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RAPID ENVIRONMENTAL AND SOCIAL ASSESSMENT OF GEOTHERMAL DEVELOPMENT IN CONSERVATION FOREST AREAS IN INDONESIA

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Executive summary

Background

GeoFor-Indonesia Technical Assistance is a World Bank project which promotes sustainable geothermal power development in Indonesia. This report presents the results of a Rapid Environmental and Social Assessment of Geothermal Development in Conservation and Forest Areas, undertaken as part of this World Bank assistance.

Geothermal resources are one of Indonesia's largest potential sources of renewable energy with an estimated potential of 29 GW, a potential which would support Indonesia's target of achieving the production of 23% of its energy mix through new and renewable energy production by 2025. Furthermore, the production of geothermal energy comes with relatively low greenhouse gas (GHG) emissions and airborne particulate matter, and would curb the country's dependence on fossil fuels for electricity generation. The development of the geothermal power sector provides a significant opportunity to address Indonesia's power shortages and increase its electrification ratio, especially in remote parts of the country, whilst meeting international commitments towards reducing GHG emissions.

Unlocking Indonesia's geothermal power potential, however, has been hampered by a lack of capital investment in exploration and project development as well as by policy restrictions. One of the reasons includes the Geothermal Law No. 27/2003 which defined geothermal development as a mining activity, only allowing its development in Protection and Production Forest and non-forest areas. Furthermore, a prolonged permitting process and complex compliance requirements associated with working in forest areas have delayed or cancelled many proposed geothermal power developments. In order to stimulate the industry, a major revision of the law in 2014 (Geothermal Law No. 21) removed substantial barriers whereby geothermal energy development was no longer defined as a mining activity, and allowed geothermal energy development in certain conservation areas not previously available for development.

The fact that the majority of geothermal potential is located in or close to forest areas has raised societal concerns about environmental and social impacts, especially in forests that play an important role in supplying fresh water, harbor endangered wildlife, or have high cultural or religious values. The degree to which these social and environmental risks and impacts vary between geothermal power projects is not well understood, and thus a key focus of this study. Based on the risks and impacts identified during this study, this report makes recommendations on risk avoidance and mitigation. The ultimate objective is to further stimulate the development of a clean energy source in Indonesia by de-risking it through up-front avoidance of high-risk areas and effectively mitigating social and environmental impacts through good operational management.

Micro-level assessment of geothermal energy projects in Indonesia and elsewhere

Through a micro-level assessment of 15 existing Indonesian geothermal energy projects, the GeoFor-Indonesia team developed an improved insight into the key risks and impacts typically associated with geothermal power development in forest areas. Key findings include that for each 100 MW of geothermal power generated per year, about 10 km of project access roads and 30 hectares of forest clearing is needed, while about 10 km^2 of forest is indirectly impacted through the effects of road-facilitated hunting, illegal logging, use of fire, and other detrimental activities.

Compared with geothermal energy projects in other countries, geothermal energy projects in Indonesia exhibit nearly twice as much road construction, about 10 km of roads per 100 MW capacity versus about 5 km elsewhere (note, this analysis is based on a small dataset of 15 Indonesian projects versus 9 international projects). This is likely related to the remote forested and mountainous terrain in which many geothermal projects have been established in Indonesia and the low density of the pre-existing rural road network, thus requiring the construction of lengthy new access roads.

Key issues	Recommendations
Due to their remote locations, geothermal energy projects in Indonesia on average require longer access roads than projects elsewhere with similar capacity, generating relatively high impacts on forests and wildlife. Therefore, the management of road access is crucial to mitigate the risk of increased pressure on forests and forest wildlife.	• Projects which require the construction of access roads deep into forest areas should be avoided, especially if they go into core zones of conservation areas. • Multiple directional drill holes should be established per drill pad to minimize road and drill pad construction. • Strict management of third-party access to project roads is needed to ensure that such roads do not facilitate illegal activities in forests, such as hunting.

Roads constructed in forest areas can negatively impact forests and forest wildlife if they are not effectively closed off to the public along their entire length. Long access roads into forest areas should thus be avoided. Factoring in the high maintenance costs for road networks in areas of steep terrain and high-rainfall tropical environments, infrastructure decisions should promote a more pragmatic attitude to road building - one that recognizes that it is better to build fewer roads overall and to ensure that those that are built provide strong returns on investments with fewer environmental, social, and financial impacts.

The width of forest clearings made for geothermal project roads in Indonesia vary considerably from a minimum of 8 m up to more than 100 m in very mountainous terrain, where cut and fill for road grading requires wide areas of cleared land despite the final road width being much smaller than 100 m. Wide road clearings have far greater impact on fragmentation of wildlife populations than narrow roads with canopy connectivity across them. Road widths should be kept to an absolute minimum, sufficient to enable a 16 m articulated vehicle to move drilling rigs safely between drill pads and in and out of project areas. After the initial exploration phase, road sides must be revegetated and canopy connectivity across roads re-established as much as possible. Roads with forests on either side perform best when roads are asphalted and have a good drainage system. Road construction and maintenance in mountainous terrain with high rainfall, however, presents significant challenges for geothermal project operators.

Key issues	**Recommendations**
Road widths, including the corridor cleared for roads, vary widely between Indonesian geothermal projects. The wider the roads the greater the environmental impacts.	The Ministry of Energy and Mineral Resources (MEMR) and Ministry of Environment and Forestry (MoEF) should agree to develop regulations that minimize road widths and clearing around roads and include requirements for installation of faunal crossing culverts and overpasses (e.g., arboreal bridges), and high-quality road base or asphalted

	roads with good drainage that require less forest canopy opening.

Macro-level assessment of potential and existing geothermal projects in Indonesia

Through a macro-level assessment of the officially published 330 geothermal resource potential points for Indonesia, the GeoFor-Indonesia team determined the environmental and social risk rankings for every individual point. Each of these was characterized according to weighted environmental and social variables, including forest use status (conservation area type etc.); land cover; claims for social forestry; presence of indigenous people, traditional land claims, recent deforestation history; international biodiversity values (World Heritage site, Key Biodiversity Area, Important Bird Area); size of conservation area; and location of geothermal point in relation to conservation area boundary. Based on the cumulative weighted scores of these variables, the geothermal potential points were categorized as Low, Medium, or High-risk sites.

The resulting risk assessment provides a simple and cost-effective tool for MEMR, MoEF and other key stakeholders to guide geothermal power projects towards the areas with the least environmental costs and lowest likelihood of societal concerns about these costs. This tool also helps the government, banks, other financial institutions, and geothermal energy companies to avoid material and reputational risks that can be associated with geothermal energy development in high-risk areas.

Key issues	Recommendations
• Risk level of geothermal power development in Indonesian forest areas varies greatly depending on a range of social and environmental factors. Ignoring these risks significantly raises the costs of geothermal power development. • Our analysis indicates that most projects with high potential capacity are located in areas categorized as high-risk in terms of environmental and social factors.	• Government institutions, project developers, and financiers could use the World Bank risk assessment in the prioritisation of areas for development, focusing first on project sites with low risks and high potential capacity. Risk avoidance might require targeting of lower capacity projects. • Extra risk mitigation measures are needed when higher risk locations are developed.

The macro-level risk analysis found that 20 of the 330 geothermal potential points are within a national park boundary and 9 are likely in or are on the edge or just inside a national park. Four points are within a Nature Recreation Park (*Taman Wisata*) and four in Grand Forest Park (*Tahura*). Nine points are found to be within Strict Nature Reserves (*Cagar Alam*), and two points within a Wildlife Reserve (*Suaka Margasatwa*). The relative distribution of points per island show that 21% of geothermal potential points in Sumatra are located in conservation areas, on Java and Bali 18% and on Sulawesi 13%. The relative contribution of environmental and social factors based on the data used varied slightly between islands, with the high-risk points in Sumatra mainly attributable to environmental factors, compared to Eastern Indonesia (Sulawesi, Maluku and West Nusa Tenggara) where the contribution from social factors to the risk ranking is higher, or equal to environmental factors.

The macro-level analysis revealed that most of the potential and existing geothermal energy capacity in Indonesia is located on non-forested land (some 20 GW), in degraded forest (about 6.5 GW), and in primary forest (about 1 GW). This is also reflected in the land use status, with 12 GW of potential and existing geothermal capacity located in non-state-forestland (*Areal Pengunaan Lain* or APL), 2.7 GW in Production Forest (*Hutan Produksi* or HP), 7 GW in Protection Forest (*Hutan Lindung* or HL) and 5.6 GW in conservation forest (*Kawasan Konservasi*). The assessment also indicated that the higher capacity projects (> 200 MW) are primarily located in high and medium-risk locations, with most low-risk locations having < 200 MW capacity estimates.

Key issues	Recommendations
The highest cumulative geothermal power potential is located in areas already deforested and on non-state-forest land (APL), however the individual resources are of medium to high enthalpy. This contrasts with geothermal power potential found in forested areas which comprises higher enthalpy resources individually and makes up about 27% of the total capacity in Indonesia (according to MEMR data).	• To reduce social and environmental impacts, exploration investments should preferably target the significant geothermal capacity in non-forest land (APL). These resources, however, are of medium enthalpy and are likely to be populated and agricultural areas thus presenting higher social risks for operators.

The risk assessment presented in this report is dynamic and outcomes will vary with changing environmental and social conditions. For example, the ongoing reallocation of state land to private tenure for indigenous people will result in increasing spatial overlap of areas of high geothermal energy potential and community tenure. This generates uncertainty for the geothermal power companies, because the process of mapping and legally recognizing indigenous community lands is ongoing and incomplete, as is the development of laws and regulations that determine community management responsibilities in relation to forest use status (e.g., Protection Forest, National Park).

Key issues	Recommendations
The risk assessment is determined on the basis of variables and values for environmental and social risk and geothermal capacity that will change with better data and changing conditions.	• Regularly update the risk assessment as new data become available. Government institutions should share accurate data to ensure that the tool used in this risk assessment is as accurate as possible. • Provide regulatory clarity about reconciling indigenous land rights and tenure claims with geothermal development.

Data precision was a general concern during the current study particularly as the study relied on secondary data the accuracy of which could not be verified. Government data on potential geothermal capacity of individual areas and the precise geographic location were hard to obtain, and precision of this information was unknown. One recommendation from this study is that the Government invest in exploration so that more detailed resource data are available on potential project location and capacity. Similarly, it was not possible to obtain precise data on the boundaries of protected areas, their management zones and blocks, locations of indigenous land claims, and other key variables. The current risk assessment is therefore preliminary in nature and needs to be improved with more precise spatial and other data, which will hopefully become more readily available with strengthening of the government's implementation of the One Map Policy.

Summary recommendations regarding the regulatory framework for geothermal power development in Indonesia.

The Indonesian Government, including MEMR and MoEF, are facilitating geothermal power development in forest and conservation areas by streamlining and providing clarity on key laws and regulations. An earlier version of this report provided an in-depth review of the key laws and regulations and also assessed whether they are effectively implemented and enforced. Here we provide an overview of the key findings the relevant laws and regulations in Indonesia; the full findings are available on request.

Geothermal power laws and regulations. Geothermal Law No. 21/2014 allowed geothermal power development in certain conservation areas not previously available for development, through the Environmental Service Permit for Geothermal (*Izin Pemanfaatan Jasa Lingkungan Panas Bumi* or IPJLPB) mechanism.

Key issues	Recommendations
• The prevailing regulations neither specify a mechanism on how the production bonus paid by the geothermal company to local government should be invested, nor are procedures for monitoring and reporting the use of this bonus provided. • The detailed requirements and procedures for the geothermal company to undertake community empowerment and development programs and to develop work plans and budgets for this are not specified in the prevailing regulations. • The details of closure plans and associated costs to ensure that no liabilities remain following closure of geothermal sites are not fully detailed in the current regulations. • The procedures and responsibilities regarding the need for MEMR and MoEF to reconcile the forestry or conservation status and geothermal working areas needs streamlining and strengthening.	• The mechanism for the local government for using the production bonus, including the monitoring and reporting mechanism should be regulated to ensure its transparency. • Guidelines are required to develop community programs, closure plans, work plans and budgets and periodic reporting (Note: MEMR has stipulated ministerial regulations No. 41/2016 on the detailed requirements for community empowerment programs, and No. 7/2014 for reclamation as well as closure plans for mineral and coal mining). • Develop guidelines to specify the procedures and requirements, including financial provisions that should be allocated as part of the closure plan for geothermal project sites and associated infrastructure and facilities. • Strengthening of coordination between MEMR and MoEF to assign clear responsibilities and procedures between these ministries in resolving key issues related to forestry, conservation, and geothermal working areas. Respective coordinating ministers for these ministries should endorse this process to ensure accountability.

The new Geothermal Law (2014) stipulates a number of requirements for facilitating prudent geothermal development, benefit sharing, dealing with the zoning and blocking systems in conservation areas, and implementing appropriate environmental impact assessments, but the details of how this is done are insufficient.

Natural resource conservation laws and regulations. The laws and implementing regulations prohibit geothermal power development in Strict Nature Reserves and Wildlife Reserves (*Cagar Alam* and *Suaka*

Margasatwa), but allow the mentioned development in the utilization zones (*zona pemanfaatan*) of National Parks (*Taman Nasional*) and the utilization blocks of Grand Forest Parks (*Taman Hutan Raya*) and Nature Recreational Parks (*Taman Wisata Alam*) through the Environmental Service Permit (IPJLPB) (i.e., MoEF Regulation P.46/2016). Core zones and core blocks of these conservation areas remain legally off-limits for such developments.

According to official data, some 20 existing and potential geothermal work areas fully or partly overlap with the boundaries of nature or wildlife reserves. There are currently no obvious legal ways to exempt exploration and exploitation of geothermal resources in these areas without changing the conservation status of the reserved areas. Thus, MoEF is often requested to change the status of conservation areas or conservation area zones and blocks that do not allow geothermal power development to a status that does allow this. Because of the potential impacts that geothermal projects can have, especially with regard to developing infrastructure into previously inaccessible areas, such status changes need to be carefully risk assessed up front and evaluated in terms of avoiding and mitigating negative environmental impacts. For example, if parts of national parks were originally designated as the core zones (*zona inti*) because of their intact condition and high biodiversity values, changing this to the utilization zone (*zona pemanfaatan*) and thus allowing developments, could undermine the original values the core zone meant to protect.

Key issues	Recommendations
Given the conservation objectives of conservation areas, and the fragile nature of many Indonesian conservation areas, it is likely that geothermal power development will increase pressure on these areas and wildlife populations through increased access, disturbance, and habitat fragmentation.	• Development of geothermal power projects in high-risk conservation areas, such as the core zones of National Parks should be avoided. • Changing the legal status and zones or blocks of conservation areas to allow for geothermal power development requires a thorough risk assessment process followed up with strong enforcement of avoidance and mitigation measures.

Another issue related to zonation and blocking in conservation areas is that this process has been completed for only 124 out of 521 areas (24%). A key question for geothermal operators and regulators is whether a development permit can be granted and subsequent exploration and exploitation can proceed if the geothermal working areas overlap with conservation areas, but the zones or blocks have not yet been formally designated.

Key issue	Recommendations
In many cases, zones and blocks in conservation areas with geothermal potential have not yet been formally designated.	• In cases where the zonation and block of conservation areas is not yet complete, the geothermal permit (*Izin Panas Bumi*) should not be granted without prior resolution between MEMR and MoEF.

The mechanism to calculate the tariff of the fee (known as *iuran*), to be charged once prior to the issuance of the IPJLPB, as well as that of the levy (known as *pungutan*), to be charged annually for the duration of the IPJLPB permit is reportedly being formulated by the MoEF in consultation with the Ministry of Finance. The indicative tariff of these fees and levies remains ambiguous at the time of writing.

Key issue	Recommendations
The MoEF plans to charge the IPJLPB permit holder for using the conservation areas for geothermal power development through standardized fees to be paid once upon granting of the aforementioned permit and levies to be charged per hectare per year as compensatory payment. The magnitude of these fees and levies for conservation areas has not been officially set by the MoEF.	Payments for lost ecosystem services should be determined by the ecological condition of a particular area prior to its development for geothermal power. The risk assessment in the current report may be used as a guide for setting project-specific environmental service fees (i.e., retribution and levy) as it takes into consideration the current ecological condition of the area, community dependence on forest resources, and importance for biodiversity. For example, three different environmental fee levels could be set for low, medium and high-risk locations.

Laws and regulations on Protection Forest and Production Forest. Unlike in conservation forest, geothermal power development in Protection and Production Forest is regulated through a Forestry Borrow-to-Use Permit (*Izin Pinjam Pakai Kawasan Hutan* or IPPKH), which is governed by a different set of laws and regulations. The prevailing regulations stipulate offsetting requirements and compensatory actions for the IPPKH permit holder which are complicated and costly to implement, requiring engagement of a large number of local, regional and national government agencies for designating off-site reforestation targets and implementing reforestation on these lands. Also, the level of compensation depends on where the project is located. As reforestation is often targeted in areas outside the forest area ("critical lands") where the project takes place, project buy-in into reforestation programs is limited.

Key issue	Recommendations
The Forestry Borrow-to-Use Permit Regulation (P.50/2016 Regulation) stipulates complex procedures and requirements for compensatory actions. Further, the compensatory lands subject to reforestation are not readily identified as the MoEF does not appear to have a consolidated database for this.	• A simpler regulatory framework for the IPPKH permit, particularly for offsetting requirements and compensatory actions would benefit the geothermal industry and reforestation efforts. • A new regulation for compensatory payments for lost environmental services should require that these payments are directed towards improving management of the forest areas where the project is developed. • Reforestation targets should ideally be focused on deforested parts of the conservation area or Production or Protection Forest area in which the project is located to increase project buy-in.

	• The MoEF should establish a consolidated database regarding critical lands subject to reforestation to expedite the compensatory action process.

Environmental and social impact assessment. Environmental and social impacts and risks associated with geothermal power development are complex and significant. For exploration activities, which often include extensive road construction, only an UKL-UPL document (a lighter form of environmental planning and mitigation and monitoring plan) is required, rather than the full environmental impact assessment (AMDAL) which is required for the exploitation phase. The Ministry of Environment Regulation No. 5/2012 stipulates that geothermal projects with a working area of ≥ 200 ha, cleared area of ≥ 50 ha, and a power generation capacity ≥ 55 MW, only require a UKL-UPL document in non-conservation and non-forest areas, rather than the full environmental impact assessment (AMDAL). According to the MEMR, however, in the implementation, the entire geothermal working area is always set at ≥ 200 ha and therefore all geothermal business entities require an AMDAL document at the exploitation stage.

Key issues associated with the quality of the UKL-UPL and AMDAL documents, include the wide capacity gap and resourcing issues between the national and local environmental agencies in evaluating these documents. This results in technically weak documents, while key impacts and risks of geothermal power development are overlooked and risk mitigation strategies are not well articulated. Further, a meaningful public consultation is rarely conducted by geothermal companies resulting in unnecessary community misunderstanding and opposition from the outset of the project.

Key issue	Recommendations
A UKL-UPL (a lighter form of environmental planning and mitigation and monitoring plan) is required for geothermal exploration, even though exploration often requires forest clearing and construction of roads and drill sites. An ESIA or AMDAL is required for the exploitation phase. There are significant capacity and resourcing gaps between the national and local governments in evaluating UKL-UPL, AMDAL and other environmental documents. The above observations do not provide assurance that environmental and social impacts and risks are adequately assessed and mitigated. Insufficient baseline information collection and public consultation occurs in the project development phase resulting in increased environmental and social costs in the exploitation phase and frequent project delays.	• The UKL-UPL for geothermal exploration which involves construction of new access roads in forest or conservation areas should be significantly strengthened to ensure that environmental risks are adequately assessed and include specific avoidance and mitigation measures related to road construction which effectively manage the direct and indirect impacts of road construction. Special technical guidelines with regard to road construction in high risk locations should be developed to ensure operators adequately understand the risks. • Geothermal companies and government agencies at all levels should conduct meaningful public consultations throughout the project phases, beyond the current regulatory requirements. • Due to the strategic national interests and complexity of technology and impacts associated with geothermal power development, the approval process of AMDAL documents and issuing of subsequent Environmental Permit should be

	entirely assigned to the MoEF for better capacity and robustness in the environmental approval and permitting process. This undertaking should, however, involve competent personnel of the Geothermal Directorate as one of the key stakeholders. • Better guidance is needed on mitigating environmental and social impacts of geothermal power development in forest and conservation areas, especially when projects are located in medium or high-risk areas. • Project locations that are deemed high-risk in the current analysis should require a national-level review of the AMDAL report by the AMDAL Commission of the MoEF at the central government level.

Regulating geothermal power development at the landscape level. Approximately 150 out of a total 550 provincial and local governments throughout Indonesia have undertaken the strategic environmental assessment (SEA) as mandated by the Environmental Protection and Management Law No. 32/2009. MEMR has reportedly not yet completed the SEA for its geothermal policy, plans and programs. Without the SEA, the potential environmental impacts due to government's policies, plans, and programs including those related to geothermal power development will not be understood at the landscape, regional and national levels.

Given the above ongoing SEA development, it is likely that the 330 geothermal resource potential points analyzed in this study, have not been integrated into the prevailing provincial, regency and municipality spatial plans (*Rencana Tata Ruang Wilayah* or RTRW). This means that if a proposed geothermal development is not incorporated in the prevailing spatial plans, the project cannot commence, unless the existing spatial plan is revised. The review of spatial plans is typically every 5 years.

Key issue	Recommendations
• The potential environmental impacts of government policies, plans, and programs for geothermal power development are not fully incorporated into current SEAs. • The alignment of 330 geothermal resource potential points with prevailing provincial and regency, and municipality spatial plans is unknown in the absence of such data within the government's domain.	• The geothermal resource potential points in the MEMR's database, particularly those with high potential for development should be checked against the prevailing spatial plans at all government levels, and the respective SEA should be completed for validation by respective governments.

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Abbreviations and Acronyms

AMDAL	*Analisis Mengenai Dampak Lingkungan Hidup* (Environmental Impact Assessment - the overall process of assessment on any proposed development that could conceivably affect the environment in order to determine its potential for generating significant impacts. The AMDAL itself comprises three separate documents KA-ANDAL (TOR), ANDAL, and the RKL-RPL)
ANDAL	*Analisis Dampak Lingkungan Hidup* (Environmental Impact Statement)
APL	*Areal Pengunaan Lain* (non-state-forestland for non-forestry uses)
EBTKE	*Direktorat Jenderal Energi Baru dan Terbarukan dan Konservasi Energi* (Directorate General of New and Renewable Energy and Energy Conservation)
GHG	Greenhouse gas
GIS	Geographic Information System
GR	Government Regulation
GW	Gigawatt
IPJLPB	*Izin Pemanfaatan Jasa Lingkungan Panas Bumi* (Environmental service permit for geothermal power development in conservation areas)
IPPKH	*Izin Pinjam Pakai Kawasan Hutan* (Borrow-to-Use permit in Production and Protection Forest areas for non-forestry use)
KLHS	*Kajian Lingkungan Hidup Strategis* (Strategic Environmental Assessment)
KSDAE	*Direktorat Jenderal Konservasi Sumber Daya Alam dan Ekosistem* (Directorate General of Natural and Ecosystem Conservation)
MEMR	Ministry of Energy and Mineral Resources
MoE	Ministry of Environment (before its merger with the Ministry of Forestry)
MoEF	Ministry of Environment and Forestry
MW	Megawatt
PIAPS	*Peta Indikatif dan Areal Perhutanan Sosial* (Indicative Social Forestry Maps and Areas)
PTKL	*Direktorat Jenderal Planology dan Tata Lingkungan* (*Directorate General of Forest Planology and Environmental*)
RKL-RPL	*Rencana Pengelolaan Lingkungan HIdup – Rencana Pemantauan Linkungan Hidup* (Environmental Management Plan – Environmental Monitoring Plan)
RPJMN	*Rencana Pembangunan Jangka Menengah Nasional* (Government of Indonesia's Mid-term National Development Plan)
SDG	UN Sustainable Development Goals
UKL-UPL	*Upaya Pengelolaan Lingkungan HIdup – Upaya Pemantauan Linkungan Hidup* (Environmental Management Effort – Environmental Monitoring Effort document)
UNESCO	United Nations Educational, Scientific and Cultural Organization
WKP	*Wilayah Kerja Panas Bumi* – geothermal working area

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1. Introduction

1.1. Background

The transition towards a sustainable energy sector development path through increased use of renewable energy is one of the key goals of the Indonesian government's National Medium-Term Agenda (RPJMN 2015-2019). The electrification ratio in Indonesia as of the end of 2017 was reported by the government as 95.35% (ADB 2016), but there is still a need to increase the supply of electricity to underdeveloped parts of the country and achieve universal access, especially in eastern Indonesia (Figure 1). By the end of 2024, the State Electricity Company (PLN), whose business plan (RUPTL) is currently heavily relied on by the Government for national power sector investment planning, projects that 60 percent of the 70.4GW of new capacity added from 2015 will be coal-fired generation, and 40 percent from low carbon energy solutions, which includes 20 percent gas-fired and 20 percent from renewables mainly from geothermal power and hydropower (The World Bank 2015).

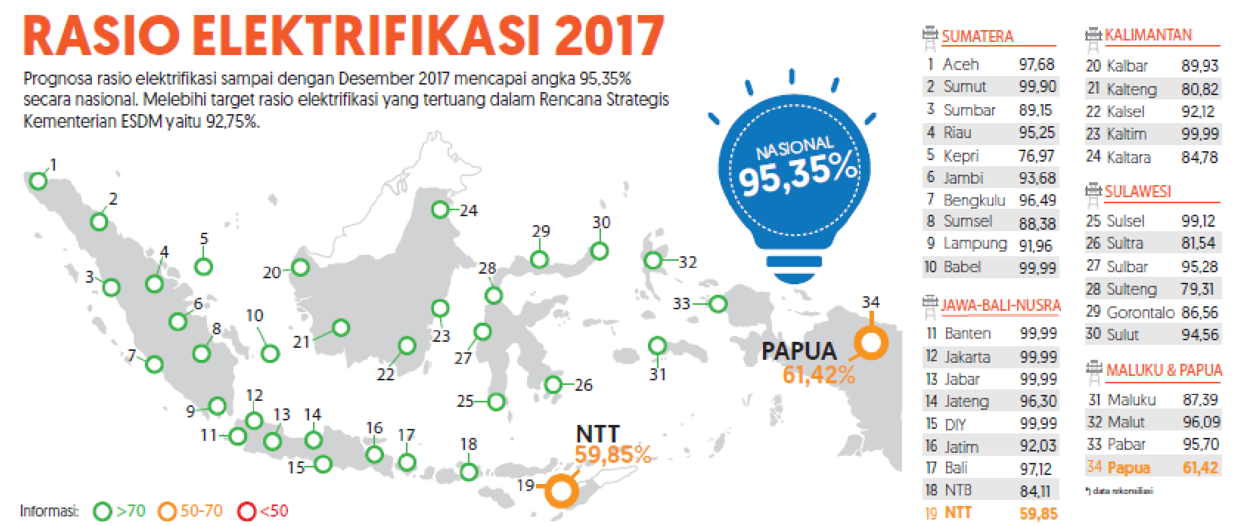


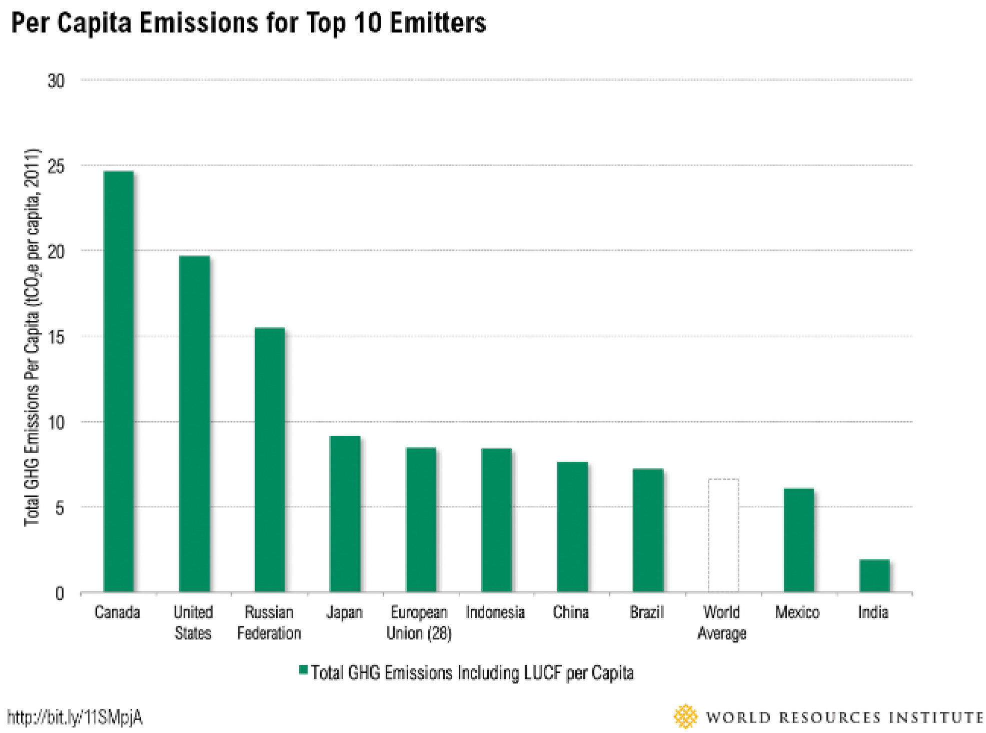
Figure 1. Electrification ratios as of December 2017 reported by the Indonesian Ministry of Energy and Mineral Resources MEMR, 2018 https://www.esdm.go.id/assets/media/content/content-rasio-elektrifikasi.pdf (accessed 1 November 2018)

The Government also recognizes the need for a strengthened policy environment, to unlock Indonesia's significant endowment of renewable and gas resources as alternatives to coal. Hydropower and geothermal resources are Indonesia's two largest potential sources of renewable energy with an estimated potential of 75GW and 29.4GW, respectively (but note that some question the accuracy of this estimate, see ADB & The World Bank 2015). However, matching responsible development of renewable potential with load centers on Indonesia's vast archipelago is a major challenge, requiring well-designed policies that make as much of the clean energy potential feasible (The World Bank 2015). Supported by the adoption of provisions in the 2014 Geothermal Law, unlocking geothermal power potential is fundamental, as geothermal power is able to serve as a base load as a direct substitute to coal-fired thermal generation. The outcome of the COP-21 process, in which Indonesia is an active participant, can also deepen reforms and accelerate a shift to a more sustainable energy development path. Indeed, Indonesia's final Intended Nationally Determined Contribution (INDC) reiterates its commitment to promoting *inter alia* renewable energy and notes it has established the development of clean energy sources as a national policy directive.

Efforts to scale up geothermal energy, are, however, constrained by implementation challenges, lack of capacity, environmental and social issues (many locations with geothermal potential are in forest areas), permitting delays, and a history of low energy pricing (Tharakan 2015). To address these constraints in the geothermal sector, the Government of Indonesia has put major efforts into promoting geothermal development with initiatives such as the Roadmap of Geothermal Development 2012–2025, the National Energy Policy 2014, the issuance of a new geothermal tariff in 2014 and the Geothermal Law No. 21 of 2014 (ADB & The World Bank 2015). Ambitiously, the Government of Indonesia has set a target of increasing geothermal power generation nearly five-fold, from 1.4GW in 2015 to 7.2GW of geothermal capacity by 2025, a 400% increase in 10 years. Others have argued that given the uncertainties in resource estimates a target of 4.8GW by 2020 might be more realistic (ADB & The World Bank 2015).

In addition to the high geothermal potential in Indonesia's largely volcanic archipelago, there are several other reasons why the country would promote geothermal energy. Unlike many other sources, geothermal energy is one of the few technologies that can be downscaled effectively (Katzner *et al*. 2013), and therefore operations can be developed across widely varying scales from single households to large industrial-scale projects.

Geothermal energy, like other renewables, also has significant environmental benefits in terms of climate change mitigation. Emissions from geothermal plants are lower (average 122 g/kWh) compared to fossil fuel combustion-based power plants (e.g., coal ca. 900 g/kWh; oil ca. 700 g/kWh), although there is high variation between different geothermal projects (ESMAP 2016). Indonesia's Intended Nationally Determined Contribution (INDC) of 2015 outlined the country's plans for transitioning to a low carbon future. The commitment included an unconditional 2030 GHG emissions reduction target of 29% below business-as-usual (BAU) levels, and a conditional 41% reduction below BAU by 2030 (pending sufficient international support). Indonesia is the sixth highest GHG emitter worldwide, in the top ten countries of per capita emitters and the most intensive global GHG emitter from deforestation and land-use change (World Resources Institute 2016). Over 63% of GHG emissions attributed to Indonesia originate from land-cover and land-use change, which is predominantly from clearing of tropical rainforest and draining deep peatlands. Emissions from energy and industrial sectors are relatively small, but are growing very rapidly. Nevertheless, a shift from fossil fuels to renewable forms of energy is in line with Indonesia's global environmental commitments.



