Republic of Indonesia

FY 2015 Ex-post Evaluation of Japanese ODA Loan Project

"Lahendong Geothermal Power Plant Project"

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## 0. Summary

The project aimed to ease the power supply demand tightness and improve the stability in the Minahasa power system, North Sulawesi, by newly constructing a geothermal power generation plant as Unit 3 of the existing Lahendong geothermal power plant.

The objective of the project which addresses the tight power supply-demand condition by supplying power through renewable energy is well consistent with the development policy and development needs of Indonesia, as well as with the Japan's ODA policy. Therefore the relevance of the project is high. Both the project cost and project period were within the planned. Therefore efficiency of the project is high. Regarding operation and effective indicators at the time of the appraisal, those showing the availability of the power plant have reached the targets, however, those showing actual energy production have not reached the targets for about five years from the start of power generation due to the quality problem of steam (although steam supply is out of the scope of project). This fact reduced effectiveness to some extent. It was confirmed, however, that after changing the supply source of the steam, planned effect of the project has been mostly observed. Negative impact on natural and social environment by the project has not been observed and it can be said that the project has contributed to a certain extent in shifting to an energy efficient power supply and utilizing domestic energy sources. Thus, effectiveness and impact of the project are fair. In regard to the operation and maintenance, although problem of the steam quality has not been solved completely at the time of the ex-post evaluation, there is a good prospect of solving the problem. No major problems have been observed in the institutional, technical and financial aspects of the operation and maintenance system. Therefore sustainability of the project effects is high.

In light of the above, this project is evaluated to be highly satisfactory.

## 1. Project Description


Project Location

Lahendong Geothermal Power Plant

### 1.1 Background

The Minahasa power system in the North Sulawesi Province, where this project is located, is situated in the region with particularly tight power supply-demand among the outer islands except Java. Actual supply capacity of 2002 was limited to 118 MW while peak demand was 113 MW as a result of the ageing of the existing facilities and operational stoppages for maintenance. The power supply-demand condition was very tight. In addition, future demand growth rate was expected to grow at an annual average of 4.4 % to 6.9 %, and peak demand was forecasted to exceed supply capacity by 2004. Consequently, the expansion of the capacity and the improvement of the stability of power supply in the Minahasa power system were necessary for the social and economic development.

### 1.2 Project Outline

The objective of this project is to expand power supply capacity of Lahendong geothermal power plant in the Minahasa power system in North Sulawesi by newly constructing a geothermal power generating facility (20 MW-class) in the existing Lahendong geothermal power plant, thereby contributing to the improvement of the stability of the power supply in the Minahasa power system.

| | |
|---|---|
| Loan Approved Amount/<br>Disbursed Amount | 5,866 million yen / 4,517 million yen |
| Exchange of Notes Date/<br>Loan Agreement Signing Date | March, 2004 / March, 2004 |
| Terms and Conditions | Interest Rate: 0.75 %<br>Repayment Period: 40 years<br>(Grace Period): (10 years) |

| | |
|---|---|
| | Conditions for Tied (Special Terms for Procurement: Economic Partnership (STEP)) |
| Borrower/ Executing Agency(ies) | Republic of Indonesia / State Electricity Company (PT. PLN) |
| Final Disbursement Date | September, 2012 |
| Main Contractor (Over 1 billion yen) | Sumitomo Corporation (Japan) |
| Main Consultant (Over 100 million yen) | West Japan Engineering Consultants, Inc. (Japan) / PT. Connusa Energindo (Indonesia) / PT. Tata Guna Patria (Indonesia) |
| Feasibility Studies, etc. | F/S (2001) |
| Related Projects | ＜Other Donors, International Organizations＞<br>France: Lahendong Unit 1 Geothermal Power Plant (20 MW) (1999)<br>ADB: Lahendong Unit 2 Geothermal Power Plant (20 MW) (2002)<br>ADB: Lahendong Unit 4 Geothermal Power Plant (20 MW) (2009)<br>WB: Lahendong Unit 5 and Unit 6 Geothermal Power Plant (20 MW each) (2014)<br>WB: Technical assistance for PT. PLN (Institutional and financial reform) |

## 2. Outline of the Evaluation Study

### 2.1 External Evaluator

Keiko Watanabe, Mitsubishi UFJ Research & Consulting Co., Ltd.

### 2.2 Duration of Evaluation Study

Duration of ex-post evaluation study was conducted as follows;

