

## Papua New Guinea Country Update

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### ABSTRACT

Papua New Guinea (PNG) is an emerging economy which stands at the threshold of economic prosperity but is constrained by the lack of access to reliable electricity. Located within the “ring of fire”, PNG has numerous active volcanoes and known geothermal systems. There are currently 55 MWe (gross) of geothermal power installed at Lihir Gold Mine in New Ireland Province. However, there have not been any additional power plants constructed in the past five years, mostly due to lack of adequate legislation and government support. The high cost of diesel and fuel oil, and the unpredictable nature of hydro power stations, has renewed strong interest in geothermal power. This paper is an overview of the current status of geothermal in PNG and progress being made to support further development.

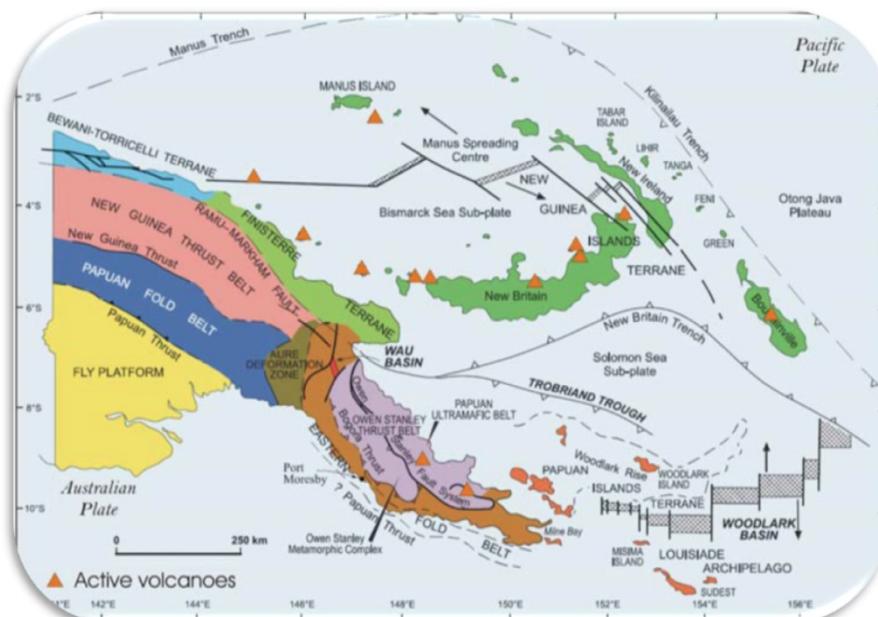
### 1. INTRODUCTION

Papua New Guinea (PNG) is a developing country with a population of 7.3 million, of which approximately 15% live in urban areas. The rural areas are sparsely populated with low access to infrastructure. The rural economy is primarily informal and based on subsistence and semi-subsistence activities. However, since PNG has substantial natural wealth (primarily minerals and forestry), the formal economy is becoming increasingly dominant, focused mainly on the large-scale export of natural resources. Mining, including copper, gold, and oil, currently account for nearly two-thirds of export earnings.

The PNG population is organized in small, fragmented social groups that speak over 800 distinct languages. Allegiance to local, clan-based groups is frequently strong and more immediate than a national identity, a situation which poses a challenge to development and the pursuit of a national vision. Connection to the land plays a central role in daily life, and kinship networks (the *wantok* system) remains the strongest source of identity for PNG people.

### 2. GEOTHERMAL RESOURCES

Papua New Guinea is located on the Pacific Ring of Fire, at the junction of several tectonic plates (Figure 1). Geologically, PNG is a northern extension of the Indo-Australian tectonic plate, forming part of a single land mass which is Australia-New Guinea. It is connected to the Australian segment by a shallow continental shelf across the Torres Strait, which in Pleistocene times was exposed as a land bridge, when sea levels were lower.



