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Country Update: Geothermal as The Backbone of Energy Security in Indonesia's Energy Transition

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ABSTRACT

Since 2016, the Paris Agreement has been ratified by Indonesia to secure their commitment of the world temperature raising less than 1,5 ^oC. As a consequence, Indonesia should achieve the ambition of its Net Zero Emission (NZE) by 2060 or even earlier. This ambition has been declared by the President of Indonesia in COP 26 held in Glasgow in 2021. The NZE target will be achieved through Indonesia Energy Transition Road Map which may transform the use of electricity from dominantly fossil fuels into renewable energy.

Indonesia is currently using oil, gas and coal which contributes to about 88% of the total national energy mix. Oil and gas is mainly used to support transportation and industrial sectors, while coal is mostly used to generate electricity and industry needs. In Indonesia, major reasons for coal-used are cheaper cost of energy generation and better base load of energy production. However, the main problem of using coal is high carbon emission, which contradicts to the world concern. These issues can be anticipated by discovering the right type of RE, such as geothermal and hydro power plants, which could substitute those fossil energy resources.

In Indonesia, there are 3 kinds of renewable energy that might substitute coal & other fossil energy and still ensure its energy security, i.e. hydro, biomass and geothermal. While solar, wind and ocean energy will face severe challenges due to their intermittency. Geothermal can be the backbone in ensuring a good energy transition in Indonesia. The potential of geothermal in Indonesia is reported to be about 24 GWe, derived from speculative resources, resources and reserves which are located in the 312 locations across Indonesia.

The current geothermal fields operate from 16 locations with the increase of 3 new geothermal fields in 3 locations compared to 13 locations in the year 2020. The total current installed capacity is 2,343 MW, which was a rise of 205 MW from 2,138.5 MW installed in the year 2020 presented in Iceland. The installed power plants are scattered in Sibayak (12 MW), Kamojang (235 MW), Darajat (270 MW), Dieng (60 MW), Gunung Salak (377 MW), Lahendong and Tompaso (120 MW), Wayang Windu (227 MW), Ulu Belu (Lampung, 220 MW), Lumut Balai (55 MW), Patuha – West Java (55 MW), Sorik Marapi Modular Power Plant (95 MW), Muara Laboh (85 MW), Ulumbu – Flores (10 MW), Mataloko – East Nusa Tenggara (2,5 MW), Sarulla – North Sumatra (330 MW, Karaha – West Java (30 MW), Rantau Dedap (South Sumatra – 91.2 MW), and Sokoria East Nusa Tenggara – 5 MW).

In terms of geothermal development and its utilization, the Government of Indonesia (GoI) has issued a revised version of the geothermal masterplan for period of 2021 to 2035. The new roadmap shows GOI's commitment to support the national energy policy and energy transition program. The total expected capacity in 2035 is 9,300 MW, that is distributed to 3,576 MW in 2025, 7,780 MW in 2030 and 9,300 MW in 2035.

This paper will provide information on the challenges and lesson-learned from geothermal development in Indonesia, geothermal resources, and the action plan required by all stakeholders to achieve energy transition target.

1. INTRODUCTION

Since 4 November 2016, the Paris Agreement has coming into force as a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 held on 12 December 2015 in Paris. Indonesia ratified this agreement to become Law No. 16/ 2016 regarding the Paris Agreement. Its goal is to limit global warming to below 2 or preferably to 1.5 ^oC, compared to pre-industrial levels. To achieve this long-term temperature goal, many countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate neutral world by mid-century. As a consequence, Indonesia has set its ambitious target of Net Zero Emission (NZE) by 2060 or even earlier. This ambition has been declared by the President of Indonesia in COP 26 held in Glasgow in 2021. The NZE target will be achieved through Indonesia Energy Transition Road Map which may transform the use of electricity from dominantly fossil fuels into renewable energy (RE).

As mentioned by the International Renewable Energy Agency (IRENA), the energy transition is a pathway toward transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century. In addition, the need of reducing energy-related CO_2 emissions is also driven by the need of mitigating climate change. Therefore, decarbonization of the energy sector requires urgent action on a global scale, and while a global energy transition is underway, further action is needed to reduce carbon emission and mitigate the effects of climate change. Renewable energy and energy efficiency measures can potentially achieve 90% of the required carbon reductions. The energy transition will also be enabled by information technology, smart technology, policy frameworks and market instruments. IRENA has assessed decarbonization pathway through RE map and well-equipped to support and accelerate the energy transition by providing the necessary knowledge, tools and support to member countries as they increase the share of renewable energy in their power sectors.

Based on IRENA's analysis, carbon-dioxide (CO_2) emission in energy-related sector has to be reduced by 70% of current level until 2050 to meet the climate goals. A large-scale shift to electricity from renewables could contribute to 60% of those reductions; 75% if it is coming from where heating and transport are factored in; and 90% with ramped-up energy efficiency.

With electricity becoming the dominant energy carrier, the requirement of global power supply could be inclined more than doubled, the report finds. As a response, renewable resources including solar and wind could meet 86% of power demand and create many more new jobs than those lost in fossil-fuel industries. Policy inputs can also further improve the socio-economic footprint of the transformation.

The GOI has set the target of 23% Renewable Energy in the national energy mix by 2025 and 31% by 2050 in the National Energy Policy. Furthermore, Indonesia has committed to a 29% reduction in emission against a Business as Usual (BAU) scenario by 2030.

Indonesia, as reported in 2020 World Geothermal Congress (WGC), has developed geothermal power plants faster in terms of capacities in the last 5-8 years. In addition, GOI gave priority to accelerate the use of geothermal in the national energy policy even if it is failed to install 7,200 MW of geothermal plants by 2025. Geothermal, in which Indonesia is the world 2nd biggest geothermal potential located in, will play an important role in leading the energy security of Indonesia's energy transition into the target energy mix and emission reduction. Over a span of 45 years (or until the year 2020, Indonesia has developed more than 2 GW out of 24 GW of geothermal potential. The additional capacity of 655 MW (compared to 2015) has contributed to the total installed of 2,138.5 MW in 2020. As of 2022, the total capacity of the geothermal power plant in Indonesia is 2,343 MW. Another 12 MW is expected to be commissioned by 2023.

There are some challenges to develop geothermal power plants since the risks are high. Now PLN, as a monopoly public utility owner in Indonesia, sets a target of installing additional geothermal plant about 3,355 MW (based on the PT. PLN (Persero)'s 2021-2030 Electricity Supply Business Plan (Rencana Usaha Penyediaan Tenaga Listrik or RUPTL)). This RUPTL is called green RUPTL with an additional RE capacity of 20.92 GW (51.6%), requiring an investment of USD 55.2 billion. The total planned installed capacity of RE power plant by 2030 is to reach 31.42 GW. PLN is also restructured to adapt for the future business of RE in Indonesia.