Duration of the Study: October 2015 – December 2016

Duration of the Field Survey: March 6 – March 16, 2016, June 26 – June 29, 2016

## 3. Results of the Evaluation (Overall Rating: A[1])

### 3.1 Relevance (Rating: ③[2])

#### 3.1.1 Relevance to the Development Plan of Indonesia

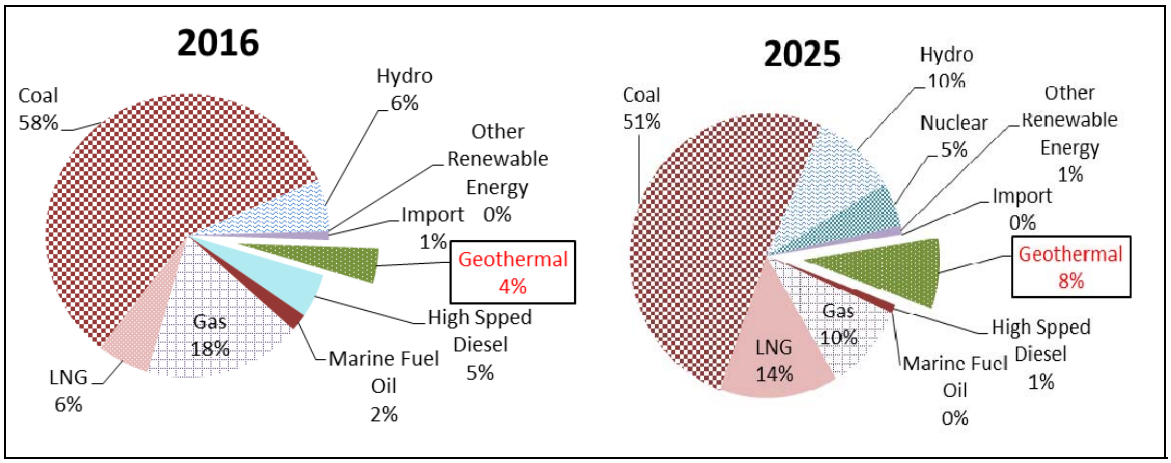
The Indonesian government has been actively promoting geothermal development and has established a business environment in order for PERTAMINA, state-owned oil

[1] A: Highly satisfactory, B: Satisfactory, C: Partially satisfactory, D: Unsatisfactory

[2] ③: High, ②: Fair, ①: Low

and gas company, to conduct geothermal development and power generation business in Indonesia by issuing Presidential Decree No. 22 of 1981 and No. 45 of 1991, which made it possible to sell steam and electricity to the state-owned power company (PT. PLN, hereinafter referred to as “PLN”). In addition, the Presidential Decree No. 76 of 2000 advocates the active utilization of geothermal power generation as a way of diversification of energy sources and a means of energy saving. The project was regarded as the expansion of the existing Lahendong geothermal power plant in the Energy Development Plan of PLN (hereinafter referred to as “RJPP”) (2003-2007) at the time of the appraisal. Accordingly, the project is consistent with the development policy of Indonesia.

At the time of the ex-post evaluation, it is also in line with the government policy which encourages the maximum use of the new and renewable energy including geothermal energy. For example, the Indonesian government sets a national goal to increase additional power generation of 35 GW within five years up to 2019. Among total increase in the power generation, 7.5 GW, 10 % to 15 % of total additional power generation is expected to be generated by the new and renewable energy including geothermal. In accordance with the national goal, the current National Medium Term Plan (hereinafter referred to as “RJPMN”) (2015-2019), and the National Energy Plan (hereinafter referred to as “RUPTL”) (2016-2025), set the electric power development as a priority policy that replaces the energy sources from diesel and other sources which have economically poor efficiency. Moreover, they promote the enhancement of power generation capacity through the new and renewable energy and diversification/combination of energy sources. In RUPTL, the actual amount of power generation by the new and renewable energy is expected to be raised at 23 % of the total amount of power generation by 2025, and 31 % by 2050. Regarding the component of energy sources, as shown in the Figure 1, the geothermal energy is planning to be increased from 4 % in 2016 to 8 % in 2025.




Source: RUPTL (2016-2025)

Figure 1: Transition Plan of Energy Source Composition

### 3.1.2 Relevance to the Development Needs of Indonesia

At the time of the appraisal of the project, development of the stable power supply system was pressing issue to cope with the tight power supply-demand in North Sulawesi. Table 1 shows the transition of power supply-demand in the Minahasa power system in North Sulawesi. In the Minahasa power system, the actual supply capacity had not caught up with the growth in demand and it had been estimated that demand would have exceeded supply by 2004. Since 1997 when the currency crises in Asia happened, no new investment in power plants by PLN had been implemented until 2002. Besides, the private investment to the power plants has not been progressed. Under this situation, aging and insufficient maintenance of the power plants were assumed to be the reasons for that. As a result, the construction of new power generation facilities was urgent need for socio-economic development of the regions.

The Minahasa power system was connected with adjacent Gorontalo power system and became as Sulbagut power system since 2011 due to the effect from the PLN structural reforms. As seen in Table 2, the power demand in North Sulawesi has been growing every year about 7-8 % even after the system became Sulbagut. Accordingly, the needs to increase power generation capacity were still high at the time of the ex-post evaluation. Although the supply-demand has still been tight, it is all the more important to supply from every single power plant. Thus, the role that the project plays is getting bigger.

In light of the above, the project, which was to complement the power supply of North Sulawesi where the supply-demand of power was very tight, is in line with the development needs both at the time of appraisal and ex-post evaluation.

Table 1：Demand and Supply of Electricity of North Sulawesi

(Estimation at the time of appraisal in 2004)

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|
| ①Peak Load (MW) | 113 | 118 | 125 | 131 | 140 | 149 | 159 | 169 | 180 |
| Demand Growth Rate (%) | － | 4.4% | 5.9% | 4.8% | 6.9% | 6.4% | 6.7% | 6.3% | 4.8% |
| ②Actual Available Capacity (MW) | 118 | 118 | 118 | 118 | 138 | 168 | 243 | 243 | 243 |
| Reserve Margin (%) = (②－①)/ ① | 4.4% | 0.0% | -5.6% | -9.9% | -1.4% | 12.8% | 52.8% | 43.8% | 35.0% |

