Indonesia's Geothermal Resource Paradox: Unbundling Risks, Unleashing Private Capital

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Abstract

The belief that resource abundance equates to energy security is roundly debunked in Indonesian geothermal. Indonesia's copious geothermal reserves remain untapped. Experts cite the usual culprits: unreliable long-term contracts, ambivalent government support, and lukewarm investors investment appetite. In this paper, we argue that the real constraints lie in investors' unresolved contradictions: Quick to complain about government's unreliable and shifting stance, investors look to the same counter-party to guarantee their "iron-clad power purchase agreements (PPAs)" to secure their returns. To unleash Indonesia's geothermal potential, we propose adopting slim-hole drilling technologies to reduce costs, while facilitating sequential commitments. This could enhance strategic flexibility that lowers costs of well failures, while facilitating adoption of resource insurance to de-risk geothermal exploration and drilling. To sustain these benefits, "cheap" energy policy needs to be phased out to allow a restructured PT Perusahaan Listrik Negara's (PLN) to flourish by embracing commercially viable strategic approaches.

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I. Introduction

Indonesia's "cheap" power policy buys popular acclaim that is fleeting and illusory. The same font from where political "goodwill" is drawn, the venom could emanate from that fuels popular unrest and discontent. Such is the fate that awaits populist policies. The privilege of "cheap power" engenders in its people a sense of entitlement, turning it into a "right" that must be protected. Once the "right" is withdrawn, by sheer economic necessity, a sense of injustice and outrage could give rise to direct actions and dissent[4].

President Joko Widodo took tentative steps to forestall such disruptions, with some success. After raising power prices by 30% each year since 2014, subsidies to PT Perusahaan Listrik Negara's (PLN) fell from $7.4 billion to $3.68 billion by 2017, but crept up in 2018[5]. PLN's financial fortunes, however, remain subjected to the vagaries of policy prerogatives. Shifting priorities could hinder, or even jeopardize, its ability to sustain its quest for commercial viability and financial independence.

As executor of the state's "cheap power" policy, the regulator mandates PLN to sell below their generation costs, and the state expects PLN to earn a profit. PLN is kept afloat financially by receiving subsidies, while consumers in theory receive "cheap" power. A happy ending, one may think!

This fairy tale deludes consumers and policy alike. Subsidizing one's way to "cheap" energy is seriously flawed. It discourages investments, making investors choose to flee rather than to commit. Without new supplies, in an expanding energy market, more subsidies may store more disasters for the future.

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[4] France's "yellow vests" movement protested against the government's move to tax energy that raised prices (https://www.bbc.co.uk/news/world-europe-47371901?intlink_from_url=https://www.bbc.co.uk/news/topics/cpzg2d6re0lt/france-yellow-vest-protests&link_location=live-reporting-story). Nigeria's attempts to align energy prices to market was previously met with violence on the streets (https://allafrica.com/stories/201807310229.html). Accessed March 4, 2019.

[5] Price were frozen in 2018 and 2019, which is feared to setting back the progress made to date on fuel use efficiency (http://theconversation.com/indonesias-electricity-subsidy-reforms-led-to-improved-efficiency-93546), and resurgence of subsidies to PLN, partly because of rising oil prices (https://www.iisd.org/sites/default/files/publications/gsi-indonesia-news-briefing-january-2018-en.pdf). Accessed March 4, 2019.

To break out of this energy logjam, Indonesia's persistent geothermal resource paradox needs closer examination. This paper seeks to address these questions:

1. How has "cheap" energy damage PLN, and impede wider deployment of geothermal energy?
2. Is an iron-clad power purchase agreement (PPAs) the silver bullet that accelerates, or the poison pill that deters, geothermal investments?
3. How are technological and financial innovations encouraged by Indonesia's energy market realignments?

Seen from a managerial decision-making perspective under uncertainties, we posit that

"cheap" energy policy's ills lie at the heart of Indonesia's geothermal resource paradox. To resolve this, Indonesia may start by dismantling its coal and cross-subsidies to bring energy prices in line with economic costs of supplies. Contrary to investors' (mis-) diagnoses, geothermal under-investments arise from unbounded exploration uncertainties that private capital is ill-equipped to manage. Rather than trying to craft an iron-clad PPA, investors and policy could instead make market conditions favorable to adopting slim-hole drilling technology. This could reduce costs and expand market scope (i.e. micro-grids), that facilitates incorporating resource insurance to de-risk exploration and exploitation for a portfolio of wells. In the process, private funding for geothermal development and power generation is encouraged. This process is reinforced when a restructured PLN embraces commercially-compliant strategic approaches. Indonesia wins with a strengthened PLN that is financially independent, a power mix that enhances low carbon geothermal energy's role, and consumers get their affordable energy through efficiency and competitive pressures.

II. Illusory benefits, seeds of energy crises

Commercially-compliant investments are premised on earning just returns as rewards for taking risks. To earn a return, the prices must exceed the costs of supplies, where the margins are sufficiently high to recoup the investments at a profit. Over time, the cumulative returns must exceed the costs of capital to create value for the investing firm. Given this context, prices generally signal to managers when to supply periodically, and when to expand (or contract) based on future expectations.

Indonesia's "cheap" power policy introduces a regulatory perversion that overturns the premises under which energy markets could function efficiently. With the whole energy system under state-control, PLN manages to keep afloat by acquiring subsidized coal so that it could sell its power below market prices (or costs). As the whole chain is cross-subsidized, consumers get their power "cheap". Under this system, PLN's ability to report profits is totally reliant on the government's generosity, as its *de facto* sovereign guarantor for its liabilities.