**Figure 1: Geological framework of Papua New Guinea, showing the main plate/micro-plate boundaries and tectonic terranes: (1) Fly Platform (yellow); (2) New Guinea Orogeny (multiple colors; spine of the main island); (3) Melanesian Arc (green). Modified from Williamson and Hancock (2005). Locations of active volcanoes are taken from Papua New Guinea Mapserver (2009).**

The country has many active volcanoes driven by subduction of the Pacific Plate and Solomon Sea Subplate. The volcanoes of PNG are found in 2 principal volcanic arcs, the 1,000 km long Bismarck Arc stretching WNW-ESE in the north of New Guinea and New Britain Island, from the north coast of New Guinea near the border with Indonesia, to Bougainville Island in the east. This arc is a result of the northward subducting Solomon Sea beneath the Bismarck Sea plate. The second volcanic arc forms the volcanoes on the south-eastern peninsula of New Guinea and is caused by the northward subduction of the Coral Sea. Many of these volcanoes exhibit geothermal activity (Table 1).

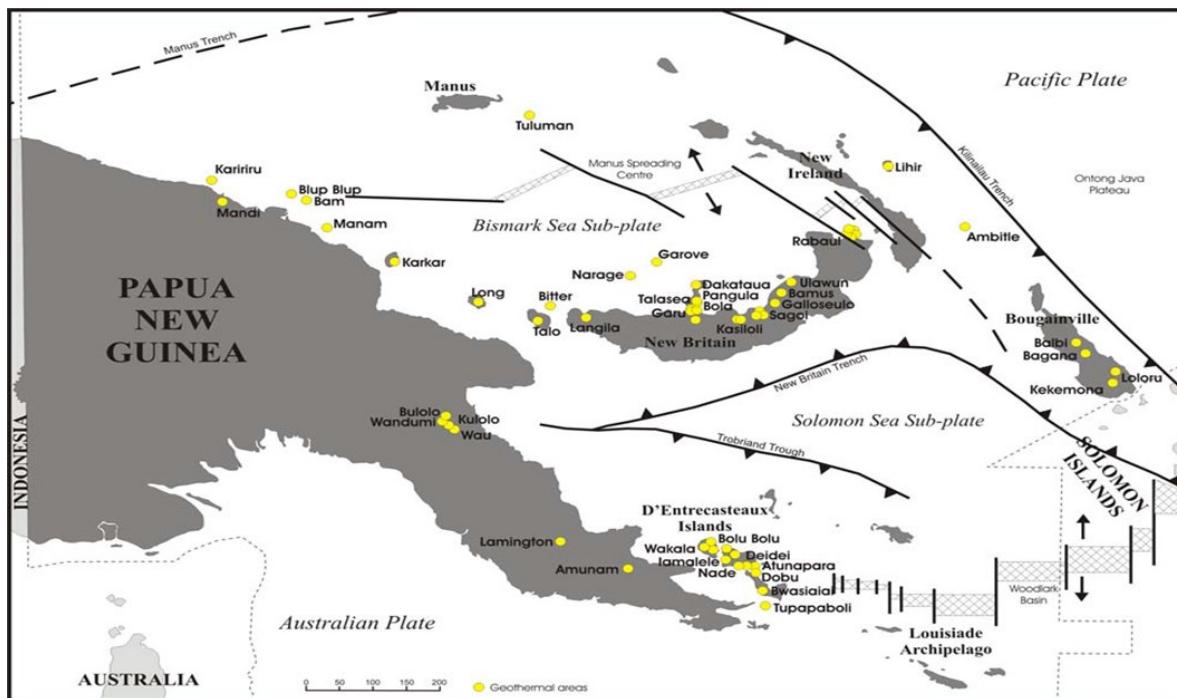
**Table 1: Some volcanic areas with geothermal features in PNG (from Grindley and Nairn, 1974b and Volcano Live, 2012)**

