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Scaling-Up Renewable Geothermal Energy in Indonesia

An Integrated Approach to Evaluating a Green Finance Investment





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KEY MESSAGES

Indonesia is rapidly increasing its power generation capacity to meet the needs of its growing economy. This has included a significant expansion of coal-based power—a cheap option with significant environmental costs. To meet its increasing energy demand in an environmentally responsible way, the government has embarked on an ambitious plan to expand its geothermal resource, which is the largest worldwide. Geothermal is a reliable and non-intermittent power source and the only renewable energy that can effectively substitute baseload generation. Electricity from geothermal plants would displace coal-based power in Indonesia.

Pertamina Geothermal Energy (PGE) is leading Indonesia's effort to scale-up geothermal, attempting a globally unprecedented expansion of over 1,000 MW of capacity. The World Bank is helping kick-start PGE's investment program through the development of the Ulubelu (Units 3 & 4) and Lahendong (Tompasso) (Units 5 & 6) geothermal fields. Loans totaling US\$ 300 million are being extended from the World Bank's facility for lending to middle-income countries through International Bank for Reconstruction and Development (IBRD) loans and from the global Clean Technology Fund (CTF) established to promote climate-friendly investments. To justify public support and evaluate the viability of this "green finance" investment, an integrated approach to decision making was utilized based on the combined assessments of financial-economic-stakeholder-risk impacts. Key conclusions resulting from the integrated project evaluation for this project are:

- There are financial and economic additional (incremental) costs associated with geothermal development when compared with a baseload power generation alternative, such as coal-based power.
- Even when accounting for the value of local externalities, the geothermal project is not economically justified unless other benefits, such as energy security and diversification, are considered.
- Once the global environmental externalities of geothermal are accounted for, the project is then "globally" justified, making a strong case for international support to the project.
- The project also is not financially viable unless it receives a price from the off-taker for the electricity that is commensurate with the cost and risks of developing geothermal resources. Since a pricing policy to make geothermal power investments financially attractive is still under development in Indonesia, immediate scale-up of geothermal investments require an "engineered" solution to buy-down the cost and bridge the financial viability gap.
- The concessional financing package, which included a CTF loan, was necessary to bridge the financial viability gap, along with government intervention to cover some of the additional (incremental) costs.
- The stakeholder/distributional analysis confirms that global compensation (i.e., CTF funds) are justified since the environmental benefits of reducing greenhouse gas emissions are global, extending beyond Indonesia. Indonesian energy consumers will also receive substantial benefits from the project.
- Given the resource and other inherent risks associated with geothermal development, it is important that the project's design is sufficiently robust to withstand the impact of such uncertainties.

GEOTHERMAL ENERGY IN INDONESIA

Indonesia is often referred to as the world's largest archipelago, comprising some 17,000 to 18,000 islands. It is located in Southeast Asia and has a population of over 220 million people, with much of the population concentrated on the islands of Java and Sumatra. The country's gross domestic product, estimated around US\$ 800 billion in 2010, has seen robust and steady growth over the past decade, generally between 5 to 6 percent per year.

The sustained economic growth has also led to increasing demand for electricity that has averaged around 8 percent per year. As a result, a capacity surplus that existed about a decade ago, following the Asian Financial Crisis, has progressively given way to a shortfall in generation characterized by power shortages. Perusahaan Listrik Negara (PLN), the national power company, has struggled to mobilize investments, and has also required growing government subsidies to keep operating a system that is highly dependent on petroleum products, which has driven up its cost of supply. Private investments that came to a halt due to several major factors¹ have rebounded somewhat in recent years, but remain far short of the country's needs. Supply is barely able to keep up with increasing demand. Brownouts and load shedding are commonplace, impacting economic growth, and affecting even ordinary consumers.

In 2006, the Government of Indonesia (Gol) responded to what, at the time, was a pending crisis by implementing a *Fast-Track Program* designed to rapidly develop 10,000 MW of generation capacity equivalent to about one third of PLN's then total existing system capacity. Newly constructed power plants, located throughout the country, would utilize Indonesia's abundant, readily available, and relatively inexpensive coal resources. They would displace high cost oil-fired generation units, increase supply at an affordable price to the economy and households, and reduce the impact of PLN's Public Service Obligation (PSO subsidy)² on the state budget. This first *Fast-Track Program* is well under implementation.

The 10,000 MW coal-based *Fast-Track Program* also poses significant challenges. It will exacerbate local and global environmental impacts and increase Indonesia's dependence on fossil fuels for power generation. Over 80 percent of the current electricity generation in Indonesia is based on fossil fuels, and environmental conditions will further deteriorate when the additional 10,000 MW of coal-based capacity is fully commissioned. To ensure a more environmentally sustainable development of the sector, the Gol launched a second 10,000 MW *Fast-Track Program* in late 2008 that is predominantly made up of renewable energy, with geothermal power making up 40 percent of the target. The expected outcome is a substantial increase in renewable energy displacing alternate investments in coal-based power production. This investment in renewable energy will reduce the carbon footprint of the power sector and substantially lower local environmental impacts. However, these benefits would come at sizable additional (incremental) costs that could undermine the affordability objective, as well as add to the already high PSO subsidy.

Indonesia has the largest estimated geothermal reserves in the world, and geothermal is an ideal option to diversify the country's power generation mix (Figure 1). It is a baseload generation technology not subject to the intermittency and variability challenges associated with most renewable electricity sources. As an indigenous and non-tradable energy source, it will also enhance the country's energy security and serve as a natural hedge against the volatility of fossil-fuel prices. Despite having an estimated 27,000 MW of geothermal power potential (the rough equivalent of the

Figure 1 | Indonesia's Geothermal Prospects



Source | Authors based on information from Ministry of Energy and Mineral Resources, Indonesia.

current PLN system capacity), less than 4 percent of Indonesia's geothermal resources have been developed to generate electricity.³ The second *Fast-Track Program* is expected to change that, with Indonesia poised to become the world leader in geothermal power generation capacity when the program is successfully implemented.

