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Geothermal Energy Resources of Papua New Guinea: Country Update

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ABSTRACT

Papua New Guinea is characterized by quaternary volcanic islands with potentially low to high-temperature geothermal resources that are yet to be systematically investigated for development and utilization. The country has an installed capacity of 50MW geothermal power plant on Lihir Island, owned and operated by Newcrest Mining Limited within its gold mining lease. Apart from this, geothermal energy research and development including other renewable energy sources has been slow due to lack of political will and support for the development of policies and legal frameworks and finance to direct and lead geothermal development including other renewable energy sources to realize the desired national goals and visions. The geothermal resource policy is yet to be passed in Parliament, however, the government has recently approved the National Energy Policy (2017-2027) which lays out the plan for the establishment of the new National Energy Authority and Energy Regulatory Commission which will be mandated to administer and regulate the energy industry. This policy provides for the development of various policies for geothermal and other renewable energy sources to develop sustainable renewable energy.

This paper aims to provide an overview of the preliminary geothermal studies initiated and conducted by the Mineral Resources Authority's Geological Survey Division since 2009 including recent government policy initiatives.

1. INTRODUCTION

Papua New Guinea (PNG) is located in the southwest Pacific (Fig. 1). It encompasses the eastern half of the island of New Guinea and shares land boundary with Indonesia in the west. The country comprises of approximately 600 smaller offshore islands east of mainland PNG. It has a total landmass of 462 840 square kilometers and a population of more than 8 million. PNG is culturally diverse with more than 800 languages and ethnic groups who have culturally diverse and unique customs and traditions. The people live in clans and are strongly connected to their land. The majority of the people live in rural settings, often in remote locations where provision of basic services such as electricity is a great challenge due to its mountainous, rugged terrains and isolated islands. Rural cash-based activities are small thus many families are unable to afford electricity.

Figure 1: Location of PNG and Lihir Geothermal Power Plant (red polygon).

1.1 Energy resources

PNG has abundant untapped renewable energy resources such as hydro, geothermal, biomass, solar, wind and tidal wave. However, developing renewable energy is challenging because of the country's cultural diversity, land tenure system, rugged terrain and largely rural population. Hydro is currently the primary source of energy which provides just under half of the 797 MW total electricity generation capacity while around one-third from diesel generators. Gas, geothermal and biogas generation represent most of the balance with the bulk of this energy used for mining. Diesel is dominant in off-grid applications. The total electricity output in 2015 was 4324 GWh, comprising hydro-electric (23 per cent), petroleum products (56 per cent), natural gas (11 per cent), and geothermal (10 per cent) (APEC Energy Outlook, 2019).

The total installed capacity estimates for 2016 was 797MW sourced from hydropower (432 MW), thermal (223), gas (85MW) geothermal (50MW) and biogas (7MW) according to the APEC Energy Outlook (2019). The gross production from the geothermal power plant on Lihir Island is currently 96 GWh/yr from 11 MWe generation capacity (Table 1). About half of the country's total installed capacity is from the private sector mainly for the mining sector. The rest serves businesses and about 13% of the total population that live in Port Moresby and other urban centers in the country. The majority rural-based citizens (87 %) including urban settlements do not have access to electricity and continue to rely on traditional wood burning for cooking. Portable off-grid solar energy is reaching many rural homes and urban settlements these days for lighting and phone charging and is having positive impacts on peoples' lives (APEC Energy Outlook, 2019).

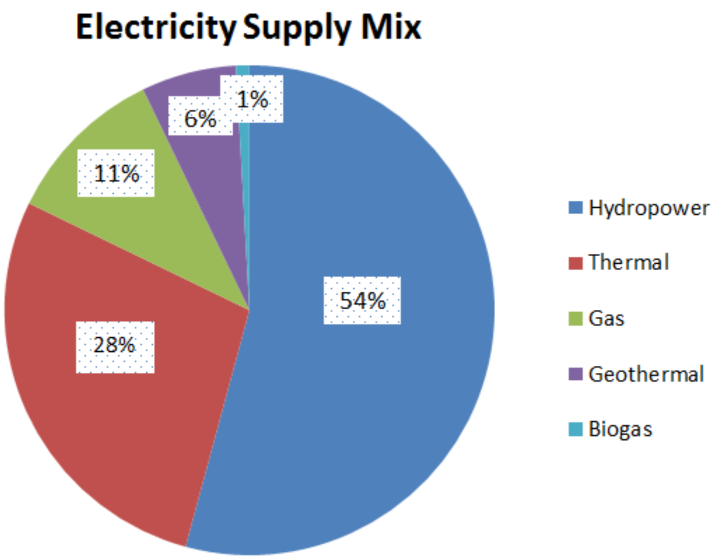

Figure 2: Total installed electricity capacity: 797 MW (source: APEC Energy Outlook, 2019).

