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Geothermal Business Outlook in Indonesia

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ABSTRACT

The Government of Indonesia (GOI) has been developing plans to support the energy transition towards new and renewable energy (NRE) and carbon neutrality by the year 2060. As stated in the national energy general plan (RUEN) and mentioned in numerous media sources, Indonesia targets 23% of NRE in the energy mix by the year 2025 by adding a sum of 38 GW capacity from various sources of NRE. One of the key resources in the realization is geothermal energy, GOI has a target that was expressed through a geothermal development roadmap with a total of 3,575 MW of installed capacity by 2025. With government investments and substantial geothermal energy potential, Indonesia's geothermal energy utilization is at 9.81 % and has yet to be maximized.

Many companies and investors take part in the development of the geothermal energy sector in Indonesia through agreements and partnerships, contributing to the 2,342.63 MW geothermal current installed capacity. These entities set ambitious goals for exploration and driving the nation's geothermal energy growth. These ambitious goals are supported by sector-related policies and regulations. These include regulations related to PLN's authority as electricity off-taker, fiscal and non-fiscal incentives, management restrictions, investment requirements, and tariff policies. Developers and investors demand higher incentives and certainties for their investments due to major challenges related to the cost and risk in every geothermal project phase. Hence, the Government of Indonesia is on the search to find the ideal balance between PLN's purchasing power and developer's requests as new tariffs and policies evolved and were put to test.

This report covers the geothermal business outlook in Indonesia, discussing regulations governing renewable energy policies in Indonesia, new geothermal tariffs, most recent changes in policies, geothermal companies and entities operating in Indonesia, and the top contributors in the geothermal sector and their company roadmaps.

1. INTRODUCTION

Indonesia lies along the Pacific Ring of Fire and has approximately 127 active volcanoes. Largely as the result of volcanic and tectonic activities, Indonesia has a significant geothermal resource base: up to 23.36 GW of potential across 356 geothermal locations (**Table 1**).

Table 1: Geothermal Resources in Indonesia (modified from Geological Agency (2021))

No.	Island	Total Location	Resources (MW)					Total Installed Capacity
			Speculative	Hypothetic	Reserves			
					Probable	Possible	Proven	
1	Sumatera	101	2.167	1.567	3.624	976	1.126,4	949,75
2	Jawa	75	1.259	1.191	3.260	377	1.820	1.253,8
3	Bali	6	70	21	104	110	30	0
4	Nusa Tenggara	34	215	146	783	121	12,5	19,08
5	Kalimantan	14	151	18	6	0	0	0
6	Sulawesi	90	1.352	342	989	180	120	120
7	Maluku	33	560	91	485	6	2	0
8	Papua	3	75	0	0	0	0	0
Total		356	5.849	3.376	9.251	1.770	3.110,9	2.342,63
					14.131,9			
			23.356,9					

Geological Agency, 2021

There are currently 16 geothermal fields under exploitation and operation: Darajat (270 MW), Dieng (70 MW), Kamojang (235 MW), Karaha (30 MW), Lahendong (120 MW), Lumut Balai (55 MW), Mataloko (2.5 MW), Muara Laboh (85 MW), Patuha (55 MW), Rantau Dedap (98.4 MW), Salak (376.8 MW), Sarulla (330 MW), Sibayak (12 MW), Sokoria (6.58 MW), Sorik Marapi (149.35 MW), Ulubelu (220 MW), Ulumbu (10 MW), and Wayang Windu (227 MW). The combined installed electrical capacity is 2,342.63 MW (**Table 2**). Currently, Indonesia is the second largest producer of geothermal energy, trailing only the United States.

Table 2: Utilization of Geothermal Energy for Electric Power Generation as of 31 December 2022

No	GWA / Area / Province	Geothermal Power Plant	Operator	Turbine Capacity (MW)	Total Capacity (MW)
1	Kamojang Darajat, Jabar	Kamojang	PT. Pertamina Geothermal Energy	1 x 30 2 x 55 1 x 60 1 x 35	235
	Kamojang Darajat (KOB), Jabar	Darajat	KKOB Star Energy Geothermal Darajat II, Ltd	1 x 55 1 x 94 1 x 121	270
2	Cibeureum Parabakti, Jabar	Salak	KKOB Star Energy Geothermal Salak, Ltd.	3 x 60 3 x 65,6	376,8
3	Dataran Tinggi Dieng, Jateng	Dieng	PT. Geo Dipa Energi	1 x 60	60
4	Sibayak Sinabung, Sumut	Sibayak	PT. Pertamina Geothermal Energy	1 x 10 2 (Monoblok)	12
5	Pangalengan (KOB) , Jabar	Wayang Windu	KKOB Star Energy Geothermal Wayang Windu Ltd.	1 x 110 1 x 117	227
	Pangalengan (Patuha Area), Jabar	Patuha	PT Geo Dipa Energi	1 x 55	55
6	Lahendong Tompaso, Sulut	Lahendong	PT. Pertamina Geothermal Energy	6 x 20	120
7	Waypanas, Lampung	Ulubelu	PT. Pertamina Geothermal Energy	4 x 55	220
8	Ulumbu, NTT	Ulumbu	PT. PLN (Persero)	4 x 2,5	10
9	Mataloko, NTT	Mataloko	PT. PLN (Persero)	1 x 2,5	2,5
10	Sibual Buali, Sumut	Sarulla	KKOB Sarulla Operations Ltd.	3 x 110	330
11	Karaha Cakrabuana, Jabar	Karaha	PT. Pertamina Geothermal Energy	1 x 30	30
12	Lumut Balai, Sumsel	Lumut Balai	PT. Pertamina Geothermal Energy	1 x 55	55
13	Sorik Marapi Roburan Sampuraga,Sumut	Sorik Marapi	PT Sorik Marapi Geothermal Power	1 x 42,4 1 x 56,95 1 x 50	149,35
14	Liki Pinawangan Muaralaboh, Sumbar	Muaralaboh	PT Supreme Energy Muara Laboh	1 x 85	85
15	Rantau Dedap, Sumsel	Rantau Dedap	PT Supreme Energy Rantau Dedap	1 x 98,4	98,4
16	Sokoria, NTT	Sokoria	PT Sokoria Geothermal Indonesia	2 X 3,29	6,58
		TOTAL			**2.342,63**

With strengthened decarbonization drive and Net Zero commitments around the world, geothermal could play a major role in providing a long-term clean energy source. The Government of Indonesia's strategy for its energy sector emphasizes diversification, environmentally sustainability, and maximum use of domestic energy resources. The National Energy Policy (Kebijakan Energi Nasional ("KEN")) 2014 targets a primary energy mix of 23% new and renewable energy ("NRE") (10% bioenergy, 7% geothermal, 3% hydropower, and 3% other renewable energies), 22% gas, 55% coal, and 0.4% oil by the year 2025. The National Electricity Plan (Rencana Umum Kelistrikan Nasional ("RKUN")) aims at a long-term goal of 28% NRE, 25% gas, 47% coal, and 0.1% oil for electricity usage (ADB, 2020). Indonesia has also committed to reach net zero emissions by 2060 or before. Geothermal power will play a key role in reaching these targets.

