GEOTHERMAL IN INDONESIA: AN ILLUSION ON SUSTAINABLE GREEN ENERGY

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BRIEFER
GEOTERMAL IN INDONESIA: AN ILLUSION ON SUSTAINABLE GREEN ENERGY

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Aksi! for gender, social, and ecological justice
2025

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PREFACE

Indonesia is located on the Pacific Ring of Fire and has at least 127 volcanoes and 40% of the world's geothermal reserves. The existing capacity in Indonesia includes 11,998 Megawatts (MW), and the reserves capacity is reaching 17,546 MW. As a result, Indonesia has become a target for investment in geothermal energy development, with massive support from international financial institutions such as the World Bank and Asian Development Bank and investments from major global corporations. The reason for this development is the assumption that geothermal is a clean energy that is low-carbon and environmentally sustainable. One of the focuses of this briefer is whether this assumption is correct by looking at the experiences of communities whose territories have been the sites of geothermal exploration and exploitation. This briefer aims to provide a comprehensive overview of geothermal in terms of the rationale for its utilization, the technology used, and its impact on the environment and communities where geothermal is developed as an energy source.

The first part of this briefing explains why geothermal is one of the energy sources to fulfill Indonesia's commitment to achieve net carbon neutrality by 2050. It is followed by an introduction to the development of geothermal as an energy source, including its history, how it works, and the technology used. Critical discourse on the social, economic, and environmental impacts of geothermal development as an energy source is also presented through the experiences of a number of geothermal projects in Indonesia.

The utilization of geothermal as an energy source in Indonesia, which is said to be one of the low-carbon and clean energy alternatives, needs to be further considered by learning from the experiences of affected communities. We hope that this briefing can serve as a reference and learning for stakeholders in their decisions regarding the utilization of geothermal as an energy source. An equitable green transition should not only consider aspects of low-carbon energy sources but should also consider aspects of gender and social and ecological justice and adhere to the principles of human rights and women's rights.

Jakarta, 21 January 2025
Titi Soentoro**,**
Aksi! for gender, social, and ecological justice.

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ABBREVIATION

AGS	Advanced Geothermal Systems
BAKOREN	Badan Koordinasi Energi Nasional (National Energy Coordinating Agency)
COP	Conference of Parties
CO2	Carbon dioxide
DPR	Dewan Perwakilan Rakyat (House of Representatives)
EGS	Enhanced Geothermal System
ENDC	Enhanced Nationally Determined Contribution
ESDM	Kementerian Energi dan Sumber Daya Mineral (Ministry of Energy and Mineral Resources)
GPP	Geothermal Power Plan
HGS	Hybrid Geothermal System
IPG	International Partners Group
JETP	Just Energy Transition Partnership
LHK	Lingkungan Hidup dan Kehutanan (Environment and Forestry)
MP3EI	Masterplan Percepatan dan Perluasan Pembangunan Ekonomi Indonesia (Masterplan for Acceleration and Expansion of Indonesian Economic Development)
MW	Megawatts
NDC	Nationally Determined Contribution
Permen	Peraturan Menteri (Ministerial Decree)
PLN	Perusahaan Listrik Negara (state-owned enterprise)
PLTP	Pembangkit Listrik Tenaga Panas Bumi (Goethermal Power Plan)
RUPTL	Rencana Usaha Penyediaan Tenaga Listrik (Electricity Supply Business Plan)
SGS	Supercritical Geothermal System

UNFCCC	United Nations Framework Convention on Climate Change
UU	Undang-Undang (Law)
WKP	Wilayah Kerja Panas Bumi (Geothermal Working Area)


NET
ZERO

PART 1. INTRODUCTION

Indonesia's Commitment to Realize *Net Zero Emission*

Climate change is an important issue that has emerged in the contemporary global era—and not without reason. The warming of the earth's temperature has threatened the lives of all creatures. Extreme weather, water and food crises, disasters, and extinction are scary specters that could occur if climate change is not addressed.

The Paris Agreement, agreed at the 21st Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) in 2015, aims to avoid the adverse impacts of climate change by keeping the global average temperature from rising more than 2° Celsius above pre-industrial temperatures and striving for an increase of no more than 1.5° Celsius. One way to achieve this goal is to reduce carbon emissions by 45% by 2030 and reach "net zero emissions" by 2050.

Net zero emissions refer to a condition where the amount of carbon emissions produced is equal to the amount of carbon absorbed by the earth. This is expressed in Article 4.1 of the Paris Agreement as a balance between emissions caused by human activities and the absorption of greenhouse gases by natural sinks.[1] A net-zero emissions target requires efforts to reduce carbon emissions to a smaller amount that can be absorbed and permanently stored by nature so that no residue remains in the atmosphere to cause the greenhouse effect.

More than 140 countries have set net-zero emission targets covering 88% of total global emissions by strengthening their Nationally Determined Contribution (NDC).

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[1] R. Kinley, "Climate change after Paris: from turning point to transformation," *Climate Policy* 17, no. 1 (2017): 9–15, https://doi.org/10.1080/14693062.2016.1191009.

Indonesia has also ratified the Paris Agreement into Law No. 16/2016 on the Ratification of the Paris Agreement to the United Nations Framework Convention. It submitted its NDC in November 2016, which contains a commitment to reduce emissions by 29% with independent efforts and 41% with international support. In September 2022, Indonesia strengthened its commitment to emission reduction to 31.89% with independent efforts and 43.20% with international assistance, as well as a net-zero emission target by 2060 or sooner submitted in the Enhanced Nationally Determined Contribution (ENDC) document.[2]

Moving towards net-zero emissions requires a total transformation in all aspects of life, including production, consumption, and distribution. The energy sector plays a key role because three-quarters of greenhouse gas emissions, equivalent to 38.5 GtCO2e per year, are generated from this sector.[3] Therefore, energy transition has become a strategic issue in reducing greenhouse gas emissions, and Indonesia is no exception.

One of the emission reduction commitments made by the Indonesian government to the world includes the energy sector, which accounts for 34.49% of Indonesia's total emission contribution.[4] Government Regulation No. 79/2014 on the National Energy Policy has scheduled a transformation in the energy sector in 2025 and 2050, in which the primary energy mix

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[2] Indonesia Ministry of Environment and Forestry, "Enhanced Nationally Determined Contribution Republic of Indonesia," 23 September 2022, can be access through https://unfccc.int/sites/default/files/NDC/2022-09/23.09.2022_Enhanced%20NDC%20Indonesia.pdf.

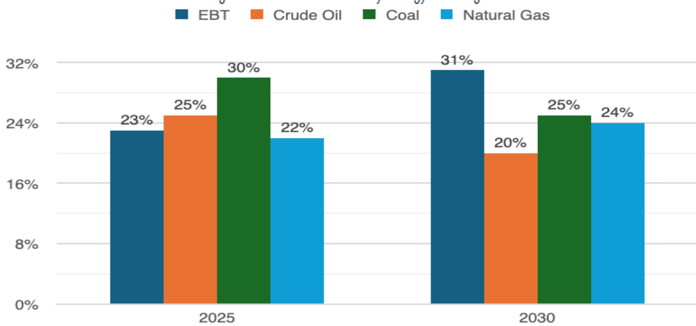
[3] United Nations Environment Programme, "Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again)" (Nairobi: United Nations Environment Programme, November 2023), https://doi.org/10.59117/20.500.11822/43922.

[4] ndonesia Ministry of Environment and Forestry, "Enhanced Nationally Determined Contribution Republic of Indonesia."

is sought to reduce the proportion of fossil energy and increase new and renewable energy.[5]

This target encourages Indonesia to develop non-fossil energy projects that are considered potential and claimed to be “environmentally friendly,” such as geothermal energy.

Image 1. 2025 and 2030 Primary Energy Mix Targets



Geothermal Development in Indonesia

Geographically, Indonesia is located on the Pacific Ring of Fire, where 85% of the world's volcanoes are concentrated in this region. Unsurprisingly, Indonesia has the most active volcanoes in the world, reaching 127 mountains spread almost throughout the region. This is also why 40% of the world's geothermal reserves are in Indonesia.[6] Indonesia has geothermal resources with a capacity of 11,998 Megawatts (MW) and reserves reaching 17,546 MW.[7] If the entire potential is utilized, the current

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[5] *Lembaga Penyelidikan Ekonomi and Masyarakat*, *Buku Putih: Analisis Bisnis and Kebijakan untuk Mendorong Investasi Pembangkit Listrik Tenaga Panas Bumi (PLTP) di Indonesia* (Depok: LPEM FEB UI, 2023).

[6] Nugroho Agung Pambudi, “Geothermal power generation in Indonesia, a country within the ring of fire: Current status, future development and policy,” *Renewable and Sustainable Energy Reviews* (Elsevier Ltd, 1 January 2018), https://doi.org/10.1016/j.rser.2017.06.096.

[7] CELIOS-WALHI, “Indonesia’s Geothermal Challenges: Amidst Potential and Exploitation in the Name of Energy Transition” (Jakarta, 2024).

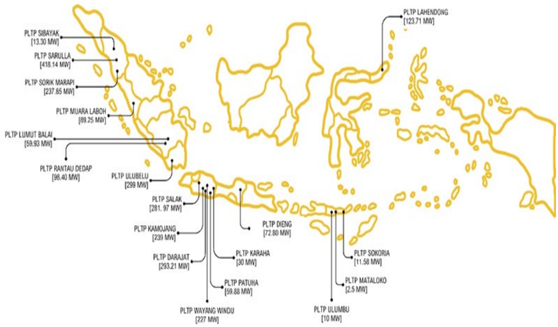
electricity production capacity can increase to 18%. Here is a map of the distribution of geothermal potential in Indonesia.

Image 2. Map of Indonesia's Geothermal Potential Locations

This fact has made the Indonesian government aggressively develop geothermal energy or Geothermal Power Plants (GPP). According to the Handbook of Energy and Economics of Indonesia in 2023 released by the Ministry of Energy and Mineral Resources (ESDM), within a period of 10 years, the development of GPP has doubled from 9 points spread across six provinces in 2013 to 18 points in 2023 with a distribution that extends to 8 provinces. The following is a map of the distribution of GPPs operating in Indonesia by 2023 based on data from the Ministry of ESDM.[8]

[8] Ministry of ESDM, "Handbook of Energy and Economic Statistic of Indonesia 2023" (Jakarta, 6 June 2023).

Image 3. Map of geothermal power plant distribution in Indonesia



As described above, the distribution of GPPs throughout Indonesia has produced 2,597.51 MW. This exploration is still relatively low compared to the geothermal potential found scattered in 252 points following the distribution of volcanoes in Indonesia.[9]

The government has prepared several policies to support the acceleration of geothermal power plant development, including easy licensing policies mandated by the Geothermal Law and the Job Creation Law, to attract geothermal investment as much as possible and meet the target of GPP development, which is predicted to replace coal-fired power plants and achieve net zero emissions before 2060.[10]

The rapid development of GPP still leaves some homework. The actual energy transition is not merely switching from fossil energy to energy that is considered more

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[9] *Dewan Energi Nasional* (National Energy Council), "Outlook Energi Indonesia Tahun 2023" (Jakarta, December 2023), https://den.go.id/publikasi/Outlook-Energi-Indonesia.