The country's huge untapped wealth of renewable energy could be used to generate sustainable clean energy to develop a low-carbon economy. However, apart from hydro, biogas and biomass projects underway in the country, there has been no further development in geothermal energy production over the years since the commissioning of the 56WM power plant in 2003.

The economy is well endowed with natural resources such as gold, copper, nickel, cobalt, oil, gas, timber, fish and other agricultural products (coffee, cocoa, tea, oil palms, spices and copra). Mining and petroleum accounts for one third of the country's GDP. Revenue generated from these natural resources including the proceeds from the LNG exports should be utilized to build the renewable energy sector.

1.2 Government policy and regulation of energy

The country lacked a coherent national energy policy to drive the energy sector over the years after gaining independence in 1975. Institutional arrangements for the energy sector are fragmented where critical functions are vested in different institutions by respective legislations. The Department of Petroleum and Energy (DPE) began work on formulation of the National Energy Policy in 1995 and was later supported by AusAID fund in 2004, as part of the government's Public Sector Reform. A decade later in 2014, this policy was workshopped by collaborative efforts of the Departments of Public Enterprise and Petroleum and Energy which was later finalised and submitted to Parliament in 2018 (National Energy Policy 2018-2028). There was a lack of government support and political will to complete this important policy over the year's hence slow improvement on the very low access to energy (13%) and other related socio-economic issues caused by energy poverty in the country.

In terms of geothermal energy policy, the Department of Mineral Policy and Geohazards Management has formulated a Geothermal Resource Policy under the directive of the National Government in 2011. It is known that this directive was made according to interpretation of geothermal as a mineral under the Mining Act 1992. The Geothermal Resource Policy was submitted to the National Executive Council in 2014 but awaits the passing of the revised Mining Act before it can be reviewed.

The Department of Petroleum and Energy (DPE), PNG Power Limited (PPL) and the Independent Consumer and Competition Commission (ICCC) are key government agencies responsible for the energy industry in the country. DPE is responsible for policy development, implementation and regulation while PPL is a State Owned Utility and Power Company responsible for generation, transmission, distribution and retailing of electricity (Fig. 3). Traditionally, PPL had a monopoly over the energy sector however, recent changes have allowed Independent Power Producers (IPPs) to enter into Power Purchase Agreements with PPL to supply power for general consumption. ICCC on the other hand, ensures the economic regulation of the industry remained relevant and in-tuned with the prevailing market conditions by administering the Third Party Access and Grid Codes. Other mandatory agencies in the energy sector are Kumul Consolidated Holdings (KCH), Department of National Planning and Monitoring, Department of Treasury and the Port Moresby Chamber of Commerce and Industry. The Energy Wing of the Department of Petroleum and Energy is the Secretariat of the Electricity Management Committee. All these institutions form the Electricity Management Committee (EMC) and perform their roles in the energy sector.