Featuring the world's most substantial potential geothermal capacity, Indonesia is well-positioned to be a world leader of this renewable energy source. However, the country is currently using only about 9.81% of its geothermal potential. Most of the geothermal power projects is colocated with demand in the regions of Sumatera, Java, northern Sulawesi, and Flores island; although geothermal potential can be found countrywide. As of 2021, geothermal energy accounted for only 2.3% of Indonesia's primary energy supply mix (ESDM, 2021).

Geothermal power project development has been given a high priority in both the Electricity Business Plan (Rencana Usaha Penyediaan Tenaga Listrik ("RUPTL")) and the National Energy General Plan (Rencana Umum Energi Nasional ("RUEN")) to meet Indonesia's NRE target. Since the Geothermal Law was enacted in 2003, the government has prioritized the development of this resource and is targeting the total installed geothermal power capacities of 3,575 MW by 2025; 5,486 MW by 2030; and 9,300 MW by 2035 (Geothermal Energy Roadmap 2020-2035; ESDM, 2022). The targeted additional installed geothermal power capacity envisaged by the Government of Indonesia is ambitious and will require all actors (public and private entities) to speed up project implementation significantly.

The overall pace of geothermal power project development in Indonesia has been slow, however. Despite being regarded as a commercially viable renewable energy technology, geothermal power project development in Indonesia faces a number of significant sector specific issues that are deterring investments, which include: (1) high upfront capital requirement; (2) insufficient policy and regulatory support for implementation of the Geothermal Law; (3) inadequate incentives and pricing mechanisms that fail to both reflect the environmental benefits of the technology and enable investors to secure a return commensurate with the higher risk they face especially when developing green geothermal fields; (4) limited institutional capability to properly plan geothermal development and sufficiently engage suitable developers; and (e) weak domestic capacity in the areas of resource assessment, equipment manufacturing, construction, and operation and maintenance of geothermal energy facilities (World Bank, 2011).

Despite the above-mentioned challenges, geothermal development remains a key development priority for the Government of Indonesia, and is a vital part of its Low Carbon Growth strategy for Indonesia. In order to move forward, the Government of Indonesia has issued some policies to de-risk geothermal power project development through easing regulations and providing incentives to the sector to realize geothermal's potential. The government has also allocated resources to support the sector through dedicated programs via the Infrastructure Financing for Geothermal Sector, as well as fiscal incentives for developers through various tax deduction possibilities. In 2017, the government revised its regulation to clarify the terms of access to geothermal development in protected and conservation forest areas. In addition, the geothermal sector is starting to implement a new cost-coefficient risk-sharing mechanism, funded by the World bank and the Green Climate Fund, to mitigate geothermal resource risk for both public and private sector enterprises. Asian Development Bank ("ADB"), along with other development partners, through the Climate Investment Fund, has helped government and private sectors develop geothermal projects, including non-sovereign financing for the development of Sarulla (USD 250 millions), Muara Laboh (USD 70 millions), and Rantau Dedap (USD 173 millions) (ADB, 2020).

This paper presents the progress of geothermal power project development in Indonesia and the role of the Government of Indonesia including the policy, regulatory framework and government incentives. It also identifies the challenges of the geothermal development, and more importantly its prospect in the future. This research uses qualitative-descriptive method focused on literature review to obtain literature or secondary data. The data used are secondary data obtained from various sources, such as, Ministry of Energy and Mineral Resources ("MEMR"), PT Perusahaan Listrik Negara (Persero) ("PLN"), as well as a range of research and other resources accessed through internet.

2. THE PROGRESS OF GEOTHERMAL POWER PROJECT DEVELOPMENT IN INDONESIA

Geothermal power project development in Indonesia can be divided into three (2) eras, namely: (1) Pre-Geothermal Law Era; and (2) Geothermal Law Era.

2.1 Pre-Geothermal Law Era

2.1.1 1920 to 1970

Serious exploration of Indonesia's geothermal systems began at Kawah Kamojang, West Java Province, in the 1920s under auspices of the colonial-era Geological Survey of Indonesia. Several shallow holes encountered flows of steam and hot water (GeothermEx, 2010). At Dieng geothermal field in Central Java Province, a shallow hole was drilled into a fumarolic area; it encountered a maximum temperature of 140°C. There appears to have been no attempt at commercial development of either of these areas for electric power.

2.1.2 1971 to 1980

The Government of Indonesia conducted a more complete inventory in the 1970s with technical assistance from Italy, Japan, New Zealand, and USA. The results of these studies were used as a basis to issue new policies to accelerate geothermal development and encourage energy diversity in Indonesia. To implement the new policy, the Government of Indonesia issues Presidential Decree 16/1974. Under this Presidential Decree, responsibility for exploration and development of geothermal resources was assigned to the national oil company (Pertamina) (for geothermal prospects within Java and Bali islands) and the Government of Indonesia (for geothermal prospects located outside Java and Bali islands). Pertamina thereupon became an active participant in exploration. A series of deep exploration wells was drilled at Kamojang in 1974. A high temperature (~240°C) vapor-dominated system was encountered, with strong flows of steam (averaging ~60 tons/hour per well) from a reservoir exhibiting a pressure of ~35 bars. The decision was made in 1978 to install a small (<1 MW) power plant at Kamojang. In 1979, the decision was taken to build a 30-MW power plant at Kamojang. Pertamina entered into a Steam Sales Agreement ("SSA") with the national electric utility, PLN. The latter built and owned the plant (Kamojang Unit 1) in part with funding from the New Zealand Government (GeothermEx, 2010).

After systematic exploration at Darajat, the first well was drilled in 1976. The second well encountered another vapor-dominated system. Pertamina, expanding the range of its activities, conducted surface exploration at Cisolok, Salak, and Kaldera Danau Banten (West Java). The Volcanological Survey of Indonesia ("VSI"), by itself and variously with Pertamina, and New Zealand and Japanese aid groups, explored the Bedugul prospect on Bali (i.e., Bedugul), and a number of prospects in Sumatera (i.e., Sungai Penuh, Muara Laboh) and Sulawesi (Lahendong). Shallow holes were drilled into several of these prospects. Many of the prospects explored during that period were later the sites of intense activity, drilling of deep wells, and in at least one case, Lahendong in North Sulawesi Province, power plant installation. The program thus had successfully identified 4 fields that at present have geothermal power generation: Kamojang, Salak, Darajat, and Lahendong, out of 7 prospects initially given high priority for exploration and assessment. Risk for this effective program was borne by foreign donors, especially the governments of New Zealand and Japan, and by the Government of Indonesia acting through Pertamina, VSI, and PLN (GeothermEx, 2010).