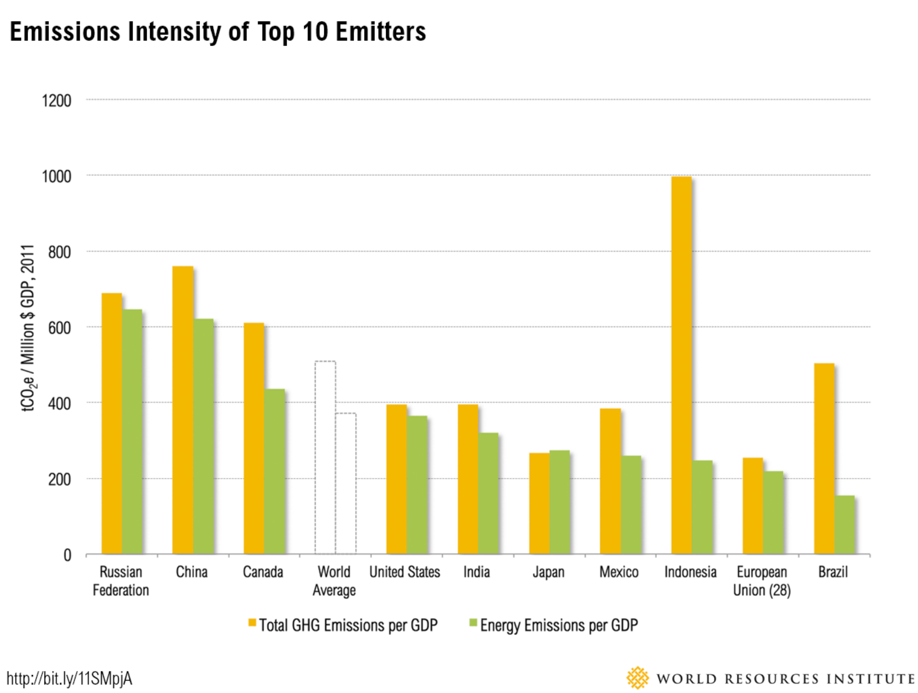


Figure 2. Top 10 global greenhouse gas emitters. Top: top 10 emitters. Bottom: emissions intensity for the top 10 emitters' whole economies and energy sectors (World Resources Institute 2016)

Indonesia's environmental commitments are expressed through the country's effort to align its National Mid-Term Development Plan 2015 – 2019 (RPJMN 2015 – 2019) with the UN Sustainable Development Goals (SDGs) which include two goals relevant to this discussion on geothermal energy development in forested areas. The first goal, SDG 7, which aims to ensure access to affordable, reliable, sustainable and modern energy for all. One of the targets is, by 2030, to increase substantially the share of renewable energy in the global energy mix. SDG 7 aligns with National Development Plan Target #3 on Energy Security. The second goal, SDG 15, which aims to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. This includes safeguarding places that contribute significantly to global biodiversity, establishment of conservation areas, and identification of key biodiversity areas. SDG 15 aligns with National Development Plan Target #7 on Protection of Natural Resources, Environment and Disaster management.

The two SDGs and the corresponding Indonesian National Development Plan Targets indicate one of the challenges and dilemmas Indonesia faces in developing its geothermal energy potential. The areas of highest geothermal potential (high enthalpy) are predominantly found in some of Indonesia's most biodiverse montane and sub-montane ecosystems. Geothermal systems are mainly associated with volcanic systems in subduction zones along continental plate margins. Because of this setting, most heat sources occur at higher altitude along the volcanic belt of Sumatra, Java, Bali, Nusa Tenggara Barat, Nusa Tenggara Timur, Sulawesi, Maluku and Papua, as well as in some non-volcanic areas (Partnership International 2013). Many of these areas remain forested and are included in Indonesia's protected area (conservation) network Figure 3. Mountainous regions are also often of spiritual and cultural importance or are claimed by indigenous people as customary lands. This co-occurrence of areas of high geothermal potential with areas of high social and environmental values has been a major barrier for the industry. According to the Directorate General of New Renewable Energy and Energy Conservation of the Ministry of Energy and Mineral Resources, 14% of the areas of high geothermal potential are located in conservation areas (5.9GW potential), and some 28% in Protection and Production Forest areas (10.3GW potential) (WWF-Indonesia 2013).

Figure 3. Example of a geothermal project partially developed in a conservation area. Photo 2017 by E. Meijaard.

To increase the pace of geothermal power development and address some key constraints, the Government of Indonesia enacted the Geothermal Law No. 21 of 2014 ("the Law 21/2014"). The Law 21/2014 established and clarified some of the issues that had hindered geothermal power development projects, particularly those located in conservation forest in Indonesia. Among others, it provided the sole authority to the Minister of Energy and Mineral Resources (MEMR) to grant "Working Areas" (*Wilayah Kerja*) for geothermal indirect utilization (i.e. power generation project) and subsequent geothermal working permit (*Izin Panas Bumi* or IPB) throughout Indonesia (but note that the law requires coordination with MoEF on this). Subsequently, related implementing regulations governing management of sanctuary reserves and nature conservation areas have also been amended to provide a legal basis to enable geothermal power development in National Parks (*Taman Nasional*), Grand Forest Parks (*Taman Hutan Raya*), and Nature Recreational Parks (*Taman Wisata Alam*). Strict Nature Reserves (C*agar Alam*) and Wildlife Sanctuaries (S*uaka Margasatwa*), however, remain off-limits to new geothermal power development projects to date.

While these developments increase the potential areas open for renewable electricity development, thereby addressing a key constraint identified by geothermal project developers, a lack of legal clarity remains on the details of how this should be done without causing net negative environmental and social impacts. Such legal challenges are common in geothermal elsewhere (for an overview, see Bapa 2003). For example, core zones (*zona inti*) of national parks remain off-limits for geothermal development, an issue that was brought to international attention recently with regard to plans for developing a geothermal project in the core area of Indonesian national park and World Heritage Site, a proposal strongly objected to by UNESCO (UNESCO 2015), but one that remains unresolved at the time of writing.

Requirements for environmental impact assessments (AMDAL) in conservation areas are also somewhat ambiguous, as is the legal authority for implementing wildlife management and law enforcement if a working area is given out within a conservation area: Who is responsible for ensuring that no harm is done to the environmental and wildlife values that the conservation area is legally required to maintain and who monitors this? With regard to social impacts, further legal clarification is also required, especially regarding community engagement and consultations, grievance mechanisms and risks associated with land acquisition, and the provisions for benefit sharing of geothermal revenues with local governments and communities.

1.2. Study Objectives

A recent report for the Indonesian government on the development of geothermal energy advocated the development of a guidance document which provides clear direction to geothermal operators, local government, and local communities on how geothermal projects can be synergized with forest conservation and community development (ARUP & WWF 2017). The current report addresses this issue. It seeks to assist the geothermal energy debate in Indonesia's forest areas by providing new information and insights that might help key government and non-government institutions involved to arrive at practical solutions for accommodating Indonesia's needs for clean energy in a manner that does not negatively impinge on the country's environmental and social objectives and commitments. This report aims to address this issue as follows:

1. Assess how the challenges of developing geothermal energy in tropical forest areas have been addressed elsewhere in the world.
2. Assess how past geothermal projects have been implemented in Indonesia and similar geographies elsewhere and what the associated environmental and social impacts have been, including the deforestation footprint of geothermal projects in forest areas.
3. Develop a macro-level risk assessment at the Indonesian national level, assessing how the geothermal potential overlaps with environmental and social values, and land use allocation, and provide a tool to Indonesian government institutions and investors which distinguishes between high and low risk project areas.
4. Conduct selected on-the-ground and desktop studies of existing geothermal projects and similar projects that affect conservation areas and forests (e.g., hydro-electric projects, road development etc.) to determine common practices in the industry, and how these relate to social and environmental threat mitigation.
5. Provide practical recommendations on project selection, design and implementation in forest areas, and management of social and environmental risks in forest areas.
6. Through desktop study, determine global best practices in geothermal energy and assess to what extent these are relevant and could be implemented in Indonesia.
7. Discuss study outputs with relevant government institutions and other stakeholders (financing institutions, environmental and social NGOs etc.)
8. Provide written output relevant to earlier mentioned stakeholders and other audiences.

The original study also included a comprehensive review of Indonesia's current legal framework with regard to geothermal development in forest and conservation areas and identification of gaps and conflicts. These findings are not presented in this version of the report but are available on request.

2. Approach and Methods

2.1. Review of geothermal power projects

The first step in this analytical process was to conduct a desktop review of existing (installed capacity) and planned geothermal power projects in Indonesia and a selection of global geothermal power projects in operation, as well as rapid site visits to selected geothermal power development projects in Java and Sumatra. The desktop review used a non-systematic search approach, starting with general internet searches for environmental and social impacts of geothermal projects, and more specific searches in the scientific literature using Google Scholar.

Based on this analysis, we recommend mitigation measures that could be applied in Indonesia to reduce impact. Among others we considered specific mitigating management strategies that could reduce biodiversity impacts, and also compensations or offsets required in the Indonesian laws or regulations to cover forest loss and other impacts that cannot be avoided or mitigated. We looked at best management practices with regard to road design, forest management, community engagement and impact monitoring.

2.2. Stakeholder consultation and site visits

The authors conducted consultations and site visits to national and local government institutions that are engaged in the policy development and regulatory enforcement implementation related to geothermal development, conservation and forestry affairs; the two primary stakeholders being the Ministry of Energy and Mineral Resources (MEMR) and the Ministry of Environment and Forestry (MoEF). In addition, meetings were held with NGOs who have an interest in geothermal energy. The meetings were conducted by Budiono Saputra, Erik Meijaard or Rona Dennis (with or without the World Bank staff). In addition, a reconnaissance visit was conducted to Darajat and Salak geothermal power projects in West Java, representing a well-established geothermal operation, and Sarulla geothermal project in North Sumatra, representing a project in the construction phase. The geothermal projects in Java and Sumatra were visited based on the consideration that these areas represent the high geothermal potential and high biodiversity landscapes of Indonesia.

The stakeholder meetings and reconnaissance site visits conducted in the period March to August 2017 are listed below:

- 17 March 2017 - Directorate General of New and Renewable Energy and Energy Conservation office, Jakarta
- 23 March 2017 - Directorate General of Natural Resources and Ecosystem Conservation office, Jakarta
- 17 May 2017 – Province-level Nature Conservation Agency (*Balai Konservasi Sumber Daya Alam*) West Java
- 18 May 2017 – Head of National Park, Halimun and Salak National Park, West Java
- 29 May 2017 -- *Direktorat Pemolaan dan Informasi Kawasan Alam* (PIKA), Directorate General of Natural Resources and Ecosystem Conservation, Bogor
- 30 May 2017 – Climate and Energy Team, Worldwide Fund for Nature – Indonesia Programme, Jakarta

- 31 May 2017 – 2 June 2017 -- Various discussions with Head of Investment and Cooperation Division, Geothermal Directorate
- 31 May 2017 – Environmental Agency, (*Dinas Lingkungan Hidup*), Tapanuli Utara District, North Sumatra
- 31 May 2017 – Forest Management Unit (KPH) office Tarutung, Tapanuli Utara District, North Sumatra
- 31 May 2017 – Head of Programme, Fauna & Flora International Indonesia Programme
- 2 June 2017 – Province-level Nature Conservation Agency (BKSDA), Medan, North Sumatra
- 2 June 2017 – Yayasan Ekosistem Lestari (YEL), Environmental NGO, Medan, North Sumatra
- 14 June 2017 – Geothermal Directorate, Jakarta
- 16 June 2017 – Environmental Service Permit for Geothermal and Carbon Sub-directorate, Ministry of Environment and Forestry (MoEF), Jakarta
- 19 June 2017 – Geothermal Directorate, Jakarta
- 6 July 2017 – Directorate of Forest Use Planning, Ministry of Environment and Forestry (MoEF), Jakarta
- 12 July 2017 – Geothermal Directorate, Jakarta
- 17 July 2017 – Head of Exploration Supervision, Geothermal Directorate
- 19 July 2017 – Directorate of Business/Activity Impact Prevention - AMDAL & UKL-UPL section of MoEF
- 29 August 2017 – Geothermal Directorate, Jakarta
- 29 August 2017 – Conservational International Indonesia Programme
- 30 August 2017 – Friends of the Earth Indonesia / Wahana Lingkungan Hidup Indonesia
- 31 August 2017 – Government workshop for feedback on preliminary analysis.
- 16 November 2017 – Dissemination workshop to government, NGOs, and industry.

2.3. Micro-level assessment of impact and risk and field studies

2.3.1. Analysis of environmental footprints of active geothermal projects

An analysis was conducted by the authors of the social and environmental impacts of existing geothermal projects in Indonesian forest areas using the following approach.

The visible infrastructure and related land clearing viewed on Google Earth Pro imagery for 16 active (operating or in construction) Indonesian geothermal projects were manually digitized on screen. Whenever it was unclear whether particular infrastructure elements seen on the imagery were part of geothermal developments or related to other developments (e.g., village roads) historic imagery were used (available in Google Earth Pro) as well as uploaded site photos from the project location were used to determine whether particular features should be included as part of the project infrastructure. The resulting digitized project infrastructure lines and polygons were imported into the GIS and converted to ArcGIS shapefiles.

From the ArcGIS files, the total road length per project was calculated. Average road width in each project area was estimated by measuring width across road clearings (from forest edge to forest edge) on Google Earth on 10 points at 250m intervals along project roads. To estimate total deforestation from project development, the total area of cleared polygons was added to the area cleared along roads (total road length * average road width).

The next part of the analysis was to create a 1,000m buffer around combined roads and other project-related infrastructure to determine approximate areas of indirect impacts around project infrastructure. The 1,000m buffer was selected on the basis that published research shows that it represents an indication of indirect impacts such as hunting and unauthorised forest clearance which decline linearly with distance from forest camps and roads (Blom et al. 2005; Clayton et al. 1997; Laurance et al. 2006), but which can still be detected at 1,000 m from the road (depending on local terrain). Similarly, from Java, these indirect impacts were also determined in a hydroelectrical project area (Figure 4), which showed that impacts declined rapidly between 1,000 and 2,500m from roads. The 1,000m buffer is therefore a conservative measure of indirect impacts and could extend as far as 5,000m from roads, as was found in Sumatra for bird trapping (Harris et al. 2017).

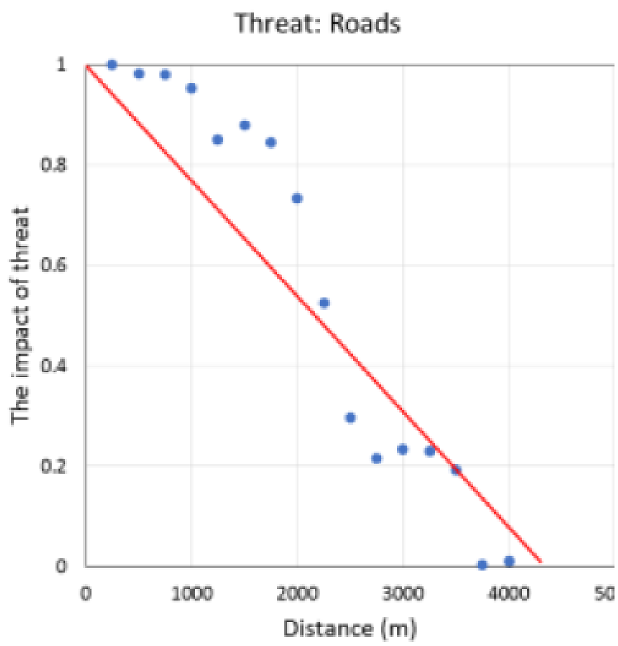


Figure 4. Fairly typical function of impacts on forest quality for biodiversity (measured as deforestation and forest degradation) as a function of distance to roads in a forest area on Java, Indonesia (CarbonTropic 2017). There is a rapid drop of impact between 1 and 2km, although impacts extend up to 4.3km.

These analyses provided data on the direct impacts in terms of the amount of forest that had been opened up to facilitate the development of the geothermal projects, and the larger potential area of indirect impact from these projects on forests and forest wildlife. These impact estimates were compared to the projects' installed capacity to investigate the relationship between energy capacity and impact on forest and forest wildlife. This was expressed as 1) deforested area per MW capacity; 2) length of road development per MW capacity; and 3) indirectly impacted forest area per MW capacity.

Where available, the analysis was augmented with very recent (late 2016 or 2017) Landsat 8 OLI 30m multispectral imagery downloaded from the USGS website. In several cases, especially where projects are still under development, certain project features (e.g., new roads), not yet visible on Google Earth imagery were revealed through use of more recent imagery.

2.3.2. Project visits

To ground-truth the findings from the image analysis of project footprints, several field assessments were made at the following selected projects to discuss how environmental and social risks were managed, and to see on the ground what those impacts typically look like:

- 16 May 2017 – Darajat geothermal project, West Java, located in a Nature Reserve (*Cagar Alam*)
- 18 May 2017 – Salak geothermal project, West Java, located in a National Park (*Taman Nasional*)
- 1 June 2017 – Sarulla geothermal project, North Sumatra, located in a Protection Forest (*Hutan Lindung*)

To assess the effectiveness of mitigation strategies and the actual impacts, the authors observed and noted aspects such as road width, quality of forest along road sides (e.g., replanted, degraded natural forest, burnt forest), signs of non-project use (e.g., farming along roads), signs of hunting (e.g., people on roads carrying hunting equipment), road use (e.g., car speed, use of roads by non-project vehicles), security (e.g., presence of guarded road portals), and signage (e.g., prohibitions on hunting, burning etc., depending on local forest status). Where available, we used biodiversity monitoring reports and survey reports to assess the effectiveness of mitigation strategies.

2.4. Macro-level risk assessment

Using the insights from the micro-assessment, a methodology was developed to produce a "macro" risk assessment based on a spatial analysis of the environmental and social risks associated with the development of geothermal resources across Indonesia. The geothermal potential point data produced by the Geological Agency (*Badan Geologi*) were used as the basic unit of analysis and the overlap of these points was assessed with nine environmental and social parameters. It is recognized that these geothermal potential points are only an approximation of the actual location of the geothermal field and the likely location of the eventual project location. The current macro-analysis is a first step in starting to qualify and quantify development risks, and more detailed spatial data on likely locations and size of project developments are required to increase the accuracy of the analysis. The parameters were selected on the basis of a) a possible impact of geothermal power development on these environmental and social values; and b) availability in spatially-referenced format for the entire geography of Indonesia. The analysis has more bias towards environmental values as these are more readily available as secondary data compared to social values.

The analysis was initially focused, similar to such assessments by government agencies, on the overlap of existing and potential developments with state designated forest land, namely conservation areas (K*awasan Konservasi*), Protection Forest (*Hutan Lindung*), but also Production Forests (*Hutan Produksi*) and land outside the Forest Estate (*Areal Penggunaan Lain*). In addition to confirming the respective overlap with conservation areas and various forest use designations, the authors also identified where geothermal potential and existing projects overlapped with internationally recognised areas of high biodiversity value (equivalent to Critical Habitat), high socio-cultural value, and also identified where overlaps existed with areas of high deforestation or with stable landcover.

The outcome of the macro-level assessment was a ranking per geothermal potential point of the possible environmental and social risks associated with development (see Annex 1).

2.4.1. Assessing environmental and social risk of potential geothermal projects in Indonesia

The analysis was conducted using the Geographical Information System software ArcGIS incorporating a variety of secondary data sources. There were a number of initial problems in obtaining some of the key datasets, such as the geothermal potential point locations from the Geological Agency (*Badan Geologi*). These points were the key dataset in the analysis and were firstly mapped using a combination of the published list (ESDM 2012) and a scanned Indonesia-wide map of the points. All of the 330 point-locations and associated attributes (ID, name, administrative region, speculative, hypothetical, possible, probable, proven, and/or installed MW capacity values) were manually digitized and entered into the GIS. Halfway through the study, as part of the MEMR One Map Indonesia policy, the geothermal potential point data became publicly available for viewing on the MEMR GIS Portal. Although it was not possible to download the native files there was sufficient information available to check the positional accuracy of the points which the team had originally manually digitised.

Other spatial data used in the assessment was either publicly available or was made available by the World Bank for the sole purpose of this study. Using up to nine different datasets from different sources showed a small amount of spatial misalignment between some of the datasets but this is to be expected and was minimised as much as possible.

Three of the datasets used are originally from the Indonesian Ministry of Environment and Forestry. The forest land use status data was a key dataset in this assessment and enabled the identification of the official forest use status at each of the 330 geothermal potential points. The conservation area categories included different types of conservation areas from National Parks to Strict Nature Reserves but for the overall assessment all types of conservation area were grouped into one with a weighting of 4 as this was considered the class with the highest potential to experience negative impacts as a result of development due to a reduction in conservation values which would result. The Production Forest category consisted of Production Forest, Limited Production Forest and Conversion Forest and was weighted as 2. Protection Forest was weighted as 3 as it was assumed that environmental values are high in this forest use category as its function is watershed protection and therefore disturbance would result in a loss or reduction in this function. Protection Forests are generally located in hilly or mountainous terrain, another reason why environmental impact is potentially weighted as 3. The non-forest category (*Areal Penggunaan Lain*) was weighted as 1 as environmental impact would potentially be relatively low compared to the other forest use classes.

The land cover categories were derived from the official forest and land cover data for 2015 published by the Indonesian Ministry of Environment and Forestry which consisted of 50 classes. For the purposes of the assessment only three classes were used in the analysis, primary forest (3 points) which equated to dense canopy cover forest, secondary forest (2 points) which equated to degraded forest and non-forest (0) which was everything but forest. These weightings conveyed the relatively high environmental values of primary forest compared to non-forest and therefore the higher environmental risks associated with developing a geothermal power project.

The third spatial dataset which originated from the Indonesian Ministry of Environment and Forestry was the Indicative Map of the Social Forestry Areas (PIAPS, 2016) which identifies areas that can be managed by communities under the Social Forestry scheme, namely the management of Village Forest, Community Forest, Community Plantation Forest, Partnership and Forest Rights. The PIAPS dataset was used as a social risk factor indicating areas where communities have rights to manage forests or could potentially have rights in the future.

Based on the authors' collective experience and on consultation with the World Bank Team supervising the assessment, a weighting system for environmental and social factors was developed (Table 1).

Table 1. Weighting system of environmental (shaded green) and social factors (shaded orange) that indicate the risk of developing geothermal projects in particular areas.

Weighting factor	Categories and weighting of category between brackets			
Forest land use status of geothermal point (MoEF, 2015)	Conservation area (4)	Protection Forest (3)	Production forest (2)	Non-forest use (1)
Land cover (MoEF, 2015)	Dense canopy cover forest (3)	Degraded forest (2)	Non-forest (0)	
Deforestation history (Hansen et al., 2013)	High forest loss (2)	Moderate forest loss (1)	No or limited recent forest loss, stable landscape (0)	
International values (UNESCO website, Birdlife International website)	UNESCO World Heritage or Cultural Landscape (2)	Birdlife International Important Bird Area (1), Key Biodiversity Area (1)	No other category (0)	
Size of conservation area	Planned geothermal impacts > 10% of conservation area (2)	Planned geothermal impacts < 10% of conservation area (1)		
Location of geothermal point in relation to area boundary	Geothermal point is deep inside conservation area (3)	Geothermal point is on the boundary of conservation area (1)	Geothermal point is outside conservation area (0)	
Presence of Isolated Indigenous People (IP Screening World Bank 2010)	Present (2)	Not present (0)		
Indicative social forestry areas (PIAPS, MoEF, 2016)	Existing claim (2)	No existing claim (0)		
Customary Land (Wilayah Adat) based on Badan Registrasi Wilayah Adat data	Certified (4)	Verified (3)	Registered (2)	Newly recorded (1)

The World Bank team provided the dataset which identified the presence/non-presence of isolated indigenous people ("isolated customary communities") at the village level across Indonesia. The development of a geothermal project was considered to potentially increase negative social impacts in areas where indigenous people lived as well as increasing the reputational risk faced by operators developing projects in these areas. The presence of indigenous people received a weighting of 2. In addition to the presence of indigenous people, the presence of customary land was also included as social factor. It was not possible to obtain raw format files of customary land boundaries; however, it was possible to visually compare data displayed on the Customary Land Registration Agency (*Badan Registrasi Wilayah Adat- BRWA*) GIS portal (http://brwa.or.id/sig/) with the geothermal potential points. The weighting used the four classes of customary land areas displayed on the BRWA GIS; certified customary land (4), verified customary land (3), registered customary land (2), and newly recorded (1). Figure 5 is a screenshot from the BRWA GIS Portal, which shows the number of customary land areas per province.

One point of uncertainty is the weighting system used in the current macro-analysis (see Table 1). This weighting system is subjective and more detailed study of individual geothermal projects is required to assess whether the current weighting system correlates well with actual social and environmental risks. For example, in the dissemination workshops it was argued that certification and verification of customary land, which was judged in the current analysis to entail high risk for project developers, could in fact be low risk because communities would be much more aware of their rights and in a better position to negotiate a fair deal with the geothermal company.

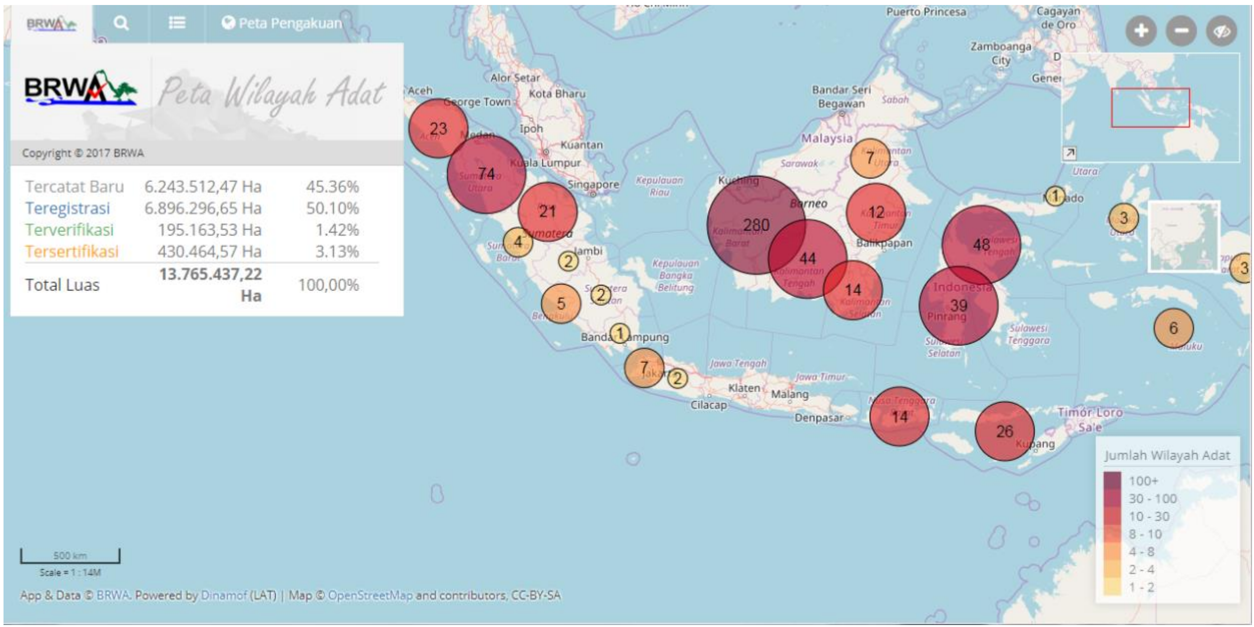


Figure 5. Customary Land Areas (Wilayah Adat) – Indonesia (http://brwa.or.id/sig/ accessed 11 November 2017)

For each of the mapped geothermal projects (existing, see under 3.2., and potential), the authors determined, using GIS analysis, whether these were located in forest or non-forest areas, the land use status of the project centre point (non-state forest land, Production or Protection Forest or conservation area), and the installed capacity in MW. It was also determined whether any of these points were located in areas of particular biodiversity importance (e.g., Key Biodiversity Areas, Important Bird Areas, UNESCO World Heritage sites).

To assess general deforestation threats in areas targeted for geothermal development, a 2000 – 2015 global deforestation dataset was used (Hansen et al. 2013). A spatial buffer area was generated with a radius of 2.5 km around each geothermal potential point (area of circle is 19.6 km^2) to approximate the average area of indirect impact around geothermal sites. This size was based on the average 20 km^2 of indirect impacts estimated for 12 existing projects in Indonesia (see Figure 15 in the Results section, chapter 3). This estimated average for each potential point had to be used as a proxy because reliable data on the potential geothermal capacity for each potential project location was not available. Within these polygon circles, the number of deforestation pixels was automatically counted. The frequency distribution of these deforestation data was calculated (Figure 6). The distribution of the points is strongly left skewed, with 50% of the points having between 1 and 523 deforestation pixels per circle and the remaining 50% between 525 and 21,399 deforestation pixels. Cut-off points were used for the first tertile, i.e., 33% of the points, ("low deforestation") between 0 and 269 pixels per circle, the second tertile "moderate deforestation" between 270 and 1062 pixels per circle, and the third tertile "high deforestation" 1063 or higher pixels per circle.

Next, the weighting system was applied to each of the 330 potential geothermal points, and the sum of the scores was calculated to determine in which risk category a potential geothermal power project falls. The weighting system can result in maximum 24 points and minimum 1 point. Cut-off boundaries were used for low, medium, and high risks, 1–3 points, 4–6 points, and 7–18 points, respectively. Points which were categorized a low risk (1 – 3) were generally found in non-forest status land areas with no forest cover and none of the three social risk factors present. Points in the medium risk category (4 – 6) were generally not in conservation areas but in non-forest, Production or Protection Forest with no international conservation values but potentially close to a conservation area, or with one social aspect present. High risk points (7 – 18) were predominantly in conservation areas, or Protection Forests with high weighted environmental and social values such as social forestry, customary land or presence of indigenous peoples.

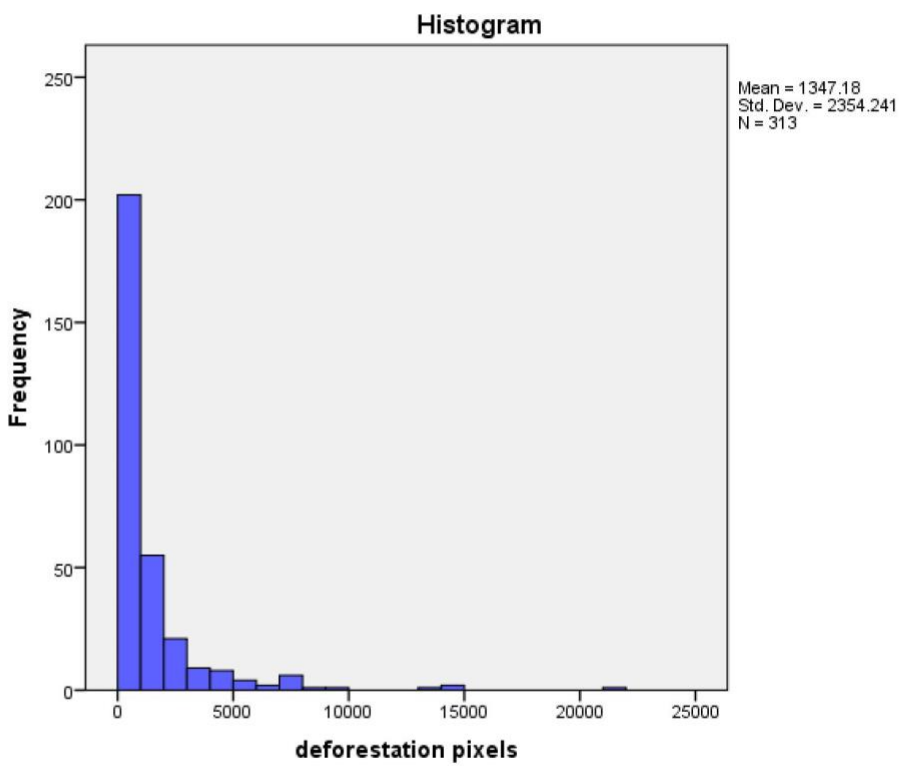


Figure 6. Frequency distribution of deforestation pixels in 330 geothermal potential points in Indonesia.

A project identified as high risk would not necessarily mean that it should not be developed, although financial institutions may be wary about financing such projects. It would certainly require specific regulatory arrangements that guarantee that only high-quality operators capable of implementing high environmental and community management standards and practices on the ground would be allowed to work in the area, and that these would be monitored more strictly in terms of adherence to environmental, conservation and community management practices in their working area.

The aim of this assessment was to predict for each of the geothermal potential points in Indonesia what their potential footprint would be if a project was implemented. This would allow various government institutions and geothermal companies and investors to predict impact on each conservation area in Indonesia, and use this to assess risks. Such assessments could also assist in the development of new regulations for geothermal developments in conservation areas, similar to those that exist for mining (underground only) allowed in Protection Forest (*Hutan Lindung*) and open pit mining allowed in Production Forests (i.e., any forest unit can never have more than 10% of the total forest area and/or concessions allocated to borrow-lease permits (*pinjam pakai*) for mining).

It is important to discuss the limitations inherent in these data due to the fact that the authors had to generate one key dataset; the position of the geothermal potential point data. The authors, however, are confident that this mapping error is small relative to the potential size of a geothermal project, and that errors remaining in the positional accuracy of the points will not significantly change the general outcome of the risk-mapping process described below. The reliability of assessments like the current one could easily be improved if government and non-government data in spatial format would be more readily available, as also noted by others (Jacobson 2017). Another consideration regarding the individual geothermal potential points and associated risk level is that the actual development is not likely to take place exactly at that point as the size and location of the geothermal field will be identified during the exploration phase. Below in Figure 7, is an example of two geothermal projects where the distance between the official geothermal potential point and the actual development is 3.8 km (Rantau Dedap) and 4.7 km (Lumut Balai) respectively.