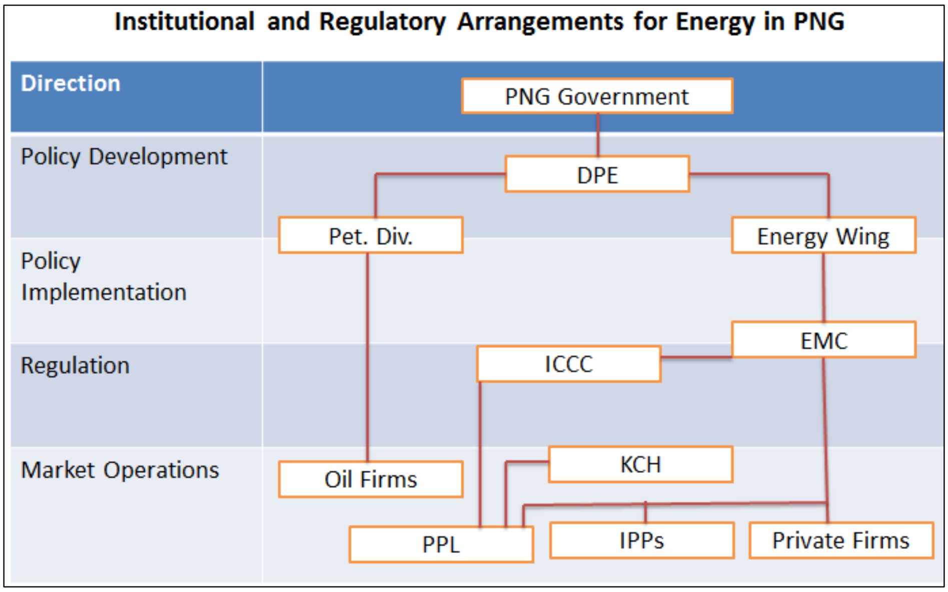

Figure 3: Institutional and regulatory arrangement for the energy sector in PNG. The Electricity Management Committee comprised of relevant government departments makes decision for the renewable energy development (source: DPE).

2. GEOLGOGY BACKGROUND

The unique geology of Papua New Guinea (PNG) and its considerable mineral resources and geothermal potential is a result of its location on the "Pacific Ring of Fire". PNG is located on an active tectonic region or a collision zone between three major plates; the north-ward moving Indo-Australian plate, the west-northwest moving Pacific plate and the eastward moving Caroline plate. A number of micro-plates occur between the Indo-Australian and Pacific Plates; the Solomon plate to the southeast and North and South Bismarck plates in the north. These micro-plates located offshore are bounded by spreading ridges, deep sea trenches and trans-form faults while those onshore are represented by thrusts, extensional and strike-slip faults and folds (Johnson and Molnar, 1972).

The geological framework of PNG comprises a series of geological terranes that are commonly separated by geological elements or structures as shown in Figure 4. Detailed descriptions of the geological terranes can be found in references found in the Geology and Mineral Potential of PNG booklet by Williamson and Hancock (2005). The components that define the tectonic setting of PNG include;

(1) The Australian Craton, which underlies the Fly Platform and much of PNG as a rigid continental block extending to the south. The Fly Platform comprises the Australian Cratonic (Proterozoic–Permian) basement that is overlain by the Triassic–Neogene sediments of the Papuan Basin. The platform is essentially unaffected by the Cainozoic deformation that is apparent in the terranes to the north. (2) The New Guinea Orogen is characterized by the mountainous spine of PNG which was formed by the collision of the major plates as discussed earlier. Most of mainland PNG (Fig. 4) is part of the New Guinea Orogen including the Papuan Islands and excluding the Finisterre Terrane. It is composed of metamorphosed sediments that have undergone fold thrust belt deformation, island arc magmatic extrusive and intrusive rocks and obducted oceanic crust. The oldest rock type found in this terrane are the Ultramafic rocks of Eocene-Oligocene or older. (3) The Melanesian Arc (Volcanic Islands) consists of now dismembered islands to the north-northeast of the New Guinea Orogen within the segmented oceanic Pacific Plate margin. The islands of the Melanesian Arc were formed by subduction-related island arc magmatism beginning in the Eocene. The geothermal activities occur within the Melanesian Island Arc where there is active volcanism as indicated in Figure 1. The historical volcanic centers on the mainland has remained dormant for decades while Tavurvur, Karkar, Ulawun, Pago and Garbuna volcanos have been active. The geothermal activity is related to volcanism in this part of the country.