Source: Information provided by JICA

Table 2: Demand and Supply of Electricity of North Sulawesi

(Actual at the time of ex-post evaluation and Estimation)

| | 2009 | 2010 | 2011 | 2012* | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|
| ①Peak Load (MW) | 165 | 173 | 193 | 271 | 292 | 310 | 332 | 379 | 462 |
| Demand Growth Rate (%) | 6.3% | 4.8% | 11.7% | 40.6% | 7.7% | 6.3% | 7.1% | 7.7% | 8.2% |
| ②Actual Available Capacity (MW) | 142 | 142 | 252 | 275 | 262 | 299 | 300 | 398 | 572 |
| Reserve Margin (%) = (②－①) / ① | -13.9 % | -17.9 % | 30.6% | 1.5% | -10.3 % | -3.5% | -9.6% | 5.0% | 23.8% |

* Note: The rapid growth in demand growth rate in 2012 is due to the expansion of the grid system. The Minahasa grid was connected with the Gorontalo grid and became Sulbagut grid system.
Source: Results of questionnaire survey to the executing agency

### 3.1.3 Relevance to Japan's ODA Policy

In the Japanese assistance policy to Indonesia at the time of the appraisal in 2004, "sustainable growth led by the private sector" was one of three pillars of assistance and "economic infrastructure development for improvement of investment environment" was raised as one of the major points. In the "Medium-Term Strategy for Overseas Economic Cooperation Operation" of JICA in April 2002, the "economic infrastructure development" which was vital for recovery towards sustainable growth through economic reforms was put as one of priority areas. Country Assistance Strategy for Indonesia (November 2002, JICA) stipulates the policy to respond to urgent needs such as elimination of economic bottlenecks including power shortage.

During the time when PLN had stopped their projects after the currency crisis, this project supported power supply which contributed to the basis of economy and stable life of people. Therefore, the project was in line with the Japan's ODA policy.

In light of the above, this project has been highly relevant to the country's development plan and development needs, as well as Japan's ODA policy. Therefore its relevance is high.

### 3.2 Efficiency (Rating: ③)

#### 3.2.1 Project Outputs

The project was to construct a power plant with capacity of 20 MW (geothermal steam turbine) as Unit 3 of Lahendong Geothermal Power Plant and transmission system to connect existing power plants. Comparison of planned and actual project outputs is summarized in Table 3. It should be noted that the focus of the project was the power generation part including development of geothermal power plant which is to be implemented by PLN. The development and supply of steam which are necessary for generating power were done by PERTAMINA Geothermal Energy (PGE), subsidiary company of PERTAMINA. The Heads of Agreement on steam sales for this project had been signed between PLN and PGE.

Regarding the power plant construction, intended outputs were produced as planned. There was a change in the output of transmission system. After discovering the fault was running under the planned construction site of the project, the site had to be relocated. Since the relocated site was close to the transmission lines of Unit 1 and Unit 2, the plan of installing transmission system was no longer necessary. Instead, the simple construction measures were applied to connect the transmission lines from the project (Lahendong Unit 3) with those of Unit 1 and Unit 2 by constructing transmission towers. Those transmission towers were constructed with the finance from PLN without delay. The investigation of the fault was implemented just before the construction of the main power plant, and it was not possible to find out the fault at the time of the appraisal. Therefore, the change of the construction site and the design changes of transmission system associated with it are judged as appropriate.

The contents of the consulting services were carried out as planned. Actual amount of input of the services was 204.88 man month (M/M) compared to the planned 227.75 M/M, which was 22.87 M/M smaller than the planned. This shortage was mainly resulted from the above change in the transmission system.

Table 3: Comparison of Planned and Actual Project Output

| Planned | | Actual |
|---|---|---|
| Civil Works, Equipment Procurement | | |
| 1. Power Plant Construction | ・Geothermal steam turbine (20 MW x 1 unit) | As planned |
| | ・Condensing system | As planned |
| | ・Electric Facilities | As planned |
| | ・Instrumentation and Control Equipment | As planned |
| | （Necessary construction for future expansion）<br>・Layout for additional power plant (Unit 4)<br>・Joint power house with Unit 4<br>・Electric line and pipe line connected to Unit 4<br>・Joint warehouse and workshop with Unit 4 | As planned |
| 2. Transmission System etc. | ・Transmission line (150 kV, 3 km) from the project (Lahendong Unit 3) to existing Lahendong Unit 1 switchyard<br>・Switchgear and Equipment of Lahendong Unit 1<br>・Auxiliary Equipment | Due to change of the construction site of the project (Lahendong Unit 3) the plan was changed. Instead of installing transmission system, the transmission lines were connected to Lahendong Unit 1 and Unit 2 by constructing transmission towers. |
| Consulting Services | | |
| Review of PERTAMINA's resource study, Assistance of PLN in bidding, construction supervision, transfer of knowledge and training of PLN's personnel, Environmental monitoring, Reporting）etc. | | As planned |

Source: Results of questionnaire survey to the executing agency

Geothermal Turbine (above) and Generator (below)

Cooling Tower

Two Transmission Towers constructed by PLN

### 3.2.2 Project Inputs

#### 3.2.2.1 Project Cost

Total project cost was planned to be 7,007 million yen (out of which 5,866 million yen was to be covered by Japanese ODA loan). In reality, the total project cost was 5,600 million yen (out of which 4,517 million yen was covered by Japanese ODA loan) which was lower than planned (80 % of the planned amount).

The reason why the total project cost was lower than planned was mainly due to the cost reduction from the transmission system compared to the plan and the effect of depreciation of Indonesia Rupiah against yen during the project period[3].

#### 3.2.2.2 Project Period

The overall project period was planned as 73 months, from April 2004[4] (conclusion of Loan Agreement) to April 2010 (completion of liability period). In reality, the overall project period was 71 months, from April 2004 (conclusion of Loan Agreement) to February 2010 (completion of liability period), which was shorter the plan (97 % of the planned period).