2.1.3 1981 - 2002

Presidential Decree 20/1981 authorized Pertamina to enter into joint venture (Joint Operation Contracts, or "JOC") to develop geothermal fields. Construction and ownership of power plants were still reserved to PLN. in 1981, the Government of Indonesia offered 5 areas for joint venture: Kaldera Danau Banten, Cisolok, Darajat, Dieng, and Salak. Salak was awarded (1982) to Union Oil Company of California (subsequently renamed Unocal). Amoseas Indonesia Inc. ("Amoseas"), a joint subsidiary of Chevron Oil Company and The Texas Company (TEXACO), entered into a JOC for Darajat (1984). SSAs were negotiated between Unocal Geothermal Indonesia ("UGI") and Pertamina, and between Amoseas and Pertamina. Pertamina in turn agreed to sell steam to PLN, who would build and operate the power plants (GeothermEx, 2010). Beginning in 1982 at Salak and 1984 at Darajat, private developers began to share the resource risk. Under terms of the JOC, UGI and Amoseas immediately began detailed exploration and exploratory drilling at their respective areas.

Indonesia's first commercial power plant (30 MW) went online at Kamojang in 1983, partly financed by New Zealand and other international lenders and donors. Drilling of additional wells continued. The decision was taken in 1984 to add two 55-MW units, and these (Kamojang Units 2 and 3) were constructed by PLN and commissioned by late 1987. Total installed capacity had reached 140 MW (GeothermEx, 2010).

At Salak, a 110-MW power plant was recommended to PLN in 1985; however, PLN delayed construction of the plant, and it was not completed until 1994. In 1988, Amoseas and Pertamina recommended construction of a 55-MW power plant ay Darajat; again, PLN deferred construction. Darajat Unit 1 (55 MW) finally was commissioned in 1994. It is reported that price, along with a continued preferred for coal-fired generation, contributed to these delays (GeothermEx, 2010).

Pertamina had continued exploratory drilling in Dieng, but had encountered problems with non-condensable gases ("NCG") and a phreatic (steam) eruption at one well, raising concerns about environmental hazards. An application in 1983 by PLN for a loan from the Asian Development Bank ("ADB") to construct a power plant at Dieng was withdrawn after these and other issues emerged regarding the project (GeothermEx, 2010).

The delays and uncertainties were costly for all parties at Salak, Darajat, and Dieng. Large sums had been spent in surface exploration, drilling wells, and constructing surface facilities, which added to the economic risk of the project. Therefore, urged by private developers and by national entities, late in 1991, the Government of Indonesia issued Presidential Decree 45/1991 which allows JOC to build and operate power plants and sell electricity to PLN. Presidential Decree 49/1991 provided implementation measures for Presidential Decree 45/1991. Private Independent Power Producers ("IPPs") were also allowed to construct power plants of 10 MW or lesser capacity, and to sell power directly to local purchaser at negotiated price (GeothermEx, 2010).

Explorations of other prospects in Java, Bali, Sumatera, and Sulawesi by Pertamina and/or VSI has continued through the decade of the 1980s, with mixed results. Areas with significant results included: Wayang Windu, Patuha, and Karaha, all in West Java Province; Lahendong and Tompaso in North Sulawesi Province; Bedugul in Bali Province; Sibayak and Sarulla in North Sumatera Province; and Ulubelu, Kunyit-Lempur, Hululais, Sekincau – Suoh, and Lumut Balai in southern Sumatera. Deep exploration wells were drilled in many of these areas in the late 1980s and early 1990s. In addition to Dieng, there has been construction of a geothermal power plant at Wayang Windu, Sibayak, and Lahendong. Projects are in advanced stages of activity at Sarulla, Patuha, Bedugul, Lumut Balai, and Ulubelu (GeothermEx, 2010). This shows the effectiveness of state-supported program, of surface exploration and drilling of discovery wells. Purwanto (2019) reported that other preliminary geoscientific exploration surveys and studies were performed (by Pertamina and/or other investigators) in at least 35 new prospects across Java, Sumatera, Nusa Tenggara, and Sulawesi; Many of these surveys and studies, however, were not followed by any exploration drillings.

In 1997, Pertamina catalogued or assessed some 250 geothermal prospects, of which about 70 were considered to have potential for generation of electricity. Of these areas, Pertamina had entered into JOCs with several private geothermal developers, in 10 separate prospects: (1) Bedugul Prospect – with Bali Energy Ltd.; (2) Cibuni Prospect – with PT. Yala Teknosa Geothermal; (3) Darajat Prospect – with Chevron Geothermal Inc. ("CGI"), a successor-in-interest to Amoseas; (4) Dieng Prospect – with Himpurna California Energy Ltd.; (5) Wayang Windu Prospect – with Mandala Nusantara BV; (6) Karaha Prospect – with Karaha Bodas Co.; (7) Patuha Prospect – with Patuha Power Ltd.; Salak Prospect – with UGI; (9) Sarulla Prospect – with Unocal North Sumatera Geothermal Ltd. ("UNSG"); and (10) Sibayak Prospect – with PT Dizamatra Powerindo (GeothermEx, 2010). In addition, Pertamina retained sole control of development at Lahendong and Kamojang. Exploration continued at such important areas as Ulubelu and Lumut Balai. Under an aid agreement with New Zealand, PLN became responsible for commercial development of the Ulumbu prospect on Flores island (GeothermEx, 2010).

During 1993-1996, ESCs were signed between PLN and Pertamina and its JOC partners for the construction of power plants at Bedugul, Cibuni, Darajat, Dieng, Karaha, Salak, Sarulla, Sibayak, Patuha, and Wayang Windu. By itself, Pertamina entered unto ESCs for the further development of Kamojang and Lahendong (GeothermEx, 2010).

The Asian financial crisis of 1997-1998 had a major impact on Indonesia's geothermal industry. Late in 1997, the Government of Indonesia issued Presidential Decree 39/1997. It cancelled various energy projects, including geothermal projects. After the issuance of Presidential Decree 5/1998, a total of seven geothermal projects were suspended indefinitely (GeothermEx, 2010). It is reported that there were no new private investors in geothermal energy during that time; even long-term investors (e.g., Unocal and Chevron) were hesitant to continue in the climate of uncertainty and risk (GeothermEx, 2010). Presidential Decree 76/2000 was then issued to cancel Pertamina's monopoly on geothermal field development (but not voiding previous signed JOCs). Pertamina then returned 18 geothermal working areas ("GWAs") to MEMR in 2002 (Purwanto, 2019). Presidential Decree 76/2000 also delegated to regional governments the authority to issue licenses, to supervise geothermal operations, and to extend beyond 30 years the term granted for development. This Presidential Decree was basically designed to encourage private investment; however, it did not have an immediate impact.

Presidential Decree 15/2002 revoked Presidential Decree 5/1998. In July 2002, Pertamina and PLN established a jointly owned subsidiary, PT Geo Dipa Energi ("Geo Dipa"), with authority to explore and develop geothermal fields and build and operate power plants in competition with private entities. Geo Dipa was placed in charge of Dieng (with its 60-MW power plant), and Patuha with authorization to proceed with development (GeothermEx, 2010).

2.2 Geothermal Law Era

2.2.1 2003 - 2010

In 2003, the Government of Indonesia issued the first Geothermal Law No.27/2003 which enabled the participation of private entities. This regulations placed geothermal energy in the spotlight, it also strengthened Presidential Decree 76/2000.

