

Opportunities for Direct Use of Geothermal Resources in the Bicol Region, Philippines

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ABSTRACT

The Philippines is the second largest geothermal energy power producer in the world with a total installed capacity of 1980 MW. Of this, Bicol Region accounts for 480 MWe installed capacity with an additional 130 MW on the pipeline. There are many identified surface thermal manifestations from the major thermal areas in the Bicol Region, which may be used for non-power use. Given these geothermal and other non-conventional and renewable sources of energy in the Bicol Region which can be tapped for power and non-power applications, growing importance should therefore be placed on the development and implementation of new programs and technologies to help provide the industry with the necessary technology.

As such, there are opportunities where researchers and technology developers can play a major role in bridging this gap. The researchers and the academe can position themselves as strategic service providers to the industry in terms of capacity building, training, information and knowledge sharing, resource and capability build-up and mobilization aside from its mandate of knowledge and technology generation, research and extension. Researches can be done along : enhancing the competitiveness of business and industry, food security & poverty reduction, gender and development, environment & natural resource management and developmental researches. Maximizing the indirect uses of geothermal energy partly depends upon the presence of specialists capable of conducting such research and development studies.

Among the studies conducted by the Bicol University College of Engineering were innovative proposals on the agro-industrial use of geothermal heat, utilization of waste silica, and environmental studies. These include geothermal resource assessments; utilization of waste in various industries such as the production of pesticide and hollow blocks from silica sludge, hand paper making, artificial incubation and brooding system, pool heating with prawn-tilapia aqua-culture, palay drying, flour manufacturing; irrigation and drinking water supply, soil sterilization, bio-fuels production, cloth dyeing, geothermal mud utilization, waste management, environmental studies and plant optimization studies.

1 INTRODUCTION

1.1 Regional geologic setting

Bicol Region is situated at the southernmost tip of the Luzon landmass. It is straddled between 11° - 30' to 14° - 20' North latitude and 122° - 20' to 124° - 30' East longitude. (Fig. 1)

One of the most active volcanic arcs present in the Philippine Mobile Belt is the Bicol Arc, which stretches

from Camarines Norte to Sorsogon in the Bicol Peninsula. The region is sandwiched between two major tectonic structures, namely, the Philippine Trench, located on the eastern side of the Bicol Arc, and the Philippine Fault Zone on the western side.

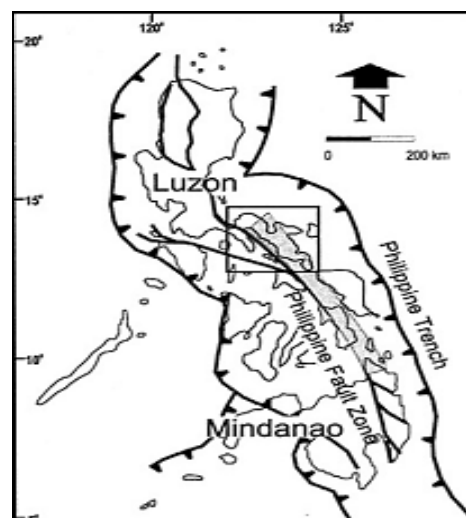


Figure 1: Location of Bicol Region (Andal et al, 2005)

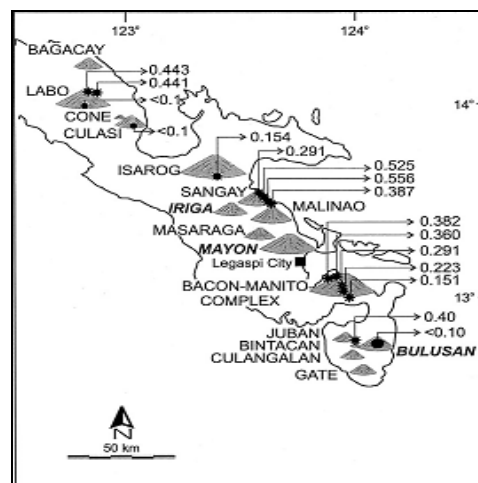


Figure 2: Regional map of the Bicol Region showing its general tectonic features. (Andal et al, 2005)

In the Bicol Arc, there are at least twelve identified eruptive centers and volcanic complexes (Fig. 2), three of which - Mayon, Iriga and Bulusan - are categorized by the Philippine Institute of Volcanology and Seismology (PHIVOLCS) as active volcanoes. The rest of the volcanic centers are inactive but are considered relatively young based on radiometric dating and morphology (Andal et al, 2005). Geothermal energy is related to this active volcanism and plate tectonics.

