| MOEJ/GEC JCM Feasibility Study (FS) 2013<br>Final Report |
|---|

# 「Geothermal Binary Power Generation」

## （implemented by Nippon Koei Co., Ltd.）

| | | |
|---|---|---|
| **Study partners** | | Hen Linn San Co., Ltd. (HLS) |
| **Project site** | | Myanmar/Tachileik |
| **Category of project** | | Renewable Energy |
| **Description of project** | | Myanmar is endowed with numerous geothermal resources, and many of the geothermal potential sites are distributed in the northeast region bordered on the south by Thailand. These huge geothermal resources still remain undeveloped.<br>Tachileik Township and surrounding area of Shan State in northeast region of Myanmar is experiencing rapid development due to the recent opening policy of Myanmar. However, this area has severe power shortage, and frequent blackouts harm economic activities. Since all electricity consumed in this area is imported from Thailand, Myanmar side would like to have its own stable energy sources.<br>Hence, this project aims to develop a geothermal binary power plant, expecting power generation of around 200 kW, to supply electricity to Tachileik Township. This project will pioneer power generation in Myanmar and contribute to poverty reduction of this area. |
| **JCM methodology** | **Eligibility criteria** | Four eligibility criteria of JCM (Joint Crediting Mechanism) methodology are as follows:<br>【Criteria 1】Geothermal binary power plants<br>【Criteria 2】Contracting with analysis agency for periodic monitoring of $CO_2$ and $CH_4$ concentration in steam produced by the geothermal plant., if production wells are applied.<br>【Criteria 3】Conducting annual monitoring of refilled amount of secondary medium, when the secondary medium is GHG listed in IPPC Assessment Report.<br>【Criteria 4】Having at least one year warranty offered by a manufacturer of a product or engineering company, and conducting annual maintenance of the power plant and incidental facilities. |
| | **Default values** | In this methodology, default values are set as follows:<br>a) Grid emission factor : 0.371 [tCO2/MWh]<br>b) Emission factor for diesel generation (mid size) : 0.56 [kg CO2/MWh]<br>c) Emission factor for diesel generation (mid size) : 0.76 [kg CO2/MWh]<br>d) GWP of secondary medium (HFC245fa) : 1,030 [tCO2e/ tHFC-245fa] |
| | **Calculation of reference emissions** | In this methodology, the following three (3) scenarios are proposed for calculating reference emissions:<br>[Scenario 1] The Myanmar grid is extended, and the electricity is provided through the grid to the project area.<br>[Scenario 2] Middle-size diesel generator is introduced, and |

| | | |
|---|---|---|
| | | the electricity is provided as off-grid power source.<br>[Scenario 3] Small-size diesel generator is introduced, and electricity is provided to each house directly. |
| | **Monitoring method** | • Monitoring for reference emissions :<br>Power generation of binary power plant shall be monitored in all scenarios.<br>• Monitoring for project emissions:<br>Monitoring items: (i) $CO_2$&$CH_4$ concentrations in steam, (ii) steam volume and (iii) filling volume of secondary medium. |
| **GHG emission reduction** | | In reference scenario 1, GHG emission reduction (468 [$tCO_2$/y]) is calculated with power generation (1,261 [MWh/y]) and grid emission factor (0.371 [$tCO_2$/MWh]). |
| **Environmental impacts** | | This Project can contribute to GHG reduction by offset with diesel power generation. Since produced steam and hot water for geothermal binary power generation is principally returned through injection wells, geothermal binary power generation is a closed system, and air/water pollution is negligible.<br>In general, produced noise and heat by power generation and changes in scenic view are considerable negative impacts of geothermal power generation. However, since the project site is located about 2 km from the nearest village, noise for the residents will be negligible. The heat is available for sauna or mill drying facilities. Although some changes of scenic view are unavoidable, negative impact such as cutting trees etc. can be minimized by the layout of the plant design. |
| **Project plan** | | The Project aims to develop a 200 kW binary power plant in the rural area approximately 8.2 km northwest of Tachileik Township. The construction and operation of the power plant is expected to start in 2015 and 2017, respectively. Construction cost is estimated at around 535 million JPY. This project will pioneer geothermal power generation in Myanmar. |
| **Promotion of Japanese technologies** | | Geothermal binary technology has already been developed, and there will be only small differences in generation performance from Japanese geothermal power plants. Thus, Japanese manufacturers can provide an appropriate follow-up system including maintenance services and technology transfer of operation and maintenance to the owner. Japanese manufacturers are much superior to other manufacturers in post-warranty O&M performance. |
| **Sustainable development in host country** | | Myanmar government is promoting the development of renewable energy to meet rapidly growing power demand. East Shan state including Tachileik township has huge potential of geothermal resources. The success of this project will accelerate domestic power sustainability, develop geothermal power in the surrounding area of Tachileik, and will contribute to GHG reduction by replacing diesel power generation. |