Table 1. PLN's Financials

Line	Perusahaan Listrik Negara (PLN) Financials	2014	2015	2016	2017	2014	2015	2016	2017
		Indonesia Rupiah - Trillion				US dollars - Billion			
		A	B	C	D	E	F	G	H
1	Reported Net Income	11,07	6,03	8,15	4,40	0,80	0,44	0,59	0,32
2	Subsidies	101,82	60,33	73,13	50,60	7,40	4,38	5,31	3,68
3	Operating Losses without Subsidies	-54,39	-8,23	-31,63	-20,18	-3,95	-0,60	-2,30	-1,47
4	Subsidies	99,30	56,55	58,04	45,74	7,22	4,11	4,22	3,32
5	Operating Income with Subsidies	44,91	48,32	26,41	25,56	3,27	3,51	1,92	1,85
6	Equity	153,30	804,79	878,40	869,42	11,14	58,49	63,84	63,18
7	Debt	454,14	509,58	393,78	465,54	33,00	37,03	28,62	33,83
8	Total Assets - Without Revaluation	595,95	683,13	643,02	716,50	43,30	49,64	46,74	52,06
9	Revaluation or Writedowns	-11,49	631,24	629,16	618,46	-0,84	45,88	45,72	44,95
10	Total Assets - With Revaluation	607,44	1.314,37	1.272,18	1.334,96	44,14	95,52	92,46	97,01
	Profitability								
11	Operating Losses to Assets (Before Revaluation)	**-9,13%**	**-1,20%**	**-4,92%**	**-2,82%**	**-9,12%**	**-1,21%**	**-4,92%**	**-2,82%**
12	Operating Income to Assets (After Revaluation)	**7,39%**	**3,68%**	**2,08%**	**1,91%**	**7,41%**	**3,67%**	**2,08%**	**1,91%**
13	Operating Loss to Equity (Before Revaluation)	**-48,00%**	**1,44%**	**5,69%**	**3,55%**	**-47,94%**	**1,45%**	**5,69%**	**3,56%**
14	Operating Income to Equity (After Revaluation)	**29,30%**	**6,00%**	**3,01%**	**2,94%**	**29,35%**	**6,00%**	**3,01%**	**2,93%**
	Debt Leverage								
15	Debt to Equity - Without Revaluation	**275,59%**	**293,62%**	**157,99%**	**185,50%**	**275,46%**	**293,66%**	**157,95%**	**185,57%**
16	Debt to Equity - With Revaluation	**296,24%**	**63,32%**	**44,83%**	**53,55%**	**296,23%**	**63,31%**	**44,83%**	**53,55%**
17	Debt to Operating Income without Subsidies	**-8,35**	**-61,92**	**-12,45**	**-23,07**	**-8,35**	**-61,72**	**-12,44**	**-23,01**
18	Debt to Operating Income with Subsidies	**10,11**	**10,55**	**14,91**	**18,21**	**10,09**	**10,55**	**14,91**	**18,29**

Source of data: Brown, M (2018). *Perusahaan Listrik Negara (PLN): A power company outn of step with global trends*. Institute for Energy Economics and Financial Analysis, April 2018; PLN Financials; and Authors' calculations.

Indonesia's energy price-setting system is seriously flawed, as Table 1 would illustrate. Subsidies do not lower power prices. It simply socializes the costs of energy that public finances bear the burdens. The record to date is far from encouraging: On a 2019 budget of IDR2,461.1 trillion ($161.65 billion)[6], energy subsidies would account for a record IDR163.5 trillion ($11.4 bln)[7], or 7% of national budget with scope to overshoot as it did in 2018[8].

Worst, "cheap" power policy distorts prices as to render any commercial ventures uneconomic. Without private capital, growth would hardly be sustained by deficit-funding. Extant regulation makes a capital squeeze imminent.

PLN sold its power in 2017 at $0.07/kWh that costs $0.095/kWh to generate on average, representing a 78% cost recovery. To sustain its "cheap" power policy, the regulator partially opened the energy market to private developers under these conditions:

1. Energy-short regional markets are more heavily subsidized than urban Java and Sumatera, hence pricing their energy lower;

6 https://uk.reuters.com/article/indonesia-budget/update-1-indonesia-parliament-body-approves-1617-bln-budget-for-2019-idUKL3N1XA3H8. Accessed March 2, 2019.

7 https://www.gulf-times.com/story/599815/Indonesia-s-energy-subsidy-to-balloon-4-8bn-on-pri. Accessed March 2, 2019.

8 https://www.indonesia-investments.com/news/news-columns/indonesia-s-energy-subsidy-spending-far-above-target-in-2018/item9036? Accessed March 2, 2019.

2. Independent suppliers are free to contract with industrial buyers, in a market where PLN may be the sole credible buyer;
3. Private power generators in theory compete with PLN as supplier, which is an entity that enjoys subsidies and controls a captive market.

Through regulatory fiat, PLN's assets were revalued by $46 billion (F9) to restore its accounting health. Its debt-to-equity ratio fell from 296% (E16) to 63% (F16). Without addressing the revenues and costs side, profitability plunged to 3.67% (F12) and continue to decline to 1.91% (H12). Debt-to-operating income (or cash leverage) is less flattering at 10x, worsening to 18.3x (H18) that far exceeds its regional peers with cash leverage of 2.0x to 2.5x[9].

As one may expect, few private investments are pursued with higher priced Java and Sumatera taking the lion's share, while regional grids are starved of capital. The future looks no brighter: With PLN selling power at below costs to all regions, no private investments are likely. This raises a question: Why not simply sustain PLN's monopoly?

What is played out in Indonesia today repeats Mindanao's (in the Philippines) failed experiments with "cheap" power policy. To attract heavy (and energy-intensive) industries, heavily discounted power prices and subsidies were offered to investors in the 1970s. Fast forward to 1990s, the carcasses of abandoned factories were the only stark reminders of a bygone era of economic folly. Years of under-investment, partly because of heavily subsidized power prices, resulted in severe power supply shortages[10].

Without private capital, Indonesia's rapidly expanding energy demand may not be met if no new capacity is built. By continuing to rely on public funding, increasing share of the national budget would have to fund subsidies, probably at the expense of infrastructures and social expenditures.

III. Are long term contracts the silver bullet?

To attract private capital, investors would want PLN to secure their returns through take-or-pay contracts, using twenty years PPAs. By locking in prices and volumes, investors could rest assured that they could recoup their investments with lucrative profits. However, PLN's parlous finances may increase investors' credit risks when they gamble on the government's magnanimity.