[10] Savira Ayu Arsita, Guntur Eko Saputro, and Susanto Susanto, "*Perkembangan Kebijakan Energi Nasional and Energi Baru Terbarukan Indonesia* (Development of Indonesia's National Energy Policy and New and Renewable Energy)," *Jurnal Syntax Transformation* 2, no. 12 (24 December 2021): 1779–88, https://doi.org/10.46799/jst.v2i12.473.

environmentally friendly; more than that, it is a system transformation in the energy supply chain. On this occasion, let us move on to an in-depth discussion to learn more about geothermal energy and what discourse is behind the efforts to utilize it.

Financing Politics Behind Geothermal

From a critical perspective, the global financing politics behind geothermal projects in Indonesia can be understood as part of broader power dynamics in the global political economy. Developing countries like Indonesia are often vulnerable to the political interests of international financial institutions and developed countries.

Funding flows for geothermal projects, including foreign loans, have begun to pour into Indonesia. Multinational private banks and multilateral development institutions confidently provided financing to geothermal plant developers from the private sector and state-owned companies.[11]

This mobilization of global financial resources led to the establishment of the Just Energy Transition Partnership (JETP) as one of the initiatives resulting from the 26th UNFCCC COP annual meeting held in 2021 in Glasgow, UK. JETP is promoted by the Governments of France, Germany, the United Kingdom, the United States, and the European Union, which are members of the International Partners Group (IPG), working with South Africa to help decarbonize in the context of domestic climate policy and support the transition of the South African economy to cleaner energy sources. A key feature of the JETP is the emphasis on an equitable transition in its investment plans and financing.

JETP conducted by IPG with South Africa is expected to be a model that can be replicated in other developing countries, especially countries with high dependence on fossil fuels in

[11] CELIOS-WALHI, “Indonesia’s Geothermal Challenges: Amidst Potential and Exploitation in the Name of Energy Transition.”

building their economies, including Indonesia.[12] In Indonesia, JETP has calculated that investment opportunities for energy transition across the electricity sector are USD 53 billion. This total includes investments in the geothermal industry of USD 22 billion, both listed in the Electricity Supply Business Plan (RUPTL) and those not.[13] The following is the priority funding scheme for energy transition prepared by the Indonesian JETP Secretariat

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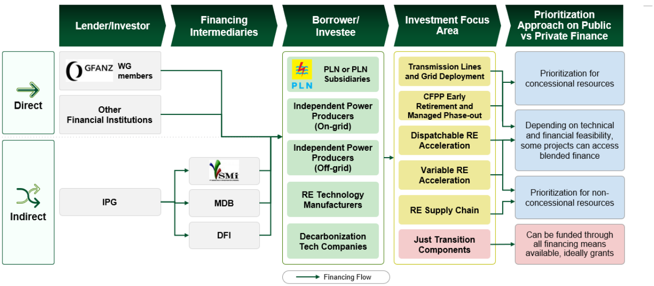
Image 4 JETP Capital Placement Prioritization



Global financing for geothermal projects in Indonesia reflects the vulnerable position of developing countries in the global political economy. Dependence on international financial institutions and developed countries can limit Indonesia's independence in determining the direction of the energy transition. The flow of funds from multinational private banks and multilateral development institutions significantly boosts geothermal development but also carries the risk of dependence on foreign capital and external policy influences. This dependence places Indonesia at the mercy of global political interests, which may not always align with local needs and conditions.

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12 Ajeng Rachmatika dkk., "Policy Brief: Just Energy Transition Partnership (JETP) Indonesia" (Jakarta, December 2022), https://irid.or.id/publication/.

13 JETP Indonesia, "Rencana Investasi and Kebijakan Komprehensif 2023" (Jakarta, 21 November 2023), https://id.jetp-id.org/berita/pemetaan-hibah-jetp.

Through the Just Energy Transition Partnership (JETP), developed countries are working together to support decarbonization in developing countries, with South Africa as a potential pilot project for Indonesia to replicate. While the JETP initiative is committed to a just transition, the model may prioritize donor-defined standards and targets, limiting Indonesia's flexibility to set its priorities. With an estimated investment requirement of USD 53 billion in the electricity sector, including USD 22 billion for geothermal, Indonesia needs to consider the balance between the benefits of energy transition and the risks of increased burden of debt as well as the political dependency that may arise from this global funding scheme.

PART 2.
GET TO KNOW GEOTHERMAL PROJECT

What is Geothermal?

We may have often heard the term geothermal lately. This energy source, which is used as an alternative to fossil fuels, has emerged as one of the government's leading projects to achieve the goal of net zero emissions and curb the rate of climate change. But what exactly is geothermal, and how does it work? Here is the discussion.

Literally, the word geothermal is taken from Greek, which consists of the words "geo," which means earth, and "thermal," which means heat. Geothermal can also be understood as a source of heat energy that is formed naturally beneath the earth's surface. It comes from the heating of rocks and water, along with other elements stored in the earth's crust.

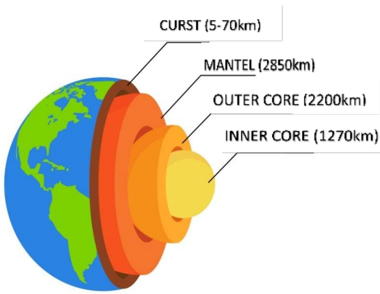

Image 5. Layers of the Earth

Our earth consists of layers of the earth's crust, mantle, outer core, and inner core. The temperature below the earth's surface will increase with the increasing depth of the position below the earth's surface or what is commonly called "geothermal gradient." The high temperature below the earth's surface can occur due to the subduction process or plate collisions under the ocean, which cause solid rock to melt into magma. The magma flows through the rocks' cracks, forming volcanic activity. Therefore, ample geothermal resources are often found in areas where the earth's plates meet and have a series of volcanoes, such as Indonesia.

Magma, as a medium that flows heat energy, plays a vital role in the expression of volcanism, providing various topographic features on the earth's surface. The results of volcanic eruptions not only produce rock cones and rocks from hardening lava flows, but the topography of previous eruptions, such as craters and caldera, provide signs of the possibility of geothermal sources, especially if the volcanic activity has been quite static. Indonesia has many volcanoes that have developed into geothermal locations over time. In Indonesia, many topographic features are also characteristics of geothermal manifestations, such as Lake Toba, a caldera topography that has become an accumulation of surface water into a lake. There is the Mount Tengger caldera in Java, where small volcanoes, namely Mount Bromo, Butak, and Widodaren, have emerged.[14]

Geothermal systems have several main parameters such as heat sources, reservoirs, cap rocks, permeable channels, fluid sources and hydrological cycles. Rainwater seeps into the ground through pore channels or cavities between rock grains, so that water freely penetrates down to the hot rock. The water accumulates and is heated by the hot rock, resulting in increased water temperature, increased volume, and high pressure. High pressure causes hot water and minerals dissolved in it to rise to the surface through cracks, cracks and associated pores. Water and minerals/materials dissolved in water appear on the surface as a manifestation of the geothermal system process.[15]

Therefore, surface manifestations of a geothermal system in a volcanic area are usually characterized when geothermal fluids (liquid or gaseous fluids) seep to the surface along fractures or through outcrops of permeable rocks. Depending on the reservoir temperature and flow rate, these surface manifestations can take the form of seeps, fumaroles (holes in the earth's crust that emit sulfur and carbon dioxide), hot springs, boiling springs, geysers (hot water jets), phreatic

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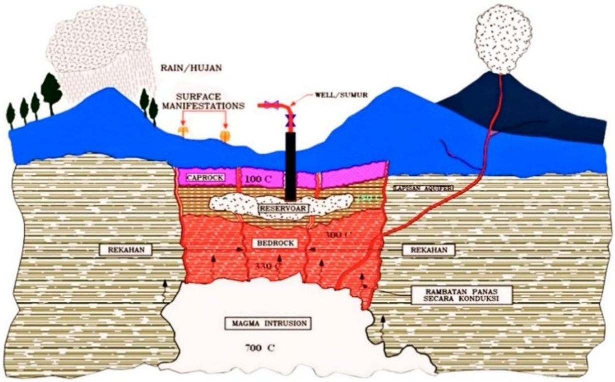
[14] Untung Sumotarto, *Eksplorasi Panas Bumi*, ed. oleh Kartika Nurgrahini (Yogyakarta: Penerbit Ombak, 2015), www.penerbitombak.com.

[15] Suharno, *Eksplorasi Geothermal*, Pertama (Bandar Lampung: Penerbit Lembaga Penelitian Lampung, 2013).

eruption craters (steam-driven eruptions underground), and acid rock alteration zones (sulfuric acid solutions that penetrate pre-formed rocks). In addition, there can be sentiments around the hot springs, such as silica sinter, travertine, and/or layered breccias surrounding the phreatic craters.[16] The following is an illustration of the geological structure in a geothermal area.[17]

Image 6. Illustration of Geological Structures in Geothermal Areas



To understand how geothermal works, we can refer to the analogy of boiling water in a kettle. The fire from the stove is like magma that heats water, whether from rain or intentionally injected. The result of magma heating the water is the production of fluid stored in a storage space (reservoir). The fluid can come out to produce surface manifestations if there is a gap, as we can observe from the kettle funnel hole.

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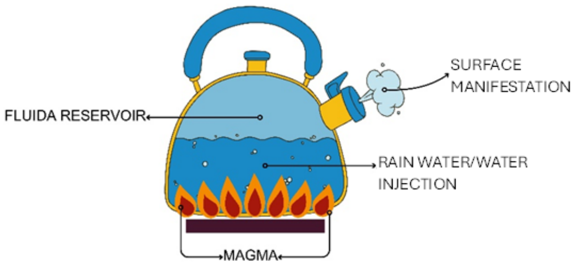
16 Sumotarto, *Eksplorasi Panas Bumi*.

17 Yuli Ermawati, Eriyana Yulistia, and Fetty Zulyanti, "Potensi Panas Bumi sebagai Energi Alternatif dalam Mewujudkan Indonesia Bebas Emisi Karbon," *UEEJ-Unbara Environmental Engineering Journal* 02 (2022): 2723–5599.

Image 7. A Simple Analogy of the Geothermal Creation Process



The characteristics that appear on the surface based on the type of fluid produced divide geothermal systems into three types: the water-dominated type, such as those found in the Sumatra and Mount Salak geothermal systems; the steam-dominated type, such as those in Kamojang and Derajat; and the two-phase type, consisting of water and steam, such as those in Wayang Windu and Lahendong.[18] These characteristics also differentiate the generating technology that converts geothermal fluids into electricity power.

From the explanation of geothermal resources above, it is important to understand how exploration and exploitation work in Geothermal Power Plants (GPP). However, before that, we need to look at the history and development of geothermal in Indonesia.

