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Sustainable Geothermal Utilization for Outstanding Universal Value Sustainability

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ABSTRACT

The Indonesian National Energy Policy year 2014 mandates that energy resources are prioritized for national development. It also requires contribution from new energy and renewable energy, including geothermal energy, for electricity. Geothermal power plants are expected to generate 7.2 GW by 2025 and 9.3 GW by 2030. Geothermal energy has become clean, environmentally friendly, reliable, and sustainable energy. The development of geothermal energy does not require extensive land. Then during operation, the utilization of geothermal energy can synergy with the surrounding ecosystems. Based on Indonesian law, geothermal development can be carried out in forest areas including conservation forest. It was permitted in National Parks, Great Forest Parks and Nature Parks. However, several National Parks in Sumatra Island have been designated by UNESCO in 2004 as the World Heritage namely Tropical Rain-forest Heritage of Sumatra (TRHS) consisting of Gunung Leuser National Park (GLNP), Kerinci Seblat National Park (KSNP), and Bukit Barisan Selatan National Park (BBSNP). The three national parks have geothermal resources reaching 2.6 GW which are feasible to be developed as electricity sources needed in the region. But until now its potential has not been utilized because the UNESCO World Heritage Committee still categorizes geothermal energy as a mining activity that cannot be carried out in World Heritage areas. The operational and management of geothermal energy in Indonesia must apply best engineering practices in terms of ecology, environment, social and economy. It can be shown by the commitment of international financial institutions that have high standards in the environment and social issues to support the financing of geothermal projects. And as the result, Environment and Forestry Ministry of Indonesia has awarded the highest achievement in environmental management to geothermal companies since 1995. The awards are received for Kamojang, Salak, Darajat, and Wayang Windu geothermal areas. Environmental management in geothermal operation areas have to take into account of: land use, air quality, water use, and biodiversity. In addition, geothermal operations in Indonesia have also been implemented in the form of Environmental and Social Impact Assessments (ESIA) and Green Corridor Initiatives. This shows that geothermal energy utilization has followed the sustainability of Outstanding Universal Value (OUV) which is become a major concern in the world heritage.

1. INTRODUCTION

Located between active fault lines, Indonesia has abundant geothermal resources. A geothermal resource investigation found that Indonesia has geothermal potential of 25.4 GW (Geological Agency, 2018). As of the end of 2018, this potential had been successfully utilized for geothermal power plants with total installed capacity of 1.9 GW, which accounts for only 7% of total resource. The utilization achievement suggests that there is a lot of room for improvement.

Along with technological advancement, electricity has become humans' basic need. The government of Indonesia has carried out a series of efforts to meet domestic energy demands, which include establishing the National Energy Policy (NEP) in 2014. Indonesia's National Energy Policy provides a guideline in directing energy management in order to ensure energy independence and security to support the national development. To achieve the national energy independence and security, the NEP mandates that energy resources are not merely exported commodities but prioritized as national development capital. To realize it, the government has set a number of targets, including the achievement of the optimal primary energy mix, one of which is by increasing the role of new energy and renewable energy, including geothermal energy by 23% in 2025 and 31% in 2050.

The electricity guideline is in line with the commitment of the government of Indonesia in the 21st Conference of the Parties (COP) in Paris in 2015, which has been ratified into Law No. 16 of 2016 concerning Ratification of Paris Agreement to reduce CO_2 gas emissions from the effects of greenhouse gases by 29% by 2030. Therefore, to implement the National Energy Policy and fulfil the commitment to COP-21, the utilization of geothermal energy for power plants is targeted to contribute 7.2 GW in 2025 and 9.3 GW in 2030. The implementation of the national action plan for reducing greenhouse gas emissions in the energy sector is carried out through the use of bio fuels and machines with higher fuel efficiency standards, energy efficiency, and the development of renewable energy. Furthermore, the government of Indonesia has issued Presidential Regulation No. 56 of 2018 concerning the Acceleration of National Strategic Projects which categorize geothermal power plant projects as part of the National Electricity Program included as a National Strategic Project.

Geothermal energy generation in Indonesia has contributed to the increase of the national electrification ratio in 2018, reaching 98.3%. Geothermal generation also contributed to the national power plant installation, which amounts to 5.3% of the total mix of electricity generation in Indonesia of 62.9 GW (Figure 1).

Geothermal energy is a source of heat energy contained in hot water, water vapor, and rocks along with other associated minerals and other gases which are genetically inseparable in a geothermal system. Geothermal energy is clean, environmentally friendly, reliable, and sustainable. In addition, the development of geothermal energy does not require a large area, and it is a reliable energy as a power plant. One of the most important significances of geothermal energy is that this energy can be developed in accordance with the surrounding ecosystem, while this is difficult for other energy sources, especially fossil.