PLN's funding model *de facto* exposes investors to the vagaries of Indonesia's ever-changing budgetary priorities. When stretched to the limits,

[9] Brown, M (2018). *Perusahaan Listrik Negara (PLN): A power company out of step with global trends*. Cleveland, Ohio: Institute for Energy Economics and Financial Analysis, April 2018.

[10] https://www.doe.gov.ph/energists/index.php/83-categorised/electric-power-industry/4116-power-crisis-dims-mindanao-s-promise. Accessed March 2, 2019.

PLN may opt to default, or renegotiate their obligations that investors may be unable to resist.

Ironically, a move to commercially-compliant energy market may widen the alternatives to investors and PLN to secure their finances. Such transition to more openness may constitute the following:

1. Equalize power prices to market soonest, taking advantage of falling fuel prices as a back drop.
2. Restructure PLN's finances, and place its operational structures on similar footing as commercial ventures by eliminating subsidies, while injecting new cash equity.
3. Introduce market pricing for power by moving its regulations away from long term contracts (PPAs), at least for Java and Sumatera, where demand and scale allows competition to work.

Over-emphasis on low energy prices, and subsidizing coal to meet this objective have left Indonesia's geothermal resources under-exploited. This is ironic given Indonesia's abundant geothermal resources that remains untapped. Accelerating geothermal energy's development could better satisfy its "cheap" energy aspirations sustainably.

Investors may have, and continue to, mis-diagnose what ails Indonesia's geothermal development. Rather than finding security in PPAs, the ability to unbundle uncertainties, and finding a structure to bound the financial costs of failures, holds greater promise. Examine, for instance, the following realities:

High exploration costs front-load cash commitments when the prospect of finding commercially viable resources is most uncertain, and prospects for revenues being earned are poor.

Each drilling yields information that guides the decision to proceed or abandon. On striking a seam of viable reserves, the subsequent wells are more likely to strike pay dirt. At this point, spending on well testing and validation of reserves, could unlock the potential power affordably at lower risks.

Committing to PPAs prior to establishing the viable reserves of the geothermal reserves, investors take on default risks it may not be able to manage. Inadvertently, investors plan on success by ignoring the costs of failures. In the event of successive well failures, the costs to abandon increase exponentially. Without steam, investors default as supplier, while buyers could sue for compensation. In this situation, the only resolution is for the investor to pay up or declare bankruptcy.

Arguably, investors may commit to PPAs once they know the viable reserves, hence gaining the ability to bound (or estimate) the steam or energy that they could deliver (more or less). Managers may opt to lock-in prices and volumes to secure stable cash flows. PPAs however, does not provide the cash flow security that private investors and lenders hoped for. By fixing prices and volume commitments, under a take-or-pay obligation, the counterparties are exposed to repetitive renegotiations when actual prices or volumes deviate significantly from those contracted. As the deviations increase, the incentives to renegotiate heighten.

Continual PPA renegotiations are far from a theoretical exercise. Following Indonesia's price-setting rules, a twenty years PPA signed on March 28, 2018 would fall under the 2017 price caps set at $0.1076/kWh. When the new price cap takes effect on April 1, 2018, the same contract on the same project signed on April 2, 2018 would fetch $0.1700/kWh, because coal prices have gone up[11]. Applied to geothermal projects, the annual revenue difference is $491,961 ($0.17/kWh - $0.1076/kWh, and the difference is multiplied by 7,884 MWh/year) for each MW installed.

This is where the private investors' narratives become contradictory. Decrying the government's penchant for arbitrary actions, hence increasing "regulatory" risks, they turn to the same "unreliable" government to secure their PPAs' cash flows for two decades.

Under these circumstances, increased uncertainties are the likely outcomes. Billions of dollars are committed, trusting in a foresight that hardly exists among investors, lenders, or policy. All these are done in the hope of securing profits through regulatory fiat under volatile fuel and energy markets.

IV. Remedies and counter-intuitive approaches

Geothermal exploration and exploitation are capital intensive ventures with variable success rates. For this reason, investors are only prepared to part with their cash when their revenues are secured. This is where Indonesia's subsidies driven energy system is ill equipped to broaden wide-scale geothermal deployment.

Geothermal power's risks are front-loaded in exploration. With huge capital invested before the first drill is sunk, a failed venture sets back an investor by several millions of US dollars. Without taking these risks into account, signing PPAs before knowing how much reserves could be exploited, is tantamount to committing to a volume one may not have, as we previously pointed out.

In the sections that follow, we argue that the remedies may lie outside accepted energy wisdoms.

[11]http://www.gbgindonesia.com/en/main/legal_updates/indonesian_government_publishes_2017_cost_of_electricity_generation_figures.php. Accessed February 27, 2019.

4.1. Slim-Hole Technology

Slim-hole drilling and small turbines may radically alter how geothermal resources is exploited, and power generation is developed. To accelerate geothermal power's adoption, technological and financial innovations are employed to de-risk geothermal ventures.

Conventional geothermal drilling is influenced by the American preference for large hole drilling that are best suited to large, contiguous areas, that benefits from economies of scale. This involves mobilizing heavy equipment that requires large sums invested in civil works and roads, before the first drill is sunk on the ground. For this reason, geothermal power is usually associated with large volume energy markets, almost at the exclusion of micro-grids.

Slim-hole drilling changes the geothermal economics that could adapt better to archipelagic geography characterized by small, often isolated markets[12]. Its more modest front-end cash commitments, and allow small sequential cash disbursements. As a result, small-scale ventures are made feasible, reduces costs of failed wells, and lowers financial risks.

