October 2020

Papua New Guinea an emerging Geothermal energy market

The Australian Geothermal Association (AGA) would like to highlight the geothermal potential in Papua New Guinea (PNG) in light of recent developments in light of the government's new Geothermal Resource Policy in late August 2020 which provides a clear legal framework for undertaking geothermal projects in the country.

PNG is composed of a group of islands in the south Pacific, only 150 kilometres north of Australia. PNG islands are remote, largely rural and dependent on diesel/fuel oil and hydropower for electricity generation and on rain harvesting for water (minimal groundwater). However, the volcanic islands of PNG are gifted with several natural resources including geothermal. While some geothermal exploration has been carried out, only one power plant exists, and other uses are based around tourism and cultural practises.

The utilisation of geothermal resources can contribute significantly to achieving water and energy related targets identified in PNG's Vision 2050.

https://www.treasury.gov.pg/html/publications/files/pub_files/2011/2011.png.vision.2050.pdf

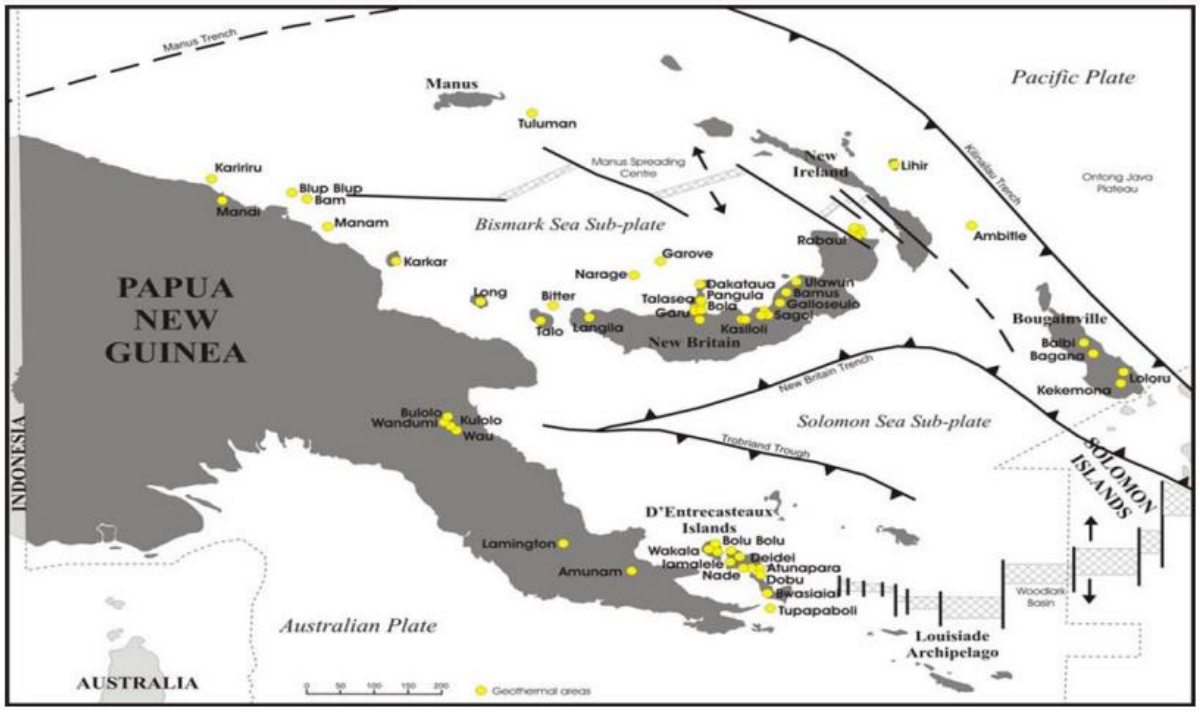

Figure 1: Geothermal manifestations from McCoy-West et al, 2011. in PNG

Mining is a part of the resources sector (mining and petroleum) in PNG, generating 26% of GDP (2017), and is the highest consumer of energy (~45 % of total). Existing and proposed

mining operations are in remote areas throughout PNG where infrastructure is limited (electricity, water, road networks) and logistics is an ongoing challenge leading to high operating costs. As such, mining entities are open to innovative and technical solutions that can contribute to improving production and reducing costs while protecting the environment.