### 3.2.3 Results of Calculations of Internal Rates of Return (Reference Only)

Financial Internal Rate of Return (FIRR)

Table 4 shows the comparison of FIRR between as of appraisal and ex-post evaluation.

Table 4: FIRR as of Appraisal and Ex-post Evaluation

| | Appraisal | Ex-post Evaluation |
|---|---|---|
| FIRR | 5.4 % | 1.8 % |
| Benefit | Revenue from electricity sales | |
| Cost | Construction cost, Operation and maintenance cost, Fuel cost (steam price) | |
| Project Life | 30 years after the completion of the project | |

Source: (Appraisal) Information from JICA, (Ex-post evaluation) Calculated by the evaluators using data from the executing agency

FIRR at the time of the ex-post evaluation was lower than planned. It is assumed that main reason for this was due to the significant increase in the steam price (fuel cost) than assumed price at the time of the appraisal (more than three times in Indonesia

[3] At the time of the appraisal, it was estimated as JPY 1 = 71.4 Indonesian Rupiah (IDR) and USD 1 = JPY 118. However, actual rate was a strong yen trend as JPY1 = 90.9 IDR and US$ 1 = ¥ 89.9 (average rate by IMF during 2004 and 2012)

[4] Since the loan agreement date was 31 March, 2004, the project period was calculated from April 2004.

Rupiah).

In light of the above, both the project cost and project period were within the plan. Therefore, efficiency of the project is high. It should be noted that there was no impact on the project cost and project period by the application of procurement condition of Special Terms for Economic Partnership (STEP). According to the interview to the executing agency on STEP, there was no problem in the process of procurement of equipment and consultant, and they were almost satisfied with their quality.

### 3.3 Effectiveness (Rating:②)

#### 3.3.1 Quantitative Effects (Operation and Effect Indicators)

Table 5 shows the comparison of operation and effect indicators between planned at the appraisal and actual figures after the completion of the project.

As seen in the actual figure of the target year of 2011, after 1 year of completion of the project, maximum output and availability factor among operation indicators have reached the target value. Therefore, it can be said that the project has the operational capability as planned. On the other hand, plant load factor and net electric energy production have not reached the targets. In this project, the electric power is to be generated by receiving steam supply which has been developed by PGE. However, the problems occurred from the start of the operation. Those included high acidity of the hot water discharging from the major steam production well (No. 23) for this project[5], and higher contamination of non-condensable gas (NCG) in the steam compared to the level indicated in the steam sales contract[6]. For these problems, Unit 3 had to be operated with reduced output from the start of the operation. As seen in Table 6, the steam problems became serious in 2012. The Unit 3 stopped operation almost a year as PGE has stopped the supply of steam from the main production well for changing a well head of main production well in order to prevent adherence of silica scale. Therefore, the values of indicators of plant load factor and net electric energy production which take into account the actual amount of electricity generated were extremely low as 14.5 % and 13.9 GWh respectively in 2012.

[5] When the hot water from the geothermal steam had high acidity, silica (siliceous contained in the water) scales adhere to hot water supply pipes, which creates problems of decrease or stop in steam supply.

[6] In the steam sales contract between PLN and PGE, NCG level was stipulated as 1% or less for the steam quality. According to this information, the project procured the gas extractor which has capacity of NCG up to 1%. However, actual NCG level was 2.5% which was higher than expected. When the level of NCG is higher than the capacity of gas extractor, it cannot extract gas sufficiently and the pressure becomes high in the condenser. As a result, it lowers the efficiency of turbine. Therefore, the power plant has to operate with reduced output. Although the project conducted the resource study of the steam supplied by PGE as a component of the consulting services, the focus of the study was on whether the ample amount of steam could be secured or not in the future, not on the quality of steam.

Table 5: Operation and Effect Indicators of the Project (Unit 3)

| | Indicator* (Unit) | Baseline 2004 Baseline Year | Target 2011 1 Year After Completion | Actual | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2009 Start Generating Year | 2010 Completion Year | 2011 1 Year After Completion | 2012 2 Years After Completion | 2013 3 Years After Completion | 2014 4 Years After Completion | 2015 5 Years After Completion |
| Operation Indicators | Maximum Output (MW) | - | 20 MW | 15.5 | 20 | 20 | 20 | 18.1 | 18.7 | 20 |
| | Availability Factor (%) | - | More than 91.8 % | 99.6 | 99.5 | 99.3 | 99.9 | 99.5 | 99.0 | 99.2 |
| | Plant Load Factor (%) | - | Over 85 % | 60.6 | 73.7 | 52.7 | 14.5 | 75.4 | 77.4 | 91.7 |
| Effect Indicator | Net Electric Energy Production (GWh/year) | - | 140 GWh/ year | 46.8 | 82.5 | 59.6 | 13.9 | 82.3 | 88.8 | 153.7 |

*Note: Availability Factor (%) = (Annual operation hour / Annual hours (365*24)) x 100. Annual operation hours include stand by hours.