# JCM Feasibility Study (FS) 2013
# "Geothermal Binary Power Generation"
(Host country: Republic of the Union of Myanmar)

**Study Entity: Nippon Koei Co., Ltd.**

## 1. Study Implementation Scheme

This study was carried out by the following scheme:

| Entities | Country | Study |
|---|---|---|
| Nippon Koei Co., Ltd. | Japan | Feasibility Study Consultant |
| Associates: | | |
| Hein Linn San Co., Ltd. | Myanmar | Owner of the Project |
| Fuji Electric Co., Ltd. | Japan | Conceptual design, estimates |
| Geothermal Engineering Co., Ltd. | Japan | Geothermal reservoir analysis |
| Electrum Services Co., Ltd. | Myanmar | Electric exploration |
| SGS Thailand | Thailand | Geochemical analysis |

## 2. Overview of Proposed JCM Project

### (1) Description of Project Contents:

Myanmar is endowed with numerous geothermal resources, and many of the geothermal potential sites are distributed in the northeast region bordered on the south by Thailand. These huge geothermal resources still remain undeveloped.

Tachileik Township and surrounding area of Shan State in northeast region of Myanmar is experiencing rapid development due to the recent opening policy of Myanmar. However, this area has severe power shortage, and a frequent blackouts harm economic activities. Since all electricity consumed in this area is imported from Thailand, Myanmar side would like to have its own stable energy sources.

Hence, this project aims to develop a geothermal binary power plant, expecting power generation of around 200 kW, to supply electricity to Tachileik Township. This project will pioneer power generation in Myanmar, and contribute to poverty reduction of this area.

The success of this project will accelerate domestic power sustainability, develop geothermal power in the surrounding area of Tachileik, and will contribute to GHG reduction by replacing diesel power generation. An overview of the Project is shown in Table 1.

**Table 1 Overview of the Project**

| | |
|---|---|
| Location | East Shan State, Tachileik township |
| Type, generation capacity | Geothermal binary power generation, around 200 kW |
| Counterpart/Owner | Hein Lien San Co., Ltd. (HLS) |
| Project Description | The Project aims to develop a 200 kW geothermal binary plant in the rural area approximately 8.2 km northeast of the Tachileik Township, The operation is expected to start from 2017. Total construction cost is about 535 million Yen. This project will pioneer geothermal power generation in Myanmar. |

Source: Study Team

**(2) Situation of Host Country:**

In Myanmar, there are 30 power plants (19 hydropower, 1 coal and 10 gas/steam) and electrical power generation capacity is 3,584 MW as of June 2012. About 70% of the power is generated by hydropower plants. Energy demand in Myanmar has risen steadily over the past 10 years. To meet rapidly increasing power needs, Myanmar government intends to formulate the best mix of advantages of power energy sources in addition to strengthening hydroelectric infrastructure. Renewable energy is expected to be rapidly developed, and become 15%-20% of total electricity generation by 2020.

## 3. Study Contents

### (1) JCM METHODOLOGY DEVELOPMENT

#### a. Eligibility criteria

| Issues | Studies implemented |
|---|---|
| - Current situation of geothermal binary power plant market and foreign/domestic manufacturers<br>- Differences of technology, function and maintenance between Japanese and foreign manufacturers<br>- Handling of NCG and secondary medium in binary power plants | - Interview with manufacturers and engineering companies<br>- Data collection of Japan/foreign technologies on geothermal binary power plants<br>- Pre-confirmation of geothermal binary power plants<br>- Confirmation of NCG and secondary medium in binary power plants |

Source: Study Team

In this methodology, the following eligibility criteria are proposed.