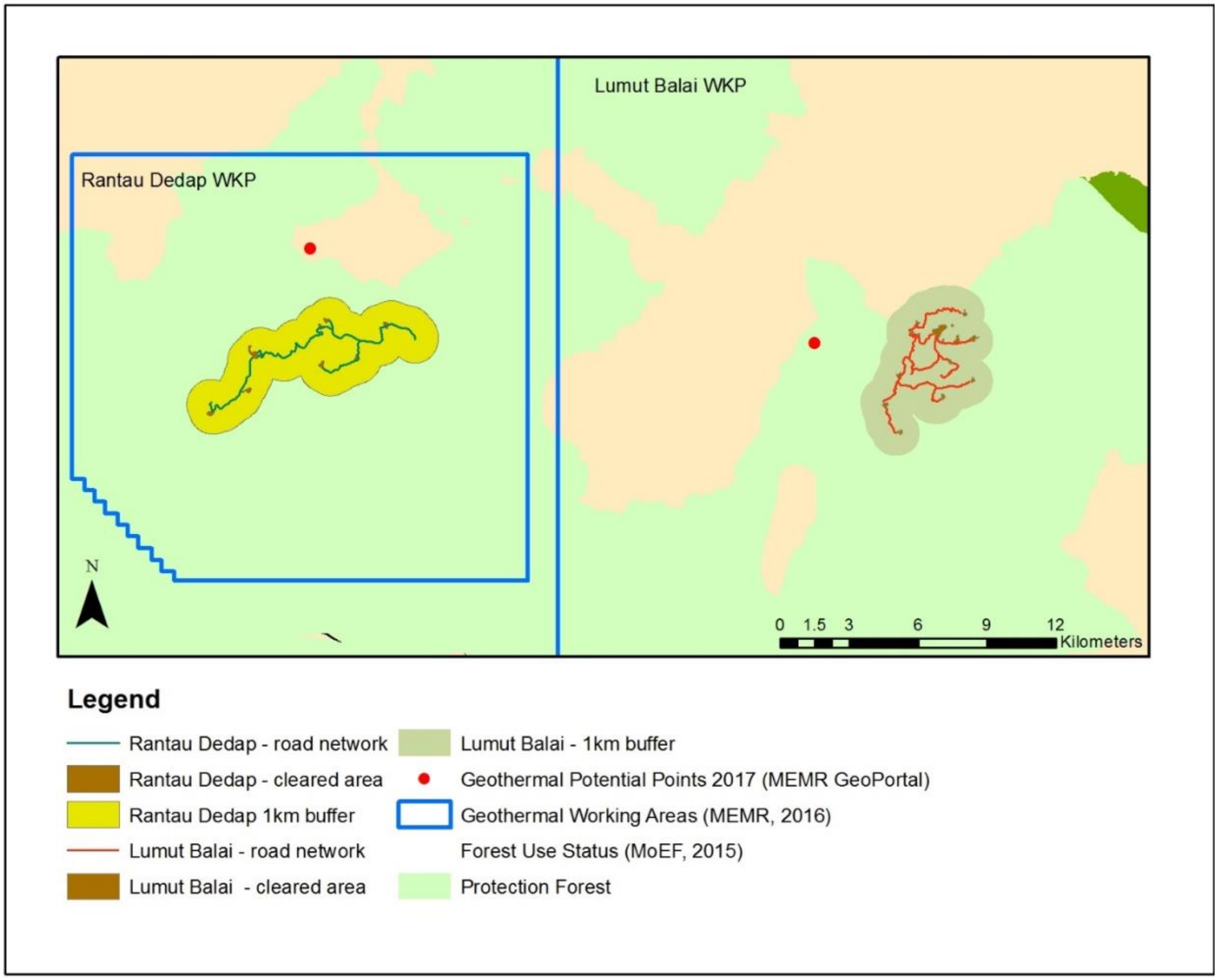


Figure 7. Example showing the geographical location of a Geothermal Potential Point (*Badan Geologi*) in comparison to the actual development on the ground for the Lumut Balai and Rantau Dedap developments in Sumatra.

2.4.2. Assessing correlation between project capacity and potential impact on forests

Building on the insights from the micro-assessment (see 2.3.) regarding the relationship between installed capacity and the environmental footprint (deforested area, road length and indirectly impacted area), the potential impacts were predicted for the 330 geothermal potential areas across Indonesia. It was found to be somewhat problematic to estimate potential capacity on the basis of available data. Figure 8 shows that the correlation between speculative, hypothetical, possible, or probable capacities, with installed capacity as provided by MEMR is poor ($r^2 = 0.02$, i.e., 2% of the variation in installed capacity is explained by the data on speculative, hypothetical, possible, or probable capacities). This means that it is very difficult to predict potential installed capacity on the basis of data currently available, and current Indonesian production capacity estimates have been referred to as essentially meaningless (ADB & The World Bank 2015).

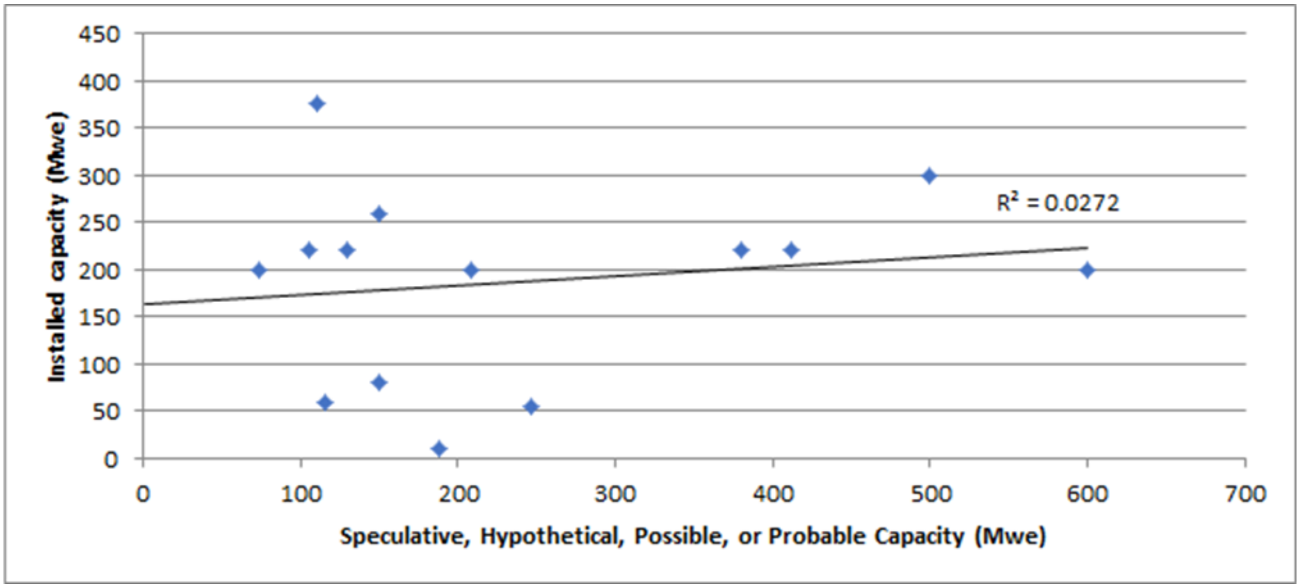


Figure 8. Relationship between resource estimates for geothermal at different levels of predictive value and ultimate installed capacity in these projects (data from Ministry of Energy and Mineral Resources).

Only at the proven resource level does the predictive value of the final installed capacity increase (Figure 9), with a coefficient of determination (r^2) of 0.73. Few of the 330 geothermal potential points in Indonesia (existing and potential) have proven resource estimates: speculative (n = 115); hypothetical (n = 70); possible (n = 110); probable (n =11); proven (n = 15); and installed (n = 18). This basically means that future installed capacity cannot reliably be predicted on the basis of available resource estimate data.

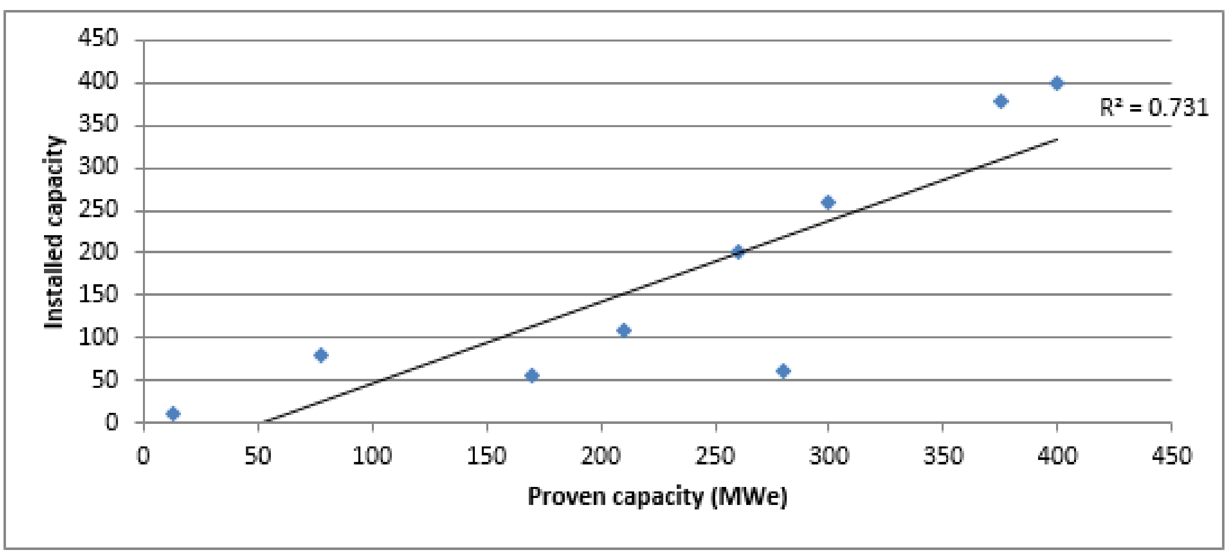


Figure 9. Relationship between proven resource estimates for geothermal and ultimate installed capacity in these projects (data from Ministry of Energy and Mineral Resources).

Because of the above-mentioned uncertainties in resource estimates, the following approach was used to predict potential impacts of future geothermal projects in Indonesia. Minima, maxima, and means of the road length and area of indirect impact of existing Indonesian geothermal projects (Table 2) were calculated and applied to all potential geothermal points in Indonesian conservation areas. Next, the team calculated for each of these conservation areas whether geothermal development would likely affect > 10% of a particular conservation area, based on the size of that conservation area.

Table 2. Road length and area of indirect impact for 15 active geothermal projects in Indonesia.

	N	Minimum	Maximum	Mean	Std. Deviation
Road length (km)	15	0.11	39.82	15.3	11.28
Area of indirect impact (km^2)	15	4.09	40.00	23.4	10.96

2.5. Review of geothermal technologies in Indonesia and elsewhere

An assessment was made of the influence of system type (steam or liquid dominated geothermal systems) on impacted forest areas in 12 Indonesian geothermal projects. To better understand how the impact of different geothermal technologies on forest environments in Indonesia compared with projects elsewhere in the world. For this, 12 projects in a range of different countries and using different technologies were selected to see how this affected environmental impacts. Similar to the Indonesian projects, we digitized project infrastructure in Google Earth, and calculated road length and other variables in ArcGIS. These international projects included Northern Negros, Makban, Mount Talinis and Mount Apo in the Philippines; Mori and Kakkonda in Japan; Aluto-Langano in Ethiopia; Las Pailas in Costa Rica; Lihir in Papua New Guinea; Eburru in Kenya; and Momotombo and San Jacinto – Tizate in Nicaragua. These projects cover a range of different methodologies, including small-scale wellhead modular geothermal production (e.g., Eburru).

3. Outcomes

3.1. Typical project phasing in Indonesian geothermal developments

All forms of electricity power generation have environmental and social impacts but it is the relatively small magnitude of these impacts that make geothermal energy power generation highly appealing compared to fossil fuels. In general, although minimal compared to the footprint from fossil fuels, the main environmental impacts of geothermal energy are air emissions, noise pollution, water usage, land usage, waste disposal, subsidence, induced seismicity, and impacts on wildlife and vegetation. Geothermal energy whether utilized in a binary, steam, or flash power plant, cooled by air or water systems is by most considered to be a clean, reliable source of energy, with only minimal environmental impacts, even when compared with other renewable energy sources. One source of impacts, however, remains relatively understudied and underreported. This is the impact of geothermal development on forest environments, and especially high biodiversity tropical forest areas. Overall, public perceptions about geothermal energy are relatively positive compared to other energy sources, but knowledge about impacts is low as the technology is not widely used and therefore not well known (Carr-Cornish & Romanach 2014). Such situations of insufficient public understanding of impacts from geothermal development have frequently led to conflicts in many parts of the world.

Table 3. Key Potential Environmental Impacts by Project Phase. Impacts are not in any particular order of severity.

Preliminary Survey (PS)/ PS & Exploration (PSPE)	**Exploitation and Utilization**		**Closure / Recovery**
PS: 12 – 18 months PSPE: 3 to 5 years Feasibility (up to 7 years)	30 years + 20 years per extension		Few years
	Construction	Exploitation / Utilization	
Negligible environmental impact for the PS (without drilling) **Direct** • Land clearing for drill pad & construction of access tracks causes forest loss/fragmentation • Road construction and clearing cause increased run-off and sedimentation of water courses • Noise and vibration disturb wildlife • Hydrocarbon contamination of water courses **Indirect** • Illegal logging & hunting • Wildlife poaching **Cumulative** • Existence of other industries such as timber companies within the same operating area will lead to an increase in overall cumulative impacts • Encroachment by local communities for extensive agriculture	**Direct** • Land clearing for construction result in forest loss/ fragmentation • Road construction and clearing cause increased run-off and sedimentation of water courses • Noise and vibration disturb wildlife • Dust disturbs wildlife and nearby community • Sedimentation and hydrocarbon contamination on surface water courses • Disturbance to river ecosystem • Ground subsidence **Indirect** • Illegal logging & hunting • Wildlife poaching **Cumulative** • The presence of timber companies and key industries operating in the area • Encroachment by local communities for extensive agriculture	**Direct** • Wildlife kills from traffic • Geothermal brine accidentally enters natural environment, water supplies for wildlife • Hydrogen Sulphide emission • Nitrogen Oxides, and vehicle exhaust related to machinery • Noise pollution disturbs wildlife • Induced seismicity • Ground subsidence **Indirect** • Illegal logging & hunting • Wildlife poaching	• Surface disturbance due to demolition and site restoration • Land Rehabilitation and Restoration • Disposal of hazardous waste • Sedimentation and hydrocarbon contamination on surface water courses

When assessing the environmental and social impacts it is important to categorize these according to whether the nature of the impact is direct, indirect or cumulative. Direct impacts are defined as adverse and/or beneficial impacts that can be immediately traced to a project activity. Indirect impacts are adverse and/or beneficial impacts that cannot be immediately traced to a project activity but can be causally linked. Finally, cumulative impacts are the combination of multiple impacts from existing projects and other land users.

Table 3 and Table 4 summarise the environmental and social impacts through the various stages of geothermal project development from preliminary survey to closure and recovery of the area. It should be noted that direct impacts tend to be the most obviously visible and easiest to manage for an operator because these impacts are usually within the sphere of control of the operator, whereas indirect and cumulative impacts are much less obviously visible and the responsibility for managing the negative consequences of these impacts is unclear and requires involved parties working together co-operatively together to resolve issues.

Table 4. Key Potential Social Impacts by Project Phase. Impacts are not in any particular order of severity.

Preliminary Survey (PS)/ PS & Exploration (PSPE)	**Exploitation and Utilization**		**Closure / Recovery**
PS: 12 – 18 months PSPE: 3 to 5 years Feasibility: up to 7 years	30 years + 20 years per extension		Few years
	Construction	Exploitation / Utilization	
• Negligible social impacts for the PS (without drilling) • Concerns and misunderstanding by local community • Some of the key social impacts during the exploration phase (which required road construction, drilling etc.) are similar to those during exploitation and utilization, in particular impacts on rivers and streams which flow to downstream communities, e.g increased sediment load which can impact water quality, fish stocks and irrigation water, as well as recreation areas such as waterfalls and lakes.	• Surface water extraction for construction and power plants impacts local supplies for household use and agriculture • Spontaneous in-migration • Involuntary resettlement • Health risk due to fugitive dust and excessive H_2S emissions • Community nuisance due to noise and vibration • Communicable diseases from influx of construction workers • Loss of forest livelihoods in immediate area of construction • High expectation for local employment and business opportunities • Loss of cultural heritage	• Community expectation for local employment and business opportunities • Loss of aesthetic value of the area if facilities are located close to population centers/tourist sites • Loss of forest livelihoods in immediate area of the project due to restricted access. • In-migrants establish settlements along access roads • Loss of access to land through land acquisition process • Actual or perceived unequal share of benefits lead to community tensions	• Loss of local employment and business opportunities

3.2. Micro-level assessment of Indonesian geothermal power developments

3.2.1. General overview of typical environmental impacts in Indonesian geothermal projects

The key Indonesian government guidebook on geothermal development in conservation areas (Sugiharta 2016) discusses the typical environmental impacts of different stages of geothermal project development in forest areas. These focus on noise, air pollution, water pollution and other environmental impacts, fragmentation of ecosystems, disturbance of wildlife; interruption of animal dispersal; and release of H_2S. It also mentions increased access to conservation areas through new roads, although there is no specific mention of human factors (illegal settlement, hunters, bird poachers etc.). As in most other countries, a typical environmental impact management approach is recommended that focuses on monitoring environmental changes and trends in indicator species.

Figure 10. Environmental impacts depend strongly on the quality of project implementation and avoidance of damage. At 15-20 m, road clearings in Lumut Balai (left) are twice as wide as the 8 m wide roads in Gunung Salak (right) doubling deforestation, and increasing fragmentation and edge effects. Lumut Balai photo from internet search, and Salak photo 2017 by E. Meijaard

The potential impacts of geothermal developments in Indonesian protected forest areas need to be seen against the baseline of what is happening without such developments. Indonesia's conservation areas are currently not sufficiently well managed to prevent deforestation and loss of biodiversity. For example, Indonesia's terrestrial conservation areas lost approximately 0.37 million hectares (Mha), or 2.6% of their 2000 forest cover by 2010 (Fuller et al. 2013). Mean annualized deforestation rate for National Parks were 0.22% and for Nature Reserve and Wildlife Reserves were 0.35% (Fuller et al. 2013). This is lower than the average annual forest loss for the entire country (Abood et al. 2015; FAO 2009), but it indicates that conservation areas are not effectively protected from forest loss. Unsustainable hunting is also affecting wildlife populations in conservation areas in Indonesia (Corlett 2007; Lee et al. 2005; Natusch & Lyons 2012; Nijman 2005), indicating insufficient levels of patrolling and law enforcement.

3.2.2. Roads, forest access and fragmentation

Indonesian conservation area management is not yet optimal, with, for example, illegal deforestation occurring in many sites (Fuller et al. 2013; Gaveau et al. 2009), undermining the objectives of protecting forest biodiversity. This means that additional care is needed when projects such as geothermal power developments are allowed within these areas. Key concerns are that road infrastructure associated with geothermal projects provides access to core parts of conservation areas. The 16 active Indonesian geothermal projects analysed in this study had an average length of road network of 15.3km (minimum 0.11km and maximum 39.8km), with total road length correlating well with installed capacity (Figure 11). The two steam-dominated projects in Indonesia (Kamojang and Darajat) appear to have shorter road lengths relative to installed capacity (Figure 11), which is to be expected as they need fewer injection wells. We note that Wayang Windu, Dieng and Sibayak have had exploration drilling for a significantly larger capacity than is currently installed, which does to some extent show up in the graph (J. Lawless *in litt*. 18 October 2017).

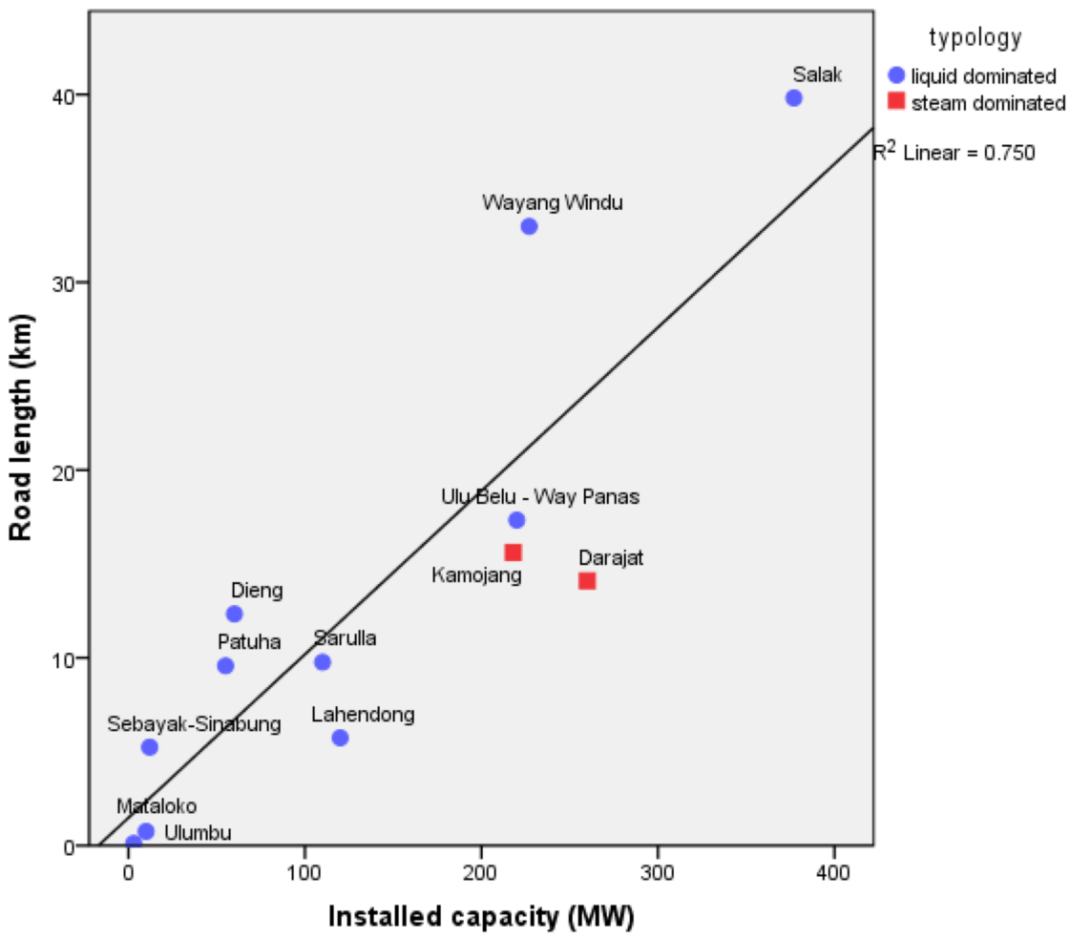


Figure 11. Graph of installed geothermal capacity in 12 Indonesian projects versus total road length of projects. Blue projects are liquid dominated, red projects are steam dominated. R^2 of linear fit = 0.75.

Road clearing width in forest areas as measured from Google Earth satellite imagery varied considerably between Indonesian geothermal power project sites. The widest road clearings were measured in the Rantau Dedap project (which was under construction at the time of writing), where clearings from forest edge to forest edge across roads were sometimes as wide as 100m. Average road clearing width across the Indonesian geothermal projects was 14m (Figure 12), with average maximum road clearing width 31 m. If we take the average road length for Indonesian projects (15.3km) and multiply this with the average road clearing width (14m), an average deforestation area for infrastructure development results of 21ha (note this does not yet include clearings for buildings and other project infrastructure). There was no clear correlation between installed capacity and road width ($r^2 = 0.04$), indicating that road width and length is determined by terrain (possibly steep terrain requiring wider road clearings), or operator (different operators using different standards for road construction). Difficult terrain will tend to mean longer roads as well as wider. With regard to road width, as a generalisation the terrain could be classed as follows: Easy: Lahendong, Sibayak; Medium: Wayang Windu, Darajat, Ulubelu, Sarulla, Kamojang, Darajat, Patuha; and Difficult: Rantau Dedap, Lumut Balai, Hulu Lais, Salak (J. Lawless *in litt*. 18 October 2017). This to some extent seems to explain the variation in both road length (Figure 11) and road width (Figure 12), although there are obvious exceptions, such as the narrow roads in Salak, despite the difficult terrain.

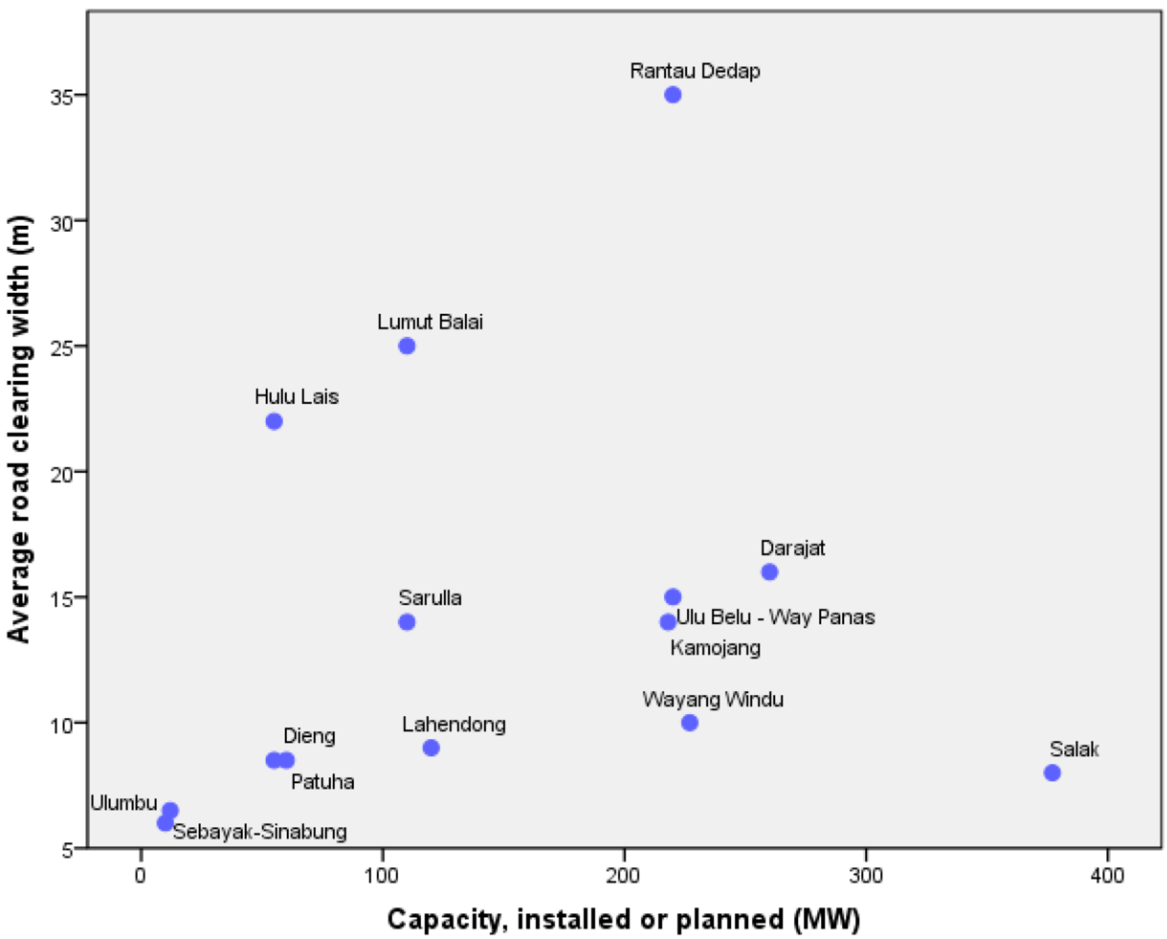


Figure 12. Average road clearing width in Indonesian geothermal projects. Installed capacity for the projects currently under development in Hulu Lais, Rantau Dedap, and Lumut Balai projects was estimated at 55, 220, and 110 MW respectively.

According to various geothermal experts consulted during this assessment, the actual road pavement width has to be sufficient for a 16-m articulated vehicle and trailer combination to move the drilling rig around the project site. As drilling equipment movement is only an occasional activity, many developers will aim for one-way traffic during the rig moves, but allow for two-way traffic of smaller vehicles for operational purposes. Cut and fill construction in steep terrain and required slope stabilization explains wide road clearings to some extent.

Road widths are important for determining the degree of fragmentation caused by roads. For example, our field surveys in the Salak geothermal project showed canopy connectivity across roads in many places. This allows arboreal species to safely cross road clearings. Similarly, narrow roads are much less of a barrier to terrestrial species than wide road clearings. A gibbon, for example, may come to the ground to cross a narrow road but may not do that when the road is too wide, and would certainly prefer to use the arboreal route. If geothermal roads extend deeply into forest areas, wide roads may effectively cut the forest area into isolated forest blocks for species unable to cross road clearings. This affects the likelihood of survival of individual populations.

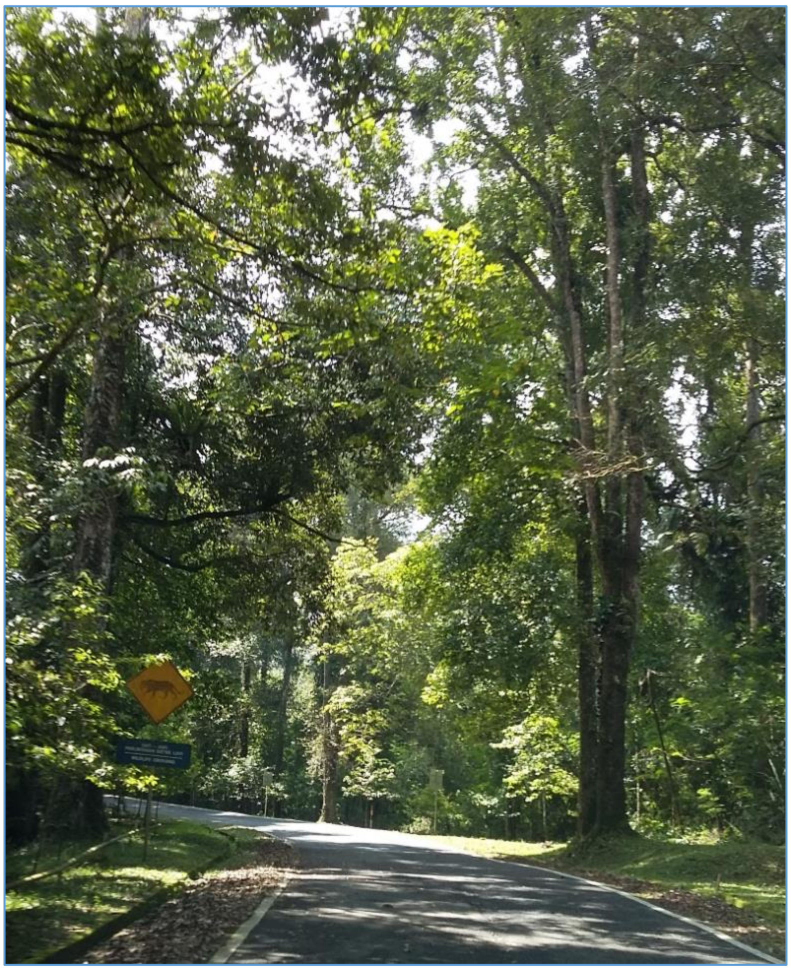


Figure 13. Example of canopy connectivity across a geothermal project road in West Java. Photo 2017 by E. Meijaard.

As noted in the Indonesian guidebook on geothermal projects in conservation areas (Sugiharta 2016), roads also provide access to previously remote forest areas. This aspect of geothermal development remains under studied, but our field observations indicate that this is a cause for concern. In one of the visited sites in this assessment, for example, project staff showed us a location where people had come in to open up forest areas for agricultural use alongside the project road, despite a prohibition on forest clearing. In another site, the Protection Forest part of the geothermal work area (WKP) had been largely cleared of forest and had been extensively converted to agricultural lands and recreational areas (Figure 14).

One of the concerns raised by NGOs that were interviewed during the assessment is that geothermal projects in conservation areas require the development of road infrastructure, often going into areas that were previously much less accessible. The current study indicates that for every 10 MW of installed capacity, 1 km of roads need to be built. Unless access to such roads is carefully controlled, people can use them to settle in conservation areas, or harvest trees or wildlife, making it more difficult to implement effective conservation management. The examples highlighted here indicate that control of road access varies. In the Salak geothermal project, very few people apparently entered through the road network, although people reportedly entered the geothermal area through forest paths to bypass the road gates. In Darajat, people commonly used the roads through the Protection Forest part of the concession, but less so to access the Nature Reserve. In Sarulla, which was still under development at the time of our visit, road access appeared to be more difficult to control with people using roads to access forest areas where they had informal land use claims.

Figure 14. Project road through deforested Protection Forest "*Hutan Lindung*" areas in an Indonesian geothermal site. Photo 2017 by E. Meijaard.

The interviews for this assessment with some NGO groups indicate that there is concern that geothermal projects, as one of the few legally sanctioned developments in conservation areas, could be developed to provide a stepping stone for additional development in conservation areas, including roads. For example, a geothermal project is developed in the center of a national park, requiring a road coming in from the park boundary. It then increases the risk of another road coming in from the opposite direction for additional access, thus creating a road that effectively cuts the park in two. These are some of the current concerns of opponents of the proposed geothermal project in Gunung Leuser National Park, in northern

Sumatra, where it is thought that the geothermal project could potentially function like a Trojan Horse to allow development of a major road through the park – a road that was previously rejected by the government.

3.2.3. Indirect impacts

While the direct impacts of geothermal development are relatively small, the indirect impacts may be more significant. These indirect impacts refer to increased threats that are associated with but not directly caused by the geothermal power developments. This includes factors such as increased hunting and collecting pressure through improved access to forests areas, increased fire risk through drying out of forest edges along roads and project infrastructure, and increased likelihood of people using the project infrastructure to move into previously inaccessible forest areas (also see above on section on road impacts). As explained in section 2.3., these indirect impacts were modelled by buffering the geothermal project infrastructure in forest areas with a 1 km buffer area.

