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# REVIEW OF THE STATUS OF GEOTHERMAL DEVELOPMENT AND OPERATION IN INDONESIA 1985 TO 1990

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## ABSTRACT

The electric power sector in Indonesia will be expanded by an additional generating capacity of about 1,225 MW at the end of the fifth 5-year development plan (1989/1990 to 1993/1994) from the existing 8,529 MW. At present a 140 MW geothermal condensing plant (one unit of 30 MW and 2 units of 55 MW, all in Kamojang) and two noncondensing monobloks (2 MW in Dieng and 25 kW in Kamojang) have been operating successfully since 1979. Based on the fifth 5-year development plan the government of Indonesia has decided to install an additional 235 MW on the island of Java and 15 MW on North Sulawesi, for a total installed capacity of 377.25 MW.

## INTRODUCTION

Indonesian is one of the richest countries in the world in geothermal energy resources. The volcanic belt in Indonesia is associated with a 7,000 km long plate boundary that stretches from Sumatera in the west to Java, Bali and the Lesser Sunda islands in the east. The volcanic belt further bends to the north through Maluku up to Sangihe Island.

There are 177 volcanic centers in Indonesia, and 88 of these bear evidence of fumarolic and solfataric activity. The geothermal potential of the country has been estimated to be about 16,035 MWe (see Figure 1).

In 1918, the Volcanological Survey of Indonesia (VSI) started geothermal investigations in Kamojang, and five exploration wells were drilled there in 1926 - 1928. However, it was not until 1983 that the first large geothermal power plant (30 MW) was commissioned in Kamojang. Prior to that a 0.25 MW pilot station had been operated in Kamojang since 1979, and a 2 MW pilot plant in Dieng since 1981. Even though it is recognized that geothermal investigations were not carried out in Indonesia between 1928 and 1964, it appears that it has taken a relatively long time for Indonesia to start commercial utilization of the geothermal resources of the country.

Geothermal exploration was reactivated in Indonesia in 1964. In the following years many domestic and foreign organizations were involved in this work. The Indonesian organizations are VSI, Indonesia State Electricity Corporation (PLN), Bandung Institute of Technology (ITB) and PERTAMINA. Foreign organizations such as UNESCO, UNDP, USAID, the New Zealand government and JICA have contributed to the geothermal development in Indonesia during the past 20 years. The largest external contribution has come from the New Zealand government, which has provided US$24 million in aid for the 30 MW power plant and steam-field development in Kamojang, West Java.

In 1981 PERTAMINA was granted the authority to undertake the exploration and exploitation of all geothermal energy resources in Indonesia. Presidential Decree No. 22 of 1 June 1981, which granted PERTAMINA this authority, enables PERTAMINA, with the consent of the Minister of Mines and Energy, to enter into Joint Operation Contracts (JOC) with companies interested in developing geothermal resources in Indonesia. At present there are two foreign companies working in Indonesia under the JOC system. They are UNOCAL Geothermal Indonesia, Inc. since February 1982 in G. Salak field, West Java and AMOSEAS Indonesia, Inc. since November 1984 in Darjat field, West Java.

Based on the 5-year development plan (1989/90-1993/94) the government of Indonesia has decided to install an additional 235 MW, for a total installed geothermal capacity of 377.25 MW at the end of REPELITA V.

## DEVELOPMENT OF GEOTHERMAL RESOURCES

### Stages of Development

Geothermal development in Indonesia has been conducted in roughly four stages. It is roughly estimated that the total geothermal potential may be 16,035 MWe.

#### Stage 1. Inventory/Reconnaissance

Geothermal resources in Indonesia that have already been inventoried can be classified into four types according to decreasing expected reservoir temperatures and heat flow.

#### Stage 2. Surface Exploration

Detailed field work is carried out to discover additional features that were previously unknown or unrecognized. The successful interpretation of the data obtained from surface exploration is based on having complete results from a combination of geological, geochemical, geophysical and hydrological studies. The interpretation results in development of a coherent conceptual model of the field that is consistent with all the observed data. At this stage a tentative three-dimensional model is formulated. More than 20 geothermal areas in Indonesia are in this

**5TH FIVE YEARS PLANNING OF GEOTHERMAL ENERGY DEVELOPMENT ( MWE )**

| | 1989/90 | 1990/91 | 1991/92 | 1992/93 | 1993/94 | |
|---|---|---|---|---|---|---|
| 1. KAMOJANG | | | | | | |
| PLN | 140 | 140 | 140 | 140 | 140 | ( 195) |
| OWN USE | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | ( 0.25 ) |
| 2. DIENG | | | | | | |
| PLN | - | - | - | - | 55 | ( 55 ) |
| OWN USE | 2 | 2 | 2 | 2 | 2 | ( 2 ) |
| 3. SALAK | | | | | | |
| PLN | - | - | 110 | 110 | 110 | (165) |
| 4. DARAJAT | - | - | - | - | 110 | (55) |
| 5. LAHENDONG | - | - | - | - | 15 | (30) |
| MWE | 142.25 | 142.25 | 252.25 | 252.25 | 432.25 | (502.25) |
| BOPD | 6227 | 6227 | 11042 | 11042 | 18921 | 21985 |

N O T E

1 KWH = 0.29 LITRE DIESEL OIL
1 BARREL = 159 LITRE

development stage. Surface exploration on Java is mostly done by PERTAMINA and its contractor, while surface exploration outside Java to some extent has been conducted by the VSI.

Stage 3. Subsurface Exploration

Exploratory wells must be drilled to confirm the extent of the geothermal reservoir, the average rate of fluid production per well, and the chemical characteristics of the fluid. The geothermal areas already at this stage include: Kamojang, Salak, Dieng, Banten, Cisolok and Drajat on Java, Lahendong on North Sulawesi and Kerinci on Sumatera. Drilling of exploratory wells in Kerinci, Jambi province, was carried out by the VSI in 1980 with the technical assistance of JICA through a bilateral aid programme signed in 1981 and 1986 for the feasibility study.

Stage 4. Exploitation

This stage includes the drilling of production wells and the design and construction of the steam-transport and utilization system. Three geothermal fields belong in this stage: Kamojang, Darajat and Dieng on Java. The activities in these fields are carried out by PERTAMINA as the field developer and PLN as the power-plant developer.

**Results of Drilling and Scientific Exploration**

Producing Fields

At present Kamojang on West Java is the only producing geothermal field in Indonesia. It is known as a vapor dominated geothermal system. A total of 48 wells have been drilled by PERTAMINA; most of the producing wells are tied in to supply steam for the 140 MW power plant. The 0.25 MW monoblok that was installed to well No. 6 in 1979 is still in operation for PERTAMINA's own use.

Developing Prospects

Other developing prospects are Dieng, Central Java; Gunung Salak and Darajat, West Java; and Lahendong, North Sulawesi.

Drilling Prospects

Exploratory drilling is underway at three prospects. One prospect lies outside of Java, namely the Lempur prospect in the Jambi province, Sumatera. The exploratory well intersected a reservoir temperature of 202°C and produced a mixture of water and steam. The other two prospects are on West Java, the Cisolok and the Rawa Danu prospects. One exploratory well drilled in each prospect, however, failed to intersect high permeability and high temperature zones.

Scientific Prospects

Based on the evaluation of scientific data, three prospects have been classified as first-priority prospects to be drilled. These three prospects lie on West Jave, namely Wayang Windu, Karaha and Patuha. The Wayang-Windu prospect is a neighbor prospect to the west of Darajat.

Interpretation of the scientific data shows that this prospect is similar to that of the Kamojang and Darajat fields. Supported by temperature gradients from shallow wells, the Wayang-Windu prospect could be a steam-dominated system; a potential of about 200 MW is expected from this prospect. In Karaha geophysical methods were used to survey a prospect area of about 6 $km^2$. The depth of the reservoir is estimated to be about 1,000-1,500 m, and reservoir temperatures of 215-240°C are indicated by chemical geothermometers. In Patuha two prospects, which covered areas of about 14 $km^2$ and 6 $km^2$, respectively, are indicated from geophysical data. A temperature of 260°C was estimated and a total potential of 250 MW is expected from these two prospects. Review of all scientific data shows that the national potential of Indonesia is about 16,035 MWe (Tables).

## NATIONAL GEOTHERMAL DEVELOPMENT

### Kamojang Geothermal Field

Kamojang unit 1 has the longest history of investigation in Indonesia. The first well was drilled in 1926. Kamojang is also the most intensively studied field in Indonesia, with a total 48 wells having been drilled by the end of 1989. The reservoir is considered to be vapor dominated and all production from the wells is dry steam. The output of the wells is variable with a range of 0-125 tons/hour (t/h) and a mean value of 39 t/h (10.8 kg/s).

