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# Preliminary Environment Impact Assessment of Pangalu Geothermal Field in Papua New Guinea

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## ABSTRACT

Pangalu Geothermal System is one of the identified geothermal fields in Papua New Guinea in the recently geological reconnaissance studies undertaken by PNG Mineral Resource Authority. It is highly potential reservoir to be commercially exploited for power plant. The preliminary geological studies have demonstrated the possibility of geothermal reservoir not only in Pangalu but other sites in Talasea Local Level Government in Hoskins Electorate of West New Britain Province in Papua New Guinea. In this report, a preliminary environmental impact assessment is presented for Pangalu Geothermal Field. Although ad-hoc basis, PNG Mineral Resource Authority has conducted ongoing studies into Pangalu and other sites in the province for the possibility of using the geothermal energy to produce electricity. A desktop review was carried out of the possible environmental and social effects of this proposed project to model the formulation of environment impact assessment (EIA) in Papua New Guinea. In this review, desktop analysis has been made to identify the possible key impacts of sequence of geothermal phases from exploration to operation, and the potential environment management strategies. It is based on reviews that preparation of Environment Impact Assessment will be modelled in reference to the type of required information to fully disclose the baseline studies and risks that are not catered for so that detailed studies are completely provided in the EIA considering physical, biological, geological, socially, historical and institutional factors in West New Britain Province

## 1. INTRODUCTION

PNG geology is characterized by two major crustal tectonic plates, the Australian Plate and Pacific Plate which are attributable to its location along the Pacific Ring of Fire (Figure 1). The tectonic plates cause major fault events especially in the mainland of Papua New Guinea. PNG hosts a highly mobile zone of tectonic interaction between the continental crust on the south and oceanic crust to the north.

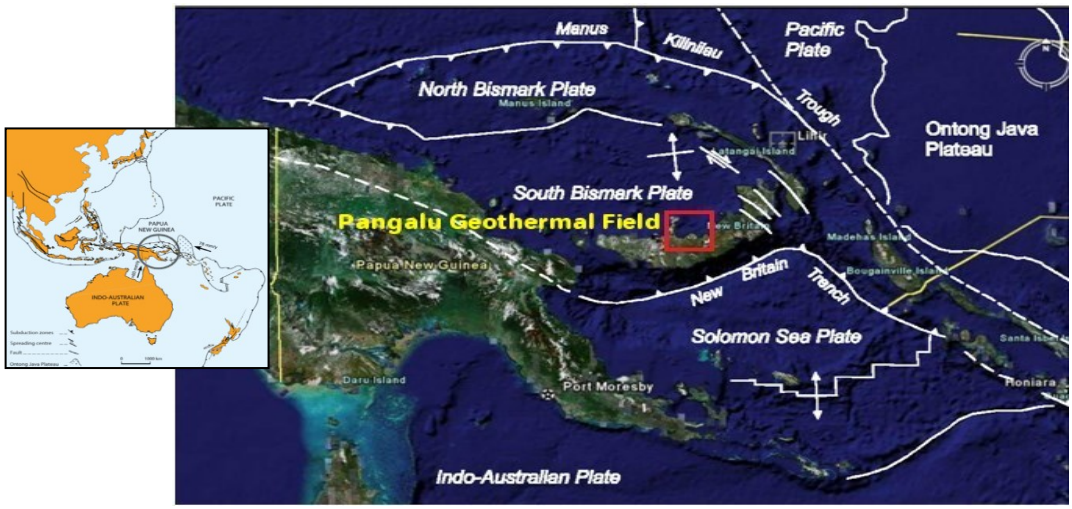


**FIGURE 1: Tectonic Plates in Papua New Guinea with major plates, Indo-Australian Plate and Pacific Plate ( Adapted from Williamson and Hancock, 2005)**

The geological development of PNG forms young folded and faulted mountains, volcanic landforms, island arcs and other geomorphological processes. The mineral resources, geology and geophysics publication by Dow et.al (1972) further explains that besides the geological framework of PNG, its stratigraphy and structure, active volcanoes and earthquake activities are common features associated with the plate tectonics. Dow et al (1972) specifically describe the two main faults within the New Guinea Mobile Belt that are responsible for the displacement along the fault zone, which are Owen Stanley Fault and Markham-Ramu Fault Zone. These cover the investigated geothermal areas of Wau-Bulolo in Morobe and the Lamington-Mangalase-Trafalgar in Oro Province. These account for geothermal systems and manifestations where occurrence of magma intrusion is established that could produce the convective circulation of groundwater (Utami, 2011).

## 2. ENERGY RESOURCES AND UTILISATION

### 2.1 National Context – Papua New Guinea

PNG has a promising geothermal utilization with huge geothermal potential that could support the economy at 21.92 terawatt-hours (REEP, 2012). There are several sound developmental and strategic reasons for suggesting a geothermal energy approach (as part of a wider energy mix strategy in PNG). PNG is blessed with a range of resources and options for energy. It has petroleum, coal, hydropower, solar, and geothermal energy potential as the main options. Many rural areas have relied for decades on stand-alone diesel generators and more recently, solar energy. There are limited gridded electricity networks: 93% of the population are situated out of reach from the electricity networks (UNDP 2017). There is increasing pressure and encouragement for non-fossil fuel energy options from NGOs (Green Climate Fund, 2016). For PNG this already includes solar energy, wind energy, hydropower and geothermal energy. It is prudent to develop and expand a range of options for power to enhance energy security and economic development and mitigate further contributions to anthropogenic climate change. There is government and donor commitment to development and expansion of hydropower and solar power. Therefore, geothermal power generation has potential to fix into the mix of options for PNG as part of the national energy development program as per the PNG government commitments to extend power to a much wider percentage of the population, using renewable resources where possible.

Geothermal utilization is insignificant in PNG but is becoming a new player in the field of energy for the near future. Studies have demonstrated that potential geothermal capacity in PNG is 5,000 to 6,000 megawatts (MW). PNG's PNGNEP2017-2027 (PNGNEP) has been approved recently to pave the way forward for improvement of the energy sector to fulfil the PNG National Vision 2050 (NV2050). The policy, legalities and regulation of geothermal energy need to be strengthened to achieve its aspiration to accelerate geothermal exploration and development. PNG has not been able to progress into geothermal exploration and drilling for commercialization of geothermal development. PNG has not been able to progress into geothermal exploration/drilling and to commercialize geothermal development apart from the existing Lihir Geothermal Power Plant. The Lihir Geothermal Power Plant is a first geothermal power plant in PNG which is an ancillary component to the Lihir Gold Mine to support power generation for mining development. There are obstacles that block the enactment of the geothermal policy from government endorsement. PNG resource ownership, legal implications and the electricity market remain to challenges to potential geothermal development.

The geothermal energy potential to produce electricity and to stimulate economic opportunities from its direct utilization has been recognized by the government of PNG to support national development plans and the PNG Vision 2050. There is reported interest from several geothermal companies to carry out geothermal utilization. The absence of geothermal regulation and policy prevents further geothermal exploration and surface drilling in PNG. Rabaul, Karkar and Talasea geothermal sites are the main places of interest for geothermal companies

### 2.2 Regional Context – West New Britain Province

West New Britain has a promising geothermal utilization with huge geothermal potential that could not only support the economic but also to improve socio—economic wellbeing of the people of the province. Three geothermal sites have been identified to be used as future geothermal power plants. The National Energy Policy produce strategic and development reasons for suggesting a geothermal energy approach in the province and as part of the a wider energy mix strategy in PNG. West New Britain still relies for decades on stand-alone diesel generators and small scale hydropower schemes.

According to the National Energy Policy 2017-2027, West New Britain Province is the key province for future geothermal development with the potential capacity of more than 1,000 MW. Ambitiously, Amber and Fisher (2014) proposed that West New Britain Province, if hot springs developed, could supply the power to two other provinces namely Morobe Province and East New Britain via submarine cables.

### 2.3 Current Electricity trend/Statistics

According to PNG Power Limited (2015), the total installed electricity capacity in West New Britain is less than 10 MW in 2015. Hydropower accounted for about 40 per cent with diesel 60 per cent. As a result, about 70 per cent of the population has no access to electricity. Most of the electricity is available centrally in the Kimbe-Hoskins. The province has had capacity problems in providing power to urban developments and the major economic activities and numerous power interruptions have taken place. Electricity in the province is often unreliable, and relatively expensive. This has led to difficulty in accessing proper power for most of the population and hence contributes to poverty in rural areas. Most of the populations still use petroleum products for the energy needs of their everyday lives. Such regular usage of petroleum products for energy leads to environmental problems and the high costs of their socio-economic lives.