Name	Location	Type	Surface Features
Bagana	Bouganville	Lava cone	Hot springs, solfatera
Balbi	Bouganville	Stratovolcano	Boiling mud, active fumaroles, solfatera
Bamus	New Britain	Stratovolcano	Fumaroles, sulphur deposits
Deidei	Fergusson Island	Rhyolite volcano	Hot springs, sinter
Doma Peaks	Papua New Guinea	Stratovolcano	Geothermal activity
Garbuna	West New Britain	Stratovolcano	Hot springs, boiling mud, sulphur vents
Garua	West New Britain	Volcanic field	Hot springs, geysers, fumaroles
Hoskins	West New Britain	Andesitic to ryholitic volcanoes	Hot springs, hot ground, boiling mud, fumaroles
Iamelele	Fergusson Island	Complex volcano	Hot springs, boiling mud, fumaroles
Kairuru	Papua New Guinea	Crater	Hot springs
Karkar	Karkar Island	Stratovolcano	
Lihir	Lihir Island	Active epithermal system	Hot springs, boiling mud, solfatera
Mt. Lamington	Papua New Guinea	Stratovolcano	Hot springs
Musa	Papua New Guinea	Hydrothermal field	Hot springs
Rabaul	East New Britain	Active caldera	Hot springs, fumaroles
Talasea	West New Britain	Basaltic to ryholitic volcanoes	Hot springs, hot ground, boiling mud, fumaroles, native sulphur
Witu Islands	Witu Islands	Stratovolcano	Hot springs
Walo	West New Britain	Hydrothermal field	Boiling mud, solfatera, hot ground

The geothermal resources in PNG are often located in isolated areas far away from load and population centers, except for Rabaul which is within the Rabaul grid area on the periphery of the town. There are approximately 55 known geothermal sites in PNG (Figure 2). The surface occurrences on New Britain Island appear highly prospective. At Talasea, Pangalu and Kasoli, on the north coast of West New Britain and Rabaul, East New Britain Province, the geothermal fields are associated with a belt of recent volcanic activity. Reconnaissance geological surveys have been carried out in many areas, including New Britain Island. Although these geothermal resources occur in isolated locations, they are associated with volcanoes that may contain exploitable epithermal and porphyry base metal deposits.

The geothermal areas comprise numerous hot springs, geysers, fumaroles and mud pools at temperatures that range from 90°-101°C (194°-214°F; boiling point). Those near the coast appear to tap both meteoric and seawater sources. Many of these geothermal manifestations have low pH, suggesting that geothermometer estimates from them are untrustworthy. One sample from Gridley and Nairn (1974b) from the Deidei geothermal area (pH 8.0) yields quartz and cation (Na-K-Ca with Mg correction) of 219° and 263°C, respectively. The presence of sinter at some locations also indicates temperatures suitable for flash plants.

Geothermal utilization in PNG has been proven by the resource on Lihir Island, the only geothermal power plant in PNG. Here electricity is being generated from a >300°C reservoir, primarily to provide electricity for the mine operated by Lihir Gold, LLC (Ellis and Smith, 2004). Power generation was commissioned in April 2003, and in February 2007 power generation was expanded to the current gross capacity of 56 MWe. This success has engendered interest from mining companies who use diesel generation in their operations



**Figure 2: Map of PNG showing the locations of known geothermal areas from the Mineral Resource Authority (Mosusu (2008) and Heming (1969))**

The Geothermal Energy Association estimates PNG's geothermal potential at 21.9 TWh. The association also categorizes the country as an economy that could, in theory, meet all its electricity needs well into the future from geothermal sources alone (GEA, 2010). However, the lack of a geothermal development policy framework has adversely delayed exploration and utilization of this resource. Reconnaissance geological, geophysical and geothermal surveys have been undertaken in the past but could not progress due to this lack. Several private groups, including Geothermal Development Associates, KuTh Energy, and Reykjavik Geothermal have performed reconnaissance work and/or submitted license applications under the Mining Act of 2002, but work is on hold pending a more appropriate legal framework.