Geothermal Law No.27/2003 provides more flexibility to all businesses to strive in the field of geothermal energy through an auction process before getting a Geothermal Mining Permit (Ijin Usaha Pertambangan or "IUP"). Local governments were empowered to take an active role in the development of these geothermal resources. This Law granted powers to both the Central Government and Local Governments to conduct preliminary exploration surveys and exploration drilling, and then utilize the data obtained from these exploration studies as a basis for setting up GWAs. These GWAs were then used in auctions by either the Central Government or Local Government (Setiawan, 2014).

MEMR introduced two new schemes of geothermal enterprising, namely Geothermal Business Permit ("GBP") and Preliminary Survey Assignment ("PSA") (Purwanto, 2019):

- The GBP follows the GWA tender. The GBP is issued to a bidder which satisfies the entire tender requirements. The GBP holder must conduct a geoscientific exploration, an exploration drilling, and a feasibility study within 7 years after the issuance of the GBP. During this period, the regional government is responsible for monitoring and supervision.
- The PSA enables a business entity to conduct a preliminary survey without performing an exploration drilling. This was decided in order to reduce upstream risk(s) and attract potential investor(s). These potential investors were enabled to conduct investigations that have not yet been performed by Geological Agency (or "Badan Geologi"). In this scheme, the business entity is required to complete a geoscientific exploration within 1 year and present a pre-feasibility study to MEMR prior to the establishment of a GWA.

After the enactment of Geothermal Law No. 27/2003, the Government of Indonesia issued a total of 35 GWAs. A total of 15 additional prospects were to be offered for bid by private entities, with interest expressed by Australian, America, Dutch, Iceland, the Philippines, and Japan companies. During this period, construction of power plants by PGE and PLN has been renewed, with Kamojang Unit 4 (60 MW) coming online at the end of 2008, followed quickly by Lahendong Unit 2 (20 MW) and construction of a 10-MW unit at Sibayak. At Wayang Windu, Star Energy constructed Unit 2 of 117 MW. Pertamina's Kamojang Unit 5 and 6 were in various stages of development, with funding pledged or under consideration by several international lenders. Pertamina is progressing with plans for power plants at Lahendong (Units 5 and 6, of 20 MW each), at Ulubelu (2 x 55 MW), and at Lumut Balai (also 2 x 55 MW). Even a long-delayed 55-MW development at Patuha was being financed. Slightly over 1,100 MW was online at 7 fields by 2010 (GeothermEx, 2010).

2.2.2 2011 - 2022

Geothermal Law No. 21/2014 revoked Geothermal Law No. 27/2003. This new law includes some major changes such as: (1) the Central Government is now allowed to take control over exploration activities; (2) state-owned enterprises (SOEs) are allowed to obtain direct assignments from the MEMR to conduct exploration studies, and (3) the PSA has now been changed to Preliminary Survey and Exploration Assignment ("PSEA") which requires business entities to complete a geoscientific exploration and at least one (1) exploration well within three years. Under the Geothermal Law No. 21/2014, geothermal-related activities are no longer considered mining activities. Mining activities are prohibited in high conservation value areas and thus require mining licenses. Under Geothermal Law No. 27/2003, geothermal activities require a Geothermal Mining License issued by the MEMR, governor, or major. Under Geothermal Law No. 21/2014, geothermal activities only require a Direct Utilization License (Ijin Pemanfaatan Langsung, or "IPL"). The issuance of Geothermal Law No.21/2014 lifted many constraints and sparked significant growth in geothermal activities as most geothermal activities were done near conservation value forests.

Geothermal Law No. 21/2014 governs that geothermal project development should commence as soon as a feasibility study has been submitted and approved by the MEMR. Generally, project completion time for geothermal projects is measured from the start of the exploration stage to the first unit's commercial operation date ("COD"). For GWAs developed by Pertamina (including JOCs Projects), the project completions took approximately 8 to 11 years (e.g., Salak, Darajat, and Wayang Windu Geothermal Power Projects); however, some projects took longer (ranging from 17 to 23 years; e.g., Lahendong, Sarulla, and Dieng Geothermal Power Projects) due to the Asian financial crisis of 1997-1998, negotiations of Power Purchase Agreements ("PPAs"), and actions leading to changes in the ownership of geothermal fields and power plants (Purwanto, 2019).

For GWAs established after 2003, GBP holders are required to perform and complete exploration activities within 7 years after the issuance of the GBP. The Government of Indonesia requires GBP holders to return the GBP if the exploration activities are not completed within that 7 years.

As of the end of 2022, a total of 63 GWAs have been offered to geothermal developers, including 26 GWAs assigned to SOEs (PLN, PGE, Geo Dipa, and PT Sarana Multi Infrastruktur ("SMI")). In addition, a total of 13 PSEA and 2 PSA areas have been assigned to private companies; and 2 other PSEA areas (i.e., Cubadak and Pentadio) will be tendered in the near future.

Geothermal Law No. 21/2014 classifies utilization of geothermal energy in Indonesia into two types: direct use and indirect use for electricity generation. Geothermal resources in Indonesia are predominantly utilized for electricity generation. As previously discussed, as of the end of 2022, 2,342.63 MW power plants from geothermal energy have been installed in Indonesia. It is an increase of approximately 904.13 MW from its total installed capacity of 1,438.5 MW in 2015 and almost double from 1,187 MW in 2009. The total installed capacity from 1990 to 2022 is shown in **Figure 1**, and the list of power plants are summarized in **Table 2**.