On top of 64 existing areas, 13 new geothermal areas (which are assigned to the private companies for geothermal exploration, namely WSPE) has been set as target for the next new geothermal development roadmap. By neglecting any obstacles on the ceiling price policy, Ministry of Energy and Mineral Resources (MEMR) has reviewed its Regulation No. 10 Year 2017 and Regulation No. 50 Year 2017 related to mandated PLN to buy the energy from renewable energy, including geothermal. The President of Indonesia has also issued the Presidential Regulation (PR) No.112 Year 2022 to accelerate the development of RE and geothermal. Besides determining the tariff of RE and geothermal, PR also governing the coal phasing out programs. Therefore, despite of major obstacles in infrastructure and tariff of geothermal development, the release of this PR could allow the business on geothermal development to be more attractive in the future.

To support this acceleration of geothermal development, Indonesia has also strengthened the financing schemes support through de-risking of exploration program. It is conducted by PT. SMI and PT. Geo Dipa Energi as well as Geological Agency (*Badan Geologi*) of MEMR on behalf of the GOI. On the other hand, the direct use of geothermal in Indonesia has also opened for business since the last 3 years. This ambitious program will contribute to the addition of 18 GW geothermal plants by 2050. Starting from the planned installed capacity of 3.3 GW for period of 2021-2030, then adding another 6.5 GW in 2031-2040, subsequently another 3.0 GW in 2041-2050, and finally 3.0 GW from 2051 to 2060. With this target, geothermal will become a part of the backbone of the energy transition beside hydro and biomass power plant. As a note, other than the high availability in Indonesia, geothermal should be considered to be the backbone of energy transition because it is a more stabilized power plant (in terms of operation), low operating cost, high capacity factors (i.e. more than 90%), sustainable, etc.

2. NET ZERO EMISSION AND ENERGY TRANSITION PROGRAM

Energy transition is the process of shifting energy sources from fossil fuel-based sources to other source that does not produce carbon emissions, such as renewable energy sources. The GOI encourages the energy transition process through renewable energy (RE) and energy efficiency. The transformation of fossil-sourced energy to renewable energy is correlated to Indonesia's ambitious target of Net Zero Emission (NZE) by 2060 or even earlier. The target was declared by the President of Indonesia in COP 26 held in Glasgow in 2021. In the last 5 years, the trend of providing support for power plants development indicated the GOI's commitment in promoting cleaner electrical energy. Starting from supporting RE-sourced power plants, introducing Clean Coal Technology (CCT), and recommending Variable Renewable Energy (VRE) plants that have intermittent characteristics with the operation of wind power plants and solar power plants (Solar PV). The priority in national energy use is also put based on the use of renewable energy, the economic level, as well as optimization of coal-used for national energy reliability.

Indonesia has set renewable energy (RE) target of 23% in its national energy mix by 2025. This policy, combined with Indonesia's commitment to reduce emissions by 29% by 2030, is a clear effort towards a cleaner energy system and sustainability. We must also consider that RE and energy efficiency will play an important role in the economic recovery plan after the COVID-19 pandemic conditions and ensuring energy security in the long term. However, in the electricity sector, the role of RE is only accounted to about 14% of national energy mix condition, while oil, gas and coal contributes to about 88% of the total national energy mix.

In Indonesia, major reasons for coal-used are due to cheaper cost of energy generation and better base load of energy production. On the other hand, the main problem of using coal is high carbon emission, which contradicts to the world concern. These issues can be anticipated by discovering the right type of RE, such as geothermal and hydro power plants, which could substitute those fossil energy resources. Coal is still dominantly used in Indonesia's electricity sector and covered about 63% of the total source of the national power supply. However, due to the NZE target, Indonesia has committed to replace coal by RE in a long term program from 2025 until 2056. To achieve NZE by 2060, Indonesia set the following strategies:

a. Retirement of coal fire plants in stages starting in 2025. Replacement plan for CFPP and GFPP with 1.1 GW baseload of RE Power Plant in 2025. First stage of subcritical retirement (1 GW) will be done in 2030, followed by 9 GW in 2035 for the second stage. Next stage is the retirement of 10 GW supercritical CFPP in 2040. The first retirement of 24 GW ultra-supercritical will be due by 2045. And finally, the last retirement of 5 GW ultra-supercritical CFPP will be conducted gradually from 2045 to 2056;
b. Acceleration of RE development including hydro and geothermal for base load support energy reliability;
c. More efficient use of technology;
d. Encouraging the use of electric vehicles for transportation and electric stove for cooking facilities to replace gas; and
e. Implementation of smart grid to overcome VRE (Variable Renewable Energy).

Coal retirement program has been declared by PLN & GOI and to be started in 2025. The development of RE-based power plants in Indonesia has several challenges. The RE potential is abundance, in which it is mainly composed of solar (i.e. more than 3,000 GW), but the locations are scattered. Systematic and continuous socialization and education are needed to minimize community resistance to RE-based power projects. In addition, other challenges include limited availability of soft loans in the country, limited availability of supporting infrastructure especially in Eastern Indonesia, and high dependence on technology and imported RE equipment. Besides that, not all RE power plants can be integrated and connected to the local electricity system, especially for power plants with intermittent characteristics.

3. GEOTHERMAL POTENTIAL

The current calculations of the Indonesia geothermal potential is approximately about 24 GWe (as presented in **Table 1**). Indonesia's geothermal potential lies between the eastern end of Mediterranean Volcanic Belt and western side of Circum-Pacific, which is also blessed with abundant volcanic activities. Indonesia now becomes the world 2nd largest geothermal producer and counted to be the world 2nd biggest geothermal energy potential. The geology and geochemical surveys have been carried out on the 356 locations in Java, Bali, Sumatera, Sulawesi, Nusa Tenggara, Maluku, Papua and Kalimantan. A geophysical survey was conducted on the 45 locations (Darma, 2015). Most of the geothermal prospects are high temperature geothermal systems.

No.	Island	Number of Locations	Resources (MW)					Installed Capacity (MW)
			Speculative	Hypothetic	Reserve			
					Possible	Probable	Proven	
1	Sumatera	101	2.167	1.567	3.624	976	1.126,4	944.2
2	Jawa	75	1.259	1.191	3.260	377	1.820	1,253
3	Bali	6	70	21	104	110	30	0
4	Nusa Tenggara	34	215	146	783	114,4	19,1	17.5
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	1.763,4	3.117,5	2,334.7
					14.131,9			
Grand Total			23.356,9					

Table 1: The energy potential of Indonesia geothermal prospect (DGEBTKE, 2023).