PGE is a leading geothermal developer and a fully owned subsidiary of the state-owned oil and gas company, Pertamina. PGE has been mandated by the government to undertake a globally unprecedented scale-up of over 1,000 MW of geothermal capacity, which would make it a global leader in geothermal development. The World Bank is working with PGE to help kick-start this ambitious program by immediately developing the fields where preparation is advanced and to strengthen the company's capacity to successfully implement its investments.

THE PROJECT

The project financed by the World Bank includes the development of two geothermal fields: Ulubelu, which is located in the Lampung district in the southern part of the island of Sumatra, and Lahendong (Tompaso), located in the northern part of the island of Sulawesi. PGE plans expansions of approximately 110 MW in Ulubelu (Units 3 & 4)⁴ and 40 MW in Lahendong (Tompaso) (Units 5 & 6).⁵ The 150 MW of total power generation capacity to be developed through the project is expected to displace an equivalent amount of coal-based capacity. As a result, the investment will reduce local pollution, such as sulfur dioxide (SO₂), nitrogen oxide (NO_x), and total suspended particulates (TSP); as well as curtail global greenhouse gas impacts by reducing the emission of carbon dioxide (CO₂).

The project is budgeted at a total cost of US\$ 574.7 million, including contingencies.⁶ Approximately half of the costs associated with the development of the upstream steam

field will be funded by PGE's own resources (equity) through the support of its parent company, Pertamina. The World Bank is providing loans totaling US\$ 300 million.⁷ The financing package includes a US\$ 175 million loan from the IBRD with a variable spread loan (LIBOR + variable spread), maturity of 24.5 years, and a grace period of 9 years. The CTF, which is a part of the global Clean Investment Funds, a group of funds established by the international community to promote climate-friendly and transformational investments, is providing a US\$ 125 million loan at concessional terms, through the World Bank. The terms of the CTF loan are: 0.25 percent service charge (interest), total maturity of 40 years, and a grace period of 10 years.



ECONOMIC JUSTIFICATION FOR THE PROJECT

Is this project economically justified? This is a particularly important question since the second *Fast-Track Program* is being promoted on behalf of Indonesia by its government while also taking steps to facilitate financing, including the World Bank loans. Therefore, an analysis was carried out from the viewpoint of the entire Indonesian economy, to confirm the GoI's rationale for promoting the project. Indonesia is predominantly expanding coal-based capacity to meet its baseload power needs and the development of geothermal power would displace coal-based generation. The relevant question was not whether the generation of electricity was justified but rather which alternative technology would be best to produce it. Therefore, the appropriate methodology compared geothermal power generation costs with the avoided costs of coal-based power generation (Table 1).

The analysis first compared the investment and operational costs of coal with that of the combined 150 MW geothermal operations at Ulubelu and Lahendong (Tompaso). Economic or "shadow prices" were estimated to reflect the true economic resource costs of the investment and operation of the project, including the impact of a foreign exchange premium of 10.8 percent for tradable content in goods. All economic resource flows were discounted by the economic opportunity cost of capital (EOCK, or the social discount rate) estimated to be 10 percent for Indonesia. Several technical parameters specific to geothermal and coal were also applied in order to evaluate the investments. The capital cost of a medium-size coal plant was estimated at US\$ 1,400 per kW, with a plant operating capacity factor of 75 percent.⁸ In contrast,

Table 1 | Project Financing by Component and Source of Funding

Project Component	Total	PGE Internal Sources	World Bank Financing	
			IBRD	CTF
(US\$ million)				
Investments in Geothermal Field Development and Power Generation				
a. Ulubelu	326.2	140.2	108.5	77.5
b. Lahendong (Tompasso)	191.8	105.8	50.2	35.8
Total Baseline Costs	518.0	246.0	158.7	113.3
Physical & Price Contingencies (10%)	51.8	23.8	16.3	11.7
Total Project Cost	569.8	269.8	175.0	125.0
Interest During Construction	4.1	4.1		
Front End/MDB Fee (0.25%)	0.8	0.8		
Total Cost and Financing Required	574.7	274.7	175.0	125.0

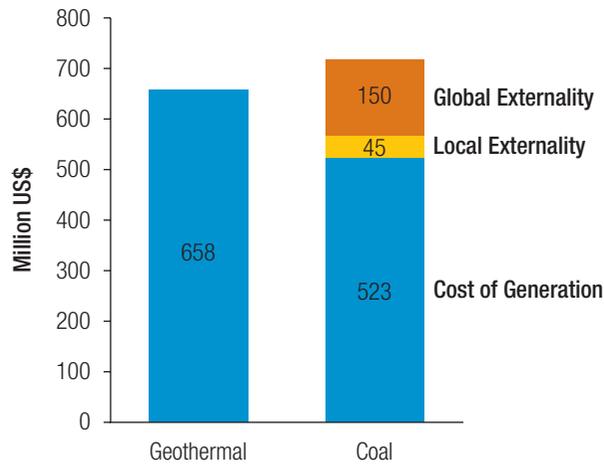
Source | Authors.

based on experience in Indonesia,⁹ geothermal plant operating capacity factors are estimated at 92 percent. Investment costs for Indonesia's geothermal plants are based on feasibility studies carried out by PGE with the assistance of international consultants.¹⁰ The cost of fuel is a key operational factor, especially in the case of coal-fired power plants. In Indonesia, PLN mostly utilizes a medium-grade coal, with an average heat content of 4,200 kcal/kg, which is predominantly used for domestic purposes. The cost of this coal is estimated at US\$ 40 per ton in Sumatra—including a relatively low US\$ 5 per ton transportation cost—since it is available locally on the island, and assumed to be US\$ 50 per ton in North Sulawesi and elsewhere factoring in the additional cost of transportation. The operational costs for geothermal plants are less significant since the fuel source—the geothermal steam field—is developed at the investment stage. Therefore, the operational costs for the Ulubelu and Lahendong (Tompasso) geothermal fields are largely comprised of the drilling of make-up and reinjection wells and routine operational and maintenance expenditures.

