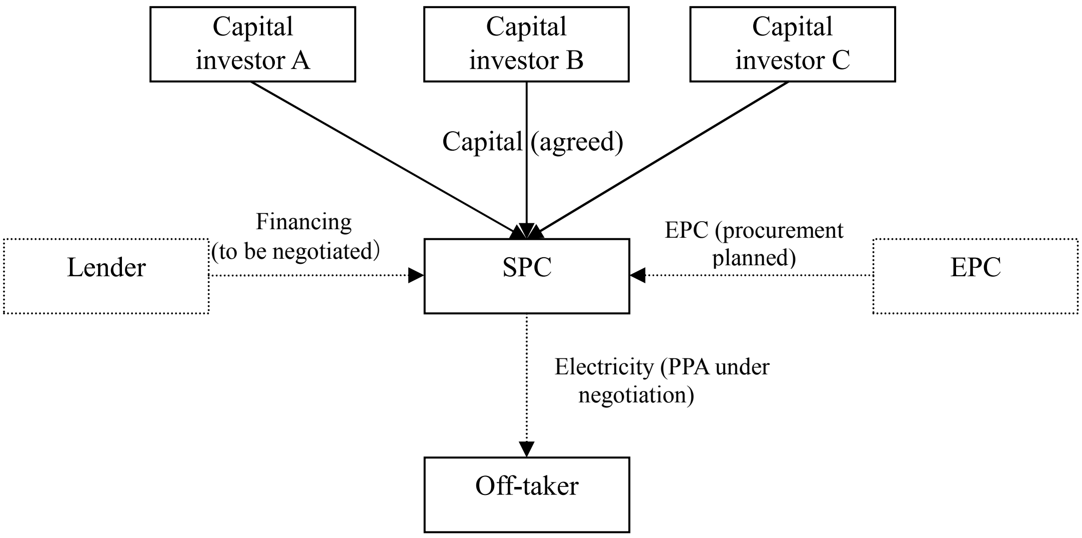

Figure: Prospected implementation structure of this project

(Note) The dotted lines indicate that the relationship has not been finalized but is expected in the future.

The project implementer is a special-purpose corporation (SPC) legally established in Ethiopia. The SPC prefers full turnkey EPC (including laying electric cables to power generation facilities and substation facilities, etc.) with the expectation that it will take 15 months to complete the construction, by September 2016.

○ Management system and track record of the project implementer

We consider that the project implementer has been backed by a strong technical capability because it is an SPC established through capital investment by foreign companies with a proven track record of renewable energy development and geothermal power generation.

○ Evaluation of the project's economic viability

Based upon estimated expenses (construction and O&M costs) and earnings according to various preconditions to create annual financial statements, we evaluated the tariff to meet the target EIRR, which are indicators important to the sponsor respectively.

The following table outlines the tariff to meet the target EIRR, resulting from the project in accordance with the conditions that we assumed.

Table: Results of a preliminary economic evaluation of this project

Contents	Results
Target Equity IRR	12.0 %
Average Tariff	7.35 cent/kWh
- Capacity Charge	5.72 cent/kWh
- O&M Charge	1.63 cent/kWh
- Fuel Charge	0.00 cent/kWh

(Source) This study.

○ Financing plan for the initial investment, maintenance and management, and MRV

The SPC plans to use its own funds for small-scale power generation facilities of 20-MW output capacity.

○ Risk analysis

In terms of the main risks assumed in the implementation of this project, we analyzed risks including the following:

The first is resource risk. In the area where the project will be implemented, previous surface explorations suggest that there is a high-temperature geothermal reservoir; however, an actual geothermal reservoir has not been confirmed to exist because no exploratory excavation has been conducted so far. Hence, the SPC plans to reduce the resource risk by promoting the development in a phased manner by starting with small-scale development and subsequently expanding the development scale while checking the potential of the geothermal reservoir.

The second is construction delay risk. There are people living around the project site. If such residents have to be relocated, delays may be potentially caused in starting the project.

The third is business operation risk. This risk must be borne by the SPC, as the project implementer, in principle. However, if this project is awarded with the Financing Programme for JCM Projects and then the project is terminated due to an unexpected problem, the Japanese company, as the delegate of the recipient of the subsidies, shall take responsibility to return the subsidies to the Japanese government. Therefore, we had discussions with the SPC to secure a certain guarantee from the SPC to mitigate the risk for a Japanese company of potential return of the subsidies.