### 3. ENERGY INFRASTRUCTURE AND FUTURE ENERGY NEEDS

The Asian Development Bank Asian Development Outlook (ADO) predicts a 6% growth rate for PNG in 2014, due to increased commodity exports. For example, a consortium led by Exxon Mobil has commissioned a liquefied natural gas (LNG) production facility that exported its first LNG cargo in 2014. This is the largest investment project in the country's history, and has the potential to double GDP in the near-term and triple Papua New Guinea's export revenue. ADO expects GDP to accelerate to 21% after the first LNG export.

This type of development requires energy. The total installed electricity capacity in PNG was 582 MWe in 2010 (REEP 2012). Hydropower accounted for about 40% of this total, diesel and heavy fuel oil (HFO) 37%, natural gas 14%, and 9% geothermal (all from the Lihir gold mine; see below). Generation and transmission are developed for the major urban areas only; about 90% of the population has no access to electricity.

PNG has had capacity problems in providing power to urban centers. System reliability is a major concern as blackouts are frequent in all local grids. Ageing generation equipment coupled with obsolete spare parts has a compounded effect on availability of machinery. Besides being unreliable, electricity in PNG is relatively expensive due to the high proportion of diesel and HFO generation. This lack of energy infrastructure has contributed to poverty in both urban and rural areas.

PNG Power Ltd. (PPL) is a vertically integrated State Entity responsible for generation, distribution and retail of electricity in Papua New Guinea. PPL has traditionally monopolized the electricity industry. However, in recent times, several independent power producers (IPP's) have emerged, limited to power generation only with PPL managing electricity distribution and sale.

PPL manages three regional electricity power grids (Figure 3). The Port Moresby system serves the National Capital District and surrounding areas in the Central Province. Generation consists of hydropower (62.2 MWe), diesel and gas (30 MWe), and HFO (privately owned; 24 MWe). The Ramu system's main source of generation is hydropower (87 MWe) but also included four diesel plants that serve as standby units (21 MWe). Power is also purchased when required from the privately owned Baiune hydropower station (1-2 MWe). The Gazelle Peninsula system serves the townships of Rabaul, Kokopo and Kerevat and is powered by the 10 MWe Warangoi hydro plant, the 8.4 MWe Ulagunan diesel plant, and the 0.5 MWe Kerevat diesel plant.

#### 3.1 New Britain Island PNG Power Ltd Grids

PNG Power Ltd.'s Gazelle grid in Rabaul and Kimbe grids are located on the New Britain Island and can all be powered by geothermal energy as the island is the most prospective geothermal region.

Current maximum demand on this grid is 9.68 MWe with an estimated increase of 3% per annum. The available capacity in the Rabaul grid is 10.86 MWe, energy configuration of Diesel 5.86 MWe and Hydro 5.0 MWe (Figure 4). If no additional generation capacity is added to the Rabaul Grid by the year 2017 the grid would collapse.