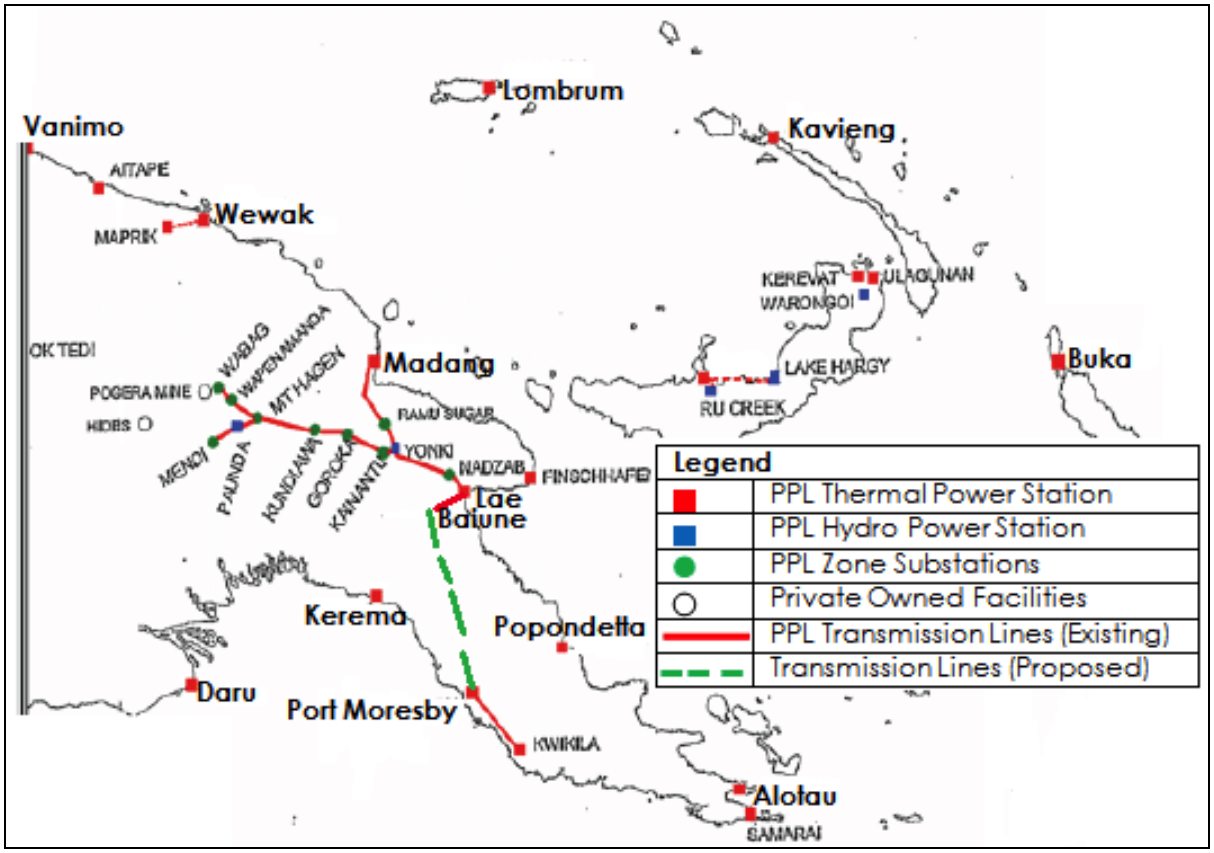


**FIGURE 2: Map showing the power network and transmission system operated under monopolistic utility, PNG Power Limited in Papua New Guinea. (Red line indicates the transmission line and blue box indicates the power station/substations/generators)** ***Source: PPL, 2015***

Electricity in West New Britain has been transformed successively with constraints in providing power. PPL (formerly PNG Electricity Commission) has been building, operating and maintaining the existing power activities from generation, transmission and distribution from Kimbe Thermal Power Station, small-scale Ru Creek Hydro Power Station and Lake Hargy Hydro Power Station since the 1970s (Figure 2). In fact, hydro is and continues to be the main source of generation for the province which supplies electricity at 60% compared to the fuel burning power system/plant 30% (PPL, 2006). The New Britain Palm Oil limited (NBPOL through palm oil developer under Independent Power Producer (IPP) manages the total of 10% of electricity supply to the province especially the associated palm oil activities but purposely built for running their own industrial operational activities

The Ru Creek Hydro-electric operates 0.8 MW while the Lake Hargy provides the power capacity of 2MW which supply the power to the Bialla Township and the Kimbe-Hoskins (ADB, 2009).

### 2.4 Future Electricity Project

It is desirable for the National Government to accelerate energy expansion programs for PNG and West New Britain Province is no exception. Currently, there is a $US1.7 billion multi-bilateral partnership deal which aims to electrify 70 per cent of PNG by 2030. This is the commitment that PNG Government wants to embark on in accordance with the NV2050, National Development Strategy 2010-2030 and the MTDS III 2018-2022. Simultaneously, PPL works to develop power from the renewable energy resources in PNG. As part of the commitment to the NV2050, PNG has produced the Least Cost Development Plan paving the way forward for energy expansion and the transmission and network programs. It comes at the right opportunity to capture the benefit from the K3 billion multi-country electricity initiative.

The development of the PNGNEP2017-2027 and the PPL.'s Least Development Plan drives not only hydro expansion opportunities but also petroleum and natural gas, geothermal, solar, biomass and other available energy resources. It is also in line with PNG's National Development Plan to critically address the power shortage considering increased economic opportunities. The future electricity project as documented from the PNGNEP2017-2027 and the PNG Power Section Plan in consultation with WB are:

(a) Town Electrification Investment Programme (TEIP)

- 150km 66kV Kimbe-Bialla Transmission Line Interconnection – WNB Province (Supplying power from Lake Hargy Hydro-electric Station to Kimbe Township)
- Rehabilitation of Warongoi Hydropower Plant in East New Britain
- Rehabilitation of 2.5MW Lake Hargy Power Plant in West New Britain

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- Rehabilitation of 1.5MW Ru Creek Power Plant in West New Britain

(b) Renewable Energy Development Plan – Talasea Geothermal Site – > 1,000 MW

(c) Power Infrastructure Plans (currently underway and proposals)

- IPP – New Britain Palm Oil Ltd – Oil Palm Waste under Clean Development Mechanism – WNB Province, Oro Province and MBP

- Hydro potentials –40 MW Lake Hargy Hydro in WNB, 40 MW Gazelle Hydro, 2-5 MW mini hydro in provinces

**2.5 Geothermal Policy**

PNG does not have a regulatory framework to cater for geothermal development. There are reported numbers of proposed exploration applications being made to carry out geothermal exploration in PNG areas. There are several applications pending the setup of a proposed regulatory framework. One case example is Kuth Energy PNG Ltd which has pursued geothermal exploration at three geothermal potential sites which in 2008 were put on hold due to lack of a regulatory framework mechanism but still maintain their strategy to further explore the selected areas (Kuth Energy, 2012). Hence, a regulatory framework is required to motivate further geothermal research and exploration as PNG is potentially expected to benefit greatly from geothermal utilization and its possibilities to improve the living standards of people.

The concept of development of geothermal plans, policies and legislations began in the 1970s when Japan and USA deliberated the proposal to utilize volcanic energy from Rabaul site (Furumoto, 1974). There was not a GRP, legislation or plan developed until the significant emergence of Lihir Geothermal Field. This triggered the interest for more preliminary documentation of volcanology and geothermal resources, specifically the geothermal manifestations throughout PNG.

Lahan (2016) summarized the history of geothermal studies in PNG and that the geothermal policy began dating back to 1988 when the Stefansson reviewed all data held by then Geological Survey PNG (GSPNG). Stefansson provided three recommendations; the national exploration program, geothermal unit within the GSPNG and the training of geothermal scientists (Lahan, 2016). The recommendations were not implemented until 2008 when Lihir Geothermal Power Plant became operational. This initiated the significance of geothermal energy as alternative power generation from 2009 onwards.

**2.6 National Vision 2050**

In a country-wide plan, PNG has embraced the National Vision 2050 paving a long-term strategy that maps out the future direction for PNG. The vision of the long-term strategy is to become a smart, wise, fair and happy society by 2050 (PNG Treasury, 2010). The Vision 2050 is supported by seven pillars and these are:

- Human Capital Development, Gender, Youth and People Empowerment
- Wealth Creation
- Institutional Development and Service Delivery
- Security and International Relations
- Environmental Sustainability and Climate Change
- Spiritual, Cultural and Community Development,
- Strategic Planning, Integration and Control.

One of the seven pillars concerning renewable energy is Environmental Sustainability and Climate Change. This is the pillar that sets out the need for development of large renewable energy projects to promote sustainable development in all sectors and expects the provision of 100 per cent power generation from renewable energy sources by 2050. Hence, geothermal energy is covered in the context of renewable energy and this will enable the formulation of short-term and long-term development plans for increased utilization of renewable energy resources in line with Vision 2050 and the development of sustainable development policies to increase the electricity needs. According to the Treasury (2010), Vision 2050 also expects the establishment of a Sustainable Development Policy in all sectors, especially forestry, agriculture, mining, energy and oceans by 2015. This provides PNG with an opportunity to come up with the proposed regulatory framework to meet demands for geothermal exploration and utilization. The establishment of sustainable development policies, especially the provision of 100 per cent of power generation from renewable energy sources allows the possibility of future geothermal utilization in PNG in line with the Vision 2050. Such a policy drive will improve the wellbeing of the people and the economy of the country.

**2.7 National Development Strategies 2010-2030**

PNG Development Strategic Plan 2010-2030 is the home-grown document that provides development aspirations for the period of 20 years to achieve the NV2050. It is simply a development pathway to improve the living standards for the people of PNG by setting out the broad framework, targets and strategies to progress into the next 20 years leading up to 2050.

The energy development is one of the key development pathways in the 20-year plan which is aimed at two goals:

1. To ensure that all households have access to affordable energy

2. To provide sufficient power to be generated and distributed to meet future energy needs and demands.

It is also targeted that by 2030 over 70% of all households and businesses should have access to reliable, affordable and modern clean energy sources. Therefore, the 2010-2030 focuses on promotion of energy from hydro power and gas. The National Government aims to increase the power production from hydro power at 1,020 MW by 2030 followed by gas thermal at 390 MW. This is reflected in energy demand that projects to increase in preparation for future economic developments as outlined in the National Development Strategies 2010-2030.

In addition, the National Government also intend to make use of renewable energy as part of the environment sustainability and climate change in accordance with PNG Visions 2050. Although the National Government want to pursue renewable energy resources in partnership with private sector, it is acknowledged that there will be a huge amount of investment to establish the utilization of renewable energy resources in the likes of solar, biomass, geothermal and wind. As part of the projection by 2030, about 500 MW should be expanded from the use of renewable energy for electricity.

Specifically, geothermal is part of the renewable energy strategies. It is ideally fitted into the key economic corridor concept where the National Government identified the corridors of poverty where living standards and the basic services are very poor. It requires substantial investment of infrastructures in those economic corridors.