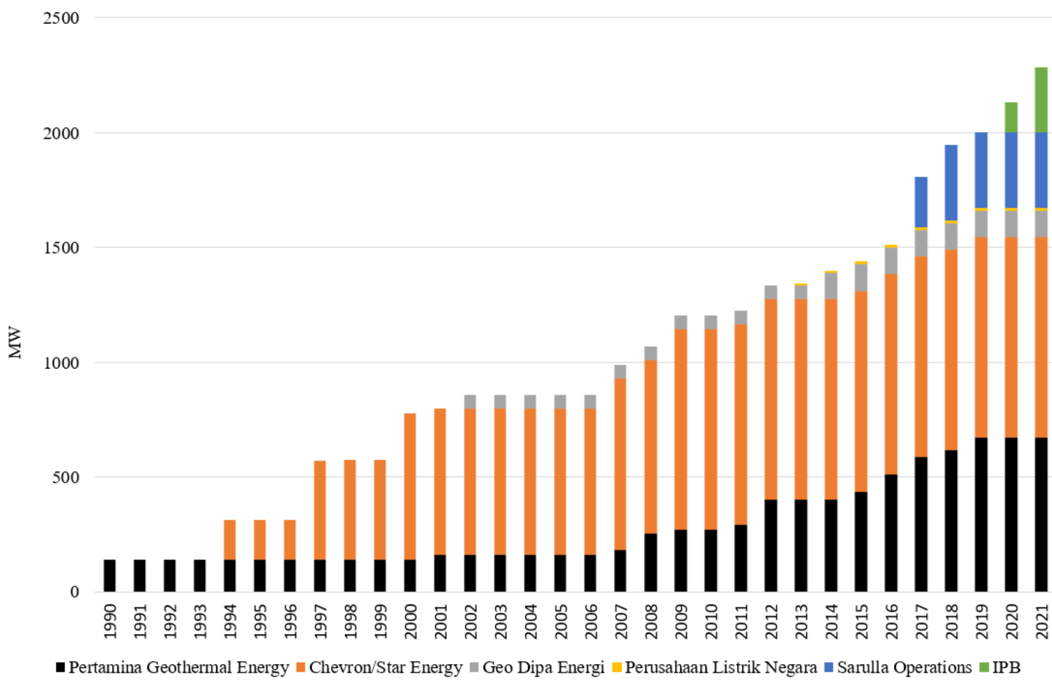

Figure 3: Annual Increments of Installed Geothermal Capacity in Indonesia

Examples of geothermal direct use in Indonesia include: (1) an aquaculture facility in Lampung that utilizes geothermal fluid; it is a traditional freshwater fishery which mixes natural geothermal hot water with freshwater from a river to grow large catfishes. The farmer reported that the fish grow better in the geothermal fluid and freshwater mixture; (2) Copra drying in Lahendong (North Sulawesi), Mataloko (Flores Island), and Wai Ratai (Lampung); (3) mushroom cultivation, (4) tea drying, and (5) pasteurization in Pangalengan (West Java); (6) (Darma et al., 2021). It is also reported that palm sugar processing using brine produced from Lahendong Geothermal Power Project has currently been suspended.

3. CHALLENGES OF GEOTHERMAL POWER PROJECT DEVELOPMENT IN INDONESIA

Unlocking Indonesia's geothermal potential, however, has been constrained by some challenges, which include upstream and downstream sides challenges.

3.1 Upstream Side Challenges

Upstream side challenges include the following:

3.1.1 Resource / Exploration Risk

Every geothermal project is unique, and, to some degree, presents its own distinct challenges and risks, because of the variability of geologic conditions and geothermal systems. However, resource-related risks can generally be categorized as follows:

- Insufficient heat resource: this refers to the amount of heat within the volume that be economically exploited by drilling to be fundamentally too small to support a project of the intended size.

- Inadequate or inconsistent well capacity: even if the heat resource within a drillable volume is adequate to support a project, it cannot be exploited without drilling and operating production and injection wells of adequate capacities. Production well capacities are a function of temperature, reservoir permeability, and reservoir pressure; injection-well capacities are mainly a function of permeability and pressure. In both cases, permeability is the most difficult reservoir property to predict, and poor or inconsistent permeability tends to be the most important factor in the occurrence of poor or inconsistent well capacities.

- Resource degradation: the capacities of production wells almost always decline over time. This is planned for and addressed by having some spare capacity initially and/or by drilling new wells (make-up wells) over the period of project operation. However, excessive rate of decline will lead to either excessive costs for make-up drilling or a decline in generation over time. Resource degradation occurs mainly as the results of one or both of: (1) reservoir pressure decline; and (2) reservoir cooling.

- Operational problems: a variety of phenomena that are not directly related to heat extraction may have an impact on project economics, particularly if they are not properly assessed and addressed in advance. The include: (1) scaling of wells and surface facilities by mineral deposition; (2) corrosion of wells and surface facilities caused by acidic or highly saline fluid produces from reservoir; (3) high-level of non-condensable gases in produced steam; and (4) mechanical problems with wells (such as collapsed or parted casing, or collapsed wellbore).

3.1.2 High Upfront Capital Requirements

Developing geothermal energy in Indonesia comes with high upfront costs for exploration surveys and drilling, and high risks that a company could invest a lot of capital in exploration but not find any viable resources. Geothermal resources in Indonesia are mostly located in remote and challenging (e.g., mountainous and rugged terrain) areas with limited to non-existing infrastructure. Much has to be invested in the development of infrastructure before exploration is begun. Exploration drilling is also high-cost (cost average: USD 7,600,000 per well; Purwanto, 2019), and several wells require to be drilled just to prove the availability of the resources using developers' or investors' owned equity before moving to the exploitation with access to external financing (Ibrahim et al., 2019).

Richter (2021) indicated that to develop geothermal potential in Indonesia, USD 4,000,000 to 5,000,000 is needed to obtain 1 MW of power generation capacity. Purwanto (2019) reported that the average geothermal exploration cost in Indonesia per MW is USD 4,100,000. Thus far, exploration costs are solely borne by developer and are not reimbursed by the Government of Indonesia as is the practice in oil and gas industry.

3.1.3 Overlap with Forest Lands and Heritage / Historical Sites

Most of the geothermal resources in Indonesia are situated in forested areas. These forested areas mainly designated in combination of the following categories: (1) Production Forest (Hutan Produksi); (2) Protection Forest (Hutan Lindung); (3) Conservation Forest (Hutan Konservasi); (4) Nature Recreational Park (Taman Wisata Alam); (5) Grand Forest Park (Taman Hutan Raya); (6) Nature Reserve Area (Kawasan Suaka Alam); (7) Nature Conservation Area (Kawasan Pelestarian Alam); (8) Strict Nature Reserve (Cagar Alam); (9) Wildlife Sanctuary (Suaka Margasatwa); and (10) National Park (Taman Nasional).

As previously discussed, Geothermal Law No. 21/2014 establishes and clarifies some of the issues that had hindered geothermal power development projects, particularly those located in / utilized for conservation forests in Indonesia. Among others, it provided the sole authority to MEMR to grant a WKP for geothermal indirect utilization and a subsequent geothermal working permit throughout Indonesia (but note that the law requires coordination with Ministry of Environment and Forestry on this). Subsequently, related implementing regulations that govern management of Nature Reserve Areas and Nature Conservation Areas have also been amended to provide a legal basis to enable geothermal power development in National Parks, Grand Forest Parks, and Nature Recreational Parks. Strict Nature Reserves and Wildlife Sanctuaries, however, remain off-limits to new geothermal developments to date (World Bank, 2019). Core zone (Zona Inti) of National Parks remain off-limits for geothermal development. Activities related to a geothermal project development cannot be performed inside the Nature National Park's protection, rehabilitation, and traditional blocks.

Geothermal project development within areas with heritage / historical sites may be affected by restrictions imposed by cultural interest in these sites. There was an issue that was brought to international attention currently with regard to plans for developing a geothermal in core area of an Indonesian National Park and World Heritage Site, a proposal strongly objected to by UNESCO (World Bank, 2019).

3.1.4 Social Acceptance

Social acceptance is defined as willingness of various stakeholders to approve the construction of a geothermal power plant. Most geothermal project developers and authorities assume that it will be easy to obtain public support for their activities related to geothermal project developments. However, this is not always the case; there are several proposed geothermal project developments that have resulted in significant protests from local communities and/or nongovernmental organizations (NGOs). These protests are mainly about: (1) potential environmental hazards associated with geothermal power project development; (2) potential significant impacts on population of critically endangered animals; (3) potential for geologic hazards; and (4) potential negative impacts on the livelihood of local people who rely on natural resources within the geothermal prospect areas.