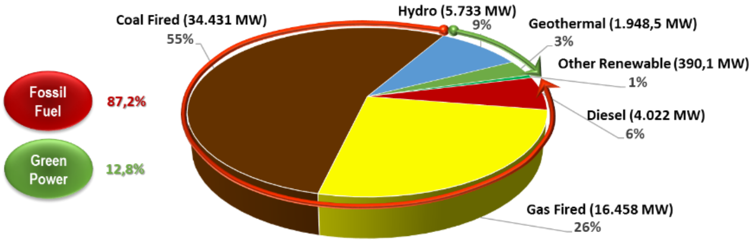


Figure 1: Indonesia's geothermal power plant in Indonesia's power plant mix (2018)

Most of the geothermal resources in Indonesia are located in forest areas, including protected forest and conservation forest areas. Particularly in Sumatra Island, geothermal resources are located in forest areas which have conservation and protection functions, and the amount is substantial, at 8.7 GW from the overall total of 10.5 GW.

The government of Indonesia has allowed the utilization of geothermal energy in forest areas. Meanwhile, conservation forest areas are limited to national parks, great forest parks, and nature parks. In 2004, several national parks in Sumatra Island were designated by UNESCO as the world's natural heritage, namely the "Tropical Rainforest Heritage of Sumatra (TRHS)", which consists of Gunung Leuser National Park (GLNP), Kerinci Seblat National Park (KSNP), and Bukit Barisan Selatan National Park (BBSNP). The three national parks have geothermal resources amounting to 2.6 GW, which are feasible to be developed into power plants compared to geothermal resources in other regions. However, until now, this potential cannot be developed because the UNESCO World Heritage Committee categorizes geothermal energy exploration as a mining activity that cannot be carried out in an area that has been designated as a World Heritage.

The challenge of developing geothermal energy in TRHS areas can potentially inhibit the achievement of the government's targets, considering that the utilization of geothermal resources for power plants in the three regions can contribute to the national energy mix that has been targeted by the government of Indonesia in order to increase energy security and independence, specifically in Sumatra Island. In 2018, the utilization of geothermal energy for electricity just reached 1.9 GW (around 27%) or 5.3 GW away from the target that must be achieved by the government of Indonesia.

2. GEOTHERMAL UTILIZATION

2.1 Geothermal Energy and Geothermal Development in Indonesia

Geothermal energy utilizes and extracts heat from underneath the Earth, which is contained in reservoir rocks and subsequently converted by turbines and generators into electricity. Geothermal energy has an important role in reducing greenhouse gas emissions in Indonesia. In 2017, geothermal power plants managed to help reduce greenhouse gas emissions by up to 8 million tons of CO_2, or approximately 17.9% of the targeted reduction figure from the energy sector. Geothermal energy is one of the most reliable and sustainable types of renewable energy because it has available steam resources from wells and can be produced consistently. Therefore, a geothermal power plant can be operated as an electricity base load compared to other renewable energy sources, for example, wind and solar power plants.

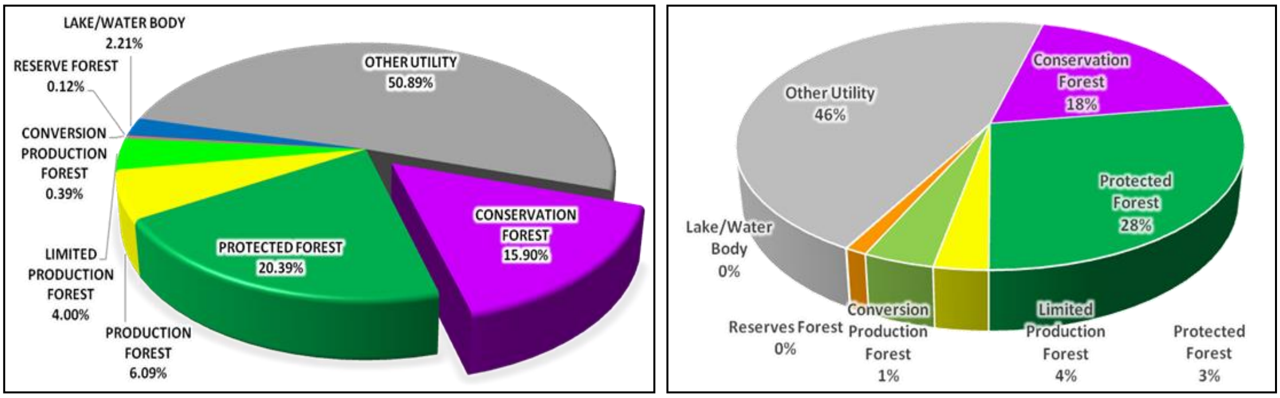
There are 13 geothermal power plants located in 11 geothermal working areas (GWA), as described in Table 1. In 2018 alone, geothermal generated electricity of 14,011 GWh. Geothermal electricity generation in Indonesia is quite significant since the uptake of renewable energy sector investment in the last 5 years reached an average value of USD 1 billion annually. Geothermal generation also contributes to non-tax state revenues, approximately reaching USD 78 million annually.

