

PHASES OF GEOTHERMAL DEVELOPMENT IN THE PHILIPPINES

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ABSTRACT

The Philippines lies in the Circum-Pacific rim of volcanic systems and has an abundance of geothermal resources that can be commercially developed. The country presently has a total installed geothermal power capacity of 1,905 MW and now ranks second in the world next to the United States. An aggressive geothermal exploration and development program was formulated following the energy crisis of the 70s. Philippine Geothermal, Inc. (PGI), a private company, and PNOC Energy Development Corporation, a government owned and controlled corporation, undertook the exploration and development of known geothermal areas. PGI now operates 756 MW of geothermal steam field capacity while PNOC EDC operates 1,149 MW.

The exploration, development and utilization of geothermal resources in the Philippines is governed by Presidential Decree (P.D.) 1442, or the Geothermal Service Contract Law. Developers must enter into a Geothermal Service Contract with the Department of Energy (DOE). Geothermal projects undergo pre-feasibility stage consisting of the definition and reconnaissance evaluation phase, detailed exploration phase and exploratory drilling and delineation phase. The feasibility stage follows, to assess the extent of the resource and establish the potential for development. The feasibility study proposes a development strategy, estimates investment and maintenance and operating costs, evaluates economic and financial viability considering market and price of geothermal energy, and addresses regulatory matters and environmental issues. At this point, an Environmental Impact Assessment is prepared; this becomes the basis for the issuance of the Environmental Compliance Certificate (ECC) by the Department of Environment and Natural Resources (DENR). Upon availability of financing, the project goes into the implementation phase during which production and reinjection wells are drilled, the fluid collection and reinjection system of pipes and control instrumentation are installed. Parallel implementation of the geothermal power plant is pursued with the implementation of field development. The steam production and resource management phase is important in sustaining the capacity of the resource over the long term. This phase has become a challenge for PNOC EDC because of its contractual obligations on the supply of geothermal steam and/or electricity. In the course of its experience in the operation of 1,149 MW of geothermal production fields, PNOC EDC has made innovations on resource management to sustain generation capacity. Project implementation can be delayed by lack of funds to drill deep exploratory wells, and by the delayed issuance of an ECC for projects in protected areas like National Parks.

1. INTRODUCTION

The Philippines lies in the volcanic belt known as the Circum-Pacific rim of fire. A considerable number of high quality geothermal resources can be found in the country. The geothermal fields drilled to date are liquid dominated in the natural state, with maximum temperatures in the high range of 300 to 340°C. The most exploitable of these systems are found in mature volcanic complexes which have reacted out their acidic volcanic gases over geologic time. A number of younger volcanic systems are still influenced by acid gases and are considered non-exploitable within the limits of today's technologies.

Philippine geothermal fields are all associated with volcanism developed above trench and subduction zone systems. From north to south, these major trench systems and volcanic belts include the following: a) the Manila trench lying to the west of Luzon with an associated on-shore volcanic belt ranging from the Cordilleras in northern Luzon to Mt. Mariveles west of Manila; b) the Philippine trench running parallel to the eastern coasts of Luzon, Samar and Leyte which defines several major onshore volcanic belts which host the biggest geothermal developments in the Philippines; c) the Negros trench to the west of Negros Island which also defines a volcanic belt composed of the mature and dissected volcanic complex of Cuernos de Negros in southern Negros, and the active Canlaon volcano in northern Negros; and, d) several trench and subduction zones in Mindanao, the most significant of these systems is an extension of the Sangihe volcanic arc from Indonesia northwards into central Mindanao..

The first area to be explored was the Tiwi geothermal area in southern Luzon. In 1970, the National Power Corporation (NPC), the state-owned electric utility firm, was given the responsibility of administering the exploration and development of Tiwi. Because it needed technical expertise and financial support, NPC entered into a contract with Philippine Geothermal, Inc. (PGI), a subsidiary of Union Oil Company of California, to develop Tiwi, and later on, the Makiling-Banahaw (Mak-ban) geothermal area south of Manila. NPC also initiated the exploration of the geothermal areas of Tongonan in Leyte and Palinpinon in southern Negros with the assistance of consultants from New Zealand.