The key economic corridors that relate to potential geothermal infrastructures for power generation are:

1. Central Corridor (Central, Oro, MBP and Morobe)
2. Morobe – Madang Corridor
3. South Coast Corridor (ENB and WNB)
4. Momase Corridor (Madang, East Sepik and West Sepik)
5. Solomons Corridor (Autonomous Region of Bougainville)

**2.8 MTDS III 2018-2022**

The Medium-Term Development Strategy III is the third consecutive national development strategy for PNG, setting out the National Government's development priorities for 5 years between 2018 and 2022. Affordable and clean energy is the key areas to the sustainable development goals as part of the NV2050. It was integrated into MTDS from NV2050. According to the MTDS report, the performance of the previous development strategies shows that the target of household electrification rate in 2015 by 27% was not achieved. In reference to development strategies between 2010 and 2015, the National Government only achieved 21% in delivering electricity access to households.

MTDS acknowledges that energy is the backbone of the economic growth and development of the country. This is demonstration of the current National Government's collaboration and joint effort with private sectors to plan, improve and invest in energy sectors apart from agriculture and manufacturing sectors. In addition, the National Government has been working hard to achieve the target and produce results to commit the funds into quality infrastructure and utility. This is about the deteriorating conditions, in this case, the energy, on the context of creating an enabling environment for economic growth and the improvement of service delivery. The energy sector and other two sectors (ICT and Transport) are key areas that have the potential to address the deteriorating conditions in infrastructure and utility.

The National Government is committed to the infrastructure strategies of increasing electricity supply with extension of transmission power grid on to communities through National Electricity Supply Roll-out Plan. Compared to the previous MTDS, the National Government clearly states that more investment is needed in clean energy sources including hydro and geothermal to accelerate the energy expansion with moves to do away with dependence on diesel power generation.

**2.9 PNG Economic Road Network Development & Maintenance Plan**

The PNG Economic Road Network Development & Maintenance Plan is the national road development strategy that supports the National Development Strategy 2010-2030. This provides guidance for investments to economic corridors that is explained in Section 2.7.2. It is established key investments in a sustainable energy supply program that are feasible once the development of the new road is fully achieved.

This accelerates the demand for energy and the expansion of energy access to households. In addition, it enables the supply of reliable and renewable electricity supply with reduction of fuel imports. Such development of key economic corridors where presence of potential geothermal sites is located provides the opportunity to tap into geothermal heat not only for power generation but to construct power transmission along the roads.

**2.10 PNG National Energy Policy 2017-2027 (PNGNEP)**

The PNGNEP sets out the blueprint for energy expansion in PNG. The policy comprehensive and provides an overview, challenges and strategies for both fossil fuels and renewable energy. It addresses the development of electricity, institutional reform of the electricity, local participation in the energy sector, energy financing, trading, pricing and socio-economic issues, and the land, environment, health and safety. Specifically, fossil fuels entail expansion of upstream petroleum, midstream and down petroleum, mid and downstream natural gas and clean coal resources. It is also the centrepiece connecting PNG Visions 2050, National Development Strategies 2010-2030 and 5-years Medium Term Development Strategies and the corresponding policies in the likes of the National Electrification Rollout Plan, PPL Least Cost Development Plan and the PNG Economic Road Network

Development & Maintenance Plan. Geothermal energy is heavily specified under the PNGNEP hence it should be become a catalyst for the management of the resources to be managed administratively under proposed National Energy Authority (NEA).

PNG is blessed with a range of resources and options for energy. It has petroleum, coal, hydropower, solar, and geothermal across the country. In addition to fossil fuels from petroleum, natural gas and coal, most of the renewable energy resources are not fully explored and exploited. The PNGNEP provides the right time solution to enable further exploration and exploitation especially when there is less than 50 percent electricity coverage to the increasing population and the increased economic development activities. PNG's population is growing at a fast rate where youth group dominates the population pyramid which is straining the government's effort to provide goods and services. Business houses are subject to frequent power blackouts and a lack of power accessibility and reliability remains a major factor to doing business in PNG.

The development of policy on energy now enables the plan for renewable energy resources to become a reality. With the support from the WB, the introduction of renewable energy policy and rural electrification policy enables the funding opportunities for utilization the renewable energy resources specifically the hydro and geothermal to take place. This is highlighted with the support geared towards the new Naoro Brown Hydro Power Plant Project and the massive improvement to the aged small-scaled hydro power stations (World Bank, 2019). The energy development stimulates the economic growth and geothermal resources is no exception that can offer enormous potential to utilize energy not only for power generation but also for other economic uses including cocoa drying, mining operation, tourism and other direct uses.

### 2.11 National Electrification Roll out Plan (NEROP)

This is an upcoming plan that will be completed in July 2019 supported by the WB under PNG Energy Sector Development Project. It focuses on expanding the distribution grid and establishing mini-grid systems for electricity access to households. It is vital plan other than the National Energy Plan and Policy that aims to strengthen the rural electrifications where most of the population lives in the rural areas. This will align with provincial and district development plans for electricity supply and distribution.

### 2.12 National Compatible Climate Change Management Policy 2014

The Climate Change Policy 2014 is an important policy that relates to the promotion of renewable energy. It is a compatible management approach with strategies that cross all sectors in response to impacts of climate change. The vision of the policy is to have a robust and sustainable economy for PNG through low a carbon pathway and green economic growth.

It is acknowledged that this policy is formulated to stage-manage the adaptation and mitigation frameworks. Amongst the issues and gaps that calls for a climate change policy, it is considered that there was no promotion of utilization of clean energy technologies considered for sustainable development. It is also related to greenhouse gas emissions (GHG) from economic sectors including the energy sector. The policy also recognizes CCDA as National Designated Authority in accordance with the Kyoto Protocol. This enables a pathway for PNG to tap into the Green Development Fund for energy technologies and development. The energy becomes key participation in the CCMP where DPE collaborates with CCDA in its efforts to reduce GHG related to the production and use of energy.

Energy-related strategies that promote low-carbon growth development are:

a) energy sources reduce climate change

b) support a transition to renewable energy

c) incentives for the small-scale use of renewable energy systems.

d) local energy generation from renewable sources

e) design for alternative sources of energy.

f) energy generation

g) eliminate regulatory barriers to the use of renewable energy systems.

Investing in geothermal energy is significant for the renewable energy sector with a policy that recognizes to be transformed with hydro power. Simply, geothermal is one of the renewable energies that is also regarded as low carbon growth.

### 2.13 PPL.'s Least Cost Development Plan

Like the NEROP, the PPL Least Cost Development Plan is nearing completion. Developed by PPL.'s state owned power utility, it is going to be PNG's power sector report intended to guide the sector on collaboration with private energy investors on sector basis, generation opportunities from renewable energy sources, transmission network expansion and the improvement to the resource requirement in the existing infrastructures in PNG. This policy guidance is technically dominated by PPL with consultation with PNG's ICCC and the DPE. It basically guides PPL to follow its internal processes by planning,

Geothermal energy may not be an option for the business now as the focus is now on least cost generation options such as hydro and gas. It is acknowledged that geothermal resources are scattered around the country and not much development has taken place. Hence, it will be some years down the line unless PPL want to look at off- grid solutions in areas where geothermal resources are placed. Furthermore, coal and fossil fuels are not in the plan either. PNG CEPA is a party to the UN Conventions and Kyoto

Protocol that advocates on climate change and its adoption and fostering of greener energy. PPL intends to make sure that it only delivers cheap, reliable, safe and clean energy to its current and future users in all sectors. Coal is not in the picture for the country.

### 2.14 PPL.'s Independent Power Producer and Major Infrastructure Policy

This is the policy relating to collaboration between PPL, a state-owned power electricity and private sectors explicitly independent power producers (IPP). The policy recognizes that IPPs are critical to the electrification program in PNG when PPL does not have funding to establish new power plants. There are no IPPs for geothermal energy to support PPL.'s Least Cost Development Plan. PPL strongly envisages for the power utilization from renewable energy sources. The policy clarifies the situations and way that private sector partners can participate in implementing PPL's least cost development plan and other strategic and economic enhancing opportunities in the power sector.

### 2.15 International Support for electricity/energy development in PNG

WB Power Section Support Program

This program is termed as PNG Energy Sector Development Project approved from February 2013 to the end of July 2019. The project aims to strengthen the policy development and strategic framework for renewable energy and rural electrification and to enable attractive investment in new hydropower development to supply the Port Moresby electricity grid (the capacity city of Papua New Guinea is Port Moresby). The major component of the project is the Naoro Brown River Hydroelectric Project (80MW) which began its feasibility studies in 2017.

APEC 2018 Multi-Bilateral Electrification Support Program

This is termed as Papua New Guinea Electrification Partnership and is a major established commitment by combined Australia, New Zealand, Japan and United States in 2018 following the APEC Leaders meeting in Papua New Guinea. It is committed to provide US$1.3 billion support to expand the electricity coverage throughout Papua New Guinea. The PPL (monopolistic power utility) declared the initiative that funding from the PNG Electrification Partnership would assist the roll-out of electricity and thus, increase the number of connections with special focus on hydropower. The electrification partnership is expected to complement PPL Limited's Least Cost Development Plan on expansion of renewable energy projects.

## 3. REGIONAL GEOLOGICAL, VOLCANOLOGY AND GEOTHERMAL SYSTEM – WEST NEW BRITAIN PROVINCE

Pangalu is one of the potential geothermal field identified within the Talasea Geothermal site and is considered to be the economical high temperature geothermal system. The geothermal studies has been ongoing under the Mineral Resources Authority (MRA) with collaboration with international institutions from New Zealand, China and the Pacific Regional Secretariat. . Figure 3 exemplifies the locations of possible geothermal thermal areas based on several publications especially the Mosusu (1997), Loffler (1972), Heming (1964), and Williamson and Hancock (2005). WNB Province, ENB Province, Madang Province, Morobe Province, Oro Province and MBP are classified as potential geothermal provinces (Figure 3). This relates similarly to the geological and structural framework in the publication of Loffler (1977) and the Williamson and Hancock (2005) on the settings of geothermal areas characterized by volcanic landforms and faults.