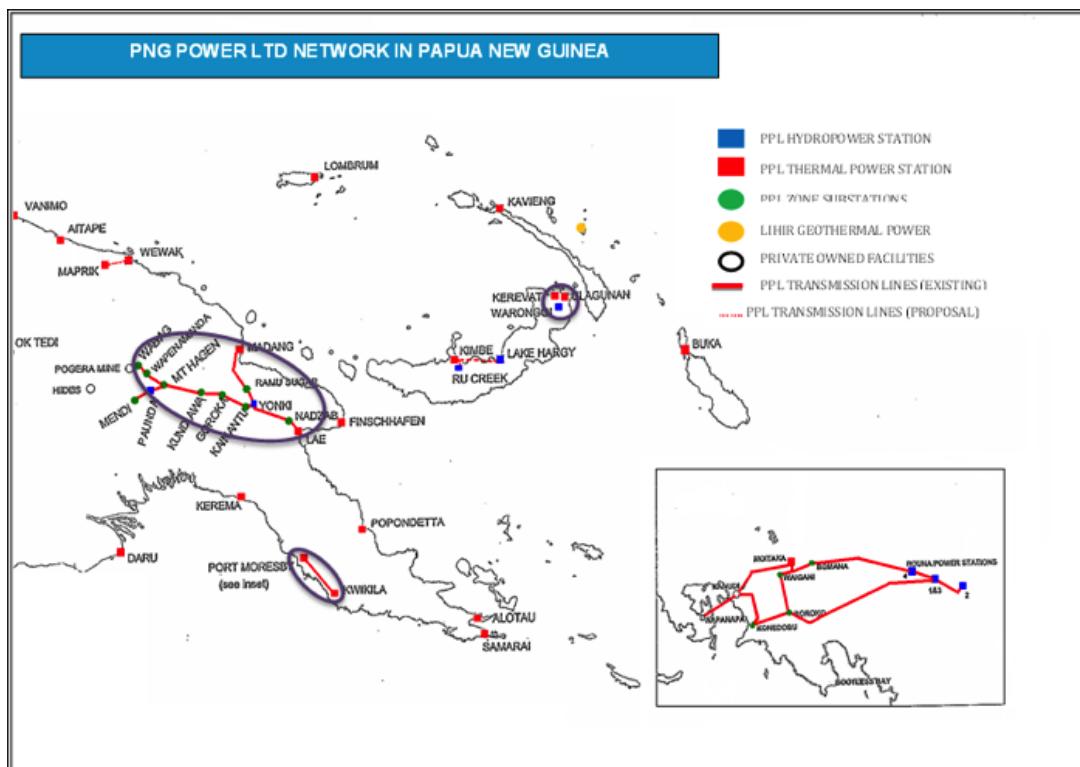


Figure 3: Map showing the transmission infrastructure of Papua New Guinea.

Power sensitive captive loads of approx. 7.0 MWe does exist within the Rabaul grid but isn't connected onto the grid due to inefficient and unreliable power supply from PNG Power Ltd. This should be addressed by introducing geothermal power into the Rabaul grid. A 6.0 MWe wellhead geothermal power plant would not only alleviate the short fall in generation but also shut down the inefficient and uneconomic diesel power stations.