In 1976, the Philippine government, through the Philippine National Oil Company (PNOC), created the subsidiary company, PNOC Energy Development Corporation (PNOC EDC), to take over the exploration and development functions of NPC in the Tongonan and Palinpinon geothermal fields. PNOC EDC would then become the government's arm in implementing a national geothermal program. NPC would still be responsible for the power generation side and would become the buyer of geothermal steam.

The Geothermal Service Contract Law, or Presidential Decree 1442, was promulgated in 1978 to govern and regulate geothermal exploration, development and utilization activities. A developer or investor must enter into a Geothermal Service Contract with the Bureau of Energy Development of the Ministry of Energy (now the Department of Energy), the implementing arm of the government. Under the Geothermal Service Contract, the contractor will provide the necessary expertise, technology and financing to explore, develop and utilize the geothermal resource.

In 1990, Executive Order 215 (E.O. 215) was issued, which effectively removed NPC's monopoly in power generation and allowed the participation of the private sector in the construction, ownership and operation of power plants. EO 215 facilitated the entry of independent power producers (IPPs) into geothermal power generation through Build-Operate-Transfer (BOT) contracts or similar arrangements.

With over 20 years of experience in geothermal development and power generation, the geothermal industry in the Philippines is now in a mature state. The installed geothermal power capacity, by mid-2005, has already grown to 1,905 MW (refer to Table 1). In 2004, geothermal accounted for 14% of

the country's generated electricity. Only two geothermal resource developers, PGI and PNOC EDC (refer to Figure 1 for the location of the geothermal power facilities), actively pursued the government's geothermal program, with private sector participation in the power plant side through BOT arrangements with PNOC EDC.

TABLE 1: Installed Geothermal Power Capacity in the Philippines

| Geothermal Facility | Capacity (MW) | Power Plant Operator | Steamfield Operator |
|--------------------------|---------------|----------------------|---------------------|
| Luzon | | | |
| Mak-ban | 426 | NPC | PGI |
| Tiwi | 330 | NPC | PGI |
| Bacman | 150 | NPC | PNOC EDC |
| Leyte | | | |
| Tongonan I | 112.5 | NPC | PNOC EDC |
| Leyte-Luzon/Optimization | 386 | CalEnergy/Ormat* | PNOC EDC |
| Leyte-Cebu | 202 | CalEnergy* | PNOC EDC |
| Negros | | | |
| Palinpinon | 192.5 | NPC | PNOC EDC |
| Mindanao | | | |
| Mt. Apo | 106 | Marubeni* | PNOC EDC |
| Total Philippines | 1,905 | | |
| Subtotal, PNOC EDC | 1,149 | | |
| Subtotal, PGI | 756 | | |

Note: *Under Build-Operate-Transfer (BOT) contract with PNOC EDC.

PNOC EDC, as the leading geothermal company in the Philippines, developed its expertise and capability over the years. The geothermal technology that it has applied evolved from a host of technologies available from geothermal producing countries like the United States, Iceland, New Zealand, Italy and Japan who have sent their geothermal experts in the Philippines to do some evaluation of the geothermal areas in the Philippines through technical assistance grants. To further develop its technical personnel, PNOC EDC also sent most of them to train in the geothermal training centers abroad.

2. STAGES OF GEOTHERMAL DEVELOPMENT IN THE PHILIPPINES

The producing geothermal fields in the Philippines underwent systematic investigation and evaluation processes in the course of their initial exploration, development until steam production and management of the resource. These studies and evaluation processes are fairly similar to those applied in other geothermal areas in the world with corresponding modifications and innovations to suit the particular geothermal area of interest. PNOC EDC, as a geothermal company, has followed the widely accepted procedures in the industry in implementing geothermal projects.