The New Zealand government made a large contribution (US$24 million) toward the geothermal development of the Kamojang field in 1975. The bilateral aid program from New Zealand included exploration surveys, drilling of steam wells, development of the field, and construction of a 30 MW power plant (Unit 1) commissioned in February 1983. The bilateral aid project was completed with the commissioning of the power station.

Even before the completion of unit 1, there was already a surplus of proven steam capacity available for power generation (45 MWe from the first stage production wells alone). Results obtained from wells drilled after the completion of unit 1 soon confirmed earlier indications that there was obviously potential for a substantial extension to the installed electrical generation capacity at Kamojang.

In 1981, PLN requested Geothermal Energy New Zealand Limited (GENZL) to carry out a study to determine the feasibility of increasing the installed generating capacity at Kamojang. A review of all the relevant available data on reservoir size and resource potential included the latest data gathered from geological, geochemical, geophysical and well measurement surveys. As well as the scientific review, a full engineering, economic, environmental and power-demand assessment were carried out in order to formulate recommendations on the next stage of development at Kamojang. It was concluded that an addition of 110 MW was the most suitable size for the second stage development.

Following the feasibility study, GENZL was contracted in June 1982 to design an extension to the existing plant to allow for the addition of 2 x 55 MW turbo-generators and ancillary equipment, cooling towers and electrical facilities. Site work commenced in August 1984, and with the power house substantially completed, the installation of turbo-generator equipment commenced in late 1987. Kamojang unit 2 was finished in July 1987 and, following successful commissioning of Kamojang unit 3 2 months later, the entire project was completed on schedule in November 1987 and officially opened by the President of the Republic of Indonesia on February 3, 1988. Units 2 and 3 were built with a US$55 million loan from IBRD to PLN.

The following is an outline of what are seen to be the necessary steps to undertake the prudent, further exploitation of the Kamojang resources. There are five distinct phases involved, with the first three aimed at data collection (quantifying the resource), the fourth a formal resource feasibility study, and the fifth a power station feasibility study. With regard to resource quantification, the three phases are scientific surveys, stepout drilling, and reservoir engineering.

Scientific Surveys

The geophysical data show closure (a limiting reservoir boundary) only in an area on the northern side of the resource. The areas east, south and west are "open" and require further definition, by additional geophysical survey.

Furthermore, the immediately neighboring prospects within several km of Kamojang, (toward G. Masigit-Guntur in the east and Darajat in the southwest) either have received more exploration attention or the exploration data have been made available to the government. Darajat itself is being developed as another dry steam field, and the potential of G. Masigit-Guntur has been recognized through previous work including the recent IGSEP study. The proximity of these prospects to Kamojang optionistically indicates that significant resource potential exists beneath the immediately surrounding areas. Surveys need to be carried out, to both test these zones, and to seek the field limits of Kamojang. This scientific work, probably of 3-4 month's duration, could be started immediately and needs to be carried out prior to stepout drilling.

Stepout Drilling

Existing wells at Kamojang have been drilled to provide steam for a 140 MW power station only. They are all grouped together within a defined geographic area and no wells have been drilled outside this zone, which can be used to give any positive indications of a far larger resource. Once the scientific work has been completed, stepout wells need to be drilled to prove the expanded zones of interest. A minimum of three wells can be envisioned to "sound the eastern, southern and western zones," assuming the results confirm the logic of this approach. However, a "comfort margin" on resource potential is a prudent approach and more wells should seriously be considered prior to committing to further major capital investment. Allowing 45-60 drilling days per well plus about 2 months per well for well testing gives some indication of the time necessary for this activity.

### Reservoir Engineering

The importance of regular and consistent well measurements and analysis over the life of a producing field cannot be over emphasized, especially during the early years of exploitation. This forms an integral part of prudent resource management. The 110 MW increment being brought on-line at present represents a major step increase in the exploitation of the Kamojang reservoir. Careful, ongoing resource measurement at the 140 MW level of generation is required to gauge the behavior and continuity of the reservoir. Drawdown in existing wells may occur, as experienced in other fields, and maintaining steam flows by the drilling of make-up wells is a natural consequence. This activity needs to be planned for in an ongoing steam-field management plan.

All of the above are essential to ensuring the successful ongoing generation of electricity at Kamojang. Until this work has been substantially completed, there will be insufficient technical data to proceed with the fourth phase of the resource assessment for increased generation capacity.

### Resource Feasibility Study

The resource feasibility study involves an integration of the various technical data, given an overall understanding and status of the resource and also should involve a numerical simulation of the capability. This audit can be completed within a 3-6 month period.

### Power Station Feasibility Study

The power station feasibility study primarily addresses the choice of a site, geotechnical considerations, the steam pipeline routing, plus a host of more conventional engineering issues that need attention. Again this work can be completed within a 3-6 month period. The degree of overlap in timing of the resource and power station feasibility studies depends on the integration and degree of knowledge shared between the steam-field and power station organizations. The New Zealand government is interested in assisting the Indonesian government to finalize the feasibility study of Kamojang units 4 and 5 as is the IBRD Bank.

Calculations have been made on the basis of well bore data, an areal extent of 14 $km^2$ and lumped parameter assumptions, which indicate the resource can produce about 200 MWe for 25 years of exploitation. Thus for an area of 21 $km^2$, a potential of about 300 MWe can be expected.

### Gunung Salak Geothermal Field, West Java

The Gunung Salak prospect lies in West Java about 80 km to the south of Jarkarta, the capital city of Indonesia. It is operated by UNOCAL Geothermal of Indonesia, Ltd. under a JOC with PERTAMINA and an Energy Sales Contract (ESC) with PLN.

Salak is a hot water dominated area. By the end of 1989 nine exploration wells already had been completed, with the depths ranging from 1,250 to 2,590 m. Average production is 40 t/hr (4 MW) for standard wells and 175 t/hr (17.5 MW) for a big hole. Total well capacity is 72 MW. The measured reservoir temperature ranges from 260 to 275°C.

Fluid chemistry indicates proven reserves of 230 MW and potential reserves of 370 MW. The NaCl brine has a TDS of 13,000 ppm, 1 percent NC gas in the steam, permeability of 500,000 MDC, and 17 to 25 percent steam flash. Construction of the first unit of 2 x 55 MW capacity by PLN is scheduled such that the unit will be operated commercially in 1992 under an Italian soft money loan of US$71 million to Indonesia. The field has been evaluated since 1986 by Electro Consult (ELC) Italy under the IBRD loan. Plans have been made by UNOCAL for additional drilling of six production wells to supply the first 100 MWe power plants.

### Dieng Geothermal Field, Central Java

The Dieng prospect is centered on the Dieng caldera, which is on the east end of the Dieng plateau in Central Java. Within this area, there are four isolated geothermal prospects, namely Sikidang (6 km) Sileri (4 km), Candradimuka (7 km) and Sroja (8 km). The hot springs in the Dieng field occur at 950-2,500 m above sea level.

A total of 14 wells had been drilled at Dieng prior to 1989. Reservoir temperatures range up to 300°C, with high enthalpies of about 2,100-2,200 kj/kg. The field is now being evaluated by West Japan Engineering Consultant (West Jec) under the ADB loan to PLN. Since 1986 a 55 MW power plant has been scheduled to be in operation by 1993/1994. Plans have been made by PERTAMINA for additional drilling of nine production wells in 1990/1991 and three production wells in 1991/1992.

The reservoir potential of the Sikidang area and three other isolated prospects has been estimated by the stored-heat method. Those potentials are as follows:

ESTIMATED POTENTIAL IN MW FOR 30 YEARS

| | Sikidang | Sileri | Candradimuka | Srodja | Total |
|---|---|---|---|---|---|
| Condensing Steam Turbine | 306 | 204 | 358 | 408 | 1,276 (MW) |
| Noncondensing Steam Turbine | 153 | 102 | 179 | 204 | 638 (MW) |

The noncondensable gas in steam under the operating conditions of the power plant is estimated to be 2.2 percent by volume. The composition would be 92.5 percent carbon dioxide gas by volume. Optimum well head pressure is estimated at about 8 bar, and the enthalpy of fluids produced by the wells, about 2,200-2,800 kj/kg with the temperature at the well head, 164°C, and the turbine-inlet pressure,A 6 bar. The temperatures of extremely high Cl concentration water, and low Cl concentration water are estimated at 300°C and less than 240°C, respectively.