1.2 Geothermal energy utilization in the Philippines

Geothermal resources as defined by Republic Act No. 9513 or the “Renewable Energy Act of 2008” refers to mineral resources, classified as renewable energy sources, in the form of: (i) all products of geothermal processes, embracing indigenous steam, hot water and hot brines; (ii) steam and other gases, hot water and hot brines resulting from water, gas or other fluids artificially introduced into geothermal formations; (iii) heat or associated energy found in geothermal formations; and (iv) any by-product derived from them (R. A. 9513, 2008).

Geothermal energy in the Philippines is used primarily for electric power generation. The Philippines is the second largest geothermal energy power producer in the world with a total installed capacity of 1980 MW. In 2007, the installed capacity (gross) for electric power generation reached 2027 MWe with approximately energy generation total of 9676 GWh for the year representing about 18 % of the country's total energy generation (Bayrante et al, 2008).

In the Bicol Region, geothermal energy is a well known resource. Two of the country's major geothermal fields are located in the area. The Tiwi geothermal complex, is located in the province of Albay. The non-power application of the said area was offered for investment in the Philippine Energy Contracting Round (PECR) 2005. The Bacon-Manito Geothermal Field, on the other hand, is located in the provinces of Albay and Sorsogon. The Bicol Region hosts 11 geothermal power plants with total installed capacity of 495.5 MW. Three potential geothermal resource sites on the pipeline can provide a combined capacity addition of 120 MW for the next years. A total of 64 new wells will be drilled, thus improving steam availability to 627.4 MW in 2014. For the next ten years, technologies utilizing acidic reservoir and low enthalpy type of fluids are expected to be available in the market to allow areas like Mt. Labo in Camarines Norte and others in the Bicol Region to provide additional capacities (NAPOCOR 2008).

The development of some promising geothermal areas has been temporarily set aside pending technological breakthroughs in handling acidic wells. An example is Mt. Labo which is located within the boundaries of Quezon, Camarines Sur, and Camarines Norte. Eight wells have been drilled in Mt. Labo from 1990 to 1997 but all intersected acidic geothermal fluids (DOE, 2009; Maturgo et al., 2000).

1.3 Direct use in the Philippines

While the emphasis is on developing geothermal energy for the generation of electricity, Benito, et al., (2005) reports that the government is looking to increase non-power uses of geothermal energy. The direct-use applications of geothermal energy in the Philippines are limited to bathing and balneology and drying of agricultural and marine products. Temperature of geothermal resources being utilized ranges from 30 to 100 degrees Celsius. Direct use of geothermal heat is currently at a low level and is limited to numerous hot springs and two agriculture drying plants, located in Palinpinon, Southern Negros Geothermal Production Field and in the Manito, Albay in Bacman Geothermal Field. Total installed thermal capacity is 3.30 MWt and thermal energy used is 1.25 MWt. Capacity factor stands at 0.39 while total energy used is 39.58 TJ/year (Ulgado and Gular, 2005).

Most of those accounted under bathing and swimming are the hot springs in Laguna. There are, however, operational

hot springs in other regions of the country which have not yet been assessed and hence were not included in the study.

The direct utilization of geothermal energy is difficult to determine since there are many diverse uses of the energy and these are sometimes small and located in remote areas in the Philippines. There is difficulty in finding knowledgeable persons except for indigenous knowledge among the people. This is especially true of geothermal waters used for swimming pools, bathing and balneology. In addition, even if the use can be determined, the low rates and temperatures are usually not known or reported; thus, the capacity and energy use can only be estimated. (Lund, 2007).

The Department of Energy reported that the country has yet to take off in terms of development of non-power applications of geothermal energy resources. This is due to a lack of financing and public awareness. The development of spa resorts and crop drying facilities using geothermal heat is still in the early stages as compared to other countries. There exists a huge potential for geothermal heat in crop drying but this is hampered by the preference of a lot of farmers for solar energy which traditionally is the source of energy for drying in the country. People have yet to realize the benefits of using geothermal heat, especially in terms of time saved in drying owing to its high temperature and non-seasonality compared to sunlight (DOE, 2009).

