Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Geothermal Development in Papua New Guinea a Country Update Report 2005-2009

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Keywords: Lihir, Papua New Guinea

ABSTRACT

Lihir Island is located about 700 kilometers northeast of the capital of Papua New Guinea, Port Moresby (Figure 1). Gold ore was discovered on the island in 1982, and gold production began in May 1997 by Lihir Gold Ltd (LGL).

The Lihir gold mine project is located in an area with abundant geothermal energy. In 2001, LGL contracted with Geothermal Development Associates (GDA) to design and supply a 6 MW non-condensing geothermal plant. The installation was commissioned in April 2003. In July 2003, LGL contracted GDA to supply a 30 MW, single flash, condensing geothermal unit that was commissioned in mid 2005. Due to the success of the two plants, LGL contracted with GDA again in 2005 to add a 20 MW extension, which was commissioned in February 2007. This increased the mine's total geothermal capacity to 56MWe - approximately 75 percent of total electrical power required by LGL in 2007.

Geothermal power provides significant cost savings for LGL compared to heavy fuel oil powered generation. The geothermal plants have also been formally certified as facilities that reduce greenhouse gas emissions, enabling LGL to generate carbon credits and sell them on global markets. Drilling to assess the potential for additional steam reserves for further geothermal power generation is ongoing.

Presently PNG government agencies are establishing policies and programs which are aimed at encouraging the diffusion of new and affordable renewable energy technologies, one of them being geothermal energy. However, at present, there are no other recorded geothermal power projects planned elsewhere in PNG.

1. INTRODUCTION

Papua New Guinea is a nation of some 600 islands located in the South Pacific, north of Australia and east of Indonesia, and having a land area of 453,000 square kilometers. It is inhabited by nearly 5.3 million people having a cultural base including more than 800 languages and ethnic groupings.

Total electricity production in 2002 was 781.4 GWh, derived from hydro (65 percent, 512.7 GWh) and fossil fuels (35 percent, 268.7 GWh). There were no imports or exports of electricity (Hairai, 2004). Tariff rates for electricity are low, so renewable energy for power generation is not widely used. The average cost of producing a kWh of electricity in PNG, derived from the PNG Electricity Commission's hydro plants, is US$ 0.021, while for diesel oil plants it is US$ 0.1750 - over eight times more expensive (Hairai, 2004).

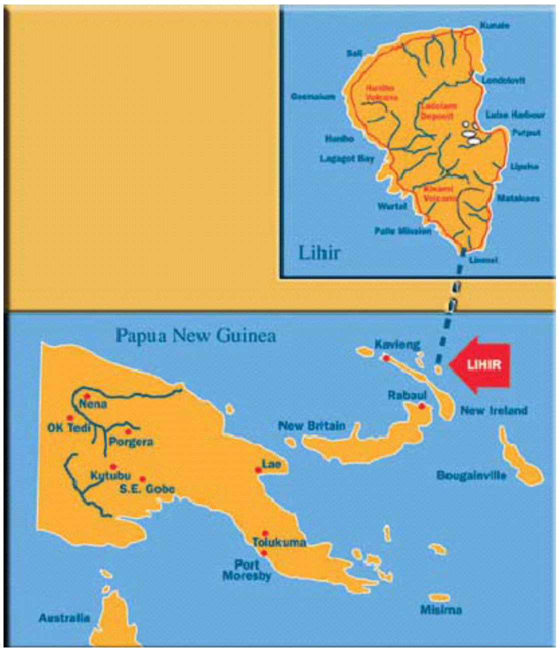

Figure 1: Location of Lihir Island

About 90 percent of the population lives in rural areas, of which only 5 percent have electricity, mostly from diesel generators. (Mongillo, 2004). Private electricity generation by some industries for their own use (e.g. West New Britain Palm Oil and the Lihir gold mining project) exists. There are also several smaller privately owned power generation facilities (Mongillo, 2004).