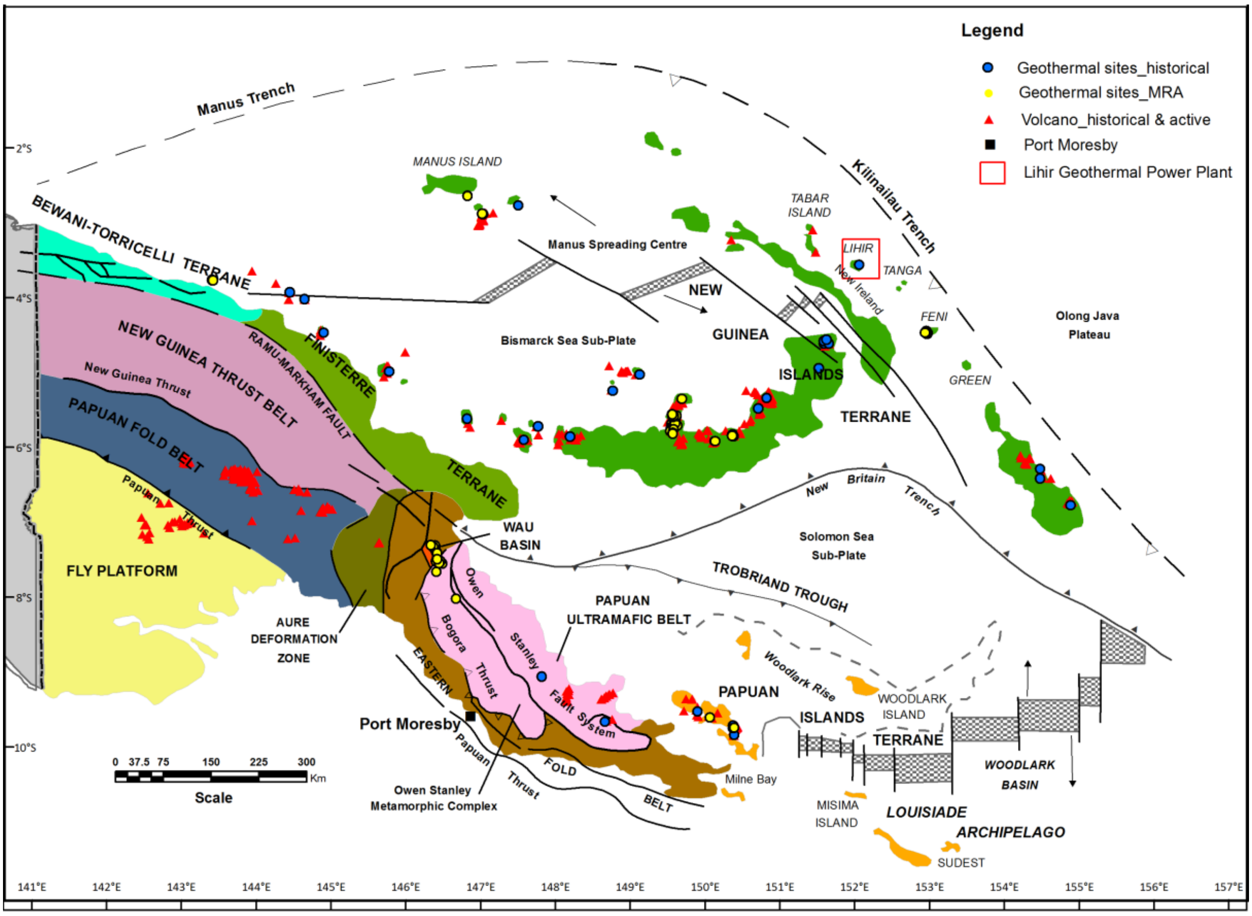

Figure 4: The main geological terranes and tectonic setting of PNG (map adapted from Williamson and Hancock, 2005). The locations of geothermal occurrences are indicated as historical (1960-1970 studies) and recent studies by MRA (2009-2016).

3. GEOTHERMAL RESOURCES AND POTENTIAL

There are 55 known geothermal sites which have been identified and recorded in the past. Of these, seven regions have been mapped and sampled; Talasea, Hoskins, Wau Bulolo and Kairiru, Manus, Fergusson and Feni Islands (Fig. 4). Hot spring sampling and geochemistry analyses were undertaken for each region and prospective sites identified.

The Mineral Resources Authority (MRA) through its Geological Survey Division has so far, covered the above mentioned seven regions since it commenced geothermal research work in 2009. Previous studies were conducted under the former Departments of Mining and Energy. Historical geothermal sites and sites investigated by MRA are shown on Figure 4. Historical information on geothermal features and volcanic sites were presented by Kuna and Zehner (2015). Brief descriptions of the geothermal prospects are provided below.