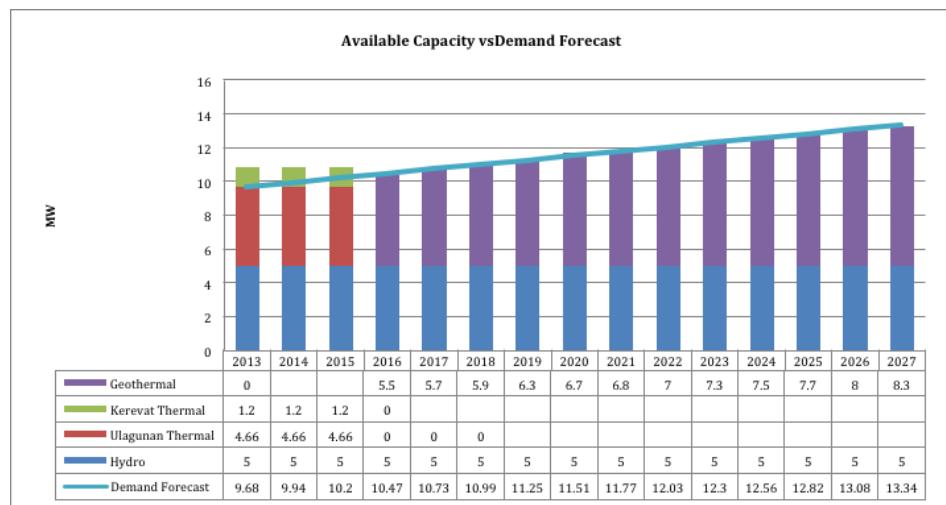
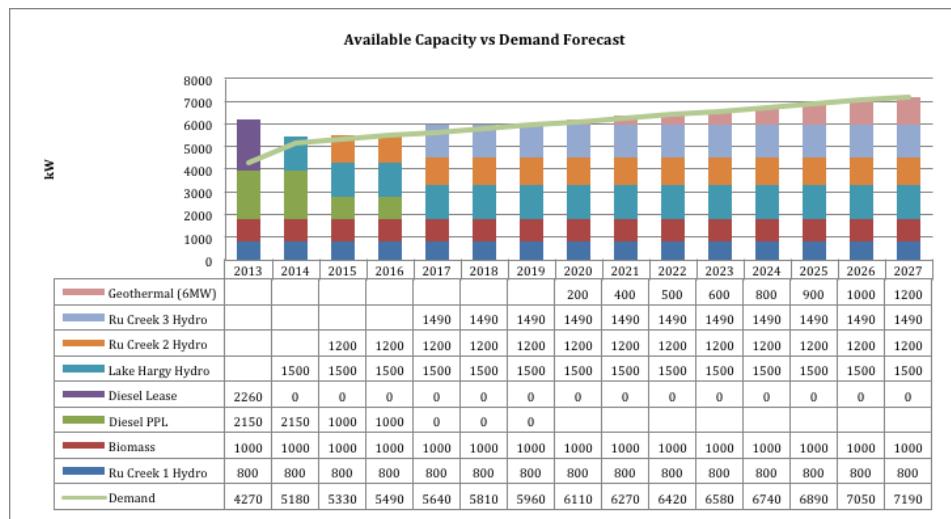


Figure 4: PNG Power Ltd.'s Rabaul Grid Forecast.

Kimbe Grid is in a similar situation as of the Rabaul Grid dependent on diesel power station operated on 24 hours basis to support the hydropower (Figure 5), maximum demand of 4.27 MWe and available capacity of 6.31 MWe with an annual increase at 3%.

A cascaded hydro power on the Ru Creek and Lake Hargy is currently under development. These plants will effectively displace the diesel plants but only up to 2018 and return back to the same state. This scenario can be effectively eliminated by introducing geothermal power in the grid.

**Figure 5. PNG Power Ltd.'s Kimbe Grid**

## 4. GOVERNMENT AND LEGAL FRAMEWORK

### 4.1 Geothermal

Papua New Guinea is currently enjoying a period of political stability. Following independence in 1975, the country went through a long period of political instability, characterized by rapid changes in government and the removal of Prime Ministers through votes of no confidence. However, since 2002 the country has seen two successful general elections and only one change in government (the removal of Prime Minister through a vote of no-confidence).

The land tenure system in Papua New Guinea is such that land is customarily owned by indigenous tribes, clans and families. Connection to land plays a significant role as it remains the strongest form of identity to the people of PNG. The resource development laws (e.g. mining and petroleum) state that any resource found 6 feet underground belongs to the State.

These current laws are not appropriate for geothermal development, but energy legislation directed specifically towards geothermal has not yet been established. This should probably begin with a policy framework as to the classification of geothermal energy as a separate grouping from mining or petroleum, and both the Department of Mining and Petroleum and the Department of Energy appear to be in conflict over responsibility for the industry. Parliament still needs to appoint a group or agency to delegate policy and regulatory functions.

Progress does seem to be occurring. The government recognizes geothermal as a next generation energy source and is beginning to focus on its exploitation. The PNG government has set an ambitious target of 100% renewable energy by 2030, so streamlining policy and regulation is mandatory in order to achieve this goal. The government plans to collaborate with the private sector to pursue the development of renewable sources. By 2035, about 500 MWe of new geothermal electricity generating capacity could be put into operation in the economy (DNPM, 2010a).