3.2 Downstream Side Challenges

Downstream side challenges include the following:

3.2.1 Less Attractive Geothermal Electricity Price

Another obstacle in unlocking Indonesia's geothermal potential is Indonesia's uncompetitive power tariffs. Through government subsidies, power tariffs are kept cheap.

Moreover, PLN holds a monopoly on the distribution of electricity in Indonesia and therefore, electricity from independent power producers is required to be sold to PLN. This becomes a problem to the sellers because they have a weak bargaining position. Tariff agreements with PLN often are renegotiated, thus, offering minimal price guarantees for geothermal developers.

3.2.2 Local Electricity Demand

Some of the geothermal resources in Indonesia are situated in a remote area with a small population and inferior infrastructure. The demand of electricity in such a remote area is usually very small (i.e., small market) compared to demand in areas on Sumatera, Java, and Bali islands.

A lack of reliable and consistent market and high costs for exploration activities, construction and operation of transmission lines will have major impacts on project feasibility and cost. A lack of local infrastructure can increase development cost by requiring new construction and the importation of goods and services from a considerable distance.

3.2.3 Complex Bureaucracy System / Regulatory Uncertainties

As previously discussed, some of the geothermal resources in Indonesia are situated in National Parks, Grand Forest Parks, and Nature Recreational Parks; thus far, obtaining approval for geothermal exploration in such areas is slow and complex; though regulations that govern management of Nature Reserve Areas and Nature Conservation Areas have also been amended to provide a legal basis to enable geothermal power development in these areas.

Overlapping jurisdictions and too many stakeholders have increased lead time and complexity to obtain permits. Local Government often delay projects that have been approved by the Central Government; it also complicates the requirements for geothermal project permitting. Local government also lacks "geothermal" expertise which makes the processes related to geothermal power project development more complex and time consuming.

3.2.4 Lack of Awareness among Society about Renewable Energy Development

In general, consumers have low awareness of their role in supporting renewable energy development; though many of them have associated renewable energy with environmental benefits. The market for renewable energy electricity is indeed driven by the awareness and willingness of consumers to choose renewable energy as their source; however, this has not been the case in Indonesia.

5. THE POLICY, REGULATORY FRAMEWORK, AND GOVERNMENT INCENTIVES

5.1 Government's Roles and Initiatives towards Geothermal Upstream Challenges

5.1.1 Resource / Exploration Risk

In an effort to mitigate the costs and risks of geothermal exploration, the Government of Indonesia initiates an exploration program. The Government of Indonesia will now take part in data acquisition, infrastructure construction, and exploration drilling. These activities will be carried out in 13 GWAs. So far, the Government of Indonesia has executed geoscience data acquisition in three GWAs, Bituang, Marana, and Gunung Endut. The exploration drilling started in the year 2022 and has been performed in two GWAs, Cisolok Cisukarame, and Nage. Knowing that the costs of exploration account for up to 40% of total project costs, the Government of Indonesia aims that this program can lower the risks and costs burdened by state-owned and private enterprises to accelerate geothermal development (EBTKE, 2022).

The Government of Indonesia understands how geothermal drilling is one of the major challenges in geothermal projects as it accounts for around 20-25% of the total geothermal project cost, and is highly unpredictable. To lift the burdens coming from geothermal drilling, the Geological Agency of MEMR initiates a government drilling program as part of the government exploration program. The Government of Indonesia is taking part in the drilling of 20 geothermal working areas (GWA). This is a development plan of 683 MW and will occur until 2024. Within the same program, there is another 60 MW development plan in 2 GWAs that will be executed by SMI and the Ministry of Finance (EBTKE, 2022).

Moreover, the Indonesian Government has prepared de-risking facilities for geothermal exploration activities, both for government drilling and SOE drilling regulated in PMK no. 62/PMK.08/2017 through the issuance of 80/PMK.08/2022. These include Optimizing the use of clean technology fund (CTF) grants from multi-laterals, the implementation of continuous geochemical surveys to increase the accuracy of reservoir temperature measurements, implementation of deep slim hole drilling technology to increase subsurface data, and decision-making by a stop-and-go mechanism in the exploration well drilling phase. For SOEs, The Government of Indonesia provides 50% de-risking PISP initial funds and 50% blended loan IBRD/GCF/CTF. As for private enterprises, The Government of Indonesia provides a 50% blended loan IBRD and financial instrument reimbursable grants. The Government of Indonesia also implemented the non-tax state revenue (PNPB) policy of 2021 regarding the expansion for the application of online licensing, encouraging simplification of licensing in the forestry sector and local governments, improved business governance, improvement of data and information, mitigating the risk of upstream geothermal activities, updating the use of technology for efficient production, and exploration activities using the state budget (APBN).

5.1.2 Overlap with Forest Lands and Heritage / Historical Sites

Government's initiatives related to these challenges have been discussed extensively in the previous sections.

5.1.3 Social Acceptance

The social aspect of geothermal activities has also been one of the main concerns of the government as it was of utmost importance that geothermal activities were to be done with the intention to benefit and that the environment or human territories were to be protected (Government Regulation No.21/2014).

There are several regulations concerning the social aspect of geothermal activities. The government created standards and safeguard requirements that are to be fulfilled by geothermal developers. An environmental impact assessment is required for geothermal GWAs to prevent negative impacts on the environment as stated in the Ministry of Environment Decree No. 5/2012. It is also a prerequisite that the locals were informed and involved in conducting environmental impact assessment and the issuance of environmental permits as stated in the Ministry of Environment Decree No.17/2012.

In addition, The Government of Indonesia is also in support of CSR programs conducted by SOEs and private companies. Companies have managed to benefit locals through implementing geothermal innovations like steam-powered cultivation or other direct utilizations and fulfilling community needs like education, tourism, and poverty alleviation programs.

5.2 Government's Roles and Initiatives towards Geothermal Downstream Challenges

5.2.1 Less Attractive Geothermal Electricity Price

Over the years, the government has been updating the geothermal tariff to find the most suitable price for developers with respect to the limitations of the sole buyer, PLN. Previously in the year 2016, the Government of Indonesia set the geothermal ceiling tariff at a national tariff (BPP) of 7.5 US cents/KWh with a range of price distributions across 21 main islands. Later in the year 2017, the Government of Indonesia revised the geothermal tariff by increasing the price of some provinces while decreasing the others. The total BPP on that year was 7.39 US cents/KWh. In both years, Maluku and Nusa Tenggara Timur hold the highest tariff price of around 17 US cents/KWh (MEMR regulation No.12/2017). The government aims to attract developers in these provinces with comparably higher ceiling prices and support the feasibility of projects that are and are to be done in these more difficult and costly locations (Van Campen et al., 2017), not to mention some areas having only medium-temperature resources that have only gotten some attention quite recently.