Sumatera has large geothermal potential, yet only 900 MW geothermal power plant capacity is installed. This installed capacity comes from Ulubelu (220 MW) and Sibayak (12 MW) constructed and operated by PGE, and Sarulla (330 MW) which is constructed by the consortium of Sarulla Operation Limited (SOL) under Joint Operating Contract (JOC) scheme with PGE. On the other hand, Java has installed 1,254 MW of geothermal plant capacity distributed in Kamojang (235 MW), Darajat (from 270 MW), Dieng (60 MW), Gunung Salak (377 MW), Wayang Windu (227 MW), Patuha (55 MW), and Karaha (30 MW). And the remaining others spread in Sulawesi (Lahendong – 120 MW) and Nusa Tenggara (29 MW) with a total of 139 MW. According to MEMR Directorate General of New & Renewable Energy (DGEBTKE), total proven reserve in Indonesia is about 3,117 MW, while the probable reserve is 1,763 MW and the possible reserve is 9,251 MW. The total reserve of 14,132 MW is more than enough for 9,300 MW development by 2035. These capacities are conducive to support the first stage of CFPP subcritical retirement (1 GW) in 2030 and 9 GW in 2035 for the second stage of subcritical retirement.

4. GEOTHERMAL INSTALLED CAPACITY

As of 2022, there are 2,334.7 MW power plants from geothermal energy have been installed (as illustrated in **Figure 1, Table 1** and **Table 2**). It was increased for about 196.2 MW from the 2,138.5 MW installed capacity in 2020 and almost doubled from 1,189 MW in 2010 reported in Bali. The installed geothermal power plants are located in 18 geothermal areas, such as: Kamojang, Darajat, Patuha, Wayang Windu, Karaha and Salak in West Java; Dieng in Central Java; Sibayak, Sarulla and Sorik Marapi in North Sumatera, Lumut Balai and Rantau Dedap in South Sumatra, Muara Laboh in West Sumatera, Ulu Belu in Lampung, Lahendong in North Sulawesi, Ulumbu, Mataloko and Sokoria in Flores – Nusa Tenggara.

Most of the geothermal power is generated from high temperature geothermal system which is mainly dominated by hot water system, except Kamojang and Darajat which is mostly a vapor geothermal system. The first geothermal power plants were commercially operated in 1982, which is located in Kamojang geothermal field. While the latest geothermal power plants commissioned in 2022 are Rantau Dedap and Sokoria. In total, there are 18 geothermal power plants operated in Indonesia, they are Kamojang (235 MW), Darajat (270 MW), Sibayak (12 MW), Dieng (60 MW), Gunung Salak (377 MW), Lahendong (120 MW), Wayang Windu (227 MW), Ulumbu (10 MW), Mataloko (2.5 MW), Patuha (55 MW), Ulu Belu (220 MW), Sarulla (330 MW), Karaha (30 MW), Sorik Marapi (140 MW), Muara Laboh (85 MW), Lumut Balai (55 MW), Rantau Dedap (91.2 MW), and Sokoria (5 MW). Total yearly production of electricity as of 2022 is16.592.417,95 MWh as shown in the Table 2. These numbers account for 3% of approximately 73 GW of total installed electric capacity of PLN and of about 14 GW of IPPs generation captive power. The lesser portion of geothermal in the electricity energy source mix is due to the huge increase in coal fire plants in the last 10 years. Total numbers of wells drilled until 2022 is about 708 wells from 18 geothermal production areas out of 8 geothermal areas under development and construction. It were drilled about 50 wells (refer to **Table 3**).

No	Power Plant Location	Power Plant & Year of Commission		Annual Steam and Energy Produced			Installed Capacity & Number of Wells	
		Power Plants - Name of Developers	Year of Commission	Number of Unit	Type of Unit[2]	Electricity (MWh)[3]	Number of Wells	Installed Capacity (MW)
1	Salak, West Java	Salak Unit 1 to 6 – Star Energy Salak Geothermal	1994 & 1997	6	1 F	2.855.017,00	115	377
2	Darajat, West Java	Darajat Unit 1,2,3 – Star Energy Geothermal Indonesia	1991, 2000, 2007	3	D	2.106.062,24	58	270
3	Wayang Windu, West Java	WWD Unit 1 to 2 – Star Energy Wayang Windu	2000 & 2009	2	1 F	1.884.115,39	65	227
4	Sarulla, North Sumatera	Sarulla Unit 1, 2, 3 – Sarulla Operation Ltd	2017 & 2018	3	B	2.032.577,19	46	330
5	Dieng, Central Java	Dieng Unit 1 – Geodipa Energy	1998	1	1 F	350.642,48	58	60
6	Patuha, West Java	Patuha Unit 1 – Geodipa Energy	2014	1	1 F	445.347,54	19	55
7	Ulumbu, Flores	Ulumbu 1,2,3,4 – PT PLN	2013 & 2014	4	1 F	54.036,49	6	10
8	Mataloko, Flores	Mataloko 1 (N)[1] – PT PLN	2013	1	1 F	-	3	2.5
9	Kamojang , West Java	Kamojang Unit 1, 2, 3, 4, 5 – PT PGE	1983, 1987, 2008, 2015	5	D	1.679.389,66	93	245
10	Ulubelu, Lampung	Ulu Belu unit 1,2, 3, 4 – PT PGE	2012, 2016, 2017	4	1 F	1.553.200,97	56	220
11	Lahendong, North Sulawesi	Lahendong unit 1 to 6 – PT PGE	2001, 2007, 2009, 2011, & 2016	6	1 F	864.222,49	53	120
12	Sibayak, North Sumatera	Sibayak Monoblock (R) – PT PGE	1996	1	0 - Back Pressure	-	1	2
12A	Sibayak, North Sumatera	Sibayak Unit 1, 2 (N) – PT PGE	2008	2	1 F	-	9	10
13	Karaha, West Java	Karaha Unit 1 – PT PGE	2018	1	1 F	84.252,67	10	30
14	Lumut Balai, South Sumatera	Lumut Balai Unit 1 and 2 – PT PGE	2022	1	1 F	448.528,72	31	55
15	Sorik Marapi, North Sumatera	Sorik Merapi 1, 2, 3 – PT. SMGP - KS	2019, 2021, 2022	3	1 F	828.928,67	39	140