From the perspective of the resource, a geothermal project can be divided into the following phases:

- Project definition and reconnaissance evaluation
- Detailed exploration
- Exploratory drilling and delineation
- Resource analysis and assessment of development potential
- Field development
- Steam production and resource management
- Shutdown and abandonment

Upon confirmation of a resource for development, a complete feasibility study undertaken on the project would also consider the corresponding geothermal power plant to be set up for converting the energy from steam to power. The power plant will undergo the following phases, in parallel with geothermal field development: bid tendering, design, manufacturing and delivery, construction, commissioning and operation.

A discussion of the different phases is as follows:

2.1 Project Definition and Reconnaissance Evaluation Phase

This phase involves collecting information from previous geological, geochemical and geophysical studies made in the area with particular emphasis on mapping of young volcanic activity, thermal manifestations such hot springs, steam jets, groundwater boreholes and even known traditional utilization of geothermal resources. The existing scientific information are re-interpreted to determine the more detailed investigation that need to be conducted. This review may reveal what methods of interpretation previously employed need refinements and may show the existence of a more attractive resource than previously envisaged. In the case of the Philippines, an inventory of prospective geothermal areas and initial surface investigation results are available from the Bureau of Energy Development (BED) of the Department of Energy.

A reconnaissance trip to the area is imperative if the scientific and environmental considerations are favourable. This is to confirm the data review findings and explore the sentiments of the local community on the project. The reconnaissance would include the assessment of access roads, communication, accommodation and security.

2.2 Detailed Exploration Phase

The detailed surface exploration program usually includes the geology, geophysics, geochemistry, heat flow measurements, hydrogeology and baseline environmental studies that have not yet been done or need to be redone. In areas that had not been mapped in detail, the required work would include lithological mapping, petrogenesis, volcanology, structural geology, hydrogeology, geo-hazard and environmental geology. Among the geophysical surveys used are gravity surveys to determine the density pattern of the geothermal structure and magnetotelluric (MT) surveys to show resistivity anomalies. In the Philippines, implementation of this phase would require a Non-Exclusive Exploration Permit issued by the BED of the DOE. After completion of this phase, the geothermal prospect is evaluated as to its priority for drilling compared with other areas that have been similarly evaluated.

During this phase, detailed mapping of geothermal manifestations and detailed study of geological controls on the distribution of the geothermal resource are very important in developing the conceptual model of the geothermal system. Target structures for drilling are identified after consolidation of the interpreted results of the detailed geological, geochemical and geophysical investigations.

2.3 Exploratory Drilling and Delineation Phase

Two or three exploratory wells, 2500 to 3000 meters deep, are prioritized based on the conceptual model of the reservoir. Location of drill pads will depend on environmental considerations in the area. The first well is perhaps the most critical as it is meant to maximize down-hole information. The target structure must have permeability and high temperature in order for a geothermal resource to be present. Prior to drilling the first well, the DOE requires a pre-negotiated Geothermal Service Contract (in accordance with P.D. 1442, or the Geothermal Service Contract Law) setting forth the work commitment of the service contractor and granting exclusivity on the area to the contractor in case of discovery.

If the first well does not produce steam, down-hole data is evaluated in conjunction with the initial detailed geological, geochemical and geophysical studies before deciding on the next target drill site. If the first exploration well is a success, a step-out well is drilled. The succeeding step-out (appraisal) wells should not be too distant from the first well and should normally target fractures and other geological structures.

In the Philippines, where geothermal prospects are normally located in mountainous terrain, exploratory well drilling would require the cutting of trees and opening of new roads in order to prepare the drill pad. Tree cutting permits need to be obtained from the DENR and an Environmental Impact Assessment of the exploration drilling activities need be prepared. Deviated or directional wells are most often drilled because of drill pad location constraints, vis-a-vis, the target structures deep below.

Well logging and discharge tests follow after the completion of drilling. Results of the well surveys and tests may confirm the resource and together with the earlier investigation results, a more defined conceptual model can be developed.

Wells often do not readily discharge after drilling even if there are sufficient indications of permeability and high temperature. In such cases, PNOC EDC resorted to well stimulation with the use of a boiler or with a high pressure, high volume air compressor.