Table 2. Comparative Costs of Geothermal Technologies

Line	20 MW equivalent drilling Program - In $ million	Project Capture	3G Surveys	Exploration / Delineation	Appraisal	Cost to Final Investment Decision	Exploitation	Total Costs of Steam Supplies	Financial Costs of Steam Supplies - $/kWh	Cost Difference - %	C_{FX}	C_{VAR}	C_{Steam}	C_{LCOE}
		A	B	C	D	E	F	G	H	I	J	K	L	M
	90% Success Rate													
1	**Convetional Drilling**													
2	Costs incurred per segment	0,50	2,50	60,00	30,00	93,00	96,00	189,00	0,0379		0,0267	0,0190	0,0530	0,0987
3	Cumulative costs to abandon	0,00	-0,50	-3,00	-63,00	-63,00	-93,00							
4	**Slim-hole Drilling**													
5	Costs incurred per segment	**0,50**	**2,50**	**20,00**	**60,00**	**83,00**	**34,00**	**117,00**	**0,0234**	**-38,10%**	**0,0182**	**0,0095**	**0,0328**	**0,0605**
6	Cumulative costs to abandon	**0,00**	**-0,50**	**-3,00**	**-23,00**	**-23,00**	**-83,00**							
	70% Success Rate													
7	**Convetional Drilling**													
8	Costs incurred per segment	0,50	2,50	77,14	30,00	110,14	96,00	206,14	0,0413		0,0267	0,0190	0,0578	0,1035
9	Cumulative costs to abandon	0,00	-0,50	-3,00	-80,14	-80,14	-110,14							
10	**Slim-hole Drilling**													
11	Costs incurred per segment	**0,50**	**2,50**	**25,71**	**60,00**	**88,71**	**34,00**	**122,71**	**0,0246**	**-40,47%**	**0,0182**	**0,0095**	**0,0344**	**0,0621**
12	Cumulative costs to abandon	**0,00**	**-0,50**	**-3,00**	**-28,71**	**-28,71**	**-88,71**							
	40% Success Rate													
13	**Convetional Drilling**													
14	Costs incurred per segment	0,50	2,50	135,00	30,00	183,00	96,00	279,00	0,0559		0,0267	0,0190	0,0782	0,1240
15	Cumulative costs to abandon	0,00	-0,50	-3,00	-153,00	-153,00	-183,00							
16	**Slim-hole Drilling**													
17	Costs incurred per segment	**0,50**	**2,50**	**45,00**	**60,00**	**108,00**	**40,00**	**148,00**	**0,0296**	**-46,95%**	**0,0182**	**0,0095**	**0,0415**	**0,0692**
18	Cumulative costs to abandon	**0,00**	**-0,50**	**-3,00**	**-48,00**	**-48,00**	**-108,00**							

Source of data: Jacobs (August 2017) and authors' estimates. Lifecycle costs of energy (LCOE) is estimated based on the methods shown in Barcelona (2017). *Energy Investments: An adaptive approach to profiting from uncertainties* , London: Palgrave Macmillan, 2017.

To validate how the economics is changing, we analyze the financial costs of large-hole (row A2 to G2) vs slim-hole (row A5 to G5) geothermal drilling in Table 2. At each stage of the exploration, the firm may decide to proceed or abandon (usually to avoid farther losses). The cumulative costs of abandoning the exploration is compared (row A3 to G3 for conventional; row A6 to G6 for slim-holes). The drillers that achieve low well failures are said to have a high probability of delivery the required steam. Using this as an indicator for drilling

[12] Garg, S.K. et al (1993). "Use of slim-holes for geothermal exploration and reservoir assessment: A preliminary report on Japanese experience". *PROCCEEDINGs: Eighteenth Workshop on Geothermal Reservoir Engineering*, Stanford University, United States, January 26-28, 1993.

performance, life cycle costs of energy (LCOEs) would be lower for "high probability" drillers. They would need less wells to drill, hence lowering the costs of producing the required amount of steam supplied to ensure that the power generators operate at full capacity.

Using 2018 costs for Indonesian drilling, as provided by firms such as Jacobs, Iceland's ISOR and North Tech, the economic advantages of using slim-hole technology lies in the following:

1. Reduced drilling costs minimize the losses from a failed exploration. In this case, conventional drilling could imply a loss of $63 million (D3), against $23 million (D6), should the appraisal yield a negative result;
2. Low drilling success rates would increase the costs given that more wells have to be drilled to achieve a similar geothermal steam yield (i.e. 90% success rate).
3. Lower resource use, such as water and above surface installations, reduces slim-hole exploitation costs.

The implications for the financial costs (Column H), particularly for steam supplies, is significant. This could vary from 40% to 46% (Column I) representing the costs reductions by using slim-hole drilling. As this translates into costs of supply (Column M), the costs differences are significant (i.e. M5, M11, and M17).

4.2. Geothermal Resource Insurance and Subsidies

Geothermal resource insurance is perceived as expensive[13] using large-hole drilling's costs. Slim-hole drilling could reduce the costs of failed wells. Consequently, insurance premia could likewise fall *ceteris paribus*.

There are two types of generic risks associated with geothermal resources. First, investors could lose what it spent to drill when the resource is insufficient to support a commercially viable well (i.e. a failed well); and second, on becoming operational, wells could be damaged, or resources are degraded as to impede achieving its expected cash payoffs[14]. We focus on the first in examining how a largely untested geothermal resource insurance in Indonesia could facilitate private investments, and reduce Indonesia's budgetary burdens by progressively decreasing energy subsidies.

[13] http://www.geothermalcommunities.eu/assets/elearning/9.17.COSTS.pdf. Accessed February 23, 2019.

[14] A more extensive discussion is covered by Fraser, S. et al (2013). *European geothermal risk insurance fund (EGRIF)*. Brussels: Geo-Elec, June 2013.

To articulate the challenges that resource insurance is addressing, the World Bank's ESMAP[15] comparisons in Table 3 of the various resource insurance schemes is our starting point.

Table 3. Geothermal Resource Insurance Schemes

Number	Development Stage A	Surface exploration B	Exploration drilling C	Production drilling D	Power Plant E	Where Implemented F	Comments G
Government as developer							
1	Sources of funding	Public funding			Private	Costa Rica	Strain on public finances
2	Developer	SOE	SOE	SOE	Private		Exposed to vagaries of politics
Cost shared exploration and drilling							
3	Sources of funding	Public funding		Private	Private	Turkey, Nicaragua,	Derisking geothermal exploration by government
4	Developer	SOE	SOE	Private	Private	Kenya (Olkaria III)	Credit worthiness of parties
Government as enabling co-investor							
5	Sources of funding	Public funding		Private	Private	USA, Japan	Works in developed markets
6		Private					
7	Developer	Private	Private	Private	Private		Credit worthiness issues in emerging markets
Redeployment of social capital							
5		Public funding or guarantees					
6	Sources of funding	Grants or international aid		Private	Private	Indonesia (Flores)	Pilot schemes by Dutch multilateral or aid agencies; Private insurance firms
7		Multilateral agencies or CSR funds					
8	Developer	Private	Private				In need of track record

Notes: SOE - State-owned or controlled enterprises; CSR - Corporate Social Responsibility

Source: Adapted from Trainn Fridriksson, Energy Sector Management Assistance Programme, World Bank Group, April 2016; Authors.