History and Development of Geothermal Energy in Indonesia

The development of geothermal energy in Indonesia actually began in 1918, during the Dutch colonial period. It started

[18] Pertamina Geothermal Energy, "Eksplorasi and Eksploitasi Geothermal" (Jakarta: Institute Teknologi Surabaya, October 2023), diakses melalui https://www.its.ac.id/tgeofisika/wp-content/uploads/sites/33/2023/10/Pendahuluan-Eksplorasi-dan-Eksploitasi-Geothermal_Materi-Webinar-Teknik-Geofisika-ITS_Potensi-Panas-Bumi-Indonesia.pdf.

with the idea of a teacher at the Hoogere Burgerschool te Bandoeng (HBS Bandung) named J.Z van Dijk, which was written and published in the magazine Koloniale Studien under the title Krachtbronnen in Italie (in Indonesian, it means Electricity Sources in Italy). [19]

Van Dijk discussed the use of geothermal energy as an alternative source of electricity by showing the success of the development of the GPP in Larderello, Tuscany, Italy. Van Dijk was impressed by the use of geothermal energy that began to be developed by Piero Ginori Conti in 1904. Italy succeeded in building the first GPP in the world in 1913 to supply electricity to the textile factory owned by the Lardarello family, whose name was later immortalized as the name of the area.[20]

Van Dijk's idea was the forerunner to constructing the Kamojang Geothermal Power Plant, Indonesia's first geothermal power plant. Although it only started operating in 1983 with a capacity of 30 MW, the exploration process first began in 1926. In 1928, there were five examples of drilling for exploration, but after several trials, only one well, namely KMJ-3, succeeded in producing dry steam at a depth of 66 meters. Exploration was then stopped and continued in 1972. In 1974, Pertamina and PLN collaborated with Geothermal Energy New Zealand Ltd. to conduct geological mapping and more detailed geochemical and geophysical exploration, followed by constructing the first geothermal power plant unit in Kamojang.[21] This activity was carried out based on Presidential Decree No. 16 of 1974, which specifically assigned Pertamina to conduct geothermal surveys and exploration in and outside Java-Bali; the task was handed

[19] Pambudi, "Geothermal power generation in Indonesia, a country within the ring of fire: Current status, future development and policy."
[20] Carlo Cariaga, "Larderello, Italy celebrates 120 years of geothermal electricity generation," Think Geoenergy, 5 July 2024, https://www.thinkgeoenergy.com/larderello-italy-celebrates-120-years-of-geothermal-electricity-generation/.
[21] Pambudi, "Geothermal power generation in Indonesia, a country within the ring of fire: Current status, future development and policy."

over to the Directorate of Volcanology. Then, Pertamina was mandated to sell electricity to PLN through Presidential Decree Number 22 of 1981 and Regulation of the Minister of Mining and Energy Number 10/P/M/MENTAMBEN/81.[22]

In addition to Kamojang, the Dutch East Indies government developed geothermal energy in Dieng in 1918. In 1964, UNESCO recognized Dieng as a geothermal resource with good prospects in Indonesia. In 1970, the United States Geological Survey (USGS) began conducting geophysical surveys, and between 1976 and 1994, PERTAMINA completed 27 test wells. It was only in 1993 that electricity production began through the operation of a power plant. Himpurna-California Association of Energy and PERTAMINA then entered into a Joint Operating Contract.

Dieng's installed capacity is 60 MW, but there is still more than 300 MW of untapped potential. In 2008, the installed capacity experienced a direct and significant decline of 20 MW. Therefore, the electricity distributed to the network was only 40 MW; in 2010, it fell again to only 20 MW. The very high silica content caused this decline. Geodipa Energy is trying to restore geothermal steam production capacity by reworking production wells, especially cleaning narrowed well holes.

The development of the Kamojang and Dieng GPPs has been based on the issue of energy transition, which prioritizes reducing dependence on oil through the development of non-oil fuels. In 1981, the government formed the National Energy Coordinating Agency (Badan Koordinasi Energi Nasional – BAKOREN) chaired by the Minister of Energy and Mineral Resources, which has the task of formulating energy policies, formulating energy development and utilization programs and coordinating the implementation of energy programs. BAKOREN then issued the General Policy in the Energy Sector (Kebijakan Umum Bidang Energi – KUBE) with the primary energy transition

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[22] Muhamad Azhar, "Aspek Hukum Kebijakan Geothermal di Indonesia," *Jurnal Law Reform* 11, no. 1 (2015): 123.

agenda.[23] So, the Kamojang GPP also operates to fulfill the energy transition agenda even though the main priority is still to replace oil energy with coal and gas, which were considered potential with large reserves at that time. This was done to respond to global dynamics influenced by wars that caused fluctuations in world oil prices, the condition of small oil reserves, and the increase in fuel consumption, which affected the growth in Indonesia's oil imports and subsidies that disrupted the budgeting of the APBN.

The development of GPP was then continued at several geothermal exploration and exploitation points such as Gunung Salak and Darajat GPPs, which were developed by Unocal Geothermal Indonesia (UGI), which is a subsidiary of Chevron in collaboration with Pertamina, Lahendong GPP, which was produced since 1971 through cooperation between Germany and Indonesia, Mataloko GPP which has been identified since 1997 and is currently operated by PLN, KESDM, and the Ngada Regency Government with a capacity of 2.5 MW,[24] as well as other points throughout Indonesia which presently a total of 18 Power Plants.

Geothermal power plant development is increasingly intensive because it has emerged as one of the alternative energies developed to meet the commitment to reduce emissions and achieve net zero emissions. The former Indonesian President Susilo Bambang Yudhoyono, in his speech at the 2010 World Geothermal Congress forum in Bali once, conveyed Indonesia's ambitious target to almost quadruple geothermal electricity production[25] from the output at that time - from 1,189

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[23] Hanan Nugroho, "Transisi Energi Indonesia: Janji Lama Belum Terpenuhi," Volume II (Jakarta, 2 May 2021).

[24] Pambudi, "Geothermal power generation in Indonesia, a country within the ring of fire: Current status, future development and policy."

[25] Hillary Brenhouse, "Indonesia Seeks to Tap its Huge Geothermal Reserves," The New York Times, 26 July 2010, https://www.nytimes.com/2010/07/27/business/global/27iht-renindo.html?_r=1&ref=geothermal-power.

MW (2010) to 3,967 MW - no later than 2014. In a meeting between the National Energy Council (DEN) and the House of Representatives (DPR) in May 2010, when presenting the Seven Main Directions of National Energy Policy, the President as chairman of DEN first mentioned geothermal energy as the focus of the renewable energy policy direction, followed by other renewable energies. This plan is placed in the Acceleration Program for the Development of 10,000 MW Power Plants Phase II within the Masterplan for Acceleration and Expansion of Indonesian Economic Development (MP3EI) 2011-2025.[26]

In the current situation, Indonesia has an aggressive plan for developing geothermal power plants in the future. In 2005, the geothermal roadmap target was released to generate 9500 MW. However, this target was later evaluated to be more realistic to 7000 MW by 2025. In 2016, an additional 35 MW Kamojang unit-5, 40 MW Lahendong 2 × 20 MW, and 55 MW Ulubelu unit-3 were inaugurated. Furthermore, five more power plants were operated in Ulubelu, Lahendong and Sarulla, Karaha Bodas, and Lamut Balai. To promote more geothermal energy development, the government has issued laws such as Law No. 21 of 2014, which is a change from the policy of Law No. 27 of 2003. The important point of the revision is that geothermal power generation is no longer classified as a mining operation.[27]

How Does Geothermal Energy Work?

Like power plants in general, geothermal energy power plants have the same components. These components consist of a generator, a turbine as a generator driver, a heat exchanger, a chiller, a pump, a separator, and several others.

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[26] Sigit Setiawan, "Energi Panas Bumi dalam Kerangka MP3EI: Analisis terhadap Prospek, Kendala, and Dukungan Kebijakan," *Jurnal Ekonomi and Pembangunan* 20, no. 1 (2012): 57–69.

[27] CELIOS-WALHI, "Indonesia's Geothermal Challenges: Amidst Potential and Exploitation in the Name of Energy Transition."

Geothermal energy can be obtained by drilling into a reservoir at 1,500-2,500 meters. The hot fluid in the reservoir is then channeled to drive the turbine, and the generator at the PLTP is rotated to produce electrical energy. There are at least four geothermal extraction systems, as follows:

1. ***Engineered/Enhanced Geothermal System* (EGS)**

Natural geothermal systems, known as hydrothermal systems, require three essential elements to produce electricity: heat, fluids, and the ability of the fluids to move through underground (permeable) rock. However, the underground rock is hot in many areas but lacks natural fissures to produce fluids. In these situations, EGS can be achieved by engineering an artificial reservoir to harness the hot rock as an energy source.[28]

EGS is done to enhance and/or create geothermal resources in hot, dry rocks by creating fractures in the rocks and injecting high-pressure cold water through injection wells. The hot rocks heat the water and can be used as an artificial geothermal fluid to generate electricity.[29] This system drills wells 5-7 km deep into crystalline bedrock with more than 180° Celsius temperatures. EGS power plants are operated in Germany and Australia. EGS can be done anywhere in the world, which offers the possibility of expanding geothermal power generation.

2. ***Advanced Geothermal System* (AGS)**

Advanced Geothermal Systems (AGS), also known as Closed-loop Geothermal Systems, are geothermal heat

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[28] Nidia S Caetano, Florinda F Martins, and Gisela Marta Oliveira, "Life cycle assessment of renewable energy technologies," dalam *The Renewable Energy-Water-Environment Nexus*, ed. oleh Shahryar Jafarinejad and Bryan S Beckingham (Elsevier, 2024), 37–79, https://doi.org/https://doi.org/10.1016/B978-0-443-13439-5.00002-8.

[29] János Szanyi, Ladislaus Rybach, and Hawkar A. Abdulhaq, "Geothermal Energy and Its Potential for Critical Metal Extraction—A Review," *Energies* (Multidisciplinary Digital Publishing Institute (MDPI), 1 October 2023), https://doi.org/10.3390/en16207168.

extraction systems that flow fluid through rocks below the surface to heat the fluid. This system works like a closed heat exchanger underground.[30]

AGS designs are based on the shape, type of fluid, and physical principles used. Several tests have shown that AGS can be attractive because they accurately predict heat production. In addition, AGS does not require reservoir stimulation, which reduces earthquake risk and water use. In theory, AGS could be applied anywhere. However, these systems require very deep wells to increase the surface area for heat transfer, which can increase drilling costs. Other challenges include complex well completions and ensuring sufficient heat transfer area with the surrounding rock. The commercial viability of AGS may depend on lower drilling costs.[31]

3. Hybrid Geothermal System (HGS)

Geothermal energy is a low-quality energy source with low energy extraction efficiency. Therefore, innovations to combine geothermal energy with other renewable energy sources through hybrid systems have begun to be developed to increase efficiency and cover needs that geothermal energy cannot meet, including reducing the capital and operating costs required.[32] Geothermal energy can be combined with many different energy sources depending on their availability in the exploration area.

A simple example from a hybrid energy system that integrates geothermal and solar power in one generating system

[30] Y. Sakai, "Advanced geothermal steam turbines," *Advances in Steam Turbines for Modern Power Plants*, 1 January 2017, 455–86, https://doi.org/10.1016/B978-0-08-100314-5.00019-1.

[31] Adam E. Malek dkk., "Techno-economic analysis of Advanced Geothermal Systems (AGS)," *Renewable Energy* 186 (1 March 2022): 927–43, https://doi.org/10.1016/j.renene.2022.01.012.

[32] Abdul Ghani Olabi dkk., "Geothermal based hybrid energy systems, toward eco-friendly energy approaches," *Renewable Energy* 147 (1 March 2020): 2003–12, https://doi.org/10.1016/j.renene.2019.09.140.

can be learned. Solar thermal collectors can generate additional thermal energy to cover the deficit of the geothermal system.[33] In addition, it can also be used to stabilize the geothermal system, while geothermal energy can be used as a second heat source to support solar power generation. This combination is generally called Solar Assisted Ground Source Heat Pump (SAGSHP). This system can reduce annual operating costs, increase overall efficiency by 3.6%, and reduce carbon emissions even though the initial capital required is very significant compared to the system.[34]

4. *Supercritical Geothermal System* (SGS)

Supercritical geothermal systems are characterized mainly by very high temperatures and natural reservoirs containing fluids in a supercritical state (e.g., water at a temperature of at least 374° Celsius and a pressure of at least 221 bar). These systems (and others that flow water through rocks at temperatures above 400° Celsius) are called "superhot rock" systems.[35]

Accessing affordable superheat resources could transform the electricity industry but will require drilling and reservoir engineering innovations. The injected water is superheated. The superfluid, which scientists call "supercritical" water, can penetrate fractures more quickly and flow more easily through

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[33] Valentin Trillat-Berdal, Bernard Souyri, and Gilbert Achard, "Coupling of geothermal heat pumps with thermal solar collectors," *Applied Thermal Engineering* 27, no. 10 (July 2007): 1750–55, https://doi.org/10.1016/j.applthermaleng.2006.07.022.