More recently, at the start of September 2022, the Government of Indonesia introduced Presidential Decree No. 112/2022 with a new tariff system. The government has introduced new purchase and ceiling prices that are based on power plant capacities and locations. The implementation of the renewable energy regulation will be carried out gradually. The Government of Indonesia has also introduced an F-factor (location) as a price multiplier. It can be inferred that the new geothermal tariff will be slightly higher on average than the one introduced in MEMR regulation No.12/2017. Locations in Eastern Indonesia have higher F-factors while Java, Madura, and Bali do not have any F-factor "bonuses." This new tariff system, along with The Government of Indonesia's initiatives to lower geothermal development risks and costs will aid more projects in feasible and assist in the realization of the Geothermal Development Plan.

5.2.2 Local Electricity Demand

To aid in alleviating the challenge of low electricity demand, mainly in Eastern Indonesia, the Government of Indonesia's involvements are through programs called Renewable Energy Based on Economic Development (REBED) and Renewable Energy Based on Industrial Development (REBID). REBED focuses on implementing new and renewable energies (NRE) to power areas or the 3T areas (Frontier, Outermost, and Disadvantaged). Flores is one of the islands in East Nusa Tenggara that is currently under implementation and geothermal energy is expected to be the cornerstone for the electrification of this island due to its immense 660 MW potential geothermal capacity. REBID focuses on the large-scale use of NRE, mainly hydro and geothermal, to create industry growth. Examples of PLTP development through REBID scheme include PLTP Hamiding (200 MW), PLTP Jailolo (30 MW), PLTP Songa Wayaua (10 MW), PLTP Blawan Ijen (165 MW), and PLTP Arjuno Welirang (180 MW).

5.2.3 Complex Bureaucracy System / Regulatory Uncertainties

Law No.11/2020 on Job Creation, the Omnibus Law, was enacted in December 2020. This law aims to streamline regulations and simplify complex bureaucracy systems. Unlike the Geothermal Law, the Omnibus Law provides the central government the authority to set rules and procedures regarding geothermal direct use which would be followed by the local government. The central government now also has a broader authority from creating national policies to urging research and exploration. In the Geothermal Law No.14/2014, geothermal permit holders were to pay production fees for direct utilization. In the Omnibus Law, this requirement was removed, and permit holders are only required to pay local taxes and retributions. Furthermore, this law provides that separate licenses from the Minister of Maritime Affairs and Fisheries are no longer required. This law was intended to enhance investment and job creation.

5.2.4 Lack of Awareness among Society about Renewable Energy

As previously discussed, the market for renewable energy electricity is driven by the awareness and willingness of consumers to choose renewable energy as their source. The industry sector, businesses, contribute to more than 30% of the total energy consumption in 2021 (ESDM, 2021). To tap into this market, in 2020, the State Electricity Company (PLN) launches the Renewable Energy Certificate (REC). This has led to many businesses have switched to renewable energy to get a REC that will be internationally audited and confirms their use of sustainable energy. PLN hopes that this initiative will assist in growing the demand for renewable energies and would spark adoption across other sectors.

6. INDONESIA'S GEOTHERMAL FUTURE

6.1 Planned Installed Capacity and Upcoming Commercial Operation Dates

As earlier mentioned, the Government of Indonesia plans to achieve a total installed capacity of 9,300 MW by the year 2035. As a measurement to achieve the target, the state electricity company (PLN) creates an electricity procurement business plan (RUPTL) 2021-

2030 as an update to the previous, RUPTL 2019-2028. According to RUPTL 2021-2030, several geothermal projects in various provinces are to be expected to reach commercial operation dates.

Starting from Aceh Province, a total of 50 MW additional power plant capacity is expected to reach COD by the years 2023 (5 MW), 2024 (10 MW), 2025 (30 MW), 2027 (3 MW), and 2030 (3 MW) with a total of 390 MW potential new geothermal power plant projects are spreading across the area of Seulawah Agam to Lokop. North Sumatra Province has a total of 235 MW additional capacity that is expected to reach COD during the period of 2021 to 2025 and with a total of 449 potential new power plant capacity to be developed. West Sumatra Province has a total of 185 MW additional capacity that is expected to reach COD by the years 2024 (10 MW), 2025 (110 MW), and 2028 (65 MW). The potential capacity for new power plant projects in this province is 300 MW, spreading across the area of Gunung Talang and Panti. For Jambi Province, a total of 95 MW new capacity is expected to reach COD by the years 2024 (10 MW) and 2025 (30 MW). The potential capacity for new power plant projects in this province is 155 MW, spreading across the area of Graho Nyabu to Sungai Tenang. For South Sumatra Province, a total of 335 MW new capacity is expected to reach COD by the years 2021 (86 MW), 2022 (55 MW), 2024 (10 MW), 2025 (164 MW), and 2028 (20 MW). The potential capacity for new power plant projects in this province is 115 MW, spreading across the area of Lumut Balai and Tanjung Sakti. For Bengkulu Province, a total of 220 MW new capacity is expected to reach COD by the years 2021 (0.3 MW), 2025 (110 MW), and 2028 (110 MW). The potential capacity for new power plant projects in this province is 245 MW, spreading across the area of Bukit Daun to Hululais. For Lampung Province, a total of 260 MW capacity is expected to reach COD by the years 2024 (10 MW), 2025 (140 MW),and 2029 (110 MW). The potential capacity for new power plant projects in this province is 285 MW, spreading across the area of Ulubelu to Sekincau. For Banten Province, a total of 150 MW capacity is expected to reach COD by the years 2025 (30 MW), 2028 (80 MW), and 2030 (40 MW). The potential capacity for new power plant projects in this province is 46 MW in the areas of Pasundan and Gunung Endut. For West Java Province, a large total of 645 MW capacity is expected to reach COD by the years 2023 (55 MW), 2024 (10 MW), 2025 (70 MW), 2026 (155 MW), and 2030 (355 MW). The potential capacity for new power plant projects in this province is 815 MW, spreading across the areas of Cibereum Prabakti to Wayang Windu. For Central Java Province, a large total of 720 MW capacity is expected to reach COD by the years 2023 (75 MW), 2025 (220 MW), 2026 (55 MW), 2028 (110 MW), 2029 (75 MW), and 2030 (185 MW). The potential capacity for new power plant projects in this province is 315 MW, spreading across the areas of Gunung Lawu and Umbul Telumoyo. For Eastern Java, a total of 55.2 MW capacity is expected to reach COD by the years 2022 (2.4 MW), 2023 (8.3 MW), 2024 (10.9 MW), and 2025 (33.7 MW). The potential capacity for new power plant projects in this province is 405 MW, spreading across the area of Arjuno Welirang to Songgoriti. For Bali Province, a total of 65 MW capacity is expected to reach COD by the years 2025 (10 MW) and 2030 (55 MW). The potential capacity for new power plant projects in this province is 225 MW, spreading across the area of Banyu Wedang to Tambanan. For North Sulawesi, a total of 75 MW capacity is expected to reach COD by the years 2023 (5 MW), 2027 (40 MW), 2029 (30 MW). The potential capacity for new power plant projects in this province is 90 MW, spreading across the area of Klabat Wineru to Lahendong. For North Maluku, a total of 30 MW capacity is expected to reach COD by the years 2025 (25 MW) and 2027 (5 MW). The potential capacity for new power plant projects in this province is 270 MW, spreading across the area of Telaga Ranu to Jailolo. For West Nusa Tenggara, a total of 10 MW capacity is expected to reach COD by the year 2029. The potential capacity for new power plant projects in this province is 41.6 MW, spreading across the area of Wanokaka to Sembalun. For East Nusa Tenggara, a total of 115 MW capacity is expected to reach COD by the years 2021 (5 MW), 2022 (3 MW), 2024 (16 MW), 2025 (41 MW), 2026 (15 MW), 2027 (20 MW), 2028 (10 MW), and 2029 (5 MW). The potential capacity for new power plant projects in this province is 150 MW, spreading across the area of Gou - Inelika to Way Pesi.