| Eligibility Criteria | Reasons |
|---|---|
| Criterion 1:<br>The project activity is installation of geothermal binary power plant. | There are several types of geothermal power plants. So plant shall be defined properly. |
| Criterion 2:<br>Contract is made for regular monitoring of $CO_2$ and $CH_4$ concentrations in the produced steam with the chemical analysis company. Criterion 2 is applied only in case that the steam obtained from a newly drilled well is used to heat the secondary fluid. | There are several types of chemical substances involved in geothermal steam. Normally the steam contains NCG and shall be monitored whether GHGs are in NCG or not. Therefore, it is necessary to make a contract for regular monitoring of $CO_2$ and $CH_4$ concentrations in the produced steam with the chemical analysis company.<br>In addition, Criterion 2 is applied since the steam is obtained from a newly drilled well and is used to heat the secondary fluid. |
| Criterion 3:<br>In case the secondary fluid is listed in the Assessment Report published by IPCC, a monitoring plan to check the refilled amount of secondary fluid to the geothermal binary power plant is prepared. The minimum frequency of the monitoring is once per year. | Normally there is no leakage of secondary medium in geothermal binary power plant. However, it is difficult to state whether Japanese product leak or not.<br>In order to consider this item conservatively, it is necessary to check the refilled amount of secondary fluid at the geothermal binary power plant. |
| Criterion 4:<br>The geothermal binary power plant is guaranteed for more than one year by the manufacturer and/or the engineering company, and yearly maintenance plan for the geothermal binary power unit as well as ancillary facility is prepared. | To maintain good performance by power plant, it is necessary to conduct periodic maintenance.<br>According to the engineering company, once in year is normal frequency for the maintenance contract. |

Source: Study Team

**b. Data and parameters fixed *ex ante***

| Issues | Studies implemented |
|---|---|
| - Consideration of data and parameters to be collected<br>- Consideration of $CO_2$ and $CH_4$ concentration<br>- Consideration of Myanmar national grid emissions | - Identification of required data & parameters<br>- Confirmation of CO2 and CH4 concentration in case of CDM registration<br>- Calculation of Myanmar national grid emissions |

Source: Study Team

b-1. Default values

Emission factor for Myanmar national Grid

In this methodology, 0.371 [tCO2/MWh] is used as emission factor of Myanmar national grid.

According to item ③ Calculation of emission reduction, JCM methodology proposes the concept of suppressed demand to be applied. Hence, the reference scenario is set as the base scenario including future anthropogenic emissions which are projected to rise above current levels.

Normally value of grid emission factor is used for that of combined margin emissions. CM emission is calculated with OM and BM emissions under the following options:

a. Weighted CM
b. Simplified CM

To apply simplified CM, it is required to confirm that (i) project is located in Least Developed Country (LDC), (ii) number of total CDM registrations is less than 10 or an island state, and (iii) data is not sufficient for BM calculation.

For this Project, Myanmar belongs to LDC regarding calculation of grid emission factor. Also, there is insufficient data for BM calculation, but there is enough data for OM calculation. Therefore, in this case, item ② above is the proper choice. Accordingly, calculation of Myanmar grid emission factor is referred to as "Simplified CM".

CM emission factor can be calculated using the following table.

$EF_{CM,y} = W_{OM} \times EF_{OM,y} + W_{BM} \times EF_{BM,y}$

$= 1 \times EF_{OM,y} + 0 \times EF_{BM,y}$

$= EF_{OM,y}$

**OM emissions**

| Year | 2010 | 2011 | 2012 | Average (2010-2012) |
|---|---|---|---|---|
| $CO_2$ emissions (tCO2) | 2,426,383 | 3,351,111 | 3,644,442 | |
| $EG_y$ (MWh) | 6,873,000 | 8,839,862 | 9,537,685 | |
| $EF_{OM,y}$ (tCO2/MWh) | 0.353 | 0.379 | 0.382 | **0.371** |

Source: GEC CDM Study in FY2013

**b-2. Preliminary Default Value**

Secondary medium (GWP, 100 years) is set as preliminary default value. In this project, HFC245fa

(1030 $tCO_2e$/tHFC-245fa) is applied.