[34] Scott Hackel and Amanda Pertzborn, "Effective design and operation of hybrid ground-source heat pumps: Three case studies," *Energy and Buildings* 43, no. 12 (December 2011): 3497–3504, https://doi.org/10.1016/j.enbuild.2011.09.014.

[35] Keigo Kitamura dkk., "Evaluation of a potential supercritical geothermal system in the Kuju region, central Kyushu, Japan," *Geothermics* 107 (1 January 2023), https://doi.org/10.1016/j.geothermics.2022.102602.

wells to the surface—roughly five to ten times the energy produced by current commercial geothermal wells or what is predicted for low-temperature engineered wells. This means that a few wells of superhot rock could bring substantial commercial energy to the surface. Such systems would be well suited to volcanic hydrothermal resources. Supercritical geothermal systems face several technical challenges. Fluids with high enthalpy (heat of reaction) are often highly corrosive.[36]

Geothermal Generation Technology

As previously explained, geothermal power generation technology is divided into three types based on the geothermal characteristics or the type of fluid produced: Dry Steam Power Plants, Flash Steam Power Plants, and Binary Cycle Power Plants.[37]

Dry Steam Power Plants is the first type to be developed. This type is usually used in reservoirs dominated by hot steam with temperatures above 225° Celsius. This system does not use a separator, so the hot steam is directly directed to the turbine to activate the generator so that it can work to produce electricity. The remaining heat from the production well is channeled back into the reservoir through the injection well. This oldest power plant was first used in Lardarello, Italy, in 1904, and it still functions well. In the United States, dry steam power is still used,

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[36] Mateo Acosta, Benoit Gibert, and Marie Violay, "From brittle to ductile deformation in the continental crust: Mechanics of crystalline reservoirs and implications for hydrothermal circulation," dalam *Proceedings World Geothermal Congress* (Reykjavik: Research Gate, 2020), https://www.researchgate.net/publication/351458674.

[37] Moediyono, "Pembangunan Pembangkit Listrik Tenaga Panas Bumi," *Gema Teknologi* 16, no. 1 (April 2010): 5–10.

as in Geysers, Northern California.[38] In Indonesia, this system is applied in the Kamojang GPP.[39]

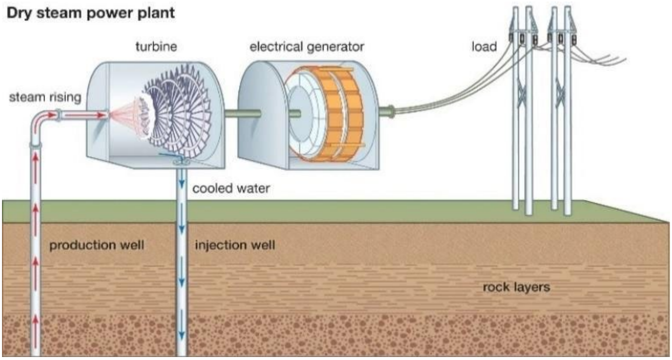

Image 8. Illustration of Dry Steam Power Plants

Flash Steam Power Plants type is a geothermal power generation system where the fluid is dominated by water with a temperature above 170°-225° Celsius. Unlike Dry Steam, this technology uses a separator to separate hot water and steam. Furthermore, the separated hot steam flows into a steam tank with a lower pressure so that hot steam can be produced quickly to drive a turbine that can drive a generator to generate electricity. Unused hot water will be re-injected into the reservoir through an injection well. Examples of Flash Steam Power Plants are the Dieng GPP in Wonosobo, Central Java, and Cal-Energy Navy I

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[38] Ibrahim Dincer and Hasan Ozcan, "Geothermal Energy," dalam *Comprehensive Energy Systems*, ed. oleh Ibrahim Dincer (Oxford: Elsevier, 2018), 702–32, https://doi.org/https://doi.org/10.1016/B978-0-12-809597-3.00119-X.

[39] Ice Fahmi dkk., "Peran Teknologi Pada Pembangkit Listrik Tenaga Geothermal Guna Mendukung Tercapainya Net Zero Emission (NZE)," *Jurnal Kewarganegaraan* 6, no. 2 (2022).

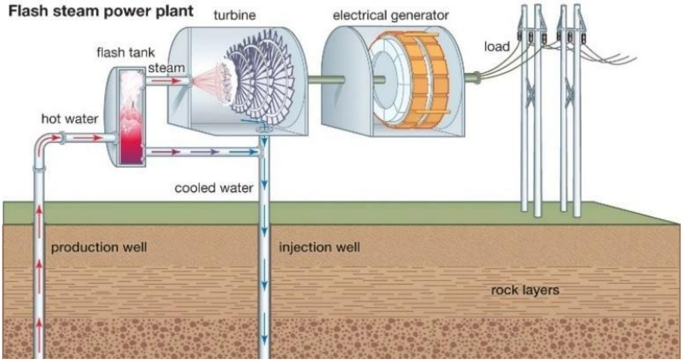

Image 9. Illustration of Flash System Power Plants

flash geothermal power plants in the Coso Geothermal Field, California, United States.[40]

Unlike the technology in the two previous types of geothermal generators, the binary cycle system uses hot water from a reservoir. Water from the reservoir will be channeled to the power plant circuit through pipes, and the hot water will then be distributed to each generator in the interconnected power plant circuit. Each generator will produce its power simultaneously. In this binary system, the reservoir water does not come into contact with the turbine, but its heat is transferred to the secondary working fluid as it passes through the coil in the tank. Because the secondary working fluid has a lower boiling point than water, this fluid will produce steam quickly, and the steam will be channeled to the turbine, which will rotate the shaft on the generator to produce electricity. Hot water passed through the power plant circuit will be channeled back to the reservoir through injection wells to be reheated by magma. This Binary Cycle Power Plant is a closed system. So, no waste is released into the

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[40] Chijindu Ikechukwu Igwe, "Geothermal Energy: A Review," *International Journal of Engineering Research and Technology* 10, no. 3 (2021): 655–61, www.ijert.org.

atmosphere during production. The advantage of Binary Cycle Power Plants is that they can be operated at lower temperatures, namely 90-175° Celsius.[41]

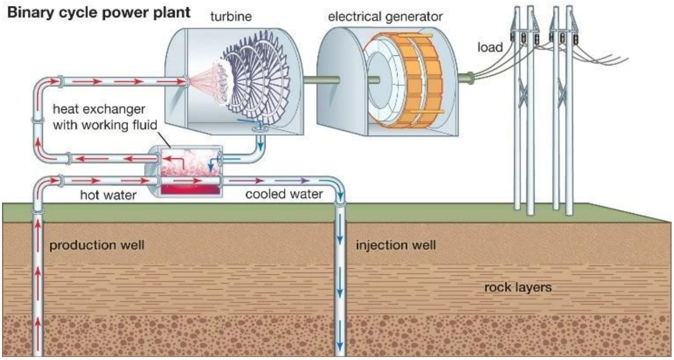

Image 10. Illustration of Binary Cycle Power Plants

[41] M. El Haj Assad, E. Bani-Hani, and M. Khalil, "Performance of geothermal power plants (single, dual, and binary) to compensate for LHC-CERN power consumption: comparative study," *Geothermal Energy* 5, no. 1 (1 December 2017), https://doi.org/10.1186/s40517-017-0074-z.


PART 3.
GEOTHERMAL DISCOURSE IN A JUST ENERGY TRANSITION AGENDA

Misconceptions about energy transition have almost become a common view, often promoted by policymakers at the national and global levels. The meaning of energy transition, which is only limited to changing the use of fossil-based energy sources that are not environmentally friendly to non-fossil, has negated the work of the fragile and problematic energy supply chain system and is prone to crises.

Indonesia has experienced a massive energy transition process since the 1970s. Due to the unstable global situation caused by war and domestic dynamics, the policy of switching from oil-based energy to gas and coal became the government's strategic choice. The acceleration of infrastructure development is high, which in turn has significant social, economic, and environmental impacts. Reflecting on this experience, the development and utilization of new renewable energy, especially geothermal, must prioritize the principle of caution so as not to cause the same problems in the future.

The use of geothermal energy in Indonesia has only reached 5% of the total target set. However, it has caused many problems, such as land grabbing, technological failure, and pollution residents feel around the GPPs. This is a bad precedent in the energy system that has the potential to cause multidimensional problems. This situation is inseparable from the discourse and criticism developing toward the choice of geothermal as a renewable energy commodity. The following is an explanation of the developing discourse.

Responding to Geothermal's Claim of Low Emission Energy

Geothermal energy is generally considered low-emission because it produces less carbon than other renewable energy plants, thus reducing the rate of global warming. However, this statement is not entirely true.

Areas with potential geothermal generally produce natural greenhouse gases such as Carbon Dioxide (CO2) and Methane Gas (CH4). The discussion below will focus on CO2, which PLTP makes the highest compared to other gases.

There are at least three main sources of CO2. First, CO2 in geothermal reservoirs comes from the same source as the geothermal fluid. The fluid is dissolved in the refill fluid, seawater, or meteoric water (rain) when entering the heating system. Second, most CO2 comes from chemical reactions between the dominant igneous rocks in volcanic geothermal systems and fluids. Finally, CO2 can enter geothermal reservoirs from below, either from deep crustal or mantle sources or from magma bodies, the heat source of volcanic geothermal systems.[42] This natural greenhouse gas can be exposed outside during the exploration and pre-production of geothermal energy.[43]

At the operating stage of the GPP, the emissions produced range from 2 to 20 gCO2e/kWH, assuming a project lasting 30 years. This also aligns with a global study of 85 GPPs operating in 2021 in 11 countries with a total generating capacity of 6,648 MW. The study showed that the range of CO2 emissions was between 4 and 740 gCO2e/kWh, and globally, the average emission factor produced was 122 gCO2e/kWh. CO2 emission data from California's geothermal power plants for 2011-2013 also showed that the CO2 emission factor ranged from 150 to 300 gCO2e/kWh with an average of 245 gCO2e/kWh.[44]

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[42] Thráinn Fridriksson dkk., "Greenhouse Gas Emissions from Geothermal Power Production," dalam *42nd Workshop on Geothermal Reservoir Engineering* (Standford Unversity, 2017).

[43] Halldór Ármannsson, "CO2 emission from geothermal plants," dalam International Geothermal Conference (Yeykjavik: Research Gate, 2003), 56–62, dapat diakses melalui: https://www.researchgate.net/publication/228405084.

[44] Alimuddin dkk., "Analysis of CO2 Emissions from Geothermal Power Plant Ulubelu and Its Contribution to Development of Electricity Generators in

This emission production is indeed relatively small when compared to other renewable energy sources, especially fossil energy, especially coal. However, the accumulation of emission production, which is considered smaller, does not take into account the natural absorption capacity that decreases due to land clearing for the construction of GPP, which is located in areas with good carbon absorption capacity.