3.1 Talasea prospect

The Talasea prospect is located along the Willaumez Peninsula on New Britain Island. About 40 surface manifestations (hot springs, mud pools, hot grounds, fumaroles, geysers and solfatara) were mapped and several hot springs sampled. The Peninsula comprises dormant and active volcanoes with a crater lake on the northern tip of the peninsula. The Garbuna volcano erupted in October 2005 and is an active solfatara. It is believed to be the source for the acidic springs around its foothills in places like Galu, Haella and Kimbe-Talasea road to its east. Other manifestations north of Garbuna have low pH including Pangalu and Talasea Station springs which yield cation geothermometers. Mrcozeck and Rae (2013) and Lahan et al (2015) inferred high temperature reservoir (300°C) for Pangalu and Talasea Station springs but concluded both springs may have been complicated by sea water contribution and suggested further investigation to ascertain its potential for development.

3.2 Kasiloli prospect

Kasiloli prospect is located near the active Pago volcano in Cape Hoskins area in New Britain Island. Pago last erupted in 2012. The prospect covers a large area of hot clear water pools, mud pools and small geysers. Kasiloli is a neutral chloride spring also referred to as Magouru. The cation geothermometry work by Mrcozeck and Rae (2013) and Lahan et al (2015) indicate high temperature reservoir of >250°C, a favourable prospect for further studies to develop this prospect.

3.3 Silanga prospect

Silanga is located about 30 km east of Mt Pago on New Britain Island. A total of 5 springs were mapped and sampled. Cation geothermometry calculations for Bakama and Sakalu Mato springs yield favorable indicators for high temperature reservoir of

300°C (Mrcozeck and Rae, 2013 and Lahan et al., 2015). Mrcozeck and Rae (2013) and Lahan et al (2015) concluded that Silanga and Kasiloli are the most promising for further work.

3.4 Deidei prospect

Deidei and Iamalele geothermal sites are located on Fergusson Island which is part of the D'Entrecasteaux Islands in Milne Bay Province. Iamalele is located southwest of Deidei on the same island and comprises mostly of acidic springs. Small geysers, fumaroles, boiling springs, mud pools, heated grounds and silica terraces were mapped and two springs (Yaiyaiboalana and Seuseulina) were sampled at the Deidei prospect. Mrcozeck and Rae, (2013) inferred these springs were neutral chloride springs fed from high temperature geothermal reservoirs conservatively >200°C from T_{QZ} and probably >250°C based on cation geothermometer temperatures. Steeply dipping east-west structures occur within the prospect and perhaps related to the Woodlark Spreading Ridge. Although, the island is small with respect to development of the resource, the prospect is very promising for geothermal energy development as well as the tourism industry.

3.5 Feni prospect

Feni prospect is similar to Lihir, having similar geological setting including hydrothermal gold deposits formed by deposition of ascending fluids at temperature range of 50 – 100°C (KRTA Ltd, 1985). Hot springs, fumaroles, mud pools and sinter terrace occur on the island's geothermal areas. Feni is located approximately 160km south-east from Lihir and lies within the Tabar-Lihir-Feni Group of islands. Study by KRTA Limited (NZ) for Esso PNG Inc. in 1985 revealed reservoir temperatures of 234°C at Waramong and 280 – 300 at Kapkai Creek. Preliminary study by Kumul (2019, unpublished report) revealed reservoir temperatures >250°C for Waramong and Kapkai creek springs. These springs are to the western end of the crater. The prospect seems promising and further studies were recommended to ascertain its potential.

3.6 Rabaul prospect

The Rabaul prospect is well known for its active Tavurvur volcano and many consider it a possible source for geothermal energy. However, there is lack of information on the prospect to prove its potential as very little work has been done in the past. The area lacks surface manifestation except for two hot springs near Tavurvur-Matupit area where it is currently attracts tourists. The two hot springs are few meters off the sea shore and appear clear with deposition of reddish amber color by one of them. There may be manifestations behind the volcano and elsewhere near it apart from the volcanic activity and possibly buried under the lava. Preliminary geochemistry result indicates the springs to be neutral chloride-sulphate waters and not suited for geothermometry considerations. However, more information is expected for the prospect from geophysics surveys (TEM & MT) planned to be conducted in October this year.