**Darajat Geothermal Field, West Java**

The Darajat geothermal field is located in mountainous terrain in West Java, Indonesia, about 2 km southeast of the city of Bandung. AMOSEAS Indonesia became involved with the exploration and development of the field after signing JOC and ESC contracts with PERTAMINA and PLN in November 1984.

Reservoir Development

In February 1987, at the request of PLN, AMOSEAS submitted a report entitled "Geothermal Assessment of the Darajat Contract Area, West Java, Indonesia Phase I." The report summarized exploratory work up to that time and included data from geological, geophysical and geochemical surveys, shallow temperature hole drilling and the wells DRJ-1, -2, and -3. A preliminary model of the Darajat system was proposed and estimates of reservoir extent and possible energy reserves were made.

Based on exploration work that consisted of drilling four wells from 1987 to 1988, long term testing, and a reservoir evaluation, a vapor-dominated geothermal system has been identified at the Darajat field. The proven reservoir area covers 5 $km^2$ and its geothermal reserves are sufficient to provide 55 MW of electrical power for 25 years. Additional probable reserves may exist in an areal extension of the proven area, which could be confirmed by development drilling for the first power plant.

To operate a 55 MW power plant in the currently proven area, two additional development wells will be required initially and three more later, for infill drilling.

Based on the interpretation of data from well DRJ-5 it appears that a vapor-liquid interface may exist at an elevation of 100 m above sea level. For modelling purposes this was not taken into account in defining the base case. However, the additional potential from the bottom water was estimated as a sensitivity case. Wells produce mainly dry steam with a noncondensable gas content averaging 1.5 mass percent. During early stages of the flow periods, however, some reservoir liquid was produced on the order of up to 4 percent by weight, but later it stabilized at less than 1 percent.

The measured concentrations of $H_2S$ and $CO_2$ in the noncondensable gas support the average water saturation value of 33 percent in the vapor zone.

Conversion to Electrical Power

Flow test results in the Darajat field as well as observed performance in the Kamojang field indicate that all wells will produce only vapor (100 percent quality steam). Based on actual performance of power plants installed at the Kamojang field, it was established that 2.18 kg/s-MW of vapor production at a wellhead pressure of 7 bar abs is a reasonable conversion factor. This value includes a 5 percent safety factor to account for any production losses on the field side. It is also based on a plant inlet pressure of 6.5 bar abs. The equivalent value for a plant inlet pressure of 14 bar abs is 1.78 kg/s-MWe.

Estimating Geothermal Reserves By Conceptual Modelling

A conceptual reservoir model for the Darajat field was formulated on the basis of geology, drilling results, well tests and expected producing mechanisms. The reservoir area was divided into three parts.

The following specific power fields (MWe/$km^3$) were assigned to various reservoir types on the basis of their reservoir properties and recovery efficiencies, which were estimated from a correlation chart formulated using an approach similar to Gomaa's method, assuming a 25-year life at 310 operating days/year. The reservoir types and yields are:

| RESERVOIR TYPE | ELECTRICAL POWER YIELD, MWe/$km^3$ | | |
|---|---|---|---|
| | Densily faulted part | Moderately faulted part | Fractured matrix part |
| Upper part of reservoir (upper 100 masl) | 16.8 | 11.9 | 7.1 |
| Lower part of reservoir (below 100 masl) as bottom water | 16.5 | 7.9 | 4.6 |
| Lower part of reservoir (below 100 masl) without bottom water | 11.7 | 4.9 | 2.6 |

The estimated electrical power yield from the 5 $km^2$ proven area (without the presence of bottom water) ranges from 65 to 87 MWe depending on the distribution of various reservoir types within the area. The corresponding range for the 7.8 $km^2$ proven-plus-probable area is 101 to 123 MWe.

Power Plant Development

In January 1990, GENZL was engaged by the PLN to study the feasibility of constructing a 55 MW unit. The power plant is expected to be on line in 1993/1994.

**Lahendong High Enthalpy Geothermal Project, North Sulawesi**

The Lahendong geothermal field is located in the district of Minahasa, North Sulawesi, approximately 30 km south of Manado City. In 1978, PLN and VSI conducted a series of exploration surveys. In 1982-1986, three wells (LH-1, -2 and -3) were drilled in the Linau Lake zone at depths ranging between 380 and 660 m. In 1984 PERTAMINA drilled seven deep wells, having a maximum depth of 2,500 m. The results of the production tests may be summarized as follows: the proven reserve covers an area of 10 $km^2$, with a total potential of 150 MWe or more.

The Lahendong main reservoir is a water-dominant system located at a depth of approximately 1,400 m. The temperature is over 250°C (340°C maximum) and the enthalpy is 1,200 to 2,050 kj/kg. Noncondensable gas (mainly $CO_2$) seems to be low (less than 1 percent). A secondary steam/water reservoir is located at shallow depth (approximately 300-900 m).

Two wells are commercially productive: LHD-4 and LHD-5. Their main characteristics are given in the following table (with reference to the PERTAMINA report of Sept/Oct 1988).

Table 3. LHD-4 and LHD-5 main characteristics

| | LHD-4 Average | LHD-5 Average |
|---|---|---|
| Well Head Pressure (bars) | 25 | 10.7 |
| Enthalpy (kj/kg) | 2050 | 1160 |
| Temperature (°C) | 180 (estimated) | 182 |
| Dryness ( % ) | 61 | 20 |
| Total flow (kg/sec) | 20.8 | 62 |
| Steam flow (kg/sec) | 12.2 | 12 |
| Water flow (kg/sec) | 8.5 | 51 |
| Electric capacity (MW) | | |
| - estimated with steam counter pressure turbine | 3 | 3 |
| Condesing turbine | 5.5⁻ | 5.4 |
| -estimation with water ORC | 0.4 | 2 |

In December 1989, a protocol agreement was signed by both the Indonesian and the French governments, where FF3 million has been allocated for the power plant feasibility study. An additional FF105 million will be allocated for the construction of the 15 MW power plant if the results of the study show it is feasible.

## RURAL GEOTHERMAL DEVELOPMENT

### Ulumbu Geothermal Field, Flores Island, Nusatenggara Timur Province

The main objective of this project is to improve the social and economic conditions in the Manggarai Regency, Flores Island, by providing electricity from the installation and subsequent operation of a 3 MWe geothermal power station in the Ulumbu geothermal field.

In March 1989, KRTA Ltd was engaged by the Ministry of External Relations and Trade (MERT), New Zealand, to undertake a technical, environmental and economic feasibility study of a geothermal development with an anticipated scale of about 3 MWe. Field work was undertaken during May 1989 with the assistance of PLN, Directorate of Volcanology. Based on the feasibility study, a large hydrothermal system is believed to exist in the area, about 4 km east of the village of Ponggeok.

Geothermometry on the Ulumbu fumaroles suggests that they are derived from a fluid with a temperature of at least 260°C. Initial estimates of the surface heat discharge range from 20 to 68 $MW_t$, which is roughly equivalent to 2-7 MWe if converted. It is a high grade resource proven by drilling; it is likely to be as large as 30 MWe or greater.

The New Zealand government has already committed to cover the cost of stage II development (well drilling and testing, completion and assessment of drilling data), around NZ$1.5 million during the fiscal years 1990/91 and 1991/92. The Ulumbu geothermal project is the first project where the steam field development and power plant construction/operation will be done by PLN. This project is scheduled to be commissioned in 1993/1994.

### Kerinci Geothermal Development Project, Jambi Province

First Phase: (1981-1983)

This study was the first phase survey for geothermal development in the Lempur area of the Kerinci district, Sumatera Island, financed by the Japanese government (JICA). In 1981 it consisted of a Landsat-image and photo-geological interpretation, a geological survey, a geothermal manifestation survey, a hydrogeological survey, and a geochemical survey. The objectives of the first survey were to define the geothermal reservoir in the Lempur area and to determine the scope of the next phase of the survey.

The purpose of the second part of the survey, conducted in 1982, was to estimate the geological structure, faults, and the geothermal reservoir, and to select the drilling sites for exploratory wells for the third phase of the survey. The Sikai and Duabelas areas were selected on the basis of their geological structure as promising areas for geothermal development.

The Sikai area consists of an upper cap rock and a second layer having a clay alteration zone (low resistivity zone of about 11 m). The depth to the basement complex is presumed to be 1,000 to 1,300 m below the ground surface. These areas are located near the Sikai fault and Sikai fumarole.