The results of the economic analysis of the investment and operational costs, as indicated in Figure 2, suggest that the geothermal project is not competitive with an equivalent scale coal-based project when comparing the present values of the economic resource costs for investment and operations only. Based on the analysis, the present value of the investment and operational costs for geothermal is US\$ 658 million, a full US\$ 135 million more than the comparable coal-based option. However, these initial results do not take into consideration the environmental costs associated with utilizing coal or, conversely, the benefits of geothermal. Therefore, a complete economic analysis requires the inclusion of all externalities.

Local pollution arises from emissions that result from burning coal that are released into the atmosphere unabated. Emissions commonly associated with coal include SO₂, NO_x, and TSP. These emissions can adversely impact the health of people residing in

Figure 2 | Results of the Economic Analysis Comparing Geothermal to Coal (Present Value of Costs)



Source | Authors.

the vicinity of the power plants. A health impact estimate undertaken for the Suralaya coal-fired power plant in Indonesia was updated to extrapolate the local health impacts from coal-based power.¹¹ These negative local environmental externalities were estimated to be US\$ 0.00546/kWh of electricity produced from coal. As a result, the present value costs for the equivalent coal-based power plant increased by US\$ 45 million.¹² In contrast, geothermal power generation does not emit SO₂, NO_x, or TSP.

The development of geothermal energy also has global benefits, since it substantially reduces the emission of CO₂ when compared with a coal-fired power plant. The reduction in greenhouse gases, such as CO₂, will positively impact global climate change. It is important to note that this is a benefit that extends beyond the economy of Indonesia since the entire global community stands to benefit. The prices in the carbon markets at the time of the study were considered a proxy for the value placed by the global community on the reduction in CO₂ from the earth's atmosphere. Historical settlement prices in the European Carbon Exchange fluctuated between €12 and €34 per ton of CO₂ from 2005 to 2010, roughly the same time frame in which the project was being prepared, and some studies have estimated prices in excess of US\$ 100 per ton of avoided CO₂. For the purposes of this analysis, a conservative estimate of US\$ 20 per ton was utilized as a proxy valuation for the global benefits of reducing CO₂ emissions. The result is a global economic externality resulting from the project that is at least US\$ 150 million in present value terms.¹³

The present value of the economic costs of the prospective coal-based operation is, therefore, US\$ 718 million when its local and global environmental costs are considered. This exceeds the present value of the cost of developing the geothermal sites at Ulubelu and Lahendong (Tompaso), which amounts to US\$ 658 million. Even if the geothermal investment cost were 10 percent higher, the present value of a geothermal project cost at US\$ 707 would be less than a coal-based project; while the valuation of the global externality remains conservative. As such, it can be concluded that the geothermal project is economically justified when its local and global environmental impacts are considered. These externalities would be substantially internalized if Indonesia were able to access carbon revenues for the emissions reductions (ERs) that result from the geothermal project, making the economic justification more

explicit. However, given the considerable uncertainty surrounding the global carbon markets and its future structure,¹⁴ such prospects are unlikely to catalyze decisions by developers to proceed with investments in geothermal. It is nevertheless appropriate to consider the global externalities in this particular case since Indonesia has voluntarily pledged to reduce its carbon footprint in the future (including through changes in the energy sector) and that CTF funds serve as compensation from the global community for undertaking climate-friendly investments. It should be noted that the government maybe considering other strategic benefits to geothermal development, such as energy security, hedging against the volatility of fossil fuels, and technological interests. These benefits are difficult to quantify, yet may factor into Indonesia's ultimate motivation in pursuing its ambitious scale-up of geothermal resources.

ENGINEERING A SOLUTION TO BRIDGE THE FINANCIAL VIABILITY GAP

Although the geothermal project is economically justified, PLN's estimated (avoided) cost of coal-based electricity of US\$ 6.4 cents/kWh does not reflect a potential tariff that is adequate to cover the financial cost of the geothermal project and provide private developers, or even PGE, with a return commensurate with the risks they face with the undertaking. The project's environmental benefits do not help in this case as they do not necessarily translate into financial revenues as previously noted. Raising financing for geothermal investments can be challenging in itself due to the high upfront capital expenditure required. In the Ulubelu and Lahendong (Tompaso) projects, the initial capital costs account for 75 percent of the total project costs in present value terms, while the investment costs for a comparable coal-based plant make up only about 45 percent of the total costs. In absolute terms, the capital investment cost per MW of capacity is significantly higher for Ulubelu (US\$ 3.3 million) and Lahendong (Tompaso; US\$ 4.6 million) compared to a medium-sized coal-fired power plant (US\$ 1.4 million). On the other hand, PLN—already running losses before it is compensated through the PSO subsidy—is under pressure to reduce its cost of supply. Therefore, it seems that the most financially attractive option for the power company to fulfill its baseload power needs is to rely on coal rather than geothermal.

It is not uncommon for renewable energy technologies to cost more than fossil-based alternatives on a purely financial basis when externalities are not considered. Since this represents a market failure, it is also common practice for governments to intervene through pricing and other policies designed to help scale-up the development of renewable energy. Comprehensive renewable energy pricing policies generally include a mandate to electricity utilities to off-take power at a higher (premium) price while it is compensated for any associated additional (incremental) financial costs. The Gol has been attempting to implement such a policy for scaling up geothermal, but this has been done through a piecemeal approach that has not been successful thus far. The Gol continues to pursue the implementation of a comprehensive pricing and compensation policy,¹⁵ but it is understood that such reforms may take more time. In the absence of such a policy, developers must resort to long, drawn out negotiations with PLN, which is hardly conducive to a time sensitive scale-up of the proposed magnitude. Moreover, delays in implementing the geothermal program would result in the construction of more coal-fired power plants to meet Indonesia's baseload power demand. This would lock the country into an environmentally detrimental path since a coal-fired power plant, once constructed, will operate for the duration of its commissioned period, which typically ranges from 20 to 25 years. Therefore, there is an urgent need to begin investments in geothermal immediately while longer

term improvements to the regulatory framework are developed. Consequently, the developments at Ulubelu and Lahendong (Tompaso) required an engineered solution to bridge the financial viability gap confronting the project.