No	Power Plant Location	Power Plant & Year of Commission		Annual Steam and Energy Produced			Installed Capacity & Number of Wells	
		Power Plants - Name of Developers	Year of Commission	Number of Unit	Type of Unit[2]	Electricity (MWh)[3]	Number of Wells	Installed Capacity (MW)
		Orka Renewables						
16	Muaralaboh, West Sumatera	Muaralaboh Unit 1, PT. Supreme Energy Muara Laboh	2019	1	1 F	723.925,53	18	85
17	Sokoria, Flores	Sokoria 1, PT SGI - Sokoria Geothermal Indonesia	2022	1	1 F	30.204,42	8	5
18	Rantau Dedap, South Sumatera	Rantau Dedap 1, PT SERD – Supreme Energy Rantau Dedap	2022	1	1 F	651.966,48	20	91,2
Total (as of 2022)						**16.592.417,95**	**708**	**2,334.7**

[1] N = Not operating (temporary), R = Retired; [2] 1F = Single Flash. D = Dry Steam, B = Binary Cycle; [3] Electrical installed capacity in 2022

Table 2. Utilization of geothermal energy for electric power generation as of 31st December 2022

The additional capacities of geothermal plants are commissioned in Sumatra and Flores Island during 2021 and 2022. Those are: Lumut Balai unit 1 (55 MW), Sorik Marapi (55 MW), Muara Laboh (85 MW), Rantau Dedap (91.2 MW), and Sokoria (5 MW).

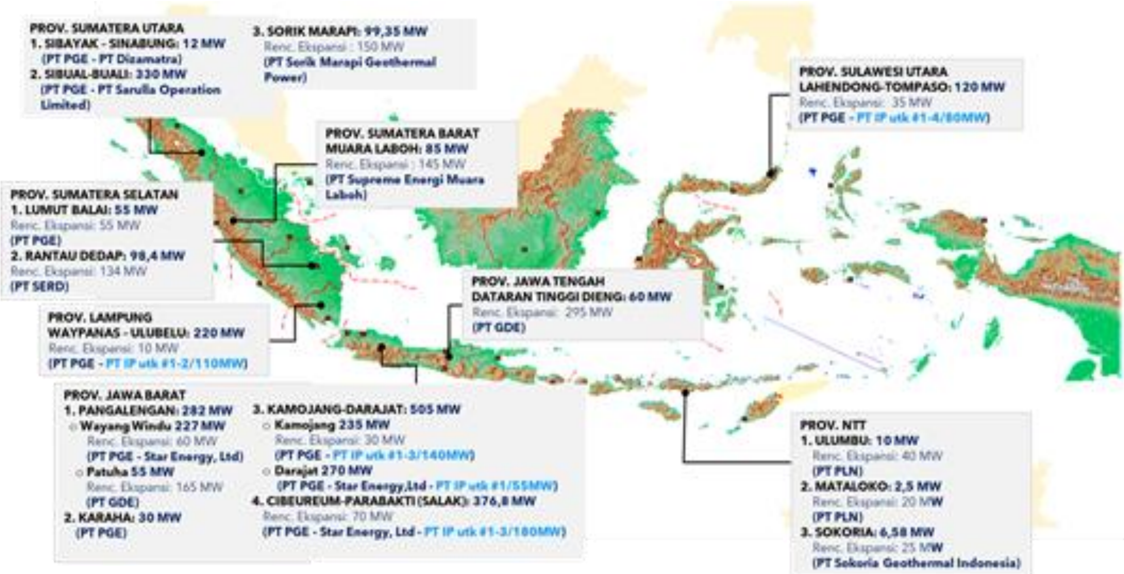

Figure 1: Location map of Indonesian geothermal resources and its installed capacity from 18 WKPs that have been produced (2,334 MW) with plans for expansion of 1,234 MW.

In addition, 439 MW projects are currently undergoing and will be commissioned in the year 2023 and 2024, as seen in **Table 3**. Total of 50 wells were drilled for these developments are: Hulu Lais (24 wells), Sungai Penuh (5 wells), Bedugul (3 wells), Cibuni (3 wells), Tulehu (4 wells), Blawan Ijen (6 wells), Jaboi – Aceh (2 wells) and Baturraden (3 wells).

On the other hand, there are also 61 areas of which exist and being developed out of 15 Preliminary Survey and Exploration Assignment Area or Wilayah Penugasan Survei Pendahuluan dan Eksplorasi ("**WPSPE**") since the last few years. The projects are going for power plant operations, exploration drilling and development using the existing geothermal rule, i.e. PD No.45 Year 1991. The remaining 44 working areas are under exploration status and other activities for geothermal development using the Geothermal Law No.27/2003 as amended by Law No. 21/2014. 19 WKP of those areas are in the exploration stage to develop 1.290 MW (**Figure 3**). Out of those fields mentioned, there are also 13 additional working areas to be explored by the government exploration program before it is tendered. Total power plant capacity from geothermal is predicted to be 9,300 MW (see **Table 5**) in 2035 as it is shifted from 2030.

Province	Location/Power Plant	Business Entities	Number of Existing Wells	Capacity (MW)	COD RUPTL
Sumatera Selatan	Lumut Balai #2	PGE, PT	31	55	2022
Nusa Tenggara Timur	Sokoria #2	Sokoria Geothermal Energy, PT	8	3	2022
Sumatera Utara	Sorik Marapi #3	Sorik Marapi Geothermal Energy, PT	39	50	2022
Jawa Tengah	Dieng #2	Geo Dipa Energy, PT	58	55	2023
Jawa Tengah	Dieng Small Scale #1	Geo Dipa Energy, PT	-	10	2023
Jawa Tengah	Dieng Small Scale #2/ Dieng binary	Geo Dipa Energy, PT	-	10	2023
Jawa Barat	Patuha #2	Patuha Geothermal Energy, PT	19	55	2023
Sulawesi Utara	Lahendong Small Scale #1	PGE, PT	-	5	2023
Aceh	Jaboi #1	Sabang Geothermal Indonesia, PT	2	5	2023
Sumatera Utara	Sorik Marapi #4	Sorik Marapi Geothermal Energy, PT	39	50	2023
Jawa Barat	Cibuni	Kopjasa Keahlian Teknosa, PT	3	10	2024
Jawa Timur	Ijen #1	Medico Cahaya Geothermal, PT	6	55	2024
Lampung	Ulubelu Small Scale #1	PGE, PT	-	10	2024
Nusa Tenggara Timur	Atadei #1	PLN (Persero), PT	-	5	2024
Nusa Tenggara Timur	Sokoria #3	Sokoria Geothermal Energy, PT	8	11	2024
Sumatera Utara	Sorik Marapi #5	Sorik Marapi Geothermal Energy, PT	39	50	2024
Bengkulu	Hululais	PGE, PT	24	110	2028
Jambi	Sungai Penuh	PGE, PT	5	110	2028
Bali	Bedugul	Bali Energy, Ltd.	3	75	?
Maluku	Tulehu	PLN (Persero), PT	4	20	2026
Central Java	Baturaden	Sejahtera Alam Energi, PT	2	55	2026