2.4 Resource Analysis and Assessment of Development Potential

After successful discharge of steam from the initial wells, a comprehensive resource assessment is prepared. This is now the feasibility phase of the project. The exploitable size of the resource is established based on the conceptual model of the heat source, geological structure, fluids present and reservoir characteristics. A development strategy has to be formulated together with the conceptual design of the fluid collection and reinjection system (FCRS). The power station initial design, location and interconnection to the power grid are established at this stage. The feasibility study will yield project cost estimates, development timelines and the economic and financial analyses under probable power demand scenarios.

At this stage, in accordance with Philippine environmental laws and regulations, a full-blown EIA is prepared which will serve as the basis for the issuance of the project's ECC by the DENR. Public consultations with local residents, local government units and other stakeholders are also undertaken as part of the endorsement and approval process if a geothermal project is proposed for implementation.

The final output of this phase is a complete technical and financial feasibility study that can be used to solicit funding from financiers for the development of the project.

2.5 Field Development Phase

Upon successful negotiation and closure of financing for the project, the next phase involves production and reinjection drilling, detailed design, procurement and construction of the FCRS. Development of the field, in many of PNOC EDC's geothermal projects, involved multi-well pad sites. From a single site, up to four cellars can be constructed; from these cellars, up to four directional wells can then be drilled with their bottom targets deviating away from each other. This scheme of development results in a very compact production field and can be highly applicable in rugged and mountainous terrain, such as the 112.5 MW Palinpinon I Geothermal Production Field in the southern part of Negros Island.

The detailed engineering, procurement and construction of the geothermal power station and associated substation and transmission lines are done simultaneously with the production and reinjection well drilling. In the Philippines, the power plant portion used to be implemented by NPC, the government's power utility company. E.O. 215 issued in 1990 allowed the private sector to participate

in power generation; hence, power plants in the large geothermal fields of Leyte and Mt. Apo in Mindanao were set up through BOT contracts between PNOC EDC and private power companies.

2.6 Steam Production and Resource Management Phase

The satisfactory and efficient operation and maintenance of the geothermal production facility and the power plant after the completion and commissioning tests will be the key to the fulfillment of contractual commitments and the realization of cash flows from the project over the long term. In the process of exploitation, the behaviour of each individual well is closely monitored. This leads to a better understanding of the geothermal reservoir and a more comprehensive model is portrayed. PNOC EDC uses TETRAD and TOUGH2 to simulate and predict reservoir behaviour under certain exploitation scenario, to forecast the number of maintenance wells, as well as the drilling targets, over the project life.

PNOC-EDC operates and maintains 1,149 MW of steam production fields and its experience has been fraught with a lot of challenges. It has developed several strategies to field management using old and new technologies in order to sustain generation capacity. First, the fluid collection and reinjection system (FCRS) must be properly managed. This involves steam quality monitoring, steam washing to prevent suspended solid particles from entering the turbine, regular cleaning and removal of deposits in the lines, and energy audits to identify areas susceptible to energy losses. In the production fields of Leyte, PNOC EDC constructed an interconnection system of the various FCRS pipelines in order to balance the steam supply coming from different sectors of Sambaloran, Upper Mahiao, Malitbog and Mahanagdong, to the respective power plants. This additional flexibility has allowed the sharing of steam resources among power plants in Leyte to optimize generation capability.

Second, production and reinjection wells must also be managed in order to maximize their capacity and extend their useful lives. PNOC EDC has extensive experience in well bore intervention through a process called acidizing. Acidizing is done on wells producing less than their predicted capacity in order to clean out their production zones oftentimes blocked by drilling mud and other formation damaging scale depositions. Another scheme used to maintain well productivity is the Calcite Inhibition System (CIS), applied to wells with high occurrence of calcite mineral deposition in the well bore. In a few cases, wells often produce acidic fluids which are destructive to the pipelines; in order for these wells to be hooked up to the FCRS, PNOC EDC has devised the Acid Inhibition System (AIS) for such wells.

In some reservoirs, injection wells become available for production as a consequence of extensive boiling and pressure drawdown. This has been the case in Tongonan, Leyte where four injection wells have been converted into production wells contributing more than 20 MW of generation capability. Other injection wells are programmed for production hook-up. Idle peripheral wells, which delineated the boundaries of the exploitable reservoir, are also later on hooked up to the system in order to sustain generation capacity.