2) Permits and License for the project development and implementation

According to the SPC, the project implementer, it has completed its registration as a special-purpose corporation in Ethiopia. Other permits and licenses required, including concessions, have already been obtained and the negotiations on the PPA with the off-taker have almost concluded.

Since the above information is based on a report from the project implementer and capital investors, it is desirable to check the relevant documents, such as the actual written agreements, for confirmation.

3) Advantage of Japanese technology

In the delivery record of global geothermal power generation installations, regardless of size, three Japanese companies—Mitsubishi Heavy Industries, Toshiba Corporation and Fuji Electric—occupy the top three spots (for details, see the following figure). Japanese technology is advantageous, offering long durability.

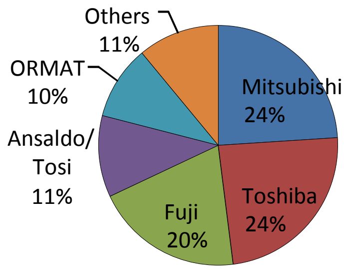

Figure: Market shares of geothermal power plant manufactures

(Source) Ruggero Bertani, Geothermal Power Generation in the World 2005-2010 Update Report, World Geothermal Congress, 2010

4) MRV structure

The SPC is going to perform measurement, reporting and verification (MRV) for greenhouse gas emissions reduction at the project site after the start of operation in case the project is approved as a JCM project. A comment was received from the SPC, saying that the assumed monitoring work (e.g. to check the amount of steam and the concentration of non-condensable gases (NCGs), such as CH4) is not considered to place any particular burden on regular power generation activities.

The following table outlines a draft monitoring method, which was proposed to the project implementer with the following two points taken into consideration. No particular comments were consequently made.

- With regard to the monitoring point, for simplicity, actual measurement is assumed to be taken at the sampling opening of the steam transport piping.
- With regard to monitoring frequency, based on the actual status of, for example, the operation condition at the site, a reduction in monitoring frequency will be within the scope of the agreement if the NCG concentration is stable.

Table: Monitoring method (Draft)

Emission sources	GHG	Frequency	Sampling method	Sampling location
Non-condensable gases	CO_2	Once every 3 months	ASTM E1675-95a	Sampling from the steam transport piping
	CH_4	Once every 3 months	ASTM E1675-95a	Sampling from the steam transport piping
Fossil fuel at the site	CO_2	Once a year	Fuel meter (needs to be studied)	Power generator installation location

(Source) This study.

5) Environmental integrity and sustainable development in host country

According to the SPC, the environmental and social impact assessment (ESIA) for this project has already been approved by the Ministry of Mines of Ethiopia. However, it has emerged that some residents living around the project site need to be relocated, and the ESIA is being performed again only for that part.

On the other hand, hydropower accounts for 98% or more of the power sources of the host country, and power outages frequently occur due to drought almost every year, threatening the sustainable development of the country. Under such circumstances, only thermal and geothermal power generation can be base load power sources, but the country has already suspended the operation of existing thermal power plants, which are considered to be reserve power for emergency use, and the only geothermal power plant (Aluto Langano) is out of operation for technical reasons. This project is therefore expected to significantly contribute to the sustainable development of the country by providing a stable electricity supply.

6) Toward project realization (planned schedule and possible obstacles to be overcome)

○ Study on the project's feasibility

- We will continue to endeavor to obtain the documents pertaining to the permits and licenses for this project and clarify the issues related to the project's feasibility, such as the potential of geothermal resources to be exploited from the project site.
- We will continue seek possibility to apply this project for the Financing Programme for JCM Projects provided by the Ministry of the Environment, Japan.

○ Study on JCM methodology development

- Based on the draft JCM methodology examined in this present study, we will aim to obtain approval from the Japan-Ethiopia Joint Committee.

(2) JCM methodology development

1) Eligibility criteria

○ Challenges

Eligibility criteria under the CDM methodology relevant to this project, ACM0002 provide no technical specification regarding the introduced facilities.