To address the financial viability gap, the Gol took steps to facilitate the buy-down of project costs. In its absence, under a business-as-usual scenario, PLN was likely to offer a geothermal electricity purchase tariff of around US\$ 6.4 cents/kWh, which, as mentioned earlier, is not sufficient to cover geothermal costs, including adequate return on equity that, in the case of private developers, may be in excess of 20 percent. It is also not uncommon for large geothermal development companies to use equity to finance a majority of the investment based on the strength of their balance sheets.¹⁶ Under a full equity financing scenario, the projected losses for the project in net present value (NPV) terms are –US\$ 269 million. The project was far from being financially attractive to developers.

The Gol took a number of actions to bridge the financial viability gap of this project. First, the government convinced PGE to accept a lower rate of return on its equity of 14 percent. PGE agreed given the public-good imperatives of the project even though investments by its parent company, Pertamina, typically generate substantially higher returns. Second, the government agreed to facilitate tariff/power purchase agreement (PPA)¹⁷ negotiations between PLN and PGE, which, by virtue of existing law, would result in an increase in the PSO subsidy in the absence of the higher costs being passed through to electricity consumers. Third, the Gol made low-cost public financing options available for the purposes of implementing the project. Ultimately, PGE was able to secure electricity purchase tariffs of US\$ 7.53 cents/kWh for Ulubelu and US\$ 8.25 cents/kWh for Lahendong (Tompaso). The additional financial costs associated with these tariffs will initially be funded through an increase in the PSO subsidy to PLN (over and above what is already being provided to the utility), but could eventually be passed on to electricity consumers. As illustrated in Table 2, even at the negotiated rates, the financial NPV of the project is highly unattractive at –US\$ 126 million and would create serious financial hurdles for PGE to overcome.

As a part of its effort to advance the implementation of its second *Fast-Track Program* by facilitating low-cost financing, the Gol sought assistance from the World Bank. The World Bank was able to offer a concessional loan package of US\$ 300 million to

Table 2 | Summary of Financial Scenarios

	Financial Metrics	Ulubelu	Lahendong (Tompaso)	Combined Project
PGE all equity financing @ 14% ROE Tariff @ US\$6.4 /kWh ¹	Nominal FIRR NPV (US\$ million)	9.0% –109.9	6.8% –79.0	8.3% –188.8
PGE all equity financing @ 14% ROE Tariff @ PPA ²	Nominal FIRR NPV (US\$ million)	11.0% –71.1	9.4% –55.8	10.4% –126.2
PROJECT SCENARIO IBRD + CTF financing Tariff @ PPA ²	Nominal FIRR NPV (US\$ million)	17.4% 46.8	14.6% 4.0	16.5% 51.4

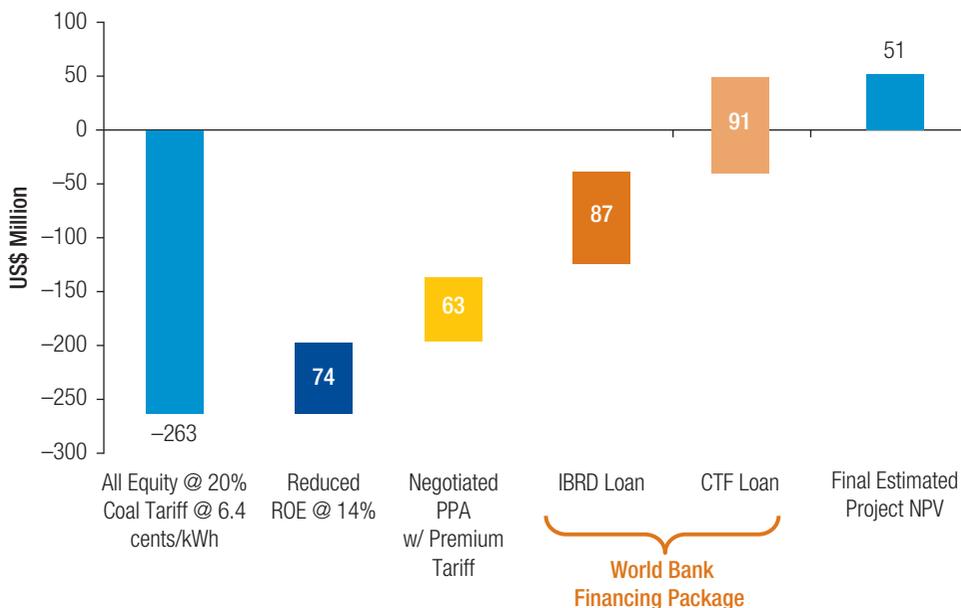
¹ US\$ 6.4 cents/kWh is cost of coal-based electricity as estimated by PLN in its 2010 official statistics.

² PPA tariff rates are US\$ 7.53 cents/kWh for Ulubelu and US\$ 8.25 cents/kWh for Lahendong (Tompaso).

Source | Authors.