Geothermal energy development for power generation in Papua New Guinea is presently restricted to the 28-square kilometer Lihir Island, which is part of New Ireland Province, located about 700 km northeast of the national capital, Port Moresby (Figure 1). The first use of geothermal energy for power generation was realized in April 2003, when Lihir Gold Ltd brought on-line a 6 MW backpressure unit, designed and supplied by Reno, Nevada-based Geothermal Development Associates, to support their gold mining and processing operations which produce over 600,000 ounces of gold each year. At that time, Lihir Gold Ltd's major shareholders were Rio Tinto plc, the Papua New Guinea Government, Niugini Mining Ltd and Vengold (Lihir Gold Ltd, 2004).

With respect to national policies, the national government has jurisdiction over energy matters. The generation, transmission, distribution, and sale of electricity are controlled by the PNG Electricity Commission (Elcom), which was incorporated in July 2002, and is now referred to as PNG Power Limited (Hairai, 2004; Mongillo, 2004). The Department of Finance and Treasury is responsible for setting prices or tariffs for electricity. The provincial governments work with PNG Power, and the Energy Division of Department of Petroleum and Energy as well as with private companies to organize new projects such as grid extensions or development of hydro or other renewable resources.

The Energy Division of the Department of Petroleum and Energy implements policies and programs which are aimed at encouraging the diffusion of new and affordable renewable energy technologies. It also works closely with PNG Power to increase the available amount of electricity. PNG's Rural Electrification Policy is aimed at improved rural access to electricity.

2. GEOLOGIC BACKGROUND

Papua New Guinea lies within a complex and active tectonic region of numerous plate boundaries, several microplates, and many areas undergoing active deformation (Tregoning, 2000). An active volcanic environment, common in nearby Indonesia and Philippines, exists on a number of the islands.

Lihir Island is made up of five Miocene-Pleistocene age volcanic units, of which three are recognizable volcanic craters. Luise Caldera is the youngest major volcanic center on the island (White and Others, 2003). The geothermal resource is located within and to the north of the Luise Caldera, which is a gravity collapse structure on the east coast of the island. The Luise Caldera rim rises to about 600 meters above sea level. The central area of the collapse structure is approximately 100 meters above sea level.

3. GEOTHERMAL RESOURCES AND POTENTIAL

The main geothermal resource on the Lihir Island is located within the Luise Caldera. However, recent geophysical studies indicate the possible extension of the resource further to the north and northwest outside the caldera rim. To date about 40 geothermal wells have been drilled.

Shallow temperature exploration wells were drilled down to 200-300m depths in the early to mid eighties to investigate the viability of open pit mining. Extensive testing of the shallow aquifer near the planned mine area was done during this time.

In 1999 eight deep geothermal wells were drilled and fitted with standard 9-5/8" production casings and 7" slotted liners. Because of restricted access due to mining operations, and to keep the wellheads outside the pit boundaries, all the initial wells were drilled directionally from two drill pads located on the southwest corner of the mining area.

The wells were drilled from the edge of the mine, under the bottom of the Minifie and Lienetz pits, to determine permeability and temperature at depth and to establish whether such wells could successfully intercept the recharge flows into the bottom of the pit. Measured well depths ranged from 1260m to 1790m with true vertical depths ranging from 1120m to 1400m. This deep drilling program helped to characterize the deep pressure profile and define the area of high temperature upflow.

Three of the wells (drilled northwards) encountered highly permeable zones and are large producers. Three additional wells (drilled southwards) produced at lower flow rates. The well fluids have high pH and high levels of chlorides and sulphates. Separated water at atmospheric pressure has a pH of about 9, a chloride concentration of 30,000 ppm and a sulphate concentration of 40,000 ppm. Non-condensable gas content of the reservoir fluid is about 0.6% by weight of which 98% is CO2.