Other industries present in PNG could also benefit from geothermal heat and electricity. For example, in the census that AGA conducted in Australia in 2019, it was found that geothermal heat was used by a wide range of industry ranging from aquaculture, meat processing, remote communities and leisure and tourism. In PNG prospective industries include the fishing industry, the pulp paper and forestry industry, heavy industry such as smelters. Remote communities could also benefit greatly from geothermal developments.

PNG Geothermal Potential

PNG belongs to the Melanesian region of the Pacific islands and is home to >600 islands. The islands are located on the rim of the Pacific *Ring of Fire*, a tectonically active zone of earthquakes and volcanism. This zone is rather complex as it passes through PNG and includes island arcs associated oceanic trenches, volcanic belts and transform faults. The regional structure and history of igneous activity (particularly the Pre-Miocene igneous intrusions) led to the formation of several world class gold and copper deposits.

Geothermal resources associated with these volcanic chains have great economic and utilisation potential. Geothermal manifestations through the islands include hot springs fumaroles, mud geysers, sulphur deposits, hot and altered ground.

Over 50 areas with surface manifestations have been identified, but PNG has only one producing geothermal power plant: on Lihir Island (installed capacity of 56 MWe and temperatures of 240 to 300°C). Outside of Lihir, geothermal resources are limited to local utilisation for cooking and tourism. But geothermal resources have been described on e.g., New Britain, and the D'Entrecasteaux (Milne Bay) Islands with surface temperatures ranging from 60 to 100°C and reservoir temperatures (using geochemistry) estimated at 200 to 320°C.

The utilisation of geothermal resources can contribute significantly to achieving water and energy related targets identified in PNG's Vision 2050.

Opportunities for further development

Based on the data available and knowledge of geothermal systems we have identified potential applications discussed below.

Electricity Generation

Geothermal resources identified in PNG are generally remote, far away from populous areas. However, some are located near mining developments. This provides an opportunity for the utilisation of geothermal resources by mining companies for power generation thus decreasing operating expenses while also reducing the carbon footprint of those developments.

The Lihir geothermal powerplant provides a good (and unusual) example of geothermal power production in mining. Newcrest's Lihir Gold Mine, located on Lihir (Niolam) Island in the New Ireland Province of PNG, is one of the world's largest epithermal gold mines. During the development of the mine, a series of wells were drilled to de-pressurise the geothermal aquifers in order to allow mining to take place.

Two geothermal reservoirs were identified, a shallow reservoir (5-600 m) with temperatures of 240 to 250°C and a deep reservoir with temperatures of 250 to 300°C (>1000 m). In 2003, a 6 MWe geothermal powerplant (noncondensing unit) was commissioned resulting in savings of US$ 200,000 per month. In 2005, a 30 MWe (single flash, condensing geothermal unit) powerplant was commissioned with projected savings of $US 7 million (AU$ 8.82 million) for the remainder of 2005 and $US14 million in 2006. Since 2008, the powerplant's capacity sits at 56 MWe, approximately 75% of the operation's power needs. Additionally, the powerplant has contributed US$ 3.8 million (AU$ 4.5 million) in revenues from carbon credit sales.

Based on the review of available public data, similar geothermal resources to that of Lihir exist across PNG (200 to 320°C) and can be used to generate off grid production for other current or future mining operations.

Figure 2: Lihir geothermal project

District Heating and Cooling

Heat plays a significant role in several processes related to mineral extraction. Figure 3 illustrates the applications of geothermal fluids in terms of geothermal resource temperature in mining.