Table 3. The target of geothermal development in the expansion of the existing field from 2022 -2024 with total capacities of 439 MW

Out of 16 existing operated geothermal field, there is a plan to expand the field capacity by another 1234 MW for 2030 road map program which consists of Lumut Balai 55 MW, Rantau Dedap 134 MW, Ulubelu 10 MW, Muara Laboh 145 MW, Sorik Marapi 150 MW, Pangalengan 65 MW, Patuha 165 MW, Salak 70 MW, Kamojang 30 MW, Dieng 295 MW, Lahendong - Tompaso 35 MW and Ulumbu 40 MW, Mataloko 20 MW, and Sokoria 25 MW (see **Figure 1**).

5. ONGOING PROJECT AND FIELD DEVELOPMENT STATUS

In order to support the energy transition program continuing the geothermal development road map since 2010 at World Geothermal Congress in Bali in 2010, Indonesia still has the ambitious program to be the world's leading geothermal energy producer. So far, 64 geothermal working areas ("**GWA**"/"**WKP**") have been offered to the private companies including 12 GWA assigned to state owned companies (PLN and Geo Dipa Energi) out of 13 geothermal working areas assigned to the private sectors for preliminary survey and exploration. The status of WKPs are: Exploitation (5 WKP with) 290 MW development plan. They are Sungai Penuh Jambi, 55 MW, operated by PT PGE to be commissioned by 2028; Hululais Bengkulu, 140 MW operated by PT PGE to be commissioned by

2025; Cibuni, West Java,10 MW operated by PT KKT, to be commissioned by 2024; Tabanan (Bedugul) Bali, operated by Bali Energy Ltd., 65 MW (Target COD: 10 MW 2025; 55 MW 2030); and Tulehu Maluku, 20 MW, operated by PT PLN (Persero), to be commissioned by 10 MW in 2025 and 10 MW 2026).

19 WKP is planning for exploration activities to install 1,290 MW geothermal power plants (**Figure 2**), while 13 WPSPE is developed to support the installation of additional 851 MW. Beside those areas, there are 24 WKP and 2 WPSPE which have no developer yet. This counting would be expected 9,300 MW installed by 2035 to achieve renewable energy target in the national energy mix policy as well as the backbone of coal retirement program.

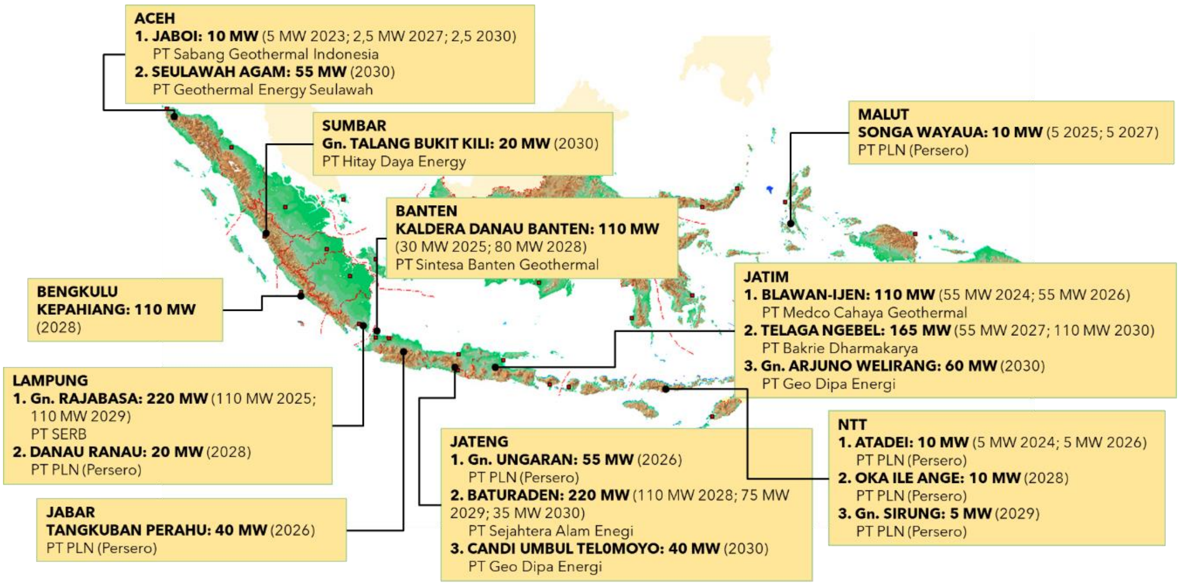

Figure 2: 19 WKP for exploration to develop 1,290 MW power plant done by the GOI.

However, due to the uneconomical viability of the project, most of them have no realization progress. Only very few projects are running for exploration and development based on the permit. Only a few projects are moving from the new regulation regime and the rest are projects run by PGE with its own operation and or with its partner on Joint Operating Contract as well as PLN. Most of the project still difficult to move forward due to investment uncertainty as the price of electricity set by GOI is without consider the economic viability of geothermal development cost. Most of the investors are waiting and see for the President Regulation on the accelerating of geothermal development and pricing policy.

Since early 2020, the pricing policy of RE has been reviewed by GOI and RE stakeholders and the new regulation should be issued before the end of 2020. But, due to Covid-19 and negative economic growth, the PR is canceled to be launched. These conditions cause a lot of uncertainty in the geothermal business. While the position of Indonesia in the G20 Presidency in 2022 with committed to energy transition pushed Indonesia to finally issue the President Regulation number 112 Year 2022 regarding the acceleration of the RE and RE Tariff to Mandated PLN. It is expected that the geothermal development will have a new attractiveness even though the pricing policy is still not economically viable due to the negotiable and agreed price scheme introduced in PR.

However, GOI now works more realistically in facing the world energy crisis caused by the Russian – Ukraine war. The crisis will impact the national economy and energy crisis but also toward the energy transition era. MEMR must face the year 2025 by issuing the new road map and establish a new model for energy transformation such as EV and other electrical use.