3.7 Others

Other prospects are Karkar and Kairiru Islands, and Mt Lamington and Wau Bulolo on mainland of PNG. Karkar and Lamington have not yet been surveyed. The Wau Bulolo geothermal activity in Morobe Province was inferred to be structurally controlled (Lahan et al., 2015, unpublished report) and unrelated to volcanism.

PNG has vast geothermal resource potential as can be seen for MRA's work and proven by the producing high temperature/permeability Lihir geothermal system which has been producing for over 16 years. The country's geothermal resource potential is estimated to be around 9GW based on Stefansson's (2005) work. The prospects identified require further investigation to understand the geothermal systems for development.

4. GEOTHERMAL UTILIZATION

The geothermal operation in Lihir is within the gold mining lease owned and operated by Newcrest Mining Limited (Fig. 5). Lihir is located in the New Ireland Province of Papua New Guinea, about 900 kilometers northeast of Port Moresby. Geologically, Lihir is located within the tectonic convergence zone between the Pacific and Indo-Australia Plates on the western side of the Pacific Rim. Both the geothermal activity and epithermal gold mineralization are associated with the Luise volcano which had an explosive unroofing event followed by a sector collapse along the northeastern flank. Those events led to the formation of the Luise Caldera and the breaching by the ocean formed the Luise Harbour.

The Lihir gold mine (Fig. 4) started operation in 1997 but it was in April 2003 when the first 6 MWe back-pressure plant was commissioned. In 2005, a 30MWe single-flash condensing plant was added, followed by a 20 MWe extension in 2007. The 6 MWe plant was decommissioned sometime in 2009. Currently Lihir has a total installed capacity of 50 MWe.

Geothermal utilization in Lihir is primarily to provide electricity to support the mine and process plant operations. In the early years of operations, the power generation from geothermal provided more than 50% of the power requirement of Lihir operation. Currently, with the expanded operations and increased power requirement and with the decline in geothermal production due to the mining out of geothermal wells through the years and the reservoir pressure decline, the current level of geothermal power generation (15-18 MWe) now provides for 15% of the power requirement in Lihir.

The geothermal resource at Lihir has been exploited for 16 years without any of the pressure support that is typically provided by hot brine reinjection, which has allowed some groundwater and seawater incursion. Geothermal field management has adapted to the requirements of the mining activities at the site. Well maintenance activities such as periodic well mechanical workovers have been carried out but ongoing replacement well drilling has not been a priority. These factors have combined to gradually reduce the output from the Lihir geothermal power plants.

Figure 5: Lihir Mine and the geothermal steam field. The power plant is located at the bottom left corner of the photograph where the built up infrastructure area.

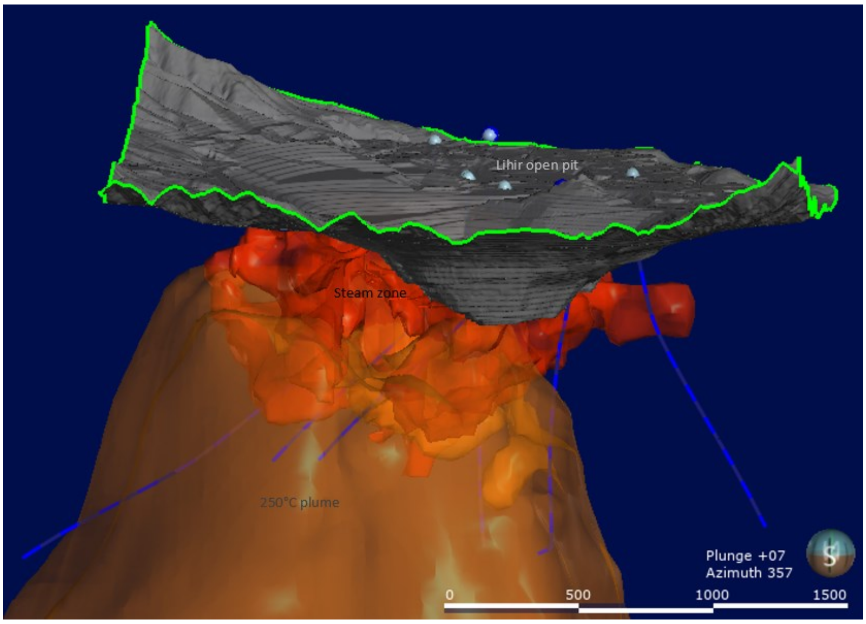

Figure 6: Lihir geothermal model (Source: Newcrest Mining Limited)