Duabelas has a wider, more promising range for drilling and the depth of its basement complex is assumed to be 500 to 700. This area also has a second layer clay-alteration zone (reistivity zone of about 10). This area is close to the Duabelas faults and the Duabelas fumarole as well as to Abeng hot spring. In 1983, as a result of the 1981 and 1982 studies, the most promising drill site was selected for the first exploratory well.

Following is an outline of the well drilling information:

1. Number of wells: one (vertical)
2. Depth of drilling: about 100 m
3. Final diameter of the well: HQ bit (dia, 101 m)
4. Core investigation: principally all coring
5. Period of drilling: 5 months (July 1982-November 1982)

Analysis of a physical-characteristics test on well Lempur LP-1 shows that the steam-flow rate, the hot-water flow rate, and the enthalpy were 3.5 t/h, 17.35 t/h, and 200 kcal/kg, respectively, at well-head pressure. According to the results of a chemical-characteristics test, the reservoir that supplies hot water to LP-1 is a hot water-dominated reservoir of the $Cl-HCO_3$ type. Power output from the 1.5 $km^2$ area in Kerinci is estimated to be 30 MW.

Feasibility Study: (1987-1988)

A feasibility study for a 5 MW power plant was conducted in 1987-1988. It considered the area's population (about 8,000), and the electric power generation facilities of PLN (1-1 MW) and for a tea plant (2 MW). The present electric power demand in the Lempur area is estimated to be 5 MW. As a result of this study in order to obtain enough steam to generate 5 MW electric power, one exploratory well (LP-2, 1,200 m in depth) has been drilled.

The resource feasibility study completed in March 1989 showed that the Duabelas geothermal system has a potential for about 55 MW for 40 years with operation by back pressure steam turbine, and about 5 MW for 90 years with operation by condensing steam turbine.

The existing LP-2 well drilled as an exploratory well to 1,026.5 m depth is producing steam with an electric energy of about 350 kW. The temperature of the deep reservoir in the Duabelas geothermal system is 200°C to 300°C and the temperature of the vapor dominated zones is 135°C to 160°C. The characteristics of LP-2 are about 5 t/hr of steam flow rate and 35 t/hr of water flow rate at a wellhead pressure of 5.2 ata. The development of 2.35 MW is sufficient for the time being to meet the power demands in the project area.

In order to use steam produced from well LP-2 as early as possible, first a power unit with a back pressure turbine of 350 kW should be installed. The study also recommended installation of production wells LP-3 and LP-4, followed by a generating unit (back pressure type) of 1,000 kW.

**2.5 MW Geothermal Binary Cycle Project, Lahendong, North Sulawesi**

Content of the Project

The Indonesian authorities have expressed their wish to develop the medium enthalpy geothermal resource in the Lahendong area, North Sulawesi for the purpose of energy generation, especially in a rural area. The project will be financed by the French government via a grant signed November 1988 for nearly FF38 million. The grant is for the study, design and installation of a 2.5 MW electric power plant to be completed within 56 weeks, starting May 15, 1989.

Present Status

The present status of the area has been described in a previous section of this report on the high-enthalpy project in the area.

General Conclusions of the Study

During the first months of the study, started in late 1987, the consultant Enersystem and its French partners performed the preliminary thermodynamic engineering study while simultaneously completing a site survey and a testing program of the geothermal resources. These studies have lead to the following conclusions:

a. The feasibility of the project is confirmed;
b. The technology selected (binary cycle) is well adapted to medium enthalpy geothermal plants;
c. The site and the geothermal resources in Lahendong are suitable for the development of a demonstration project;
d. The geothermal resources meet the thermodynamic requirements for the installation of a power plant within the range of an installed capacity of 2.5 MWe;
e. A comprehensive program for the transfer of engineering and manufacturing know-how, defined by both parties, has been initiated, and will be developed during the implementation of the future contract;
f. The two wells already drilled on the site are to be put at Enersystem's disposal during implementation of the contract; and
g. The tests performed during the preliminary studies have confirmed that the quality of the reservoir will support the expected capacity. In other words, it is possible to maintain the target of an installed capacity of 2.5 MWe.

It must be mentioned that, through financing by the French authorities, it was possible to carry out the present preliminary study and thus identify problems that would otherwise have arisen during the actual performance of the contract.

Potential Market

Indonesia is a volcanic country where a great number of high-enthalpy geothermal resources have been identified. However, the number of potential areas with medium-enthalpy geothermal resources, such as Lahendong, is larger. There are many villages throughout the country in remote areas and islands that are connected to local isolated grids where the cost per kWh generated from diesel is very high. Geothermal, medium-enthalpy power plants is one answer to rural electrification in Indonesia.
There are presently some 80 medium-enthalpy geothermal sites in Indonesia, located throughout the country: Sumatera, Java, Bali, Lombok, Sumbawa, Flores, Sulawesi, and Maluku. At least 10 of these 80 potential sites can be equipped very quickly with a medium-enthalpy geothermal power plant, for numerous reasons such as: proximity of a local grid or the existence of a sufficient number of consumers, easy and inexpensive drilling (shallow geothermal resource), or the existence of wells already drilled.

For development of the Ciwidey small scale geothermal plant, West Java, in February 1988, the Department of Cooperation got a permit to develop a geothermal plant for the use of a tea plantation. The feasibility study was completed in 1989. Drilling of the exploration wells is scheduled for 1990.

**INTERNATIONAL ASSISTANCE AND DEVELOPMENT**

**Power Development Study for PLN Regions IX (Maluku) and XI (Nusatenggara) (ADB Technical Assistance No. 785 INO).**

Existence of Geothermal Potential

Indonesia is a volcanically active country, rich in geothermal potential. The major islands of Region XI are part of the main volcanic arc of Indonesia and include Sumatera and Java. The chain of islands, Bali, Sumbawa, Flores and part of this volcanic group turns towards the north and ends at Ambon Island of Region IX. Halmahera belongs to another volcanic group. Therefore, Regions IX and XI have a lot of potential geothermal sites.

The New Zealand consultant studied the geothermal potential of Bratan on Bali and of Ulumbu on Flores. A grant aid from New Zealand for construction of a small scale geothermal plant, 2,000 to 3,000 kW, at the Ulumbu site was decided. In addition, the VSI has surveyed seven prospective sites in the project areas of Rinajai on Lombok, Hu'u on Sumbawa, Mutubusa and others on Flores, Jailolo on Halmahera, Ambon Island and others. The geothermal field on Bali was determined to be the most promising; however, the development of this site was suspended in view of the potential environmental impact. The field is in an important sight-seeing spot that attracts foreign visitors.

## Evaluation of Geothermal Potential in Project Areas

There are many known geothermal fields in the project areas and various studies have been done by foreign consultants and VSI. The consultants inspected some prospective sites. Evaluation of each geothermal field is summarized below.

### Hu'u Geothermal Field on Sumbawa

The Hu'u field is located about 30 km to the south of Dumpu. The load centers of the Hu'u geothermal plant will cover not only Hu'u and Dompu but also Bima (40 km from Dompu) and other centers on the way, Sila, Tente, etc. Transmission to Sumbawa (150 km from Dompu) will also be studied in case hydropower is not available for this load center. The total peak demand in the supply area for the Hu'u project is about 4,000 kW at present.

VSI has conducted specific resistance measurements, gravity measurements and geochemical analyses. From the results of those investigations, the existence of anomalous zones, which may represent magma reservoirs is suspected. Also from the other data, this is judged to be a very promising site. However, discrepancies were found in the data. Therefore, further study covering a wide area is required.

### Ulumbu Field on Flores

Very conspicuous geothermal manifestations are seen in this field: an inferno with hot water springs, fumaroles and alteration. The New Zealand government has decided to provide grant aid for construction of a small geothermal plant of 2 to 3 MW capacity for power to Ruteng and its surrounding areas.

### Geothermal Fields between Ende and Maumere on Flores

In this area, four fields have been reported with geothermal manifestations. Two sites, Mutubusa-Sokoria and Lesugolo are very promising. PLN and VSI already have estimated the development scales of these two sites to be 25 MW and 100 MW, respectively. From these sites two major load centers on Flores, Ende and Maumere and their surrounding areas, can be supplied by connecting these load centers by a 70-kV transmission line. The total peak demand as of 1986/87 in the area was 1,800 kW.

### Geothermal Field of Jailolo on Halmahera

There are several hot springs in this field. A site survey by VSI is in a preliminary stage, so the suitability of this site for power generation cannot be judged at the present time. The nearest load center for this field is Jailolo; to supply Ternate, a submarine cable line is required.