**c. Calculation of GHG emissions (including reference and project emissions)**

| Issues | Studies implemented |
|---|---|
| - Consideration of suppressed demand in Myanmar<br>- Consideration of current situation and future electrification plan in whole Myanmar and project area.<br>- Consideration of BAU and reference emissions, taking account of Myanmar electrification plan<br>- Examine handling of NCG and secondary medium | - Confirmation of suppressed demand in Myanmar<br>- Study of current situation and future electrification plan in whole Myanmar and project area.<br>- Establishment of BAU and reference emissions<br>- Establishment of handling with NCG and secondary medium |

Source: Study Team

In this project, geothermal binary power plant will connect to Thai grid and support emission reduction of Thai grid. Under JCM scheme, such situation will not be considered.

**c-1. Establishment of Reference Scenario**

In this methodology, the concept of suppressed demand is applied. The reference scenario is set as the base scenario including future anthropogenic emissions which are projected to rise above current levels. Based on the above, reference scenarios of this methodology are as follows:

[Scenario 1] The Myanmar grid is extended, and the electricity is provided through the grid to the project area.

[Scenario 2] Middle-size diesel generator is introduced, and the electricity is provided as off-grid power source.

[Scenario 3] Small-size diesel generator is introduced, and the electricity is provided to each house directly.

**c-2. Calculation of Reference Emissions**

Reference emissions are calculated with the following formula.

$$\underline{RE = EF_{grid} * EG_{PJ}}$$

*RE* :*Reference emissions* [$tCO_2/y$]

$EF_{grid}$ :*Grid factor in Myanmar* [$tCO_2/MWh$]

$EG_{PJ}$ :*Electricity exported from the project* [MWh]

**c-3. Calculation of Project Emissions**

Project emissions are calculated with the following formula.

$$\underline{PE = PE_{NCG} + PE_{BM} = (W_{s,CO2} + W_{s,CH4} * GWP_{CH4}) * M_s + M_{BM} * GWP_{BM}}$$

*PE* :*Project emissions* [$tCO_2e/y$]

$PE_{NCG}$ :*Project emissions due to the release of NCG* [$tCO_2e/y$]

$PE_{BM}$ :*Project emissions due to the release of secondary fluid* [$tCO_2e/y$]

$W_{s,CO2}$ *:Average mass fraction of* $CO_2$ *in the produced steam [*$tCO_2$*/t steam]*

$W_{s,CH4}$ *:Average mass fraction of* $CH_4$ *in the produced steam [*$tCH_4$*/t steam]*

$GWP_{CH4}$ *:GWP of* $CH_4$ *[*$tCO_2e/tCH_4$*]*

$M_s$ *:Quantity of produced steam [t steam/y]*

$M_{BM}$ *:Quantity of secondary fluid filled into the plant [t/y]*

$GWP_{BM}$ *:GWP of secondary fluid [*$tCO_2e/tBM$*]*

** In case that the hot spring naturally discharging without drilling of new well is used, or hot water is used :*$PE_{NCG} = 0$

### c-4. Estimation of Emission Reduction

Emission reduction by geothermal binary power plant in 2017 is calculated below.

| Reference emissions [tCO2/y] | Project emissions [tCO2e/y] | Emission reduction [tCO2e/y] |
|---|---|---|
| 1,059 | 0 | 1,059 |

Source: Study Team

Note : This project uses hot water, therefore $PE_{NCG} = 0$. Also, it is difficult to identify $PE_{BM}$ currently, so $PE_{BM} = 0$.

## (2) DEVELOPMENT OF JCM PROJECT DESIGN DOCUMENT (PDD)

a. Monitoring Plan

| Parameter | Monitoring Method |
|---|---|
| Power generation (MWh/y) | Measurement: Monitoring sending out put automatically and constantly.<br>Recording: Saving data (daily data and monthly data) in PC |
| Replenishment volume of secondary working fluid (t/y) | Measurement: Collection and check of annual maintenance data of replenishment volume of secondary working fluid from maintenance companies.<br>Recording: Saving data in PC |

Note: Monitoring of $W_{s,CO2}$ and $W_{s,CH4}$ is not necessary for binary power plant.

Source: Study Team

Mentoring plan of the Project is shown in Figure 1.