Plant Load Factor (%) = Annual energy production / (Rated output x Annual hours (365*24)) x 100

Net Electric Energy Production (GWh/Year) = Annual energy production – Power consumption in the power plant

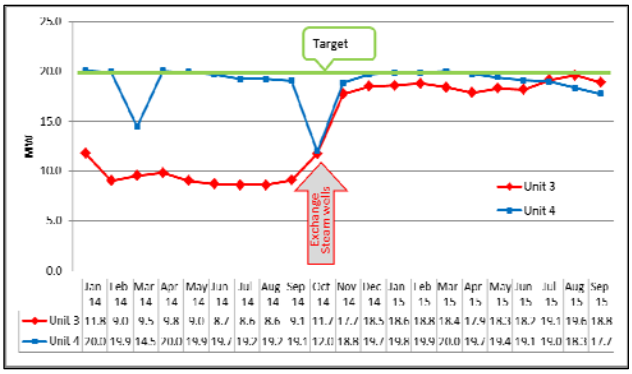
Source: Information from JICA and results of questionnaire survey to the executing agency

Table 6: Outage Time of Lahendong Unit 3

| **Year** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** |
|---|---|---|---|---|---|---|---|
| Outage Time (hour) | 1,895.82 | 1,848.35 | 3,782.12 | 8,020.95 | 1,372.08 | 87.18 | 31.40 |
| (In Days) | 78.9 | 77.0 | 157.6 | 334.2 | 57.2 | 3.6 | 1.3 |
| Of which outage time due to machine problem (hour) | 3 | 11 | 8 | - | 3 | 17 | - |

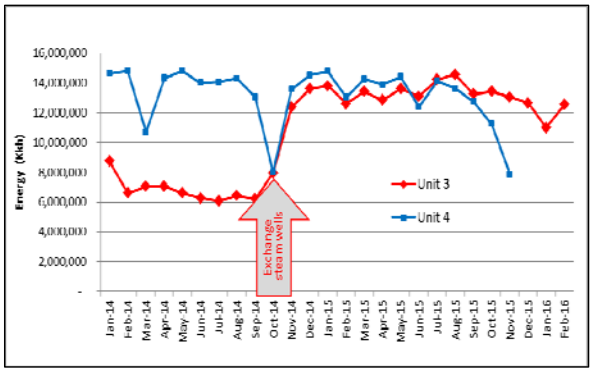
Source: Compiled utilizing information from the executing agency

On the contrary, by exchanging the main steam of Unit 3 for Unit 4 (No. 28 steam production well) in October 2014, the operation and effect indicators have reached the target since 2015. Besides, as shown in Figure 2 and Figure 3, after the exchanging the steam wells, the output and actual power generation from Unit 3 became stable.




Source: Information from the executing agency

Figure 2: Monthly Average Output (2014/2015)




Source: Information from the executing agency

Figure 3: Monthly Average Energy Production (2014/2015)

Although the effectiveness cannot be said as high since the project could not generate the expected amount of power nearly five years after the completion of the construction in 2009. However, after 2014 when the steam wells have exchanged, it was confirmed that effectiveness of the project has been confirmed. It should be noted that the issue of steam is out of scope of the project (it is the development project by PGE). Besides, the gas extractor which was procured by the project has been decided based on the contents of steam quality stipulated in the steam sales contract. Therefore, it was difficult to respond the problem in advance. The discussion has been made between PLN and PGE periodically since the beginning of the problem occurred. In relation to the high acidity problem, PGE side has implemented mitigation measures to the extent possible such as injecting a neutralizing agent (sodium hydroxide).

### 3.3.2 Qualitative Effects

The qualitative effects on relaxation of tight power supply-demand and Carbon dioxide emissions reduction are elaborated in the next section of “3.4 Impacts”.

Gas extractor for Lahendong Unit 3

Exchange point of steam pipeline (No.23/No.28)

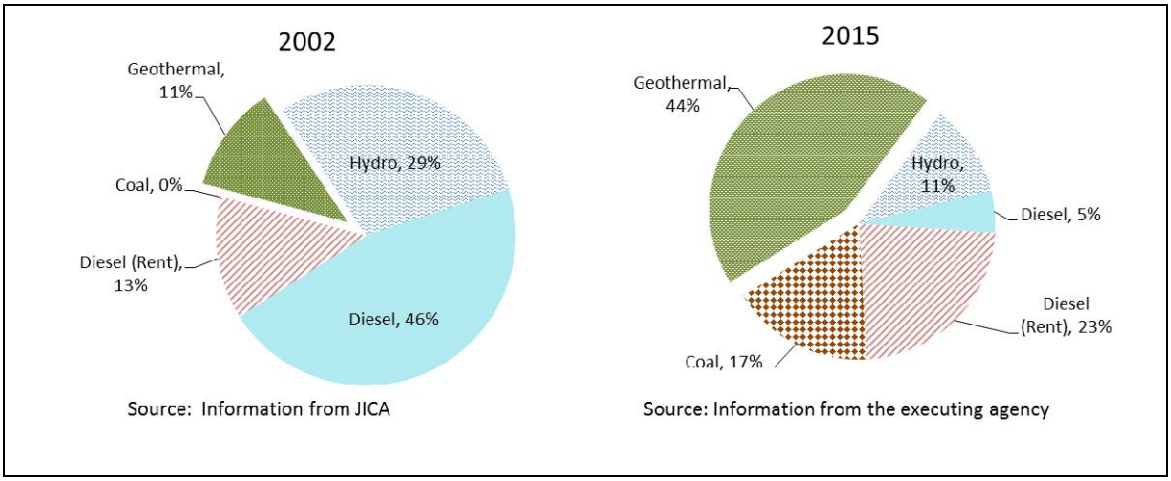
## 3.4 Impacts

### 3.4.1 Improvement of Stability of Power Supply

The available installed capacity in whole region of North Sulawesi in 2015 was 300 MW excluding the loss from aging and maintenance and the net electric energy production of the region in 2015 was 1,625 GWh. Among them, 20 MW is from this project and it generated 153.7 GWh. In other words, the project accounted for 6.7 % of the installed capacity and for 9.4 % of the net electric energy production in the North Sulawesi region. Accordingly, the project has been playing a role for the stable supply of electricity to some extent but not to a large extent.