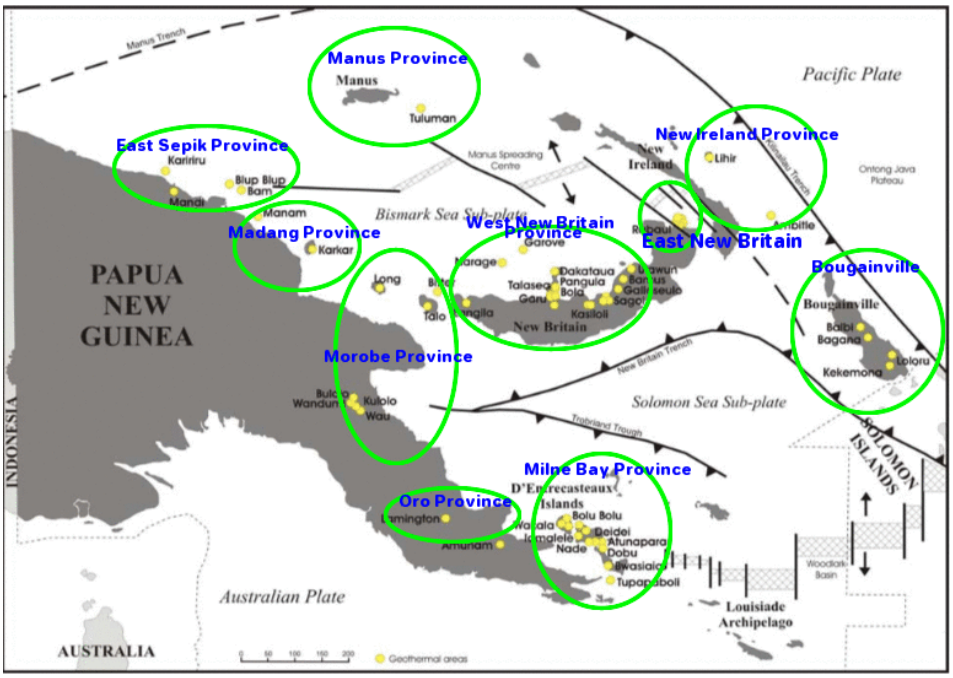


**FIGURE 3: Map of geothermal areas in Papua New Guinea. The yellow dots indicate the geothermal areas adapted from Mosusu (2008) and Heming (1969). The black lines indicate two types of plate and micro plate boundaries modified from Williamson and Hancock (2005). The green circles with blue names highlight the name of the administrative province in Papua New Guinea where geothermal areas are located. (Source: modified from McCoy-West at, 2002)**

**TABLE 1: Listing of geothermal areas in provinces derived from Figure 3 of map of geothermal areas in Papua New Guinea**

| NO | GEOTHERMAL PROVINCE | GEOTHERMAL AREAS |
|---|---|---|
| 1 | East Sepik Province | Kairiru, Mandi, Blup Blup, Bam |
| 2 | Madang Province | Manam, Karkar |
| 3 | Morobe Province | Long Island, Bulolo, Wandumi, Kulolo, Wau |
| 4 | Oro Province | Lamington, Amunam |
| 5 | Milne Bay Province | Bolu Bolu, Deidei, Wakala, Iamalele, Nade, Atunapara, Dobu, Bwasiaia, Tupapaboli |
| 6 | West New Britain Province | Talo, Bitter, Narage, Garove, Talasea, Langila Garu, Bola, Pangalau, Dakataua, Kasiloli, Sagoi, Galloseullo, Bamas, Ulawin |
| 7 | East New Britain Province | Rabaul |
| 8 | New Ireland Province | Lihir, Ambitie |
| 9 | Autonomous Province of Bougainville | Balbal, Bagana, Loloru, Kekemona |
| 10 | Manus Province | Tuluman |

Therefore, West New Britain Province has more than 10 geothermal systems compared to other provinces of PNG (Figure 3 and Table 1). Given the literature on volcanology and morphology background in West New Britain Province, it is clearly documented that Talasea and Pangalu have many associated geothermal manifestations. The geothermal manifestations include hot springs, hot lakes and pools, fumaroles and solfataras. This exhibits the potential location of potential geothermal systems associated discharge features on the surface.

In addition, significant geothermal manifestation in Talasea has attracted both international and domestic tourists due to its beauty, uniqueness and heat. This is in reference to tourist hotspots in Walindi and Garu where the PNG Tourism Promotion Authority has aggressively promoted the geo-tourism to boost the tourism revenue not only in West New Britain Province but throughout PNG. The PNG Tourism Promotion Authority (PNG Travel, 2019) identifies three major tourism attractions that associate with geothermal manifestations, namely Mt. Tavurvur in East New Britain, Fergusson Island in Milne Bay Province and Talasea in West New Britain. In addition, geothermal manifestations are associated with a significance of biological diversity values. It is clearly observed that geothermal manifestation harbours flora and fauna. Mutia (2011) explains that most geothermal resources are located within remote and protected areas. PNG is no exception where PNG government through the CEPA aims to cover as much as possible in line with PNG Sustainable Development Plan to protect the tourism, recreation and scenic areas. There are less than 15 protected areas closely associated with geothermal resources having the presence of geothermal manifestations. However, only 9 protected areas are classified as legal protected areas. (Figure 4). Pokili Wildlife Management Area (WMA) and Garu (WMA) are two protected areas in WNB Province where the Talasea Geothermal site is located. The emergence of the PNG Protected Areas Policy 2020 provides more room to cater for the increased coverage of additional protected areas especially the hot springs, geysers and other associated geothermal manifestations.

Generally, the geothermal manifestations in PNG comprises hot springs, hot lakes and pools, fumaroles and solfataras and other geothermal features that are spread across the country. These are the main potential geothermal systems that exhibit direct (concentrated) discharge features on the surfaces. Table 1 and Figure 3 highlight some of the recording of geothermal manifestations from the Volcanoalive (2019) associated with the types of volcanoes and the fault systems, and from Berhane and Mosusu (1997).


**FIGURE 4: Locations of direct discharge features and manifestations in PNG. The number highlights the names of the geothermal manifestations in the Table 6 below. The orange triangle indicates the types of volcanisms (modified from Bjornsson, 2011 and Volcanoalive, 2019)**

**TABLE 2: Main geothermal manifestations in West New Britain recorded from the Volcanoalive (2019) and from Berhane & Mosusu (1997)**

| | Name of Volcano | Province | Type | Summit Elevate. | Geothermal Features |
|---|---|---|---|---|---|
| 8 | Garua* | WNB | Volcanic Field | 656 m | Hot springs, boiling pools, fumaroles, geysers |
| 9 | Dakataua | WNB | Caldera | 400 m | Solfataras, warm springs |
| 10 | Walo | WNB | Hydrothermal Field | 15 m | Solfataras and mud springs |
| 11 | Karai | WNB | Strato Volcano | 565 m | Hot springs |
| 12 | Narage | WNB | Strato Volcano | 307 m | Hot springs and geysers |
| 13 | Garove | WNB | Strato Volcano | 368 m | Solfataras field and thermal areas |
| 14 | Baimus* | ENB | Strato Volcano | 2248 m | Fumaroles |

The geothermal manifestations are not fully mapped and documented throughout the identified sites to classify the thermal manifestations. Utami (2018) highlights the types of thermal manifestations namely diffused discharge, direct/concentrated discharge, intermittent discharge, catastrophic discharge and concealed discharge. The recordings of thermal manifestations from Figure 3 and Table 1 also relate to the volcanic landforms and fault structural regimes pertaining to Bismarck Sea Volcanic arcs (Loffler, 1977). Therefore, the classification of surface discharge features is non-existent in PNG between the 1960s and 1990s. Until 1997, the initial geothermal reconnaissance was undertaken to document the key geothermal manifestations to constitute the geothermal investigation in PNG attributable to the efforts of Mineral Resources Authority's Geological Survey team.