PGE towards developing the Ulubelu and Lahendong (Tompaso) geothermal fields. This lowered PGE's equity exposure in the project to less than half the investment and provided an attractive debt-financing package. As previously noted, US\$ 175 million was from the World Bank's middle-income borrowing window (IBRD) while US\$ 125 million was a highly concessional loan from the CTF. The CTF is a part of the US\$ 6 billion Climate Investment Funds (CIFs) established by the global community to promote activities and investments that would positively impact climate change. Renewable energy is eligible for the softest CTF terms: long-term financing (40-year maturity with a 10-year grace period) at concessional interest rates (0.25 percent annual service charge/interest rate). The IBRD loan also has a long-term maturity (24.5-year maturity with a 9-year grace period). Although PGE opted for an interest rate on the IBRD loan that has a variable spread over LIBOR, for the purposes of the analysis of what is a long-term investment, a fixed rate of 5.02 percent based on a forward LIBOR rate of 3.87 percent and a fixed spread of 1.15 percent¹⁸ is applied. The IBRD rate is more costly than the CTF service charge but considerably lower than commercial lending rates and significantly lower than PGE's reduced financial return expectations on its equity. The financing package offered by the World Bank in conjunction with the negotiated tariff rates and PGE's reduction of its nominal required rate of return to 14 percent results in a US\$ 51 million NPV projection for the project. In the absence of World Bank financing, the financial viability of the project would rest on either PGE accepting an even lower rate of return on its equity or on securing higher tariffs from PLN for electricity purchases, which in turn raises the PSO subsidy burden on the government. It is worth noting that the offer for World Bank financing was not sequentially last. Instead, the prospects of World Bank financing were made by the government to PGE at the onset of project design, which partly provided the assurance to PGE to accept the early phase geothermal resource risks by using its own equity to begin investments in exploration drilling in order to develop the upstream steam field. Although the financing terms and the loan were finalized later, the involvement of the World Bank from the early stages of preparation played a catalytic role in the initial investment decision. Figure 3 graphically illustrates the

Figure 3 | Bridging the Financial Viability Gap (NPV from PGE's Equity Point of View)



Source | Authors.

buy-down that bridged the financial viability gap and resulted in the final outcome. It indicates how actions by multiple stakeholders were required in order to bridge the financial viability gap, since someone has to pay for it. PGE agreeing to a lower return on its equity, the government providing PSO subsidy support to underwrite the premium tariffs that were negotiated, and the concessional financing package from the World Bank—each was instrumental in “buying down” the additional financial costs and improving the financial standing of the project.

THE NEED FOR ROBUST PROJECT DESIGN TO HANDLE INVESTMENT RISKS

Although there is a sound rationale for the CTF loan, there is also a reasonable question as to how much CTF financing is actually required by the project. With the current IBRD/CTF loan package, the project is expected to have a financial NPV of US\$ 51 million and a financial internal rate of return (FIRR) of 16.5 percent. The deterministic analysis presented thus far could lead to the conclusion that the project would remain financially viable even if the CTF concessional funds were reduced. For example, the CTF loan could be reduced to as much as US\$ 54 million and replaced with equity and the project would still break even with a NPV just above zero. However, to evaluate the project in this manner ignores the risks that the project will face, including those that are specific and inherent to geothermal development. It unrealistically assumes certainty of the estimated deterministic results (i.e., estimated NPV and FIRR).

A Monte Carlo simulation¹⁹ was carried out to assess the project’s risks and their impact on the project’s outcomes. Although a complex operation such as the development of a steam resource and the construction of a power plant can face various risks, for the purpose of the analysis, only the major risks that could substantially impact the project were considered. Instead of using one value for each of these “risk” variables that would lead to a single value for a project outcome (such as the NPV, for example), probability distributions were assigned to reflect the variability of the selected risk parameters. As a result, a probability distribution illustrating a likely range of values for each of the outcomes was analyzed. The evaluation of a range of outcomes based on probabilities allows for a better understanding of the risks involved in a project, and also provides insights as how best to mitigate them. The key risks that were modeled for the Ulubelu and Lahendong (Tompaso) projects related to the geothermal resource and the operational capacity of the power plants:

- **Well Productivity** | The contribution to power generation capacity (i.e., MW) from each well can significantly alter the required investment costs and impact the viability of a geothermal project. It is also a factor that has a considerable degree of uncertainty ex-ante until the wells are actually drilled and tested. The considerable number of wells that were already drilled at Ulubelu provided the basis for a more informed assumption about productivity of future wells. A mean value of 8 MW per well was used with a uniform distribution that ranged from 7 to 9 MW. Since there was limited drilling in Lahendong (Tompaso) at the time of the assessment, a custom distribution with a mean of 6 MW per well with a wide range of 0 to 21 MW that reflected actual Indonesia-wide probabilities for geothermal well productivity, was used to model the risk.
- **Geothermal Steam Resource Availability** | There should be sufficient geothermal steam available to operate a power plant if a project is to realize its full benefits. The steam resource should be available at the required capacity (MW) for the duration of the project (30 years, in this case). If the estimated steam availability is less than the

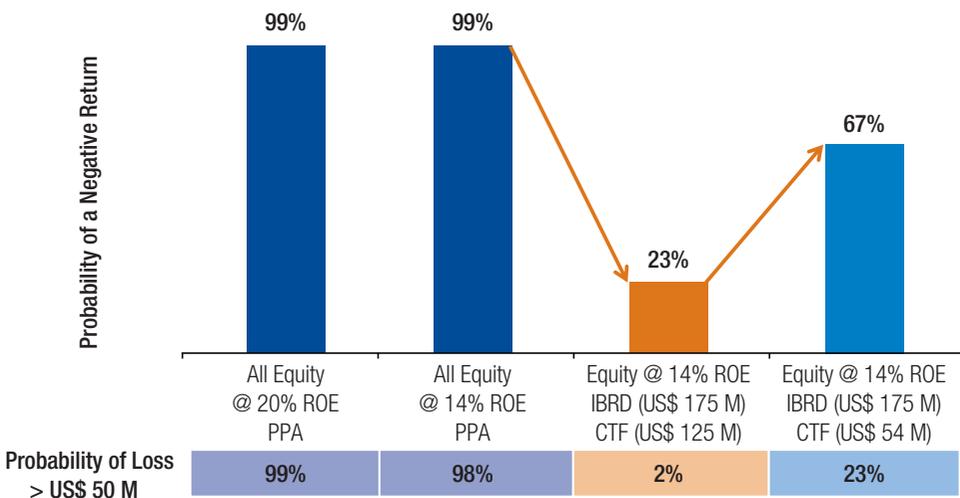
desired capacity of the power plant, then the project should be scaled-down in design to match the level of steam available to fuel the power plant. In the case of Lahendong (Tompaso), at the time of the evaluation, the steam resource was estimated at 83 MW at a highly certain 90 percent probability, far exceeding the 40 MW of steam that is required by the plant’s design. However, at Ulubelu, for Units 3 & 4, only 65 MW was confirmed with the same 90 percent probability. Efforts were underway to confirm more steam availability. However, if only 65 MW of steam capacity were to be available for Ulubelu Units 3 & 4, then it would shorten the duration that the 110 MW power plant could sustain its operations to less than the full 30-year life-cycle. The prospect of a steam resource being exhausted prematurely poses a risk to the project. Given the assessment at the time of evaluation, it was necessary therefore to model the likelihood that Ulubelu Units 3 & 4 would run out of steam prior to the required 30-year plant life and assess the resulting financial impact of foregone revenues.