Injection management is the third strategy of sustaining generation capacity. Re-injecting the separated brine and power plant condensate should be accomplished with extra care because of their adverse effect on the production sector. Uncontrolled reinjection may cool down sections of the reservoir irreversibly. Monitoring the injection returns employs the use of chemical tracers. The results of chemical tracer tests will play a big factor in implementing the injection dispersion of the brine and condensate among new, idle or active injection wells.

After years of modelling the reservoir, a decision to expand generation capacity may be arrived at. This can be implemented in several ways. Topping turbines can be set up where high wellhead pressures can be sustained over the long term. Bottoming turbines can also extract additional power from used steam. Topping plants were set up in the Tongonan I and Mahanagdong fields, and a bottoming plant has been set up in the Malitbog field, all in Leyte. Increasing the production of steam

to supply another power plant is also possible after long term monitoring of the reservoir. In the Nasuji sector of Palinpinon II geothermal project in southern Negros, it was established that another 20 MW power plant can be supported by the existing resource. The Mt Apo project has been found to be capable of producing an additional 20 MW from the modelled reservoir.

2.7 Shutdown and Abandonment Phase

This phase represents the last stage of a geothermal project. As the geothermal reservoir is exploited, it is expected to decline in pressure and steam output over the long term. In addition, the surface equipment may start failing to an extent that it is no longer economical to run the plant, and as such, require to be shut down and abandoned. But this stage seems to be a long, long way into the future for as long as proper resource management is implemented. The first 110 MW geothermal power plants in Tiwi and Makban are already 26 years old. The 112.5 MW Tongonan I and 112.5 MW Palinpinon I are already 23 years old. These geothermal fields and power plants are predicted to last another 25 years.

3. TIMETABLE OF THE DIFFERENT PHASES OF GEOTHERMAL DEVELOPMENT

Table 2 shows the implementation chart of the different phases of geothermal development. A geothermal project of the size of 40 to 100 MW can be completed in five years without the problems associated with financing. Detailed surface exploration and deep exploratory drilling can be done within two years from project identification. Preparation of the feasibility study and the conduct of a development EIA can be timed such that these documents, which are necessary for development financing, can be available within the first quarter of the third year.

The decision to proceed with deep exploratory drilling is often the first major hurdle in implementing a new geothermal project because this is the point when major investments start to be incurred. In the Philippines, the costs of opening and constructing new roads and drill sites are substantial because of remoteness of geothermal prospect areas. Then the costs of drilling deep deviated wells are even more substantial. In the 1980s, the World Bank assisted the Philippines by providing financing for exploration and delineation well drilling in six prospective geothermal areas of PNOC EDC. Nowadays, however, PNOC EDC would proceed with deep exploratory drilling only when it has uncommitted excess funds; otherwise, it would have to defer exploratory drilling until more auspicious times. There are at least three prospective geothermal areas (Kayabon in Bacman area, Dauin in Southern Negros and Cabalian in Southern Leyte) ready for drilling, but which PNOC EDC still cannot implement in the immediate term.

Project implementation can be delayed because of the difficulty in obtaining the Environmental Compliance Certificate, especially for a project located in environmentally sensitive areas like National Parks or protected areas. The Northern Negros Geothermal Project of PNOC EDC was delayed by at least 3 years because the geothermal area had to be carved out of the Kanlaon National Park in Negros Island.

The field development may take two-and-a-half years, but another area of major delay is in obtaining financing before the development stage can start. Project appraisal and loan processing can take one year. Other factors can make it longer, such as the country's political situation, availability of counterpart funds, and environmental and tribal issues. Financiers look at field development and power plant construction as inseparable components of a geothermal project. The technical and financial feasibility of both components must be ensured in terms of market, pricing, regulatory and environmental considerations. The Tanawon project near the Bacman area in southern Luzon is one project of PNOC EDC which is already technically feasible by exploratory drilling; however, because of the prevailing excess in power capacity in the Luzon grid, this project has not obtained development funding.