In Indonesia, this essence is overlooked so that the regulation that stipulates geothermal energy is no longer considered a mining operation and legalizes PLTP to be built in conservation areas as stated in Law (UU) Number 21 of 2014, Government Regulation (PP) Number 108 of 2015, and Regulation of the Minister of Environment and Forestry (Permen LHK) Number P.46/Menlhk/Setjen/Kum.1/5/2016 which is not by the spirit of moving towards net zero emissions that requires emission reduction efforts to be carried out at a level that can be absorbed naturally.

Recently, Law Number 32 of 2024 concerning the Conservation of Biological Natural Resources and Ecosystems (UU KSDAHE) was passed on July 9, 2024, which reaffirms that conservation areas can be used for geothermal exploration and exploitation.[45]

Geothermal and the "Green Sacrifice Zone"

This reflects the energy transition from oil to coal in the 1980s when coal mining concessions and the construction of steam power plants proliferated throughout Indonesia. Along with that, ecosystem damage, pollution, clean water crisis, land grabbing, and agrarian conflicts, disasters that caused misery for many people, occurred from upstream to downstream. This does

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Lampung Province," *Jurnal Pengelolaan Sumberdaya Alam and Lingkungan* 9, no. 2 (6 October 2019): 287–304, https://doi.org/10.29244/jpsl.9.2.287-304.

[45] Satrio Manggala, "Opini: Aturan Konservasi yang Mengancam Masyarakat Adat," Koran Tempo, 16 August 2024, https://koran.tempo.co/read/opini/489554/masyarakat-adat-dan-uu-konservasi.

not include social problems that emerged as a follow-up impact, such as poverty, increasing prostitution, the emergence of child labor, violence against women, population migration, and so on. Those impacts are similar to renewable energy projects such as geothermal.

Measuring and evaluating the energy transition only on the contribution of greenhouse gas reduction has provided a partial understanding of the broad impacts, especially on local communities and ecosystems. Infrastructure development in the energy sector has been criticized since its inception. The need for extensive land and natural resources to support energy production has required areas to be sacrificed or compromised to meet energy supply targets. This is called the “green sacrifice zone”, a general term referring to local negative impacts related to extractive practices with an environmentally friendly label.

The Ministry of Environment and Forestry (KLHK) stated that 330 geothermal potential locations in Indonesia are in forest areas, production forests, protected forests, and conservation forests.[46] In West Java, for example, based on the Ministry of Energy and Mineral Resources report, 649,911 hectares have been released as Geothermal Working Areas (WKP) for the construction of GPPs in 11 spots with a total capacity of 700 MW. The WKP is in conservation forests, protected forests, production forests, and other public areas.[47]

Water is also a vital resource for GPP. Its system uses water for cooling and re-injection. At least 1,700 to 4,000 gallons of water per megawatt per hour are needed. Although the development of GPP is claimed to be able to use geothermal

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[46] Kementerian Lingkungan Hidup and Kehutanan, “Siaran Pers: Pemanfaatan Panas Bumi untuk Kesejahteraan Rakyat,” ppid.menlhk.go.id, 9 March 2017, dapat diakses melalui https://ppid.menlhk.go.id/siaran_pers/browse/556.

[47] Iwan Gunawan, Jaka Windarta, and Udi Harmoko, “Overview Potensi Panas Bumi di Provinsi Jawa Barat,” *Jurnal Energi Baru and Terbarukan* 2, no. 2 (5 July 2021): 60–73, https://doi.org/10.14710/jebt.2021.11072.

fluids or groundwater, not all water released from the reservoir is re-injected because some is lost as steam. Outside water must still be used to maintain a constant volume of water in the reservoir. This post-utilization water injection is important to maintain soil stability so that there is no threat of land subsidence.[48] Land subsidence has been recorded in several geothermal areas such as in Wairakei, New Zealand, land subsidence reaches 400 mm per year, while in Svartsengi, Iceland, land subsidence occurs around 10 mm per year, and in Larderello, Italy, land subsidence reaches 250 mm per year.[49]

Geologically, the threat posed is land subsidence and increased risk and frequency of more intense earthquakes. This experience occurred in Pohang, South Korea, in 2017, where a 5.5 magnitude earthquake triggered by a geothermal project of the Enhanced Geothermal System (EGS) type injured dozens of people and forced more than 1,700 people to evacuate.[50] A similar thing also happened in Basel, Switzerland 2006, where a high-powered underground water pump during exploration triggered a 3.4 magnitude earthquake that caused physical damage. Even after the activity was stopped, thousands of small earthquakes continued.[51]

In addition, the construction of the GPP also causes noise pollution from drilling activities during the exploration stage. This experience was felt by the Indigenous people in Wapsalit Village,

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[48] Union of Concerned Scientists, "Environmental Impacts of Geothermal Energy," uscusa.org, 5 April 2013, dapat diakses melalui https://www.ucsusa.org/resources/environmental-impacts-geothermal-energy.

[49] Hrefna Kristmannsdóttir and Halldór Ármannsson, "Environmental aspects of geothermal energy utilization," *Geothermics* 32, no. 4–6 (2003): 451–61, https://doi.org/10.1016/S0375-6505(03)00052-X.

[50] Josie Garthwaite, "Lessons from Pohang," Standfort Report, 23 May 2019, dapat diakses melalui https://news.stanford.edu/stories/2019/05/lessons-south-korea-solving-geothermals-earthquake-problem.

[51] Sarah Freeman, "Geothermal energy could save the planet. But watch for earthquakes," Wired, 24 March 2021, dapat diakses melalui https://www.wired.com/story/swiss-rock-lab/.

Buru Island, Maluku, in April 2024—geothermal exploration by PT. Ormat, which is very close to the traditional village, has caused vibrations and explosions that are thought to have come from the construction of geothermal wells. The frightened community was forced to flee to a place 10 km from the village, which was reached by walking through the forest and bushes and crossing the river at night.[52]

Geothermal power plants can also cause environmental pollution. In an open-loop geothermal power plant system, for example, the gases produced can also be Ammonia (NH3), Boron (B), and Hydrogen Sulfide (H2S), which have the potential to cause chemical reactions in the atmosphere to become sulfur dioxide (SO2) which results in acid rain that contaminates water, damages plants, soil, and acidifies lakes and rivers. Although the release of SO2 is relatively small, its accumulation is still dangerous for environmental health. In addition, geothermal power plants also have the potential to produce mercury in small amounts. Scrubbers, which are components of geothermal power plants, can reduce air pollution but produce watery mud that traps sulfur, vanadium, silica compounds, chlorides, arsenic, mercury, nickel, and other heavy metals.[53] These elements can become dangerous sedimentation or flow into water sources that humans and other living things use.

Geothermal projects have transformed into new extraction, processing, application, and disposal forms that pollute ecosystems, adversely affecting biodiversity, habitats, functioning ecosystems, and subsequent impacts on air and water quality and human health. The risks and threats posed by

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[52] Edison Waas and Christ Belseran, "Kala Proyek Panas Bumi Ancam Ruang Hidup Masyarakat Adat di Pulau Buru," Mongabay, 30 April 2024, https://www.mongabay.co.id/2024/04/30/kala-proyek-panas-bumi-ancam-ruang-hidup-masyarakat-adat-di-pulau-buru/.

[53] National Research Council, *Hidden costs of energy : unpriced consequences of energy production and use* (Washington: National Academies Press, 2010), https://www.ourenergypolicy.org.

geothermal power plant development, such as land grabbing, marginalization of indigenous peoples from their customary territories, threats of drought, environmental pollution, and disasters due to ecological damage or technological failure, have made public acceptance of geothermal projects low. This has also given rise to rejection in several regions of Indonesia.

Unconsidered Losses in Geothermal Projects

The Ministry of Energy and Mineral Resources (ESDM), through the Directorate General of New, Renewable Energy, and Energy Conservation (EBTKE), stated that through geothermal business activities, developers have deposited a production bonus of IDR 185.18 billion for the period 2014 to the second quarter of 2018. Geothermal developers must deposit this production bonus to the Producing Regional Government. There are 25 regencies/cities recorded as producing regions that have received production bonuses, and the Bandung Regency Government is the largest recipient, with Rupiah 79.06 billion.[54] This is undoubtedly good news for several parties, but not for those sacrificed by the project.

Indonesia is one of the developing countries that has relied on its local, regional, and national economy for the extractive industry. Unsurprisingly, geothermal energy is in great demand to meet energy needs. Various supporting arguments are built to support this dependence pattern, especially those related to investment opportunities and economic benefits. Meanwhile, the negative consequences felt by parties not directly related to the geothermal system, such as the community and ecosystem components, are never considered.

The environmental conditions that become uninhabitable due to geothermal exploitation are one of the most impacts felt by

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[54] Humas EBTKE, "Pemerintah Daerah Raup 185 Miliar dari Bonus Produksi Panas Bumi," , 6 November 2018, https://ebtke.esdm.go.id/post/2018/11/06/2050/pemerintah.daerah.raup.185.miliar.dari.bonus.produksi.panas.bumi.

local communities, including indigenous peoples, women, children, people with disabilities, and other vulnerable groups. The challenges these groups face are often greater than others, such as increased difficulty in accessing clean water, increased health risks from pollution, and disruption of sustainable livelihoods.

Indigenous communities, who have strong ties to the land and the environment, often lose access to natural resources that they have relied on for generations. This threatens their economic survival and the continuity of their culture, identity, and knowledge.

Due to polluted environments, women, who are usually responsible for household management and family care, may have to travel longer distances to obtain clean water or food. This not only increases the workload but also reduces the time available for other activities, such as education or participation in economic activities. Children may suffer long-term health problems from exposure to pollution and may also experience disruptions in their education if families have to move to another area.

People with disabilities and other vulnerable groups also face significant impacts, such as reduced accessibility to health services and limited basic infrastructure. In many cases, specific needs are often overlooked in the planning and implementing geothermal projects, increasing the risk of further marginalization.

Although production bonuses given to local governments may increase revenues and provide short-term benefits, unaccounted impacts on society and the environment can result in much greater costs in the long term. Therefore, it is important to consider a more holistic and inclusive approach beyond mitigation-at-all-costs in geothermal project development, where the well-being of all community members, including the most vulnerable, should be a top priority in the planning and implementation process.

PART 4.
LESSON LEARNED FROM SEVERAL GEOTHERMAL POWER PLANT PROJECTS

Sarulla Geothermal Project: Sulfur in Rice Fields and Gardens to Terrifying Explosions

Sarulla Geothermal Power Plant is developed in two locations, namely the Silangkitang (SIL) project with a development capacity of 1x110 MW (Unit I) and the Namora - I - Langit (NIL) project with a development capacity of 2x110 MW (Units II and III). This project is located in the Mount Sibual-built Geothermal Working Area (WKP), with an area of 437,458 hectares. In the 2019 Sarulla booklet, the construction of the Sarulla Geothermal Power Plant began in May 2014 and began operating in March 2017 with a generating capacity of 330 MW and a total project value of USD 1.7 billion.[55] Of the total project costs, the Sarulla GPP obtained a loan from the Bank for International Cooperation (JBIC) and the Asian Development Bank (ADB) worth USD 1 billion. Sarulla Operations Ltd., a consortium of Medco Power Indonesia, Itochu Corporation, Kyushu Electric Power Company, and Ormat Internasional, manages the Sarulla Geothermal Power Plant.[56]

Sarulla GPP is a power plant that uses Binary Cycle technology to manage geothermal fluids with temperatures reaching 100° to 200° Celsius and pressures reaching 6-14 Bar. Geothermal fluids in Sarulla come from two-phase production

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[55] Sarulla Operations Ltd., "Informasi Proyek PLTP Sarulla," Booklet Sarulla, 2019, dokumen dapat diakses melalui sarullaoperations.com/images/lookup/6149b705ddc961632220933.pdf.