The Palinpinon agro-industrial drying plant was put up in 1992 and operated by PNOC-EDC until 1997. Installed thermal capacity of Palinpinon agro-industrial plant is 1.0 MWt. Thermal energy used is 0.55 MWt and capacity factor is 0.55. Annual energy used is 17.34 TJ/year. It was turned over to a local farming cooperative to operate and manage. However, due to lack of financial resources, low market price of the main product and deterioration of the plant, the drying plant has ceased operation in 2001 (Ulgado and Gular, 2005).

In 1998, as part of the government's thrust to help the marginalized communities, the Manito Lowlands in the Province of Albay was re-evaluated for industrial use. The Manito Geothermal Livelihood Project (MGLP), which comprise of a 1.5 MWe pilot power plant and a multi-crop drying plant, was put up in 1998 at the Manito Lowlands, Pawa, Manito, Albay (Padua et al., 2000). The Project was a joint undertaking by the Department of Energy (DOE), National Power Corporation (NPC), National Electrification Administration (NEA), Philippine National Oil Company-Energy Development Corporation and the Local Government of Manito, Albay (Karunungan and Requejo, 2000). Total estimated installed thermal capacity in Manito is 0.63 MWt. Thermal energy used is at 0.34 MWt. Capacity factor is 0.48 while total energy used is 9.59 TJ/year. The operation of the Manito Livelihood Geothermal Project, however, has been suspended by PNOC-EDC due to scaling and major turbine problems (Ulgado and Gular, 2005).

With the extensive exploitation of the economically viable, high-enthalpy geothermal resources and since most of the remaining geothermal prospects of the country are of the intermediate to low-enthalpy types, there is a need to refocus on the development of small-scale geothermal resources for direct utilization.

1.4 Relevant direct use technology

Direct-use of geothermal resources worldwide is primarily for direct heating and cooling. Geothermal direct-use systems use a fairly simple and established technology that generally involves three basic elements: (1) A production system that brings water up through a well to the surface; (2) A delivery system that distributes hot water through pipes; and (3) A disposal system where the cooled water is injected back into the reservoir, (GHC, 2004).

The main utilization categories are: (1) swimming, bathing and balneology; (2) space heating and cooling ; (3) agricultural applications such as greenhouse and soil heating; (4) aquaculture application ; (5) industrial applications such as mineral extraction, food and grain drying; and, (6) geothermal heat pumps (GHP), used for both heating and cooling (Lund et al., 2005).

In agriculture, geothermal water is used mainly as a source of heat and moisture. Agricultural applications make direct use of geothermal water, using it to heat and water plants, warm greenhouses, or to dry crops. The aim of geothermal aquaculture is to heat water to an optimum temperature for animal growth. Species typically raised include carp, catfish, bass, tilapia, mullet, eels, salmon, sturgeon, shrimp, lobster, crayfish, crabs, oysters, clams, scallops, mussels and abalone. In addition there is a rising interest in aquaculture crops, such as water hyacinth, duckweed, algae species, kelp and *spirulina* (NZ GNS, 2007). The experiences of some countries in utilizing geothermal energy for industrial applications have been well documented.

The most important energy considerations for an industrial application are the cost, quality, and reliability. Geothermal energy may be attractive to an industry providing: (a) the cost of energy/kg of product is lower than that presently used, (b) the quality of geothermal energy is as good or better than the present supply, and (c) the reliability of geothermal energy is available for the life of the plant. The Department of Energy recommends bringing geothermal heat to industrial installations or bringing industries near geothermal fields (DOE, 2009).

The production of biofuels has become a popular issue since it can reduce dependency on imported fossil fuels for the transportation sector. Two types of biofuels can be produced: ethanol and biodiesel, both of which may be used as a blend with conventional fuels to power cars and trucks. Many of the steps require the use of fossil fuels. Geothermal energy can be used by replacing some of the energy inputs. Studies have shown that using heat exchangers, biofuels can be produced economically (GHC, 2007).

In waste management, sewage treatment schemes use geothermal heat to dry digested sludge. Similarly, geothermal energy has been used as a heat source and geothermal water as a mordant in cloth dyeing.

2. OPPORTUNITIES FOR DIRECT USE OF GEOTHERMAL RESOURCES

As in all other studies for direct use of geothermal resources, several elements of direct-use geothermal energy are important: (a) the geologic parameters of the resource; (b) the engineering criteria or the technical practicality of the project; and (c) the economics of the venture and (d) the legal frameworks - applicable environmental laws, regulations, ordinances and required permits.