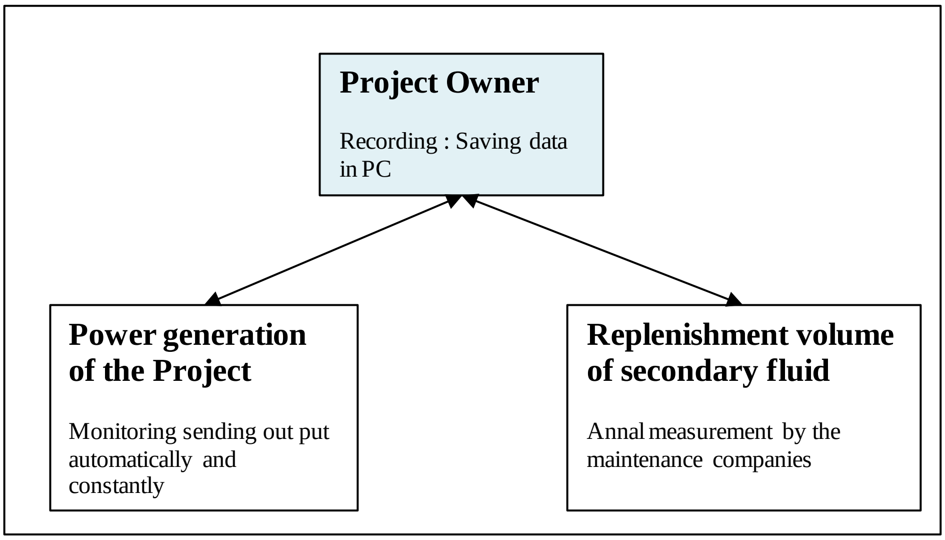



**Figure 1 Monitoring Plan**

Source: Study Team

## (3) PROJECT DEVELOPMENT AND IMPLEMENTATION

### a. Project organization and plan

Planned project organization is shown in Figure 2. Special purpose company (SPC) will be established under HLS to operate and manage the facility.

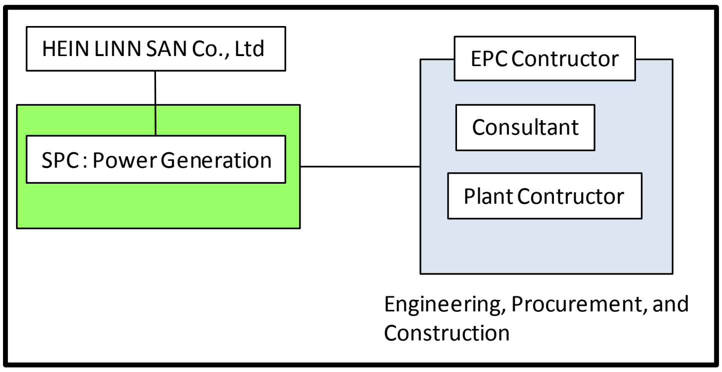



**Figure 2 Project Organization**

Source: Study Team

Condition of the geothermal brine is estimated based on the results geochemical survey, electric exploratory survey, and interview with staff of Fang Geothermal Power Station. Design concept of geothermal binary plant is shown in Table 2. Each parameter in the Table will be reviewed based on the results of test wells and field tests to be carried out in the next stage.