### Geothermal Field on Bali

VSI selected the area around two lakes, Buyan Bratan at the center of the island, as the most promising site for geothermal development. The New Zealand consultant also confirmed the suitability of this site. However, further activities have been suspended by the government due to the fact that the proposed site is within a tourism spot attracting foreign visitors.

### Geothermal Fields on Lombok and Ambon

Hot springs have been identified, but VSI's investigation is in a preliminary stage. Therefore, the suitability of these sites cannot be judged at the present time. The demand size as of 1986-87 is about 13 MW in Lombok and 11 MW in Amobn. If the future growth of power demand is taken into account, the demand will be enough to construct plants with 20 to 30 MW capacity. For these sites it has been recommended to continue the preliminary survey in order to estimate the geothermal potential.

## Recommendations for Further Surveys

For the development of geothermal power projects, further surveys for the identification of magma reservoirs, test borings for confirmation of steam conditions, etc., are essential. Taking into account the situation mentioned above, the following two sites are recommended for further detailed studies:

First priority: Hu'u geothermal field on Sumbawa;

Second priority: Mutubusa and Lesugolo geothermal fields in the area between Ende and Maumere on Flores.

## Selected Geothermal Development

Two geothermal projects, Hu'u on Sumbawa and Mutubusa or Lesugolo in the Ende-Maumere areas of Flores, have been selected as candidate projects for development during the plan period up to 2003/04. If the survey of the geothermal field had commenced in 1988, the commercial operation would start in 1990. The main project areas are assumed to be accompanied by a 70 kV transmission system. The projected peak demand of the interconnected system of each project is given in kW:

(continued)

| Hu'u Project: | 1993/94 | 1998/99 | 2003/04 |
|---|---|---|---|
| without Sumbawa[1] | 5,839 | 9,209 | 13,741 |
| including Sumbawa[2] | 9,383 | 14,486 | 22,686 |
| **Ende Maumere Project:** | | | |
| peak demand[3] | 4,359 | 7,292 | 11.643 |

(1) Bima, Dompu, Kompe, Hu'u Sila, Wowo, Seriutu and O'o
(2) Including Sumbawa, Plampang, Semamung, Empang Lape Lopok and Lanangguar.
(3) Ende, Maumere, Nita, Paga, Nangapanda, Wolowaru Datusuko and Lela.

In deciding the installed capacity, the following factors shall be taken into account.

a. The power supply is to be executed under joint operation with diesel plants; the geothermal plant is for base-load supply and the diesel plants for peak-load supply.

b. The day time demand of the load center is estimated to be 35 percent of the evening peak; the suitable capacity of the geothermal plant will be around 50 percent of the peak demand of the load center.

c. Consideration is to be made to maintenance service of one unit.

d. Installed facilities shall meet growing demand for at least 5 years. The estimated installations will be 2 units of 7,500 kW for the Hu'u project and 2 units of 5,000 kW for the Ende-Maumere project.

**Indonesia Geothermal Study and Evaluation Project**

A vast potential of geothermal energy exists in Indonesia awaiting utilization. The government of Indonesia (GOI) plans to accelerate the development of this resource, as part of its energy policy to become less dependent on fuel oil as a source of primary energy.

To assist in implementing this policy, the GOI has completed a study to determine suitable priorities for the exploration and development of steam-supply alternatives. The study is being implemented with financial assistance (grant of US$1 million) from the New Zealand Development Assistant Programme to Indonesia, 1987-1988. Based on the study, prospects are divided in the following manner:

1. Prospects for which only the name, approximate location, and possible value from heat potential are know:

| | |
|---|---|
| Sumatera | 34 |
| Java | 10 |
| Elsewhere | 58 |
| | 105 |

2. Prospects included in detail in the present listings:

| | |
|---|---|
| Sumatera | 37 |
| Java | 43 |
| Elsewhere | 32 |
| | 112 |

Total of prospects 1 and 2: 217 locations. The numbers of prospects can be presented with reference both to current exploration status and to broad locality.

| | |
|---|---|
| Prospects with wells drilled | 7 |
| Prospects with geophysics | 41 |
| Prospects with geochemistry/geology | 64 |
| Prospects with minimal data | 105 |
| Total | 217 locations |

**UNDP Mission to Indonesia**

At the request of the government of Indonesia Mr. Valgardur Stefansson, Interregional Adviser on Geothermal Energy, Natural Resources and Energy Division, Department of Technical Cooperation for Development, United Nations, undertook an advisory trip to Indonesia from 1 to 16 May 1987. The main findings of the mission were the following:

1. A detailed reservoir study on the Kamojang reservoir should be carried out in cooperation with the Department of Technical Cooperation for Development of the United Nations.

2. A detailed reservoir study of the Awibengkok field in the Salak geothermal area should be carried out prior to considering an extension of 110 MW.

3. The result of the planned experiment by PNOC to inject calcium-rich fluid into acid zones of geothermal reservoirs should be followed, given a successful result from this experiment, by the development of the Dieng field in central Java.

4. If a Joint Operation Contract for the Dieng field is to be discussed, it is recommended that the relatively high investment of PERTAMINA in the field be recognized.

5. The selection of drill bits for geothermal drilling and the operational procedure for these drill bits should be examined carefully in order to investigate possible ways to increase the lifetime of drill bits in geothermal drilling.

6. Carefully consider the possibility of predrilling the first 50 m of a geothermal well with a cable tool rig.

7. Use the method of periodical heating of a well during drilling in order to estimate the bottom hole rock temperature.

8. The use of upstream reboilers in the development of the Dieng field.

9. The government of Indonesia should make preparations for the setting up of reservoir-simulation facilities in Jakarta.

10. The security of the acid well in Lahendong should be considered carefully to determine if the well should be plugged.

11. The government of Indonesia should carry out the drilling of about two new exploration wells per year during the next years.

12. Surface and subsurface exploration work should be coordinated in such a way that there would be a natural balance between surface exploration and exploratory drilling.

13. The government of Indonesia should consider the possibilities of external funding for geothermal exploration.

14. A comparison should be made between the long term cost of a geothermal project developed by a domestic developer and a project developed by foreign investors.

15. Both geothermal and coal resources should be developed in Indonesia, in order to distribute primary energy demand to various energy sources.

16. The benefits of an integrated development of geothermal fields (where responsibilities for the development of the field and construction of the power plant are vested in a single agency) should be considered carefully in comparison to the case where these two components are developed separately.

## Indonesian Assistance to Malaysian Geothermal Development

### Introduction

The occurrence of several hot springs in Sabah, especially on the Semporna peninsula, has aroused the interest of the Malaysian Geothermal Working Group to assess the possibility of the existence of geothermal resources. Geothermal missions DSIR New Zealand (1979) and UNDP (1984) have visited the Sabah geothermal prospects. Interest in possible utilization of the Sabah Malaysian geothermal resource was further stimulated by the ASEAN Geothermal Cooperation Meeting, where one of the resolutions was that the Malaysian Geothermal Working Group will continue with its present assessment of the Sabah geothermal potential, with assistance from the ASEAN member countries where required.

### First Mission From Indonesia

After the seventh ASEAN Geothermal Cooperation meeting, a geothermal mission of PLN visited the Sabah prospect from 26 to 31 March 1989. The visit was purely a (preliminary) data gathering exercise to assess the geothermal activity and to:

1. Advise on the planning and development of geothermal with respect to short, medium, and long term implications.

2. Advise on the present activities by the Malaysian Working Group on geothermal with respect to its deliverables and limitations.

3. Identify and advise on priority and work activities.

4. Provide technical advice on equipment for the initial surveys and studies to be conducted.

5. Provide advice on technical assistance and international financial assistance.

Past records indicated that the temperatures of the hot springs at Tawau Sabah were as high as 93°C and also the available geological and geochemical data suggest that the area has good potential for geothermal resources. Mr. Vincent T. Radja and the Malaysian Geothermal Working Group visited the Andrassy hot spring and found the "old steaming ground," which is the first such thermal phenomenon recorded in Sabah and which resembles that found in Kizildere, Turkey and Flores, Indonesia. The Malaysian Geothermal Working Group has made a detail investigation at Andrassy steaming ground, targeting it for an experimental project.

### Second Mission from Indonesia

The second mission from PLN was sent to Sabah from 23 September to 5 October 1989. Mr. James Simanjuntak, geochemist, helped the Malaysian Geothermal Working Group to evaluate the chemical characteristics of the geothermal reservoir of the Andrassy steaming ground. A complete set of water samples was analyzed. The temperatures as measured and calculated are shown below.