A primary consideration is the cost of finding, developing and utilizing the geothermal resource. These can be done in close cooperation with the local geothermal plant operators where the resources lie, with the local government units and financing institution. With the availability of the technology, and given the promise of the Philippine Renewable Energy Act of 2008, there are bright prospects for direct use of geothermal energy in the Bicol region.

The Philippine Renewable Energy Act of 2008 (R. A. 9513) aims to hasten the exploration and development of renewable energy resources and promote their use by providing fiscal and non-fiscal incentives. The law encourages the development and utilization of renewable energy resources as tools to effectively prevent or reduce harmful emissions and thereby balance the goals of economic growth and development with the protection of health and the environment.

The Renewable Energy Trust Fund (RETF) created under the law aims to provide: (a) Financial support to the research, development, demonstration and promotion of the widespread and productive use of Renewable Energy (RE) systems for power and non-power applications as well as to provide funding for R & D institutions engaged in renewable energy studies undertaken jointly through public-private sector partnerships, including provisions for scholarship and fellowships for energy studies; (b) Support in the development and operation of new RE resources to improve their competitiveness in the market; (c) Support in the conduct of nationwide resource and market assessment studies for the power and non-power applications of renewable energy systems; (d) Support in the propagation of Renewable Energy knowledge by accrediting, tapping, training and providing benefits to institutions, entities and organizations which can extend the promotion and dissemination of RE benefits to the national and local levels.

Electricity has been primarily generated from these geothermal plants. There is however limited direct utilization of geothermal energy in these fields as well as in other undeveloped ones. In Tiwi Geothermal Power Plant, "only 60 MWe out of the 150 MW produced by the geothermal plant were being used by NAPOCOR during off-peak hours and 100 percent on peak hours" (Aguilar and Calleja, 2007). This might also be true for other geothermal plants since geothermal plants are used as peaking plants and not as base load plants in the Philippines.

In the geothermal fields that have been developed and utilized, both in the BacMan and Tiwi Fields, there are production wells that have depleted pressures and temperatures, hence production rates have decreased. Some of these wells have been converted as re-injection or monitoring wells. As of 2003, 156 wells have been drilled throughout the Tiwi field. Of these, 48 wells provide current steam requirements and 16 wells are used for brine and condensate re-injection (NGAP 2009).

BacMan Geothermal Field, on the other hand, has 23 production wells and 10 injection wells (Fajardo, 2000), with a projected additional 64 wells for the next five years. Other wells have been capped due to technical difficulties in producing fluids at the desired pressure, temperature and discharge rates. Waste geothermal fluids from geothermal power plants are re-injected into the reservoir as part of a sustainable reservoir management program. The waste heat contained in these geothermal fluids can still be extracted

for productive use and other direct utilizations. Similarly, waste heat from power generation processes can be used as energy sources for other non-power applications. These resources offer a lot of opportunities for direct use.

In designing geothermal energy recovery and utilization systems, alternate possibilities could be considered for various applications. The usual approach for utilization of geothermal fluid by proposed industries is to fit the industry to the available fluids. An alternate approach is to fit the available fluids to proposed industries. This alternate approach requires developing ways to economically upgrade the quality of existing geothermal fluids or the fluids derived from them.

Mongillo (2008) said that the challenge is to address all aspects of direct use technology with emphasis on improving implementation, reducing costs and enhancing use. These can be done through: (a) resources characterization, (b) identification of barriers and opportunities for direct use, (c) validation of equipment performance, (d) development of design configurations and engineering standards.

The existence of geothermal energy resources commonly found in mountainous and inland areas of the Region have its advantages. The major agricultural products of the Bicol Region include palay, corn, abaca and coconut. There are agricultural plantations and forestry areas in the Region in which the products require processes such as drying, preservation, heating, sterilization, etc. The agricultural and plantation product processing requiring heat are for example: rice, corn, abaca and coconut drying, mushroom cultivation, etc. Geothermal waters can be utilized to improve post harvest operations for these products. Traditionally, the energy demand in processing these products would have been satisfied by fossil fuels or by using biomass fuels which are abundant. Therefore, substituting these with geothermal heat helps not only to reduce the need to import hydrocarbons, but also to reduce the emission of the greenhouse gas carbon dioxide to the atmosphere.