The geothermal systems that are most attractive for power development are those with high temperatures and high permeability, which together yield highly productive wells. Such a system exists (and has been exploited for geothermal power) at Lihir and this has been confirmed by the latest reservoir modelling. A roadmap for Lihir geothermal operations for the next 5 years has been developed and can be summarized as follows:

Phase 1: Implement a hot brine reinjection for pressure support which will reduce the production decline rate. It can also mitigate the further spread of seawater incursion. Maintain existing production wells operating at optimum levels by performing routine maintenance workovers to reduce calcite and silica scaling.

Phase 2: Carry out a make-up well drilling campaign to replace wells that have been lost due to mining requirements and the decline in the active wells.

Phase 3: Complete a pre-feasibility study to determine the most suitable project to optimize the geothermal production, with consideration of, but not limited to, binary plant technology.

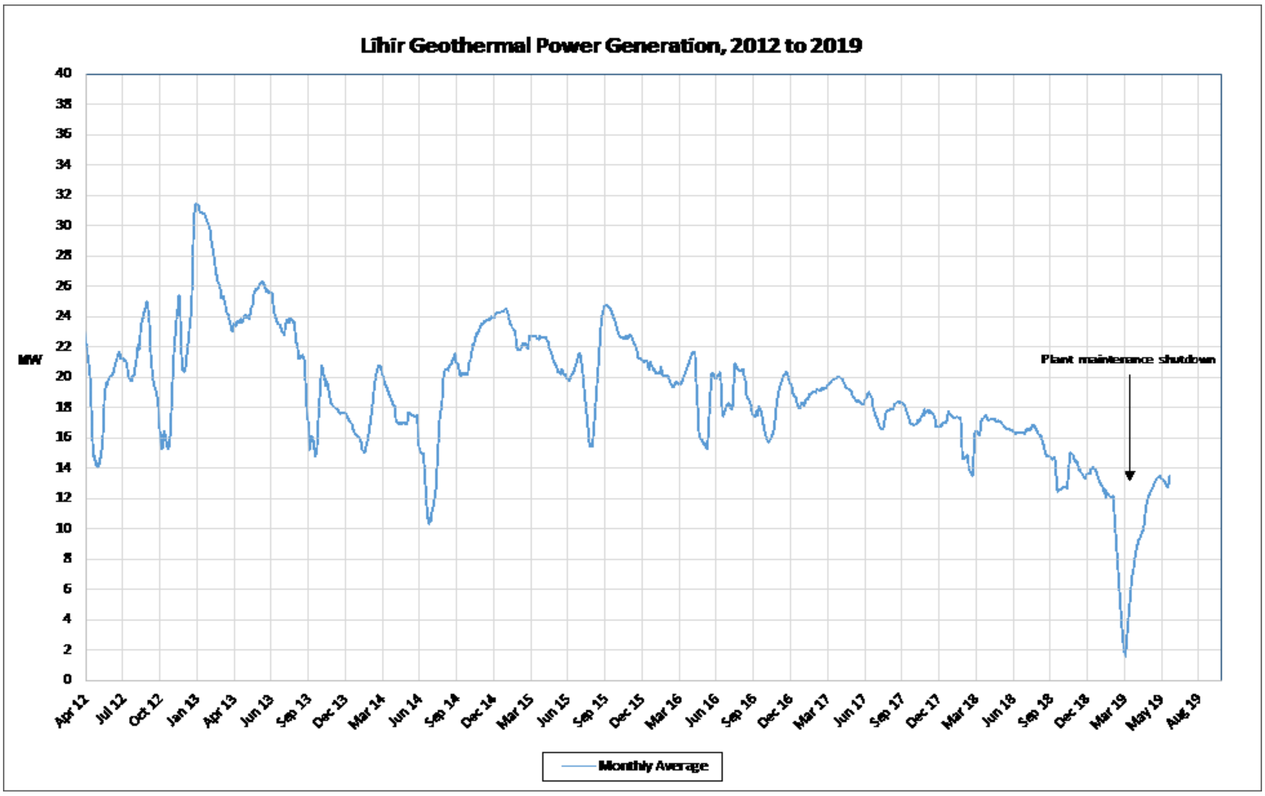

Figure 7: Geothermal Production History 2012- 2019 (Source: Newcrest Mining Limited)