The Geological Agency in 2018 concluded that Indonesia has 25.4 GW geothermal resources which are spread out across Indonesia at 349 prospects. 49% of the geothermal resources are located in forest areas. Furthermore, based on the overlay with the forestry and land use maps, it is known that 139 of 349 prospects with the total resources reaching 13.6 GW are located in forest areas (Figure 2a), 39 other geothermal prospects with total resources of 4.9 GW are located in the area with a protection function (Figure 2b).

Specifically, geothermal resources in Sumatra Island reach the magnitude of 10.4 GW with details as follows: exploration phase of 3.7 GW, exploitation phase of 1.4 GW, GWA offering of 2.7 GW, and TRHS area of 2.6 GW. Geothermal resources in TRHS include the establishment of GWA, Preliminary Survey Assignment Areas (PSA), and Preliminary Survey Assignment and Exploration (PSAE). Geothermal development plan in the TRHS area is expected to provide reliability contribution to electricity supply in Sumatra Island of 1,305 MW installed capacity, while simultaneously being anticipated to reduce greenhouse gas emissions by 6.13 million tons of CO_2. The value of geothermal development investment in TRHS area is estimated at USD 6.5 billion, with the contribution to the regional government revenues of around USD 8 million per annum. Meanwhile, the construction of 1,305 MW power plants in the TRHS area only requires about 1,248 hectares or 0.048 percent of the total 2.6 million hectare in the TRHS area.

Table 2: Geothermal power plants' installed capacity in Indonesia as of 2018

No	Geothermal Working Areas	Geothermal Power Plants	Developers	Turbine Units	Installed Capacity (MW)
1	Kamojang Darajat	Kamojang	PT. Pertamina Geothermal Energy	1 x 30 MW 2 x 55 MW 1 x 60 MW 1 x 35 MW	235
	Kamojang Darajat (JOC)	Darajat	Star Energy Geothermal Darajat II, Ltd	1 x 55 MW 1 x 94 MW 1 x 121 MW	270
2	Cibeureum Parabakti	Salak	Star Energy Geothermal Salak, Ltd.	3 x 60 MW 3 x 65,6 MW	377
3	Dataran Tinggi Dieng	Dieng	PT. Geo Dipa Energi	1 x 60 MW	60
4	Sibayak Sinabung	Sibayak	PT. Pertamina Geothermal Energy	1 x 10 MW (monoblok) 2 MW	12
5	Pangalengan (JOC)	Wayang Windu	Star Energy Geothermal Wayang Windu Ltd.	1 x 110 MW 1 x 117 MW	227
	Pangalengan (Patuha Area),	Patuha	PT Geo Dipa Energi	1 x 55 MW	55
6	Lahendong Tompaso	Lahendong	PT. Pertamina Geothermal Energy	6 x 20 MW	120
7	Waypanas	Ulubelu	PT. Pertamina Geothermal Energy	4 x 55 MW	220
8	Ulumbu	Ulumbu	PT. PLN (Persero)	4 x 2,5 MW	10
9	Mataloko	Mataloko	PT. PLN (Persero)	1 x 2,5 MW	2,5
10	Sibual Buali	Sarulla	Sarulla Operations Ltd.	3 x 110 MW	330
11	Karaha-Cakrabuana	Karaha	PT. Pertamina Geothermal Energy	1 x 30 MW	30
		TOTAL		**39 Units**	**1.948,5**



2.a. Geothermal resources land use

2.b. Geothermal resources (MW) distributions

Figure 2: Indonesia's geothermal land use and geothermal resources distribution (DGNREEC, 2019)

Geothermal energy is known as a clean and environmentally friendly energy source because it produces lower greenhouse gas emissions than those of other types of power plants. A study by Bloomfield et al. (2003) compared carbon dioxide (CO_2) emissions between various types of plants in the United States. The results of the comparison of emissions can be seen in Figure 3.

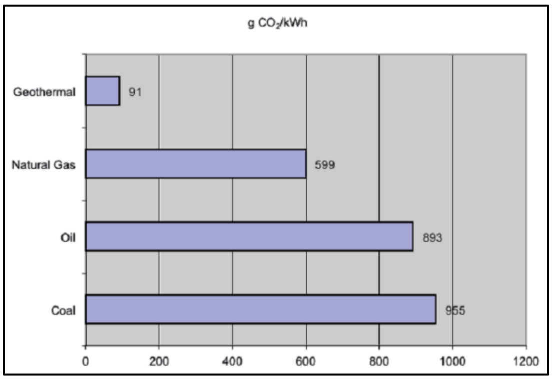


Figure 3: Comparison of CO_2 emissions between various types of plants in the United States (Bloomfield et al., 2003)

The steam from geothermal fields contain Non-Condensable Gas (NCG) consisting of Carbon dioxide (CO_2), Hydrogen sulfide (H_2S), Ammonia (NH_3), Nitrogen (N_2), Methane (CH_4) and Hydrogen (H_2). Among these NCG components, CO_2 and H_2S are the most dominant. CO_2 is the largest element in NCG release, which is around 95-98% of the total concentration of NCG, while H_2S is only about 2-3% of the total concentration of NCG. The result of the study describes that the emissions produced by geothermal power plants are less than fossil energy power plants.