The high mineral content of the fluids resulted in calcite deposition in the wellbore and silica scale in the discharge pipelines. Due to the severity of the calcite deposition, some of the wells could only sustain discharge for a period of several months before the wellbore became blocked by the deposition. The successful deep producers tapped liquid conditions at about 250°C at vertical depths of about 1,000 meters. Maximum temperatures of more than 300°C were measured at 1,000 meters depth in the deep wells drilled toward the western margin of the caldera (Bixley 2003).

Scale inhibitor trials were conducted on two wells. The results of the trials indicated more work was necessary before these wells could be used for long-term steam production.

Following the deep drilling program, close to twenty intermediate-depth wells (400-800m) were drilled within the pit boundaries in order to accelerate the cooling and depressurization of the mine. Most of these wells encountered high temperature fluids and produced steam that was suitable for power generation.

The down-hole temperatures in these intermediate depth wells were close to boiling from depths of about 200 meters down to 700 meters. These wells produce higher enthalpy fluids and have less scaling and rundown behavior than the deeper wells.

Due to the favorable fluid characteristics, certain wells were selected for power generation. The productive wells have temperatures of approximately 240° to 250°C, with several wells having a potential to produce more than 10 MW equivalent (Bixley, 2003).

The first 6MW geothermal power plant was connected to four of these wells to supply the required steam. The wells selected for power generation were drilled as depressurization wells and are outside the current pit area. However, some of the production wells and the plant had to be relocated as the pit expanded.

4. GEOTHERMAL UTILIZATION

Lihir is an island and therefore not connected to a larger power grid system. Power is generated solely for the Lihir Gold Ltd mine, process plant, and associated infrastructure – camps, offices, housing and local villages. Of the total 55 MW load, 30MW is required for the oxygen plant, with some other large individual uses being the ball mills and mine dewatering. Less than 5 percent of the total load is used offsite. The original generation plant was comprised of eleven 6 MW heavy fuel oil generators. With the commissioning of the geothermal plants, an additional 56MW of geothermal generation has been realized.

On New Britain Island, also within the volcanic archipelago, low enthalpy geothermal heat is sometimes used to boil megapod (local fowl) eggs, and the megapods themselves use the hot ground in volcanic areas to incubate their eggs. The eggs are harvested by the local population – creating something of a tourist attraction. During World War II, at Rabaul on the north end of the island, the Japanese used the hot springs for bath houses, and using oil drums split lengthwise, evaporated sea water for the salt using a combination of the hot springs and solar heat (Saunders, 2004).

Recent Status

The 6MW backpressure unit has been in operation since May 2003. Part of the 6 MW strategy was to use this plant to confirm the viability of using geothermal steam for power generation in the mining environment before considering larger scale geothermal development.

The steamfield for the 6MW plant was composed of four wells connected to a common header delivering fluid to a cyclone separator with a bypass to atmospheric vent silencer. The separated steam was piped to the turbine through a main steam line. A steam scrubber was used to remove any carryover in the steam. The power plant is composed of a 6MW conventional steam turbine and generator set producing power at 11kV.

The plant has been operating reliably since commissioning. Except for shutdowns caused by external factors, the plant has been operating at greater than 95% availability.

While the 6 MW plant was still under construction, a feasibility study for an additional 30 MW of geothermal capacity was carried out. Also at this time the final geothermal depressurization wells were being completed with an average power generating potential of approximately 10MW each. In July 2003 approval was given to proceed with an additional 33 MW (gross)/30 MW (net) geothermal power facility with a provision for expansion to 50 MW. The 30 MW plant was constructed and commissioned in early 2005. Soon after completion of the 30MW plant, work started on the planning of a further 20MW plant that was completed and commissioned in 2007.

Steam for the power plants was supplied by the intermediate depth wells located on the margins of the existing mine pit. These wells were originally drilled as depressurization wells. However, because of their high productivity they were re-categorized for power generation. It was expected that steam from some of these wells would be affected as they fall within the mine pit area as mining expands outwards. Make-up wells would be planned and drilled ahead of time to ensure that the power plant is supplied with sufficient steam.