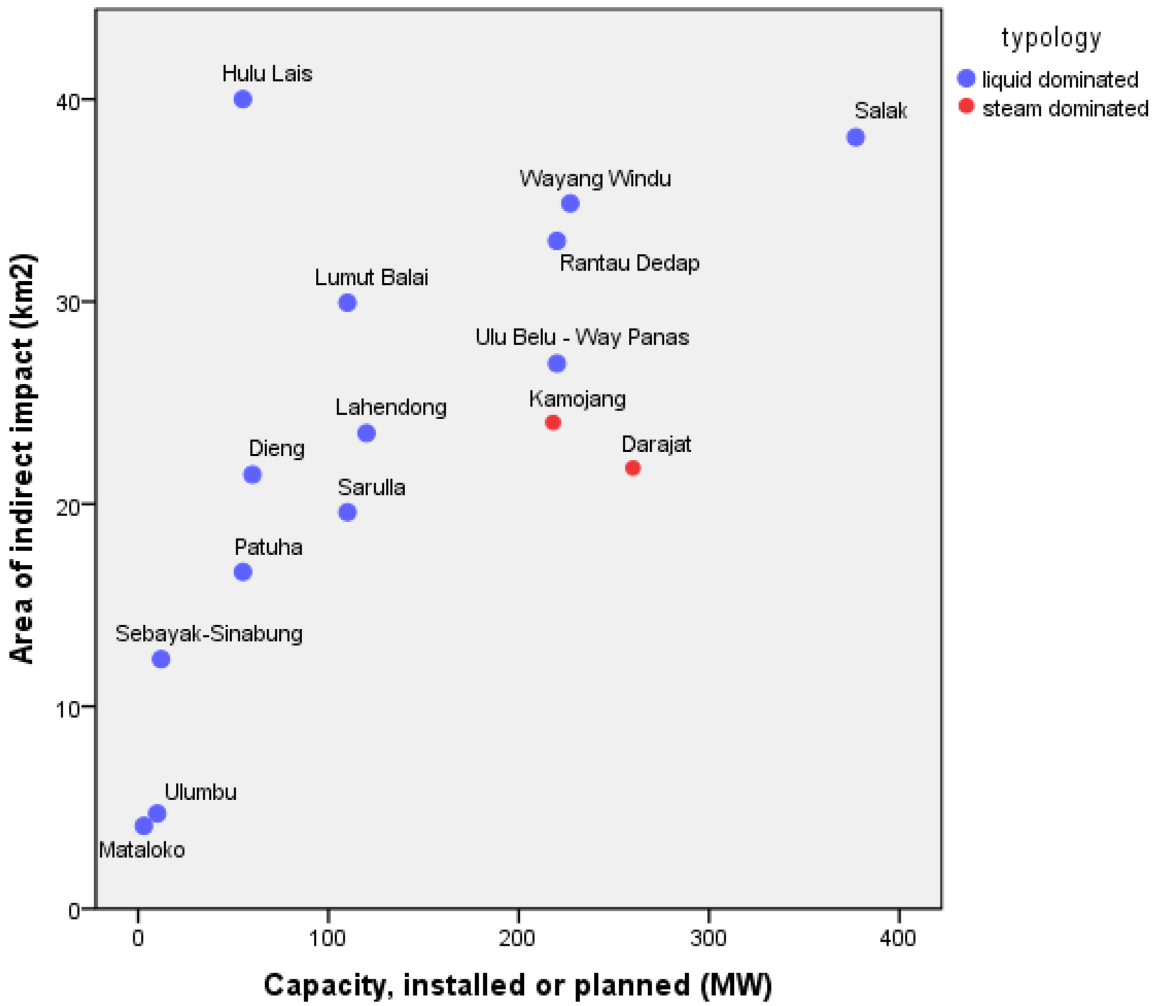


Figure 15. Graph of installed geothermal capacity in 12 Indonesian projects versus total area of indirect impact of project. Blue projects are liquid dominated, red projects are steam dominated. R^2 of linear fit = 0.43.

Figure 15 indicates that indirect impacts increase with increasing installed capacity. Every additional 100 MW adds about 10 km^2 of indirectly impacted forest area. The average indirectly impacted area of 15 project areas in Indonesia (including several projects under development) is 23.4km^2 or 2,340ha. These estimates of indirect impact could help government authorities to determine the relative impact a proposed geothermal project could have on a particular forest or conservation area. For example, a 200 MW project with an indirect impact area of 20km^2 in a small conservation area of 40km^2 would potentially negatively impact half of that conservation area, and government authorities may decide that this is too much.

As with the linear road features, the two steam-dominated projects, Kamojang and Darajat both fall under the linear regression line, which may indicate that steam-dominated projects have smaller environmental footprints in terms of forest impacts. A sample size of two is, however, too small to draw definitive conclusions on this issue.

It is noted that the linear regression coefficient of 0.43 is low, but that a power function has a much better fit (r^2 = 0.76), which indicates that larger project capacities have relatively small increments in areas impacted. One outlier in Figure 15 is Hulu Lais, which has a very long access road of some 8 km with few side roads. Such linearly-shaped project areas, much longer than they are wide, have relatively larger areas of impact than more compact, rounded project areas.

3.2.4. Deforestation by geothermal projects

Geothermal projects are generally considered to have low environmental impacts because their ecological footprint on forest areas is relatively small compared to, for example, an open-cast coal mine or hydro-electric dam. Surprisingly though there appear to be no quantitative studies of what the deforestation impacts actually are. The mapping of geothermal infrastructure in Indonesia in the current study indicates the following deforestation associated with geothermal development (Table 5). As generally thought, the actual direct footprint is small, although there is quite a degree of variation between projects. It should be noted that these deforestation estimates are based on measurements taken from imagery on Google Earth, or Landsat imagery, and may underestimate the actual area cleared on the ground. These deforestation estimates are not official figures reported by the individual projects.

Table 5. Deforestation estimates for geothermal projects in Indonesia. Deforestation for roads was estimated by multiplying average road width in each project with measured road length. Deforestation from clearings was measured from project infrastructure digitized on Google Earth in 2017.

WKP (Project Name)	Status	Installed capacity (MW)	Location relative to forest	Deforestation for roads (ha)	Deforestation from other clearings (ha) - well pads, buildings etc.	Total deforestation (ha)
Sebayak-Sinabung	Inactive	12	Mainly outside	1.2	3.4	4.6
Sarulla	Operating	110	Mainly within	12	78	90
Hulu Lais 1	Operation	55	Mainly outside	10.6	7.9	18.5
Rantau Dedap	Construction	220	Mainly within	30	25	55
Lumut Balai	Construction	110	Mainly within	62	74	136
Ulu Belu - Way Panas	Operating	220	Not within	0	0	0
Salak	Operating	377	Mainly within	32	69	101
Kamojang	Operating	218	Partially within	5.7	9.5	15.2
Darajat	Operating	260	Partially within	10	7.5	17.5
Wayang Windu	Operating	227	Mainly outside	1.0	2.0	3.0

Patuha	Operating	55	Mainly outside	1.75	3.6	5.35
Dieng	Operating	60	Not within	0	0	0
Lahendong	Operating	120	Not within	0	0	0
Ulumbu	Operating	10	Partially within	0	0.6	0.6

3.2.5. Comparing the footprint of Indonesian versus other geothermal projects

A comparison of road length and indirect project area impacted by development for 15 Indonesian projects and 9 projects in the Philippines, Central America and Japan indicated that Indonesian projects require relatively more road construction and impact larger areas than non-Indonesian projects. As discussed above, Indonesian projects require ca. 10km of roads and impact 10km^2 for every 100MW produced, whereas the international projects that were analysed required ca. 5km of roads and impacted between 6 and 7km^2 for every 100MW produced. The slopes of the regression lines for Indonesian and international project differ significantly for both road length (Figure 16) and area of indirect impact (Figure 17). All four regression lines in the figures were statistically significant ($p < 0.01$).

Table 6. Nine international geothermal projects and their project footprint as established in the current study

Project Name - country	**Installed capacity (MW)**	**Road length (km)**	**1km Buffer Area (km^2)**
Mount Apo - Philippines	106	12.8	17.6
Mount Talinis - Philippines	223	22.9	23.37
Northern Negros - Philippines	49	8.56	14.09
Makban - Philippines	458	23.5	27.78
Las Pailas - Costa Rica		17.01	21.2
Momotombo - Nicaragua	43	9.58	10.46
San Jacinto - Tizate Nicaragua	77	6.01	15.99
Kakkonda - Japan	80	6.63	11.29
Mori - Japan	50	2.75	8.27

It is not immediately clear what causes the differences between Indonesian and international projects and whether these differences are indeed meaningful. Firstly, the dataset is small and analysis of a larger number of projects would be needed to confirm that there are significant differences in project infrastructure in Indonesia compared to other countries. Overall it appears that Indonesian projects often have long access roads, which might relate to the generally low density of existing roads in Indonesia, especially in forest areas which thus requires development of new infrastructure. The average number of well pads was lower for Indonesia (10 per project for an average project capacity of 137.1 MW) versus international projects (14.8 well pads per project for an average project capacity of 137.7 MW). This indicates that Indonesian projects take up larger areas than average international projects, but with fewer well pads.

Certainly, quite a few Indonesian projects are in remote areas and hence need longer roads to actually get into the development area, although these may not be within conservation forest areas. The topography in Indonesia is challenging in many resource areas with little pre-existing infrastructure and this will also increase the length of road to actually move the same direct distance. Rantau Dedap is a case in point, with particularly long access roads. The developer constructed a more direct road between two sectors of the resource, but the road is reportedly in very steep terrain and there are concerns potential slippage. The two Nicaraguan projects (Momotombo and San Jacinto) in our analysis are in less steep terrain and are accessed by quite short spurs directly off existing national roads.

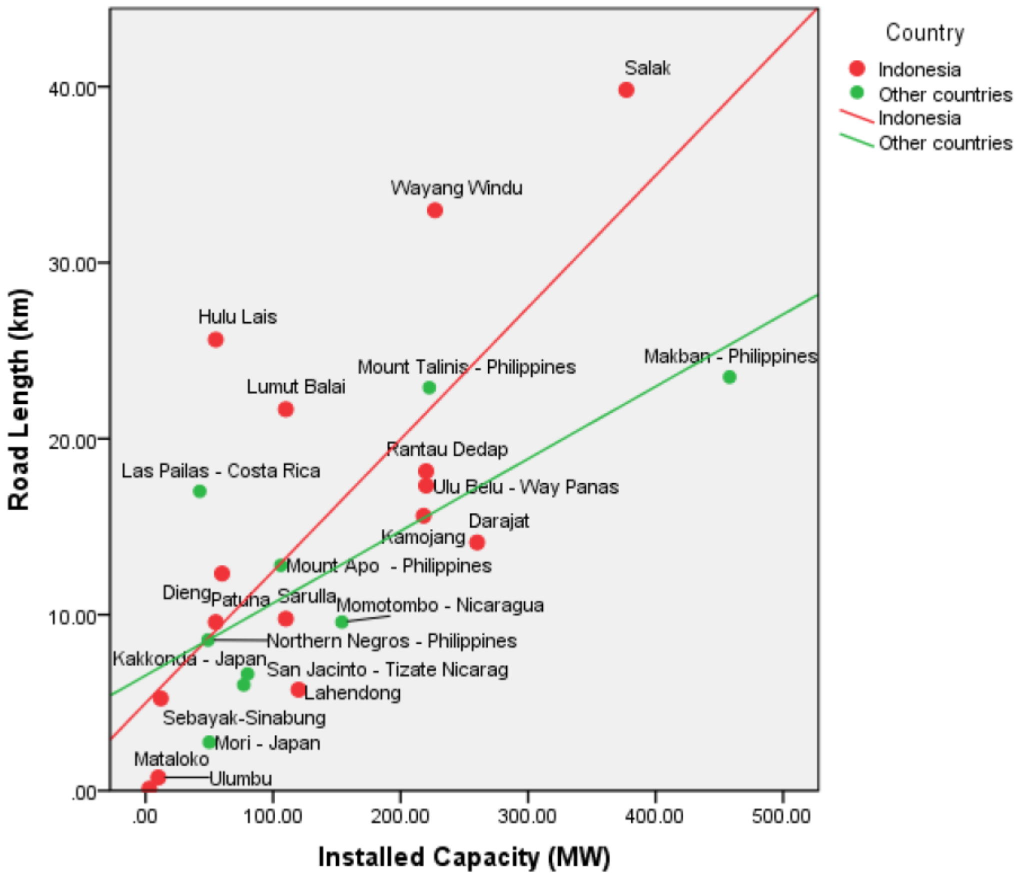


Figure 16. Installed capacity versus road length for 15 Indonesian and 9 international geothermal projects. Lines show the linear regression for each subgroup.

One other possible explanation for the differences between Indonesian and other projects is geology. As a general rule, geothermal projects in island-arc settings such as Indonesia tend to be in mountainous areas associated with andesitic volcanoes, whereas geothermal projects in countries like New Zealand tend to be in flat-lying basins associated with rhyolitic volcanism, so the access is easier. The Philippines is similar to Indonesia, but Japan and some of Central America are in intermediate geological settings, so there is a mixture of mountains and basins (Lawless 1993).

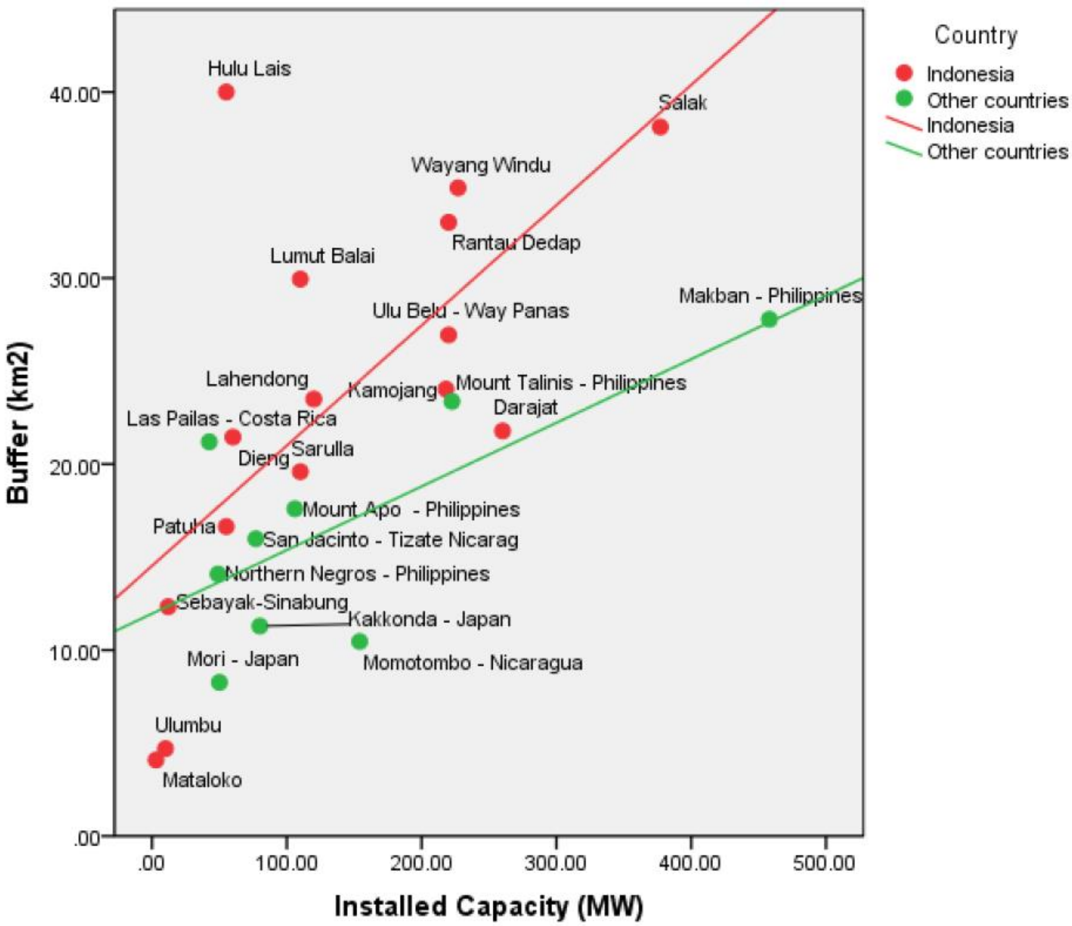


Figure 17. Installed capacity versus area of indirect impact for 15 Indonesian and 9 international geothermal projects. Lines show the linear regression for each subgroup.

The issue of greater impact on forests in Indonesia compared to similar projects elsewhere is real however and requires further consideration. Special geological setting, the concentration of high biodiversity in remaining forest areas with highest geothermal potential, and the relatively low density of Indonesia's rural road network, means that Indonesian geothermal power developments in forest areas are highly likely to have higher environmental and biodiversity impacts than projects elsewhere. This in turn requires that greater precaution is taken in developing the Indonesian geothermal sector, also justifying the macro-risk assessments developed in this report.

3.2.6. Geothermal in National Parks – Salak Geothermal Project

3.2.6.1. Project Background

The Salak geothermal project (Figure 18) was initially developed before the Salak area became a national park, which happened when the original Halimun National Park was extended in 2003 to include a corridor area and the Mount Salak Protection Forest (*Hutan Lindung*) area. Chevron which operated the project until 2016 when it was acquired by Star Energy, set up a 'Halimun Salak Green Corridor Initiative' which aimed at restoring the degraded corridor between Mount Halimun and Salak in collaboration with park staff and local communities (Henneman 2012). It also provided support to a range of local NGOs for conducting studies on biodiversity and threats to wildlife (e.g., Kusrini et al. 2008), including the "Eye on the Forest" project implemented in 2014 with Conservation International. Wildlife surveys conducted in 2006 and 2014 reportedly noted an increase in numbers of species like leopards, although no actual data to substantiate this claim were found (https://www.chevron.com/stories/keeping-an-eye-on-the-forest).

Figure 18. Top left. The lower slopes of Mt Salak adjacent to the geothermal project primarily consists of tea plantation. Top right. Banner reading "Protect Mount Salak wildlife by not hunting and disturbing animals". Bottom left: geothermal facilities directly adjacent to primary forest edge. Bottom right: Typical project roads in Salak are narrow, asphalted and have forest right up to the road edges. Photos 2017 by E. Meijaard.

In terms of management, the Salak Geothermal Project is considered as one of the "best-case examples" of Indonesian geothermal power development in forests and conservation areas. Geothermal exploration wells in the Gunung Halimun–Salak National Park were first established in 1983, and production in units 1 and 2 started in 1994. With 330MW in installed capacity this is one of the largest projects in Indonesia.

Key environmental issues that were identified during project development included forest loss and loss of wildlife habitat, soil erosion, changes in stream water quality, increased hydrogen sulphide concentration in ambient air, and traffic congestion and accidents on narrow roads (Slamet & Moelyono 2000). A number of mitigation measures were implemented including compensatory offsets, reforestation, and avoidance of forest fragmentation (Slamet & Moelyono 2000), but none dealt with issues like hunting, illegal logging, and uncontrolled collection of plants and animals. The project has expanded over the years and our analysis found that the infrastructure currently covers some 40km of roads and 0.69km^2 of other cleared areas, with an estimated total indirect impact area of some 38km^2, based on a 1km buffer approach (Figure 19).

One impact has reportedly been the commercial collection of lucanid beetles that are attracted by the project's light sources, and also collected elsewhere in Gunung Salak, and which generate significant income for communities (Center For Conservation and Insect Studies 2003; Henneman 2012). At least six species of beetle are commercially collected for sale locally, but also as far as Japan, and fetch high prices (anonymous 2007). No scientific names of the species are provided in the report by the Center For Conservation and Insect Studies (2003), but the species are apparently not of global conservation concern. The existence of lucanid beetle plays a vital role in forest ecosystem especially in maintaining the stability and equilibrium of forest food web. Furthermore, beetle collectors set up traps in the forest for which they need to clear a small area. They then stay in the forest for up to a week, potentially collecting other species as well.

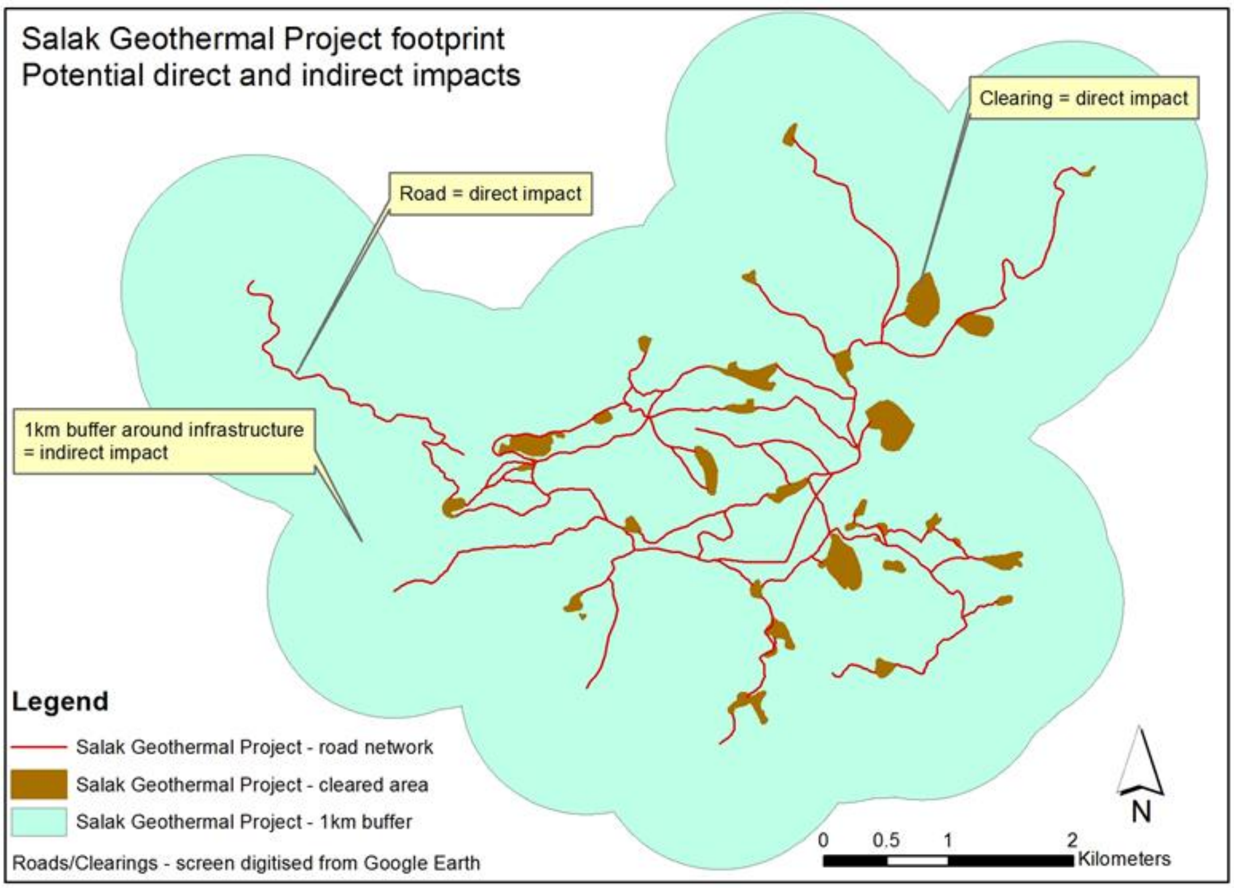


Figure 19. Digitized road network and forest clearing with a 1 km disturbance buffer in the Salak geothermal area

When Star Energy staff in Salak were interviewed for this assessment, they recognized the issue and explained that measures had been taken to reduce threats to these beetles. The company replaced all white lights in the project site with yellow ones (that do not attract as many insects), and since doing this the number of beetles coming into the geothermal site has decreased significantly, as has the number of people collecting them (which is now near zero) (Ali Sahid, pers. comm.).

3.2.6.2. Regulatory challenges in national parks

The new Geothermal Law 21/2014 of 2016 now allows geothermal exploration and exploitation in National Parks. According to the Nature Conservation Law 5/1990, a National Park is an everlasting nature area with original ecosystems and a zonal use system designated for the purpose of scientific research, education, cultivation support, tourism and recreation, with the basic function of preserving flora and fauna. It is thus clear that geothermal development in national parks needs to be in line with these objectives of nature preservation.

The conservation planning within geothermal working areas in national parks is stipulated through the Government Regulation (GR) 108/2015 regarding the amendment of GR 28/2011 on Management of Nature Reserve and Nature Conservation Areas. Subsequently, the MoEF issued the Ministerial Regulation P.46/2016 that specifies technical and permitting requirements that must be met by existing and future geothermal power projects operating in national parks, grand forest parks, and nature recreational parks. These regulations and change in the forest status from Protection Forest to national park have as a consequence that the Salak geothermal power project is required to convert its forestry permit from the Forestry's Borrow-to-Use Permit (*Pinjam Pakai*) to the Environmental Service Permit (*Izin Pemanfaatan Jasa Lingkungan Panas Bumi or IPJLPB*).

In reference to these changes in the Forestry's permitting requirements, the key issues that were brought up in discussion with both Salak geothermal project staff and Halimun-Salak park management staff included the land compensation/reforestation already completed under the Forestry's '*Pinjam Pakai*' permit and also the new obligations that must be fulfilled under the IPJLPB permit regime:

- The Salak geothermal's working area is reportedly 10,000ha and the forest area used for operation and subject to the Forestry's Borrow-to-Use permit is 228ha. Under this permit, when the project was still located in a Protection Forest (*Hutan Lindung*), the Company reportedly compensated this 228ha at a 1:2 ratio (i.e. 2ha area need to be reforested for each hectare of forest area used/cleared). Thus, the company has reforested an area of 456ha to compensate for the 228ha of deforestation they had caused. These reforested lands were reportedly located outside the Protection Forest and National Park area.
- Following the expiration of the Forestry's '*Pinjam Pakai*' permit of the Salak Geothermal, the Company has applied for and been granted the IPJLPB permit in August 2016, and consequently is subject to complying with the new permit's conditions. Among the conditions that the Company is concerned with is that when one tree need to be cut as part of land clearing, it must be replaced with 100 tree saplings (*anakan pohon*). These trees should be planted in an area determined by the Head of National Park and maintained up to the expiry date of the IPJLPB Permit. Average tree densities in South-East Asian rainforest vary between 300 and 1100 stems per hectare (Glick et al. 2016; Slik et al. 2010), so clearing one hectare would require planting between 30,000 and 110,000 trees, or up to 10 million trees for a higher capacity project in a forest area (see section 3.2.4.). With normal reforestation planting densities of about 1000 trees per hectare (Otsamo 2002), it would also indicate that for each hectare of forest lost some 30 to 110 hectares may need to be replanted. At a cost of about US$ 1,200/ha (Budiharta et al. 2014), the new reforestation compensation regulation would indicate

reforestation costs of some US$ 7 to 20 million for a project requiring some 200 hectares of forest land.

The requirement for reforestation under the Forestry's Borrow-to-Use regulations creates a few problems for geothermal power projects, like Salak, in that the Company has to comply with new requirements each time a new regulation is stipulated, and these reforested areas are located outside the former Protection Forest and existing national park. Some companies might prefer to implement compensatory actions within the forest or conservation area rather than outside as is now often the case, as it is easier to demonstrate the benefits of compensatory actions relative to environmental impact of project development. In the case of Salak geothermal, offsetting within the National Park where the project has a reforestation project anyway, would make more sense than the currently required offsetting outside the park boundary.

Another issue of concern to geothermal power projects aiming to work in national parks is the ongoing discussion about levying a compensatory payment for loss of forest ecosystem services. The MoEF and other related ministries are reportedly developing new Government Regulations that will determine the rate per hectare of annual payments that will be charged to the permit holder for lost ecosystem services caused by deforestation. At the time of writing, it remains unclear how much companies will have to pay, and without knowing this number the financial feasibility of developing geothermal in conservation areas is unknown.

Box 1. Lore Lindu: The problem of unmanaged roads into national parks

Lore Lindu National Park in Central Sulawesi provides a good example of the risks associated with the development of infrastructure in a national park. Significant deforestation occurred after 1998 along a road passing through the park's core area to a community enclave (Mehring & Stoll-Kleemann 2011). There was significant illegal logging and settling around this road with the highest amount of clearing spatially coinciding with the areas of favourable land conditions for agriculture (Mehring & Stoll-Kleemann 2011).

Roads in Indonesian conservation areas mostly result in deforestation and illegal settlement if these roads are located on or lead to fertile flat land. The agricultural suitability of lands where roads and other infrastructure are developed for geothermal projects could therefore be important determinants for project-induced deforestation in these areas. Keeping roads out of protected areas was one of the key recommendations in a recent study showing the general ineffectiveness of Indonesian protected areas (Brun et al. 2015).

Finally, the issue of zonation in national parks is an important one for geothermal power development in conservation forest. The MoEF Regulation 76/2015 provides guidance on the zonation system of national parks and block system of nature and wildlife reserves, and grand forest parks and nature recreational parks. This MoEF regulation supersedes the Ministry of Forestry Regulation No. P.56/2006 on Zonation for National Parks. Zones or blocks are determined on the basis of ecological, social, economic and cultural functions and these need to be revised at least every 10 years. Outside the zones in conservation areas, there can also be enclaves where the conservation area laws do not apply (Box 1). According to the mentioned MoEF regulation, geothermal power development is only allowed in the utilization zone of the national park.

3.2.7. Geothermal in Nature Reserve and Protection Forest – Darajat Geothermal Project

3.2.7.1. Project background

Darajat has reportedly one of the highest energy conversion efficiencies of geothermal projects in the world (Moon & Zarrouk 2012), i.e., the ratio of net electric power generated to the geothermal heat produced from the reservoir. The company Amoseas (later acquired by Chevron) developed this project partly in the Papandayan Nature Reserve, see Figure 20. Geothermal development is now not allowed in Nature Reserves (*Cagar Alam*) and Wildlife Reserves (*Suaka Margasatwa*) according to the GR 108/2015. Nevertheless, the existing geothermal power projects have reportedly been given exemptions in the 1990s for development in nature reserves, among which Darajat geothermal site in West Java. Part of the Darajat project site is also located in Protection Forest (*Hutan Lindung*) (Figure 20). The legal basis covering the use of this nature reserve area by Darajat is based on the Forestry's '*Pinjam Pakai*' permit and the agreement between the Company and the Nature Conservation Agency of West Java.

The visit to the Darajat geothermal site for the current assessment showed that the Protection Forest outside the project area (and outside the Nature Reserve) had been almost entirely deforested and replaced by intensive agriculture and establishment of recreational sites for tourism. The Darajat project did not seem to have played a role in this deforestation process, but rather it appeared to be driven by local communities seeking access to fertile soils. The State-owned Forestry Company, Perhutani, has engaged Star Energy, the current geothermal operator in Darajat, in a community collaboration aiming to reforest these illegally cleared Protection Forest, but their community forestry plans have not been effectively implemented. In relation to this deforestation, the assessment team was told that the Darajat geothermal power project had been blamed by communities for contributing to a major flood that occurred in Garut in 2016 and killed at least 12 people. It appears though that the company cannot be blamed for this incident (Cahyani 2016) as it cannot easily influence the management of, or prevent deforestation in, Protection Forest outside their Borrow Use (*Pinjam Pakai*) area.

As observed, part of the Papandayan Nature Reserve within the proximity of the Darajat geothermal project is quite degraded and heavily influenced by human activities, such as illegal logging and hunting, although a range of Critically Endangered and Endangered species still remain, including Javan Leopard, Javan Hawk-Eagle, Javan Surili and others (Iqbal 2016). Bird diversity appears to have declined significantly since the 1940s when 115 bird species were identified compared to 72 in recent years (Iqbal 2016).

3.2.7.2 Regulatory challenges in Nature Reserves

The main regulatory issue associated with the Darajat geothermal is that parts of the operational site are located within the Papandayan Nature Reserve, where legally no geothermal activities are allowed according to GR 108/2015. Due to this legal constraint, the Company was granted with an entry permit, known as *Surat Izin Masuk Kawasan Konservasi* or abbreviated 'Simaksi' to operate in the Nature Reserve. The Simaksi only serves as a temporary permit, which does not allow exploration and exploitation activities to be undertaken in the nature reserve. As a result, Star Energy is working closely with the Nature Conservation Agency (BKSDA) of West Java, as the key nature conservation authority responsible for the area, to investigate the solution to this legal constraint. One of the options discussed is to downgrade the status of the Nature Reserve, already occupied by the geothermal site and convert it to a nature recreational park (*Taman Wisata Alam*), which would then legally allow geothermal project development to take place. Another issue under discussion was the question whether or not Papandayan was already a Nature Reserve when the initial geothermal license was granted. One complication in this respect is that

Papandayan was already established as a conservation area (*Natuurmonument*) in 1924, but this initially concerned only an 824-ha area around the mountain's crater, while in subsequent steps the Nature Reserve was enlarged first to 6,000 ha in 1979 and to 6,807 ha (with an additional 225 ha of Nature Recreation Park) in 1990. Knowing exactly where the conservation area boundary was in different stages and how this coincided with the various geothermal licenses might be difficult. Irrespective of this, during interviews for this assessment, the regional conservation authorities (BKSDA) of West Java appeared to support the downgrading of the conservation areas status. For the objectives of conservation, however, such status changes that facilitate development are a concern, as the lower status conservation area provides less legal protection to threatened wildlife and their habitats.