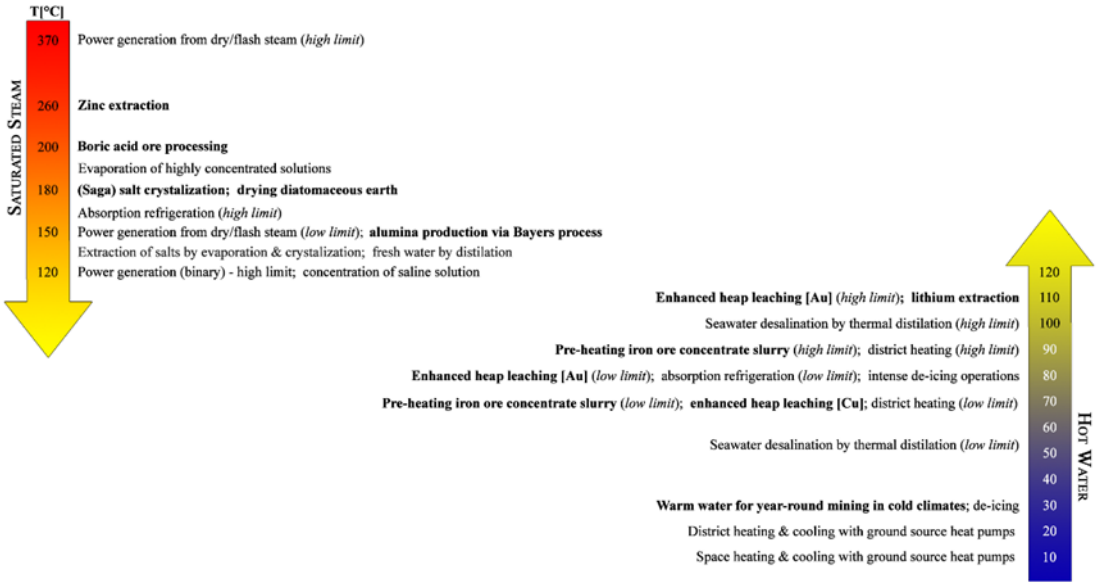

Figure 3: Lindal diagram showing applications of geothermal fluids based on temperatures in mining (after Patsa et al 2015)

Mining in PNG is dominated by gold, copper, silver, nickel and cobalt. Heap leaching is a method commonly used to recover metallic minerals, where broken ore is soaked with an aqueous leachate solution for an extended period of time. Adding heat to this solution, commonly referred to as enhanced heap leaching, has been shown to accelerate mineral extraction, increasing gold extraction rates by 5-17 % and copper extraction rates by 1.2 % per °C change in the heap solution temperature.

Mining conditions throughout PNG are known to be hot. Low temperature geothermal resources (70-80 °C) could be used to improve working conditions via cooling using absorption/adsorption chillers.

Water treatment

Water is a vital resource for mining operations as it is utilised for a wide variety of processes (ore processing, slurry transportation etc), as well as the employees. The remoteness of many mines adds another challenge for mine water security. In order to secure water supplies and to improve water management for mining operations, desalination has been used and is being considered by several mining entities globally. Throughout Chile operators including BHP Billiton, Antofagasta Minerals and Candelaria Mining are using desalination to provide potable water, water for mining operations and for wastewater treatment (since 2003). In 2009, a reverse osmosis desalination plant was commissioned in Newmont's Boddington open pit mine making it one of Australia's lowest cost gold mines. Several other desalination plants have been commissioned and/or are being developed in a variety of mines globally (e.g. uranium, iron ore, coal, copper) for example Olympic Dam in South Australia.

As noted above, desalination has been proven to be useful in many mining operations globally; however, it requires high energy input. To reduce costs, geothermal resources can be used to power desalination plants. Globally, a number of geothermal desalination projects have been carried out at temperatures of 60 to 100°C with produced water cost of USD1.2-1.6/m^3.

Based on current available data, PNG's geothermal resources could be used to operate conventional and/or modular desalination systems, particularly multi-effect distillation which

does not require the generation of electricity to drive the distillation process. Geothermal multi-effect distillation was extensively studied as part of the Western Australia Geothermal Centre of Excellence which operated between 2009 and 2012. This treated water can be used as potable water and or utilised throughout the mining process for, e.g., dust suppression, slurry transportation, cleaning of equipment, processing ore, etc.