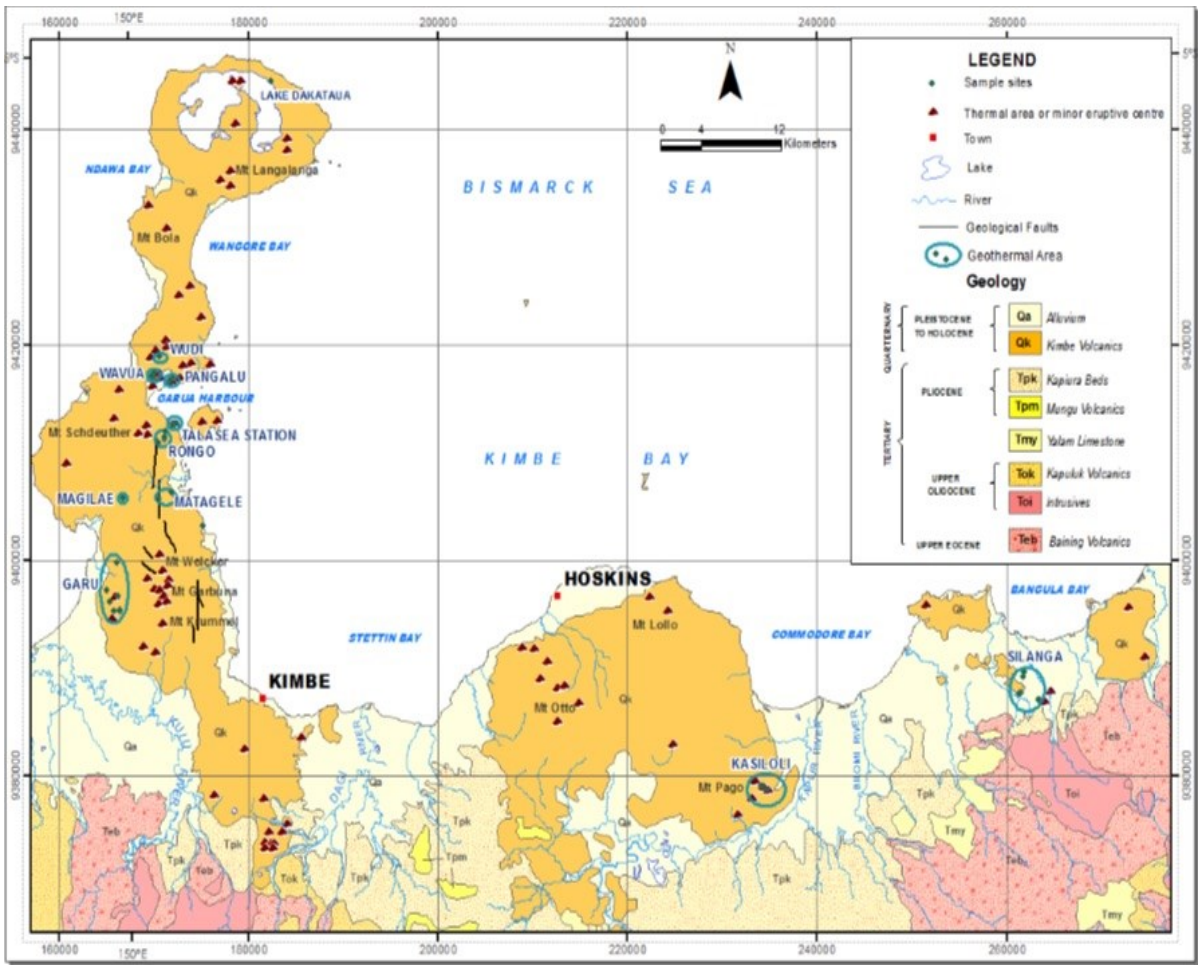


**FIGURE 5: Geology of Talasea-Hoskins area showing locations of geothermal sites, from Lahan, 2015** ***Source: Lahan et al, 2015***

Mosusu & Berhane (1997) developed a preliminary overview of surface discharges of key geothermal manifestations using the context of occurrence of thermal waters. They further mapped and documented key thermal waters with chemistry of water and gas emissions. Furthermore, they attempted to modify the geochemical work to estimate the natural surface heat flow. Although not all geothermal areas with manifestations identified in Figure 5 were undertaken for advanced geothermal studies, the proper classification of surface discharge features and thermal manifestations could be put forward to promote the field development. The mapping of thermal manifestations by Mosusu and Berhane (1997) were done to identify possible changes of hydrology of the geothermal system and investigate whether the changes of manifestations are natural, or due to geothermal fluid production. Furthermore, recent studies undertaken to revive the geothermal studies where only four (4) provinces are mapped and documented with further expansion of studies on Talasea-Hoskins of WNB in Province and Wau-Bulolo of Morobe Province (Figure 31). Other provinces are East Sepik Province (Kairuru Island) and MBP (Deidei on Fergusson Island). The studies of West New Britain are illustrated with recent geochemistry results produced during the 2010-2012 geothermal studies. Lahan et al (2015) studies are progressive studies of the Mosusu (2011) and Mosusu & Berhane (1997) as illustrate in Figure 6.

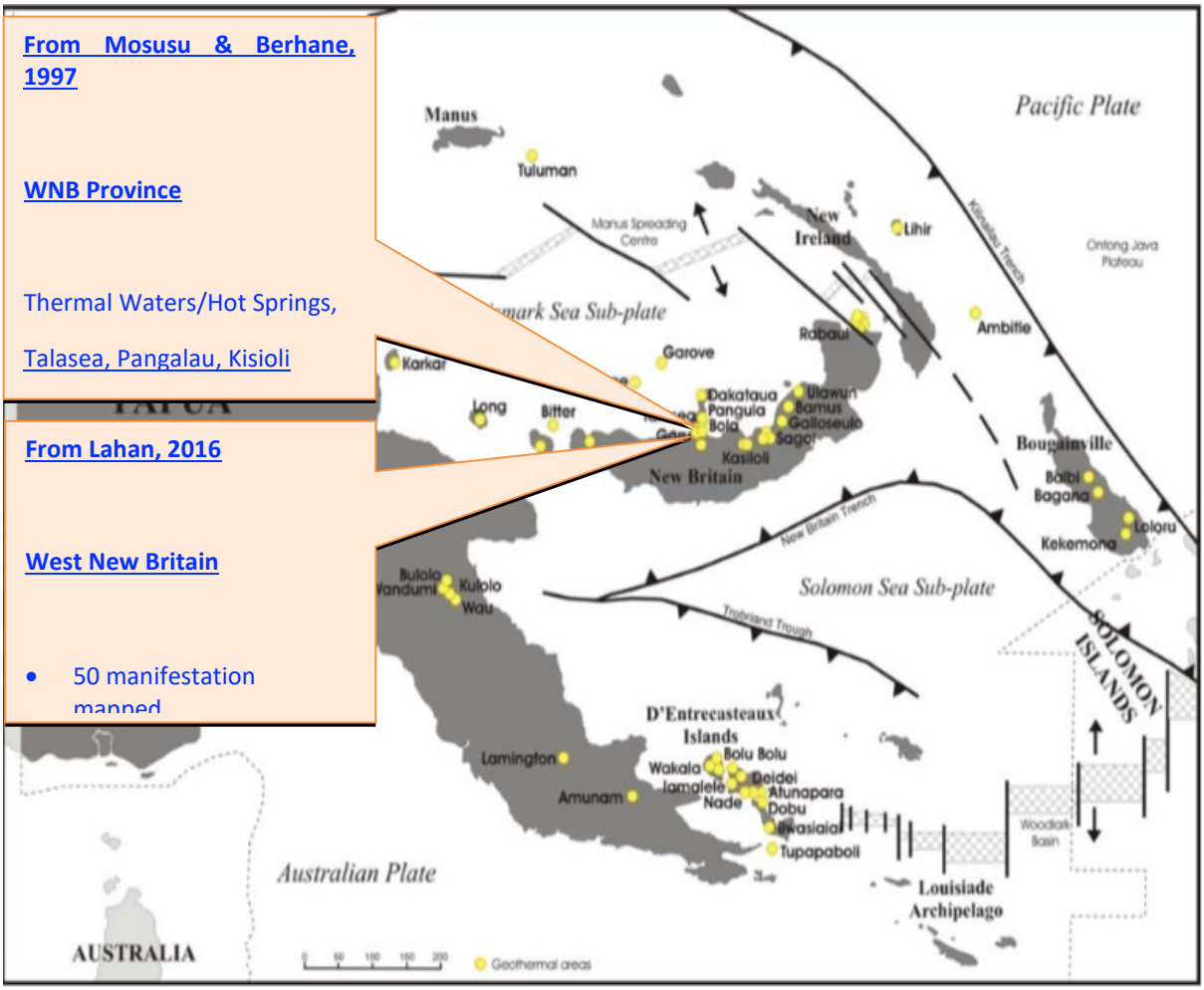


**FIGURE 6: Summary of mapping of thermal features and geochemistry results in West New Britain Province from Berhane & Mosusu (1997) (modified from Mosusu & Berhane, 1997)**

### 3.2.1 Volcanic Geology in Talasea Geothermal Site

The role of volcanic geology is very important to the exploration of geothermal energy. Volcanoes provide key geological information about magma movement, hydrothermal circulation, types and the permeability of reservoir rocks and the volcanic hazards. The geological information of magma movement is a key to locate the heat source and intrusion. Volcanoes provide clues about magmatic intrusions that are emplaced in the lithospheric crust especially above subduction zones that induce convection circulation of groundwater. Volcanic zones provide information on hydrology where groundwater is heated forming hydrothermal resources. Volcanic hazards provide useful information not only about the location of active volcanoes and potentially active volcanic terrain but also the hydrothermal eruptions that are pertinent to geothermal areas.

### 3.2.2 Types of volcanoes and Geothermal System

The types of geothermal systems also relate to types of volcanoes, such as active volcanoes, mature composite cones, basaltic volcanoes, calderas, surface manifestations and pyroclastic rocks.

Utami (2019) identifies that those volcanoes that host geothermal resource are polygenetic volcanoes where eruption activities take place more than once. Muffler and Duffield (1995) claim that a major volcanic field sustains the heat anomaly from 1,000,000 to 10,000,000 years which is characterized by an andesitic strato cone. It is also claimed that age, volume and composition of volcanic rocks also influence the type of geothermal system (Muffler and Duffield, 1995). Old volcanoes that are characterized by basalt/basaltic andesite are not suitable for a geothermal system while young silicic volcanic rocks consisting of very young igneous rock indicate a possible crustal heat source.

It is interesting to note that given that Talasea Geothermal Site is one of the western Pacific systems that correctly define within the category of suitable high temperature geothermal systems associated with volcanic complexes. Therefore, historical inactive volcanoes host economically producible geothermal systems. There are active, dormant and extinct volcanoes spread across the West New Britain. Recent active volcanoes lie in New Britain Province. The Southern Bismarck Sea Volcanic Arc consists of West New Britain Province which hosts many volcanoes (Figure 7). Active, dormant and extinct volcanoes are spread across the province linking both Morobe Province on western side and, East New Britain Province on eastern side. Loffler (1977) points out that it is very difficult to detail all the volcanic landforms in Southern Bismark Sea Volcanic Arc which comprise several provinces

of East Sepik, Madang, East New Britain and some parts of Morobe Province. Several volcanic fields are documented and mentioned that show connection to potential geothermal systems. There are about 50 volcanic centres spreading across the southern Bismarck areas with most of them classified as andesitic strato-volcanoes (Loffler, 1977). In addition, most of the volcanoes are heavily concentrated in West New Britain (Figure 7) compared to other provinces. Recently, active volcanoes, Langila, Ulawin and Pago are active volcanoes with records of eruptions in both 1990s and 2000s as well recent years between 2010 – 2018.