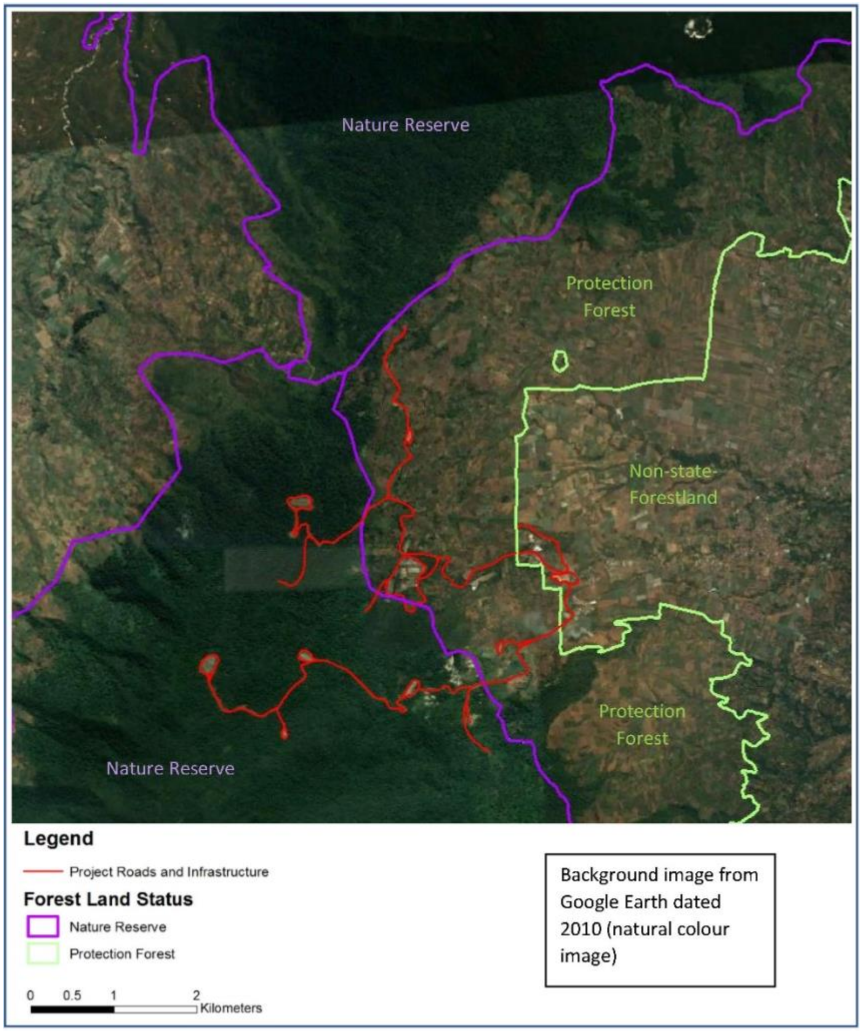


Figure 20. Darajat Geothermal Project footprint.

3.2.8. Geothermal in Protection Forest and non-forest areas – Sarulla geothermal project

3.2.8.1. Project background

Figure 21. Sarulla power station in development with surrounding Protection Forest (Photo 2017 by E. Meijaard).

The assessment team visited the Sarulla project and discussed environmental issues with project staff, the local government's environmental office (*Dinas Lingkungan Hidup Tapanuli Utara*), the provincial government's natural resources conservation authority (*BBKSDA*), and an NGO that had been involved in the development of the biodiversity management plan for the Sarulla area. The Sarulla geothermal project is currently under development (Figure 21). It will eventually consist of three new power plants with a combined capacity of 330 MW connected by a 20-km transmission line that will in turn connect with a transmission line to be built by the State Electricity Company (PLN). Sarulla is slated to be the largest single-contract geothermal power project in Indonesia. The project is partly developed in the Batang Toru Protection Forest area (*Hutan Lindung*) which serves to protect the watershed functions of this mountainous area and prevent erosion, while one of the power plant units is constructed in a non-forest area, *Areal Penggunaan Lain* (APL).

The Sarulla project adheres to high environmental standards as required by its international lenders (Asian Development Bank, Japan Bank for International Cooperation, Canadian Climate Fund for the Private Sector in Asia, and others). One concern in the area is that forest areas surrounding the geothermal site have informal claims of local use, for example, for benzoin harvests. Local people use project infrastructure to assess these lands, and there were some signs of recent forest clearing and burning adjacent to the road. It is difficult for company staff to prevent people from doing this, both because they lack the legal enforcement capacity, and also because there are strong land right claims in this area.

It remains to be seen how the issue of access will play out in the future when the Sarulla project becomes fully operational. In that respect, it does not help that the project has created quite large road clearings around the project roads which might be attractive for potential settlers who seek easier access to the forests (Figure 22). This is a feature identified in other geothermal projects in Protection Forest area such as Rantau Dedap and Lumut Balai (see section 3.2.2.) that needs to be carefully assessed.

Figure 22. Sarulla project road showing wide cut-and-fill related clearing on either side of road for slope stabilization. Photo 2017 by E. Meijaard.

3.2.8.2. Regulatory challenges in Protection Forest and non-forest areas

Discussions with the Sarulla personnel indicated that the Company has reforested part of the critical land at a ratio of 1:1 (i.e. 1-hectare area of critical land reforested for each hectare of forest use) in order to fulfil the conditions attached to their Forestry's '*Pinjam Pakai*' Permit. As pointed out during the discussion, key issues associated with this permit included the prolonged, complex process for the provincial forestry to designate the critical area for reforestation; and the location of this area is quite far away from the forest area granted with the Forestry's '*Pinjam Pakai*' permit.

3.2.9. Community aspects of geothermal projects

This review summarizes several proposed geothermal projects that have resulted in significant protests from local communities or NGOs to indicate the type of concerns commonly raised about geothermal development. It is not meant to be exhaustive and address every conflict that has occurred. Rather it aims to provide an overview of the various contexts and dynamics of these conflicts to inform policy, planning and mitigation measures.

3.2.9.1. Sorik Marapi

The Sorik Marapi geothermal working area (WKP) in Sumatra was issued in 2008 covering an area of 62,900 ha based on an estimated reserve of 200 MW. The western edge of the WKP abuts Batang Gadis National Park, and also contains large areas of Protection Forest and some areas claimed as community forestry (PIAPS); the remainder is non-forest land which is used for agriculture land and agroforestry. The

Regent of Mandailing Natal District issued the decree for geothermal power development in 2010, and a power purchase agreement with PLN was signed in 2014. Subsequently, however, the Regent revoked the license in December 2014, following significant community protests about the potential environmental hazards associated with geothermal power development. In November 11, 2014, this culminated in protests involving thousands of people blocking the trans-Sumatra road, resulting in one fatality and dozens of arrests. Subsequently, representatives from the Ministry of Energy and Mineral Resources (MEMR) met with community representatives, arguing that geothermal energy was an environmentally friendly way to generate local electricity, which in turn would local drive economic development. A permit to develop the geothermal project was issued by MEMR in April 2015, and in April 2016 KS Orka Renewables Pte Ltd of Singapore (KS ORKA) acquired 100% of the shares of Sorik Marapi Geothermal Power. Drilling in Sorik Marapi started in October 2016, and the KS Orka team reportedly aimed to bring the first pilot power plant into operation in 2017. Assurances to the public have been made that project development will not affect groundwater supplies or have other negative environmental impacts, such as those associated with the much publicized Sidoarjo mudflows in East Java. Local government now support the project. It is unclear what will be done to actually track any impact on groundwater, or other environmental impacts, and how the information will be made publicly accessible.

In the macro-level risk assessment in section 3.3, the three geothermal potential points in the Sorik Marapi WKP of Sampuraga, Roburan, and Sorik Marapi received low, high and medium risk scores of 3, 8, and 6, respectively in terms of environmental and social risk as none of the points actually fall within the national park or within social forestry areas, however two points are located in Protection Forest one of which is very close to the National Park. Both the medium and high-risk points are also in secondary forest areas with high deforestation in the vicinity which increases the risk. None of the points fell within PIAPS, or customary land areas, although PIAPS areas were located close by. As was pointed out in the Methods, quite often there is significant spatial difference between the location of potential geothermal points and where projects are ultimately developed, so the actual risks can only be determined once the project location has been determined.

3.2.9.2. Mount Slamet (Baturaden)

Proposed developments for geothermal energy in the Mount Slamet area, Central Java, known as the Baturaden Geothermal Project have recently led to significant protests from NGOs, with the Indonesian organization Pemuda Pancasila leading protests against the project (Figure 23). The main concern is focussed on land clearing for road construction which has increased sediment loads in streams flowing through the project area which are affecting downstream communities and their livelihoods such as agriculture and water supply. Another concern raised is that disturbance from geothermal activities will drive wild boar and long-tailed macaques out of the forest, causing more crop damage to farmers (Muzakki 2017a). Other concerns include increased levels of deforestation, even more severe soil erosion, and flooding (Muzakki 2017a).

Figure 23. NGOs reject geothermal development on Mt Slamet in a public meeting (Muzakki 2017a).

Some of these protests appear to be based on lack of information. PT Sejahtera Alam Energy (PT SAE), the geothermal developer, explained that public perceptions that the project would open up 24,660 ha of forest were misguided. The 24,660 ha is their working area (WKP) and according to their *Izin Pinjam Pakai Kawasan Hutan* (IPPKH) or the forestry borrow-to-use permit, they can only use 488ha (Muzakki 2017b). Nevertheless, there are concerns from the environmental community that even the 488ha will have significant impacts on populations of Critically Endangered Javan Leopard and Endangered Javan Gibbon and Javan Hawk-Eagle (anonymous pers. comm. to EM, 7 April 2017). Others worry about mudflows that could be triggered by geothermal development on the still active Slamet volcano.

In the macro-risk assessment (see section 3.3), the potential Baturaden site on Gunung Slamet received a medium risk score of 5 as the point is located in Protection Forest, with IBA and KBA values. There is no contribution to the overall score from the three social values assessed as the area does not overlap with social forestry or customary land areas; according to the data there are no indigenous people present. This, however, is a good example of a project area which is surrounded by a high density of people and agriculture downstream of activities. Therefore, strict implementation of environmental management for project activities such as land clearing, construction and control of run-off is imperative to ensuring that project impacts are not felt by communities downstream.

3.2.9.3. Kappi Plateau in the Gunung Leuser World Heritage Site

A proposed geothermal power development in the Gunung Leuser National Park recently resulted in NGO protests. In 2016, a consortium of local environmental groups supported including Forest, Nature and Environment Aceh (HAkA) and the Sumatran Orangutan Conservation Program lobbied the Indonesian and Aceh state governments to reject the proposed plan to build geothermal plants and road networks into the Gunung Leuser National Park and Leuser Ecosystem, a UNESCO World Heritage site for Sumatran

Tropical Rainforest Heritage. The Kappi region, the part of the National Park where the project was proposed, is the core of the only remaining major forest corridor connecting the eastern and western forest block of the National Park, and home to some of the last remaining viable populations of Sumatra's most iconic species such as the Sumatran tiger, rhinoceros, elephant and orangutan. UNESCO called on the Indonesian government not to develop any mining concessions including geothermal energy within the Tropical Rainforest Heritage of Sumatra (Indonesia) World Heritage Site (UNESCO 2015). Following national and international protests, the Ministry of Environment and Forestry rejected a letter from Aceh Governor Zaini Abdullah asking that a section of the park's "core zone" be changed to a "utilization zone" so that a Turkish company, Hitay Holdings, could develop geothermal there (Satriastanti 2016). The current status is unclear but concerns remain within the environmental NGO community that the geothermal project is being pushed forward as part of a larger plan to develop road and energy infrastructure through the park, linking the western and eastern coastal areas of north Sumatra. Despite promises by the new Aceh Governor, Irwandi Yusuf, to reject the geothermal project in Kappi (Hanafiah 2017), NGOs once again called on UNESCO to urge the Indonesian government to maintain the integrity of the Sumatran World Heritage Sites (Gartland 2017), which are already on the list of sites in danger.

In the macro-risk assessment (see section 3.3), the potential Kappi Plateau site (Gunung Kembar geothermal potential point) received a high-risk score of 15, primarily because it is deep inside a national park, primary forest, World Heritage Site, Important Bird Area and Key Biodiversity Area. The other two associated geothermal points of Dolok Perkirapan, and Kafi are rated as 16 and 15 respectively.

3.2.9.4. Mount Lawu

The Gunung Lawu geothermal working area, estimated to support up to 165 megawatt (MW) in capacity, stretches through two provinces and several regencies in Central and East Java. In 2016, Pertamina secured the rights to develop this project, following a bidding contest involving four other companies: Star Energy Geothermal Ltd., PT Ormat, PT Sari Prima Energi and PT Bumi Energy. The announcement of the project development resulted in community protest that primarily focused on perceived environmental impacts on forest and clean water provision (Saputra 2017). The Regent of the Karanganyar District reportedly also rejected the proposed developments, although not in a formally written manner (Bramantyo 2017). In addition to environmental impacts on water provision, concerns were raised about the many archaeological objects on Mount Lawu and the importance of the area for the local culture and wisdom of the Lawu community that are still preserved to this day.

In the macro-risk assessment (see section 3.3), the potential Mount Lawu site received a medium risk score of 4 as the point lies just outside the Protection Forest boundary otherwise this would be a high-risk point. There is no contribution to the total risk value from the three social risk factors assessed, although as with any site upstream of communities and agricultural areas the risks associated with poorly implemented environmental management of land clearing, run-off and sedimentation will elevate the social risks.

3.2.9.5. Gunung Ciremai

The tender for the Gunung Ciremai project was won in 2013 by Chevron, but a few years later Chevron decided not to take on the project. The WKP Gunung Ciremai is estimated to have a potential of 110 MW, with an area of 24,000 ha located in the Majalengka and Kuningan Districts of West Java. The WKP abuts the Gunung Ciremai National Park, although the geothermal potential point is located well within the national park boundaries and potentially within the core zone; the point is outside the WKP boundary. Gunung Ciremai National Park has a small utilization zone (*zona pemanfaatan*) of 324 ha where geothermal activities could be developed (Dulhadi 2012), but this zone is fragmented into many smaller areas as shown in the parks zonation plan 2012 (Figure 24).

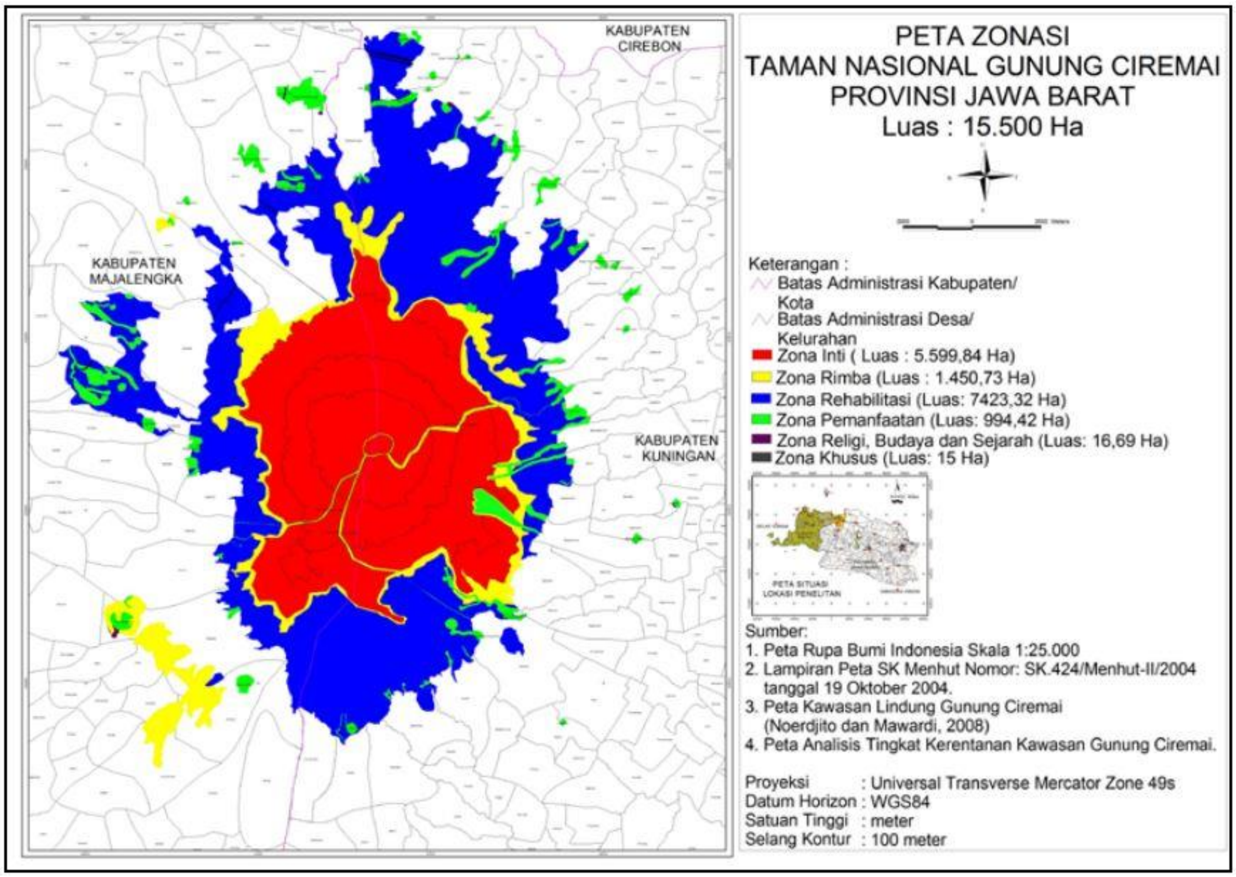


Figure 24. Map of Gunung Ciremai National Park zonation based on area sensitivity and community activities (Yuniarsih et al. 2013).

In the macro-risk assessment (see section 3.3), the potential Ciremai site received a high-risk score of 13, mostly because of the high biodiversity of this mountain and its location in a national park. There is no contribution to the overall total risk weighting from the three social risk values (social forestry, customary land and presence of indigenous people), although as with any site upstream of communities and agricultural areas the risks associated with poorly implemented environmental management of land clearing, run-off and sedimentation will elevate the social risks.

3.2.9.6. Bedugul, Bali

Exploration of the Bedugul Geothermal Field started in 1974, as part of a New Zealand bilateral aid project. Exploration was continued by Pertamina from 1978 until 1987. In 1994 Bali Energy, a joint venture between California Energy and a local company, signed a joint operation contract with Pertamina to develop a 4x55MW geothermal power plant. In 2008, the estimated power production capacity of 175 MW corresponded to about half of the whole island's electricity needs. However, the project was put on hold, after being opposed by local residents, who feared that it could damage a sacred area and affect water supplies from the nearby lakes. Development plans also continue to be strongly opposed by environmental activists, who fear that the construction of this site would inflict irreversible environmental damage. Religious leaders have also raised further opposition to the plan, claiming that the Bedugul area and the nearby Batukaru Mountain are sacred points in the island's divine cosmology (Henry 2015). Because the opposition to the project was formalized with a DPRD-Bali resolution in 2005, any permission to now allow the Bedugul Geothermal project to resume would require a new resolution and majority approval from the House (Richter 2015). Despite the various controversies, government authorities remained optimistic in 2017 that the Bedugul project could be further developed (Ariyanti 2017). The related WKP is called Tabanan and contains three geothermal potential points, although only one, Buyan-Bratan, is of any significance in terms of potential.

In the macro-risk assessment (see section 3.3), the Buyan-Bratan point receives a high-risk score of 16 due to being located in a national park and in primary forest with high biodiversity values, and in addition the point is also within the UNESCO Cultural Landscape of Bali Province: the Subak System as a Manifestation of the Tri Hita Karana Philosophy inscribed in 2012.

3.2.9.7. Rajabasa

Mount Rajabasa in the Sumatran Province of Lampung is a geothermal project area with plans for development of a power plant with capacity of 2×110MW. Supreme Energy and its partners plan to invest more than US$800 million for both geothermal exploration and the power plant in Rajabasa. The consortium won the permit to develop the area in 2010. In 2013, around 1500 indigenous peoples rallied to reject the development of the Rajabasa geothermal project out of fear that the geothermal exploration would negatively impact their livelihoods. The Rajabasa WKP covers an area of 19,520ha with Mount Rajabasa located in the center. The mountain is classified as Protection Forest and almost completely covered in social forestry claims (PIAPS). Key concerns were the dozens of springs in the area, the presence of historic monuments and fortresses, and the important role Mount Rajabasa played as refuge during the Krakatau eruption and ensuing tsunamis in 1883 (Arrazie 2013). In 2014, the Ministry of Environment and Forestry gave out the Forestry Borrow and Use Permit (IPPKH), and, in 2015, the Regent of the South Lampung District came out in support of the geothermal development because of the major contribution this would make to local electricity supplies (Hendra 2015). Supreme Energy has since then constructed a jetty, piping systems, sea water facilities, pumping facilities, and facilities for the supply of electricity generators.

In the macro-risk assessment (see section 3.3), the Rajabasa site which contains two geothermal potential points which are classified as low and high medium risk with scores of 2 and 8 as one point (Pematang Belirang) is located in non-forest land and the other (Kalianda) is located in Protection Forest classified as primary forest with social forestry areas. The WKP covers the entire area of Mount Rajabasa which is Protection Forest and proposed for social forestry.

3.3. Macro-level risk assessment

3.3.1. Geothermal energy development risk mapping in Indonesia

Most of the geothermal potential points in Indonesia are on the islands of Sumatra, Java, Sulawesi, and Flores (Figure 25). The other large islands of Kalimantan and Papua have far fewer geothermal potential points. The islands where high biodiversity and high geothermal potential intersect are Sumatra, Java, Maluku and Sulawesi. The highest number of high-risk geothermal potential points are found on Sumatra (30 points) which has some of the highest geothermal potential and also very high biodiversity values, social values were lower but this may be a result of the lack of data relating to social factors mapped.

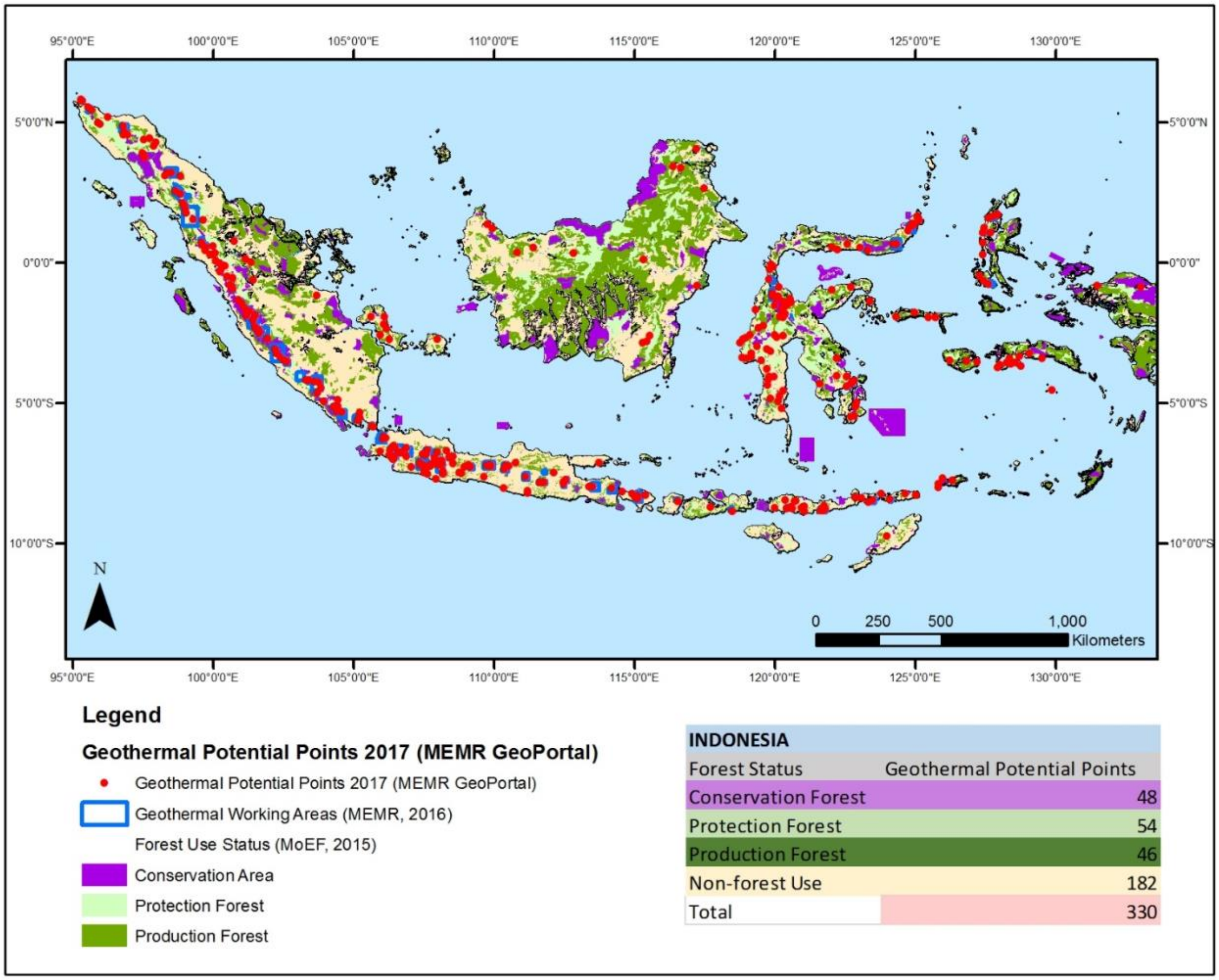


Figure 25. Geothermal potential in Indonesia in relation to land use (based on current analysis).

Table 7 presents an overview of the number of geothermal potential points for Indonesia according to forest status and use categories. These totals are based on our analysis which differs slightly from those unofficially stated by the MoEF.

Table 7. Number of geothermal potential points in relation to different forest status and use (based on current analysis)

	Number geothermal potential points (330)	Number according to MoEF (297 points) (Mongabay, 10 March 2017)
In National Parks, Nature Recreation Park, Grand Forest Park	**37**	**46 (all conservation areas)**
In Wildlife and Nature Reserves	**11**	
In Protection Forest	**54**	**56**
In Production Forest	**46**	**50**
In Non-Forest Use (APL)	**182**	**145**

The macro-level risk analysis found that twenty of the geothermal potential points were clearly within a national park boundary and nine were likely in or were on the edge or just inside a national park. Four points were within a Nature Recreation Park (*Taman Wisata*) and four in Grand Forest Park (*Tahura*). Nine points were found to be within Strict Nature Reserves (*Cagar Alam*), two points within a Wildlife Reserve (*Suaka Margasatwa*). The relative values per island show that 21% of geothermal potential points in Sumatra are located in conservation areas, for Java and Bali this dropped to 18% and 13% for Sulawesi.

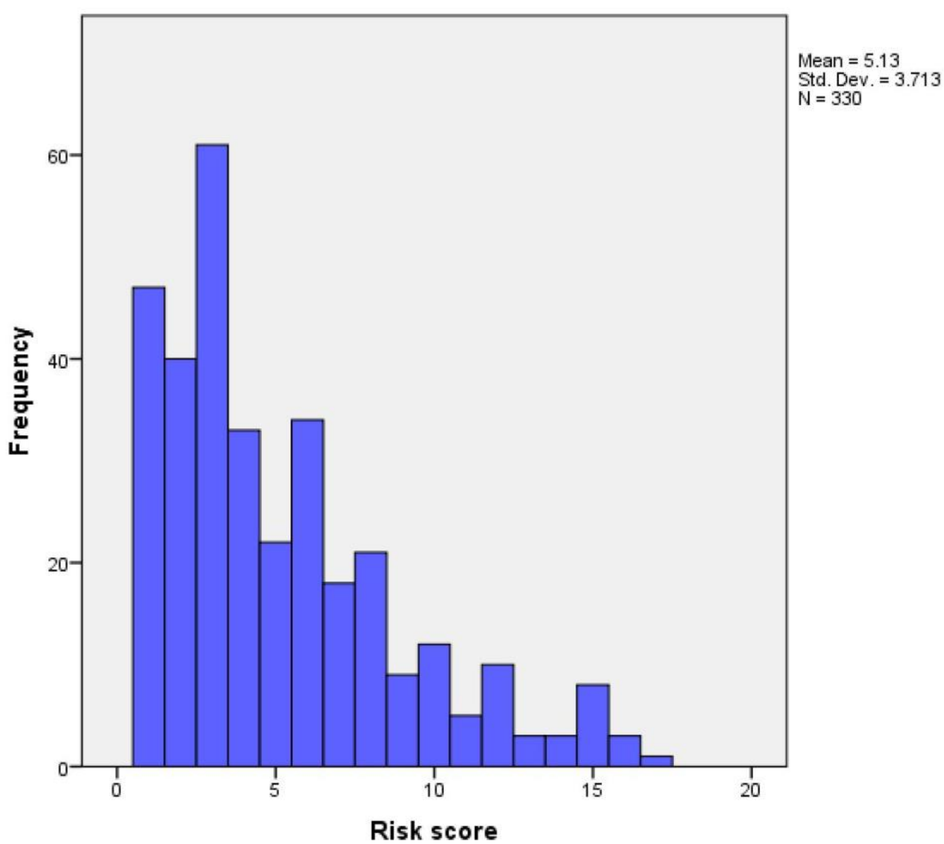


Figure 26. Frequency distribution of risk scores (1 to 17) of 330 geothermal potential points.

To assess other indicators of biodiversity value, an overlay was created of UNESCO World Heritage sites with geothermal potential sites resulting in twenty points, all located within the Tropical Rainforest Heritage Site of Sumatra.

The results of the Indonesia-wide risk mapping are presented on a regional basis in order to provide a clearer analysis as each island, or region, is characterized by different ecologies and landscapes. Out of a total of 330 potential geothermal points, 148 are ranked low risk (0 – 3 points), 89 are ranked medium risk (4 – 6 points), and 93 are ranked high risk (7 – 17 points) (Figure 26).

The current assessment determined the potential geothermal capacity that was located in forest areas, degraded forest areas and on cleared land based using data from *Badan Geologi* on the speculative, hypothetical, possible, probable or proven reserves. For this assessment, the most reliable resource estimate for each potential geothermal point was used, with "speculative" being the lowest reliability and "proven" the highest. This differs from the approach of the Directorate of Geothermal (2016, p. 34 and onward) where the resource capacity is calculated by summing the estimates for speculative, hypothetical, possible, probable or proven reserves for each geothermal point. This allows a comparison of the resource capacity of each potential project location and its individual risk level (Figure 27). This assessment indicates that the higher capacity projects (> 200 MW) are primarily located in high and medium risk locations, with most low risk location having < 200 MW capacity estimates.

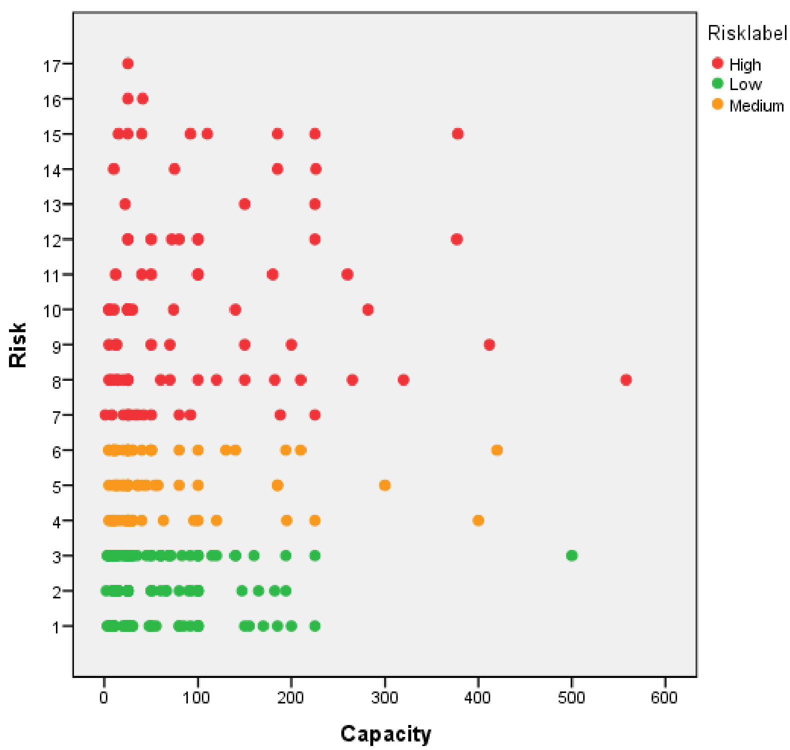


Figure 27. Comparing the most reliable project capacity estimate (speculative, hypothetical, possible, probable, proven or existing reserves) for each potential project point with social and environmental risk levels as determined in the current study.

Taking the current approach indicates that 66% of Indonesia's estimated geothermal capacity is on cleared land (in 218 geothermal locations), and 34% in degraded and primary forest (in 112 locations). Taking the government approach indicates a higher percentage of total capacity on non-forested land (73%) (Table 8).

Table 8. Overview of potential capacity in 314 geothermal points for which resource estimates were available in relation to land cover. Potential capacity is estimated by using the most reliable resource estimate for each geothermal point. The Sum of resource estimate uses the approach by the Geothermal Directorate (Directorate of Geothermal 2016).

Land cover	Potential capacity (MW)	Sum resource estimates (MW)
Cleared land	14,832	20,285
Degraded forest	5,173	6,418
Primary forest	1,076	1,076
Total	**21,081**	**27,779**

The same approach as above was used to estimate the geothermal potential in different land use categories. Most geothermal potential is in non-forest use land (APL), i.e., 38% of total capacity in 154 geothermal points. Protection Forest has the second highest potential capacity, i.e., 27% of total in 55 points. The remainder of the potential capacity is in Production Forest areas (11%) and in conservation areas (23%).

Table 9. Overview of potential capacity in 314 geothermal points for which resource estimates were available in relation to land use. Potential capacity is estimated by using the most reliable resource estimate for each geothermal point. The Sum of resource estimate uses the approach by the Geothermal Directorate (Directorate of Geothermal 2016).