With regards to drilling activities, the number of wells drilled is more than 697 well composed of exploration wells, production wells, monitoring wells and re-injection wells. The depth of the wells vary from a few hundred meters until 4000 meters. The cost of geothermal well drilling from various fields can be seen in Table 5 below. Average the exploration well drilling cost from 39 wells available (2011-2021) is 7.6 million USD per well. Exploration well drilling cost ranges between 1.2 – 12 million USD per well. Exploration well depths (successful & unsuccessful) vary from 500 – 3,477 meters. Exploration drilling cost tends to be higher compared to development and operation.

No	Area of Prospect	Status	Resources (MW)	Dev. Planning (MW)	Est. Temp. (ºC)	Infrastructure Prep.	Exploration Drilling	Target COD
1	Cisolok Cisukarame, Jawa Barat	WKP	45	20	200	2021	2021-2022	2028
2	Nage, NTT	WKP	19	10	230	2021	2021-2022	2028
3	Bittuang, Sulawesi Selatan	Open Area	24	20	200	2023/TBC	2022/TBC	2029
4	Marana, Sulawesi Tengah	WKP	28	20	198	2023/TBC	2022/TBC	2029
5	Gunung Endut, Banten	WKP	38	20	180	2023/TBC	2022/TBC	2029
6	Guci, Jawa Tengah	WKP	100	55	280	2024/TBC	2025/TBC	2032
7	Gunung Galunggung, Jawa Barat	WKP	220	110	225	2024/TBC	2025/TBC	2032
8	Papandayan, Jawa Barat	Open Area	21	10	290	2024/TBC	2025/TBC	2032
9	Sumani, Sumatera Barat	WKP	52	30	190	2024/TBC	2025/TBC	2032
10	Cubadak, Sumatera Barat	WPSPE	66	20	235	2025/TBC	2026/TBC	2033
11	Krucil Tiris, Jawa Timur	Open Area	74	30	280	2025/TBC	2026/TBC	2033
12	Sungai Tenang, Jambi	Open Area	74	10	176-225	2025/TBC	2026/TBC	2033
13	Massepe, Sulawesi Selatan	Open Area	15	10	198	2025/TBC	2026/TBC	2033
Total 13 Prospect Areas			776	365				

Table 4. Area of geothermal prospect to be explored by GOI to support reducing geothermal exploration risk.

Geothermal Area	Average cost per Meter (USD/meter)	No.Wells	Years	Notes
Baturaden	7.420	3	2018	IPM, Eksplorasi, Jawa
Sarulla	5.492	33	2014-2017	IPM, Pengembangan, Sumatera
Jaboi	4.436 *Learning Process*	2	2017-2018	IPM, Eksplorasi, P. Sabang
Hululais	3.932 (2,888 USD/m; 10 develop; 2018)	22	2015-2018	Semi-IPM, Pengembangan, Sumatera
Ulubelu	3.793 (2,916 USD/m; 5 Make-up; 2018)	22	2014-2016	Semi-IPM, Make-up, Sumatera
Kamojang	3.302 Penyesuaian kontrak (semi IPM → direct)	5	2015	Semi-IPM, Make-up, Jawa
Wayang Windu	3.253 IPM (<2016) to direct (2019-2021)	10	2018	Semi IPM, Make-up, Jawa
Lumut Balai	3.176	13	2014-2018	Semi-IPM, Pengembangan, Sumatera
Darajat	3.120	16	2011-2021	Discrete, Make-up, Jawa
Blawan Ijen	3.051	4	2020-2021	Full-IPM & Bundling, Eksplorasi, Jawa
Karaha	2.984	3	2014 & 2020	Semi-IPM & Discrete, Pengembangan, Jawa
Tulehu	2.949 *Learning Process*	4	2017-2018	IPM, Eksplorasi (appraisal), Maluku
Muaralaboh	2.725 (4,289 USD/m; 6 Ekxploration well 2013)	13	2017-2018	Discrete, Pengembangan, Jawa
Lahendong	2.701	10	2015-2016	Semi-IPM, Make-up, Sulawesi
Sokoria	2.535 *Learning Process*	5	2017-2018	Bundled, Pengembangan, NTT
Rantau Dedap	2.334 (3,262 USD/m; 6 Exploration well; 2014-2015)	26	2018-2021	Discrete, Pengembangan, Sumatera
Sorik	2.026 (3,029 USD/m; 10 Exploration well; 2016-2017	44	2016-2019, 2020-2021	Bundled, Semi IPM& IPM, Pengembangan, Sumatera. 2021 dengan rig sendiri

Table 5. Cost comparison between geothermal fields drilled in the last 7 to 8 years in Indonesia.

6. GEOTHERMAL LONG TERM DEVELOPMENT PLAN

The growth rate of energy in the National Energy Policy (NEP), is predicted the growth rate of electricity demand about 7% annually. As a consequences, electricity supply is over since the Covid 19 is spread out over the world due to economic crisis. As a result, geothermal development has also experienced a delay in its development while waiting for the return of economic growth to a better direction. In addition, geothermal development geothermal as the first priorities to support 23% of renewable energy target in 2025 and 31% in 2030 respectively is also canceled. This might affect the accelerated development of geothermal to achieve its target in the near future due to the fact that the sector has not been able to make adequate developments/investments in the power supply capacity. The target of 7,200 by 2025, is expected to be delay. In fact, there is very few investors who continue develop the project as GOI investment plan. Consequently, GOI has revised and released the plan for 2025 geothermal development and re-evaluate to established new road map of geothermal development for 2035. The future development and power plant installation expected are shows in the **Figure 3**.

The geothermal development road map that released in 2017 is planned to installed power plant for electricity generation for 3,120 MW by the year 2020, for 5068 MW by 2021, toward a 7242 MW by 2025 (targeted in the National Energy Policy-NEP) respectively, and 9300 MW by the year 2030. However, the realization of geothermal development is still low and quite far from the target and looks hard to achieve. Due to the high demand on the low carbon emission energy, it was re-established the new road map of geothermal development in Indonesia until 2035 (see **Figure 3**). The target of geothermal development by 2030 is shifted to 2035. Total capacity of the target is still 9,300 MW. These capacities are correlated to support the first stage of CFPP subcritical retirement (1 GW) in 2030 and 9 GW in 2035 for the second stage of subcritical retirement. The next stage of CFPP retirement of 10 GW supercritical CFPP in 2040 and the gradual retirement of 24 GW ultra supercritical from 2045 to 2056 will be replaced by hydro power plants. In total, geothermal and hydro will be the best solution for CFPP retirement.