Consequently, the present study checked the technical applicability to wellhead geothermal power generation based on ACM0002 with the following two eligibility criteria as preliminary drafts. In addition, from the perspective of reflecting the technical strength of Japanese manufacturers, a study was conducted to revise the eligibility criteria as necessary.

- ✓ Eligibility criterion (draft) 1: The project activity is installation of a geothermal power plant at Ethiopia.
- ✓ Eligibility criterion (draft) 2: Net electricity generated by the project activity is delivered to Ethiopian national power grid system.

○ Outline of the study

As for eligibility criterion (draft) 1, it was confirmed that ACM0002 version 15.0 requires that the baseline greenhouse gas (GHG) emissions should be deemed as the emissions from existing power plants for capacity addition, improvement, restoration, or replacement. Since this project pertains to new construction, it was decided to delete "capacity addition, improvement, restoration, or replacement" from eligibility criterion (draft) 1 in the interests of simplicity.

As for the advantages of Japanese technology, it is difficult to reflect specific technical conditions because a specific technology must be selected in most cases in response to various conditions (such as temperature and pressure) particular to individual wells in the case of geothermal power generation. Nevertheless, essential advantageous points common to Japanese technology are (a) longer life and (b) extensive proven track record. Based on the following five points, we decided to add the following criterion: "The project activity employs a geothermal power generation unit supplied by a company which has a past experience to supply a geothermal power generation unit which steadily operated for at least 15 years." to the criteria.

○ Final draft eligibility criterion

- ✓ Eligibility criterion 1: Geothermal power generation facilities are newly constructed in Ethiopia.
- ✓ Eligibility criteria 2: Electricity is fed into the national grid in Ethiopia.
- ✓ Eligibility criterion 3: The project activity employs a geothermal power generation unit supplied by a company which has a past experience to supply a geothermal power generation unit which steadily operated for at least 15 years..

2) Calculation of GHG emissions (including reference and project emissions)

○ Calculation of project emissions

As project GHG emissions, it was determined to count the following in the same manner as ACM0002:

- ✓ CO_2 emissions from combustion of fossil fuels for electricity generation at grid power plants that are replaced due to the project activity;
- ✓ CO_2 and CH_4 emissions from combustion of fossil fuels for electricity generation from

the baseline technology to meet suppressed demand for electricity that would be replaced due to the project activity

The formulas are as follows:

PEy = PEFF,y + PEGP,y
where
PEy: Project emissions in year y [tCO_2/y]
PEFF,y: Project emissions from fossil fuel consumption in year y [tCO_2/y]
PEGP,y: Project emissions from the operation of geothermal power plants due to the release of NCGs in year y [tCO_2/y]

Since it is not assumed to combust fossil fuels for the time being, the determination of NCGs emissions is the key to calculating the project emissions.
While the project implementer has not started exploratory excavation at the site yet, it indicates the estimated upper values of NCGs concentration as outlined in the following table.

Table: Assumed upper values of NCGs concentration of this project

Parameters	Description of data	Estimated Values	Units
wsteam,CO_2,y	average mass fraction of CO_2 in the produced steam in year y	0.01000000	tCO2/t steam
wsteam,CH_4,y	average mass fraction of CH_4 in the produced steam in year y	0.00000500	tCH4/t steam

(Source) Project implementator

This present study decided to use the values shown in the above table in the interests of consistency with the basic design of the power generation unit. The estimated upper values were obviously used to ensure a conservative estimate.
Based on the expected steam consumption rate of the power generation facilities and with an assumption of an operating rate of 92%, the quantity of steam produced per year will be 2,030,918 tons.
Based on the above, 20,522.43 [tCO2/y] can be obtained as a result of the calculation of the project emissions.

○ Calculation of reference emissions

Reference emissions are the total GHG emissions from grid power plants and GHG emissions from baseline power generation technology to satisfy the minimum service level under "suppressed demand."