CHEMICAL GEOTHERMOMETER

Silica Geothermometer

| Sample | Location | Temperature Hotspring | Sub Surface Truesdel(1975) | Temperature Fournier(1971) |
|---|---|---|---|---|
| W-01 | Tawau | 50.3 C | 118.4 C | 118.9 C |
| W-02 | Andrassy | 75.6 C | 127.9 C | 130.2 C |
| W-03 | Andrassy | 72.2 C | 129.9 C | 132.6 C |
| W-09 | Andrassy | 69.0 C | 126.9 C | 128.9 C |
| W-14 | S. Jepun | 64.9 C | 106.8 C | 105.7 C |
| W-15 | S. Jepun | 64.1 C | 108.3 C | 107.2 C |

Na/K Geothermometer

| Sample | Location | Temperature Hot Spring | Sub Surface Truesdel(1975) | Temperature Fournier(1971) |
|---|---|---|---|---|
| W-01 | Tawau | 50.3 C | 168.4 C | 201.6 C |
| W-02 | Andrassy | 75.6 C | 191.9 C | 220.5 C |
| W-03 | Andrassy | 72.2 C | 193.1 C | 221.4 C |
| W-09 | Andrassy | 69.0 C | 189.6 C | 218.7 C |
| W-14 | S. Jepun | 64.9 C | 50.7 C | 99.3 C |
| W-15 | S. Jepun | 64.1 C | 49.9 C | 98.5 C |

Na-K-Ca Geothermal

| | | | |
|---|---|---|---|
| W-01 | Tawau | 50.3 C | 235.6 C |
| W-02 | Andrassy | 75.6 C | 254.6 C |
| W-03 | Andrassy | 72.2 C | 256.6 C |
| W-09 | Andrassy | 69.0 C | 255.7 C |
| W-14 | S. Jepun | 64.9 C | 127.4 C |

Surface activity in Andrassy and the S. Jepun areas is minor. Only the hot spring and mud pools in Andrassy and hot springs in the S. Jepun area are scattered around the hot area and seepages occur and come into the Apas Kiri and S. Jepun.

The water of the Andrassy hot springs contains high concentrations of chloride, sodium, bicarbonate and has a pH characteristic of neutral water. This is supported by subsurface temperatures estimated from the Na/K geotheromomter. The higher temperature springs are generally highest in Cl, Na, K, Li, and $SiO_2$ relative to surrounding ground waters. The geothermal system in the Andrassy area is hot water dominated.

The S. Jepun hot spring contains a high concentration of sulfate, and a relatively high concentration of calcium, sodium and bicarbonate, which are characteristic of acid sulfate water. The pH is near neutral and the elevation is low: perhaps heat comes to the surface from a far source along major fractures and comes into contact with ground water (water table about 4.5-12 m deep).

The Na/K and Na/K/Ca ratios indicate the Andrassy area is closely related to the heat source of the Tawau area at depth, but hot water of the Tawau springs has travel far from the source. The high bicarbonate concentration in the Andrassy area may be due to the water coming into contact with travertine deposits.

Using the silica geothermometer, the subsurface temperature in the Andrassy area is about 128°C, and by the Na/K geothermometer about 192°C (Truesdell, 1975) and 220°C (Fournier, 1981); by the Na/K/Ca geothermometer the average temperature is 255°C.

## ASEAN Cooperation on Geothermal Power Development

The focal point country is the Philippines. The previous meetings of the cooperation were held:

| | |
|---|---|
| 1st Meeting: | Quezon City, Philippines, March 24-25, 1982. |
| 2nd Meeting: | Manila, Philippines, February 1-6, 1983. |
| 3rd Meeting: | Chiang Mai, Thailand, November 7-11, 1983. |
| 4th Meeting: | Bandung, Indonesia, April 30 - May 4, 1984. |
| 5th Meeting: | Leyte & Negros Oriental, Philippines, November 26-29, 1985. |
| 6th Meeting: | Tawau, Sabah, Malaysia, November 23-25, 1987. |
| 7th Meeting: | Bandung, West Java, Indonesia September 27-29, 1988. |
| 8th Meeting: | Chiang Mai, Thailand, December 12-15, 1989. |
| 9th Meeting: | Bagio, Philippines, Scheduled for June 1990. |

The highlights of the 7th ASEAN Geothermal Cooperation Project (AGCP) Meeting held in Bandung, Indonesia were as follows:

1. Delegates from Indonesia, Malaysia, Thailand and the Philippines attended the meeting. Resource speakers from ORMAT (USA), GENZL (New Zealand) and Mitsubishi (Japan) also participated in the meeting.
2. Indonesia, Malaysia, Thailand and the Philippines presented their respective country status report on geothermal power development.
3. The following technical papers were presented at the meeting:

   Small Sized Geothermal Power Plants (Philippines)

   PRIMO SOFTWARE on Geothermal Policy Pricing (Philippines)

   Kamojang Geothermal Power Station Units 2 and 3 (2 x 55 MW), West Java, Indonesia.

   ORMAT's Modular Binary Moderate Temperature Geothermal Power Plants (USA).

   Small Capacity Portable Turbine to Large Capacity Modular Turbine (Mitsubishi-Japan).

On the same occasion, the first meeting of the Ad-Hoc Study Team on Small Sized Geothermal Power Plants was held/organized. As with the Cooperation Project on Geothermal Power Development, the Philippines was appointed as the coordinator (focal point country) due to their experience and technical capabilities in the development of geothermal power derived from the construction and operation of geothermal power plants with a capacity of 895 MW, which is the second largest installed capacity in the world after the USA. The highlights of the meeting were as follows:

Small sized geothermal units were standardized at 1 MW, 3 MW and 5 MW capacities, either condensing or noncondensing, to lower the cost of manufacturing and to improve spare-parts availability.

The operating pressure of the wellhead and plant turbine was considered as the focal point based on existing conditions in the Philippines and Indonesia.

On 17 January 1989, the final specifications for (1) noncondensing, (2) condensing, (3) biphase, and (4) binary cycle turbine generator units for standard 3 and 5 MW geothermal units, including smaller capacities (less than 1 MW), were submitted by NPC to the respective heads of the ASEAN utilities.

The delegates to the meeting adopted the following resolutions between AGCP member countries:

1. A commitment to establish the ASEAN Geothermal Research Center in the Philippines, as adopted at the last AGCP meeting.
2. Information sharing on nonelectric direct-use of geothermal energy.
3. The Malaysian Geothermal Working Group will continue with its present assessment of Sabah geothermal potential with the assistance of other ASEAN member countries, as required.
4. Cooperation between member countries in various aspects requiring international assistance and financing for geothermal power development project within the ASEAN region.

5. Formulation of Environmental Impact Assessments (EIAs) covering geothermal development and consideration of base-line-data gathering as essential input for determination of new geothermal potential areas.

6. Sharing of computer software and tools for the economic evaluation of geothermal development currently available in the Philippines, subject to formal approval of ADB. The participants agreed to request ADB to organize a seminar on geothermal pricing policy.

7. The next meeting of the ASEAN Geothermal Cooperation Project, to be held in the Philippines next year, will concentrate on steam pricing. This agenda was suggested by the Indonesian delegation.

8. The Ad-Hoc Study Team on Small Sized Geothermal Power Plants approved the draft presented by NPC during the last meeting.

**Participation in International Geothermal Seminars**

Papers were submitted to the following meetings:

Sixth Conference on Electric Power Supply Industry (CEPSI) November 3-7, 1986, Jakarta, Indonesia: The role of ASEAN geothermal generation in the world geothermal scenario.

First UNITAS/UNDP Workshop on Small Geothermal Resources, May 11-22, 1987, Pisa, Italy: Mini Geothermal Power Plant Development in Indonesia.

Third National Energy Seminar, July 21-23, 1987, Jakarta, Indonesia: 20 Years of Geothermal Development in Indonesia and its Problems.

Indonesian Geothermal Development Seminar March 1, 1990, Jakarta, Indonesia.