In Tiwi, Albay, the site being offered for non-power utilization of geothermal brine lies in a government-owned area proposed to be a special economic zone. Economic activities in the area consist mainly of agriculture, fishing, hat/mat weaving and pottery. Several non-power applications of geothermal brine such as a multi-purpose drying facility for the hat/mat raw material and pottery, fish canning and refrigeration, salt-making and spa development maybe applied in the area (PERC, 2005).

The Sunwest Group of Companies is studying the possibility of developing a hot spring-mud bath spa facility at the Nag-aso Spring, a hot sulfur-rich lake in the municipality of Manito, Albay (PNA 2008). Plans to utilize other geothermal resources for spa and balneological applications can be coordinated with hot spring resort owners and developers. With the numerous hot springs in the Bicol Region, notably in Albay and Sorsogon, balneology may become one of the top industries in the area. Other areas in the country have used this strategy in developing their tourist industry.

The experiences of other countries in the utilization of these resources have shown that only the hottest water can be used to generate electricity. However, some places have naturally heated groundwater that is not hot enough to produce the steam needed to turn turbines. These type of water is still usable for other purposes but not as a workable

power source. This is the area where the researchers and developers can make the most out of what Bicol Region has.

In some situations where available geothermal fluid temperatures are lower than those required by the industrial application, the temperatures can be raised by means of integrating thermal systems. In designing geothermal energy recovery and utilization systems, alternate possibilities could be considered for various applications. The usual approach for utilization of geothermal fluid by proposed industries is to fit the industry to the available fluids. An alternate approach is to fit the available fluids to proposed industries. This alternate approach requires developing ways to economically upgrade the quality of existing geothermal fluids or the fluids derived from them.

Geothermal waters contain many dissolved chemicals, most notable of which is silica. Not only are these metals often available in significant quantities in geothermal brine, but they provide a new and important source of such mineral produced through solution mining in an environmentally responsible manner. (Bloomquist and Porarov, 2008). How to extract and utilize these chemicals is one of the challenges of the industry.

The government is moving towards a policy environment that will facilitate the transition of the country's energy sector to a sustainable system by developing renewable energy as a viable and competitive fuel option. There are plans to utilize geothermal drying for spa and balneological applications which are being coordinated with hot spring resort owners and developers. The Government through the Department of Energy has entered into a Memorandum of Agreement for this purpose with the Department of Tourism and Department of Health (Benito et al 2005). With the numerous hot springs in the Philippines, balneology may become one of the top industries in the country. Other countries have used this strategy in developing their tourist industry.

One of the difficulties in coming up with an updated profile on the extent of direct use of geothermal resources in the Philippines and specifically Bicol Region is the lack of adequate data. An inventory and survey of surface thermal manifestations such as springs, vents etc. and their physical and chemical characteristics is of primary importance. A socio-economic profiling of geothermal prospect areas hosting the untapped geothermal resources can also be undertaken simultaneously with these inventories. The challenge, for governmental agencies and the private sector alike, is to assess the amount and distribution of these resources, to work toward new and inventive ways to use this form of energy, and to incorporate geothermal into an appropriate energy mix for the Nation and the world.

As such, there are opportunities where researchers and technology developers can play a major role in bridging this gap. The researchers and the academe can position itself as a strategic service provider to the industry in terms of capacity building, training, information and knowledge sharing, resource and capability build-up and mobilization aside from its mandate of knowledge and technology generation, research and extension.

3. GEOTHERMAL STUDIES CONDUCTED

Among the studies conducted by the graduates of BS Geothermal Engineering of the Bicol University College of Engineering-Legazpi City were proposals on the agro-industrial use of geothermal heat to increase agricultural

productivity, utilization of geothermal wastes such as silica from geothermal sludge, site developmental studies on the thermal spas, balneology and eco-tourism and environmental studies and preliminary assessment of new thermal areas (Aligan, 2006).

Noteworthy among the projects were the geothermal resource assessments of three new areas based from indigenous knowledge, production of hollow blocks from silica sludge, heat exchanger designs for miscellaneous industries such as hand paper making, artificial incubation and brooding system, pool heating, prawn-tilapia aquaculture, palay drying, boiled water station, irrigation and drinking water supply, soil sterilization, environmental studies and plant optimization studies.