Reference emissions can be calculated by multiplying the quantity of net electricity generation fed into the grid in a year and the reference emission factor (EF) as follows:

REy = RGPJ,y * RF,CM,y
where
REy: Reference emissions in year y [tCO2/y]
RGPJ,y: Quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the JCM project activity in year y [MWh/y]
RF,CM,y: Combined margin CO2 emission factor for grid connected power generation in year y calculated the latest emission factor [tCO2/MWh]

The reference emission factor shall be the weighted average of the emission factor of grid power sources and the emission factor of the baseline technology to satisfy the suppressed demand, and the calculation thereof requires the following items:

- Grid emission factor;
- Quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the JCM project activity;
- Minimum service level of electricity consumption per capita;
- Actual electricity consumption per capita;
- Type of baseline power generation technology and its emission factor (Use the IPCC default value.)

The reference emission factor can be calculated using the following formula if the actual electricity consumption per capita is lower than the minimum service level:

$$RF_y = \frac{EF_{BT,y} * (MSL - EC_y) + EF_{grid,y} * EC_y}{MSL}, \text{ if } MSL - EC_y > 0$$

$$RF_y = EF_{grid,y}, \text{ if } MSL - EC_y \leq 0$$

Where

EFBT,y: CO_2 emission factor from power generation by the baseline technology in year y [tCO2/MWh]

EFgrid,y: CO_2 emissions factor from the grid power plants in year y [tCO2/MWh]
ECy: Electricity consumption per capita [kWh/y]
MSL: Minimum service level of electricity consumption per capita [kWh/y]

This is because "suppressed demand" is considered to exist as recent electricity consumption per capita in Ethiopia (ECy) is 51.96 kWh (2011, The World Bank) to 60 kWh/y (2012, EIA) and lower than the threshold value of 120 kWh/y (MSL, Sanchez, T. (2010)) for energy poverty, which is considered to be the minimum service level (for details, see the following figure). The present study sets ECy at 60 kWh/y in order to utilize new data and to ensure a conservative estimate.

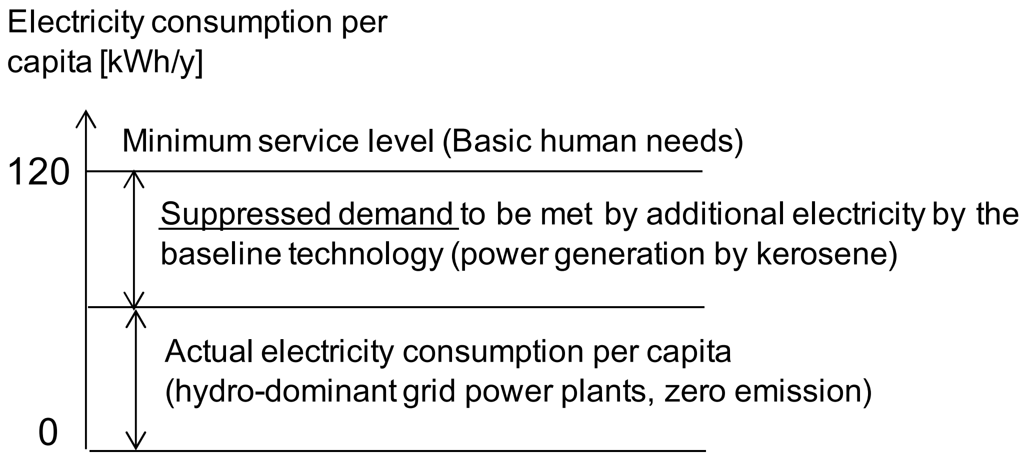

Figure: Suppressed demand for electricity consumption per capita

As the baseline power generation technology, kerosene power generation is considered appropriate because kerosene is now widely used for off-grid power generation in Ethiopia at the present time. Using the IPCC default value, 0.86 [tCO_2/MWh] was obtained as the emission factor of kerosene (for details, see the following table).

Table: Main default values to calculate reference emissions

Parameter	Fuel	Value	Unit
CO_2 emission factor of the baseline technology	Other Kerosene	0.07	tCO2/GJ
CO_2 emission factor of the power generation by the baseline technology	Other Kerosene	0.86	tCO2/MWh
Default efficiency factors for power plants	Oil	0.30	—

(Source) IPCC (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories; UNFCCC (2013) Tool to calculate the emission factor for an electricity system Version 04.0 (Tool07)

With regard to the grid emission factor EFgrid,y, according to the plan of the Ethiopian Electric Power Corporation (EEPCo), the EEPCo stopped the operation of the existing diesel plants and off-grid diesel power generators in 2012 to 2014 to turn them into standby power sources and plans to use only renewable energy starting in 2015. Based on the planned breakdown of 90% hydropower, 6% geothermal power, and 4% wind power, it will be reasonable to set both OM and BM to zero in the interests of conservativeness and simplicity.