The primary legal and regulatory issues that need to be resolved include where resources are to be utilized, by whom and how, both on private and public land. Geothermal legislation has currently been drafted by the Department of Mining & Geohazards and the Department of Petroleum & Energy.

Any regulatory framework must not be a barrier to geothermal development. Future geothermal legislation will be influenced by laws already on the books. Some of the main acts and policies that will probably impact geothermal resource development in PNG include:

1. Petroleum & Energy (Electricity Industry Act 2002)
2. The Mining Act of 1992
3. The Land Act of 1996
4. The Physical Planning Act of 1989
5. The Independent Consumer and Competition Act (ICCC)
  - a. Third Party Access Code (ICCC)
  - b. Grid Code (ICCC) (after 2015 DPE will be responsible)
6. Environment Act of 2000
7. Conservation Areas Act of 1978

#### 4.1.1. Example: The Lihir Geothermal Power Project

In the absence of geothermal energy specific legislation and policies, development of the geothermal power plant at Lihir was developed using legislation under the Mining Act 1992. The steam field is located inside the Special Mining Lease (SML) and within the mining operation. The mine started operation in 1997 and at that time high temperature steam was vented into the atmosphere for mine safety reasons. In 2001 Lihir Gold Ltd. (LGL) requisitioned a 6 MWe non-condensing power plant for the mine site, the first geothermal power plant in PNG. The system worked so well that LGL requested an additional 30 MWe non-

condensing plant in 2003, followed by a 20 MWe extension in 2005. The original non-condensing unit has been decommissioned, but the geothermal plant is currently producing 50 MWe (net).



**Figure 6: Location of Lihir geothermal plant on Lihir Island.**

The Mining act was utilized for Lihir geothermal power plant only because there was no geothermal-specific legislation. The steam field is in the mine which is already covered by the Special Mining Lease. However, as the Mining Act comes with an integrated fiscal regime which is geared around exploration sunk costs and recovery rates, it is inappropriate for geothermal development. The Mining Act does not support CO<sub>2</sub> mitigation issues and adoption of a fiscal regime for economic compensation to a developer.

#### 4.2 Third Party Access Code

Both the Third Party Access Code and The Grid Code were launched in 2013 and are governed by the Independent Consumer and Competition Commission (ICCC). The ICCC acts as the regulator for the PNG electricity industry. PNG Power Ltd had the monopoly in the electricity industry in the past but the government has recently opened up the industry for competition. The purpose of this legislation is to now allow IPP's access to the national transmission grids and ensure fair pricing for the production and sale of electricity.

The objectives of the Third Party Access Code are to:

1. Improve transparency with regards to power purchase contracting between IPPs and Regulated Retailers.
2. Constrain the ability of Regulated Retailers to unfairly discriminate against potential competitors.
3. Protect Transmission Network Operators' commercial interests by clarifying how they are remunerated by Third Parties connecting to and wheeling power through their network.
4. Constrain the ability of Transmission Network Operator/s that performs System Operator functions from unfairly discriminating against Third Parties.

The Grid Code is also overseen by ICCC, although in 2015 it may delegate its functions with respect to the Grid Code to the technical regulator now being established as part of the Department of Petroleum and Energy (DPE). The objectives of the Grid Code are to support the access, reliability, safety and affordability objectives of the Electricity Industry Policy by:

1. Promoting transparency and non-discriminatory connection and access to the Transmission Network; and
2. Improving reliability and safety of the electricity networks by setting standards, rules and procedures in connection, planning and operation of Transmission Network.

#### 5. CONCLUSION

Papua New Guinea is a developing country with a need for clean, affordable energy to enable long-term growth and reduce poverty. Although PNG is endowed with geothermal resources, information on these resources is generally sparse. The Geothermal Energy Association estimates PNG's geothermal potential at 21.92 TWh. It also estimates that PNG's economy could, in theory, meet all its electricity needs well into the future from geothermal sources alone (GEA, 2010).