■ **Plant Factor** | Geothermal power plants usually have a high plant capacity factor, which is a measure to indicate the number of hours the power plant operates and its reliability during the year. This variable directly affects the amount of electricity that is generated, thereby impacting financial revenues and environmental benefits. The power plant capacity factor was modeled using a custom distribution with a mean of 0.92²⁰ based on experience from operations of existing geothermal power plants in Indonesia.

The probability distributions of the above-mentioned variables were used in the Monte Carlo simulation risk assessment. One thousand simulations were run, each reflecting a different potential financial scenario. The simulations were carried out for each of the considered financing options. The key risk analysis conclusions are illustrated in Figure 4 and discussed below.

In the first two financing scenarios, where PGE is receiving negotiated tariffs that have a premium over coal and is fully financing the project by equity, the probability that the NPV will be positive is less than 1 percent for a required rate of return of 14 to 20 percent. Furthermore, there is more than a 98 percent chance that the losses

Figure 4 | Results of Risk Analysis: Probability of a Negative Financial Return and Excessive Loss



Source | Authors.

will be in excess of US\$ 50 million, even for a required financial rate of return of 14 percent. Needless to say, no investor would take on such downside risks. However, when the World Bank IBRD/CTF financing is incorporated, then the probability of a negative return is reduced to a more manageable 23 percent. Moreover, the likelihood of an excessive loss of US\$ 50 million drops to 2 percent. The financial robustness of the project under this scenario enables PGE to withstand substantial risks while maintaining the viability of the project. If the circumstances were altered, with the CTF financing reduced to the financial break-even level of US\$ 54 million and financing increased to make up the difference, then the probability of a negative return would increase significantly to 67 percent and the chance for excessive losses would also rise, to 23 percent. Even if the reduction in CTF financing is replaced by an increase in the amount of the IBRD loan, which is still much cheaper than equity financing, the probability of a negative return would be about 40 percent (not shown in Figure 4). Therefore, it is important that a project's financial outcome be sufficiently robust to withstand key uncertainties and allow for the sustainability of operations. As such, it can be concluded that the size of the concessional CTF loan (US\$ 125 million) is necessary to mobilize investments and ensure project sustainability.



WHO BENEFITS AND WHO BEARS THE COST OF THIS PROJECT?

A distributional analysis was also carried out to evaluate the impact of the project on key stakeholders. In previous analyses, financial evaluations assessed the financial feasibility of the project from the perspective of the sponsor (PGE) while the economic analysis evaluated the project's impacts from the point of view of the entire country. Due to the existence of a global externality (the climate change benefits) and the compensation provided by the international community through concessional financing, the boundaries of the economic analysis were expanded to include the broader global community. The difference between the economic and the financial values represents

Table 3 | The Benefits of Increased Electricity Consumption (in US\$ millions)

Benefits	Financial Payments @ 10% EOCK	Economic Benefits @ 10% EOCK	Consumer Surplus
To Residential Consumers	260	670	410
To Commercial Consumers	168	206	38
To Industrial Consumers	223	415	192
TOTAL	651	1,291	640

Source | Authors.

externalities that accrue to a party other than PGE.²¹ These externalities can be further allocated to the beneficiaries (winners) and those who bear the costs (losers) to evaluate the magnitude of the distributional impacts from the project on these groups.

The primary beneficiaries of the project are electricity consumers in Indonesia. The project is expected to generate over 1.2 billion kWh of electricity annually, which could facilitate nearly 1 million new electricity connections. The additional electricity consumed would provide an economic benefit to the various groups of consumers: primarily residential customers, commercial entities, and industrial users. The maximum willingness to pay (MWTP) for electricity, as measured by the next best alternative, is a proxy for the gross economic benefit of the electricity produced by the project, which is estimated to be about US\$ 1.4 billion over the life of the project in present value terms. What these consumers actually pay, however, is the retail electricity tariff in Indonesia. Based on the weighted average retail electricity tariffs for each of the consumer categories, the estimated total financial payments made by consumers of this electricity is US\$ 651 million over the life of the project in present value terms. The difference between the gross economic benefit and the actual payments for electricity is the additional benefit or consumer surplus that accrues to consumers. It is important to note that this benefit is generated due to the additional electricity supplied and not as a result of a specific technology used. In other words, consumers would receive this benefit whether the electricity was generated using geothermal or coal.