[56] Nisrina Syafa Hanifah, "Mengenal PLTP Sarulla, Proyek Energi Panas Bumi Terbesar di Dunia," goodnewsfromindonesia.id, 2023, diakses melalui https://www.goodnewsfromindonesia.id/network/content/mengenal-pltp-sarulla-proyek-energi-panas-bumi-terbesar-di-dunia-51lQEP.

wells: the gas phase (steam) and the hot water phase, which are separated using a separator.[57]

The construction of the Sarulla GPP has been rejected by the Toba community around the project site, with more than 80% of the work as farmers. However, in the Environmental Impact Analysis document released by Pertamina Geothermal Energy and Sarulla Operations Ltd, it is claimed that a survey conducted in 2009 stated that 94.4% of the community in Pahae Julu and 93.3% of the Pahae Jae community gave an optimistic response to the GPP construction because it can provide employment opportunities for the surrounding community who have a reasonably high workforce.[58]

This perception contrasts the factual conditions where the construction of the Sarulla GPP inflicts social conflict. This is because the project is considered high risk and can cause environmental degradation, impacting the community's economic decline, which has depended on healthy ecological conditions. The government ignored the community's rejection, and the Sarulla Geothermal Power Plant construction was forced to continue. The community's concerns were proven. Two years after the Sarulla GPP operated, the community experienced significant crop failure. The plants were burnt, and sulfur-scented foam emerged from holes in the community's rice fields. The sulfur smell was powerful and had entered the community's villages. This impact was felt up to a radius of 20 km from the Sarulla GPP.[59]

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[57] Jonius Christian Harefa and Nazaruddin Sinaga, "Tinjauan Singkat Sistem PLTP Siklus Gabungan Sarulla Menggunakan Ormat Energy Converter," *Jurnal Mineral, Energi, and Lingkungan* 6, no. 2 (2022): 8–14.

[58] Pertamina Geothermal Energy and Sarulla Operations Ltd, "Environmental Impact Statement: Development of Sarulla Geothermal Field and Power Plant of 330 MW Capacity" (Sumatera Utara, August 2009), https://www.adb.org/sites/default/files/project-documents/42916-01-ino-eia-02.pdf.

[59] Della Syahni, "Keluhan Seputar Pembangkit Panas Bumi, Ada Omnibus Law Khawatir Perburuk Kondisi," Mongabay, 12 September 2020,

Not only the losses experienced due to disruptions in the community's lives and livelihood. Sarulla GPP has also experienced incidents in the systems and technology used. In 2015, an explosion occurred during a geothermal OK test in Silangkitang at 01.00 in the morning. The blast made a loud noise and thick smoke, causing panic among the surrounding community because they were afraid that the smoke contained poison. This incident caused anger among the surrounding community until a fight broke out with GPP officers.[60] This incident was not the last. In 2019, another explosion occurred at Unit 1 Silangkitang GPP, which was identified as originating from a hose leak and pentane burning from the heat from a portable generator used for additional lighting near the hose when the contractor released the pentane.[61] This incident resulted in 1 person dying and two people being injured.[62] Due to the impact experienced by the community and the two incidents that occurred, the community around Sarulla GPP demanded that the government stop operating Sarulla GPP before the effect gets bigger and the number of fatalities increases.

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https://www.mongabay.co.id/2020/09/12/keluhan-seputar-pembangkit-panas-bumi-ada-omnibus-law-khawatir-perburuk-kondisi/.

[60] Feriansyah Nasution, "Ledakan Proyek PLTP Sarulla Buat Warga Panik," Tribun News, 23 April 2015, https://medan.tribunnews.com/2015/04/23/ledakan-proyek-pltp-sarulla-buat-warga-panik.

[61] Sarulla Operations Ltd., "Siaran Pers Sarulla Operations Ltd: Insiden di PLTP Uni 1 Silangkitang," *Sarulla Operations* (Jakarta, 27 May 2019), https://sarullaoperations.com/media/press-release/5ceb8e6e4fa311558941294.pdf.

[62] Robert Fernando Siregar, "Sumur Bor PLTP Sarulla Meledak, Satu Karyawan Tewas," Oke Zone, 5 March 2019, https://news.okezone.com/read/2019/03/05/340/2026183/sumur-bor-pltp-sarulla-meledak-satu-karyawan-tewas.

Salak Mountain Geothermal Project: Three Overlooked Active Faults

Pertamina Geothermal Energi and Star Energy Geothermal Salak manage Salak GPP. The current installed capacity of Salak GPP is 377 MW, divided into six generating units with a total WKP area of 102,200 hectares. This WKP is located in conservation forests, protected forests, production forests, and most in public or other places. The Salak geothermal system is in a mountainous area with an altitude range of 950 to 1500 MDPL. In the western part of the Salak geothermal, there is the Cianten Caldera, which is an older volcano.[63] From the six generating units operated, units 1-3 supply steam for the generator operated by PT. Indonesia Power, while Units 4-6 are operated independently to supply electricity sold to PLN.[64] To gain support for the Salak GPP project, Star Energi Geothermal set the value of guaranteed green bonds at USD 1.11 billion, divided into two phases, namely USD 320 million, with a coupon rate of 3.25%, with a term of 8.5 years (due in April 2029) and USD 790 million with a coupon rate of 4.85%, with a term of 18 years (due in October 2038).[65] Both stages are listed on the Singapore Exchange Securities Trading Limited. Credit Suisse, DBS Bank Ltd, and Deutsche Bank are the Joint Global Coordinators for this transaction and are assisted by Barclays as Joint Bookrunners and BPI Capital as Co-Manager

The Salak geothermal system is a reservoir dominated by high-temperature water with temperatures exceeding 240° to

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[63] Iwan Gunawan, Jaka Windarta, and Udi Harmoko, "Overview Potensi Panas Bumi di Provinsi Jawa Barat," *Jurnal Energi Baru and Terbarukan* 2, no. 2 (2021): 60–73, https://doi.org/10.14710/jebt.2021.11072.
[64] Star Energy Geothermal Salak Ltd., "Laporan Keberlanjutan 2020: Reliable Operation During Pandemic" (Jakarta, 2020), dokumen dapat diakses di https://www.starenergygeothermal.co.id/wp-content/uploads/2021/07/SR-SE-SALAK2020-WEB-1607.pdf.
[65] Star Energy Geothermal, "Star Energy Geothermal Group Menghimpun Dana Sebesar US$ 1,11 Miliar dari penerbitan Green Bond," www.starenergygeothermal.co.id, 20 October 2020.

316° Celsius with pressures reaching 175 Bar and high release enthalpy of up to 1,465 kJ/Kg).[66] Salak PLTP exploits geothermal energy through wells with depths reaching 6,665 ft (2,032 m).[67]

Drilling activities at the Salak GPP have triggered seismic activity in the form of high-intensity and frequency earthquakes. This is because the Salak geothermal area is located in an area prone to high and medium earthquakes that are crossed by three active faults.[68] Residents on the slopes of Mount Salak have complained about earthquakes that have occurred more frequently since the Salak GPP began operating. This indication was seen in the 3.2 magnitude earthquake on October 12, 2023. It was found that the earthquake's epicenter was located right in the middle of the geothermal extraction installation of the Salak GPP. Therefore, the community asked the Meteorology, Climatology, and Geophysics Agency (BMKG) to investigate the relationship between the Salak Geothermal Power Plant and increased earthquakes.[69]

In addition, the existence of the Salak GPP also does not provide a good economic impact on the surrounding community. The management claims to have offered social accountability funds to the sub-districts around the GPP area. Also, 60 to 80 billion production bonus funds have been distributed to the

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[66] Glenn U. Golla dkk., "The Salak Field, Indonesia: On to the next 20 years of production," *Geothermics* 83 (1 January 2020), https://doi.org/10.1016/j.geothermics.2019.101715.

[67] Frederick Libert, "Evaluation of the Deepest Production Well in Salak Geothermal Field, Indonesia," dalam *Proceedings The 5th Indonesia International Geothermal Convention and Exhibition (IIGCE)* (Jakarta: Research Gate, 2017), https://www.researchgate.net/publication/319001433.

[68] Raden Ariyo Wicaksono, "Pascagempa Gunung Salak, BMKG Diminta Terbitkan Bahaya Geothermal," Betahita, October 2023, https://betahita.id/news/detail/9388/pascagempa-gunung-salak-bmkg-diminta-terbitkan-bahaya-geothermal.html?v=1697664337.

[69] Jaringan Advokasi Tambang (JATAM), "Surat Terbuka Kepada BMKG," Jatam (Jakarta: Jatam.org, 17 October 2023), dapat diakses melalui https://jatam.org/wp-content/uploads/2023/10/Surat-Terbuka-BMKG-17-October-2023_tembusan.pdf.

Sukabumi Regency Government (Pemkab) with a proportion of 30% and the Village Government (Pemdes) with a proportion of 70%.[70] However, the community does not feel the budget. The Kabandungan and Kalapanunggal sub-districts, which are 'poverty areas' in Sukabumi, for example, instead of feeling the benefits from the development of Salak GPP, the community is becoming more vulnerable due to the increasing potential of earthquakes occurring amidst the extreme poverty conditions.[71]

Wayang Windu Geothermal Project: Cibitung Village is now Only a Name

Wayang Windu is a Joint Operation Contract (JOC) project between Star Energy Geothermal and PT. Pertamina will develop geothermal resources in 146,500 hectares (36.67 km x 39.95 km) based on the Decree of the Minister of Energy and Mineral Resources No. 76K/034/M.PE/1989, dated January 25, 1989.[72] The energy sales agreement between Star Energy Geothermal, PT Pertamina, and PT. PLN includes the right to develop electricity up to 400 MW for 42 years. The first unit of Wayang Windu Geothermal Power Plant, which has a power generation capacity of 110 MW, was completed in 1999 and has been producing at full capacity since 200. Then, the second unit of Wayang Windu Geothermal Power Plant, with a power generation capacity of 117 MW, began operating in March 2009. In total, Wayang Windu Geothermal Power Plant currently

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[70] Afdhalul Ikhsan and Aprillia Ika, "Warga Sekitar Gunung Salak Dapat Bonus Produksi Panas Bumi," Kompas, 9 September 2021, https://regional.kompas.com/read/2021/09/09/194350078/warga-sekitar-gunung-salak-dapat-bonus-produksi-energi-panas-bumi?page=all.

[71] Ferry, "Berharap Panas Geothermal Gunung Salak di Lumbung Kemiskinan Sukabumi," Independen.id, 13 March 2024, https://independen.id/berharap-panas-geothermal-gunung-salak-di-lumbung-kemiskinan-sukabumi.