### 3.4.2 Contribution to Diversification of Energy Sources and Utilization of Domestic Energy

Figure 4 shows the composition of energy sources of the Minahasa power system in 2002 and 2015. The Indonesian government has been promoting diversification of energy source and utilization of domestically produced energy in order to save fuel and as a shift to the power generation by environmentally friendly and economically efficient energy. As in Figure 4, the geothermal power generation increased from 11 % in 2002 to 44 % in 2015, which came to account for about half of the Minahasa power system. In the Minahasa power system, as of 2015 there are four geothermal power units including this project and each of them has 20 MW output. Therefore, the project accounts for 11 % of the Minahasa power system. From the perspective of geothermal power generation in the Minahasa system, the project accounts for 25 %. In light of this, it can be said that the project contributed to a certain degree to the diversification of energy sources and utilization of domestically produced energy.




Note: “Rent” means that PLN rents diesel power generating facilities which are developed by the private company.

Figure 4: Composition of Energy Sources of Minahasa Power System

### 3.4.3 Impacts on Reduction of Carbon Dioxide Emissions

In general, it is said that the geothermal power generation produces less carbon dioxide emission ($CO_2$ emission) in lifecycle of power generation compared to other power generations. According to the Agency for Natural Resources and Energy of Japan, the $CO_2$ emission of geothermal power generation (15 g-$CO_2$/kWh) consists of only 1.5 % of coal fired power generation (975 g-$CO_2$/kWh) [7]. The effect of $CO_2$ emission reduction by the project cannot be identified exactly since the data on $CO_2$ emission have not been taken by the executing agency. However, since the project releases less carbon dioxide than the thermal power generation when it covers the amount of power generation from the project, on such assumptions, it can be considered that the reduction effect has been realized.

### 3.4.4 Other Impacts

#### 3.4.4.1 Impacts on the Natural Environment

According to the interview to the executing agency and the monitoring records, it was found that the environmental monitoring has been continuously conducted on a quarterly basis during and after the project in accordance with the environmental management policy (UKL) and the environmental monitoring policy (UPL) of the Indonesian government. The environmental monitoring had also been implemented for the transmission towers which PLN has constructed. Results of all of the critical environmental indicators for geothermal power generation shown in Table 7 (4th quarter of 2015) were lower than the standards of the Indonesian government. It was also confirmed by the interview with local residents that there were no negative impact on natural environment such as air pollution and water quality of neighboring areas.

Table 7: Results of Environment Monitoring (4th Quarter of 2015)

| Indicator | Standard | Result |
|---|---|---|
| Sulfur hydrogen in air （$H_2S$） | 0.02 ppm | 0 ppm |
| Arsenic in the reinjection wells （As） | 0.05 mg/L | Under the detection limit of 0.003 |
| Mercury in the reinjection wells （Hg） | 0.001 mg/L | Under the detection limit of 0.0007 |

Source: Results from the questionnaire to the executing agency

[7] http://www.enecho.meti.go.jp/category/resources_and_fuel/geothermal/explanation/development/merit/clean/ (November 16, 2016)

#### 3.4.4.2 Land Acquisition and Resettlement

About 3 ha of land acquisition were required for the power plant construction. It was confirmed to the executing agency and the implementing consultant of the project that the compensation procedure to the land owner was carried out in accordance with the appropriate process and there was no problem in land acquisition, and no impact on the construction works. Since both construction sites of the power plant and the transmission towers by PLN were wooded area, agricultural land and grassland, there were no resettlement issue. Therefore, there was no negative impact by the land acquisition.

#### 3.4.4.3 Other Impacts

According to the executing agency and the implementing consultant, about 200 people, which was about half of the 400-500 workers during the construction period, have been employed for the project locally. It can be said that the project contributed to increase employment and income for the local residents. The contribution from the project was also confirmed even after the project. At the time of the ex-post evaluation, three operators and two security guards have been hired from neighboring community for Unit 3.

In light of the above, this project has to some extent achieved its objectives. Therefore, effectiveness and impact of the project are fair.

### 3.5 Sustainability (Rating: ③)

#### 3.5.1 Institutional Aspects of Operation and Maintenance

The operation and maintenance of the power plant after the completion of the project is undertaken by the PLN Lahendong (Lahendong Geothermal Power Plant) under the supervision of North and Central Sulawesi-Gorontalo Regional office (hereinafter referred to as “regional office”) located in Manado, North Sulawesi. The regional office is belonging to the Sulawesi Nusa Tengarra Regional Division in PLN Headquarters. Before the restructuring of PLN, the operation and maintenance of PLN Lahendong was used to be undertaken by the North Sulawesi regional office under the East Indonesia Regional Division of PLN Headquarters. The East Indonesia Regional Division was divided by the restructuring of PLN and the Sulawesi Nusa Tengarra Regional Division took it in charge.

PLN Lahendong has four units of geothermal power plants and allocates division managers to each plant who take responsibility for operation, maintenance, and administration under the head of the plant. Those managers including the head of the plant are assigned from the PLN headquarters. As of the ex-post evaluation, total number of staff was 92, 33 from the PLN headquarters, 39 outsourcing staff, 16 security guards

and four policemen. The operators of power plants of four units work in shifts and about 5-6 operators work in one shift per unit. In this way, the staff members from the PLN headquarters have been assigned in each division and sufficient number of staff has been allocated.