The distributional impacts specific to the geothermal project and their allocation are illustrated in Table 4. The magnitude of the impact on stakeholders is the difference in externalities between the Ulubelu and Lahendong (Tomposo) geothermal investments and an equivalent coal-based project. The major stakeholders impacted by the geothermal project are the Government, the local community in the area of the project, and the global community. The net impact on the Government, in present value terms, is –US\$ 78 million. This represents US\$ 110 million in additional subsidies that are partially offset by an additional US\$ 84 million in tax receipts that the Government is expected to receive from PGE over the life of the project. There is also a cost to the Government of US\$ 52 million in present value terms due to the impact of the foreign exchange premium on the tradable portion of project investments. The local community in proximity to the project is expected to enjoy an estimated US\$ 45 million in health benefits from the avoided pollution from the generation of geothermal power instead of coal. Another major beneficiary of the geothermal project is the global community due to the reduction in potential greenhouse gases in the atmosphere resulting from the avoided CO₂ emissions. The gross global benefit that was estimated on a conservative basis in the economic analysis is US\$ 150 million. However, the global community also provides compensation for receiving this benefit through a CTF concessional loan that

Table 4 | Distributional Impacts of Project (in US\$ millions)

Geothermal Generation	Financial ¹	Economic Local ¹	Additional Economic "Global" ^{1,2}	Total Externality	Allocation of Externalities		
					Government	Local Community	Global Community ²
Revenue/Benefit	637	527		(110)	(110)		
Investment	(454)	(493)		(39)	(39)		
Make-Up Wells	(65)	(70)		(5)	(5)		
O&M	(87)	(95)		(8)	(8)		
Tax	(84)	–		84	84		
Health Benefit	–	45		45		45	
Reduction of GHG	–		150	150			150
CTF Compensation	86	86	(86)	(86)			(86)
					(78)	45	64

Coal-Based Generation	Financial ¹	Economic Local ¹	Additional Economic "Global" ^{1,2}	Total Externality	Government	Local Community	Global Community
Investment	(207)	(225)		(18)	(18)		
Fuel Cost	(218)	(237)		(19)	(19)		
O&M	(56)	(61)		(5)	(5)		
Tax	(38)	–		38	38		
Health Benefit	–	–		–			
Reduction of GHG	–	–		–			
					(4)	0	0

NET DISTRIBUTIONAL IMPACT: GEOTHERMAL VS. COAL-BASED GENERATION				Government	Local Community	Global Community
				(74)	45	64

Notes

¹ Discounted at the economic discount rate (EOCK) of 10%

² The global economic benefits accrue to entire global community, including Indonesia

Source | Authors.

is made available by the international community to promote climate-friendly projects. The global impact of this concessional financing, estimated at US\$ 86 million in present value terms, is a cost borne by the international community.²² The final net global benefit (or global consumer surplus) of the project is US\$ 64 million in present value terms.

The top panel in Table 4 presents the net distributional impacts as a result of the geothermal project. Some of these impacts are a direct result of displacing equivalent coal-fired power plants, as illustrated in the second panel in Table 4 under “Coal-Based Generation.” These avoided distributional impacts largely affect the government as

it avoids US\$ 42 million in foregone costs associated with the foreign exchange premium on tradable goods but also loses potential corporate income tax revenues of US\$ 38 million that is no longer accrued since the coal-based operation will no longer take place. The net impact is that the government avoids a US\$ 4 million outlay because the coal-fired power plants are not constructed. The resulting difference between the impact to the Government from the geothermal power plant (–US\$ 78 million) and the avoided impact of the coal-based operations (–US\$ 4 million) is –US\$ 74 million, which is the net distributional impact on the government from the geothermal project.

AN INTEGRATED APPROACH TO EVALUATING THE RATIONALE FOR EXTENDING GREEN FINANCING

The economic analysis undertaken for this project confirms the rationale for undertaking this investment and explains why the international community needs to share the costs given the project's global environmental benefits. However, without financial support, the project is not financially viable since the international and domestic policy environments do not “internalize” the “externalities” that would have adequately compensated the project's investor. This global market failure was addressed, in this particular project, through a financing package that included a concessional loan from the CTF, which was instrumental in bridging the financial viability gap of the project. Combined with the costs borne by Indonesia through the higher geothermal tariffs and lower return expectations by PGE, the concessional financing package was essential for the financial viability of the project. As a result, the investments in the geothermal fields at Ulubelu and Lahendong (Tompasso) are proceeding without delay. This is particularly important given the urgency with which action is needed to address climate change.

According to the International Energy Agency (IEA), immediate investments are required globally at a staggering scale if a widely accepted climate change goal, known as the *450 Scenario*, is to be met. The *450 Scenario* aims to limit the average long-term increase in global temperatures to no more than two degrees Celsius (2°C) compared with pre-industrial levels, which the IEA estimates will require that the CO₂ equivalent concentrations in the atmosphere are limited to no more than 450 parts per million (PPM). However, the IEA cautions that 80 percent of the expected future emissions will result from the existing global capital stock, implying that there is limited time and opportunity to reverse the business-as-usual emissions trend. Moreover, if urgent action is not taken, by 2017, the IEA predicts that the world will lock in the emissions of the existing capital stock, leaving little room to maneuver and only far costlier options to consider thereafter for curtailing greenhouse gas emissions. This is well exemplified in Indonesia, where delays in expanding geothermal power generation will directly lead to the development of coal-based power to meet baseload energy needs. Thus, this particular investment, as well as other similar geothermal projects, represent global and local development imperatives.

An integrated approach to decision making, as illustrated in this paper, is a useful way to evaluate a green finance investment in geothermal power. It helps bring together multiple perspectives that are important to making a well-informed investment decision. In this specific project, the economic analysis provided the development rationale for the undertaking and confirms that geothermal power is competitive with coal when its environmental and other benefits are considered. The financial assessment provided the basis for designing the green finance scheme that made the project financially feasible for PGE to undertake. The Monte Carlo simulation, carried out as a part of the risk analysis, provided a stochastic perspective with multiple

scenarios based on probabilities. It enabled the design of a more robust structure for the project with sufficient financing to withstand the risks that often face geothermal developers—a major factor in the project’s sustainability. Finally, the distributional analysis evaluated the impacts on various key stakeholders beyond PGE. It confirmed that there were net global environmental benefits from the geothermal project even after the compensation provided by the international community through the concessional loan from CTF. The analyses were key reasons, among others, on the basis of which the World Bank’s Board of Executive Directors approved the *Geothermal Clean Energy Investment Project* on July 26, 2011. The geothermal operations at Ulubelu and Lahendong (Tompaso) are presently under development.