[72] Djati Murjanto, "Mampukah Menjawab Program Percepatan Energi di Indonesia?," *Warta Mineral, Batubara, and Panas Bumi* (Jakarta, 7 August 2010), www.djmbp.esdm.go.id.

supplies 227 MW of electricity to the electricity transmission network of PT. PLN in Java, Madura, and Bali.[73]

The Wayang Windu geothermal field is located in a unique reservoir, which is a transition from steam and water dominance in an area of 40 square kilometers. This is one of the very large potentials.[74] The current installed capacity is 227 MW or 16 percent of geothermal production for national electricity.[75]

The construction of the Wayang Windu GPP became a milestone for massive damage in the surrounding area, a quaternary volcanic zone of Java where volcanic and magmatic activity is very high. Mount Wayang Windu is also located above the Garsela fault or fracture. This active fault structure stretches 42 kilometers from Garut's south to Bandung's south. The Cibitung community felt the culmination of the damage on May 5, 2015, at 14.30 WIB. The high rainfall in the Pangalengan area could no longer be accommodated by the slopes that had been converted. Landslides were unavoidable. The National Disaster Management Agency (BNPB) recorded six people dead, three people missing buried, six people seriously injured, seven people lightly injured, and 170 people relocated. A total of 32 houses were buried, burying the Cibitung village. The Cibitung village is now only a name.[76]

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[73] Fridolin Malau, "Analisis Manfaat Biaya Pembangkit Listrik Tenaga Panas Bumi: Studi Kasus PLTP Wayang Windu," dalam *Economics Student Conference*, ed. oleh Billy Cancerio dkk. (Bandung: Universitas Katolik Parahyangan, 2022).

[74] Riostantieka Mayandari Shoedarto dkk., "Application of Rare-Earth Elements in Spring Waters to Indicate Surficial Water-Rock Interaction Process in the Wayang Windu Geothermal Field, Indonesia," dalam *Proceedings World Geothermal Congress* (Reykjavik: Research Gate, 2020), https://www.researchgate.net/publication/364209651.

[75] Silvita Agmasari, "Wayang Windu Bagian Dari Potensi Panas Bumi Dunia," National Geographic, 5 August 2016, https://nationalgeographic.grid.id/read/13306201/indonesia-wayang-windu-bagian-dari-potensi-panas-bumi-dunia.

[76] Muhammad Akmal Firmansyah, "Geothermal and Sebuah Kampung yang Hilang di Pangalengan," Bandung Bergerak, 17 November 2023,

After constructing the Wayang Windu GPP, the surrounding community felt the intensity of small earthquakes increasing. It was difficult to distinguish between tectonic earthquakes and vibrations caused by geothermal well drilling activities. Landslides have become a common sight for the community. To prevent disasters from occurring, the community has made efforts ranging from planting trees for years to anticipate landslides to performing rituals to ward off disaster. However, the community was unable to prevent the disaster. The landslide submerged Cibitung Village and triggered a technological failure at the Wayang Windu GPP. The landslide also hit the Wayang Windu PLTO pipeline, which caused the steam line to break and cause a large explosion.[77]

After the disaster, the people of Cibitung Village were forced to build houses in new locations. They sold their livestock to build homes and covered the remaining costs by applying for bank loans. Meanwhile, people who did not have sufficient resources had to rent houses. Instead of taking responsibility, the company and the government were busy denying that the operation of the Wayang Windu GPP did not trigger the landslide.

Lumut Balai Geothermal Project: From a Threat of Water Crisis to the Disturbed Sumatran Tiger

Lumut Balai PLTP is located in Panindayan Village, Semendo District, Muara Enim Regency, South Sumatra Province. The geothermal exploration area in Lumut Balai is 130 hectares. Exploration drilling activities in the unit I area started in 2007. This GPP began operating in 2019 with a capacity of 55 MW. PT. Pertamina Geothermal Energy (PGE) has completed

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https://bandungbergerak.id/article/detail/159084/geotermal-dan-sebuah-kampung-yang-hilang-di-pangalengan.

[77] DetikNews, "Ini Kata Star Energy Geothermal Soal Pipanya yang Meledak Akibat Longsor," Detik.com, 5 May 2015, https://news.detik.com/berita/d-2906764/ini-kata-star-energy-geothermal-soal-pipanya-yang-meledak-akibat-longsor.

this project, from geothermal field management to its power plant. In the core zone of the Lumut Balai area, there are drilling wells for geothermal exploration. Each well that has been tested has a capacity of around 15 MW. In addition to exploration wells, a center for converting heat energy into electricity was built in the Lumut Balai area.[78] At the end of 2023, PGE will work with SEPCO III Electric Power Construction Co., Ltd, Japan, through Mitsubishi Corporation and BUMN PT. Wijaya Karya Tbk. will build unit II with a capacity of 110 MW, which is targeted to be completed by the end of 2024.[79] In 2023, the Lumut Balai PLTP received funding from the Japan International Cooperation Agency (JICA) amounting to JPY26.966 billion or USD188.618 million.[80]

PGE has a Forest Area Borrow-Use Permit (IPPKH) in the Jambul Asahan Hill Forest conservation that covers 133.27 hectares. From exploration to geothermal exploitation by PGE, area conversion, and deforestation continue to occur. These activities include drilling geothermal wells, building and operating GPP, building road access, and other supporting infrastructure. These activities impact river water quality, vibrations from drilling activities, and a decrease in community economy production, most of whom are coffee farmers.

The Sepanas River is polluted by waste from Lumut Balai geothermal exploration activities. The water color has changed to

[78] Media Center Kementerian ESDM, "Mengenal PLTP di Indonesia (4): PLTP Lumut Balai Unggulan Sumatera Selatan," Kementrian ESDM RI, November 2009, https://www.esdm.go.id/id/media-center/arsip-berita/mengenal-pltp-di-indonesia-4-pltp-lumut-balai-unggulan-sumatera-selatan.

[79] Sultan Ibnu Affan, "PGEO Patok Pembangunan PLTP Lumut Balai Rampung Akhir 2024," Bloomberg Technoz, December 2023, https://www.bloombergtechnoz.com/detail-news/24251/pgeo-patok-pembangunan-pltp-lumut-balai-rampung-akhir-2024.

[80] Hermansyah, "JICA beri pendanaan US$188.618 juta kepada Pertamina Geothermal Energy," Alinea.id, 8 September 2023, https://www.alinea.id/bisnis/jica-beri-pendanaan-us188618-juta-kep-pertamina-geothermal-b2hXo9OoJ.

murky, and it is suspected to be contaminated with toxic waste. This condition makes it difficult to meet the needs of residents to access clean water.[81] The pollution comes from the sediment trap of the Lumut Balai GPP, which can no longer hold sediment due to the increasing intensity of rain, resulting in high levels of water turbidity. Not only that, the habitat of the Sumatran tiger is also disturbed due to the decreasing food for the animals.[82] Tigers also leave their habitat and appear in areas of human activity. Tigers also leave their habitat and appear in areas of human activity. In 2019, at least seven cases of tiger attacks occurred within a period of two months.[83]

Sokoria Geothermal Project: Behind the Success Story, There are Impoverished Farmers

Sokoria GPP is located in Ende Regency, East Nusa Tenggara. PT. Sokoria Geothermal Indonesia is a Special Purpose Company (SPC) formed by a Consortium of KS Orka Renewables Pte. Ltd. (Singapore) with 95% shares, PT. Bakrie Power (Indonesia) has 3% shares and PT. Energy Management Indonesia (Persero) currently has 2% shares—the PLTP developer, namely PT. Sokoria Geothermal Indonesia (SGI) has conducted drilling activities for five exploration wells centered on the Sokoria-Mutubusa (MTB) prospect location. The cost of developing the Sokoria GPP project with a capacity of up to 30 MW reached USD 212.85 million. The Sokoria GPP project has a

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[81] Gite, "Sungai Sepanas Diduga Tercemar Limbah PT PGE," Sumatra Ekspres, March 2024, https://sumateraekspres.bacakoran.co/read/41918/sungai-sepanas-diduga-tercemar-limbah-pt-pge-lumut-balai-cek-ke-lokasi/15.

[82] Taufik Wijaya, "Panas Bumi Sumatera Selatan, Antara Energi Bersih and Habitat Harimau," Mongabay, 10 March 2024, https://www.mongabay.co.id/2024/03/10/panas-bumi-di-sumatera-selatan-antara-energi-bersih-dan-habitat-harimau/.

[83] Anugrah Ardiansyah, "Akhir 2019, Serangan Harimau ke Manusia di Sumsel Meningkat," VOA Indonesia, 31 December 2019, https://www.voaindonesia.com/a/akhir-2019-serangan-harimau-ke-manusia-di-sumsel-meningkat/5226324.html.

WKP land area of 42,570 hectares (ha) as stipulated in the Decree of the Minister of Energy and Mineral Resources Number 1534 K / 30 / MM / 2008 and is also included in the Kelimutu National Park area and the surrounding production forest.

Regarding the technology applied, Sokoria GPP uses a system, namely a phased development model. This model was fully developed by KS Orka, one of the consortiums in Sokoria GPP, to minimize risks and operational costs, converting each well with a pressure of 4 bars or more into electricity. This reduces the risk of drilling wells that do not generate income and accelerates the development process, which only takes five years to reach the target capacity of 220 MW. Then, by using an expander instead of a turbine, the company can simplify energy conversion into electricity. The phased development model uses the concept of a modular power plant using technology from Kaishan Manufacture. Kaishan's power plant technology has high flexibility in terms of well characteristics. Wells with low pressure can still be used for power generation so that the subsurface risk, one of the biggest risks in geothermal development, can be minimized.[84]

However, behind the "success" story of the Sokoria GPP exploration, local communities are affected by the activity. The community complains that the water source that the community has used is polluted and becomes a threat. Residents' agricultural plantations are also affected, and plants are damaged. The growth of plants and fruits is disrupted. Therefore, no agricultural products can be harvested by the residents around the GPP area. The results of economic modeling conducted by CELIOS using the IRIO (Inter-Regional Input-Output) method project showed that the presence of GPP in three locations in East Nusa Tenggara (NTT), namely Wae Sano, Sakoria, and Ulumbu has

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[84] Ibnu Prabowo, "Model pengembangan bertahap KS Orka meningkatkan keberhasilan proyek panas bumi," Asian Power, 2023, https://asian-power.com/indonesian/exclusive/model-pengembangan-bertahap-ks-orka-meningkatkan-keberhasilan-proyek-panas-bumi.

risks in reducing farmers' income by Rupiah 470 billion during the construction phase.

Meanwhile, losses to economic output had reached IDR 1.09 trillion in the second year of the geothermal extraction process. Meanwhile, the number of workers is estimated to decrease from 20,671 people in the first year and 60,700 people in the second year. The tendency of capital-intensive geothermal projects does not have a multiplier impact on the local economy. On the contrary, for the local economy, geothermal is often seen as an obstacle to productivity in the agricultural and fisheries sectors.[85]

Lahendong Geothermal Project: Debunking the success of geothermal power plants (GPP)

Geothermal Lahendong is located in Tomohon, North Sulawesi. The Lahendong Geothermal Working Area (WKP) has 39 wells spread across 11 clusters, namely the Lahendong Region, with details of 14 production wells, six reinjection wells, and 19 monitoring wells. These wells are spread across units 1 to 4. In units 5-6, the power plant has 14 wells in five clusters in the Tompaso Region, with details of five production wells, four reinjection wells, and five monitoring wells. So, the total capacity of the Lahendong PLTP is 1,222 MW, and it has been operating under PT Geothermal Energi since 2009. The Lahendong geothermal project is co-financed by the Asian Development Bank (ADB) and the World Bank with a total financing of USD 500 million.[86]

Lahendong GPP has long been considered a successful GPP, not only in geothermal management but also in overcoming the social and environmental impacts around it. It is not surprising

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[85] CELIOS-WALHI, "Indonesia's Geothermal Challenges: Amidst Potential and Exploitation in the Name of Energy Transition."