The project studies conducted were initial researches in the direct and in-direct uses of geothermal resources within the Albay-Sorsogon areas. These were done in close coordination with the local geothermal industry. Support in terms of technical expertise and access to information, technology and resources were given by PNOC-EDC now Energy Development Corporation / First Gen Holdings, National Power Corporation - Tiwi Geothermal Power Plant (now under Aboitiz Power Renewables Inc), Chevron Geothermal Philippines Holdings Inc. (formerly Unocal), Department of Environment and Natural Resources, Mines & Geo-Sciences Bureau RO V, Department of Public Works and Highways RO V, Philippine Coconut Authority, Bureau of Fisheries and Aquatic Resources RO V, Department of Agriculture RO V, Department of Science & Technology and the National Geothermal Association of the Philippines.

The preliminary researches and studies conducted by the Bicol University College of Engineering were aimed at generating and disseminating new knowledge and technologies towards Poverty reduction & sustainable development. They could be springboards for the development of technologies for utilizing the available geothermal resources of the Bicol Region.

3.1 Coconut-coir sterilization

Belgica (2008) studied the utilization of geothermal water in coconut by-product sterilization. The study presented a new means of employing geothermal water in the processing of coco coir and pith, both by-products of coconut husking process which abound on the country side and has no more commercial value other than leaving them to rot (Uyenco and Ochoa, 1984). The waters of thermal springs from Nag-aso Boiling Lake in Hulugan, Manito, Albay were used. It was noted that the utilization of geothermal waters is a feasible means for sterilizing growing media from coconut by-products.

The study was an attempt to improve on the current need by industry to produce coco peat growing media composed of coconut coir dust sieved in 5 mm mesh or less which are sun dried and sterilized at 120 deg C. These materials are suitable for nurseries (CTC, 2007). The sizable volume of coconut husks and its by-products and the presence of geothermal waters can perhaps be eventually turned into an economic opportunity for the Bicolanos where there is a thriving coconut industry.

3.2 Geothermal amorphous silica suspension as pesticide

Baria et al (2006) conducted laboratory experiments to demonstrate the feasibility of using processed geothermal silica sludge as pesticide and compared its effectivity

against existing commercial silica based pesticide. The study was based on the use of diatomaceous earth as an environment friendly, non-toxic pesticide which can kill insects by desiccation or absorbing the oily or waxy outer cuticle layers by direct contact. Using brine samples from the thermal pond of the Botong Sector of the Bacon Manito Geothermal Resource Area, Manito, Albay, amorphous silica was produced for the experiment which was subsequently processed into a silica suspension. Amorphous silica suspension was sprayed on Asian Cockroach (*Blatella asahinai*) samples at different concentrations. Results indicated that the effectivity of the amorphous silica suspension approached that of the commercial pesticides.

The chemical and physical properties of the geothermal well silica qualifies it as an amorphous silica-based insecticide even without major processing. However, due to market considerations and safety, minimum processing procedures would have to be done to maximize its non-toxicity and insecticidal properties. The simplicity of the procedure, minimum processing requirements and saleable nature of the end product of the geothermal well silica makes it economically appropriate as an alternative silica disposal and utilization option from the geothermal power plants. The study recommended that parallel studies be made to ensure that geothermal silica are purely isolated, free of heavy metals and tested again on insects to ensure wider range of application of its insecticidal properties. Likewise, detailed biological testing of the proposed amorphous silica suspension insecticide is made for both the target insects and the human and animal exposures that come with its usage.

3.3 Geothermal Resource Characterization Studies

3.3.1. - Buhatan Thermal Area

Miraballes and Balunso (2008) validated verbal reports that thermal manifestations (hot springs) are present in Barangay Buhatan, Sto. Domingo, Albay. Since there were no existing studies about the thermal occurrences, the researchers utilized the protocol procedure of data gathering through sampling of thermal waters from different reported sites. The sites were properly located using a Global Positioning System. Field analysis of unstable parameters such as pH and temperature were conducted *in-situ*. Documentation and familiarization of the site and field checking of existing geologic maps of the area were conducted. Related studies and literature were adopted, especially those pertaining to the geology of the Buhatan thermal area. Interviews with local residents were also made to obtain historical background data of the site. Chemical analyses of the water samples were conducted and the geochemistry was evaluated using a ternary diagram and geothermometers.

Results of the study indicated that Sto. Domingo, Albay specifically the Buhatan Thermal site lies along the margins of the northern end of the transtensional Legazpi Lineament (San Vicente-Linao Fault). The Buhatan Thermal Area I located on a non-volcanic terrain is underlain by the Buhatan Member of Libog Formation. These rocks of pillow lavas are overlain by metamorphosed conglomerate, arkosic sandstone and siltstone sequences. A few other northwest-trending faults have been mapped by previous workers around the thermal area and these faults or one of these faults could have acted as conduits of hot water that were derived from the same magma source that feeds the magmatic fluids to Mayon Volcano.