Figure 3: The target of geothermal development from 2020 - 2030 as it is shifted to 2035 with total capacities of 9,300 MW

Geothermal development plan for the long term period is planned to be from 2021 to 2060. The geothermal development from 2050 to 2060 is maximized to 18 GW, through the development of enhanced geothermal systems (EGS) and other non- conventional geothermal systems. Furthermore, the first period of long term planning is to install geothermal power plants with a total capacity of 5,5 GW. This means, there is an additional capacity of 3,3 GW from 2021-2030. Then, 12,0 GW installed capacity with additional capacity of 6,5 GW (2031-2040), 15,0 GW with additional capacity of 3,0 GW (2041-2050), and 18,0 GW with additional capacity of 3,0 GW (2051-2060).

The long-term geothermal development plan will cover as follows:

a. Policy and Regulation

In the period of 2021-2030, to support geothermal development as it is stipulated in the long term program, there are some policy and regulation to be established include:

- Reenactment of geothermal tariff policy
- Sustaining Government’s geothermal exploration program funding
- Geothermal Infrastructure support by Government
- Conservation forest zone adjustments
- Carbon market mechanisms
- Power wheeling
- Geothermal hydrogen industry regulation and project implementation

In the 2031-2040, there are some other policy and regulation should be established:

- Adjustment of IPB time period for development expansion suited with PPA time frame
- Integrating regulation with Oil and Gas enterprising
- Policy adaptation to enable deep drilling and EGS technology

In the period of 2040-2050, the policy adaption to support geothermal development should be established for:
- Non-conventional utilization
- Heating process in the industrial sectors

b. Installed Plan capacities:
In 2021-2030:
- Brown field development optimization
- Small Scale power plant development
- PPA 2023-2025 (443 MW) to be COD up to 2030 and 6.210 MW to be COD on 2031-2035. PPA 2028- 2030 (1.000 MW) to support COD 2036-2040)
- Public hearing, social engagement and stakeholders mapping to avoid social

In 2031-2040:
- Electricity interconnection
- PPA (3.000 MW) to support COD 2041-2050
- Geothermal utilization from oil and gas field
- Geothermal power plant hybrid with photovoltaic

In 2041-2050:
- PPA (2,950 MW) to support COD 2051-2060
- Deep drilling geothermal project
- Large scale-geothermal industrial heating
- Non-conventional utilization project

7. GEOTHERMAL DEVELOPMENT STRATEGY

To accelerate the geothermal development in Indonesia, and substitute the replacement of coal retirement on time, GOI facilitate some program such as:

a. Preparing WKP for accelerating geothermal power plant development through:
   i. Acceleration of new WKP offerings (through auctions/assignments to SOEs); and
   ii. Accelerated bidding of the Preliminary Survey and Exploration Assignment Area (WPSPE) to the business entity.

b. Seeking Government support for geothermal development access road and others infrastructure by Ministry of Public Works and Housing,

c. Expanding and accelerating the implementation of geothermal exploration financing schemes including:
   i. Government drilling to bear 100% risk of the exploration phase. Government drilling is done through:
      - Exploration scheme through PT SMI (GEUDP, Geothermal Energy Utilization Development Program)
        Settings in PMK 62/2017, mandated to be carried out by PT SMI to obtain the geothermal data and information based on a special assignment from the Minister of Finance. In PMK 80/2022, the Ministry of Finance assigned two Special Vehicles Company - SOEs under the Ministry of Finance, namely PT SMI and Geo Dipa Energy and separated roles for financial management and implementation field (currently in PMK 62/2017 both are implemented by PT SMI).
      - State budget exploration scheme through the Geological Agency
        This scheme of the risk mitigation is exploration drilling done by BLU (Lemigas) for the area of Cisolok Cisukarame, West Java and a slim hole drilling for exploration studies by drilling contractors for the area of Nage, Flores, East Nusa Tenggara. The exploration drilling is done base on MEMR Regulation No. 37/2017 concerning Geothermal Working Areas for Indirect Utilization and MEMR Decree No. 12.K/HK.02/MEM.E/2021 dated 22 January 2021 regarding the Implementation of Geothermal Exploration Activities by Government. The objective of this drilling is to get the additional data on WKP and Open Areas by the Minister, covering detailed 3G survey activities, drilling temperature gradient, and exploratory drilling.
   ii. De-risking facilities: Government drilling (both by MEMR and collaboration with MoF) in exploration.
      Funding and risk sharing to lower exploration risks to support electricity tariff reduction.
      - State Own Enterprise (SoE) Drilling – GREM, Geothermal Resources Risk for Exploration Mitigation as a Public Window: exploration phase risk up to 50% borne by the Government (all SOEs can participate). GREM is a financing facility for geothermal exploration that is accessible to the private and public sectors in Indonesia. This activity aims to reduce the risk of early stage project development through the method of de-risking or risk sharing. This funding facility was approved by Green Climate Fund (GCF) in 2018 and listed as a proposal first funding approved in Indonesia. The total of this facility is USD 651.25 million with source funding from GCF, International Bank for Reconstruction and Development (IBRD) World Bank, Clean Technology Fund (CTF), and the Ministry of Finance through PT Sarana Multi Infrastruktur (PT SMI). The initial duration of this facility is 10 years and will be completed in 2030. GREM facilities support public developers (BUMN/subsidiary BUMN) through the provision of multilateral loans (IBRD, GCF, and CTF) and provision of de-risking facilities from Geothermal Sector Infrastructure Financing Fund (PISP Fund) with maximum aggregate limit of USD 30 million.
      - Private Drilling - GREM Private Window: 50% exploration phase risk borne by the World Bank. The GREM facility supports private developers through conventional loan combination and subscription systems with financial instruments (financial instrument/FI) issued by developers (based on 50:50). Conventional loans come

from IBRD loans and the subscription system for FI originates from the GCF Reimbursable Grant and/or Contingent Recovery Grant CTF.