ESMAP's "Government as developer" (B1 – D1 in Table 3) relies on public funding, and state-owned enterprises (SOEs) to undertake risky geothermal exploration and drilling investments. PLN's parlous finances, and the government's desire to reduce subsidies, practically rule out this model as impracticable.

This brings us to considering the virtues of the two subsets on costs sharing:

1. "Cost-shared exploration and drilling (B3–C3); and
2. "Government as enabling co-investor" (B5–C5).

Given the scale of the required investments, the government may come to the view that extending a sovereign guarantee (which it is loath to provide) would be cheaper. Taking this step, the government may as well guarantee, as it *de facto* already does, PLN's investment programs. Unfortunately, this perpetuates Indonesia's policy and budgetary approaches that produce persistent deficits for PLN.

4.3. Private Geothermal Insurance and Partial Public Funding

This leaves us with how Indonesia's coal and energy subsidies could be redeployed to facilitate the energy market's transition into a more sustainable model. This is where public funding, combined with redeploying social capital, may offer a workable geothermal resource insurance scheme, Indonesian-style.

[15] Refer to the report authored by Sungal, S.K. et al (2016). *Comparative analysis of approaches to geothermal resources risk mitigation*. Washington DC: World Bank Group, Energy Sector Management Assistance Program (ESMAP), Knowledge Series 024/16.

This brings us to a question as to who would act as the natural insurer of failed wells. In aiming to reduce public funding, private insurance and social capital's contributions come to mind. We examine these alternatives:

1. *Reallocation of coal subsidies* where the government could act as the resource insurer.
2. *Realign aid or climate subsidies to complement commercial insurance* to cover in whole or partially the payout for "failed wells".
3. *Purely commercial endeavor by insurers* where insurance companies could back the resource insurance with their global risk portfolios.

In the analysis that follows, let us consider a geothermal investment with similar profiles as those described in Table 4. For simplicity, we have two drilling technology choices – large-hole and slim-hole drilling – for wells with depth of 2,500 meters each.

Table 4. Comparative Exploration and Drilling Costs

Large Hole Geothermal Drilling and Exploration	Units	Number	Preparatory costs	Mobilisation	Drilling	Well Testing	Site Operation	Total
Field or portfolio size	MW	55						
Number of wells drilled	Units	4						
Drilling depth	Meters/Well	2.500						
Drilling costs	$/Meter	3,00						
Uninsured costs	$ mln		**3,75**	**19,00**	**0,00**	**0,00**	**0,00**	**22,75**
3 G Initial survey	$ mln		0,00	1,50	0,00	0,00	0,00	
Access roads, pads, land	$ mln		0,00	15,00	0,00	0,00	0,00	
Logisitics and rig mobilisation	$ mln		0,00	2,50	0,00	0,00	0,00	
Insured resource costs	$ mln		**0,00**	**0,00**	**30,00**	**0,00**	**0,00**	**30,00**
Drilling costs	$ mln		0,00	0,00	30,00	0,00	0,00	30,00
Others	$ mln		**0,00**	**0,00**	**0,00**	**2,00**	**4,00**	**6,00**
Segment Total	$ mln		**3,75**	**19,00**	**30,00**	**2,00**	**4,00**	**58,75**
Slim Hole Geothermal Drilling and Exploration	**Units**	**Number**	**Preparatory costs**	**Mobilisation**	**Drilling**	**Well Testing**	**Site Operation**	**Total**
Number of wells drilled	Units	16						
Drilling costs	$/Meter	1,20						
Uninsured costs	**$ mln**		**3,75**	**6,75**	**0,00**	**0,00**	**0,00**	**10,50**
3 G Initial survey	$ mln		0,00	1,50	0,00	0,00	0,00	
Access roads, pads, land	$ mln		0,00	4,50	0,00	0,00	0,00	
Logistics and rig mobilisation	$ mln		0,00	0,75	0,00	0,00	0,00	
Insured resource costs	**$ mln**		**0,00**	**0,00**	**19,20**	**0,00**	**0,00**	**19,20**
Drilling costs	$ mln		0,00	0	19,2	0,00	0,00	
Others	**$ mln**		**0,00**	**0,00**	**0,00**	**2,00**	**1,2**	**3,20**
Segment Total	**$ mln**		**3,75**	**6,75**	**19,20**	**2,00**	**1,20**	**32,90**

Sources of raw data: Authors' calculations based on API project costs presented to Indonsia's Ministry of Energy, Mining and Resources, November 2018.

Iceland's North Tech estimates that the first wells drilled, exploratory by nature, incur the highest risks of resulting as failed wells. The information gained are of value in delineating or redirecting the drilling to more promising areas, in the event the first drilled area turned out to be unviable.

Once the first reserves are located, subsequent wells could see progressive improvements in finding commercially viable reserves. Thus, substantially reducing the risks of failed wells. In effect, with each new information, the uncertainties are bounded (or narrowed) through a process of elimination.

From Table 4, we can illustrate how shifting from large-hole to slim-hole drilling could alter resource insurance's feasibility. By disaggregating the costs, two things become apparent:

1. *Front-end uninsured costs are reduced substantially*, hence lowering the capital barriers to initiate pre-feasibility and exploratory work to establish the scope of the drilling program; and
2. *Sequential disbursements reduce* drilling related insurable costs by enhancing success rates by bounding risks with adequate use of new information, thereby embedding options to delay, accelerate, expand or abort.

Using ESMAP's estimates, the insurable drilling costs represent about a third of total geothermal generation costs[16]. The exploration and exploitation costs go into calculating the life cycle costs of steam, with the capital spending for power generation calculated under capital costs recovery and variable operating costs[17].