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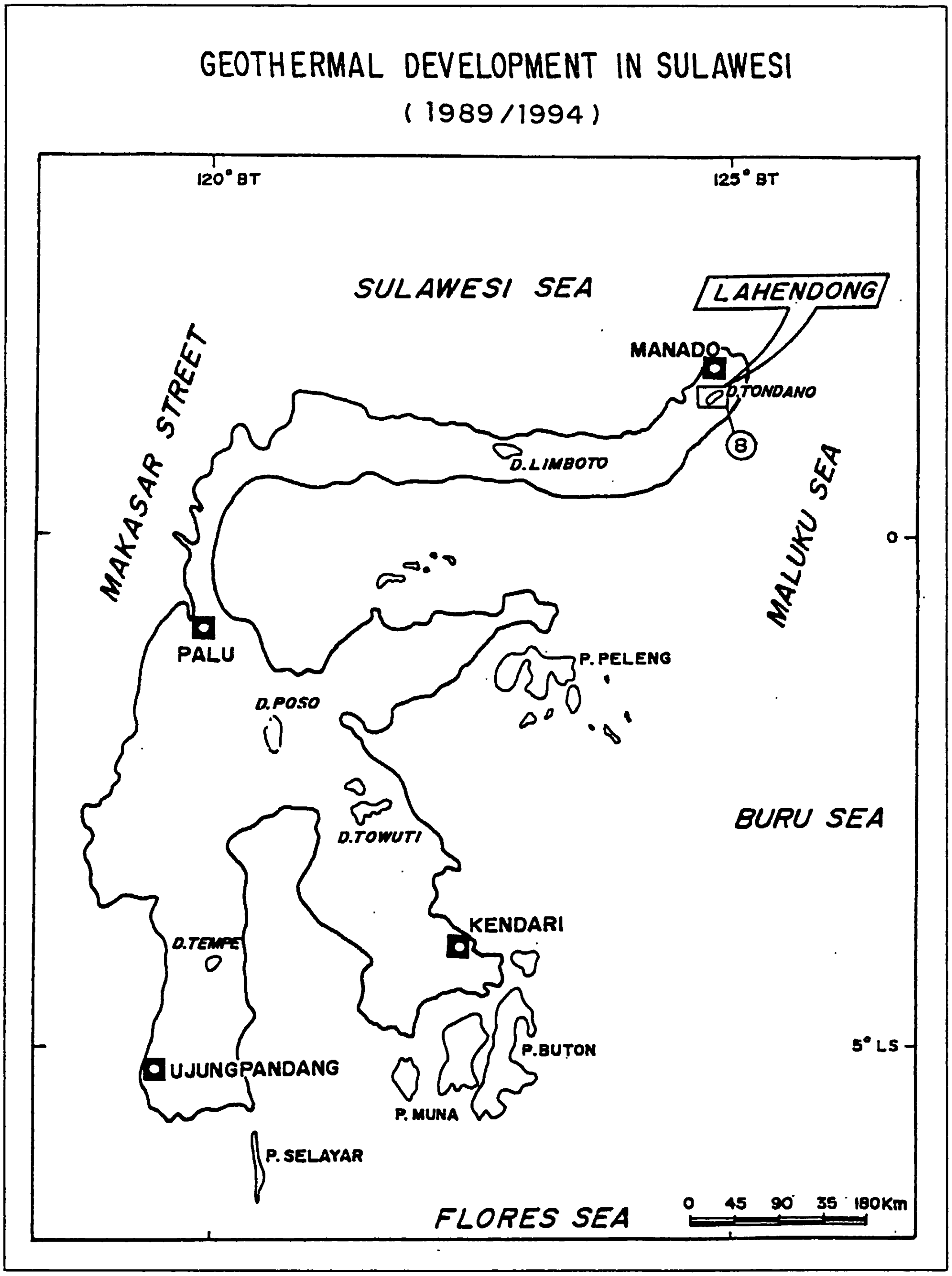
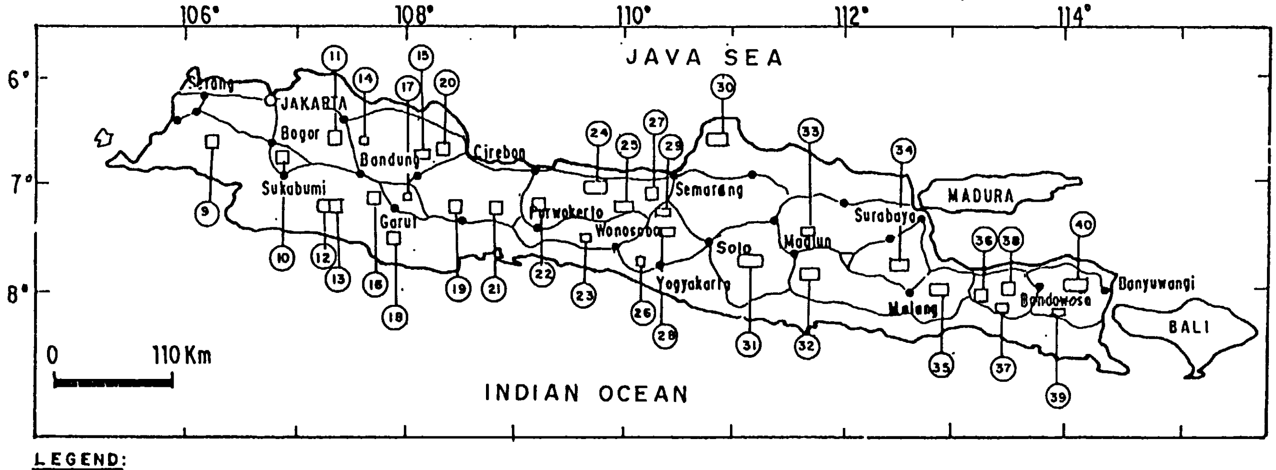

GEOTHERMAL DEVELOPMENT IN SULAWESI
( 1989/1994 )
120° BT
125° BT
SULAWESI SEA
LAHENDONG
MANADO
D.TONDANO
8
D.LIMBOTO
MAKASAR STREET
MALUKU SEA
0
PALU
P. PELENG
D.POSO
BURU SEA
D.TOWUTI
KENDARI
D.TEMPE
5° LS
P.BUTON
UJUNGPANDANG
P. MUNA
P. SELAYAR
FLORES SEA
0 45 90 35 180Km

STATUS - GEOTHERMAL EXPLORATION IN SUMATRA (1989/1990)


STATUS - GEOTHERMAL EXPLORATION IN JAVA (1989/1990)




LEGEND:

9. ENDUT
10. Gn.GEDE PANGRANGO
11. Gn.SANGGABUANA
12. Gn.PATUHA
13. Gn.WAYANG-WINDU
14. Gn.TANGKUBANPERAHU
15. Gn.TAMPOMAS
16. CIHARUS
17. Kw.KARAHA
18. CILAYU-BUNGBULANG
19. Gn.SAWAL/CITANDUY
20. Gn.CIREME
21. DANTARKAWUNG
22. Gn.SLAMET
23. KEBUMEN
24. DIENG UTARA
25. Gn.SINDORO
26. PURWOREJO
27. Gn.UNGARAN
28. Gn.TELOMOYO
29. Gn.MERBABU
30. Gn.MURIA
31. Gn.LAWU
32. Gn.WILIS
33. Gn.PANDAN
34. Gn.ARJUNO-WELIRANG
35. Gn.BISMO
36. Gn.LAMONGAN
37. Gn.SEMERU
38. Gn.IYANG ARGOPURO
39. Gn.RAUNG
40. Gn.IJEN

1 SURVEYING
2 SURVEYS COMPLETED
3 DRILLABLE
4 UNDRILLABLE

TABLE 1 - PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

| | Geothermal | | Fossil Fuels | | Hydroelectric | | Nuclear | |
|---|---|---|---|---|---|---|---|---|
| | Capacity $MW_e$ | Utilization GWh/yr | Capacity $MW_e$ | Utilization GWh/yr | Capacity $MW_e$ | Utilization GWh/yr | Capacity $MW_e$ | Utilization GWh/yr |
| In operation January 1990 | 142.25 | | 2186 | | 2012.5 | | | |
| Under construction January 1990 | 110 | | 131 ? | | 201 | | 30 | |
| Funds committed, but not yet under construction January 1990 | 127.5 | | 2012 ? | | 343 | | | |
| Total projected use by 1995 | 379.75 | | 4329 | | 2556.5 | | 30 | |

TABLE 2A - UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRICAL GENERATION IN DECEMBER 1989

| Locality | Power plant name | Year | No. of units | Status | Type of unit | Unit Rating (MWe) | Total installed capacity Dec. 89 | Total Under Const. or planned |
|---|---|---|---|---|---|---|---|---|
| West Jawa | Kamojang Unit:1 | 1983 | 1 | U | C | 30 | | |
| | Unit:2,3 | 1988 | 2 | U | C | 110 | | |
| | Kamojang Monoblock | 1979 | 1 | U | B | 2 | | |
| Central Jawa | D i e n g Monoblock | 1982 | 1 | U | B | 0.25 | | |
| SUBTOTAL FOR LOCALITY | | | 5 | | | 142.25 | | |
| GRAND TOTAL OF ALL LOCALITIES | | | | | | | | |

Notes : U = Comercial Utilization

C = Condensing Unit

B = Back Pressure Turbine

TABLE 3 - INFORMATION ABOUT GEOTHERMAL LOCALITIES

Rock[1] = Main type of reservoir rock.