Although there was change of organizational structure for maintenance by the PLN restructuring, problem cannot be observed in the system. The interview to the executing agency revealed the positive impact by the PLN restructuring. The narrowed covering areas of responsibility of the Regional Division of Headquarters made more smooth communication with the actual sites and expedited the response to the problems. The PLN Lahendong has maintained good relationship with PGE which supplies the steam. The steam problem has been discussed with PGE with holding periodical meetings.

Accordingly, there is no particular problem on the operation and maintenance of Lahendong geothermal power plant.

### 3.5.2 Technical Aspects of Operation and Maintenance

The participants of the trainings and the executing agency have highly evaluated the achievement of the on-the-job training (OJT) and training in Japan conducted by the implementing consultant of the project for the operators and maintenance staff members during the construction period. According to them, they have gained the know-how of operation and maintenance of the project by those trainings. The nine members who participated in the training in Japan have taught know-how to their colleagues through OJT after coming back from the training. As of the ex-post evaluation, there were only two operators left among those who have participated in the training of Japan since some of them have retired and some have transferred. However, those remaining two operators have become cores of the operation. The operation manuals which were developed during the construction period were also highly evaluated. Thus, those manuals were translated into Indonesian language by the executing agency and revised annually. It was confirmed that they have been utilized at the time of the ex-post evaluation.

Control Room

The PLN operators and maintenance engineers are obliged to attend trainings on their own areas of responsibility and trainings according to the level of their own qualification at the PLN Learning Centers (three centers nationwide) every six months. In this way, appropriate human resource management system has been built in PLN. The

responsible staff members of the project also have attended this kind of trainings. The daily maintenance has been conducted by utilizing manuals. The periodical maintenance has also been undertaken. In the case of necessity arises, it is supported by outsourced organizations[8]. Therefore, no particular problem has been identified regarding the technical aspects of operation and maintenance.

### 3.5.3 Financial Aspects of Operation and Maintenance

The operation and maintenance costs are budgeted by PLN Lahendong, and the budget is applied and approved by the PLN Headquarters through the regional office. The approved budget is allocated to the regional office. According to the regional office and PLN Lahendong, the operation and maintenance costs necessary to the project has been allocated sufficiently every year as planned and the good operation and maintenance has been in place[9]. Therefore, no particular problem has been identified regarding the financial aspects of operation and maintenance.

### 3.5.4 Current Status of Operation and Maintenance

As of the ex-post evaluation, almost all the defects which were found at the First Year Inspection after the completion of the project and during the warranty period have been responded and no major problem was observed in operation and maintenance.

The maintenance for Unit 3 is conducted based on the maintenance plan formulated with the type of maintenance, budget, inspection schedule, etc. The plan is reviewed and updated every year. In principle, PLN Lahendong carries out the large scale inspection (overhaul) at 48-month interval, the periodical maintenance at 24-month interval and daily maintenance (checking the status of equipment such as turbine, filters, motors, etc. based on the manuals).

Although the periodical maintenance had not been conducted since the outage time was long due to the steam problem, it has been conducted during May to the end of July at the time of the ex-post evaluation survey in 2016. Overhaul is planned to be implemented in 2018.

Nevertheless, the steam problem has not been completely solved yet. As stated above, the steam of the project has been exchanged into that of Unit 4. However, the NCG concentration level of the exchanged steam itself is 1.4 % which is still higher than the

[8] The periodic maintenance is basically conducted by the internal human resources but is outsourced to the maintenance service sector of Java-Bali power generation company (PJB-S) of PLN groups or private companies as necessary.

[9] According to the executing agency, when the necessity arises to secure the costs more than the planned budget, the regional office can flexibly secure the costs from other projects. Therefore, there is a system that can quickly cope with such situation. It was also confirmed that there is no problem on the timing of the budget disbursement.

acceptable range of Unit 3 of 1.0 %. In addition, the pressure of the exchanged steam is sometimes weak. When the steam pressure is weak, the steam for Unit 3 has been mixed with the steam from No. 23, the original steam well. Therefore, the problems of high acidity of the hot water and the concentration of NCG in the steam have not been completely solved yet[10]. According to PGE, in order to cope with the problems, they are planning to mix steams from the other two steam wells[11] by October 2016. If this is realized, it is expected that the NCG issue will be solved and the problem of high acidity of steam supplied to the project will be mitigated.

From the above, no major problems have been observed in the institutional, technical and financial aspects of the operation and maintenance system. Therefore sustainability of the project effects is high.

## 4. Conclusion, Lessons Learned and Recommendation

### 4.1 Conclusion

The project aimed to ease the power supply demand tightness and improve the stability in the Minahasa power system, North Sulawesi, by newly constructing a geothermal power generation plant as Unit 3 of the existing Lahendong geothermal power plant.

The objective of the project which addresses the tight power supply-demand condition by supplying power through renewable energy is well consistent with the development policy and development needs of Indonesia, as well as with the Japan's ODA policy. Therefore the relevance of the project is high. Both the project cost and project period were within the planned. Therefore efficiency of the project is high. Regarding operation and effective indicators at the time of the appraisal, those showing the availability of the power plant have reached the targets, however, those showing actual energy production have not reached the targets for about five years from the start of power generation due to the quality problem of steam (although steam supply is out of the scope of project). This fact reduced effectiveness to some extent. It was confirmed, however, that after changing the supply source of the steam, planned effect of the project has been mostly observed. Negative impact on natural and social environment by the project has not been observed and it can be said that the project has contributed to a certain extent in shifting to an energy efficient power supply and utilizing domestic

[10] When the steam pressure from the exchanged No. 28 is weak, about 5 % of the steam from No.23 which has been used before is additionally injected. For that reason, the level of NCG sometimes increases as high as 2%. As a result, the amount of power generation becomes lower since the power plant has to be operated with reduced output.