Furthermore, there may be potential mutliple/cascading uses for geothermal energy such as occurs at Warakei in New Zealand (eg power generation, multi-effect distillation, fish farms, greenhouses and/or other direct-use applications of the heat).

PNG geothermal resource policy

The PNG Government made a press release on 18 August 2020 in one of the daily newspapers (Post Courier) to introduce the new PNG Geothermal Resource Policy. In the press release, the Minister for Mining, Hon. Johnson Tuke, MP advised that the National Executive Council has endorsed the new policy.

Hon. Tuke stated that under the new policy, any exploration and development of geothermal resources in Papua New Guinea will be permitted under the PNG's Mining Act 1992.

Prior to this policy, there was no separate legislation, regulation or policy to assist with exploitation of geothermal resources in PNG. We note however that at least two applications were made historically under mineral exploration or mining legislation. Therefore, the endorsement of this new policy is a step in the right direction for future geothermal projects in PNG. This will also be a welcoming news for the global investment community.

The new policy will be administered by the Mineral Resources Authority of Papua New Guinea (https://mra.gov.pg). AGA will seek to provide updates on this recent development.

Historical PNG exploration

Geothermal investigations by government organisations, including those of Australia and New Zealand as well as PNG, go back more than half a century. Mosusu (2015) gives a good summary of recent work by PNG's Mineral Resources Authority.

Apart from Lihir, apparently there has been very little field work by non-government entities. In 2011, licences to explore for geothermal energy in the Mt Lamington area and at Mt Trafalgar, Oro Province were granted to the Regency Mines – Direct Nickel joint venture, but no work was carried out and the licences were allowed to lapse. In the same year Iceland's Reykjavik Geothermal visited East New Britain and concluded that the region was prospective, but did not proceed through to tenure; due, at least in part, to the moratorium on granting licences.

In 2012 Kula Energy took a managing role in KUTh Energy (PNG) Ltd which holds applications to explore for geothermal energy over the Willaumez Peninsula in West New Britain and another two areas on Fergusson Island in Milne Bay. Warden's hearings were held at each site, with recommendations to proceed to grant. However, the applications remained 'on hold' while the sector was being reviewed.

As of February 2019 (the latest listing on the Authority's website), the only licence applications specifically for geothermal exploration in PNG are those held by KUTh over Talasea in West New Britain, and Iamalele and Salamo on Fergusson Island.

Figure 4: Fumerole at Talasea where reservoir temperatures have been estimated in the range 270-310°C (Lahan et al, 2015). Photograph by KUTH Energy (PNG) Ltd.

Recent developments in the region

Fortescue Metals Group

Fortescue Future Industries Pty Ltd, a wholly owned subsidiary of Fortescue Metals Group Ltd (Fortescue) has entered into a Deed of Agreement with the Government of the Republic of Indonesia […].

The Deed of Agreement provides first priority to Fortescue Future Industries to conduct development studies into the feasibility of projects utilising Indonesia's [..] geothermal resources to support green industrial operations, principally for export to global markets.

https://www.fmgl.com.au/in-the-news/media-releases/2020/09/04/fortescue-future-industries-and-minderoo-foundation-in-indonesia

It has also been reported that Fortescue Metals, has had discussions and meetings on potential geothermal development in Papua New Guinea as well.

Pacific Centre for Renewable Energy and Energy Efficiency podcasts

Carbon and Energy Professionals (CEP), a New Zealand based association of energy efficiency and carbon reduction professionals, and the Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE), a regional centre of excellence to promote sustainable energy investments, markets, industrial development and innovation in Pacific Island Countries are hosting three webinars on renewable energy in September.

https://cep.org.nz/webinar-series-accelerating-investments-in-renewable-energy-energy-efficiency-and-smart-mobility-in-the-pacific-islands/

Regards

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