Water[2] = Total dissolved solids, in mg/kg, before flashing. Put v for vapor dominated.

Status[3]
- N = Identified geothermal locality, but no assessment information available
- R = Regional assessment
- P = Pre-feasability studies
- F = Feasability studies (reservoir evaluation and engineering studies)
- U = Commercial utilization

| Locality | Location To Nearest 0.5 Degree | | Reservoir | | Status[3] in January 1990 | Reservoir Temp. °C | |
|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | Rock[1] | Water[2] | | Estimated | Measured |
| Kamojang | 7° 8' | 107°47' | Andesite | V | U | 246 | 248 |
| D i e n g | 7° 12' | 109°53' | Diorite | | F | 325 | 280-320 |
| S a l a k | 6° 43' | 106°40' | Andesite | | F | 260 | 235 |
| Darajat | 7° 14' | 107°43' | Andesite | V | F | 241 | 243 |
| Lahendong | 1° 15' | 124°48' | Andesite | | F | 230 | 302-333 |
| Lempur (Kerinci) | 2° 12' | 101°20' | Andesite | | F | > 200 | 224 |
| Ulumbu | 8° 42' | 120°27' | Andesite | | P | > 260 | ? |
| Cisolok | 6° 53' | 106°25' | | | R | | |
| Banten (Pulos) | 6° 20' | 106°58' | | | R | | |

TABLE 4 - WELLS DRILLED FOR ELECTRICAL UTILIZATION OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1985 TO JANUARY 1, 1990
(Do not include thermal gradient wells less than 100 m deep)

Type of well*
T = Thermal gradient or other scientific purpose P = Production
E = Exploration I = Injection

| Locality (Footnote for comments) | Year Drilled | Well Number | Type of* Well | Total Depth (meters) | Maximum Temp. °C | Flowing Enthalpy kJ/kg | Flow Rate kg/s |
|---|---|---|---|---|---|---|---|
| Kerinci (Lempur) | 1983 | LP-1* | E | 1005 | 96 | 632 | 3.9 |
| | 1988 | LP-2 | E | 1026.5 | 224 | 2749 | 11.4 |
| Lahendong (Vulc.Survey of Indonesia) | 1986 | LH-3 | E | 584 | 230 | 2754 | 1.6 |
| Lahendong (PERTAMINA) | 1985 | LHD-4 | E | 2307 | 290 | 2050 | 27.5 |
| | 1986 | LHD-5 | E | 1897 | 251 | 1105 | 52.7 |
| | 1987 | LHD-7 | E | 2200 | 156 | - | - |
| D i e n g | 1985 | DNG-11 | E | 2431 | 279 | - | - |
| | 1986 | DNG-12 | E | 2104 | 326 | - | - |
| | 1986 | DNG-13 | E | 1853 | 256 | 2146 | 21.2 |
| Darajat | 1987 | DRJ-4 | E | 1592 | 243 | 2783 | 22.5 |
| | | DRJ-5 | E | 2585 | 239 | 2705 | 1.02 |
| | | DRJ-6 | E | 1822 | - | - | - |
| | 1988 | DRJ-7 | E | 1975 | 241 | 2776 | 24.6 |
| S a l a k | 1985 | AWI-7 | E | 1402 | 255 | 1190 | 115 |
| | | AWI-8 | E | 1483 | 280 | 1225 | 280 |
| | | RTU-3 | E | 2606 | 260 | 1135 | 124 |
| K a m o j a n g | 1974 | KMJ-6 | E | 616 | 238 | 2774 | 1.7 |
| | 1975 | KMJ-7 | E | 536 | 230 | 2778 | 1.4 |
| | | KMJ-8*) | E | 640 | - | - | - |
| | | KMJ-9*) | E | 763 | - | - | - |
| | | KMJ-10*) | E | 763 | - | - | - |
| | 1976 | KMJ-11 | P | 1029 | 245 | 2779 | 25 |
| | 1977 | KMJ-12 | P | 1506 | 244 | - | 5.6 |
| | | KMJ-13 | P | 1500 | 241 | - | 1.4 |
| | | KMJ-14 | P | 1000 | 244 | 2771 | 18 |
| | 1978 | KMJ-15 | P | 1800 | 246 | - | - |
| | | KMJ-16*) | P | 1278.5 | - | - | - |
| | | KMJ-17 | P | 1067.5 | 244 | 2774 | 19 |
| | 1979 | KMJ-18 | P | 935 | 241 | 2792 | 35 |
| | | KMJ-19 | E | 1354 | 234 | - | - |
| | | KMJ-20 | P | 1254 | 232 | - | 4.2 |
| | 1981 | KMJ-21 | E | 2021 | 245 | 2779 | 3.9 |
| | | KMJ-22 | E | 1223 | 245 | 2765 | 25 |
| | | KMJ-23 | E | 1545 | 245 | - | 6.9 |

Notes : * = Abandoned

(continued)

TABLE 4 - WELLS DRILLED FOR ELECTRICAL UTILIZATION OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1985 TO JANUARY 1, 1990 (continued)

(Do not include thermal gradient wells less than 100 m deep)

Type of well*
T = Thermal gradient or other scientific purpose
E = Exploration
P = Production
I = Injection

| Locality (Footnote for comments) | Year Drilled | Well Number | Type of* Well | Total Depth (meters) | Maximum Temp. °C | Flowing Enthalpy kJ/kg | Flow Rate kg/s |
|---|---|---|---|---|---|---|---|
| Kamojang | 1982 | KMJ-24 | E | 2200 | 241 | 2771 | 12 |
| | | KMJ-25 | E | 1833 | 243 | 2769 | 11 |
| | 1983 | KMJ-26 | P | 1300 | 245 | 2772 | 25.6 |
| | | KMJ-27 | P | 1245 | 245 | 2781 | 26.7 |
| | | KMJ-28 | P | 1217 | 245 | 2771 | 18.6 |
| | | KMJ-29 | P | 1194 | 244 | - | 10 |
| | | KMJ-30 | P | 1200 | 239 | 2774 | 13 |
| | | KMJ-31 | P | 1300 | 245 | 2787 | 13 |
| | | KMJ-32 | P | 1925 | 235 | - | - |
| | 1984 | KMJ-33 | P | 1399 | 233 | - | - |
| | | KMJ-34 | P | 1129 | 248 | 2762 | 18 |
| | | KMJ-35 | P | 1251 | 244 | 2761 | 9 |
| | | KMJ-36 | P | 1250 | 246 | 2777 | 33 |
| | | KMJ-37 | P | 1330 | 245 | - | - |
| | | KMJ-38 | P | 1441 | 237 | 2781 | 11 |
| | | KMJ-39 | P | 1400 | 242 | 2781 | 7 |
| | | KMJ-40 | P | 1437 | 244 | - | - |
| | 1985 | KMJ-41 | P | 1275 | 245 | 2780 | 26 |
| | | KMJ-42 | P | 1427 | 243 | 2779 | 18 |
| | | KMJ-43 | P | 1156 | 242 | - | 15 |
| | | KMJ-44 | P | 1299 | - | - | - |

TABLE 6 - ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES
(Restricted To Personnel With A University Degree)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

| Year | ( Professional Man Years of Effort ) | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| 1985 | 25 | 25 | 5 | 6 | - | - |
| 1986 | 10 | 10 | 5 | 20 | - | - |
| 1987 | 10 | 10 | 5 | 20 | 1 | - |
| 1988 | 10 | 10 | 5 | 20 | - | - |
| 1989 | 10 | 10 | 5 | 8 | - | - |
| TOTAL | 65 | 65 | 25 | 74 | 1 | - |

(4) 1985 : GENZL (New Zealand) : Kamojang
1986 : WEST JEC (Jepang) : Dieng
ELC (ITALI) : Salak
GENZL (New Zealand) : Kamojang

1987 : WEST JEC : Dieng
ELC : Salak
GENZL : Kamojang

1988 : WEST JEC : Deing
ELC : Salak
GENZL : Salak
NIPON KOEI : ADD Financing : Nusatenggara

1988 : Enersystem (France) : Lahendong
(France) : Nusatenggara
Trans ening :

(5) 1985 -
1986 -
1987 - UNDP
1988 -
1989 -