TABLE 2: Stages of geothermal development in the Philippines 40 to 100 MW geothermal project

| Stage/Activity | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 |
|---|--------|------------------------------------|--|--------|--------|------------|
| Project Definition and Reconnaissance Evaluation | <x> | | | | | |
| Detailed Exploration <i>Geological, Geochemical & Geophysical Surveys</i> | <xx> | | | | | |
| Exploratory Well Drilling and Delineation <i>Explo EIA, Tree Cutting Permits Road Construction, Drillsite Preparation Well Drilling (2-3 Wells)</i> | | <xx> <xxxx> <xxxxxx> | | | | |
| Project Feasibility Stage <i>Resource Assessment and Development Strategy Project EIA and ECC</i> | | | <xxxx> <xxxx> | | | |
| Loan Application and Financial Closing | | | <xxxxxx> | | | |
| Field Development <i>Production/Reinjection Well Drilling FCRS Engineering Design And Construction</i> | | | <xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx> <xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx> | | | |
| Power Plant Bidding and EPC | | | <xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx> | | | |
| Steam Production and Resource Management | | | | | | xxxxxxxxxx |

4. COSTS OF THE VARIOUS PHASES OF GEOTHERMAL DEVELOPMENT IN THE PHILIPPINES

Table 3 shows the development costs of a 100 MW geothermal power project in the Philippines. The costs become substantial when a decision is made to pursue exploratory drilling. Civil works costs are also significant because new roads have to be opened and the drill site must be constructed with a deep cellar, three sumps for the drilling wastes and a reservoir to contain the discharges. To complete a project feasibility study on three deep exploration wells would entail US\$ 9.84 million in risk money. Once a “bankable” project feasibility study is available, the costs of US\$ 115.66 million for a 100 MW field development and US\$ 140 million for the 100 MW power plant will need to be financed by borrowings and internal cash generation. These levels of costs have been gleaned from the projects that PNOC EDC has implemented over the years.

In implementing the geothermal exploration and delineation program of the country in the 1980s, PNOC EDC was supported by a US\$ 36 million exploration loan from the World Bank for seven prospect areas.

For the developmental projects of PNOC EDC, financing has been sourced from Official Development Assistance (ODA) agencies like the World Bank and the Japan Bank for International Cooperation (JBIC). Out of the 1,149 MW geothermal fields operated by PNOC EDC, 106 MW in Mt. Apo in Mindanao was financed by internally generated funds; 305 MW was financed by JBIC and 738 MW was financed by World Bank.

TABLE 3: Costs of geothermal development in the Philippines 100 MW geothermal project

| Stage/Activity | Unit Costs, US\$ | Total, Million US\$ |
|--|---|---------------------|
| Project Definition and Reconnaissance Evaluation | | 0.03 |
| Detailed Exploration <i>Geological, Geochemical & Geophysical Surveys</i> | | 0.10 |
| Exploratory Well Drilling and Delineation <i>Explo EIA, Tree Cutting Permits</i> <i>Road Construction, Drillsite Preparation</i> <i>Well Drilling (3 Wells)</i> | \$50 thousand, EIA/Permits \$135 thousand/km road \$458 thousand/drillpad \$2.1 million per well | 9.07 |
| Project Feasibility Stage <i>Resource Assessment and Development Strategy</i> <i>Project EIA and ECC</i> | \$500 thousand/Feasibility Study \$135 thousand/EIA | 0.64 |
| Loan Application and Financial Closing | | 0.10 |
| Field Development <i>Production/Reinjection Well Drilling</i> <i>FCRS Engineering Design And Construction</i> | \$2.1 million/well Roads & Pads: \$11.86 million FCRS: \$30 million Admin & Overhead: \$15 million | 115.66 |
| Power Plant Bidding and EPC | \$1,400 per kw | 140.00 |
| Total Development Costs | | 265.60 |

Assumptions:

| | |
|------------------------|----------------------------------|
| Average well capacity: | 5 MW per well |
| Production wells: | 21 |
| Reinjection wells: | 7 |
| Roads: | 10 km, explo; 20 km, development |

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