Land use status	Potential capacity (MW)	Sum resource estimates (MW)
Non-forest use (APL)	8,056	12,240
Production Forest	2,416	2,758
Protection Forest	5,736	7,125
Conservation Areas	4,873	5,656
Total	**21,081**	**27,779**

3.3.2. Sumatra: Risk mapping

Sumatra is an island high in both biodiversity and cultural values. The island is home to a wide range of indigenous groups many of whom claim customary lands and have a deep connection with the environment in which they live and rely on the forests for ecosystem services and livelihoods. According the registration agency for customary lands, Aceh has 23 registered customary land areas, North Sumatra has 74 and Riau has 21 (*Badan Registrasi Wilayah Adat*, http://brwa.or.id/sig/, accessed 1 November 2017). There are also a high number of social forestry areas mapped for Sumatra providing further evidence of the important link between local communities and forests. The analysis, however, does not show any overlap between geothermal potential points and customary land according to the source used, and only seven points overlap with social forestry areas.

The high biodiversity values of Sumatra are evidenced by the high number of designated conservation areas, particularly the chain of large national parks stretching from Aceh to Lampung, many of which are also recognised as part of the UNESCO Tropical Rainforest Heritage of Sumatra.

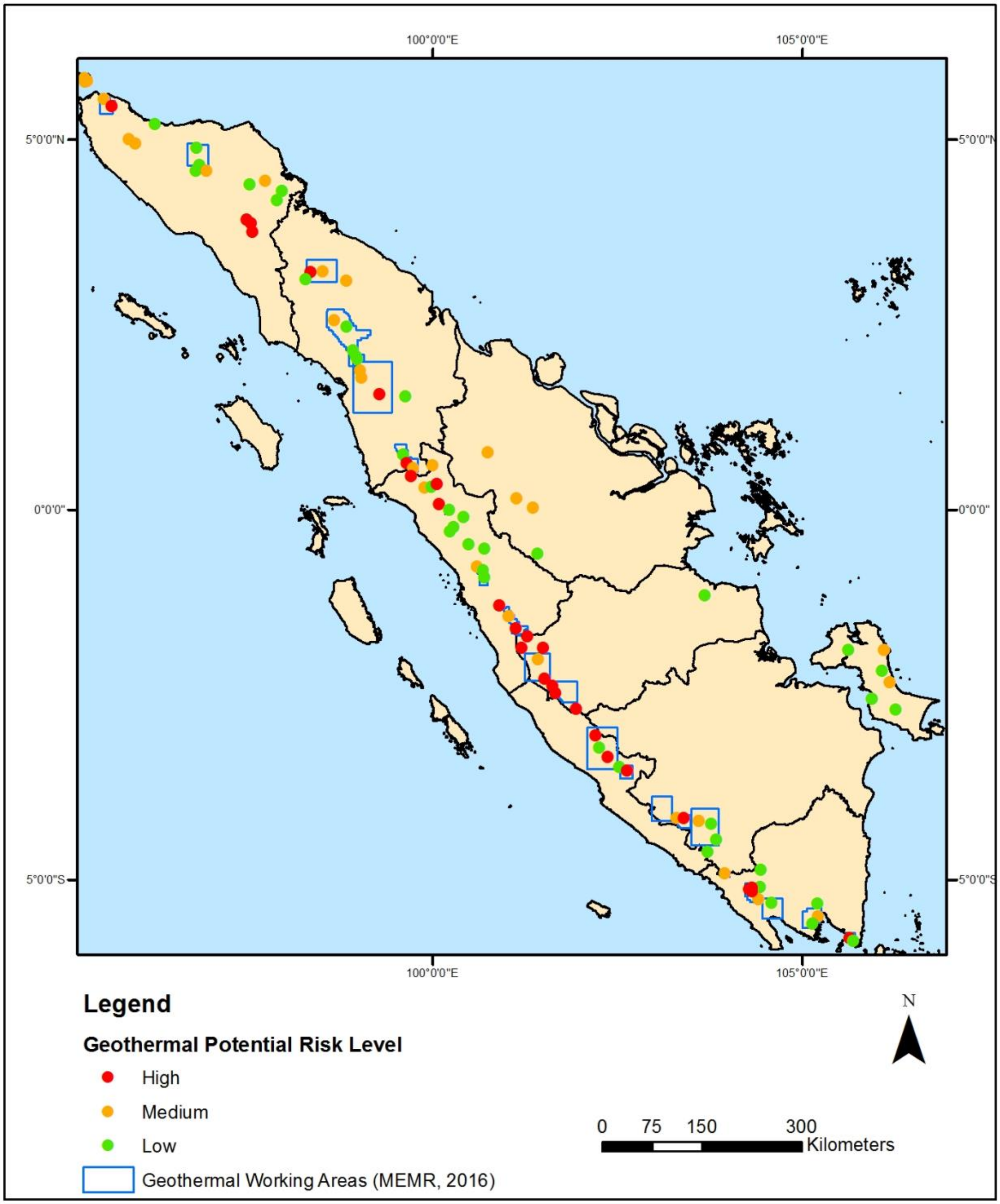


Figure 28. Overall environmental and social risk assessment for geothermal potential points on Sumatra.

There are 97 geothermal potential points distributed across the island of Sumatra, the highest concentration of points follows the volcanic mountain range (Barisan Range) which stretches from Aceh Province in the north to Lampung Province in the south. Over two thirds of the points (66) are found in three provinces; Aceh, North Sumatra, West Sumatra and Lampung. There are 20 geothermal working areas (WKP) on Sumatra some of which are in operation, some in construction, and the remainder with no activity.

The highest contribution to the overall risk ranking for the points on Sumatra is predominantly from environmental factors, such as being located in a conservation area, at the edge of a conservation area or in Protection Forest, and also from the high presence of international conservation designations such as Important Bird Areas and Key Biodiversity Areas, and UNESCO World Heritage. Forty-two percent of geothermal potential points on Sumatra are located in either conservation areas (20 points) or Protection Forests (20 points), many of these areas also located within primary or secondary forests. Although the analysis does not show a high incidence of points with high social risks compared to environmental risks, anecdotal evidence from interviews with stakeholders from Sumatra suggests that once exploration or construction activities start there is a high likelihood of community concern related to perceived loss of access to forest resources, impacts on water resources and issues relating to land acquisition which require careful management by the geothermal project operators.

Although a number of UNESCO World Heritage areas occur elsewhere in Indonesia, the only island with significant overlap with geothermal potential occurs is Sumatra. The Tropical Rainforest Heritage of Sumatra site was inscribed as a UNESCO World Heritage site in 2004 (UNESCO World Heritage Site website http://whc.unesco.org/en/list/1167 accessed July 2017) and comprises three widely separated national parks; Bukit Barisan Selatan National Park, Gunung Leuser National Park, and Kerinci Seblat National Park, all of which also contain geothermal potential points and geothermal working areas. UNESCO lists the Tropical Rainforest Heritage of Sumatra as one of 54 sites in danger across the world.

Table 10. Geothermal Points – Land Status and Risk Scores per Province – Sumatra

Province	Conservation Forest	Protection Forest	Production Forest	Non-forest	**Total**	High	Medium	Low
Aceh	4	5	2	8	**19**	4	8	7
North Sumatra	3	5	2	7	**17**	5	5	7
West Sumatra	3	2	0	12	**17**	4	4	9
Jambi	5	1	0	3	**9**	7	1	1
Riau	0	0	3	1	**4**	0	3	1
Bengkulu	2	1	0	2	**5**	3	1	1
Bangka Belitung	0	0	0	7	**7**	0	1	6
South Sumatra	0	3	0	3	**6**	2	1	3
Lampung	3	3	0	7	**13**	5	2	6
Total points	**20**	**20**	**7**	**50**	**97**	**30**	**26**	**41**
% of total	21%	21%	6%	52%		31%	27%	42%

The overall risk assessment for Sumatra is presented in Figure 28 and Table 10. A total of 31% of the geothermal potential points are classified as high risk, the highest for any of the islands/regions that were assessed in Indonesia. The majority of these high-risk points are located in conservation areas which also have international designations (IBAs, KBAs and UNESCO WHA), with the remainder in Protection Forest with high biodiversity and social values. A total of 27% of points were considered medium risk and 42% as low risk, all of which are located outside conservation areas.

Deforestation rates within the potential project footprint of geothermal potential points showed that deforestation rates are still high in some parts of Sumatra particularly on the fringe of large forested areas, these areas are considered at high risk of further deforestation if developments occur in the area due to improved forest access.

The highest totals in the high-risk category reached 17 for one point in Kerinci Seblat National Park in Jambi based solely on the contribution from environmental risk factors. Nine high risk points in Sumatra had a value of 14 – 16, all these points are located in a national park. These are high values compared to other islands assessed.

3.3.3. Java and Bali: Risk mapping

There are 73 geothermal potential points distributed across the island of Java, and 6 on Bali. The points are predominantly concentrated on or near to the volcanic mountains of these islands. The highest concentration of points is in West Java with 40 geothermal potential points and 12 geothermal working areas (WKP), and five projects which are in production and operating. Central Java contains 6 working areas all which overlap with areas of Protection Forest whereas in East Java two points overlapped with conservation areas. Across Java as a whole only 15% of points overlapped with conservation areas, which is lower than Sumatra. 14% of points were found in Protection Forests and 60% of points were located in non-forest areas.

The risk analysis results presented in Table 11 and Figure 29 show that West Java has the highest concentration of high-risk points. Generally, deforestation rates in and around the geothermal potential points were lower than in Sumatra indicating a more stable landscape of established agriculture with deforestation impacts having been greater in the past. From a social perspective one area of customary land which is certified overlapped with a geothermal potential point in Banten Province (Gunung Endut), this in conjunction with high biodiversity values elevated this point to one of the highest risk points on Java. The highest risk value achieved across Java as a whole was 14 which occurred at one point, followed by one point of 13 and five points valued at 12, this contrasts with some of the very high-risk values found on Sumatra.

Six geothermal potential points are located on Bali, with only one working area in existence. There are no geothermal projects in operation. One point is located at the edge of a conservation area (Gunung Batur) and also located within the UNESCO Cultural Landscape of Bali site and thus achieves a risk value of 16.

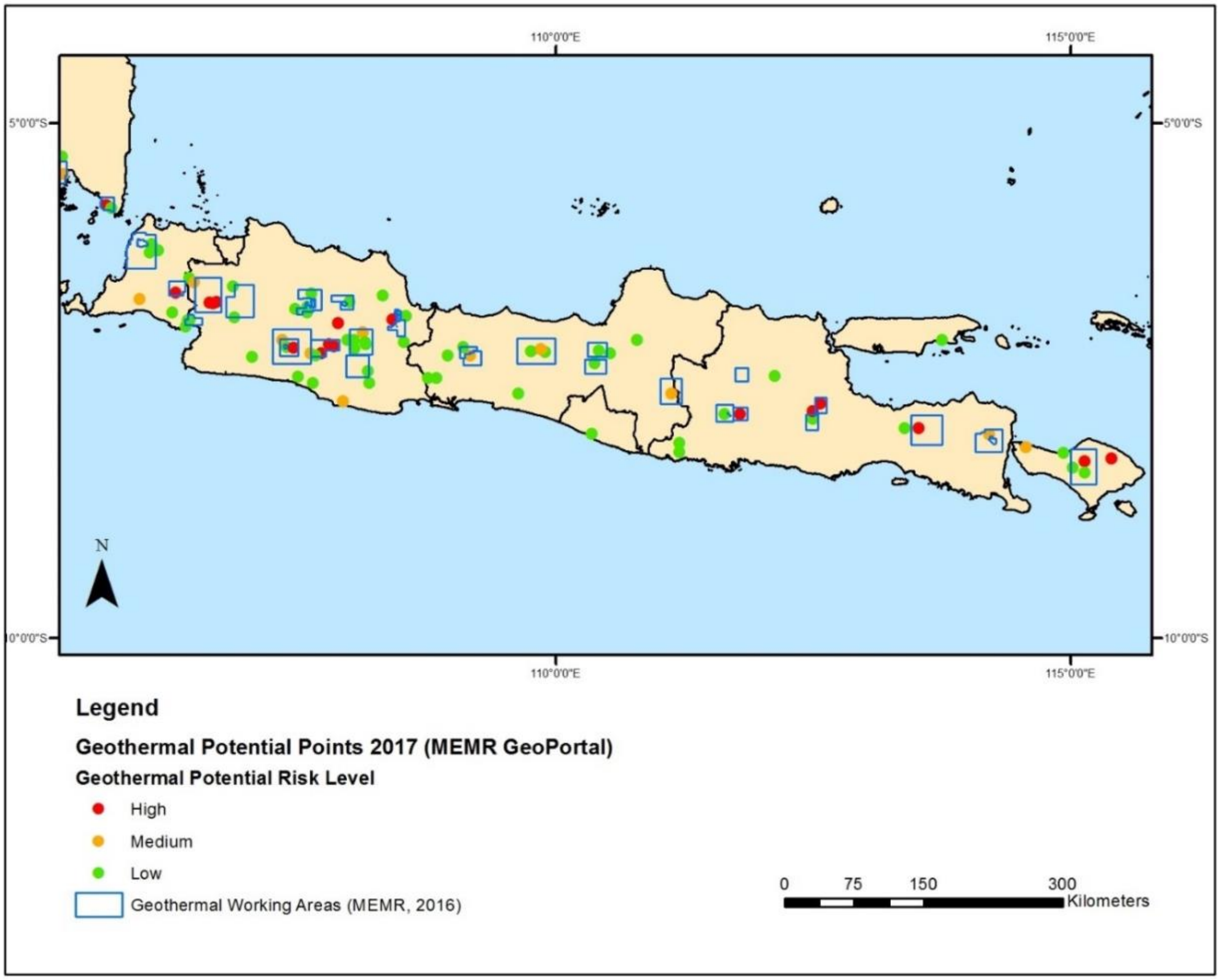


Figure 29. Overall environmental and social risk assessment for geothermal potential points on Java and Bali

Table 11. Geothermal Potential Points – Land Status and Risk Scores per Province – Java and Bali

Province	Conservation Area	Protection Forest	Production Forest	Non-forest	**Total**	High	Medium	Low
Banten	1	1	0	4	**6**	1	1	4
West Java	9	6	2	23	**40**	9	5	26
Central Java	0	2	3	9	**14**	0	3	11
East Java	2	3	1	6	**12**	4	1	7
Yogjakarta	0	0	0	1	**1**	0	0	1
Bali	2	0	0	4	**6**	2	1	3
Total points	**14**	**12**	**6**	**47**	**79**	**16**	**11**	**52**
% of total	18%	15%	7%	60%		20%	14%	66%

3.3.4. Sulawesi: Risk mapping

There are 77 geothermal potential points on Sulawesi and six WKP. Out of these 77 points, only 10 are located in a conservation area, 10 in Protection Forest, 8 in Production Forest and 49 in non-forest use areas. These figures are proportionally similar to Java and Bali for the different forest use types. Central Sulawesi contains the highest proportion of points (23) but only two points are located in conservation areas.

In terms of environmental and social risks, the analysis showed that overall for Sulawesi the highest proportion of points, 40% (31 points), fall within in the low risk category, followed by 33% (25 points) classified as high risk, and the remainder medium risk (21 points) see Figure 30 and Table 12. The analysis further revealed that in Sulawesi the relative contribution of social risk factors to the overall risk value was higher than for Sumatra and Java. For example, in Central Sulawesi only 2 points are located in conservation areas and 3 points in Protection Forests, however, the total number of high risk points out of 23 points in this province is 10 (43%). The reason for the number of high risk points in Central Sulawesi is primarily due to the presence of customary land and the presence of indigenous people particularly in Central Sulawesi, in addition to environmental aspects such as primary forest and international biodiversity classifications (IBA & KBA) despite no official status as conservation area.

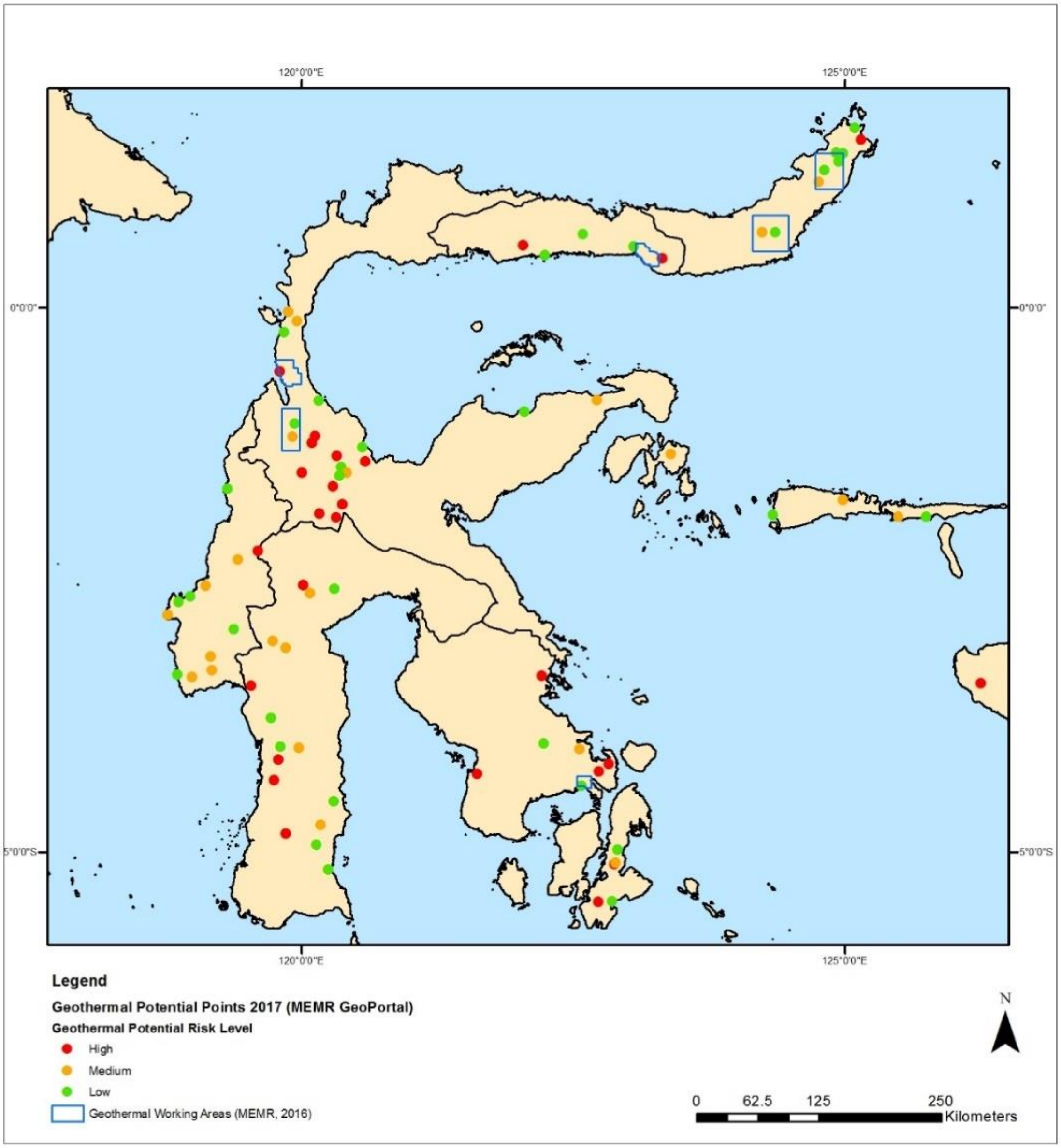


Figure 30. Overall environmental and social risk assessment for potential geothermal areas in Sulawesi

Table 12. Geothermal Points – Land Status and Risk Scores per Province – Sulawesi

Province	Conservation Area	Protection Forest	Production Forest	Non-forest	Total	High	Medium	Low
North Sulawesi	1	1	0	7	**9**	1	2	6
Gorontalo	2	0	0	3	**5**	2	0	3
Central Sulawesi	2	3	2	16	**23**	10	6	7
West Sulawesi	1	2	3	6	**12**	1	6	5
South Sulawesi	2	3	0	11	**16**	5	5	6
South-East Sulawesi	2	1	3	6	**12**	6	2	4
Total points	10	10	8	**49**	**77**	**25**	**21**	**31**
% of total	13%	13%	10%	64%		33%	27%	40%

3.3.5. Maluku & North Maluku, and Papua: Risk mapping

There are 36 geothermal potential points in Maluku, North Maluku and Papua, and five WKP. Out of these 36 points, only 2 are located in conservation areas, 4 in Protection Forest, 17 in Production Forest and 13 in non-forest use areas (Table 13). A high proportion of the Production Forest class was Conversion Forest.

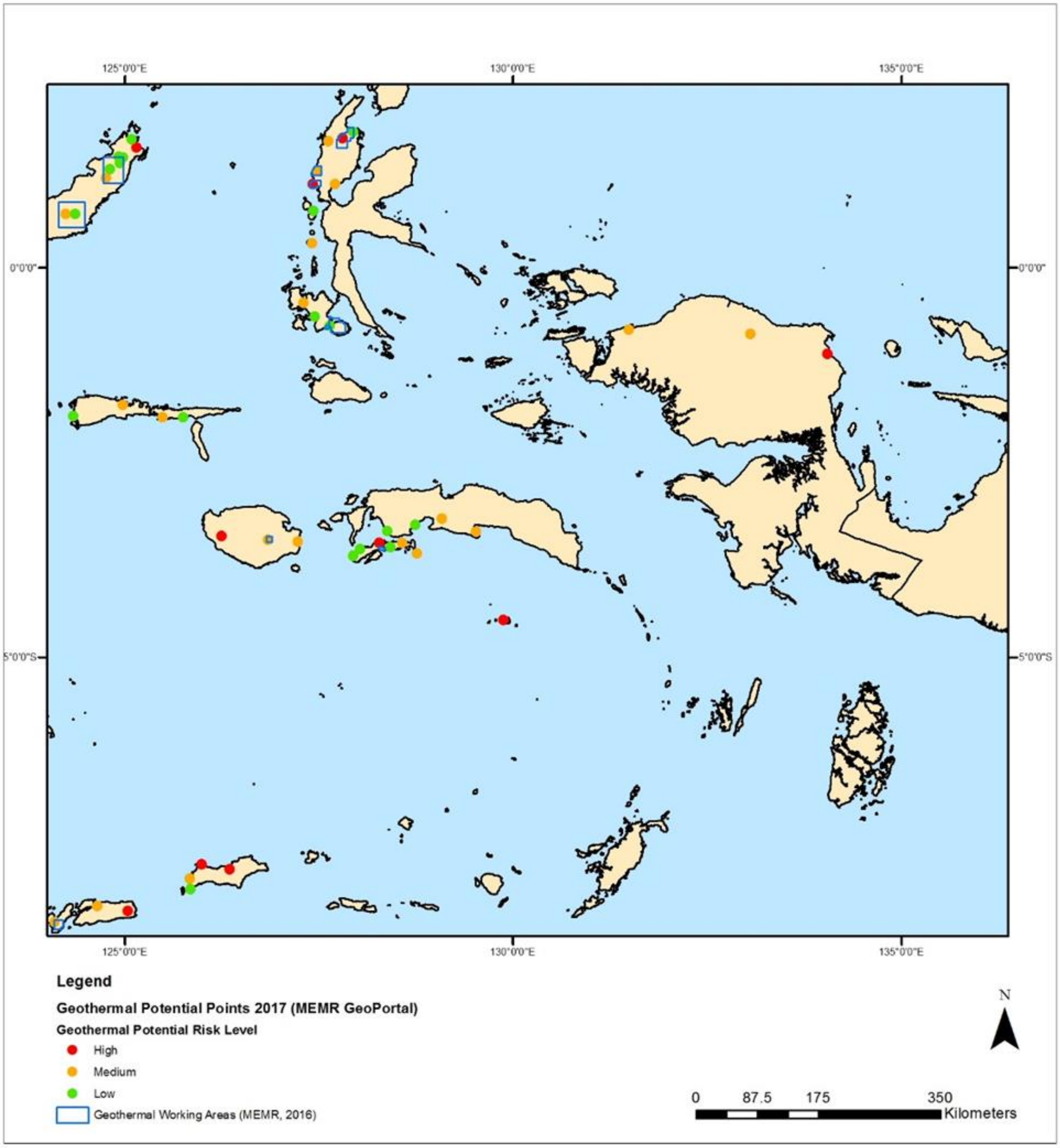


Figure 31. Overall environmental and social risk assessment for potential geothermal areas in Maluku Islands and Papua

In terms of environmental and social risks, the analysis showed that overall for the Maluku Islands and Papua the highest proportion of points 42% (15 points) fall within in the medium risk category, followed by 33% (12 points) classified as low risk, and the remainder medium risk (9 points) (Figure 31 and Table 13). The analysis further revealed that in the Maluku Islands the relative contribution of social risk factors to the overall risk value was higher than for Sumatra and Java. This is primarily due to the presence the presence of indigenous people and potential social forestry areas. In addition, compared to Sumatra and Java, there are still areas of primary forest and international biodiversity classifications (IBA & KBA) despite no official status as conservation area and areas which have experienced little or no deforestation which would all contribute to potentially high risks for development.

Table 13. Geothermal Points – Land Status and Risk Scores per Province – Maluku Islands and Papua

Province	Conservation Area	Protection Forest	Production Forest	Non-forest	**Total**	High	Medium	Low
North Maluku	0	2	8	5	**15**	2	7	6
Maluku	1	2	8	7	**18**	5	7	6
Papua	1	0	1	1	**3**	2	1	0
Total points	2	4	**17**	**13**	**36**	9	15	12
% of total	6%	11%	47%	36%		25%	42%	33%

3.3.6. West and East Nusa Tenggara: Risk mapping

There are 27 geothermal potential points in West Nusa Tenggara (3) and East Nusa Tenggara (24), and seven WKP. Out of these 27 points, only 2 are located in conservation areas, 7 in Protection Forest, 1 in Production Forest and 17 in non-forest use areas (Table 14).

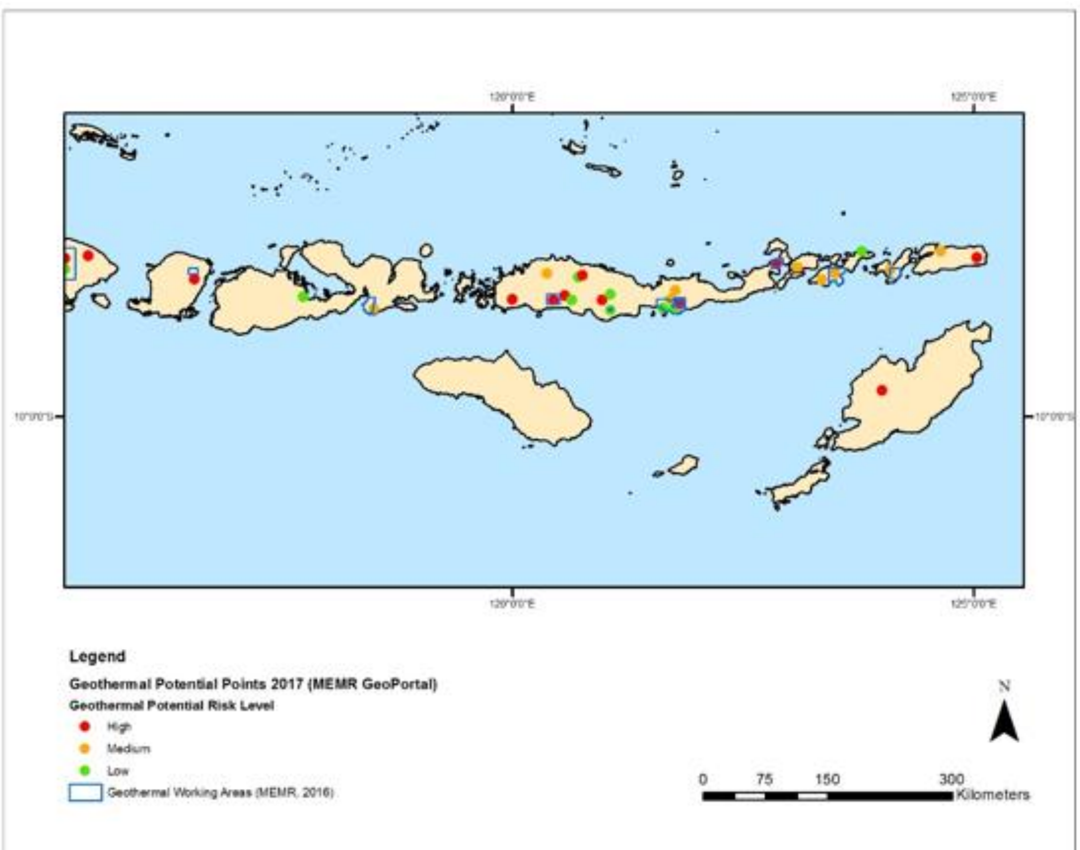


Figure 32. Overall environmental and social risk assessment for potential geothermal areas in West and East Nusa Tenggara

In terms of environmental and social risks, the analysis showed that overall for West and East Nusa Tenggara the risks were fairly evenly distributed across the three risk levels; 37% high risk, 33% medium risk and 30% low risk. This is despite 63% of the points being found in non-forest use land. The reasons for this are very similar to the Maluku Islands where the presence of indigenous people and potential social forestry areas, and primary or degraded forest raised the risk value. In addition, there are a number of IBAs and KBAs on East Nusa Tenggara which have no official status as conservation areas and have experienced little or no deforestation. All these factors combined contribute to potentially high risks for development.

Table 14. Geothermal Points – Land Status and Risk Scores per Province – West and East Nusa Tenggara

Province	Conservation Area	Protection Forest	Production Forest	Non-forest	**Total**	High	Medium	Low
West Nusa Tenggara	1	1	0	1	**3**	1	1	1
East Nusa Tenggara	1	6	1	16	**24**	9	8	7
Total points	2	7	**1**	**17**	**27**	**10**	**9**	8
% of total	7%	26%	4%	63%		37%	33%	30%

3.3.7. Kalimantan: Risk mapping

Table 15 below is the list geothermal potential points for Kalimantan of which there are 14 spread across all provinces but Central Kalimantan. The geothermal potential in terms of MW is very low for all points. There are no points found in conservation areas, only one point in a Protection Forest but the majority of points are classes as high risk (21%) or medium risk (50%) mainly due to both high environmental and social factors.

Table 15. Geothermal Points – Land Status and Risk Scores per Province – Kalimantan

Province	Conservation Area	Protection Forest	Production Forest	Non-forest	**Total**	High	Medium	Low
West Kalimantan	0	0	3	2	**5**	1	2	2
South Kalimantan	0	0	1	2	**3**	1	1	1
North Kalimantan	0	1	2	1	**4**	1	3	0
East Kalimantan	0	0	1	1	**2**	0	1	1
Total points	0	1	**7**	**6**	**14**	3	7	4
% of total	0%	7%	50%	43%		21%	50%	29%

4. Recommendations for Mitigation of Environmental and Social Impacts

From a global environmental perspective, the benefits of geothermal energy development are beyond dispute. In Indonesia, however, the fact that most of the geothermal potential is located in environmentally sensitive areas means that it is critical that the geothermal energy sector adheres to high operational standards whereby environmental and social impacts and risks are assessed early in the project cycle. Such impacts need to be avoided, if possible, or mitigated and managed. Affected communities need to be consulted throughout project preparation and development. Applying the macro-level analysis screening approach to "Geothermal Power Blocks to Be Tendered in 2017" indicates a number of high-risk project locations (in orange) which should be carefully evaluated (Table 16).

WKP Block	Capacity (MW)	Estimated Investment (million USD)	Province	Overall Risk Rank	Comments
Bonjol	60	240	West Sumatra	1	In the WKP are PIAPs areas, KBA, IBA, strict nature reserve but not where the point is.
Gn Talang Bukit Kili	20	80	West Sumatra	2 & 2	
Gunung Endut	40	160	Banten	12	Registered customary land and national park/KBA/IBA
Candi Umbul Telomoyo	55	220	Central Java	1	
Gunung Wilis	20	80	East Java	8	Protection Forest/IBA/KBA
Gunung Arjuno Welirang	110	440	East Java	14	Grand Forest Park/IBA/KBA
Gunung Pandan	10	40	East Java	2	
Gunung Gede Pangrango	55	220	West Java	1	The WKP includes the National Park but point doesn't.
Songgonti	20	80	East Java	3	The WKP contains Protection Forest and KBA/IBA. No point called Songgonti but one called Songgoriti
Sipoholon Ria-Ria	20	80	North Sumatra	2 & 2	
Simbolon Samosir	110	440	North Sumatra	4 & 3 & 1	
Graho Nyabu	110	440	Jambi	15 & 17	National Park/IBA/KBA/WH/Primary Forest/high defor in the area
Suwawa	20	80	Gorontalo	15	Point is on edge of the WKP. National Park/IBA/KBA/Primary Forest/IP
Sembalun	20	80	NTB Lombok	10	Point is outside the WKP. National Park/PIAPS/IBA/KBA/
Oka-Ile Ange	10	40	NTT Flores	7	Protection Forest/IP
Bora Pulu	40	160	Central Sulawesi	6 & 2	Pulu contains customary land areas
Gunung Hamiding	10	40	North Maluku	8	IP/Protection Forest, KBA.
Songa Wayaua	5	20	South Halmahera	3	
Gunung Geureudong	110	440	Aceh - NAD	4	Protection Forest and KBA
Gunung Galunggung	110	440	West Java	1	
Gunung Ciremai	110	440	West Java	13	National Park, KBA, IBA.

Table 16. Preliminary List of Geothermal Power Blocks to Be Tendered in 2016-2017 according to Ministry of Energy and Mineral Resources (Saifulhak 2016) and the assessment of risk according to the current study. Orange indicates high risks.