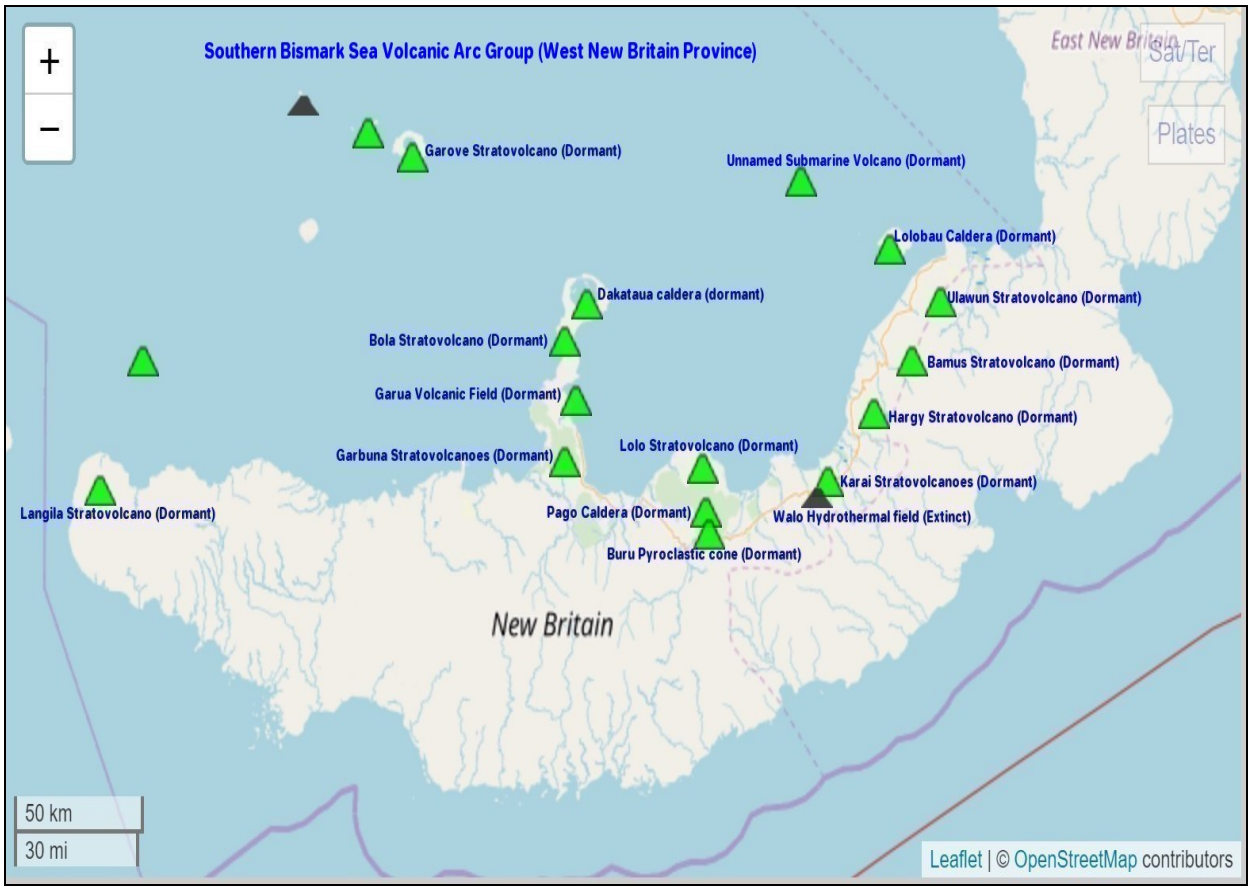


**FIGURE 7: Map showing region of Southern Bismarck Sea Volcanic Arcs in West New Britain Province on New Britain Island (Talasea Geothermal Site and Pangalau Geothermal Site are located within Garbuna-Garua-Bola volcanic field) (adapted from Volcano discovery, 2019)**

## 4. GEOTHERMAL REGULATORY FRAMEWORK

### 4.1 Regulatory framework and preparation of geothermal power developments in PNG

The definition of geothermal energy and geothermal resources in PNG is vague when comes to policy framework of governing the geothermal utilisation and resource management. At the moment and in accordance with the draft Geothermal Resource Policy 2014, the geothermal energy resource is classified as a mineral resource and is legislated for in PNG´s Mining Act 1992 (Department of Mining, 1992). Under this Act, the developer must apply for an exploration licence before starting additional research and drilling of exploration wells

The main legislations that may affect geothermal project development directly and indirectly in PNG are:

1. Mining Act 1992 and Regulation:
2. Land Act 1996:
3. Physical Planning Act 1989:
4. Electricity Industry Act 2002:
5. Independent Consumer and Competition Act:
6. Environment Act 2000:
7. Conservation Areas Act 1978:
8. West New Britain Provincial Administration

Table 3 displays a possible overview of the application process concerning Pangalu geothermal project in PNG, which permits are applied for and under what legal body issues these permits. The developer who is an applicant of the Pangalu geothermal project is responsible for applying for these permits. In terms of the application process for the planned geothermal project in West New Britain Province, the project must conform according to the PNG Mining Act 1992 and its regulation provision. The application procedures includes the location and evaluation of mineral deposits including feasibility studies and reconnaissance surveys (Department of Mining, 1992). The Mineral Resource Authority is the main body responsible for mineral exploration in PNG and it also issues exploration licenses in accordance with Section 20 of the Act. Under the current legal and regulatory framework, geothermal exploration and utilisation may be fall under the same category of mineral exploration as any drilling program at a defined prospect where the aggregate depth of holes drilled is greater than 2,500 metres before the activity is amended and upgraded to the commercialisation of the geothermal development that is operation of the geothermal power plant with the capacity of more than 2MW. The associated activity such as construction of national transmission are included in the application if covered for all brown field development

**TABLE 3: Policy framework and permitting process concerning possible geothermal projects in PNG (from Department of Mining 1992, Department of Environment and Conservation, 2000 and ICCC 2002)**

| Legislation | Regulatory Institutions | Permit | When to Apply |
|---|---|---|---|
| Mining Act 1992 | Mineral Resources Authority | Exploration Licence<br>Mining Lease<br>Special Mining Lease | Before carrying out a research and exploration program |
| Land Act 1996 | Department of Lands and Physical Planning | Land Title/State lease | During mining development |
| Physical Planning Act 1989 | Department of Lands and Physical Planning | Authority Approvals | Before carrying out substantial development projects |
| Electricity Industry Act 2002 | Independent Consumer and Competition Commission | Licence to generate, transmit, distribute and sell electricity | Before utilising resources for electricity production |
| Environment Act 2000 | Department of Environment and Conservation | Environment Permit<br>Approval in Principal | Before undertaking an exploration and research program |
| Conservation Act 2000 | Department of Environment and Conservation | Approval for Protected Area and Wildlife Management Area | During the Environment Permit Application/Assessment |

The Department of Petroleum and Energy is responsible for development of energy policies and plans including those for geothermal energy, which may involve data collection and analysis, and advice to the government on the sector issues (REEP, 2012). Fortunately, PNG now have a National Energy Policy that requires increased production of energy from renewable energy sources. Policy on geothermal energy resources tends to be lacking although it will be depend on the setup of the National Energy Authority, an administrative body for governing the approved National Energy Policy 2017-2027.

PNG Power Ltd (the Company) is the national electricity utility that has been issued with licences under the Electricity Act 2002 by the Independent Consumer and Competition Commission to generate, transmit, distribute and sell electricity in PNG (REEP, 2012). PNG Power has three main licences under the Electricity Act 2002 (ICCC, 2002) and these are:

- Electricity Generation Licence
- Electricity Transmission Licence, and
- Electricity Distribution Licence

Furthermore, PNG Power plays a leading role in power sector planning in PNG since the Department of Petroleum and Energy has extremely limited resources and suffers a lack of technical capacity to play a technical regulatory role in the energy sector. It will be changed once the establishment of National Energy Authority becomes a possible.

Pangalu Geothermal Field is already a key identified area under Department of Energy and Petroleum's energy policy where it is expected to supply more than 1000 MW from the geothermal hotspots. In addition, this contrasts the PNG Power Ltd's Least Cost Development Plan, or 15 Year PNG Power's Power Development Plan 2014-2028. The Least Cost Development Plan recommends that geothermal is not considered as least cost development option as PNG Power Ltd intends to focus on hydropower and LNG gas for electrification program in PNG. This may impede the opportunity for developing Pangalu Geothermal Field.

### 4.2 Environment Regulatory Framework

The environment regulatory framework in PNG is regulated under the Environment Act 2000 (Department of Environment and Conservation, 2000). It is this act that provides the mechanisms for dealing with activities with potential for causing environmental harm. The Environment Act 2000 is PNG´s only legislation that provides the administrative mechanism for environmental impact assessment and evaluation of activities regulating impacts on the environment through an environment approval and permitting system (Appendix 1). However, neither geothermal projects nor any other activities concerning geothermal energy are defined in the Environment (Prescribed Activities) Regulation 2002 under the Environment Act 2000 for the purpose of undertaking exploration to quantify geothermal resources and to evaluate the feasibility of large scale geothermal production. Environment (Prescribed Activities) Regulation 2002 is one of regulations under the Environment Act 2000 that categories the activity to be Level 1, Level 2 (Category A or Category B) or Level 3 activities (Figure 8).

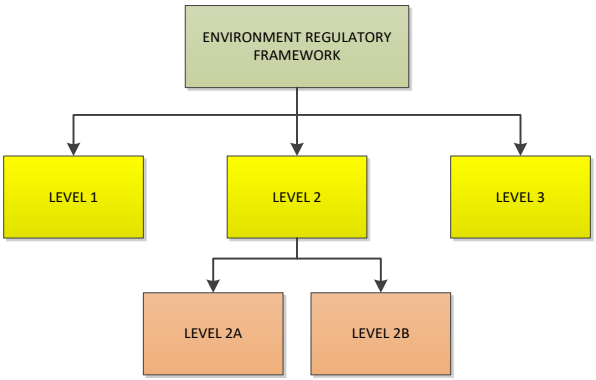


**FIGURE 8: Simple level of activities in PNG under environment regulatory framework (Modified from Environment Act 2000)**

Geothermal activity may be classified into Level 1, Level 2 or Level 3 activity. Generally, the environment regulatory framework determines criteria for geothermal project in the three-tier process that is potentially able to cause environment harm. Geothermal activities may fall into the following prescribed categories but their categorisation may be imprecise yet:

Level 2 Category A Activities

Sub-category 2.1 of Mineral Exploration – Any drilling program at a defined prospect where the aggregate depth of all holes is greater than 2,500 metres.