The utilization of geothermal energy has been proven to be able to run in harmony and environmentally friendly compared to the utilization of other energy sources, especially those derived from fossil fuels. Geothermal operation activities re-inject fluids into the Earth to a depth of approximately 2 km so that they can prevent or reduce environmental impacts due to the implementation of 'zero waste and zero spill'.

2.2 Geothermal Utilization Regulation in Conservation Areas

Based on Indonesia's Geothermal Law No. 21 of 2014, geothermal development is no longer categorized as a mining activity. Therefore, geothermal development in conservation areas can be implemented in conjunction with the Conservation of Biological Natural Resources and Ecosystem Law No. 5 of 1990. According to Government's Regulation No. 108 of 2015 concerning Management of Natural Resources Areas and Natural Conservation Areas, stipulated by the Ministry of Environment and Forestry Regulation No. P.46 of 2016 then ratified by P.4 of 2019 concerning Utilization of Geothermal Energy as Environmental Services in National Parks, Great Forest Parks, and Nature Parks, geothermal utilization can be carried out in National Parks, Great Forest Parks, and Nature Parks but within pre-determined utilization zones. The regulation also emphasizes that the utilization of geothermal energy as environmental services is the utilization of heat energy produced through an extraction process with a closed loop system, which is from and back to the Earth, and there are no materials taken other than heat energy. Therefore, the utilization of geothermal as environmental services supposedly does not disturb the landscape and its ecosystem.

Pre-feasibility studies carried out on TRHS areas indicate geothermal resources of up to 2. 6 GW, which can potentially be developed as electricity sources as needed in the region. Hence, due to road construction, logging, poaching, land clearing for plantations, and illegal mining activities, UNESCO also determined that this World Heritage is in danger. In addition, the monitoring results by the UNESCO Reactive Monitoring Team discovered geothermal exploration activities in Sekincau GWA, Lampung Province, in BBSNP and geothermal PSA activities in Gunung Kembar area, Aceh Province, GLNP. That said, until now, geothermal resources in TRHS have not been utilized because the UNESCO World Heritage Committee still categorizes geothermal energy as a mining activity that cannot be carried out in World Heritage areas.

Meanwhile, the development of geothermal energy can increase generation capacity, while reducing the use of fossil-based fuels at the same time. The electricity demand in Sumatra Island in the period of 2012-2016 grew by 7.6% per year, while the increase in power generation capacity grew by only 5.2% per year. The amount of geothermal resources is around 18.12% of the total planned increase in electricity generation capacity listed in the Electricity Supply Business Plan of PLN for 2018-2027. By assuming that 1 household needs 900 watts of power, then the development of geothermal energy in TRHS area can meet the electricity needs of 3.2 million households. Geothermal energy development projects can also lead to a multiplier effect. One that can be experienced directly by the community is the creation of jobs on site. Any geothermal project ensures the utilization of local manpower in the construction activity stage, such as the construction of drilling pads, access roads, bridges, and other civil infrastructure. The highest level of employment absorption is for the generation and steam field construction activities, including drilling of geothermal wells, piping systems, office buildings, and other supporting buildings.

In the case of Indonesia, geothermal energy can create employment opportunities for one million worker. This is far higher than other types of power plants (McInnis et al., 2010). By using data from Indonesia Geothermal Association (2004) and Shibaki (2003), the estimated job creation for several different scenarios of development of geothermal energy is up to 37,000-206,000 workers in 2015 and 61,000-325,000 workers in 2020 (Figure 4).

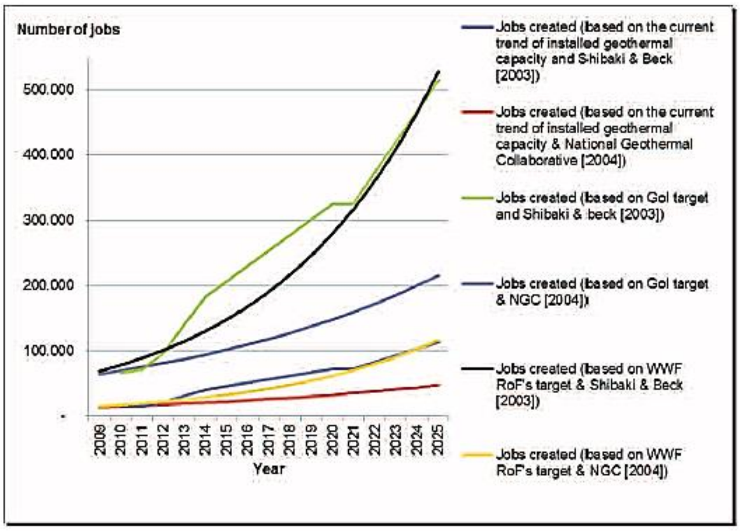


Figure 4: Estimation of job creation for several scenarios of different geothermal energy (McInnis et al. 2010)