The CDKN study suggests that by de-risking geothermal exploration and exploitation, which is the riskiest segment shun by private capital, the remaining financing could be raised from capital markets or more conventional sources following, for instance, accepted project financing structures. In effect, geothermal insurance are real options that investors could acquire before committing to invest in development and power generation[18].

On CDKN's estimates, every $1 in public fund invested, up to $60 of private capital could be deployed. For failed wells, the resource insurance could partially reimburse the sums spent on drilling and exploration.

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[16] This is estimated in Rolffs, P. et al (2017). *Innovative risk finance solutions: Insights for geothermal power development in Kenya and Ethiopia*. London: Climate and Development Knowledge Network (CDKN).

[17] As shown in the life cycle costs of energy calculations, there are three costs components: a) capital costs recovery comprising the capital spend and an imputed return, C_{FX}; b) operating variable costs adjusted for inflation, and geothermal exploration and exploitation costs, C_{VAR}; and c) fuel costs equal to zero. For more details, please refer to Barcelona, R.G. (2017). *Energy Investments: An adaptive approach to profiting from uncertainties*. London: Palgrave Macmillan.

[18] This follows the logic that by investing a smaller sum on exploration, the potential steam volumes could be estimated. Subject to the outcomes, developers may opt to abandon, or exercise their option to develop the wells. This could be followed by a decision to sell the steam, or proceed to investing in power generation, where the steam is an important input to "fuel" the production of electricity.

What does the insurer get to gain for the privilege, or for their "altruism"?

In the absence of Indonesia-specific experiences, private insurance may need a helping hand from public funding to fully underwrite the losses from failed wells. We simulate the cost sharing in Table 5, where we estimate the breakeven between the premium earned less the costs of redeemed losses. The difference is covered by public funding.

Table 5. Breakeven Insurance Premia under Levels of Costs Shared

Columns	Premium Rates	8%	12%	16%	20%	24%	28%	32%	36%	40%	44%
		AL	BL	CL	DL	EL	FL	GL	HL	IL	JL
Rows	Costs Shared by Public Funding	Large Hole Geothermal Drilling - In $ millions based on two failed wells at 80% costs recovery									
1	10%	-5,70	-4,50	-3,30	-2,10	-0,90	0,30	1,50	2,70	3,90	5,10
2	15%	-5,25	-4,05	-2,85	-1,65	-0,45	0,75	1,95	3,15	4,35	5,55
3	20%	-4,80	-3,60	-2,40	-1,20	0,00	1,20	2,40	3,60	4,80	6,00
4	25%	-4,35	-3,15	-1,95	-0,75	0,45	1,65	2,85	4,05	5,25	6,45
5	30%	-3,90	-2,70	-1,50	-0,30	0,90	2,10	3,30	4,50	5,70	6,90
6	35%	-3,45	-2,25	-1,05	0,15	1,35	2,55	3,75	4,95	6,15	7,35
7	40%	-3,00	-1,80	-0,60	0,60	1,80	3,00	4,20	5,40	6,60	7,80
8	45%	-2,55	-1,35	-0,15	1,05	2,25	3,45	4,65	5,85	7,05	8,25
9	50%	-2,10	-0,90	0,30	1,50	2,70	3,90	5,10	6,30	7,50	8,70
10	55%	-1,65	-0,45	0,75	1,95	3,15	4,35	5,55	6,75	7,95	9,15
11	60%	-1,20	0,00	1,20	2,40	3,60	4,80	6,00	7,20	8,40	9,60
12	65%	-0,75	0,45	1,65	2,85	4,05	5,25	6,45	7,65	8,85	10,05
13	70%	-0,30	0,90	2,10	3,30	4,50	5,70	6,90	8,10	9,30	10,50
14	75%	0,15	1,35	2,55	3,75	4,95	6,15	7,35	8,55	9,75	10,95
Columns	Premium Rates	8%	12%	16%	20%	24%	28%	32%	36%	40%	44%
		AS	BS	CS	DS	ES	FS	GS	HS	IS	JS
Rows	Costs Shared by Public Funding	Slim Hole Geothermal Drilling - In $ millions based on three failed wells at 80% costs recovery									
1	10%	-3,32	-2,56	-1,79	-1,02	-0,25	0,52	1,28	2,05	2,82	3,59
2	15%	-3,05	-2,29	-1,52	-0,75	0,02	0,79	1,55	2,32	3,09	3,86
3	20%	-2,78	-2,02	-1,25	-0,48	0,29	1,06	1,82	2,59	3,36	4,13
4	25%	-2,51	-1,75	-0,98	-0,21	0,56	1,33	2,09	2,86	3,63	4,40
5	30%	-2,24	-1,48	-0,71	0,06	0,83	1,60	2,36	3,13	3,90	4,67
6	35%	-1,97	-1,21	-0,44	0,33	1,10	1,87	2,63	3,40	4,17	4,94
7	40%	-1,70	-0,94	-0,17	0,60	1,37	2,14	2,90	3,67	4,44	5,21
8	45%	-1,43	-0,67	0,10	0,87	1,64	2,41	3,17	3,94	4,71	5,48
9	50%	-1,16	-0,40	0,37	1,14	1,91	2,68	3,44	4,21	4,98	5,75
10	55%	-0,89	-0,13	0,64	1,41	2,18	2,95	3,71	4,48	5,25	6,02
11	60%	-0,62	0,14	0,91	1,68	2,45	3,22	3,98	4,75	5,52	6,29
12	65%	-0,35	0,41	1,18	1,95	2,72	3,49	4,25	5,02	5,79	6,56
13	70%	-0,08	0,68	1,45	2,22	2,99	3,76	4,52	5,29	6,06	6,83
14	75%	0,19	0,95	1,72	2,49	3,26	4,03	4,79	5,56	6,33	7,10

Source of raw data: Authors' calculations based on data from API, as presented to Ministry of Energy andMining Resources, November 2018.

Insurance premia vary with the levels that public funding shares with the costs recovered by developers on their failed wells. Without public funding sharing in the costs of claims, insurance premium rates would have to be set very high for any private insurers to participate. On our estimates, this would probably in excess of 25% of the drilling costs of the portfolio of the wells considered, assuming 80% of the costs are recovered. This is the obvious part.