ENDNOTES

- ¹ Some key factors include overall capital flight in emerging markets following the Asian Financial Crisis, and the regulatory uncertainty and the institutional turmoil that followed the annulment of the 2002 Electricity Law by Indonesia's Constitutional Court.
- ² Government compensation to PLN under State-Owned Enterprise Law to cover shortfalls between the utility's cost of supply and the electricity tariffs, which in Indonesia, are set by Government policy.
- ³ 1,189 MW of capacity has been developed by 2011.
- ⁴ Units 1 & 2 are also under construction where PGE is a steam supplier to PLN operated power plants. Units 3 & 4, which are being financed by the World Bank, will be operated by PGE—including the steam fields and the power plants.
- ⁵ The adjacent geothermal field, which is also part of the government designated Lahendong geothermal work area (WKP) includes four 20 MW units (Units 1, 2, 3, & 4). The project financed by the World Bank is in the Tompasso geothermal field, which is also part of the Lahendong WKP, and therefore, referred to as Lahendong Units 5 & 6.
- ⁶ The project costs, except where otherwise noted, are based on feasibility studies for the Ulubelu Units 3 & 4 and Lahendong (Tompasso) Units 5 & 6, which were independently prepared by international consultants for PGE.
- ⁷ Given the globally unprecedented scale-up being undertaken, there is a need for PGE to enhance its institutional capacity, as well as secure significant financing, to successfully realize its investment program. The World Bank, in addition to the loans, has also facilitated grants that total about US\$ 10 million from the Governments of New Zealand and Netherlands, to provide technical assistance to strengthen PGE's capacity.
- ⁸ This is a typical plant operating capacity factor for a coal-fired power plant. In 2008, the United States Energy Information Agency estimated that the average operating capacity factor for coal-fired power plants throughout the country was 72 percent.
- ⁹ Studies and specialists' opinions confirm that it is typical for geothermal power plants to operate at plant operating capacity factors in excess of 90 percent, especially in the case of newer power plants. Operations in Indonesia are observed to typically operate between 90 and 95 percent, and at times higher.
- ¹⁰ The drilling costs at Lahendong (Tompasso) included in the feasibility study are very conservative since sufficient drilling data was not available at the time. Therefore, for the purpose of the analysis, the drilling costs were adjusted utilizing the expected value for drilling costs based on Indonesia-wide data based on the report—*An Assessment of Geothermal Risks in Indonesia, 2010, PPIAF Report*.
- ¹¹ Environmental Impact Assessment of Java's Electricity Generation Using SimPacts Model, *Liun et al.*
- ¹² Note that in this analysis, the externalities are attributed as the cost of coal-based power generation. However, these values can also be evaluated as a benefit of a geothermal power plant since it would help avoid an equivalent level of negative environmental impacts. Both approaches will lead to the same result.
- ¹³ *Ibid.*
- ¹⁴ Carbon revenues, which are intended to internalize some of the global environmental externalities, face considerable uncertainty due to the end of the Kyoto Protocol commitment period in 2012 and the absence of a global agreement on the future market structure for carbon offset trading.
- ¹⁵ This effort spearheaded by the Ministry of Energy and Mineral Resources is being assisted by the World Bank through a US\$ 4 million grant from the Global Environment Facility (GEF) under the *Geothermal Power Generation Development Project*.
- ¹⁶ Instead of through borrowing (debt finance), as has been the case previously with Pertamina/PGE. This is partly because the resource risks of developing the upstream steam field can render financing unavailable or cost prohibitive.
- ¹⁷ Commonly referred to as an ESC or Energy Sales Contract.
- ¹⁸ 30-year forward as of November 12, 2010, and long-term fixed spread for IBRD loans.
- ¹⁹ A stochastic simulation technique that generates random values based on probabilities to model uncertainty when solving a problem. It is a technique used to evaluate investment risks.
- ²⁰ Implies that the power plant operates 92 percent of the time or 8,059 hours in a year.
- ²¹ Based on the Harberger/Jenkins methodology: $\Sigma PV(\text{externalities}) = NPV(\text{economic resource flows}) - NPV(\text{financial cash flows})$, where the economic and financial streams are discounted by the EOCK, in this instance, for Indonesia. For more information on the methodology, see "Evaluation of Stakeholder Impacts in Cost-Benefit Analysis" by Glenn P. Jenkins, Development Discussion Paper No. 631, Harvard Institute for International Development, Harvard University, 1998.
- ²² The benefit of the CTF concessional financing is captured as a line item in this specific distributional analysis since this impact is not reflected in the unleveraged cash flows or in the economic discount rate.

ACRONYMS AND ABBREVIATIONS

€	Euro (currency)
CO ₂	carbon dioxide
CTF	Clean Technology Fund
EOCK	economic opportunity cost of capital
FIRR	financial internal rate of return
GHG	greenhouse gas
Gol	Government of Indonesia
IBRD	International Bank for Reconstruction and Development
IEA	International Energy Agency
kcal	kilocalorie (4,184 joules)
kg	kilogram
kW	kilowatt
LIBOR	London Interbank Offered Rate
MDB	multilateral development bank
MW	megawatt
NO _x	nitrogen oxide
NPV	net present value
O&M	operation and maintenance
PGE	Pertamina Geothermal Energy (Indonesia)
PLN	Perusahaan Listrik Negara (Indonesia's state-owned power company)
PPA	power purchase agreement
PSO	Public Service Obligation (subsidy)
PV	present value
ROE	return on equity
SO ₂	sulfur dioxide
TSP	total suspended particles
US\$	United States dollar (currency)
WKP	geothermal work area designated by Gol

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