The areas with the greatest apparent geothermal potential include New Britain and the D'Entrecasteaux Islands. A number of other geothermal prospects have been identified elsewhere. These resources are frequently distant from large population centers but are often close to areas with ongoing mineral exploration and/or development. The development of geothermal resources may therefore be particularly attractive for established and future mining operations. Some coastal towns in New Britain such as the rapidly growing Rabaul and Kimbe (population 40,000+) may benefit from small scale geothermal developments. The Gazelle, Rabaul, and Kimbe transmission grids could theoretically be entirely powered by geothermal energy if exploration and development would commence.

The most prospective region for electricity generation from geothermal resources is the New Britain Island, which are associated with calc-alkaline volcanism and subduction at the New Britain Trench. There are at least nine geothermal prospects (Rabaul, Baining, Bamus, Walo, Kasiloli-Hoskins, Garbuna, Bola, Pangalu-Talasea and Galloseulo) which host hot springs, fumaroles and mud pools, with measured temperatures of 90-101°C. Chemical surveys have been undertaken, with silica and chloride contents from surface manifestations suggesting reservoir temperatures up to ~300°C (Grindley and Nairn, 1974a).

Reconnaissance exploration surveys would be a necessary step to provide a preliminary assessment of PNG's geothermal resource potential. However, delays by the government to provide a sufficient policy and regulatory framework are hampering geothermal development.

The delay by the government in making a determination to appoint the appropriate State Agency delegating policy and regulatory functions appears to be the primary obstacle in geothermal resource development. The Agency assigned the regulatory functions shall then draw up legislation to facilitate the resource development.

Finding the way forward is;

- for the government to make a clear determination and select a State Agency to assume the responsibility to oversee the development of geothermal resource.
- for the government to develop the Geothermal Regulatory and Policy Framework; A road map needs to be developed to start the exploration of geothermal systems in order to identify potential geothermal sites. A clear policy is needed to define the road for geothermal development and utilization in PNG.
- Climate Change Office to develop a carbon trade policy that will clearly define the commercial and technical parameters to commercialization of geothermal developed carbon credits.

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PNG's real GDP in 2013 was 5.1 % (Central Bank).

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**STANDARD TABLES****TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY**

	Geothermal		Fossil Fuels		Hydro		Nuclear		Natural Gas		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe (Biogas)	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr						
In operation in December 2014	50.00	432.00	366.00	3,162.24	224.00	1,935.36	-	-	120.00	1,036.80	1.80	605.00	761.80	6,581.95
Under construction in December 2014	Nil	Nil	Nil	Nil	Nil		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Funds committed, but not yet under construction in December 2014	Nil	Nil	Nil	Nil	6.00	51.84	Nil	Nil	60.00	518.40	Nil	Nil	66.00	570.24
Estimated total projected use by 2020	20.00	172.80	366.00	3,162.24	230.00	1,987.20	-	-	180.00	1,555.20	1.80	605.00	797.80	6,893.00

Expect a decrease in geothermal energy due to forecasted steam depletion at Lihir.  
Biogas at NBPOL.

**TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2014**

Locality	Power Plant Name	Year Commissioned	No. of Units	Status <sup>1)</sup>	Type of Unit <sup>2)</sup>	Total Installed Capacity MWe*	Total Running Capacity MWe*	Annual Energy Produced 2014 <sup>3)</sup>		Total under Constr. or Planned MWe
								Total MWe*	Total GWh/yr	
PNG	Lihir	2003	1	R	1F	6	Nil			
PNG	Lihir	2005	5		1F	50				
<b>Total</b>										

**TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)**

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010						5
2011						5
2012	1					5
2013	3					5
2014	3					5
<b>Total</b>	<b>7</b>					<b>25</b>

(1) Government; (6) Private Industry