[11] NCG level of both of the steam production wells is lower than 0.8 %.

energy sources. Thus, effectiveness and impact of the project are fair. In regard to the operation and maintenance, although problem of the steam quality has not been solved completely at the time of the ex-post evaluation, there is a good prospect of solving the problem. No major problems have been observed in the institutional, technical and financial aspects of the operation and maintenance system. Therefore sustainability of the project effects is high.

In light of the above, this project is evaluated to be highly satisfactory.

## 4.2 Recommendation

### 4.2.1 Recommendations to the Executing Agency

Continuation of consultation with PGE and Monitoring the progress

Unit 3 has to generate power with reduced output since the levels of NCG and acidity of the steam are still high even the steam has been exchanged into the steam from No. 28 well in October 2014. Moreover, when the steam pressure from No. 28 well is weak, the steam has to be mixed with steam from No. 23 well which has high concentration of NCG. Thus, it becomes necessary to further reduce the output. In order to respond to this problem, PGE has developed two steam production wells, No.47 and 48 which have low level of acidity and concentration of NCG and is planning to secure the sufficient amount of steam for the project by mixing the steam from these two steam wells with steam from No. 28 by October 2016.

PLN (regional office) is required to continuously consult this issue with PGE (North Sulawesi office) at monthly meetings and to confirm the progress of the countermeasure. Furthermore, PLN Headquarters is recommended to actively address this issue such as by participating in monthly meetings at the regional level and holding a meeting with PGE Headquarters as necessary.

### 4.2.2 Recommendation to JICA

None.

## 4.3 Lessons Learned

Confirm the quality of steam before deciding specification of procuring equipment

In this project, the equipment specification was decided based on the steam sales contract between PLN and PGE, which promised to supply steam with NCG value of 1 % or less. Therefore, the equipment including a gas extractor that can accept NCG values of 1 % or less was procured[12]. In reality, the supplied steam to the project had NCG value

[12] According to PGE, since the NCG level of the steam near the No. 23 well was less than 1 %, same figure was used in the contract without actually surveying steam quality.

exceeding 1 %, therefore, the problem was observed right after the project completion and the project has not been able to produce the target amount of power generation. After learning lessons from this project, PLN obliged PGE to submit “Resource Confirmation” after signing of steam sales contract since 2014[13]. It shows the amount and quality of steam identified by the survey. This was realized after PLN learned lessons from this project. In this way, it is very important to confirm the amount and quality of steam based on the actual survey before deciding the specification of equipment. Although even after the survey the quality of steam may change afterwards since it is a natural element, it is necessary to determine the specification of equipment at least after confirming the actual findings by the survey. If the actual survey results such as “Resource Confirmation” are not available in advance, it is considered that the specification should allow wider ranges to the extent possible.

[13] As the first applied case, the Resource Confirmation was submitted to PLN in August 2014 in relation to the JICA ODA loan project “Geothermal Development Acceleration Program (Hulu Lais Geothermal Power Plant (Engineering Service)” )(L/A: Dec. 2015).

Comparison of the Original and Actual Scope of the Project

| Item | Plan | Actual |
|---|---|---|
| ①Project Outputs | 1) Civil Works, Equipment Procurement<br>・ Geothermal Turbine (Installing 20 MW-class x 1 unit)<br>・ Condensing system<br>・ Electric Facilities<br>・ Instrumentation and Control Equipment<br>・ Necessary construction for future expansion<br>・ Auxiliary Equipment<br><br>2) Transmission System<br>・ Transmission line (150 kV, 3 km) from the project (Lahendong Unit 3) to existing Lahendong Unit 1 switchyard<br>・ Switchgear and Equipment of Lahendong Unit 1<br>・ Auxiliary Equipment<br><br>3) Consulting Services<br>・ Review of PERTAMINA's resource study Assistance of PLN in Prequalification of bidders, construction supervision, transfer of knowledge and training of PLN's personnel, Environmental monitoring, Reporting | 1) Civil Works, Equipment Procurement<br>・ As planned<br><br>・ As planned<br>・ As planned<br>・ As planned<br><br>・ As planned<br><br>・ As planned<br><br>2) Transmission System<br>・ Due to change of the construction site of the project (Lahendong Unit 3) the plan was changed. Instead of installing transmission system, the transmission lines were connected to Lahendong Unit 1 and Unit 2 by constructing transmission towers.<br><br>3) Consulting Services<br>・ As planned |
| ②Project Period | April, 2004 – April, 2010<br>(73 months) | April, 2004 – February, 2010<br>(71 months) |
| ③Project Cost<br>Amount Paid in Foreign Currency<br>Amount Paid in Local Currency<br><br>Total<br>Japanese ODA Loan Portion<br>Exchange Rate | 4,494 million yen<br><br>2,513 million yen<br>(Local Currency)<br>179,500 million IDR<br>7,007 million yen<br>5,866 million yen<br><br>1 IDR = JPY 0.014<br>( as of October, 2003) | 4,430 million yen<br><br>1,170 million yen<br>(Local Currency)<br>106,374 million IDR<br>5,600 million yen<br>4,517 million yen<br><br>1 IDR = JPY 0.011<br>(Average rate during the period from 2004 to 2012) |