Sub-category 13.2 of Other Activities – Discharge of waste into water or onto land in such a way that it results in the waste entering water

Level 2 Category B Activities

Sub-category 12.6 of Infrastructure – Construction of electricity transmission lines or pipelines greater than 10 km in length

Level 3 Activities

Sub-category 14 of General –Activities involving investment of a capital cost of more than K50 million, except where such investment is made in pursuing an activity otherwise dealt with in this Regulation in which case that category of activity will apply to the investment.

Sub-category 14 of General – Activities that may result in a significant risk of serious or material environmental harm within Wildlife Management Areas, Conservation Areas, National Parks and Protected Areas or any area declared to be protected under the provisions of an International Treaty to which Papua New Guinea is a party and which has been ratified by the Parliament of the Independent State of Papua New Guinea.

Any activity with the risk of causing environmental harm and serious environmental harm is defined in the Environment Act 2000 as prescribed activities and must be permitted (Department of Environment and Conservation, 2000). Non-prescribed activities do not require permits to operate but they must operate in accordance with the requirements of the Act.

The environment regulatory framework for environment impact assessment and evaluation of activity regulating impacts through an established environment approval and permitting system. Those activities with a very low risk of causing environmental harm are classified as Level 1 activities and are exempted from the permitting requirement. Level 2 activities have a low to high potential for causing environmental harm and are subject to the permitting process. Activities that present a high risk of causing serious environmental harm are classified as Level 3 activities and hence they are put through an EIA before an environment permit can be issued (Department of Environment and Conservation, 2000).

## 5. PANGALU GEOTHERMAL FIELD

The proposed Pangalu geothermal development is located within the Talasea Geothermal Field and is one of the three seven potential geothermal fields in Papua New Guinea. It is proposed to be the largest geothermal power system in Papua New Guinea and is highly recommended by the Mineral Resources Authority (MRA). The power plant if developed from the geothermal system has a combined heat and power capacity to meet an increasing demand for electricity, direct utilizations food processing, associated

with cocoa and palm oil processing activities, and fishmeal and timber drying. According to National Energy Policy 2017-202, the proposed geothermal power plant could produce more than 1,000 MW of electrical power. The geothermal power plant was put forward in 2014 and 2016 following the completion of MRA studies and collaboration with New Zealand's GNS Science (Lahan et al 2015). The West New Britain Provincial Government led the geothermal initiatives to proceed final stage of the feasibility study into developing a proposed geothermal power plant. The development of the power plant did not succeed with several setbacks at some stages between 2016 and 2019.

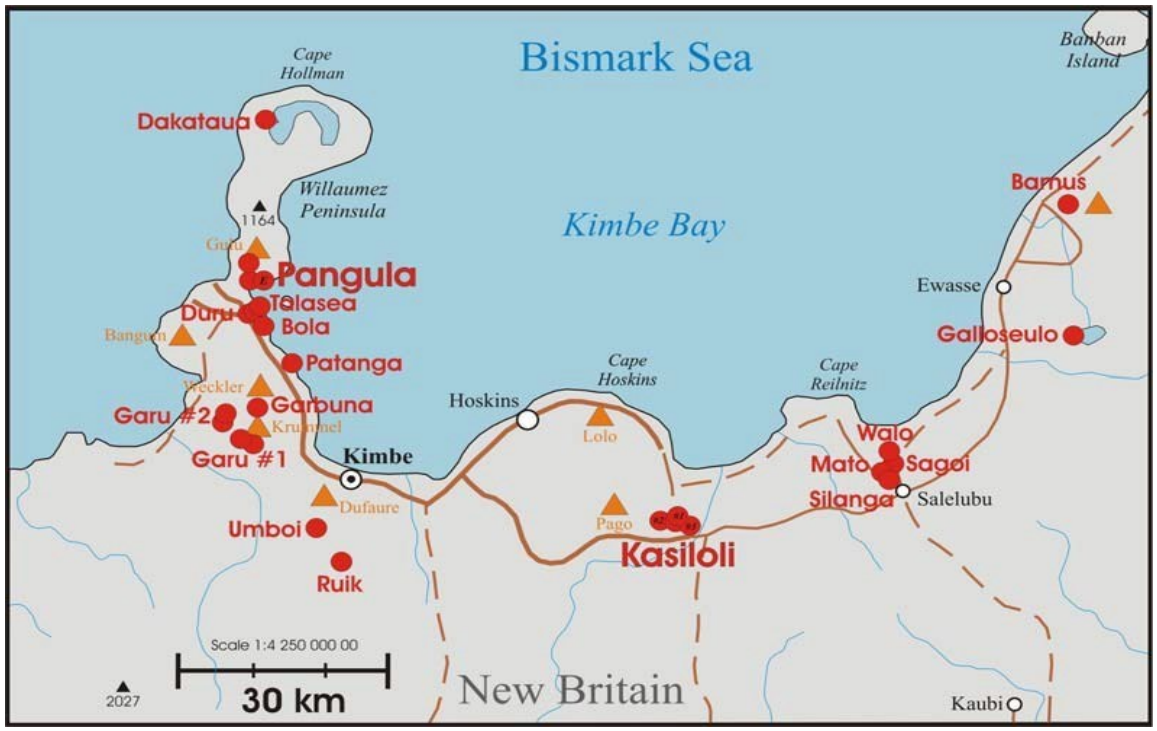


**FIGURE 9. Map of Central New Britain between Williaumez Peninsula and Banban Island, showing the location of thermal areas (red circles) and active volcanoes (triangles). Map after Grindley and Nairn (1974b) taken from Verave et al (2015).**

The Pangalu-Talasea geothermal area hosts several high-temperature geothermal fields and is considered to be the largest geothermal area in New Britain (Figure 9). The Pangalu geothermal area covers about 90 km$^2$ and it is located in the middle of the dormant volcanic zones i.e. the Garua Volcanic Field, Garbuna Strato Volcanoes and Bola Stratovolcano (Figure 7).

An EIA is not carried out in preparation and development of the Pangalu power plant however there were no drilling programs undertaken following the MRA's completion of geothermal reconnaissance studies in 2012 and 2013. According to Rojas (2014), the initial drilling with testing in 2015 was to be conducted and progressed within geothermal development in the Pangalu geothermal area. Research drilling became did not take place due to funding impossibilities.

It may assume that 10MW would be planned which should be subject to full Level 3 Environment Impact Assessment process given that the activity would involve matters of national importance and may result in serious environmental harm in accordance with the Section 42 of the Environment Act 2000. The environmental regulatory framework once having the environment policy on geothermal will restrict the production of more than 50 MW to ensure the sustainable geothermal resources.

### 5.1 Environment issues

EIA is an important part of any legal and regulatory framework. EIA and a legal environment regulatory framework play important roles in the conservation of protected areas and minimisation of adverse environment risks while ensuring the promotion of economic viability and social prosperity. Technically, it ensures that environment permits, and EIA licences are fulfilled so that permit/licence holders are held responsible and mitigation plans are adhered for both construction and operation phases.

Geothermal activity is no exception and is regulatory mechanism. Geothermal energy resources cannot be free of environment risks as there are possibilities of consequences of geothermal development (Ármannsson and Kristmannsdóttir, 1992). It is for this reason that geothermal resource management has put emphasis on the need for an effective legal environment regulatory framework. Legal and regulatory frameworks reflect the significance of geothermal resource management and these are key management issues in balancing environmental and energy interests, sustainable utilisation and how to ensure that resources are utilised for the benefit of the nation (Haraldsdottir, 2010)

The changes in the environment brought about by geothermal development projects are as follows (Ármannsson and Kristmannsdóttir, 1992).

Trawen

- Surface disturbances
- Physical effects due to fluid withdrawal
- Noise
- Thermal effects
- Emission of chemicals.

However, the production capacity is the main concern that determines the level of resource supply which controls the geothermal system by reservoir pressure decline (Axelsson, 2008a). Hence geothermal resource management plays an important role in planning and identifying risks and how to avoid problems. The issues focus on government management of regimes where resources are to be utilised, by whom and how under PNG context when dealing with geothermal resources in West New Britain.

According to Ármannsson and Kristmannsdóttir (1992), the main environmental factors that have to be dealt with in the EIS for Pangalu geothermal development project:

- *Geological factors* including the geothermal field, its size and impact on the reservoir.
- *Water resources and disposal*. This includes extensive knowledge of the groundwater systems, their size and flow patterns.
- *Landscape and visual effects*. This is one of the main factors where the local landowners and communities will be concerned.
- *Tourism and recreation*. Often there may be conflicts between developer and other uses of the land such as for tourism, which there are significant geothermal manifestations in Talasea.
- *Conservation Areas*. Two government recognised protected areas are found in the Pangalu-Geothermal field namely Pokili Wildlife Management Area (WMA) and Garua Wildlife Management Area (WMA).
- *Biology.* Vegetation, hot spring microbiology and - fauna have to be studied
- *Other parameters* such as noise, pollution, air quality and cultural relics.

The Pangalu area is known for birdwatching, hiking and recreational activity and these should be considered in the EIA. Tourism has been consistent in the Pangalu-Talasea area where the Walindi Resort and Garu attract some good number of guests per year and therefore the tourists attractions should be planned for the Pangalu. Land use will also be considered in the EIA in connection with the recreation and tourism in the Pangalu-Talasea area.