Computer models of the geothermal reservoir are updated on an ongoing basis to determine the optimum fluid withdrawal rate that will enable sufficient depressurization in the shallow aquifer for safe mining and ensure a sustainable steam supply for power generation.

Currently LGL is carrying out exploration work to prove additional reserves that will enable generation of geothermal power to support all the power requirements of the mine operation. A geophysical study was carried out in early 2004 to define the northern and western boundaries of the geothermal resource. Based on the results of the geophysical work, a slim-hole geothermal drilling program was launched to accurately define the extent of the geothermal resource and its potential for power generation.

Based on experience at other geothermal sites, given a reliable long-term source of steam, it's been proven that geothermal power can be provided more efficiently and cheaply than hydrocarbon- based power.

Considering the future power requirements at Lihir, it is evident that geothermal power is likely to play a major role in supporting the power needs of the mine operation and process plant with reduced carbon emissions. The ultimate goal is to prove sufficient geothermal reserves and replace all the remaining heavy fuel-oil fired power plants.

5. DISCUSSION AND SUMMARY

On Lihir Island, upon completion of the Lihir Gold Ltd deep drilling program, a feasibility study for geothermal power generation showed that a relatively-small, backpressure pilot plant, using steam produced from the deep wells, was a viable option, as long as wellbore scaling could be controlled. Continued drilling and well testing showed that geothermal resources from medium-depth production wells drilled to the north of the mine pit would be a better option than using deep production wells as there would be reduced or no scale inhibitor required for the production wells.

Approval to proceed with the supply of the 6 MW unit was given in June 2002. The power generation package designed and supplied by Geothermal Development Associates (GDA), including unused, modified, GE naval turbines with a new gearbox, electrical and associated components, was chosen ahead of a more modern plant, as it had significant timing and cost advantages. The plant was commissioned in May 2003, less than 12 months following contract signature. Soon after commissioning, it was estimated that the 6MW geothermal plant would save Lihir about $2,000,000 per year in fuel oil costs (Lihir Gold LTD, 2003).

In 2000, electricity sales for the country were 698.2 GWh. Growth was forecast to be 2.9 percent per annum over the following 10 years. Demand was anticipated to be 934 GWh in 2010, according to PNG Power (Mongolia, 2004).

As a result of a preliminary comparison, it appears that PNG has geological and geothermal settings comparable to those of the Philippines and Iceland. Thus it was concluded PNG may have 3,000 to 4,000 MWs of geothermal power generation potential (Hairai, 2004).

The development of renewable energy resources to replace fossil fuels, wherever economically justified, is a major objective of PNG Power Ltd. However, the emphasis, technical know-how and investment capital for these projects is not as evident as many people would like. (Hairai, 2004).

6. ACKNOWLEDGEMENTS

We would like to thank Lihir Gold LTD and Lihir Management Company LTD for their support to publish this paper, and Peter Hair of PNG Power LTD, Dr. M. A. Mongolia of Geo-Imaging Services LTD, and Steve Saunders of the Rabble Volcano Observatory for their invaluable input.

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TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2009

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash B = Binary (Rankine Cycle)
2F = Double Flash H = Hybrid (explain)
3F = Triple Flash O = Other (please specify)
D = Dry Steam

3) Data for 2009 if available, otherwise for 2008. Please specify which.

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe	Annual Energy Produced 2009[3)] GWh/yr	Total under Constr. or Planned MWe
PNG	Lihir 6	2003	1	OK	1F	6		
PNG	Lihir 30	2005	3	OK	1F	33		
PNG	Lihir 20	2007	2	OK	1F	22		
Total						61		

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PNG	Lihir 30	2005	3	OK	1F	33		
PNG	Lihir 20	2007	2	OK	1F	22		
Total						61		