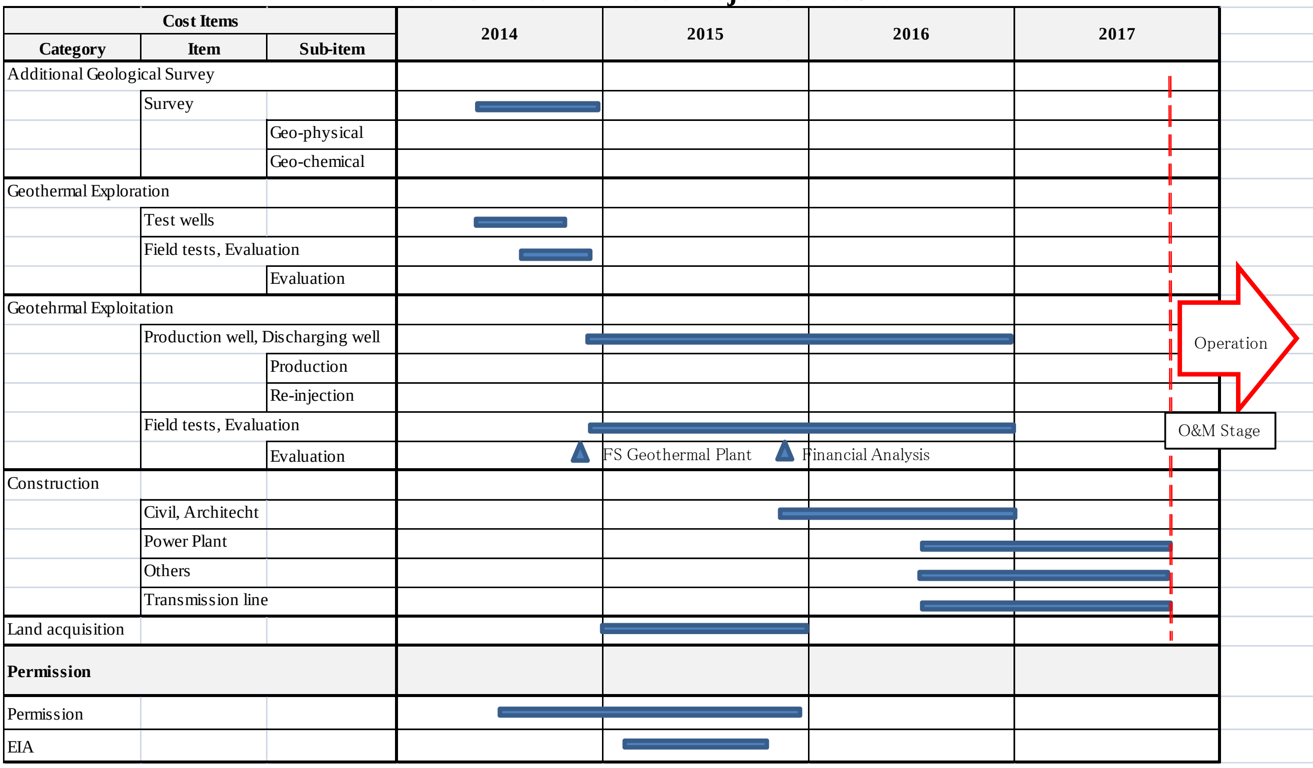
**Table 2 Design Concept of Geothermal Binary Plant**

| Binary Power Plant | | | Loc.2 | Remarks |
|---|---|---|---|---|
| Condition of geothermal brine | Pressure | [barg] | 1.5 | |
| | Temperature | [deg.C] | 130 | |
| | Volume | [L/min] | 2000 | 3 production wells (source: Fang) |
| | pH | [-] | 9.13 | |
| | SiO2 | [mg/L] | 607 | |
| Output | Temperature | [deg.C] | 95 | |
| Cooling water | cooling type | | water cooled type | |
| | Temperature | [deg.C | 25 | |
| | Volume | [t/h] | 300 | |
| | Supplimentary feed water | [t/h] | 11 | |
| Power generation | Generating end output | [kW] | 295 | 5 unit x 59 kw |
| | Plant consumption | [kW] | 115 | |
| | Sending end output | [kW] | 180 | |
| Plant Construction Cost | | [Mil￥] | 300 | |
| Cost for Civil work, transmission line, etc. | | [Mil￥] | 235 | |

Source: Study Team

Although this project might be conducted by the owner's finance alone, the benefits of financing of JICA Overseas Investment/Loan and JBIC Overseas Investment/Loan will also be studied in the next stage. Recommended project schedule is shown in Table 3.

**Table 3 Recommended Project Schedule**




Source: Study Team

## b. MRV structure

Measurement (M) and Reporting (R) of GHG emission will be principally done by the owner of the Project. Nippon Koei staff will support the activities for one year from the beginning of the operation stage. Verification (V) will be carried out by the third party at the Project site according to the Joint Crediting Mechanism Guideline for Validation and Verification.

MRV structure is shown in Figure 3.