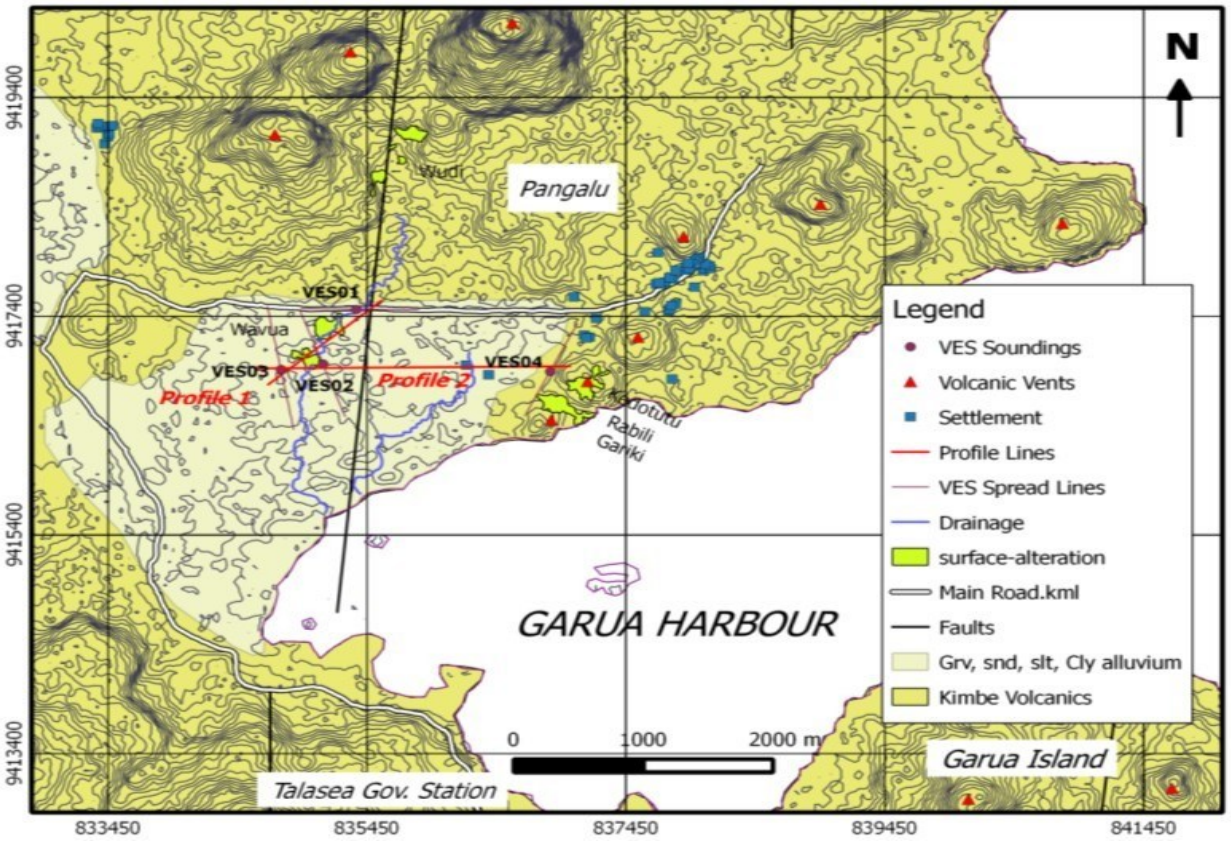


**FiGURE 10: The Talasea map showing Pangalu geothermal field. (Verave, et al, 2015)**

Some volcanic vents are located on both sides of Pangalu field where many surface manifestations including hots springs, large boiling pools, fumaroles and small geysers are also found (Figure 10). The surface manifestations are remained unchanged with human settlements found in the southern end of the shores towards the Garua Harbour. In the EIA the volcanic vents in the Pangalau area must be considered to have been undamaged before the geothermal drilling exploration and development take place. Normally, geothermal development was planned to be located within the damaged area therefore careful planning is considered to model the predicted changes of the surface (Ármannsson and Kristmannsdóttir, 1992). Luketina (2015) said the developer must the identify the areas of supply of geothermal fluid to the power plant within the consented project area. The purpose is to minimize the environmental risks and to develop the type of drilling (directional in most geothermal drilling uses) within the field in an attempt to reduce environmental damage. It is for sake of the national importance on the first basis of geothermal planning that the development of the proposed Pangalu power project follows a stepwise strategy (Steingrímsson, 2009).

Revegetation will be carried out in Pangalu area to reconstruct and reshape any damaged volcanic areas during and after drilling, testing and construction of geothermal development. In the EIA, ecological restoration should be emphasized for the selected areas within the Pangalau that will most likely to be damaged as the result of associated geothermal activities. The reason for considering revegetation in the EIA is to reconstitute the land to a relatively undisturbed state, once the geothermal power plant becomes operational.

Groundwater must also consider in the EIA for the planned Pangalu power plant as the power operation would involve extraction of geothermal fluid and the discharge of the geothermal water into the surface via reinjection. Luketina (2015) asserts that groundwater pollution is a possible environmental impact that needs to be avoided in connection with other geothermal fields such as Talasea and Bola. The project will certainly intend to map the groundwater or geothermal water systems to find suitable channels for reinjection of the geothermal fluid. There is very high precipitation and high surface runoff with some runoff taking place both and above and underground and thus the preliminary studies conclude that all separated water has to be re-injected to the geothermal reservoir to protect the groundwater system from pollution and to reduce possible pressure draw-down in the Pangalu-Talasea geothermal systems.

The case studies of global geothermal reinjection have been reviewed with mostly notable from the publications of Kaya, Zarrouck & O'Sullivan (2011). The location of a reinjection area for the planned Pangalu geothermal power plant will be screened and reviewed prior to the construction of the power plant as well as the steam field. This may be utilized for the purpose of disposal of wastewater from the power plant and to minimize decline due to mass extraction within the Pangalu-Talasea geothermal system and to maintain the production capacity at Pangalu.

Other environmental impacts that should be assessed in the EIA for planned Pangalu power plant including visual and social impacts as well as those due to air quality problems and noise. Landscape alters as a result of installations such as drill holes, pipelines and power plants (Gunnslaugsson, 2010). It will be first time for the proposed Pangalu as a major power plant and this constitutes a major concern in terms of landscape classification and visual effects. Careful planning and design of power plants, pipes and drilling platforms have to be addressed in the EIA to reduce the visual impact.

In preparation for the operation of will cause inconvenience to the public and are widely discussed, that is the amount of H2S and earthquakes associated with rejection.

### 5.2 EIA Developments

The Environment Act 2000 deals with serious environment harm from the construction and operation of geothermal power plant including the drilling activities. However, the Environment (Prescribed Activities) Regulation 2002 does not prescribe the activities in relation to geothermal projects except drilling programs under Level 2 A category within sub-category 2.1 mineral explorations and mining. However, Level 2A does not constitute the need for an EIA as it only requires an Environment Permit.

Lihir Geothermal Power Plant was not deal in accordance with the Environment Act 2000. This is due to the fact that Lihir geothermal power plant was built in accordance with the clean development mechanism process in terms of validation protocol associated with the criteria of the United Nations Framework on Climate Change Convention (UNFCCC). Such criteria were also used to evaluate the project operations, monitoring and reporting aspects of the geothermal power plant. This project according to Det Norske Veritas (2006) did not require an environment impact assessment under the PNG Environment Act 2000. Furthermore, the Lihir gold mine has been approved with licensing requirements under the Mining Act 1992 including the undertaking of drilling programmes and eventually construction of a power plant.

Because the mining operation was started in 1997 before the enactment of the Environment Act 2000, the Lihir gold mine and associated activities were re-permitted under a transitional arrangement under the Environment Act 2000 and its Environment (Permits and Transitional) Regulation 2002. This transitional arrangement prescribed that the Lihir gold mine had an approval licences under the repealed act and under Section 28(b) of the Environment (Permits and Transitional) Regulation 2002. The Lihir Gold Mine was eligible to continue carrying out the operation without any requirement to apply for a separate permit or undergoing an environment impact assessment. Hence, additional environmental impact analysis was not required for the geothermal power plant project (Det Norske Veritas, 2006).

Furthermore, under Section 28(c) of Environment (Permits and Transitional) Regulation 2002, the company submitted the Environment Inception Report (EIR for Lihir geothermal power plant in December 2004) on a voluntary basis and received approval in February 2005. Det Norske Veritas (2006) said the environment impacts of project specifically geothermal power plant were identified and evaluated in the EIR and the impact issues were in relation to discharge of steam to the atmosphere and some geothermal liquids within the host caldera. The environment permit was issued with conditions being set for the permitting of a geothermal power plant.

The Environment Permit will be issued for the planned Pangalu Geothermal Power Plant once the developer or the state investment body meets the Level 3 procedures under the Environment Act 2000.

## 6. CONCLUSION

The success of EIA during the preparation and development of planned geothermal project for Pangalu-Talasea Geothermal Field depends on the proper implementation of regulatory framework requiring team work and holistic approach and understanding the protocols involved in the EIA procedures. It also requires gathering of correct baseline data and background information to understand the environmental conditions from the onsite in Talasea crucial for sustainable geothermal resource management.

The regulatory institutions including the CEPA, MRA and the provincial government play an important role in regulating and coordinating in the preparation and development of Talasea-Pangalu geothermal project and ensuring that legal requirements are met satisfactorily. EIA is an important tool enabling relevant authorities to critically assess the impacts of geothermal development projects at the preparation stage, both for exploration and later utilisation of a geothermal resource, which is going to be first time to be staged in the country. A very important factor in the EIA process is public participation and consultation in Talasea with relevant authorities given the people concern with the impact of the geothermal project.

It is a general conclusion of this study that PNG can, and should prepare the documentation of the comprehensive environment assessment report for Pangalu-Talasea geothermal field. The baseline studies and environment management plan should address not only the management of the geothermal resources from the power plant but also wellbeing of the people of Talasea and the West New Britain as a whole in the future but must be well prepared in good cooperation with all stakeholders.

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