5. DISCUSSION

PNG's Vision 2050 formulated in 2009, planned to achieve 100% electricity from renewable-based energy sources by 2050 and full access to electricity for its citizens including greenhouse gas emissions reduction of 90% from 1990 levels by 2050. Then, in the following year, the Development Strategic Plan (PNGSDP 2010-2030) was released to translate Vision 2050 to specific targets and established an interim target of 70% electricity access by 2030. Based on these, the country's Nationally Determined Contribution under COP21 Paris Agreement is to transition the economy to 100% renewable electricity supply by 2030, dependent on funding. These targets now seem impractical to achieve as targeted due to lack of necessary policy action, institutional capacity building and investment capital, thereafter, to create the necessary mechanisms to drive the renewable energy sector. The country lacked an energy policy and fragmented institutional arrangements where, critical functions of the sector are vested in different institutions by respective legislation. For example, drafting of geothermal resource policy was done with reference to the Mining Act as there is no overarching energy policy to derive it under. The geothermal resource policy completed by the Department of Mineral Policy and Geohazards Management was submitted to the National Executive Council in 2014. This policy is related to the Mining Act (1992) and thus, awaits the passing of the reviewed Mining Act before it can be deliberated upon.

The recent PNG National Energy Policy 2017-2027 (NEP) initiative by the government through the Department of Petroleum and Energy looks favorable to boost the energy sector, particularly development of renewable energy. The NEP 2017-2027 details the development plans and signals important reforms which are necessary to drive the sector in order to achieve the government's targets. Two governing and regulatory bodies will be set up; the National Energy Authority (NEA) and the Energy Regulatory Commission (ENERCOM) which will report to the Minister for Petroleum and Energy. The NEA will be responsible for provision of domestic energy and develop and implement energy policies. ENERCOM on the other hand, will be responsible to foster competition in the domestic energy markets in terms of tariffs, licensing and electrical and petroleum safety standards (APEC Energy Outlook, 2019). This initiative is a step in the right direction for the country and will certainly improve the country's energy sector and economy with assistance from Australia, Japan, New Zealand and the United States who have pledged funding support at the APEC Leaders meeting in 2018.

6. FUTURE DEVELOPMENT AND INSTALLATION

There is currently no plan for new geothermal power plant installations in the next 5-10 years. More exploratory work is required at this stage to collect more information on the prospects identified by MRA and others. The recent policy initiative through the National Energy Policy 2017 – 2027 is a positive step towards the development of geothermal and other renewables as the new proposed National Energy Authority develops the policy and regulatory frameworks that would encourage geothermal exploration in the country and hopefully development.

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STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Renewables (biogas)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/y	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	11	96	308	2,698	432	3,784	0	0	7	61	758	6,640
Under construction in December 2019	0	0	58	508	94	823	0	0	3	26	155	1,358
Funds committed, but not yet under construction in December 2019	0	0	100						8			
Estimated total projected use by 2020	12	105										

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRICITY POWER GENERATION AS OF 31ST DECEMBER 2019

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

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

Electrical installed capacity in 2019

Electrical capacity actually up and running in 2019

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1]	Type of Unit[2]	Total Installed Capacity MWe[3]	Total Running Capacity MWe[4]	Annual Energy Produced 2019 GWh/yr	Total under Constr. or Planned MWe
Lihir Geothermal Field	*6MW Power Station*	2003	1	decommissioned	*back-pressure (single unit)*	6MW			
Lihir Geothermal Field	30 MW power station	2005	3	*operating*	*single flash, 30MW (3x10MW GW CL-55)*	30MW	9	79	0
Lihir Geothermal Field	20 MW power station	2007	2	*operating*	*20MW (2x10MW GE CL-55)*	20MW	2	18	0
Total							11	97	0