Here is how the math works:

Let us consider the insured costs of large hole drilling for the 55 MW portfolio is estimated at $30 million. Applying an 8% insurance premium to column BL in Table 5, row 14, we obtain the following:

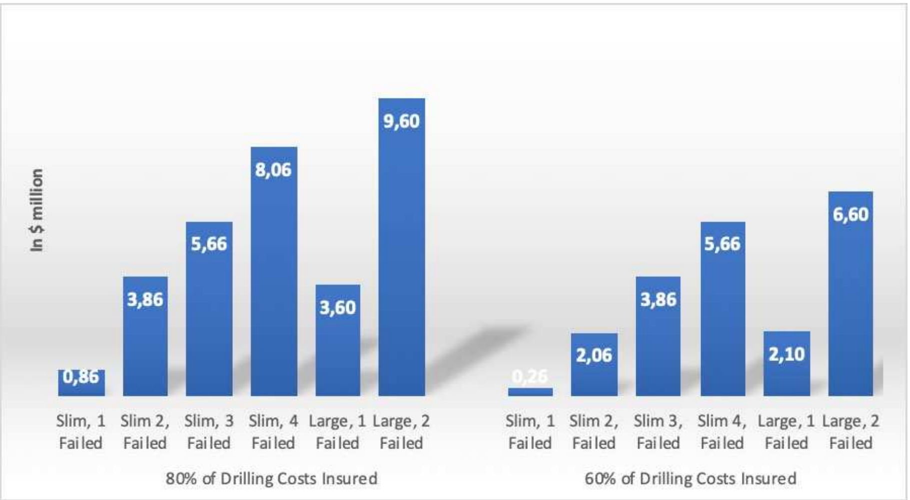
1. Insurance premium received is $2.4 million ($30 million * 0.08);
2. Cost of two failed large hole wells is $15 million ($3,000/meter * 2,500 meters * 2);
3. Costs recovered in (2) at 80% redemption of costs is $12 million ($15 million * 0.80);
4. Costs shared by public funding in (3) at 75% is $9 million ($12 million * 0.75);
5. Costs paid out by private insurer is $3 million ($12 million - $9 million); resulting in;
6. Gain to insurer of $0.15 million as shown in column AL, row 14 (AL,14).

Repeating similar calculations for a range of combinations, for large hole and slim hole wells, we complete Table 5 with the following observations:

1. Cash disbursements for failed wells are substantially lower for slim hole drilling, largely because of the lower drilling costs (hence, reducing insurable costs);
2. Public funding outlays are substantially lower than relying on the "government as developer" to underwrite the full drilling program, or self-insure the risks of failed wells.

We now try to ascertain how much is needed from public funding to make the resource insurance affordable to investors?

Chart 1. Costs Shared by Public Funding with Private Insurers



Source: Authors' calculations

We set the insurance premium at 8% of the insured costs from Table 4 for our illustration. To allow private insurers to offer this rate, public funding has to take up different levels of the payments to recover the costs of failed wells. Chart 1 compares the costs shared by public funding, under two costs recovery levels of 80% or 60%.

We now take the number of failed wells as proxy for "driller's" quality, where the lower the number the higher is the quality rating. The comparisons yield the following insight:

At an 8% insurance premium, large-hole portfolio of four wells would earn $2.4 million (8% of $30 million). One failed well would incur a redemption by the investor of $6 million (80% of $7.5 million), resulting in a premium shortfall $3.6 million. Repeating the same calculation, we obtain $0.86 million for each failed well using slim-hole drilling.

At this stage of the drilling, the relevant information is a yes/no outcome as to whether or not there is sufficient geothermal resource. Hence, the eventual output of steam that could generate a determinate MWh is not the principal consideration. The output is determined later as to how the well reservoir is designed and configured, once the source and volume of geothermal resource is estimated (or bounded).

Given this information, we can now convert what we know into a strategic or policy decision on two aspects of the venture:

1. Would the government benefit from being a cost sharer, or as a developer where it self-insures the geothermal drilling risks?
2. How do we make superior drilling performance (i.e. lower number of failed wells) matter?

PLN, as the executor of the "cheap" power policy, may opt to be the developer and self- insures any failed wells. This implies that PLN would disburse $7.5 million for every large- hole, or $3 million for slim-hole well, that fails. On a probability for the portfolio of two failed wells (large hole) or three (slim hole) respectively, PLN would incur losses of $15 million or $9 million[19]. Clearly, by co-underwriting in resource insurance, PLN minimizes its financial exposure that reduces the need for more government subsidies.

Insurers incentivizes investors and PLN to pursue a "flight to quality" in their contracting. By bounding the risks, the exposure is converted into insurable risks that allow differentiated pricing of the insurance. Hence, drillers with superior performance of getting to the resource with the least failed wells, would

[19] Iceland's North Tech indicates that in a number of areas, the drilling depth are less than 2,500 meters. The drilling costs could be adjusted accordingly by multiplying the depth drilled (in meters) by $1,200/meter to derive an approximate cost.

enjoy lower insurance premiums, on top of reducing total exploration and drilling costs.

PLN's creation of PLN Geothermal (PLN G) may offer a path to rechanneling grants and social capital to co-share in underwriting the redemption from resource risks insurance. In general, aids or grants hold no prospect of earning any return. Once disbursed, the attributed social or economic returns actually achieved could prove random.

To align grant-giving with Indonesia's objectives, particularly in alleviating energy poverty among isolated areas, grants could complement public funding in de-risking geothermal by recognizing this reality:

Faced with "dry wells", the donors are no worse off financially when their alternative is to give aid to worthy causes. With successful drilling, they may condition their grants so that part of the payoffs replenishes their aid funding. Hence, donors could demonstrate tangible social and economic impact on employment, local development, and community development.

4.4. Geothermal farms

Slim-hole drilling is given a boost by the emergence of economically viable small turbine geothermal generation. When both technologies are deployed, a geothermal farm could be scaled according to the size of the energy markets it seeks to serve. This is equivalent to turning accepted wisdom, at least under the American drilling traditions, on its head. This potentially opens the micro grid markets that to date was off-limits to large-hole geothermal power.