The study identified three thermal sites with bicarbonate and chloride waters: Buhatan 1 springs out on a mangrove swamp that has been converted into a fishpond; Buhatan 2 is manifested by warm waters that can be pumped out of a shallow tube well at the Barangay proper while Buhatan 3 lies on a tidal creek surrounded by mangroves. Buhatan 1 and Buhatan 2 thermal areas have neutral pH warm waters with temperatures 41 and 45 deg C respectively while Buhatan 3 has neutral pH hot water at 52 deg C. Two types of waters were identified: a neutral pH Na-HCO₃ type for Buhatan 2 (classified as “peripheral waters”, its CO₂ content could be related to the carbonate rocks of the Caracan Formation) and a neutral pH Na-Mg-Cl type for Buhatan 1 and Buhatan 3. Employing the cation Na/K ratio by Arnorsson et al (1983b) as geothermometer, the calculated subsurface temperature ranged from 90-117 deg C.

Considering the low estimated subsurface temperatures, the geothermal potential of Buhatan Thermal area is low in terms of power generation. However, the low-enthalpy fluids can be utilized for aqua-culture and drying of fish, crops and related products produced in the area. The study further recommended the conduct of geophysical surveys in the cited area to identify the location, size and depth of the possible reservoir. Likewise, a more detailed chemical analysis of the thermal waters involving other chemical parameters not used in the study such as SiO₂, B and Li be conducted.

3.3.2 Pariaan and Jovellar Hot Springs

Malto and Valeriano (2007) determined the geological, geophysical and geochemical characteristics of two hot springs in Albay, Philippines namely : Pariaan Hot Spring and the Pariaan Hot Spring Cave in Pariaan, Camalig, Albay and the Jovellar Hot Spring in Calzada, Jovellar, Albay.

These hot springs are being used as source of potable water, for bathing, laundry, and dish washing while the Pariaan Hot Spring Cave has become a tourist attraction because of the bats inhabiting the place and the hot spring waters inside. Prior to the study, there had been no previous studies which characterized the sites which can be used as basis for effectively utilizing the geothermal waters and developing the place.

Based from the studies conducted by Malto and Valeriano (2007), the Pariaan Hot Spring has a temperature of 30 deg C and is classified as tepid spring; the Pariaan Hot Spring Cave waters has a temperature of 35 deg C and classified as warm spring while the Jovellar Hot Spring with its 36 deg C temperature is also classified as warm spring .

Both Pariaan and Jovellar Hot Springs are located at the foot of mountainous caldera. Pariaan and Jovellar lie under a mixed type of soil called the Sorsogon Marl and the Quaternary Volcanic Cone and along a fault line, the NW-SE San Vicente-Linao Fault which obliquely cuts across the Bicol Peninsula. The southern extension of this structure to the Pocdol Mountains in Manito, Albay is represented by the Bac-Man Fault Zone.

Tests conducted on the thermal waters revealed a neutral pH and a slightly acidic pH of 6.86 for the Pariaan Cave. Bacteriological examination conducted by the Department of Health (DOH) on the Pariaan and Jovellar Hot Spring waters turned out to be negative for Fecal Coli form which meant it is safe for drinking while that of the Pariaan Cave tested positive. This is due to contamination of waters by

the bats living inside the cave. Chemical analysis conducted by the Department of science and Technology (DOST) likewise revealed that the three studied hot springs are classified as Chloride and Bicarbonate waters. The hot springs plotted as steam heated and volcanic waters in the SO₄-CL-HCO₃ ternary diagram.

Results of the study can be used in the development and promotion of the sites as potential eco-tourist areas and balneological center.

3.3.3 Irosin and Bulusan Hot Springs

Basilan and Perillo (2008) reassessed the thermal manifestations in the Irosin and Bulusan, Sorsogon areas after the phreatic explosion of Mt. Bulusan in 2006-2007. The study was intended to provide an updated reliable data on some existing hot springs in the area which can be used in development planning of the area.