[86] Luki Satrio, "ADB Salurkan 500 Juta Dolar untuk Listrik," Antara, 26 November 2009, https://www.antaranews.com/berita/163401/adb-salurkan-500-juta-dolar-untuk-listrik.

that local governments in other regions often use Lahendong GPP as a best practice for geothermal management, like the Ngada Regency Government, which brought Mataloko residents on a comparative study to Lahendong in 2021.[87] But that's the story on the surface. Lahendong GPP is not free from various social and environmental impacts caused by its operating system.

In 2005, residents of Lahendong, Tondangow, and Pangolombian sub-districts reported that pollution had affected approximately 10,000 people. This pollution is suspected to have come from exposure to H2S gas or other toxic substances. Also, the rice and vegetable plants had dried up and could no longer grow. Residents felt environmental pollution after the GPP operated. Residents suspect that this came from the hot steam emitted by the GPP. In March 2024, the Leilem community, Minahasa, again complained about the pungent odor from the Lahendong GPP geothermal drilling activities. The air pollution around the Lahendong PLTP activity area threatened the health of residents. The Minahasa Regency Health Office (Dinkes) appealed to the public to wear masks as a preventive measure against complaints of those health impacts. Therefore, the community demanded that the Lahendong GPP stop its activities.[88]

Not only complaints from the Leilem community but at almost the same time, the Tondangaw community and its surroundings also complained about the explosion sounds coming from drilling clusters 13 and 14. On that basis, the community filed demands to the Lahendong GPP, including that

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[87] Berita Energia, "Pemkab Ngada Laksanakan Studi Banding Pengelolaan Geothermal PGE di Sulawesi Utara," Pertamina.com, 21 October 2021, https://www.pertamina.com/id/news-room/energia-news/pemkab-ngada-ntt-laksanakan-studi-banding-pengelolaan-geothermal-pge-di-sulawesi-utara.

[88] Roni Sepang, "Soal Keluhan Terkait Dampak Pengeboran PT. PGE Lahendong, Warga Leilem Dihimbau Pakai Masker and Periksa Kesehatan," Kanal Metro, March 2024, https://kanalmetro.com/2024/03/26/soal-keluhan-terkait-dampak-pengeboran-pt-pge-lahendong-warga-leilem-dihimbau-pakai-masker-dan-periksa-kesehatan/.

the Management must provide information to the community regarding the well's opening and closing activities, as well as compensation for the impact of steam, H_2S, damage to houses, damage to agricultural land as previously reported. Also, the Regional Environmental Agency must conduct periodic monitoring in clusters 13 and 14 and inform the community of the monitoring results.[89]

[89] Lawra Sumilat, "Warga Tandongow Tuntut PGE Lahendong," Post Kota, 4 April 2024, dapat diakses melalui https://postkotanews.co.id/2024/04/warga-tondangow-tuntut-pgekompensasi-10-juta-per-kk/.

PART 5.
CONCLUSION – GEOTHERMAL ENERGY IS A FALSE SOLUTIONS

The current energy transition strategies focus on shifting from fossil fuels to non-fossil fuels, such as geothermal, often misleadingly and ignoring the fundamental issues in the energy supply chain and broader social, economic, and environmental impacts. While geothermal is often promoted as a clean, low-emission energy solution, it still produces significant carbon emissions and a variety of negative impacts on the environment and local communities.

In addition, geothermal projects that are often financed through debt can add to the financial burden on the people. This debt financing often leads to increased electricity rates and the transfer of the debt burden to the people through taxes or reduced subsidies. As a result, the people who should benefit bear the additional project burden, which should reduce the negative impact on the environment.

Despite being claimed as clean energy solutions, geothermal projects in Indonesia, such as the Sarulla, Salak, Wayang Windu, Lumut Balai, Sokoria, and Lahendong PLTP, significantly negatively impact the environment and surrounding communities. In the case of the Sarulla GPP, the communities experienced crop failures and economic losses due to sulfur pollution and faced explosions that caused fear and anger. The Salak GPP has increased the frequency of earthquakes, threatening the safety of the communities living in the surrounding area. In Wayang Windu, the landslide that submerged Cibitung village demonstrated the dire impacts of geothermal exploitation in an earthquake-prone zone. In Lumut Balai, water pollution and disruption of Sumatran tiger habitat have caused serious ecological and social problems.

Meanwhile, the Sokoria project has negatively impacted the agricultural sector and community incomes without providing significant positive economic impacts. Even the Lahendong geothermal power plant, which is often considered a success, continues to face complaints from the communities about pollution and health impacts. All of these geothermal projects demonstrate that while geothermal energy has the potential to provide benefits, the social, economic, and environmental risks it poses are often greater, requiring more thorough evaluation before proceeding.

Geothermal as a renewable energy solution has not only failed to fulfill its promise as truly environmentally friendly energy but has also caused serious consequences, such as land grabbing, damage to the ecosystem, environmental pollution, and social conflicts that harm indigenous peoples, women, children, and other vulnerable groups. Geothermal projects are false solutions because their negative impacts are often ignored or improperly calculated in project planning and implementation.

The approach that only pursues reducing greenhouse gas emissions without considering long-term social and environmental impacts makes geothermal more appropriately called a false solution. Instead of being the answer to energy and environmental problems, geothermal can actually create a series of new problems that are no less serious. Therefore, an in-depth evaluation and a more holistic and inclusive policy are needed in the energy transition, ensuring that the welfare of all parties, especially the most vulnerable groups, are top priorities.

Based on the dangers and risks caused by geothermal exploration and exploitation:

1. The government must not consider geothermal energy a renewable energy source because of its negative impacts on society and the environment, dependence on foreign technology, and increasing government debt for its investments.
2. The government and companies must re-evaluate the environmental impacts of geothermal projects, especially on ecosystem damage, water, soil, and air pollution, and increased disaster risks such as earthquakes and landslides. Independent research from credible institutions must be involved to identify long-term impacts on society and the environment.
3. The GPP management needs to improve the risk management system for technical incidents that can endanger the community, such as explosions and leaks of dangerous gases. The risk mitigation system must be tightened, including supervision and routine maintenance of geothermal equipment and infrastructure.
4. Geothermal project management must be more transparent in providing information related to project activities and risks to the surrounding community. A participatory communication approach must be implemented so the community is involved in decision-making, especially concerning their safety and welfare.
5. With the increasing significant negative impacts on the community and environment, the sustainability of geothermal projects that are already operating needs to be reviewed. If the impact is too great, considerations must be made for temporarily or permanently stopping the project.
6. The government and companies must adequately compensate communities affected by adverse economic, health, and societal impacts. In addition, environmental and economic recovery programs must be carried out

immediately to reduce the losses experienced by the community.

7. The regulations on geothermal operations should be strengthened to ensure better management and reduce negative impacts on the environment and communities. Government oversight must be increased to ensure the companies comply with established operating and environmental standards.

GLOSSARY

Geothermal	Heat energy that originates from within the Earth,
PLTP (*Pembangkit Listrik Tenaga Panas Bumi*)	Geothermal Power Plant (GPP)
Net Zero Emission	A condition where the amount of carbon emitted is equal to the carbon sequestered.
Gradient Geothermal	The increase in earth's temperature is proportional to depth
Reservoir Geothermal	The underground space where geothermal fluids collect
Separator	Equipment that separates steam from hot water in geothermal systems
Injection Well	Injection wells to return water to geothermal reservoirs
Binary Cycle Power Plants	Geothermal Power Plant system that uses a secondary working fluid with a lower boiling point
Dry Steam Power Plants	Geothermal Power Plant technology that uses only hot steam
Flash Steam Power Plants	Geothermal Power Plant technology to utilize high-temperature hot water
JETP (Just Energy Transition Partnership)	Partnerships to support an equitable energy transition

Enhanced Geothermal System (EGS)	Geothermal systems that utilize hot rocks with artificial engineering
Supercritical Geothermal System (SGS)	Geothermal systems with supercritical fluids at high temperature and pressure
Fumarole	A hole in the Earth's crust that emits sulfur and carbon dioxide gas
***Wilayah Kerja Panas Bumi* (WKP)**	Designated geothermal exploration and exploitation areas
Installed Capacity	Total electrical energy capacity that can be generated by a Geothermal Power Plant
H2S Pollution (Hidrogen Sulfida)	Toxic gases that can be generated from geothermal operations
Deforestation	Deforestation for geothermal infrastructure development
Permeability	The ability of rock to conduct fluids
Emisi gCO2e/kWh	A measure of carbon emissions produced by a power plant per kilowatt-hour

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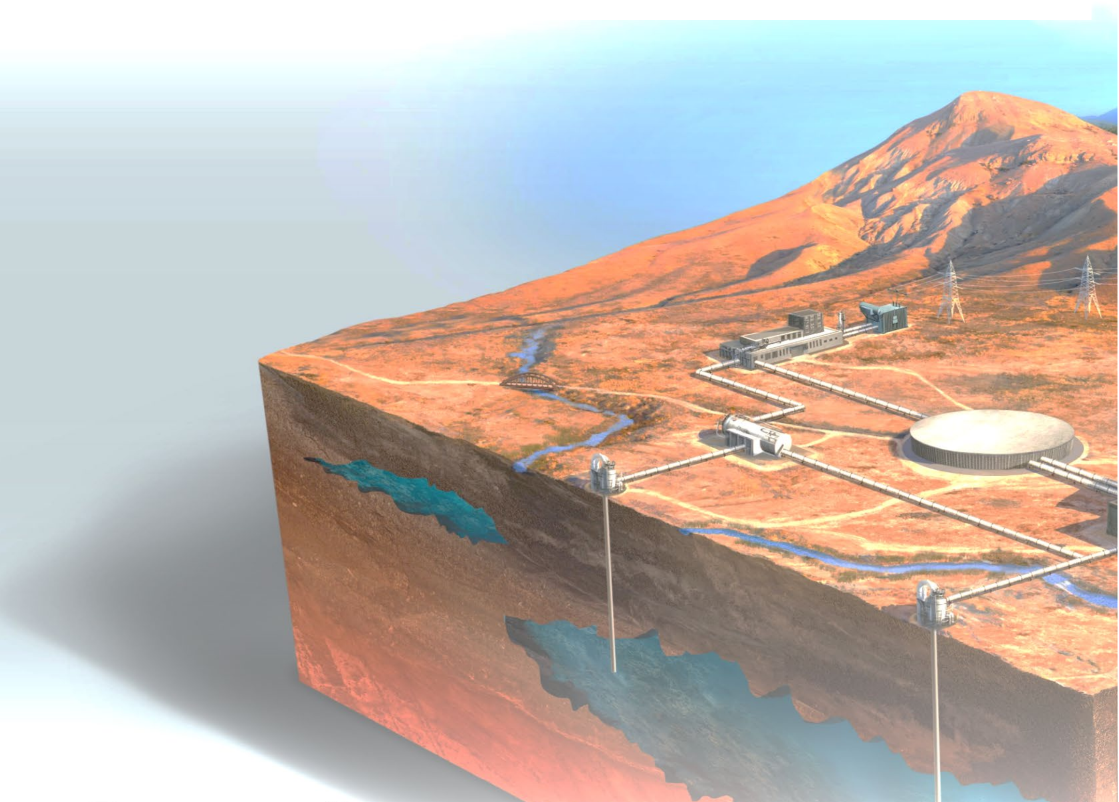

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