6.2 Government Drilling Program in Jailolo and Wae Sano

Other than PLN's RUPTL and Geothermal Development Plan, another important influence to be expected for Indonesia's geothermal development is the government drilling program. As mentioned prior, the government drilling program is a measure to alleviate the risks and costs burdened by geothermal developers and aiding geothermal projects' feasibility. An upcoming government drilling program to be expected is Jailolo in North Maluku Province and Wae Sano in East Nusa Tenggara Province. The government drilling program in Jailolo will be funded through PT SMI, performed by PT Geo Dipa Energi, and the risks are to be burdened by PT Penjaminam Infrastruktur Indonesia. The program will be carried out by 2023 and is expected to bring adequate electricity supply for the North Maluku Province (Setiaji, 2022). The government drilling program in Wae Sano is expected to be carried out in the immediate future and achieve a discovery of around 44 MW capacity.

6.3 Flores Geothermal Island

The Central Government has officially called the Island of Flores in Nusa Tenggara Timur Province a "Geothermal Island" for its potential geothermal reserves. The name was included in a Decision of the Minister of the Energy and Mineral Resources of the Republic of Indonesia No. 2268 K/30/MEM/2017. The Island of Flores has a significant geothermal resource base: up to 735 MW of potential across 18 geothermal locations (e.g., Ulumbu, Wai Pesi, Wae Sano, Mapos, Rana Masak, Rana Kulan, Uluagung, Nage, Gou-Inelika, Mataloko, Mangerunda, Komandaru, Ndetusoko, Sokoria, Jopu, Lesugolo, Oka Ile Ange, and Oyang Barang).

The Government of Nusa Tenggara Timur Province stated that the decision to call Flores with the aforementioned name would have a follow up step, that is to develop geothermal. The Government of Nusa Tenggara Timur Province, in general, supports geothermal project development, as it is one of the key resources in the Province. Currently, there are three geothermal power projects operating on Flores Island: the Ulumbu Geothermal Power Project (total installed capacity: 10 MW), the Mataloko Geothermal Power Project (total installed capacity: 2.5 MW), and the Sokoria Geothermal Power Project (total installed capacity: 6.58 MW).

6.4 Medium-Temperature Geothermal Resource Development

Potentially, Indonesia has a large amount of low- and medium-temperature geothermal resources; these resources, however, have been overlooked in favor of exploring and exploiting high-temperature geothermal resources. If Indonesia is to achieve its Net Zero commitment, it will require to considerably increase the renewable energy contribution to the electricity grid. Given the importance of geothermal energy to Indonesia's renewable energy portfolio, this will likely require a significant commitment to utilize low- and medium-temperature geothermal resources for electricity generation (Febrianto et al., 2019).

Low- and medium-temperature geothermal resources have been developed internationally. Using electric line shaft or submersible pumps, low- to medium-temperature geothermal fluids can be pumped from relatively shallow depths and electricity can be generated using a binary power plant technology. This has been proven to be a commercially viable development approach for geothermal systems hosted in a range of geologic settings. A preliminary financial model indicates that, with reasonably favorable conditions, it may be possible for a geothermal developer in Indonesia to develop a project in a tariff regime of about USD 12¢/kWh (Febrianto et al., 2019). However, further economic analysis comparing the development with other traditional geothermal developments (i.e., high-temperature geothermal resources) is warranted. Febrianto et a., (2019) also indicate that low- to medium- temperature resources may be attractive targets for pumped well developments in Indonesia it they meet the following technical criteria: (1) resource temperatures are higher than 160°C; (2) shallow / artesian piezometric level; and/or (3) the ability to locate wellpads at low elevations relatively to hydrologic system.

6.5 Direct Use

Direct utilization was mentioned to be one of the many ways for the government and geothermal companies to benefit local communities and gain their acceptance and support towards geothermal exploration and development activities that are within their area. The Government of Indonesia needs to establish a "Geothermal Direct Use" regulation in addition to indirect purposes such as electricity. Direct use of geothermal resources is the use of underground hot water to heat building, grow plants in greenhouses, dehydrate onions and garlic, heat water for dish farming, pasteurize milk, and many other applications.

As previously discussed, there were some GWAs that have managed to implement geothermal direct utilization. Moreover, the Directorate of Geothermal of Indonesia has been conducting technical guidance sessions for business permits related to geothermal direct-use applications, as reported by Cariaga (2022). These technical guidelines are expected to improve Indonesia's geothermal direct use and support the sector's development.

6.6 Enhanced Geothermal Systems (EGS)

The U.S. Department of Energy has broadly defined Enhanced (or Engineered) Geothermal Systems ("EGS") as engineered reservoirs that have been created to extract economical amounts of heat from low permeability and/or porosity geothermal resources. EGS is alternatively referred as Hot Dry Rock ("HDR") or "Hot Fractured Rock ("HFR"). In principle, EGS focuses on drilling at hot, crystalline rock, and create fractured reservoirs. The fracture will increase the permeability if the rock so that the fluid can e circulated and bring the heat energy stored in rocks to the surface where electricity can be generated.

EGS is very likely to be developed in Indonesia. Indonesia's complex tectonic setting and tectonically stressed sedimentary basin is a fine target for EGS preliminary study. There are more than 86 sedimentary basins in Indonesia; and most of these basins are tectonically stressed. Several hot springs and other geothermal manifestations are observed in some of these basins (Hendrawan and Draniswari, 2016).

6.7 Increasing the Capacity of Existing Geothermal Power Plants by the Addition of Bottoming Binary Cycles

The prevailing geothermal plant type in Indonesia is currently the single-flash plant which directly uses the steam phase from the produced steam-liquid-mixture to drive the turbine. Binary plants which transfer the geothermal heat to a separate working fluid are not yet an established technology at Indonesian geothermal sites. The first commercial binary units were commissioned at Sarulla field in 2017 although due to their adaptability they could be implemented at much more sites and increase the geothermal capacity in Indonesia. Binary power plants can extend the plant capacity at high enthalpy fields but can also be used to exploit low to intermediate temperature geothermal reservoirs and realize small scale geothermal power plants (Frick et al., 2019).

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