Reconfiguring how the steam is delivered, or converted into power, enhances slim-hole technology's competitiveness. Instead of collecting steam using expensive pipes networks, well-heads are redesigned to produce power at well-heads with up to 5 MW generation units. Borrowing from photovoltaic solar farms' playbook, the well-head generators are wired with similar configuration with one major difference: It produces more power per MW than solar farms.

As a result, power generation capital spending is reduced from $2.5 million/MW to $1.7 million/MW. As we illustrated in Table 2 previously (Columns J to M), we can now explicitly compare how LCOEs vary with drilling success rates, and technology choices, for similar levels of output.

V. What Next for Managers and Policy

We now integrate the various facets of policy and strategic approaches into a common framework to facilitate decision-framing, managing uncertainties and risks, and converting risks into profit opportunities. We refer to this framework as the ABCD of structured decision-making in Table 6, where each phase seeks to achieve the 4Cs to underline the venture's performance (or success).

Managers and policy tend to jump into problem-solving mode, where the solutions are heavily influenced by the decision-makers' prior experiences or beliefs. Indonesia is not immune from this tendency. Hence, the geothermal resource paradox is seen as a financing problem that could only be resolved with more subsidies, or government guarantees via PPAs. However, by ***articulating*** the problem we really need to address, informed by making the assumptions explicit, we could arrive at vastly different perspectives. In this case, we come to ***comprehend*** that the scale of costs and uncertainties associated with exploration and drilling far exceed any private investors' appetite to take on.

This initial insight allows us to find ways to ***bound*** the uncertainties, in order to ***calibrate*** the magnitude and the means to mitigate the associated risks. Using the various tools, we can identify the nature of the risks, the interests of the agents (or stakeholders), the limitations of the energy system, and the impetus for change or adaptation. Broken into specific areas, we come to the view that slim-hole drilling is an uncertainty-reducing tool. With its small-scale, the cost of gaining information on reserves, as derived from drilling, is substantially reduced compared to large-hole drilling.

Table 6. Structured Decision-making under Uncertainties – ABCD + 4Cs Framework

Structured Analytics and Engagement				Possible Tools	Areas of Influence and Actions	
Action	Scope	Purpose	Outcomes		Managerial Focus	Policy Focus
A	**Articulate the problem(s) we need to solve**	**C1**	**Comprehend**			
	Geothermal is superior resource		Why the funding difficulties?	Strategic dialogues	Surface assumptions, opportunities, and uncertainties	Clarify role(s) - regulagtor? developer? enabler?
			What impedes, what facilitates?	Scenarios; Portfolio Analysis	Deep analysis of business: Where are we? Where do we want to go?	Policy impact - continue or reframe?
B	**Bound the ucertainties**	**C2**	**Calibrate**			
	Large front-end costs, too risky		Who carries the risks?	Scenarios	Set out choices:	Set out policy choices:
	Lucrative payoffs if successful		Who benefits from payoffs?	Binomial trees	Large-hole or slim-hole drilling?	Geothermal vs coal?
	Aid low-carbon energy supplies		How PLN subsidies are reduced?	Option games	Risks to undertake, or offload?	Geothermal, coal and others?
	Reduce costs of supplies vs coal		What and how pathways are created?	Portfolio strategic options(1)	Pathways, and how do we get there?	Subsidies, cost-sharing, or what else?
C	**Convert to risks or opportunities**	**C3**	**Cost the choices**			
	Unbundled risks and payoffs		What are the trade-offs?	Binomial trees	Decide on strategic approaches by:	Decide on policy packages or approaches by:
	Sequence of cash use and payoffs		How do the trade-offs change?	Real options	Going the PPAs route or bust?	Enshrining into law or guidelines
	Alternative investment structures		What happens if we are wrong?	Option games (2)	Adopting the resource insurance?	Lead role as investor?
	Competitors may invest or not		How rival firms' values could change?		Innovating venture structures and execution?	Supporting role as enabler?
D	**De-risk the venture if feasible**	**C4**	**Commit or abandon**			
	Structure the financial security package		Proceed to drill and explore?	Portfolio strategic options	Manage venture actively:	Grandfather incentives, if any:
	Inject operational and strategic flexibility		Abandon or delay?	Option games	Drill - generate data - inform - decide	Pilot resource insurance scheme(s)
	Adaptive strategy, contingency, actions				Expand, contract, or abandon	Co-sharing of costs of redemption
					On successful drilling, contract with PLN	Insulate contracts from adverse change

Notes:
1. Barcelona, RG (2015). "Renewable energy with volatile prices: Why NPV fails to tell the whole story?". *Journal of Applied Corporate Finance* , 27 (1), 101-109.
2. Chevalier-Roignant, B. and Trigeorgis, L (2011). *Competitive strategy: Options and Games* . Boston: Massachusetts Institute of Technology Press.

Source: Principal author

Knowing who the potential owners of risks, and the interests and benefits each stakeholder could profit, we can now ***convert*** the bounded risks, and ***costs*** them accordingly. Following this reasoning, resource insurance could ***de-risk*** geothermal exploration and drilling when the apparently difficult to manage (by private capital) uncertainties are transformed into the foundations for creating insurance products. Public funding's role is converted from one that doles out money, into another that enables private capital to ***commit*** to a de-risked venture.

The experience to date of insurance specialists appears promising. Turkey and Kenya's geothermal investment growth is spurred partly by employing resource insurance. Once the resource risks are covered, private capital competes to stake their claim in a nascent geothermal market. Indonesia could clearly learn, and may even benefit, from such market driven instruments.

These insights serve some lessons for private capital and policy. The future of Indonesian geothermal power does not rely on having iron-clad PPAs. Its potential is unleashed, and realized, when the resource finding risks are made manageable for private capital.

An essential ingredient to sustain Indonesia's energy security, is to have an energy market that operates under competitive conditions. Strategic and operational flexibility follows, where just returns are rewards for risk-taking. In contrast, cuddling monopolies may only seek to perpetuate rent-seeking at the expense of its people, without any guarantee that the lights will be kept on.