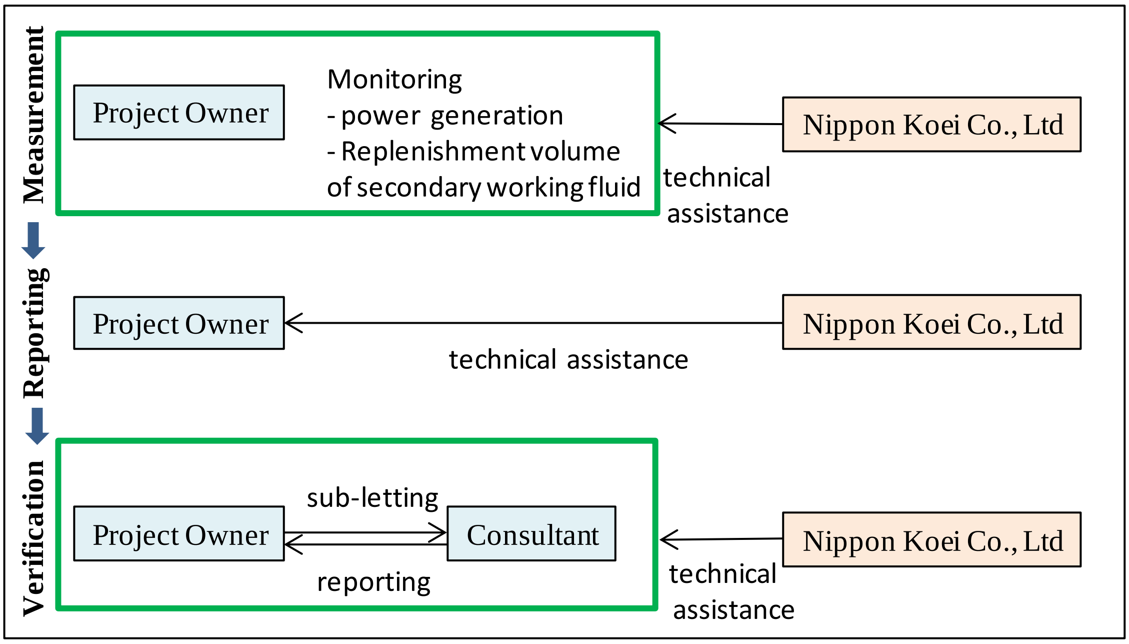



**Figure 3 MRV Structure**

Source: Study Team

**c. Permission and authorization for the project implementation**

Ministry of Electric Power (MOEP) is the administrative agency of the power sector in Myanmar, and responsible for electric power generation, transmission and distribution. Although regulations for development of geothermal power still remain unclear because there are no experiences of development of geothermal plants, Myanmar Electric Power Enterprise (MEPE), an organization of MOEP appears to be the supervisory authority of small-scale geothermal power generation.

According to Union of Myanmar Foreign Investment Law (2012), the regulations issued from Myanmar Investment Committee, IPP projects are allowed for private investors, although the detailed regulations has not been enforced yet and EIA procedures still remain unclear.

**d. Japan's contribution**

Geothermal binary technology has been already developed, and there will be only small differences in generation performance from Japanese geothermal power plants. Thus, Japanese manufacturers can provide an appropriate follow-up system including maintenance services and technology transfer of operation and maintenance to the owner. Japanese manufacturers are much superior to other manufacturers in post- warranty O&M performance.

Tachileik Township and surrounding area of Shan State in northeast region of Myanmar is experiencing rapid development due to the recent opening policy of Myanmar. However, this area has severe power shortage, and frequent blackouts harm economic activities. Furthermore, many rural areas still remain unelectrified. This project will contribute not only to stable power supply to Tachileik Township, but also to electrification of the rural area and poverty reduction.

**e. Environmental integrity**

This project will contribute to GHG reduction by replacing diesel power generation. Since produced steam of binary cycle system is principally fed back into the ground, binary power plants produce nearly zero emission.

In general, produced noise (60dBA~75dBA in general), heat by power generation, and changes of scenic view are considerable negative impacts of geothermal power generation. However, since the project site is located about 2 km from the nearest village, noise for the residents will be negligible. The heat is available for sauna or mill drying facilities. Although some changes of scenic view is unavoidable, negative impact such as cutting trees etc., can be minimized by the layout of the plant design.

**f. Sustainable development in host country**

Myanmar government is promoting the development of renewable energy to meet rapidly growing power demand. In Myanmar, at total of 93 hot springs have so far been recorded and identified, and geothermal resources are likely widespread in igneous rock regions and metamorphosed areas where ground water heated at depths has ascended through faults, and fractures (source: Myanmar Engineering Society). In Shan State, 17 hot springs were identified (source: Geology of Burma, 1934). Although East Shan State including Tachileik Township has huge potential of geothermal resources, no comprehensive survey of geothermal potential of this area has been carried out. This project will pioneer the development of geothermal power plants in Myanmar. The success of this project will accelerate to develop geothermal energy in the surrounding area of Tachileik, and contribute to GHG reduction.