Sustainable development of Indonesia's geothermal energy rests on two pillars: firstly, a strong regulatory framework which is consistently enforced and effectively monitored to ensure environmental protection and social inclusion (community engagement and consultation, grievance redress and fair benefit sharing) and secondly the implementation of high operating standards in sensitive areas and avoidance of development in very sensitive areas, such as core zones of national parks. Here in lies the major challenge for geothermal energy development in Indonesia.

There are trade-offs between the costs and benefits of geothermal development in forest areas. In certain cases where the geothermal potential is very high and the potential for environmental and social impacts low, it seems an obvious choice to support geothermal development. In the opposite case of high environmental and social impacts and low geothermal potential the opposite is true and many people may agree that the project should not be developed. This is all seems simple, but the reality is often a lot more complex. Opinions may differ on how one defines high environmental values and the extent to which these are affected by geothermal developments. Furthermore, environmental and social impacts can be much reduced by high quality operational management and impact avoidance and mitigation. A well-managed project with good security that stops people from using company roads to go hunting will obviously have lower environmental impacts than one without such high standards. A project which plans road construction in such a way that roads are kept to a minimum width and length with well managed run-off and sediment control will obviously have much lower environmental and social impacts. Government decision-makers therefore need clear and objective guidelines that facilitate decision-making about geothermal (yes/no decision), but also about the conditions under which this would happen. Below we discuss some good practice that should be implemented to reduce the impacts of geothermal development in Indonesian forest areas.

4.1. Best Practice Guidelines Indonesia

Operating guidelines which are tailored to specific geographies tend to be the most relevant as specific environmental and social aspects vary between countries. A search of specific guidelines for geothermal development in Indonesia, resulted in only one document published by the Worldwide Fund for Nature (WWF). WWF has a mature renewables program and has been understandably supportive of the sustainable development of the geothermal sector in Indonesia through its “Ring of Fire” Program which commenced in 2011. In 2013, WWF-Indonesia published its Sustainability Guidelines for Geothermal Development (WWF-Indonesia 2013) with the aim of filling the technical and information gaps between the MoEF and MEMR, by producing guidelines which could be adopted and implemented by geothermal project operators (pers. comm. to authors). The guidelines present a framework for decision-making in geothermal energy development in Indonesian forest areas. The system uses a number of indicators related to geothermal operational activity and ecological functions of the area, and scored these as having high, medium and low value, with qualitative descriptions of each of these levels of the various indicators. The system, however, is not very practical because it does not provide a mechanism for combining or comparing the various indicators. Discussions with the WWF team who wrote the guidelines confirmed that there had not been high uptake of the sustainability guidelines by operators. WWF intend to update these guidelines to accommodate changes in related geothermal laws and regulations. According to discussions with WWF, the revised guidelines would be benchmarked against international hydro-sustainability guidelines and geothermal development guidelines from Iceland.

4.2. The Environmental Mitigation Hierarchy

The most commonly used approach to avoiding and mitigating project environmental impacts is application of a hierarchy of management measures. The mitigation hierarchy approach is a step-wise approach which is most commonly used for avoiding, minimizing, and offsetting impacts on biodiversity (Figure 33). IFC Performance Standard 6 which relates to Biodiversity Conservation and Sustainable Management of Living Natural Resources, refers extensively to and requires application of the mitigation hierarchy (IFC 2012). It is based on a series of sequential steps that must be taken throughout the project's life cycle in order to limit any negative impacts on biodiversity and to achieve no overall negative impact on biodiversity or on balance a net gain (also referred to a No Net Loss and the Net Positive Approach).

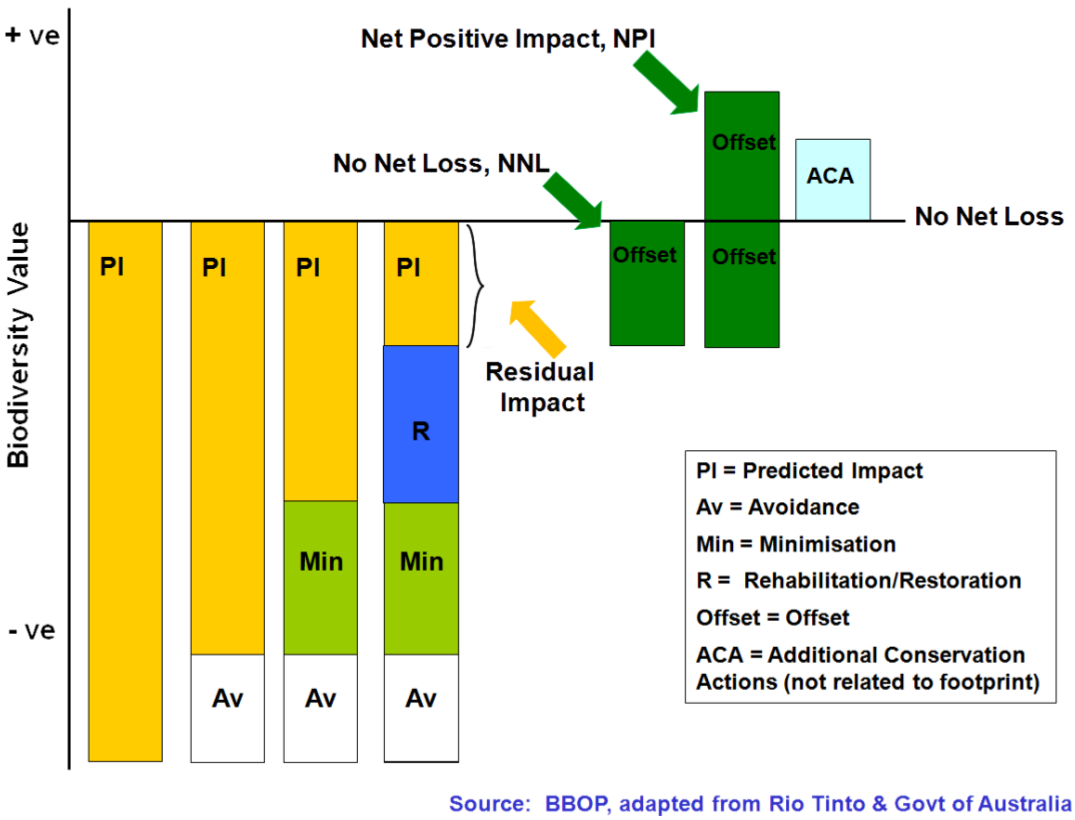


Figure 33. The Mitigation Hierarchy (Business and Biodiversity Offsets Programme (BBOP) http://bbop.forest-trends.org/pages/mitigation_hierarchy, accessed 11 November 2017)

This study has assessed various aspects of the mitigation hierarchy in relation to avoiding and minimising environmental and social impacts of geothermal development in forest areas.

1. **Avoidance:** the first step in the mitigation hierarchy comprises measures taken to avoid creating impacts from the outset, such as selecting an alternative location or careful spatial or temporal placement of infrastructure or disturbance. For example, placement of roads and large infrastructure (such as power stations) outside of rare and sensitive habitats. Avoidance is often the easiest, cheapest and most effective way of reducing potential negative impacts, but it requires biodiversity to be considered in the early stages of a project in a screening process (as shown in this study).

2. **Minimisation:** measures taken to reduce the duration, intensity and/or extent of impacts that cannot be completely avoided. Effective minimisation can eliminate some negative impacts. Examples include such measures as reducing noise and pollution, designing infrastructure lighting so that it does not disturb wildlife, or building wildlife crossings on roads, restricting public access to projects roads which enter forest areas through the installation of portals and security patrols. The Environmental, Health and Safety Guidelines for Geothermal Power Generation (IFC/World Bank 2007) comprehensively lists all of the environmental and social impacts associated with geothermal energy development and makes but only makes high-level recommendations for minimising impacts.

3. **Rehabilitation/restoration:** measures taken to improve degraded or removed ecosystems following exposure to impacts that cannot be completely avoided or minimised. Restoration tries to return an area to the original ecosystem that occurred before impacts, whereas rehabilitation only aims to restore basic ecological functions and/or ecosystem services (e.g. through planting trees to stabilise bare soil). Rehabilitation and restoration are frequently needed towards the end of a project's life-cycle, but may be possible in some areas during operation (e.g. after temporary borrow pits have fulfilled their use, or re-vegetating the road sides post construction). Collectively, avoidance, minimisation and rehabilitation/restoration serve to reduce, as far as possible, the residual impacts that a project has on biodiversity. Typically, however, even after their effective application, additional steps will be required to achieve no overall negative impact or a net gain for biodiversity.

4. **Offset:** a measure taken to compensate for any residual, adverse impacts after full implementation of the previous three steps of the mitigation hierarchy. Many Lenders, such as IFC, ADB, and also many top-tier corporate biodiversity commitments, require that in critical habitats, any significant residual impacts must be mitigated using biodiversity offsets. It should be noted that a reliable determination of residual impacts on biodiversity needs to consider the uncertainty of outcomes due to mitigation measures. This is especially relevant with respect to restoration and the project's ability to ensure adequate restoration of biodiversity. Where there is significant uncertainty, the project should take a conservative approach in ascertaining the significance of residual impacts (IFC 2012, GN15). Determining the size and type of biodiversity offset is often complex and requires specialist expertise in the evaluation, design and implementation stage. Biodiversity offsets are of two main types: 'restoration offsets' which aim to rehabilitate or restore degraded habitat, and 'averted loss offsets' which aim to reduce or stop biodiversity loss (e.g. future habitat degradation) in areas where this is predicted. Offsets are often complex and expensive and, in developing countries, difficult to implement as regulatory mechanisms are not in place to support biodiversity offsets, therefore attention to earlier steps in the mitigation hierarchy is usually preferable. The specific environmental and social context, and regulatory context within which a project is located will have a significant bearing on the type of offset which is suitable and feasible. The best biodiversity offsets should benefit biodiversity as well as local communities. The success of biodiversity offsets is very context specific.

   There are a number of good guidance sources/toolkits for designing biodiversity offsets, such as the Biodiversity Offset users guide available from the PROFOR website (https://www.profor.info/content/biodiversity-offsets-toolkit-and-sourcebook) and also from the Forest Trends Business and Biodiversity Offset Programme (http://bbop.forest-trends.org/pages/guidelines). IFC Performance Standard 6 also contains extensive guidance on biodiversity offsetting and

5. **Additional Conservation Actions:** measures taken which have positive – but difficult to quantify – effects on biodiversity. These qualitative outcomes do not fit easily into the mitigation hierarchy, but may provide crucial support to mitigation actions. For example, partnerships with conservation NGOs for species recovery programs may assist in minimising impacts, or partnerships with NGOs to implement community forestry programs with local communities may assist in minimising impacts in the wider landscape, awareness activities may encourage changes in government policy that are necessary for implementation of novel mitigation, research on threatened species may be essential to designing effective minimisation measures, or capacity building might be necessary for local stakeholders to engage with biodiversity offset implementation. A number of top tier mining companies have entered into long-term partnerships with international conservation NGOS, such as The Nature Conservancy, Conservation International, Fauna and Flora International and their country programs.

4.3. Recommendation for Environmental and Social Screening of Project Risk

From an investor and developer standpoint geothermal projects are risky with geological exploration risk (or resource risk) often considered the greatest challenge and capital intensive (ESMAP 2012). Significant investment is required before knowing whether the geothermal resource has enough potential to recover the costs. This report has demonstrated, with a number of examples, that environmental and social risk has the potential to cause significant delays or cancellations of geothermal projects.

One of the key outputs of this study has been the rapid desktop evaluation tool for environmental and social risk screening of geothermal potential points. This screening method is relatively quick and affordable, and could be feasibly institutionalised in MEMR and MoEF, to help the government (and investors) identify areas which should be avoided due to very high environmental and social risks, or it could be used to inform design and to the scope of subsequent environmental and social assessments. The benefits of this approach are shown in Table 16 and specific recommendations are made in Table 17.

Secures Investment	Reduces Costs
• Identifies high risk projects (showstoppers) and low risk alternatives and identifies specific issues which require up-front mitigation planning • Helps align projects with international financial institutions lender requirements and government policies • Increases project operational readiness through integration of biodiversity and social considerations at an early stage – front-end loading	• Helps prioritise and guide baseline survey effort towards understanding highest project risks • Focusses the AMDAL (ESIA) on mitigation for the key biodiversity, environmental and social risks within the project area of influence
Reduces Uncertainty	**Increases social acceptance**
• Increases cost effectiveness by reducing mitigation and compensation cost liabilities	• Demonstrates commitment towards sustainable and inclusive development contributing to social licence to operate

• Avoids unpredictable costs associated with project retro-fitting due to late identification of biodiversity and social risks	• Helps foster a positive relationship with local stakeholders by identifying biodiversity and ecosystem services for community livelihood and well-being

Table 16. Benefits of environmental and social screening of geothermal project locations

Key issues	Recommendations
1. Risk level of geothermal power development in Indonesian forest areas varies greatly depending on a range of social and environmental factors. Ignoring these risks significantly raises the costs of geothermal power development. According to government data, most high potential capacity projects are also high risk projects.	• Institutionalisation of the environmental and social project screening tool. Government institutions, project developers, and financiers should use the World Bank risk assessment in the allocation of areas for exploration and development, focusing first on project sites with low risks and high potential capacity. Risk avoidance might require targeting of lower capacity projects (below 250MW). Extra risk mitigation measures are needed when higher risk locations are developed.
2. Most geothermal capacity is located in areas already deforested and on non-state-forest land. Geothermal capacity in forested areas makes up about 27% of the total capacity in Indonesia according to government data.	• In order to avoid social and environmental impacts, exploration investments should preferably target the significant geothermal capacity in non-forest areas and on APL land with the caveat that these areas are likely to be more populated which comes with possible land acquisition challenges. In addition many of these resources are of lower-medium enthalpy.
3. Risk assessment is determined on the basis of variables and values for environmental and social risk and geothermal capacity that will change with better data and changing conditions.	• MEMR and MoEF jointly use the risk assessment tool in their planning for geothermal development and regularly update it as new data become available. Government institutions should share accurate data to ensure that the risk tool is as accurate as possible.

Table 17. Recommendations based on the environmental and social screening approach

4.4. Recommendations for Minimisation of Environmental Impacts

A starting point for sustainable development of the geothermal sector in greenfield sites, such as forest areas in Indonesia, is the application of pre-existing generic good practice guidelines such as the environmental and social safeguards policies developed by the International Financial Institutions (IFI), such as the World Bank Group (ESMAP 2012), the Asian Development Bank (ADB 2012), and other development banks. Many of the geothermal projects in Indonesia which are financed by IFIs follow such guidelines but continuing enforcement and maintenance of standards on the ground is variable. In addition, top tier private sector resource companies are increasingly setting high internal operating practices based on the Equator Principles (EP) and the embedded International Finance Corporation Performance Standards (IFC PS) on social and environmental sustainability and the IFC Environmental, Health and Safety Guidelines (IFC EHS Guidelines) (IFC 2007). There are some good examples of this in Indonesia. However, there is not yet an industry-specific operational guideline document for the management of the environmental and social aspects in an Indonesian context, which may be a useful addition in order to ensure that development of the geothermal sector proceeds in a sustainable manner.

This assessment has found the building of new access roads during exploration drilling, early on in the project lifecycle, is an area of particular concern for direct and indirect impacts on biodiversity and environmental services such as water. There is a significant opportunity for improvement in this area as presented below in Table 18

Key issues	Recommendations
1. Geothermal power development in Indonesian forest areas requires some 10 km of road for each 100 MW of operational capacity and indirectly impact some 10 km^2 of forest habitat. Because of their remote location, Indonesian geothermal projects require longer roads than projects elsewhere with similar capacity. Road and road access management are key factors in ensuring that geothermal roads do no increase pressure on forest and forest wildlife.	• Geothermal projects with road access deep into forest and conservation areas should be avoided where possible, especially if they go into core zones of conservation areas. Road access should be tightly managed for security reasons but also to ensure no illegal activities (hunting, logging, burning) occur using project access roads.
2. Road widths vary widely in Indonesian geothermal projects. The wider the roads the greater the environmental impacts.	• MEMR and MoEF should agree to develop road-design requirements/ regulations that minimize road width, road width and clearing around roads and the required use of culverts and overpasses (e.g., arboreal bridges and faunal underpasses), and asphalted roads and good drainage that require less canopy opening for drying out roads.  Examples of different road designs. A 5m wide tarmac road in Northern Negros NP in the Philippines with canopy connectivity across road, versus a 10-30 m wide road in and geothermal project in Sumatra in Protection Forest.
3. Remote forest areas in areas of steep terrain require lengthy access roads for geothermal power development generating relatively high impacts on forest and forest wildlife, streams and rivers.	• Geothermal Projects which require lengthy access roads through forests should be avoided as much as possible. Where possible, directional drilling from outside the forest area should be used as much as possible, and multiple directional drill holes should be established per drill pad to minimize road and drill pad construction. All means to minimise road length must be implemented and strict control of sediment run-off to water courses must be practiced.

Table 18. Recommendations for improvement in mitigation measures for road construction

There are also a host of impact minimisation measures which could be developed into practical guidelines (in the form of a manual) for reducing environmental impacts specific to geothermal projects. These could be based on existing best practice, which was observed at a number of locations in this study and include international guidelines, but must be written in a practical and prescriptive manner in order to get good industry buy-in.

- **Land Clearing Procedures** must demonstrate minimisation of impacts and include requirement for pre-clearing survey to identify any "chance" finds (not identified in baseline survey) such as caves, wallows, salt-licks, cultural sites, which should be avoided. The plan must ensure clear demarcation of the area to be cleared and that the clearing crew (usually contractors) understand the procedure. In forest areas, the owner's environmental and social team, and ecologist must supervise the clearing process. This is to ensure that wildlife is not killed or injured during the process and that appropriate action is taken

- **Awareness and training of employees and contractors regarding the biodiversity values** of the project site and why the operator seeks to minimise impacts. The information will explain the importance of forest habitats as well as protected and threatened plants and animals within the Project Area and details of the site environmental systems and regulations to protect biodiversity. All staff to be made aware of personal obligations to comply with biodiversity policy. There should be mandatory inductions for all employees and contractors.
- Procedures in place to **prevent and reduce hunting and logging** in areas opened up through the creation of new or improved access roads. Restricted access to unauthorised people using site roads during construction; restricted access barriers on site roads in habitats of conservation value following construction; and a voluntary procedure with local people on usage of site access roads.
- **Prevent and reduce mortality of wildlife from collision from vehicles**. Site surveys undertaken and monitoring systems established to identify wildlife movement patterns and response measures; the enforcement of speed limits along site roads to 30km/h through staff training and road signs; the introduction of speed reducing measures; establishment of an incident reporting response system; the establishment of a database to record number and type of wildlife injured or killed.
- **Light control within project area to minimize harm to wildlife**. Bright artificial lights in forests and other natural habitats can disturb wildlife, and deplete nearby areas of many night-flying insects. To minimize these adverse impacts during project construction and operation, (i) night construction work should be avoided and minimized wherever possible; (ii) lighting fixtures should be low to the ground as well as hooded and directed downward (not skyward or horizontally) to illuminate work areas only as needed; and (iii) sensors and switches should be used to light operational areas only when personnel are present
- **Minimize adverse biodiversity and other environmental impacts of power lines**, power lines connected to geothermal facilities should (i) follow alignments that are close to roads or otherwise minimize penetrating and fragmenting new forest or natural habitat areas; (ii) install bird flight diverters or similar devices in wetlands or other areas of high bird concentrations; and (iii) use bird-friendly power pole and line configurations to prevent the electrocution of raptors or other large birds that perch on the poles (e.g., separating individual powerlines by at least 1.5 m horizontally and 1 m vertically (this is particularly important in more open habitats, where trees or other natural perches are scarce).
- **Undertake habitat restoration within laydown and former production well areas.** The completion of restoration planting and management to ensure growth of planted species; monitoring of target species prior and following completion to determine no let loss and net gain of biodiversity.

4.5. Recommendations for minimisation of social impacts

As with environmental impacts, avoidance and minimisation of impacts on affected communities should be based on the application of pre-existing generic good practice guidelines such as the social safeguards policies developed by the International Financial Institutions (IFI), such as the World Bank Group (WBG).

The key approach is to avoid areas with high social impacts and minimise and manage impacts in areas where projects go ahead.

This assessment has found that the social issues most frequently raised against geothermal projects and include: a) lack of consultation, b) physical and economic dislocation of settlements, c) lack of benefits sharing d) encroachment of ancestral domain and e) privatization of the people's forest patrimony (de Jesus 2005). The Philippines has extensive experience in mitigating these social conflicts, and measures that have been developed there to address these concerns are relevant to the Indonesian context. Effective measures there have included: a) awareness and acceptance campaigns; b) opening up communication; c) translating commitments into action; d) third party multi-stakeholder monitoring; e) installation of an environmental guarantee fund; f) resettlement; g) provision of benefits; h) protection of prior and ancestral rights, i) protection of patrimony; and j) advocacy for appropriate public policies (de Jesus 2005). Table 19 provides key recommendations for reducing the social impacts.

Key issue	Recommendations
1. This study found that early baseline assessments of the social and cultural aspects of the potential project area were not conducted as there was no legal requirement to do so as part of the UKL-UPL.	• Early surveys of social and cultural values to produce a social screening of the area to enable adequate assessment of risks. • Identify if forest/natural resource dependent communities and/or indigenous communities are present or not within the direct area and downstream of potential impacts. This is particularly relevant in Indonesia where large populations occur around the base of mountains, although not within a geothermal working area, impacts on streams and river flowing through a geothermal project area can carry impacts far from the area, e.g. sedimentation as a result of road construction and other land clearing. • Ensure that a forest livelihood assessment is conducted with surrounding communities who depend on the forests within the project area. • Stakeholder mapping of the entire project area to ensure understanding of the various stakeholder groups.
2. One of the most common issues identified in Indonesia is a lack of proper engagement and consultation and a lack of information available to communities regarding geothermal energy.	• Stakeholder engagement and consultation early in the project cycle before any impacts occur. This is a type of "socialisation" of the project. • Involve local communities from the outset and create an environment which allows open discussion
3. This study found that there was a general sentiment from NGOs that communities lacked an understanding of geothermal energy and what the benefits and impacts could be for them.	• There is an important role to be played by grassroots organisations in raising awareness and understanding of geothermal energy amongst potentially affected communities. WWF is currently active in providing capacity building for community-based organizations in Aceh, Jambi and Lampung to assist local communities in understanding and being prepared for geothermal projects (SIDA Funding).

Table 19. Recommendations for improvement in mitigation of community issues

As with best practice environmental management, operators should ensure that they have adequate human resources and capacity to manage the complex community and other stakeholder issues which can arise with geothermal projects in forest areas. Operators need to be cognizant that negative environmental impacts may be felt by communities some distance downstream. Implementation of best practice management systems is also essential with regards to social aspects and should follow requirements such as the IFC Performance Standards. At a minimum geothermal operator must ensure that the following plans and procedures are in place:

- Implement a **Stakeholder Engagement Plan** which identifies, understands and considers the concerns, interests and relationships of stakeholders by completing stakeholder identification and stakeholder analysis; implement consultation activities that address specific needs of different stakeholders as documented in the stakeholder analysis.
- Implement a **Community Engagement Plan** which will be applied to all affected communities and individuals.
- Ensure **Land Acquisition**, and **Grievance Mechanism** procedures are in place and follow international best practice such as the IFC Performance Standards on Environmental and Social Sustainability (IFC 2012).
- Ensure that community aspects are included in the Land Clearing Procedure, for example pre-clearing surveys check the area for chance finds and that a customary leader in attendance to identify any cultural sites or objects during the pre-clearing survey with a view to these being avoided.
- Implement a **Local Procurement Plan** which includes capacity building and training for local vendors.
- Implement **Camp Policies** which determine operating standards for the accommodation of construction and permanent workforce. The option is either a closed camp whereby employees and contractors remain in the camp when not on duty or open camp whereby they can leave the camp when off duty and visit local villages and towns. There are pros and cons of both approaches.

5. References

Abood, S. A., J. S. H. Lee, Z. Burivalova, J. Garcia-Ulloa, and L. P. Koh. 2015. Relative Contributions of the Logging, Fiber, Oil Palm, and Mining Industries to Forest Loss in Indonesia. Conservation Letters **8**:58-67.

ADB. 2012. Asian Development Bank 2012 Environment Safeguards. A Good Practice Sourcebook. Draft Working Document. https://www.adb.org/documents/environment-safeguards-good-practice-sourcebook.

ADB. 2016. Achieving universal electricity access in Indonesia. Asian Development Bank, Mandaluyong City, Philippines.

ADB, and The World Bank. 2015. Unlocking Indonesia's Geothermal Potential. Page 153. Asian Development Bank and The World Bank, Jakarta, Indonesia.

anonymous. 2007. Trade of Lucanid beetles in Mount Salak. Forest for Life:1-4.

Ariyanti, D. S. 2017. Pengembangan PLTP Bedugul Diharapkan Berlanjut Maret 2017. Industri **10 January 2017**:http://industri.bisnis.com/read/20170110/20170144/20618078/pengembangan-pltp-bedugul-diharapkan-berlanjut-maret-20172017.

Arrazie, N. 2013. Masyarakat Adat Lampung Tolak Proyek Panas Bumi Tempo **29 May 2013**:https://m.tempo.co/read/news/2013/2005/2029/058484292/masyarakat-adat-lampung-tolak-proyek-panas-bumi.

ARUP, and WWF. 2017. Flores as a Geothermal Iconic Island. Road Map for Geothermal Development. Report for the Republic of Indonesia's Ministry of Energy and Mineral Resources & The United Kingdom's Foreign and Commonwealth Office. Ove Arup & Partners Ltd, London, UK.

Bapa, A. 2003. Geothermal environmental impact assessment with special reference to the Tuzla geothermal area, Canakkale, Turkey. Reports 2003, number 5. Pages 75-114. Canakkale Onsekiz Mart University, Canakkale, Turkey.

Blom, A., R. van Zalinge, I. M. A. Heitkönig, and H. H. T. Prins. 2005. Factors influencing the distribution of large mammals within a protected central African forest. Oryx **39**:381-388.

Bramantyo. 2017. Ini Alasan Warga Karanganyar Tolak Proyek Geotermal di Gunung Lawu. Okezone News **15 March 2017**:http://news.okezone.com/read/2017/2003/2015/2512/1643407/ini-alasan-warga-karanganyar-tolak-proyek-geotermal-di-gunung-lawu.

Brun, C., A. R. Cook, J. S. H. Lee, S. A. Wich, L. P. Koh, and L. R. Carrasco. 2015. Analysis of deforestation and protected area effectiveness in Indonesia: A comparison of Bayesian spatial models. Global Environmental Change **31**:285-295.

Budiharta, S., E. Meijaard, P. Erskine, D. , C. Rondinini, M. Pacifici, and K. Wilson, A. . 2014. Restoring degraded tropical forests for carbon and biodiversity. Environmental Research Letters **9**:114020.

Cahyani, D. R. 2016. Banjir Landa Garut Saat Hutan Jadi Kawasan Perkebunan. https://nasional.tempo.co/read/810228/banjir-landa-garut-saat-hutan-jadi-kawasan-perkebunan#sjvpHJHF16KkSUwy.99. Tempo **6 Oktober 2016**.

CarbonTropic. 2017. Matenggeng Pumped Storage Hydroelectric Plant (MPSHP) Project: A Preliminary Ecological Assessment. February 2017. CarbonTropic, the World Bank and PLN, Jakarta, Indonesia.

Carr-Cornish, S., and L. Romanach. 2014. Differences in Public Perceptions of Geothermal Energy Technology in Australia. Energies **7**:1555.

Center For Conservation and Insect Studies. 2003. Mengais Rejeki Memburu Serangga. Kasus Pemburuan Bangbung di Gunung Salak. Center For Conservation and Insect Studies, Bogor, Indonesia.

Clayton, L., M. Keeling, and E. J. Milner-Gulland. 1997. Bringing home the bacon: a spatial model of wild pig hunting in Sulawesi, Indonesia. Ecological Applications **7**:642-652.

Corlett, R. T. 2007. The impact of hunting on the mammalian fauna of tropical Asian forests. Biotropica **39**:292-303.

de Jesus, A. C. 2005. Social Issues Raised and Measures Adopted in Philippine Geothermal Projects. Proceedings World Geothermal Congress 2005. Antalya, Turkey, 24-29 April 2005.

Directorate of Geothermal. 2016. Peluang Investasi Panas Bumi di Indonesia. Geothermal Investment Opportunities in Indonesia. Directorate General of New, Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources, Jakarta, Indonesia.

Dulhadi. 2012. Zonasi Taman Nasional Gunung Ciremai Kabupaten Kuningan dan Majalengka, Provinsi Jawa Barat. Disusun di Kuningan pada tanggal 23 April 2012. NIP. 19610426 198802 1 001.

ESDM. 2012. Profil Potensi Panas Bumi Indonesia. Direktorat Jenderal Energi Baru, Terbarukan dan Konservasi Energi. Kementerian Energi dan Sumber Daya Mineral, Jakarta, Indonesia.

ESMAP. 2012. Geothermal Handbook: Planning and Financing Power Generation. Technical Report 002/12. Energy Sector Management Assistance Program. The World Bank, Washington, USA.

ESMAP. 2016. Greenhouse gases from geothermal power production. Technical report 009/16. Energy Sector Management Assistance Program. The World Bank, Washington, USA.

FAO. 2009. State of the World's Forests. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fuller, D., J. Miettinen, and E. Meijaard. 2013. Deforestation, degradation and forest regrowth in Indonesia's protected areas from 2000-2010. Indonesian Journal of Conservation **2**:1-13.

Gartland, A. 2017. NGOs urge UNESCO to intervene to save rainforest heritage site. Changing Times **24 March 2017**:https://time2transcend.wordpress.com/2017/2003/2024/ngos-urge-unesco-to-intervene-to-save-sumatras-leuser-ecosystem/.

Gaveau, D. L. A., J. Epting, O. Lyne, M. Linkie, I. Kumara, M. Kanninen, and N. Leader-Williams. 2009. Evaluating whether protected areas reduce tropical deforestation in Sumatra. Journal of Biogeography **36**:2165-2175.

Glick, H. B., C. Bettigole, D. S. Maynard, K. R. Covey, J. R. Smith, and T. W. Crowther. 2016. Spatially-explicit models of global tree density. Scientific Data **3**:160069.

Hanafiah, J. 2017. Aceh governor-elect: 'I myself will cancel' controversial geothermal project in Sumatran rainforest. Mongabay **11 March 2017**:https://news.mongabay.com/2017/2003/aceh-governor-elect-i-myself-will-cancel-controversial-geothermal-project-in-sumatran-rainforest/.

Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science **342**:850-853.

Harris, J. B. C., M. W. Tingley, F. Hua, D. L. Yong, J. M. Adeney, T. M. Lee, W. Marthy, D. M. Prawiradilaga, C. H. Sekercioglu, Suyadi, N. Winarni, and D. S. Wilcove. 2017. Measuring the impact of the pet trade on Indonesian birds. Conservation Biology **31**:394-405.

Hendra. 2015. Bupati Lampung Selatan, Kherlani Ajak Masyarakat Dukung PT. Supreme Energy Rajabasa. Lampung Ekspres **30 December 2015**:http://www.supreme-energy.com/bupati-lampung-selatan-kherlani-ajak-masyarakat-dukung-pt-supreme-energy-rajabasa/.

Henneman, I. 2012. Looking Beyond the Forest: Exploring the Significance of Alignment between Politics and Practices in Landscape Governance - A case study of the corridor in Gunung Halimun Salak National Park in West Java, Indonesia. Wageningen University.

Henry, K. 2015. Geothermal Project in Bedugul Raises Controversy. Energy Manager Today **8 June 2015**:https://www.energymanagertoday.com/geothermal-project-in-bedugul-raises-controversy-0112637/.

IFC. 2007. International Finance Corporation 2007 Environmental, Health and Safety Guidelines for Geothermal Power Generation. Industry Sector-Specific Guidelines. World Bank Group. www.ifc.org/ehsguidelines.

IFC. 2012. Performance Standard 6. Biodiversity Conservation and Sustainable Management of Living Natural Resources. International Finance Corporation (IFC).

Iqbal, D. 2016. Sejangkal Kawasan Untuk Keanekaragaman Hayati di Cagar Alam Darajat. http://www.mongabay.co.id/2016/04/05/sejengkal-kawasan-untuk-keanekaragaman-hayati-di-cagar-alam-darajat/. Mongabay **5 April 2016**.

Jacobson, P. 2017. Greenpeace to take Indonesian forestry ministry to Supreme Court over environmental data. Published 9 March 2017. https://news.mongabay.com/2017/03/greenpeace-to-take-indonesian-forestry-ministry-to-supreme-court-over-environmental-data/

Katzner, T., J. A. Johnson, D. M. Evans, T. W. J. Garner, M. E. Gompper, R. Altwegg, T. A. Branch, I. J. Gordon, and N. Pettorelli. 2013. Challenges and opportunities for animal conservation from renewable energy development. Animal Conservation **16**:367-369.

Kusrini, M. D., M. I. Lubis, and B. Darmawan. 2008. The Tree Frog of Chevron Geothermal Concession, Mount Hakimun-Salak National Park - Indonesia. Technical report. Wildlife Trust – Peka Foundation.

Laurance, W. F., B. M. Croes, L. Tchignoumba, S. A. Lahm, A. Alonso, M. E. Lee, P. Campbell, and C. Ondzeano. 2006. Impacts of roads and hunting on central African rainforest mammals. Conservation Biology **20**:1251-1261.

Lawless, J. V. 1993. Variations in types of geothermal system with geological setting around the Pacific Rim. Page 22 in G. E. Wheller, editor. Islands and basins: correlation and comparison of onshore and offshore geology, SOPAC Miscellaneous Report 159.