When the above values are substituted into the formula, the reference emission factor is as follows:

$$RF_y = \frac{0.86*(120-60)+0*60}{120} = 0.43[tCO2/MWh]$$

Subsequently, with an assumption of a generation capacity of 20-MW and an operation rate of 92%, the electricity generation in a year is as shown below:
RGPJ,y = 20 [MWh] * 24 [h] * 365 [d] * 0.97 [%] = 161,184 [MWh/y]

Accordingly, the reference emissions obtained are as follows:

RGPJ,y * RFy = 161,184 * 0.43 = 69,534.78 [tCO_2/y]

○ Calculation of emission reduction

The emission reductions can be calculated as the difference between reference emissions and project emissions.

According to the calculation, 49,012.35 [tCO_2/y] is obtained as the emission reductions per year.

The reduction in CO_2 that can be achieved is evaluated on the assumption that the electricity obtained from the operation of this geothermal power plant substitutes for the grid power of Ethiopia and the power sources based on baseline technology that generates the additionally required electricity to satisfy the minimum service level.

3) Data and parameters fixed *ex ante*

The previous geothermal power generation JCM/BOCM feasibility studies pointed out the monitoring method of non-condensable gases (NCG), particularly CO_2 and CH_4, as an issue.

The present study took the actual status of geothermal-related projects in Ethiopia into consideration and examined the possibility of using a default value or setting a parameter particular to the project for the following three items from the perspective of reducing the burden of the power producer:

- Candidate 1: Concentration of CH_4 contained in the steam of the geothermal development project
- Candidate 2: Grid emission factor
- Candidate 3: Fossil fuel emission factor
- Candidate 4: Ratio of diesel power generation to off-grid power generation (where used to calculate the reference emissions)
- Others

○ Concentration of CH_4 contained in steam

Following the study of whether a default value could be used for CH_4 concentration in the steam, we decided that monitoring must be conducted because it was pointed out that the value generally varies depending on the sampling location and period.

A simplified and conservative monitoring method is a calculation assuming all NCGs, including CO_2, to be CH_4 with a high GWP without the need to measure CH_4 concentration. However, as a result of using this method to calculate the emission reductions in the present study, the emission reductions turned out to be negative, leading to an excessively conservative result.

Since monitoring non-condensable gases causes no particular problem according to the comment of the project implementer, the present study proposes that CH_4 shall be monitored.

○ Grid emission factor

With regard to the grid emission factor, it will be an idea to assume the OM as zero because hydropower accounts for 98% of the power mix of the existing power plants connected to the grid in Ethiopia and the operation of thermal power plants was stopped in 2012 to 2014.

It is also an idea to assume the BM as zero because the power plants planned to be constructed in the future use only renewable energy with no thermal plants planned to be constructed.

Assuming the grid emission factor as zero is undoubtedly conservative and also helps simplify the calculation.

○ Fuel emission factor

For the fuel emission factor, the default value in the IPCC guidelines can be used.

○ Ratio of diesel power generation to off-grid power generation (where used to calculate the reference emissions)

This candidate item, reference emissions, was eliminated from the scope of the examination because it was decided not to especially use the ratio of diesel power to off-grid power generation.

○ Others

- Minimum service level of electricity consumption per capita (energy poverty) (kWh/y)

One of the internationally accepted standards which can be interpreted as a basic human need reflecting the "minimum service level" under "suppressed demand" in electricity studied in Section 5.2 is 120 kWh/y per capita set by Sanchez, T. (2010) as the threshold value for energy poverty. This value is determined to be necessary for various services, such as electric lighting, drinking water, telecommunications, improved health services, and improved education services, as well as for access to added values for local production.

- Electricity consumption per capita in a year (kWh/y)

The data of electricity consumption per capita in a year are provided by the World Bank and the EIA. Of those, it will be an idea to use the value that evaluates the emission reductions more conservatively, meaning the larger one.

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