Another practical contribution from a geothermal project to denizens around the project area is the construction of supporting infrastructure of the project, such as electricity networks, road infrastructure improvement, and bridge construction. Geothermal project developers are also obliged to conduct a Corporate Social Responsibility (CSR) program, usually in the form of public infrastructure improvement, renovation of religious facilities, and clean water sanitation improvement. With better infrastructure, it will indirectly encourage the economic growth and improve the quality of life and welfare of the community. The following are examples of CSR programs carried out by geothermal developers:

1. Health and education programs, providing wider and better opportunities for education and health services for the local community.
2. Infrastructure, providing resources to meet the community’s needs by building better infrastructure.
3. Economic empowerment, increasing the community’s purchasing power and financial capacity.
4. Community relations in the context of socio-cultural and community participation by increasing the relationship between the company and the community through participation and contribution to local values/wisdom.
5. Absorption of local labor and opening opportunities for local suppliers.
6. Access to local-level investment.
7. Multiplier effect of the electricity industry, namely the growth of industrial estates, home industries, absorption of local manpower, etc.

Geothermal development also contributes to the conservation of the Earth. Conservation ensures continuous protection to prevent environmental damage and destruction by preserving and conserving areas. Natural resources are biological elements in the nature which consist of plant natural resources (plants) and animal natural resources (wildlife), along with the surrounding non-biological elements, altogether forming the ecosystem. The conservation of natural resources means the management of natural resources to use them wisely and ensure sustainability by maintaining and improving the quality of values and diversities. Natural resources are divided into two types, namely renewable natural resources, such as animals, plants, water, air and microorganisms, and non-renewable biological natural resources, such as natural gas, petroleum, and various types of metals. Therefore, geothermal energy, together with the system that forms it, is a natural resource that can be renewed and utilized for human life.

Referring to the provisions of Article 2 and Article 3 of Conservation Law No. 5 of 1990 concerning Conservation of Biological Natural Resources and Ecosystem, the management of biological natural resources conservation aims to preserve biological natural resources and maintain the balance of the ecosystem so that they can support efforts to improve community welfare and the quality of human life. Article 5 letter b of Law No. 5 of 1990 further states that conservation of biological natural resources and their ecosystems is carried out through sustainable utilization activities. Therefore, geothermal resources that will be generated into electricity are one of the biological natural resources in a conservation area that can be used to support the efforts to improve community welfare and quality of human life while maintaining the harmony and balance of the surrounding ecosystem. To this end, the government sets out the Five-Year Forest Protection and the Biodiversity Action Plan, which includes:

1. Constructing forest security units;
2. Collecting data and mapping disturbances to forest security;
3. Controling forest fires; and
4. Increasing public awareness about the importance of preserving biodiversity and collecting data about protected fauna and flora.

Meanwhile, the components of the Biodiversity Action Plan include:

1. Reducing the death of wildlife at road crossings;
2. Carrying out assessments of high conservation value species before land clearing;
3. Constructing security gates on access roads for projects;
4. Preparing a long-term monitoring plan for endangered species;
5. Supporting the protection and preservation of forest areas; and

6. Increasing public awareness about the importance of endangered species.

In addition, a balance of biodiversity will be needed to reduce the overall habitat loss and to reduce natural habitat extinction or net gain for biodiversity.

2.3 Costs and Benefits

The Directorate General of New, Renewable Energy, and Energy Conservation (DGNREEC), the Ministry of Energy and Mineral Resources, considers geothermal development in Indonesia to be one of the most promising options to cater for the increasing demand for electricity and the commitment to preserve the environment due to the following rationales:

1. Indonesia has enormous and extensive geothermal resources which amount to 25.4 GW (Geological Agency, 2018). Geothermal energy, by nature, cannot be distributed to other areas away from the exact geothermal location and has to be optimized locally to enhance regional energy independence.
2. Geothermal energy, with a plant operating period of 30 years, has fairly high reliability compared to fossil fuel energy. Geothermal energy can support the development of sustainable energy infrastructure because it does not require fuel costs, while fossil energy can be depleted. Thus, geothermal energy is not affected by the escalation in fuel costs so that the price of geothermal energy is more stable in the future and has the highest availability factor (90-95%).
3. Geothermal energy is considered to be environmentally friendly and has minimal impact of air contamination. A study by Yuniarto (2015) informs that CO_2 emission from Ulubelu, Kamojang and Wayang Windu geothermal power plants in Indonesia is approximately 42-73 gr/kWh, respectively. Similarly, Bertani and Thain (2002) found that geothermal CO_2 emission is lower than the emissions produced by natural gas, petroleum, diesel, or coal, which can range between 315 and 915 gr/kWh, respectively. Conceivably, geothermal energy does not damage the initial landscape conditions, as opposed to mining activities, and can, therefore, contribute to maintaining biodiversity.
4. Geothermal energy also has more advantages compared to other renewable energy sources. Geothermal energy utilizes steam from wellbore, thus relatively far more stable and reliable relative to wind or solar power plants which have intermittent resources of energy, or hydro power plants which often depend on water supply and seasonal weather conditions.

By using a macroeconomic perspective approach, a cost-benefit analysis (CBA) is measured by setting improvements in social welfare as the ultimate goal of national development. Indeed, achieving the national development and fulfilling supply and demand, externalities can emerge as the results of economic activities. In the context of renewable energy development, the negative externality can be in the form of CO_2-dominated greenhouse gases. As stated in the Nationally Determined Contribution (NDC) document in 2016, the Indonesian government has committed to setting an unconditional target of 29% and a conditional target of 41% in 2030.

A CBA is focused on benefits pertaining to social welfare by calculating negative externalities of coal-fired power plants and converting these into incentives for geothermal power plants, which have fewer negative externalities, such as reduced greenhouse gas emissions, to offset higher costs of building geothermal power plants, resulting in similar costs between the two types of power plants. Assuming an emission externality cost of USD 4.75/ton CO_2, DGNEREEC (2019) estimated externality costs with an average fossil fuel emission of 0.0009 tons of CO_2/kWh and arrived at a coal fire power plant externality cost of USD 3.85 cent/kWh. Taking into account the externality costs, a comparison is made between coal-fired and geothermal power plants, as can be seen in Table 2. The current economic price of electricity generated from coal-fired power plants has not included the costs of externalities, for instance, the risk of fuel price hikes and carbon, pollution, and other environmental damages, so generation cost is relatively lower than the duly economic value.

DGNREEC (2019) also measured significant benefits of developing geothermal power plants, including:

1. Increasing environmental quality and social welfare.
2. Decreasing dependence on imported fossil fuel.
3. Geothermal electricity-driven economy.
4. Geothermal as a support for environmental sustainability.

Table 2: Generation cost comparison between coal-fired and geothermal power plants

No	Cost component ($/kWh)	Coal fired power plant (Green Paper, 2009)	Coal fired power plant (modified from Green Paper, 2009 in DGNREEC, 2019)	Actual geothermal power plant (DGNREEC, 2019)
1	Capital cost	0.054	0.064	0.126
2	Operating cost	0.007	0.008	0.024
3	Fuel cost	0.029	0.034	n/a
4	Fuel price risk cost	0.010	0.012	n/a
5	Environmental Externality	0.030	0.035	n/a
	Total	**0.130**	**0.153**	**0.150**

3. OUTSTANDING UNIVERSAL VALUES (OUV)

The Outstanding Universal Values (OUV) is a set of criteria proposed by the World Heritage Committee (WHC) in the 2005 UNESCO WHC Operational Guidelines which become the basis for evaluating if a region or culture is to be included in the World Heritage list. These criteria are shown in Table 3.

Table 3: World Heritage selection criteria

Criteria	Representation
I	To represent a masterpiece of human creative genius;
II	To exhibit an important interchange of human values over a span of time or within a cultural area of the world on developments in architecture or technology, monumental arts, town-planning or landscape design;
III	To bear a unique, or at least exceptional testimony, to a cultural tradition or to a civilization which is living or which has disappeared;
IV	To be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history;
V	To be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change;
VI	To be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The Committee considers that this criterion should preferably be used in conjunction with other criteria);
VII	To contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;
VIII	To be outstanding examples representing major stages of the Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features;
IX	To be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals;
X	To contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

TRHS is established as a national heritage for fulfilling criteria VII, IX, and X, which include aspects of natural beauty, preservation of flora and fauna habitats, and conservation of flora and fauna.

4. SUSTAINABLE GEOTHERMAL OPERATIONS TO PRESERVE OUV IN INDONESIA

4.1. Management of Geothermal Operations and Mitigations

Sustainable geothermal activities can also support the process of protection and management of world's natural heritage areas. The management of OUV and of geothermal energy shares the same main principle of sustainability for future generations. Sustainable management of OUV must absolutely be carried out for the sake of the development of human civilization and will certainly have an impact on the preservation of OUV.