- Infrastructure Financing for Geothermal Sector (Pembiayaan Infrastruktur Sektor Panas Bumi or PISP). This kind of support aim to reduce and mitigate the high exploration risk of geothermal development will encourage the private and state-owned company to develop geothermal in Indonesia. The finance support consists of: Clean Technology Fund (CTF), amount USD 49 million using for exploration drilling, Global Environment Facility (GEF) amount of USD6,25 million for technical assistance, and Government Support Fund from *Pendanaan Infrastruktur Sektor Panas Bumi* (PISP). The fund might be used as a Grant with the conditions: the winner of the auction of GWA will replace the Exploration Fund plus Premium Risk to guarantee that the revolving fund is running. The time limit for grant is 15 years. The unutilized or remaining grant at the end of the 15th year will be taken back by CTF. PT. SMI is appointed as the project owner for these funds, while MEMR, MoF and PT.SMI will establish the Steering Committee. This support is using Geothermal Resource Risk Mitigation (GREM) through a blended soft loan which is come from PISP, International Bank for Reconstruction and Development (IBRD), World Bank, and Green Climate Fund (GCF) to support state owned companies

d. Optimization of geothermal power plants that have been operating with geothermal technology.
Such geothermal binary utilization from brine and or idle wells to optimize utilization with a total capacity of 155 MW.
e. RE Electricity: tariff re-enactment geothermal steam and electricity tariff through Presidential Regulation (PR No.112 Year 2022).
f. Conservation forest: ease on land use licensing process on the conservation forest and assurance of water-use permit specifically on conservation forest.
g. Land and building tax on exploitation phase: exemption of land and building tax (PBB) on the exploitation phase to increase project economic and attractiveness.
h. PISP, Infrastructure Financing for Geothermal Sector (Pembiayaan Infrastruktur Sektor Panas Bumi) utilization. Acceleration of PISP fund to utilize the 13 project pipelines with development capacity of 705 MW (1st priority-120 MW, 2nd priority-475 MW, private windows-110 MW).

8. DIRECT UTILIZATION

Today, Indonesia promotes a direct utilization of geothermal (non-electricity) not only for spa and hot springs but also for other purposes. The country has been used for hundreds of years using natural hot springs such as bathing, washing and cooking. The direct utilization also could be done for agriculture and industrial purposes for commercial use to cascade use from geothermal power plants and utilize excess steam and hot brine for other direct processes, including for distillation of vetiver, pasteurization of mushroom, brown sugar processing, fish farming, and coffee seed and tea drying. One of the established direct use of geothermal in Indonesia is seen in **Figure 4**.

Figure 4: The suspended Palm sugar processing unit operated by Masarang Foundation using 4 tones/hour brine from Lahendong geothermal power plant.

Currently, there is a new geothermal direct use in Indonesia recorded for tea and coffee seed drying in Ulu Belu Lampung, Rantau Dedap South Sumatra and Muara Laboh, West Sumatra. The others potentials are tea drying in Malabar West Java, coffee drying and palm sugar processing in Mataloko and Ulumbu, Flores using brine from geothermal power plants. In addition, the aquaculture facility utilizes geothermal fluid for traditional freshwater fishery in Lampung Province, mixing natural geothermal hot water (outflow) with freshwater from a river to grow large catfishes. The farmer reported that the fishes grow better in the geothermal fluid and freshwater mixture. Total brine use was about 50 tonnes/hour for each field fish farming. While the palm sugar processing using brine from Lahendong geothermal field is still suspended. The more use of geothermal for agriculture such as copra drying in Lahendong, Mataloko and Cacao drying in Wai Ratai Lampung, mushroom cultivation in Pengalengan, Kamojang and tea drying and pasteurization in Pengalengan and large catfishes growing in Lampung is running well. The spa and hot springs are used and grown in Jaboi – Sabang; Langkahan – Geureudong, Aceh; Semangat Gunung – Sibayak, North Sumatra; G. Talang – West Sumatra; Tampoma, Ciater and Cipanas, West Java; Guci – Central Java; and Tompaso – North Sulawesi. The direct use is counted to support energy transition to achieve NZE and better transformation from fossil based to RE.

9. DISCUSSION

Indonesia now is the second largest producer of geothermal in the world after the USA who installed 3,676 MW from geothermal energy. The third position is now occupied by the Philippines produced from 1,918 MW geothermal plant. Indonesia's ambition to become the world's largest geothermal producer of 9300 MW can be fulfilled if the strategy to develop geothermal energy is carried out seriously. The unlikely obstacles due to geothermal energy have unique attributes which pose challenges to its development should be solved simultaneously.

The major issue caused by pricing of the energy soled to achieve the economic viability of the project, bankability of the PPA scheme and negotiation, location of the project in the conservation forest and or national park, government guarantee of the project, obligation of PLN to buy the energy from project companies, lack of human resources, social treatment issues, permit, financing, etc., should be reviewed by the GOI.

However, the award geothermal areas to the private and state owned companies to develop geothermal power plants as part of nine thousand MW respectively by 2035 is good enough to enter the geothermal businesses. The retirement of ten thousand of CFPP is also a big opportunity for geothermal development in Indonesia. Now, how is the involvement of the penta helix (GOI, academician, community, business entities and financial institution) to support development of geothermal as well as coal retirement for NZE target.

Moreover, the role of PLN as the single buyer in Indonesia should also work hand in hand with all stakeholders. The Renewable Energy Law should be one of the solutions for an integrated work. The unattractive tariff taken by PLN which is set in the Ministry of Energy Regulation No.50/2017 has been revised by Presidential Regulation No.112 Year 2022 and will depend on an agreed negotiation among players for economic viability. The developer calculated that the viability tariff varies from more than 10 cents/kWh. It depends on the scale of the project, infrastructure, location of the geothermal field as well as the type of geothermal fluid recovery.

It is good to rethink that study from the World Bank (2014) indicates that the price of geothermal energy will vary from 11 to 29 cents/kwh based on avoiding cost of coal and the region of electricity use. The price is also depending on the year of commission from 2014 to 2025. The lowest price is dedicated to the project commission in the region of Java, Bali and Sumatra in the year 2014, and the highest price is dedicated to the project commence in isolated areas to substitute a diesel power plant. This policy will standardize the geothermal price. As we are aware that the price of coal now is six times higher than that in 2021. The coal price now is USD435 per metric ton compared to a maximum of USD70 per metric ton in 2021.

10. CONCLUSIONS

In the last 3 years, there is no significant increase in geothermal installed capacities as well as a significant use of brine for direct use of geothermal. However, the NZE ambition caused GOI to issue the PR No. 112 Year 2022 and an instruction from the President of Indonesia through Inpres No.7 Year 2022 to support the private sector in developing geothermal power plants and minimizing uncertainty in the project development. The policy is expected to increase the economic viability of the project to make the business more certain and more attractive.

Other business opportunities in the geothermal sectors are geothermal direct use, low temperature geothermal potential, small scale power plant, services company to support the core business of geothermal and human resources for the country.

To achieve the targets, international support is needed in terms of finance, technology, human resources and technical assistance. Indonesia with high geothermal potential has a significant challenge to attract private power.

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