**g. Toward project realisation (planned schedule and possible obstacles to be overcome)**

Initial investment is high for geothermal development in general and drilling risks of geothermal wells are inevitable, especially in the initial stage. Thus for development of the Project, the following processes are recommended.

**Recommendation-1: Feasibility Study including Test wells**

Feasibility study including test wells of 200 m in depth are recommended before production well & injection well drillings. In the feasibility study, potential geothermal reservoir of the site will be assessed to estimate the generation capacity. Based on the results of well drillings and EIA/IEE, the project will be re-appraised. The work flow of geothermal exploration & geothermal exploitation phase is shown in Figure 4.

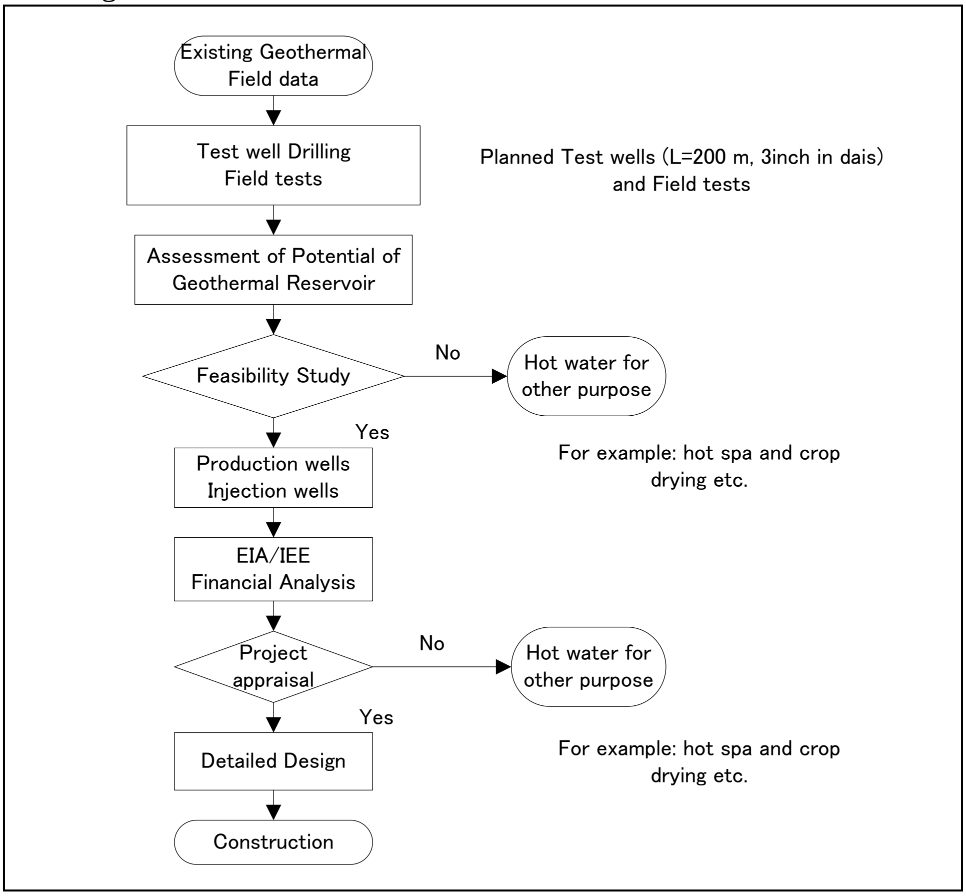



**Figure 4 Work Flow of Exploration Phase**

Source: Prepared by study team referring data of Japan Oil, Gas and Metals National Corporation

**Recommendation-2: Staged Development & Possibility to Scale-Up**

This project aims to start the operation of a 200 kW geothermal binary plant by 2017. To avoid initial overinvestment in geothermal power plant, staged scaling up of the generation capacity is recommended. Monitoring of production wells & injection wells in operation stage and additional geological survey of the geothermal reservoir are recommended. Based on the results of the survey, potential of the geothermal reservoir will be re-assessed and the generation capacity of the power plant will be optimized. If feasible, scaling up gradually to 2 MW by 2024 will be planned.