The exploitation of geothermal activities has particular impacts on the environment. However, it should be noted that geothermal exploitation requires environmental sustainability to be able to operate sustainably. Therefore, the presence of geothermal operations in accordance with the rules of engineering can help preserve the environment. The environmental impacts of geothermal activities will be first felt during the initial survey stage, increase in the exploration and construction stages, and then decline during the operation and production stages. Usually, the stage of geothermal reserves survey and determination activities has the smallest impact on the environment. In the next stage, the impacts change gradually. Haraldson (2011) describes the scheme of environmental impacts in different stages of geothermal energy development, with major changes expected to occur during the design and construction phases, namely in the activities of land clearing for pad, roads, and geothermal power plant buildings, as shown in Figure 5.

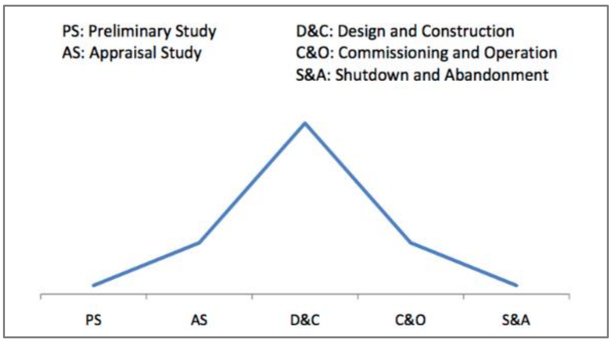


Figure 5: Level of relative impacts on the environment from various phases in geothermal power plant development (Haraldsson, 2011)

Referring to the Document of Advice Note by IUCN on Mining and Oil/Gas Activities in a Heritage Site, there are several impacts that may affect the sustainability of OUV. The management of impacts on geothermal operations includes:

1. Land use for geothermal operations
   Land-clearing in geothermal activities is inevitable, but the scale is considered very small, only 5-10% compared to land-clearing in coal-mining and solar energy development activities. An optimal planning for land use is a must so that it does not affect the OUV integrity. For example, the land use for geothermal power generation with a capacity of 2 x 55 MW is approximately 100 - 110 hectares. This land use covers all stages of activities, such as exploration, exploitation, and utilization (Table 4).

Table 4: Land use for geothermal power plant of 110 MW

No	Land Use	Area (Ha)
1	Well Pad	40
2	Office Building	4.2
3	GPP Building	8.2
4	Integrated Separator	2.6
5	Pipe Network	23.5
6	Transmission Line	3
7	Access road	25
	Total	**106**

2. Air pollution
   One of the implementations of geothermal power plant technology is that it can minimize environmental impacts and reduce the occurrence of non-condensable gases, even approaching zero especially in the binary power plant technology.

3. Water pollution
   To maintain the risk of geothermal fluid to be exposed to the surface water and ground water at the time of construction and production, the implementation of geothermal well design uses metal casing, which mainly functions to prevent geothermal fluid, in both production and injection, from entering the environmental biosphere. Geothermal wells typically have a depth of more than 1500 meters, far deeper than the groundwater level. The technique of mounting and cementing layered casings in shallow depths is also carried out to ensure that no rock formation collapses in the borehole, which can cause geothermal fluid to enter through rock formations and get mixed with groundwater and even surface water.

4. Water usage
   Water is needed in every stage of the development of geothermal activities as well as other large-scale power plant projects. However, in geothermal projects, there are two main foci of massive use of water, namely at the time of drilling wells and removing hot residue at plants using cooling towers. The use of fresh water for geothermal activities is basically not too large, temporary, and easy to control. Therefore, the use of water in geothermal activities will not interfere the surface water sources used by the local community.

5. Noise
   In a geothermal infrastructure construction stage, noise can occur during road construction, excavation for drilling locations, drilling activities, and well tests. However, the noise is temporary, and it means that after construction activities have finished, it will return to normal. The noise resulted from geothermal activities during operations in a power plant area is 50 dB, which is

below the threshold of 70 dB, with reference to Salak Geothermal Power Plant in Halimun Salak National Park Conservation Zone as described in SEGS report (2017).

6. Catastrophic occurrence
   Catastrophic occurrence, in the form of blowouts on geothermal well drilling, has never occurred since the use of blowout preventer (BOP), which is required to be installed during the drilling period. Technology and geology that continue to grow and the understanding of predictions on sub-surface conditions can also reduce the dangers that might take place in geothermal drilling activities.

4.2. Environmental Assessment

The Environmental and Social Impact Assessment (ESIA) studies are vital to know the natural state of the environment (baseline data) before going through each stage of geothermal development activities, starting from exploration, exploitation, to utilization. The collection of baseline data involves gathering information concerning physical, chemical, biological, social, and economic arrangements around the proposed geothermal power plant and is usually carried out as part of an environmental impact assessment. ESIA information can be obtained through measurements, field sampling, surveys, interviews, and consultations, and also from secondary data sources (Ogola, 2009). ESIA studies allow environmentalists to assess how significant the changes in certain environmental conditions are compared to the natural conditions during the operation phase of electricity generation.