Lee, R. J., A. J. Gorog, A. Dwiyahreni, S. Siwu, J. Riley, H. Alexander, G. D. Paoli, and W. Ramono. 2005. Wildlife trade and implications for law enforcement in Indonesia: a case study from North Sulawesi. Biological Conservation **123**:477-488.

Mehring, M., and S. Stoll-Kleemann. 2011. How Effective is the Buffer Zone? Linking Institutional Processes with Satellite Images from a Case Study in the Lore Lindu Forest Biosphere Reserve, Indonesia. Ecology and Society **16**.

Moon, H., and S. J. Zarrouk. 2012. Efficiency of geothermal power plants: A worldwide review. New Zealand Geothermal Workshop 2012 Proceedings.19 - 21 November 2012. Auckland, New Zealand.

Muzakki, K. 2017a. Proyek Panas Bumi Mengkhawatirkan, Kera dan Babi Hutan Turun Gunung Slamet. Tribun News **25 May 2017**:http://www.tribunnews.com/regional/2017/2005/2025/proyek-panas-bumi-mengkhawatirkan-kera-dan-babi-hutan-turun-gunung-slamet.

Muzakki, K. 2017b. PT SAE Bantah akan Babat Habis Hutan Gunung Slamet. Tribun News **2 June 2017**:http://jateng.tribunnews.com/2017/2006/2002/pt-sae-bantah-akan-babat-habis-hutan-gunung-slamet.

Natusch, D. J. D., and J. A. Lyons. 2012. Exploited for pets: the harvest and trade of amphibians and reptiles from Indonesian New Guinea. Biodiversity & Conservation **21**:2899-2911.

Nijman, V. 2005. Decline of the endemic Hose's langur Presbytis hosei in Kayan Mentarang National Park, east Borneo. Oryx **39**:223-226.

Otsamo, A. 2002. Early effects of four fast-growing tree species and their planting density on ground vegetation in Imperata grasslands. New Forests **23**:1-17.

Partnership International. 2013. The Indonesian Geothermal Handbook. Bappenas, Jakarta, Indonesia.

Richter, B. 2015. Continued opposition to Bedugul project in Bali, Indonesia. Think GeoEnergy **14 May 2015**:http://www.thinkgeoenergy.com/continued-opposition-to-bedugul-project-in-bali-indonesia/.

Saifulhak, Y. 2016. Indonesia Offers 19 Geothermal Blocks to Investors in 2016. https://www.indonesia-investments.com/news/todays-headlines/indonesia-offers-19-geothermal-blocks-to-investors-in-2016/item6658. Indonesia-Investments **31 March 2016**.

Saputra, A. 2017. Masyarakat Tolak Rencana Eksplorasi Geotermal Gunung Lawu. Republika **26 February 2017**:http://nasional.republika.co.id/berita/nasional/daerah/17/02/26/olzm91368-masyarakat-tolak-rencana-eksplorasi-geothermal-gunung-lawu.

Satriastanti, F. E. 2016. Indonesian environment ministry shoots down geothermal plan in Mount Leuser National Park. Mongabay **12 September 2016**:https://news.mongabay.com/2016/2009/indonesian-environment-ministry-shoots-down-geothermal-plan-in-mount-leuser-national-park/.

Slamet, U., and D. G. Moelyono. 2000. Maximizing community benefits and minimizing environmental impacts in the Gunung Salak geothermal project, Indonesia. Proceedings World Geothermal Congress 200o. Kyushu - Tohoku, Japan, May 28 - June 10, 2000:689-693.

Slik, J. W. F., S. I. Aiba, F. Q. Brearley, C. H. Cannon, O. Forshed, K. Kitayama, H. Nagamasu, R. Nilus, J. Payne, G. Paoli, A. D. Poulsen, N. Raes, D. Sheil, K. Sidiyasa, E. Suzuki, and J. van Valkenburg. 2010. Environmental correlates of tree biomass, basal area, wood specific gravity and stem density gradients in Borneo's tropical forests. Global Ecology & Biogeography **19**:50-60.

Sugiharta, A. 2016. Buku Informasi Pemanfaatan Jasa Lingkungan Panas Bumi di Hutan Konservasi. Direktorat Pemanfaatan Jasa Lingkungan Hutan Konservasi, Ministry of Environment and Forestry, Bogor, Indonesia.

Tharakan, P. 2015. Summary of Indonesia's Energy Sector Assessment. ADP Papers on Indonesia No. 9. Asian Development Bank, Mandaluyong City, Philippines.

The World Bank. 2015. Program Document on a Proposed Loan in the Amount of US$500 Million to the Republic Of Indonesia for a First Indonesia Sustainable And Inclusive Energy Development Policy Loan. November 3, 2015. Report No. 100617-Id. International Bank For Reconstruction And Development.

UNESCO. 2015. Decisions adopted by the World Heritage Committee at its 39th session (Bonn, 2015).

World Resources Institute. 2016. 6 Graphs Explain the World’s Top 10 Emitters. Available at: http://www.wri.org//blog/2014/11/6-graphs-explain-world%E2%80%99s-top-10-emitters. [Accessed 25 June 2016].

WWF-Indonesia. 2013. Sustainability Guidelines for Geothermal Development. WWF Indonesia, Jakarta, Indonesia.

Yuniarsih, A., D. Marsono, S. Pudyatmoko, and R. Sadono. 2013. Zonasi Taman Nasional Gunung Ciremai Berdasarkan Sensitivitas Kawasan dan Aktivitas Masyarakat (Zonation of Gunung Ciremai National Park Based on Area Sensitivity and Community Activities). Jurnal Penelitian Hutan dan Konservasi Alam **11**:239-259.

Annex 1. Macro-assessment for all geothermal potential point locations in Indonesia

ID	Geothermal Point Name	Resource estimate or Installed (MW)	Forest Use Status (MoEF)	PIAPS (MoEF)	Unesco WH	IBA	KBA	Land Cover (MoEF)	Defor_ history	Overlap cons.	Size cons. area	Adat Land (BRWA)	Indigen. People	Total Risk	Risk Level
NANGGROE ACEH DARUSSALAM															
1	Iboih	25	Protection Forest	0	0	0	0	2	1	0	0	0	0	6	Medium
2	Lhok Pria Laot	50	Protection Forest	2	0	0	0	0	1	0	0	0	0	6	Medium
3	Jaboi	50	Protection Forest	0	0	0	0	2	1	0	0	0	0	6	Medium
4	Ie-Suem Krueng Raya	63	Production Forest	0	0	0	0	0	2	0	0	0	0	4	Medium
5	Seulawah Agam	282	Grand Forest Park	0	0	0	0	2	1	1	2	0	0	10	High
6	Alur Canang	25	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
7	Alue-Long Bangga	100	Protection Forest	0	0	0	0	2	1	0	0	0	0	6	Medium
8	Tangse	25	Non-Forest Use	0	0	0	0	2	1	0	0	0	0	4	Medium
9	Rimba Raya	Na	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
10	G.Geureudong	120	Protection Forest	0	0	0	1	0	0	0	0	0	0	4	Medium
11	Simpang Baik	100	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
12	Sirih Nara	100	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
13	Meranti	25	Production Forest	0	0	0	0	2	0	0	0	0	0	4	Medium
14	Brawang Buaya	25	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
15	Kafi	25	National Park	0	2	1	1	3	0	3	1	0	0	15	High
16	Gunung Kembar	92	National Park	0	2	1	1	3	0	3	1	0	0	15	High
17	Dolok Perkirapan	25	National Park	0	2	1	1	3	1	3	1	0	0	16	High
300	Lokop	45	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
301	Kaloi	15	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
NORTH SUMATRA															
18	Beras Tepu	30	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
19	Lau-Debuk-Sibayak	12	National Park	0	0	0	0	3	0	1	1	0	0	9	High

20	Marike	25	National Park	0	0	0	0	2	0	3	1	0	0	10	High
21	Dolok Marawa	40	Production Forest	2	0	0	0	0	2	0	0	0	0	6	Medium
22	Pusuk Bukit-Danau Toba	Na	Protection Forest	0	0	0	1	0	0	0	0	0	0	4	Medium
23	Simbolon Samosir	150	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
24	Pagaran	Na	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
25	Helatoba	25	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
26	Sipholon Ria-Ria	147	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
27	Sarulla	80	Protection Forest	0	0	0	1	0	1	0	0	0	0	5	Medium
28	Namora Ilangit	210	Protection Forest	0	0	0	1	2	0	0	0	0	0	6	Medium
29	Sibual-buali	558	Production Forest	2	0	0	1	0	1	1	1	0	0	8	High
30	Sibubuhan	100	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
31	Sorik Marapi	420	Protection Forest	0	0	0	0	2	1	0	0	0	0	6	Medium
32	Sampuraga	140	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
33	Roburan	320	Protection Forest	0	0	0	0	2	2	1	0	0	0	8	High
266	Pincurak	50	National Park	0	0	1	1	2	0	3	1	0	0	12	High
WEST SUMATRA															
34	Simisuh	57	Protection Forest	0	0	0	0	0	2	0	0	0	0	5	Medium
35	Cubadak	70	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
36	Talu	Na	Protection Forest	2	0	0	0	0	1	0	0	0	0	6	Medium
37	Panti	150	Nature Reserve	0	0	0	0	2	0	1	2	0	0	9	High
38	Lubuk Sikaping	100	Nature Reserve	0	0	1	1	2	1	1	1	0	0	11	High
39	Situjuh	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
40	Bonjol	200	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
41	Kota Baru-Marapi	50	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
42	Maninjau	25	Non-Forest Use	0	0	0	0	2	0	0	0	0	0	3	Low
43	Sumani	96	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	4	Medium
44	Pariangan	30	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
45	Gunung Talang-Bukit Kili	66	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
47	Gunung Talang-Bukit Kili	66	Non-Forest Use	0	0	0	1	0	0	0	0	0	0	2	Low
46	Surian	75	National Park	0	2	1	1	3	1	1	1	0	0	14	High

48	Muaralabuh	194	Non-Forest Use	0	2	1	1	0	1	0	0	0	0	6	Medium
49	Liki-Pinangawan	412	Non-Forest Use	0	2	1	1	0	2	1	1	0	0	9	High
302	Talagobiru	27	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
RIAU															
326	Sahilan	5	Production Forest	0	0	0	0	2	2	0	0	0	0	6	Medium
325	Kepanasan	10	Conversion Forest	0	0	0	0	0	2	0	0	0	0	4	Medium
50	Pasir Pangarayan	25	Limited Production Forest	0	0	0	0	0	2	0	0	0	0	4	Medium
327	Sungai Pinang	5	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
JAMBI															
51	Gunung Kapur	10	National Park	0	2	1	1	3	1	1	1	0	0	14	High
52	Gunung Kaca	25	National Park	0	2	1	1	3	2	3	1	0	0	17	High
53	Sungai Betung	100	Non-Forest Use	0	2	1	1	0	2	1	3	0	0	11	High
54	Semerup	20	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	4	Medium
55	Lempur	40	Non-Forest Use	0	2	1	1	3	2	1	1	0	0	15	High
56	Air Dikit	225	National Park	0	2	1	1	3	0	3	1	0	0	15	High
57	Graho Nyabu	185	National Park	0	2	1	1	3	2	3	1	0	0	15	High
58	Sungai Tenang	74	Protection Forest	0	2	0	0	3	0	0	0	0	0	10	High
328	Geragai	3	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
BENGKULU															
59	Tambang Sawah	100	National Park	0	2	1	1	0	2	1	1	0	0	12	High
60	Bukit Gedong-Hulu Lais	500	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
61	Lebong Simpang	225	Protection Forest	0	0	0	0	2	2	0	0	0	0	7	High
62	Suban Ayam	60	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
267	Kepahiang/ G. Kaba	180	Nature Recreation Park	0	0	0	0	2	0	1	2	3	0	12	High
BANGKA BELITUNG															
63	Sungai Liat/Pelawan	25	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
64	Pangkal Pinang	25	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
65	Air Tembaga/Terak	25	Non-Forest Use	0	0	0	0	0	2	0	0	0	2	5	Medium
295	Buding	5	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low

296	Nyelanding	5	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
297	Permis	5	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
298	Dendang	10	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
SOUTH SUMATRA															
66	Tanjung Sakti	50	Protection Forest	0	0	0	0	2	1	0	0	0	0	6	Medium
67	Rantau Dedap-Segamit	92	Protection Forest	0	0	0	0	2	2	0	0	0	0	7	High
68	Bukit Lumut Balai	120	Protection Forest	2	0	0	0	2	1	0	0	0	0	8	High
69	Ulu Danau	60	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
70	Marga Bayur	194	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
71	Way Selabung	68	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
LAMPUNG															
72	Wai Umpu	14	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
73	Danau Ranau	210	Protection Forest	2	0	0	0	2	1	0	0	0	0	8	High
74	Purunan	25	National Park	0	2	1	1	0	1	3	0	0	0	12	High
75	Gunung Sekincau	378	National Park	0	2	1	1	2	1	3	1	0	0	15	High
76	Bacingot	225	National Park	0	2	1	1	0	1	3	1	0	0	13	High
77	Suoh Antatai	300	Protection Forest	0	0	0	0	0	0	0	0	0	0	5	Medium
78	Fajar Bulan	100	Non-Forest Use	0	0	1	1	0	0	0	0	0	0	3	Low
79	Natar	14	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
80	Ulu Belu	165	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
81	Lempasing	225	Non-Forest Use	0	0	0	0	0	1	1	1	0	0	4	Medium
82	Way Ratai	194	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
83	Kalianda	182	Protection Forest	2	0	0	0	3	0	0	0	0	0	8	High
84	Pematang Belirang	182	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
BANTEN															
85	Rawa Danau	155	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
86	Gunung Karang	170	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
87	Gunung Pulosari	115	Non-Forest Use	0	0	1	1	0	0	0	0	0	0	3	Low
88	Gunung Endut	80	National Park	0	0	1	1	0	0	1	1	4	0	12	High
89	Pamancalan	48	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low

313	Malinping	13	Protection Forest	0	0	0	0	0	2	0	0	0	0	5	Medium
WEST JAVA															
90	Kawah Ratu (Salak)	72	National Park	0	0	1	1	2	0	3	1	0	0	12	High
91	Kiaraberes (Salak)	225	National Park	0	0	1	1	2	0	3	1	0	0	12	High
92	Awibengkok (Salak)	377	National Park	0	0	1	1	2	0	3	1	0	0	12	High
93	Ciseeng	100	Protection Forest	0	0	0	0	0	2	0	0	0	0	5	Medium
94	Bujal Jasinga	25	Non-forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
95	Cisukarame	83	Non-Forest Use	0	0	0	0	0	0	0	0	0	2	3	Low
96	Selabintana-Gn. Pangrango	85	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
97	Cisolok	50	Non-Forest Use	0	0	0	0	0	0	0	0	0	2	3	Low
98	Gunung Pancar	50	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
99	Jampang	225	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
100	Tanggeur-Cibungur	100	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
101	Saguling	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
102	Cilayu	100	Protection Forest	0	0	0	0	0	0	0	0	0	0	3	Low
103	Kawah Cibuni	140	Protection Forest	0	0	1	1	0	1	0	0	0	0	6	Medium
104	Gunung Patuha	55	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
105	Kawah Ciwedey	140	Nature Reserve	0	0	1	1	2	0	1	1	0	0	10	High
106	Maribaya	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
107	Tangkuban Parahu	90	Non-Forest Use	0	0	0	0	0	0	1	0	0	0	2	Low
108	Sagalaherang	185	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
109	Ciarinem	25	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
110	G.Papandayan	225	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
111	G.Masigit-Guntur	70	Nature Recreation Park	0	0	0	0	0	1	1	2	0	0	8	High
112	Kamojang	200	Nature Reserve	0	0	0	0	2	0	1	2	0	0	9	High
113	Darajat	260	Nature Reserve	0	0	1	1	2	0	1	2	0	0	11	High
114	G. Tampomas	100	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
115	Cipacing	25	Game Reserve	0	0	0	0	2	1	1	2	0	0	10	High
116	Wayang Windu	400	Protection Forest	0	0	0	0	0	1	0	0	0	0	4	Medium

117	G.Talagabodas	80	Production Forest	0	0	0	0	0	0	0	0	0	0	2	Low
118	G.Galunggung	100	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
119	Ciheuras	25	Limited Production Forest	0	0	0	0	2	2	0	0	0	0	4	Medium
120	Cigunung	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
121	Cibalong	25	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
122	Gunung Karaha	30	Protection Forest	0	0	0	0	0	0	0	0	0	0	3	Low
123	Gunung Sawal	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
124	Cipanas-Ciawi	50	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
125	Gunung Cakrabuana	25	Protection Forest	0	0	0	0	3	0	0	0	0	0	6	Medium
126	Gunung Kromong	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
127	Sangkanhurip/G.Ciremai	150	National Park	0	0	1	1	2	0	3	2	0	0	13	High
128	Subang	50	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
129	Cibingbin	25	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
CENTRAL JAVA															
130	Banyugaram	100	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
131	Bumiayu	25	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
132	Baturedan	185	Protection Forest	0	0	1	1	0	0	0	0	0	0	5	Medium
133	Guci	100	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
134	Magunan-Wanayasa	92	Non-Forest Use	0	0	1	1	0	0	0	0	0	0	3	Low
135	Chandradimuka	25	Production Forest	0	0	1	1	0	0	0	0	0	0	4	Medium
136	Dieng	60	Protection Forest	0	0	0	0	0	0	0	0	0	0	3	Low
137	Krakal-Wadas Lintang	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
138	Panulisan	25	Production Forest	0	0	0	0	0	1	0	0	0	0	3	Low
139	Gunung Ungaran	100	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
140	Candi Umbul-Telomoyo	92	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
141	Kuwuk	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
142	Gunung Lawu	195	Non-Forest Use	0	0	1	1	0	1	0	0	0	0	4	Medium
143	Klepu	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
YOGYAKARTA															

144	Pangritis	10	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
EAST JAVA															
145	Melati	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
146	Rejosari	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
147	Telaga Ngebel	120	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
148	Gunung Pandan	80	Production Forest	0	0	0	0	0	0	0	0	0	0	2	Low
149	G. Arjuno Welirang	185	Grand Forest Park	0	0	1	1	2	1	3	2	0	0	14	High
150	Cangar	100	Grand Forest Park	0	0	0	0	2	1	1	1	0	0	9	High
151	Songgoriti	35	Non-Forest Use	0	0	1	1	0	0	0	0	0	0	3	Low
152	Tirtosari	10	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
153	Iyang Argopuro	Na	Protection Forest	0	0	1	1	2	0	0	0	0	0	8	High
154	Tiris	92	Protection Forest	0	0	0	0	0	0	0	0	0	0	3	Low
155	Blawan-Ijen	Na	Non-Forest Use	0	0	1	1	0	2	0	1	0	0	6	Medium
155	Gunung Wilis	Na	Protection Forest	0	0	1	1	2	1	0	0	0	0	8	High
BALI															
156	Banyuwedang	10	National Park	0	0	0	0	0	0	1	1	0	0	6	Medium
157	Seririt	10	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
158	Batukao	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
159	Penebal	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
160	Buyan-Bratan	226	National Park	0	2	1	1	3	0	3	2	0	0	16	High
299	Kintamani-Batur	36	Recreation Park	0	0	0	0	0	0	1	2	0	0	7	High
WEST NUSA TENGGARA															
161	Sembalun	100	National Park	2	0	1	1	0	0	1	1	2	0	12	High
162	Marongge	6	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
163	Huu-Daha	69	Protection Forest	0	0	0	0	3	0	0	0	0	0	6	Medium
EAST NUSA TENGGARA															
164	Wai Sano	33	Non-Forest Use	2	0	1	1	2	0	0	0	0	0	7	High
165	Ulumbu	188	Non-Forest Use	0	0	1	1	3	1	0	0	0	0	7	High
166	Wai Pesi	54	Non-Forest Use	0	0	0	0	2	2	0	0	0	0	5	Medium
167	Gou-Inelika	28	Protection Forest	2	0	0	0	2	0	0	0	0	0	7	High

168	Mengeruda	5	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
169	Mataloko	3	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
170	Komandaru	11	Non-Forest Use	0	0	0	0	2	0	0	0	0	0	3	Low
171	Ndetusoko	10	Protection Forest	0	0	0	0	2	1	0	0	0	0	6	Medium
172	Sokoria	25	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
173	Jopu	5	National Park	0	0	0	1	2	0	1	2	0	0	10	High
174	Lesugolo	45	Non-Forest Use	0	0	0	0	2	1	0	0	0	0	4	Medium
175	Oka-Ilie Ange	50	Protection Forest	0	0	0	0	2	0	0	0	0	2	7	High
176	Atadei	40	Non-Forest Use	2	0	0	0	0	1	0	0	0	0	4	Medium
177	Bukapiting	27	Non-Forest Use	0	0	0	0	2	1	0	0	0	0	4	Medium
178	Roma-Ujelewung	6	Protection Forest	0	0	0	0	0	0	0	0	0	0	3	Low
179	Oyang Barang	37	Non-Forest Use	0	0	0	0	2	1	0	0	0	0	4	Medium
180	Sirung	100	Non-Forest Use	0	0	0	1	2	0	0	0	0	0	4	Medium
181	Adum	36	Non-forest Use	0	0	0	1	2	1	0	0	0	0	5	Medium
182	Alor Timur	150	Protection Forest	2	0	0	0	2	0	0	0	0	0	7	High
303	Mapos	50	Non-Forest Use	0	0	1	1	2	1	1	1	0	0	8	High
304	Rana Masak	20	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
305	Rana Kulan	8	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
306	Ulugalung	5	Protection Forest	2	0	0	0	2	1	0	0	0	0	8	High
307	Amfoang	20	Non-Forest Use	0	0	0	0	3	1	0	0	0	2	7	High
NORTH SULAWESI															
186	Air Madidi	25	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
187	Lahendong	80	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
188	Tompaso	130	Protection Forest	0	0	0	1	2	0	0	0	0	0	6	Medium
189	Gunung Ambang	Na	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
190	Kotamobagu	185	Non-Forest Use	0	0	0	0	0	2	0	0	2	0	5	Medium
308	Kale Osan	51	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
309	Tanggari	10	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
310	Winero	20	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
311	Duasaudara	22	Nature Reserve	0	0	1	1	2	0	3	2	0	0	13	High

GORONTALO															
191	Petandio	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
192	Suwawa	110	National Park	0	0	1	1	3	2	1	1	0	2	15	High
286	Diloniyohu	15	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
287	Dulangeya	10	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
288	Pohuwato	40	Nature Reserve	0	0	0	1	2	0	3	1	0	0	11	High
CENTRAL SULAWESI															
193	Maranda	50	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
194	Kadidia/Sopu	60	Non-Forest Use	0	0	0	0	0	2	1	1	3	0	8	High
195	Langkapa	25	Limited Production Forest	2	0	0	0	0	2	0	0	0	0	6	Medium
331	Toro	8	Non-Forest Use	0	0	1	1	0	2	1	1	0	0	7	High
196	Wanga-Kalemago	60	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
197	Torire-Katu	80	Non-Forest Use	0	0	1	1	0	2	1	1	0	0	7	High
198	Toare	50	Non-Forest Use	0	0	1	1	0	2	1	1	2	0	9	High
199	Pantalongemba	25	Production Forest	0	0	0	0	3	2	0	0	0	0	7	High
200	Marana	70	Non-Forest Use	0	0	0	0	2	2	0	0	2	2	9	High
201	Bora	93	Non-forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
202	Pulu	30	Non-Forest Use	0	0	0	0	0	2	0	0	3	0	6	Medium
330	Parigi-Balesu	10	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
203	Sedoa	15	National Park	0	0	1	1	3	2	1	1	2	0	15	High
204	Lompio	30	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
205	Wuasa	25	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
206	Watuneso	25	Protection Forest	0	0	0	0	2	0	0	0	2	0	7	High
207	Papanpulu	25	Protection Forest	0	0	0	0	3	0	0	0	2	0	8	High
257	Tambu	15	Non-Forest Use	0	0	0	0	0	2	0	0	0	2	5	Medium
281	Ranang-Kasimbar	10	Non-Forest Use	0	0	0	0	0	2	0	0	0	2	5	Medium
314	Kuala Rawa	41	National Park	0	0	1	1	3	0	3	1	3	0	16	High
315	Uedeka	5	Production Forest	0	0	0	0	3	1	0	0	0	0	6	Medium
316	Pulodalagan	5	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low

317	Tatakalai	10	Protection Forest	0	0	0	1	0	2	0	0	0	0	6	Medium
WEST SULAWESI															
208	Mambosa	25	Limited Production Forest	0	0	0	0	2	2	0	0	0	0	6	Medium
209	Somba	25	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
210	Mamasa	2	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
258	Lili-Sepporaki	160	Production Forest	0	0	0	0	0	2	0	0	0	0	4	Medium
259	Riso-Kalimbua	41	Non-Forest Use	0	0	0	0	0	2	0	0	0	2	5	Medium
260	Alu	25	Protection Forest	0	0	0	0	0	2	0	0	0	0	5	Medium
289	Tapalang	30	Protection Forest	0	0	0	0	0	1	0	0	0	0	4	Medium
290	Karema	10	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
291	Ampalas	12	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
292	Kona-Kaiyangan	10	Production Forest	0	0	0	0	0	2	0	0	0	0	4	Medium
293	Panusuan	5	National Park	0	0	0	0	3	0	1	1	0	0	9	High
294	Doda	5	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
SOUTH SULAWESI															
211	Limbong	13	Protection Forest	0	0	0	0	2	2	0	0	2	0	9	High
212	Parara	30	Non-Forest Use	0	0	0	0	2	1	0	0	2	0	6	Medium
213	Pincara	12	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
214	Bituang	28	Non-Forest Use	2	0	0	0	0	1	0	0	0	0	4	Medium
215	Sangalla	12	Non-Forest Use	0	0	0	0	0	1	0	0	4	0	6	Medium
216	Watansoppeng	7	Nature Recreation Park	0	0	0	0	0	0	1	2	1	0	8	High
217	Sulili	25	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
218	Malawa	25	National Park	0	0	0	1	0	1	1	1	0	0	8	High
219	Baru	25	Protection Forest	2	0	0	0	2	1	0	0	0	2	10	High
220	Watampone	25	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
221	Todong	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
222	Kampala/Sinjal	20	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
223	Massepe	Na	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
224	Sengkang/Danau Tempe	25	Non-Forest Use	0	0	1	1	0	2	0	0	0	0	5	Medium

312	Lemosusu	12	Non-Forest Use	2	0	0	0	0	2	0	0	0	2	7	Medium
318	Sewang	80	Protection Forest	0	0	0	1	0	2	0	0	0	0	6	Medium
SOUTHEAST SULAWESI															
225	Mangolo	14	Production Forest	2	0	0	0	2	2	0	0	0	0	8	High
226	Parora	25	Protection Forest	0	0	0	0	0	2	0	0	0	2	7	High
227	Puriala	25	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
228	Amohola	18	Non-Forest Use	2	0	0	0	0	2	0	0	0	0	5	Medium
229	Loanti	25	Wildlife Reserve	0	0	0	1	3	0	1	1	0	0	10	High
230	Laenia	71	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
231/2	Kalende/Torah	25	Production Forest	2	0	0	0	2	0	0	0	0	0	6	Medium
233	Kanale	25	Production Forest	2	0	0	0	2	2	0	0	0	0	8	High
234	Wonco	25	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
235	Gondang Baru	1	Non-Forest Use	0	0	1	1	2	2	0	0	0	0	7	High
236	Kabungka-Wening	25	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
319	Sumber Sari	12	Wildlife Reserve	0	0	0	1	2	2	1	1	0	0	11	High
NORTH MALUKU															
237	Mamuya	7	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
238	Ibu	25	Non-Forest Use	0	0	0	0	2	1	0	0	0	0	4	Medium
239	Akelamo	25	Conversion Forest	0	0	0	0	0	2	0	0	2	0	6	Medium
240	Jailolo	42	Production Forest	2	0	0	0	2	1	0	0	0	0	7	High
241	Kie Besi	25	Protection Forest	0	0	0	0	0	1	0	0	0	0	4	Medium
242	Akesahu	15	Conversion Forest	0	0	0	0	0	1	0	0	0	0	3	Low
243	Indari	25	Conversion Forest	0	0	0	0	2	2	0	0	0	0	6	Medium
244	Labuha	25	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
245	Songa-Wayaua	140	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
273	Kramat	10	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
274	Losseng	30	Production Forest	0	0	0	0	2	0	0	0	0	0	4	Medium
275	Auponia	20	Conversion Forest	0	0	0	0	2	2	0	0	0	0	6	Medium
276	Bruokol	Na	Non-forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
323	G. Hamidang	265	Protection Forest	0	0	0	1	2	0	0	0	0	2	8	High

324	Telaga Ranu	Na	Conversion Forest	0	0	1	1	2	0	0	0	0	0	6	Medium
MALUKU															
246	Waisekat	14	Limited Production Forest	2	0	1	1	0	2	0	0	0	0	8	High
247	Wapsalit-Waepo	45	Conversion Forest	0	0	0	0	0	1	0	0	0	2	5	Medium
248	Batabual	25	Production Forest	0	0	0	0	2	2	0	0	0	0	6	Medium
249	Larike	25	Non-Forest Use	0	0	0	0	2	0	0	0	0	0	3	Low
250	Taweri	25	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
251	Tolehu	100	Protection Forest	0	0	1	1	2	1	0	0	0	0	8	High
252	Oma Haruku	30	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
253	Saparua	25	Non-Forest Use	0	0	0	0	2	2	0	0	0	0	5	Medium
254	Nusa Laut	25	Protection Forest	0	0	0	0	0	1	0	0	0	0	4	Medium
261	Tehoru	35	Conversion Forest	0	0	0	0	2	1	0	0	0	0	5	Medium
262	Banda Baru	21	Non-Forest Use	0	0	0	0	0	2	0	0	0	2	5	Medium
262	Pohon Batu	13	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
264	Kelapa Dua	25	Non-Forest Use	0	0	0	0	0	1	0	0	0	0	2	Low
329	Banda Neira	30	Nature Reserve	0	0	0	1	0	0	3	2	0	0	10	High
282	Warmong	30	Conversion Forest	0	0	0	0	0	0	0	0	0	2	4	Medium
283	Esulit	25	Conversion Forest	0	0	1	1	3	1	0	0	0	2	10	High
284	Iurang	20	Production Forest	0	0	0	1	2	1	0	0	0	2	8	High
285	Karbubu	10	Non-Forest Use	0	0	0	0	0	0	0	0	0	2	3	Low
PAPUA															
255	Makbau	25	Production Forest	0	0	0	0	0	1	0	0	2	2	7	High
256	Wominmarin	25	Nature Reserve	0	0	0	0	3	1	1	1	0	2	12	High
265	Kebar	Na	Non-Forest Use	0	0	0	0	2	1	0	0	0	0	4	Medium
NORTH KALIMANTAN															
277	Sebakis	5	Production Forest	0	0	0	0	0	2	0	0	0	0	4	Medium
279	Semolon	10	Protection Forest	2	0	0	0	2	1	0	0	2	0	10	High
280	Mengkauser	5	Production Forest	0	0	0	0	2	1	0	0	0	0	5	Medium
278	Sajau	13	Non-Forest Use	0	0	0	0	2	1	0	0	0	2	6	Medium

EAST KALIMANTAN															
320	Sungai Batuq	7	Production Forest	0	0	0	0	2	0	0	0	0	0	4	Medium
321	Dodang	10	Non-Forest Use	0	0	1	1	2	1	0	0	0	0	6	Medium
SOUTH KALIMANTAN															
270	Batubini	20	Non-Forest Use	0	0	0	0	0	2	0	0	2	0	5	Medium
271	Tanuhi	10	Production Forest	2	0	0	0	0	2	0	0	2	0	8	High
272	Hantakan	20	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
WEST KALIMANTAN															
183	Sibetuk	25	Non-Forest Use	0	0	0	0	0	0	0	0	0	0	1	Low
268	Sape	15	Production Forest	0	0	0	0	0	2	0	0	0	0	4	Medium
184	Jagoi Babang	10	Non-Forest Use	0	0	0	0	0	2	0	0	0	0	3	Low
185	Meromoh	10	Limited Production Forest	0	0	0	0	0	2	0	0	0	0	4	Medium
269	Nanga Dua	5	Production Forest	2	0	0	0	2	2	0	0	0	2	10	High

Geothermal resources are one of Indonesia's largest potential sources of renewable energy with an estimated potential of 29 GW. The development of the geothermal power sector provides a significant opportunity to address Indonesia's power shortages and increase its electrification ratio, especially in remote parts of the country, whilst meeting international commitments towards reducing GHG emissions.

Unlocking Indonesia's geothermal power potential, however, has been hampered by a lack of capital investment in exploration and project development as well as by policy restrictions. To stimulate the industry, a major revision of the law in 2014 (Geothermal Law No. 21) allowed the development of geothermal in forest conservation areas. The fact that most geothermal potential in Indonesia is in or close to forest areas has raised societal concerns about environmental and social impacts, especially in forests that play an important role in supplying fresh water, harbor endangered wildlife, or have high cultural or religious values. The degree to which these social and environmental risks and impacts vary between geothermal power projects is not well understood, and thus a key focus of this study.

This report presents the results of a rapid environmental and social assessment of geothermal development in conservation and forest areas. The report, through a micro-level assessment, reviewed 15 existing Indonesian geothermal energy projects to develop improved insight into the key risks and impacts typically associated with geothermal power development in forest areas. Based on the risks and impacts identified during this study, this report makes recommendations on risk avoidance and mitigation. Through a macro-level assessment of the officially published 330 geothermal resource potential points for Indonesia, the report determined the environmental and social risk rankings for every individual point. The ultimate objective is to further stimulate the development of a clean energy source in Indonesia by de-risking it through up-front avoidance of high-risk areas and effectively mitigating social and environmental impacts through good operational management.

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