An updated assessment through visual observations, surveys and chemical analyses of four (4) identified hot springs namely: San Vicente and Masacrot Mineral Spring in Bulusan, Sorsogon and San Benon and Mapaso Hot Springs in Monbon, Irosin, Sorsogon were done to evaluate if significant changes have occurred as a result of the Phreatic explosion. The results of the chemical analyses were used to determine the hot springs' water chemistry which in turn were used to reflect the hydrology of the system. The parameters used in assessing the hot springs were based from the geothermal exploration conducted by PNOC-EDC in mid 1980s while the chemical analyses of hot springs by PHIVOLCS and PNOC-EDC were the basis of comparison for any change in the hot springs.

The study found out the following:

- The pH levels of the hot springs became slightly acidic from neutral pH due to increased dissolution of country rocks.
- There was a small decrease in the temperature of the hot springs especially in the Masacrot Hot Spring due to fluid mixing with cooler ground waters.
- Increase in the HCO₃ concentrations in San Vicente, Masacrot and San Benon due to increase in CO₂ gas on the sub-surface.
- Change in SO₄ concentration as a result of dissolution / oxidation of sulfate minerals.
- Decrease in chloride anion of San Vicente hot spring which indicated a great amount of mixing with cooler fluids at shallow levels.
- The 2006-2007 phreatic explosion of Mt. Bulusan brought changes on the four studied hot springs around Irosin and Bulusan, Sorsogon.

Basilan and Perillo (2008) recommended that new assessment / survey should be carried out to determine new thermal manifestations that are reportedly manifested around Mt. Bulusan, as observed by residents in the area. Likewise a detailed study of all thermal manifestations in the Irosin and Bulusan area is recommended to completely validate the changes and provide conclusive data for development planning on tourism and health related plans of both municipalities.

3.4 Other Studies

Other opportunities for direct use include development initiatives along the conversion of thermal areas and existing hot springs into eco-tourism and balneological centers, technology development initiatives on the utilization of geothermal brine / waters / steam as heat sources for various agri-industrial applications to ensure food security & poverty reduction and support to the biofuels program of the government.

Development of the following thermal areas into eco-tourism parks:

- Inang Maharang, Manito, Albay – being developed by the Energy Development Corporation and the Local Government of Manito, Albay.
- Naglagbong, Tiwi, Albay- being developed into a Naglagbong (NAG) Park by Chevron Geothermal Philippines Holdings Inc, in cooperation with the Local Government of Tiwi, Albay
- Improvement of thermal ponds for existing hot spring resorts in Tiwi, Albay and Irosin, Sorsogon
- Tilapia & prawn farming and hot spring heated prawn pond in San Mateo Hot and Cold Spring Resort, Irosin, Sorsogon

Agri-industrial applications for food security and poverty alleviation:

- Extraction of oil from lemon grass
- Cloth dyeing using natural dyes
- Poultry dressing and artificial incubation and brooding system
- Drying coconut meat residue in manufacturing flour
- Pili pulp / oil extraction
- Drying technology in hand-paper making
- Irrigation and distilled drinking water from treated geothermal waste water
- Sterilization of spring water to produce potable water utilizing geothermal brine as a heat Source

Biofuels as alternative fuels program of the government, using separated geothermal steam as heat source:

- Methyl esteric fuel production utilizing waste vegetable oil
- Rice-ethanol production
- Coco-methyl ester production

Given the geothermal and other non-conventional and renewable sources of energy in the Bicol Region which can be tapped for power and non-power applications, including the incentives that maybe provided by R.A. 9513, growing importance should therefore be placed on the development and implementation of new programs and technologies to help provide the industry with an appropriately trained workforce and the necessary technology.

4 CONCLUSIONS

Geothermal energy in the Philippines is related to the volcanic origin of the archipelago. There are many identified surface thermal manifestations from the major thermal areas in the Bicol Region some of which may be used for non-power use.

Direct use of geothermal resources in Bicol Region is minimal except for some hot springs for bathing and cleaning purposes.

Geothermal resources can be utilized to improve post harvest operation for agricultural products in the Region. Likewise, geothermal waste and brine from existing geothermal plants can be utilized for productive uses.

Given the availability of geothermal sources of energy in the Bicol Region which can be tapped for power and non-power applications, including the incentives that maybe provided by Renewable Energy Act of 2008, growing importance should be placed on the development and implementation of new programs and strategies to help provide the industry with an appropriately trained workforce and the necessary technology to improve the socio-economic condition of the Bicolanos and help mitigate the impacts of climate change.

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