The ESIA document is an international standard that is usually requested as one of the requirements from international financial institutions that will help finance a project, including geothermal projects. The document is as important as the Environmental Impact Assessment (EIA) document, which is comprehensive enough to handle the impacts of project activities on the environment. The following are examples and best practices of ESIA studies that are equivalent to EIA.

4.3. Management of Conservation Area

The management of conservation areas in conjunction with geothermal development should be carried out properly. One of the examples of successful conservation area management is the Management of Conservation Area through the Activities of Green Corridor Initiative in Halimun Salak National Park. Chevron Geothermal Salak, Ltd. (CGS), currently called Star Energy Geothermal Salak, Ltd. (SEGS), is located nearby and even part of the area within Gunung Halimun Salak National Park (GHSNP) area. In GHSNP, a population of endangered animals live. CGS, together with stakeholders, initiated a program called the Green Corridor Initiative (GCI) program as a responsibility initiative from the developer for the social aspects, living environment, and biodiversity. This GCI program becomes one of the best practices of the development of geothermal energy in order to assist the government in preserving the environment and habitats.

CGI is an initiative to connect biodiversity in Mount Salak and Mount Halimun areas. The main purpose of the GCI Project is to restore the existing corridor forest in GHSNP. Meanwhile, there are two more particular purposes, namely to enhance community participation for sustainability preservation and conservation of corridor forest ecosystems and to enhance the function of corridor forest ecosystem through forest restoration around 500 hectares for the habitats of the Javan Gibbon, Javan Leopard, and Javan Hawk-Eagle.

The result of monitoring of flora and fauna in 2018 in several locations shows that the area was still in a good condition. A diversity calculation of types of plants in each location was compared to the monitoring in 2017, and the result shows no significant difference from the previous period. This indicates that the condition of flora and fauna within the SEGS work area is still well maintained. The GCI and internal plantation programs within the SEGS area even resulted in environmental improvements, as reported by SEGS (2018):

1. Increase in biodiversity of trees, poles, piles, and seeding.
2. Increase in biodiversity index of birds (aves), reaching 29% per annum between 2013 and 2018.
3. Increase in the number of endemic animals between 2013 and 2018.
4. Increase in the flow rate of Cisarua River water as a clean water source for 400 families in Cisarua Village, Kabandungan Sub-district, at a rate of 40% from the baseline data in 2014.
5. Empowerment of the community in Halimun Salak mountain corridor area through the utilization of their house yards to fulfill their basic necessities in the *Kawasan Rumah Pangan Lestari* (Sustainable Food Center Zone) program.
6. Successful plantation for upstream restoration program for Cikuluwumg Watershed, which is actually located in a rocky area, at a ratio of 80%. The water flow rate of the river increased by 9% from the baseline data in 2016.
7. Successful preservation of rare fish tor soro (tor sp.) after increasing the quantity of breeding fish by 2,000 fish during the period of 2017-2018.
8. Successful restoration program for national park boundary areas (Green Belt) in the form of planting on 5 hectares/annum with a 26% increase in seeding level index.
9. Increase in biodiversity of flora and fauna in the GCI and revegetation project areas within the SEGS operation area, eventually contributing to the decrease in critical land and increase in water resources in villages around the location of plantation.

5. CONCLUSION

The TRHS area as a World Natural Heritage is a pride for Indonesia and must be maintained through a mechanism of protection and management of the world's natural heritage in order to maintain the uniqueness and sustainability of the area as a source of life for the flora and fauna in it to support human life. The area is the integration of the second largest tropical rainforest in the world and is considered as a "World's Lung" because it can reduce CO_2 gas emissions, one of the greenhouse gases causing world climate changes.

Population and economy growth have implications for energy growth as a necessity. Energy supply in Indonesia is still very dependent on fossil energy, which is not renewable and is not environmentally friendly because it produces very high greenhouse gases. On the other hand, it is acknowledged that geothermal energy has characteristics of being clean, environmentally friendly, and sustainable.

Based on the aforesaid elaboration, it can be concluded that:

a. The co-existence between the development of geothermal activities and forest conservation can be carried out in harmony to support each other.
b. The experiences of developing several geothermal fields which are located in national parks in Indonesia and overseas countries indicate the capability and feasibility of developing geothermal energy projects that are environmentally friendly by following the rules of natural sustainability, as well as maintaining important values of the areas.
c. Laws and regulations in Indonesia allow geothermal exploitation activities in national parks with a reference framework in the form of License for Utilization of Geothermal Energy as Environmental Services.

Therefore, geothermal energy is possible to be developed in TRHS area by taking into account conservation rules, including OUV, which acts as the partner of UNESCO in determining an area to be a World Heritage.

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