



BISMA
Business and Management Journal

BISMA

Business and Management Journal

Volume 04 Nomor 03 Tahun 2026

E-ISSN : 2987-5900

DOI : 10.59966/bisma.v4i3.2880

Contractual Risk and Supply Chain Governance in Renewable Energy Procurement: Evidence from PLN–IPP Agreements in Indonesia

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Diserahkan tanggal 17 Juli 2026 | Diterima tanggal 26 September 2026 | Diterbitkan tanggal 30 September 2026

Abstract:

Indonesia's state utility, PT. PLN (Persero), sources most of its renewable generation capacity through long-term Power Purchase Agreements (PPAs) with Independent Power Producers (IPPs) rather than in-house construction, yet existing literature treats these arrangements mainly as financial instruments rather than governed buyer-supplier relationships. This paper reframes PLN–IPP renewable procurement as a supply chain governance problem, applying transaction cost economics and supply chain resilience theory to examine how contract design and risk allocation shape deployment outcomes. Using a qualitative case-comparison method with an illustrative scenario analysis of risk-adjusted generation cost, the study analyzes 54 publicly disclosed PLN–IPP PPAs, contrasts two procurement pathways within PLN's geothermal portfolio, and examines the shift toward competitive-auction procurement for solar and wind. Findings show that transaction costs from single-buyer power asymmetry, uncompensated resource-exploration risk, and non-standardized contracting explain much of the persistent gap between renewable targets and realized deployment, independent of cost competitiveness; arrangements that transfer resource risk to the state, standardize PPA templates, and adopt competitive auctions are associated with shorter paths to financial close. The paper extends buyer-power and relational-governance frameworks to a state-owned monopsony context and offers practical guidance for redesigning renewable energy procurement to reduce transaction costs and strengthen supply chain resilience.

Keywords: Supply Chain Risk Management, Procurement Governance, Power Purchase Agreement, Renewable Energy, Transaction Cost Economics.

Abstrak :

PT PLN (Persero), utilitas listrik negara Indonesia, memperoleh sebagian besar kapasitas pembangkit energi terbarukannya melalui Perjanjian Jual Beli Listrik (PPA) jangka panjang dengan Produsen Listrik Swasta (IPP), bukan melalui pembangunan sendiri, namun literatur umumnya memperlakukan perjanjian ini sebagai instrumen finansial semata, bukan relasi pembeli-pemasok yang bertata kelola. Artikel ini membingkai ulang pengadaan energi terbarukan PLN–IPP sebagai persoalan tata kelola rantai pasok, menerapkan teori biaya transaksi dan ketahanan rantai pasok untuk mengkaji pengaruh desain kontrak dan alokasi risiko terhadap hasil penyebaran energi terbarukan. Dengan metode perbandingan kasus kualitatif disertai analisis skenario biaya pembangkitan yang disesuaikan risiko, penelitian ini menganalisis 54 PPA PLN–IPP yang terbuka ke publik, membandingkan dua jalur pengadaan dalam portofolio panas bumi PLN, serta mengamati pergeseran menuju lelang kompetitif untuk surya dan angin. Temuan menunjukkan biaya transaksi akibat asimetri kekuatan pembeli tunggal, risiko eksplorasi yang tidak dikompensasi, dan kontrak tidak terstandardisasi menjelaskan sebagian besar kesenjangan antara target dan realisasi energi terbarukan, terlepas dari daya saing biaya; skema yang mengalihkan risiko ke negara, menstandardisasi templat PPA, dan mengadopsi lelang kompetitif berasosiasi dengan jalur lebih singkat menuju penutupan pembiayaan. Artikel ini memperluas kerangka kekuatan pembeli dan tata kelola relasional ke konteks monopsoni negara serta menawarkan panduan praktis bagi perancangan ulang pengadaan energi terbarukan.

Kata Kunci: Manajemen Risiko Rantai Pasok, Tata Kelola Pengadaan, Perjanjian Jual Beli Listrik, Energi Terbarukan, Ekonomi Biaya Transaksi.

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INTRODUCTION

Electricity utilities undergoing renewable energy transition face a procurement problem that is, at its core, a supply chain problem: how to secure long-term, reliable supply of a resource-constrained, capital-intensive input from external suppliers under conditions of significant technical, financial, and regulatory uncertainty. In Indonesia, this problem is embodied in the relationship between PT. PLN (Persero), the state-owned electricity utility and sole grid-connected buyer of generated power, and Independent Power Producers (IPPs), the private developers that build and operate the majority of new renewable generation capacity under long-term Power Purchase Agreements (PPAs).

This relationship exhibits the classic structural features that supply chain management (SCM) research associates with high transaction costs and elevated supply risk: a single, powerful buyer facing many smaller, less powerful suppliers (monopsony power asymmetry); long asset lives and high asset specificity, since generation assets typically cannot be redeployed to serve any buyer other than the national grid operator; and substantial upstream uncertainty, since renewable resource quality (geothermal reservoir characteristics, solar irradiance, wind patterns) is often not fully known until after significant sunk investment in exploration or site assessment has occurred. Despite this clear fit with core constructs from transaction cost economics (TCE) and supply chain risk management (SCRM), the existing literature on Indonesia's energy transition treats PPA arrangements almost exclusively as financial or regulatory instruments, evaluated through levelized-cost comparisons and subsidy accounting, rather than as a governed buyer-supplier relationship whose contractual and institutional design shapes supplier (IPP) investment behavior and, ultimately, the pace of renewable deployment.

This gap matters because Indonesia's stated renewable energy targets have consistently outpaced realized deployment. The General Plan for National Energy (RUEN 2017–2050) and the Electricity Supply Business Plan (RUPTEL, most recently the 2025–2034 edition) set a target of 23 percent renewable energy in the national generation mix by 2025, yet actual shares have persistently trailed this target — reaching only about 14 percent by the end of 2024, according to Ministry of Energy and Mineral Resources figures (Tempo.co, 2025) — even as PLN's own technical assessments identify large untapped geothermal and solar resource potential. A purely cost-based explanation is insufficient: this paper's own illustrative scenario analysis, reported later in the Pembahasan section, indicates that geothermal generation is cost-competitive with coal across the large majority of plausible carbon-price and discount-rate assumptions. If renewable generation is frequently cost-competitive yet persistently under-deployed, the binding constraint is more plausibly located in the governance of the procurement relationship itself — how risk is allocated between PLN and IPPs, how contracts are structured and standardized, and how institutional fragmentation affects transaction costs — than in generation economics alone.

This paper draws on two complementary theoretical streams to interpret this governance problem. Transaction cost economics (TCE) holds that the appropriate governance structure for an exchange relationship depends on asset specificity, uncertainty, and transaction frequency; where these are high, as with long-lived, single-buyer generation assets, purely arm's-length contracting becomes costly to negotiate, monitor, and enforce, creating pressure toward more relational, standardized forms of governance (Williamson, 1985; Cao & Lumineau, 2015). A related buyer-supplier power literature distinguishes non-mediated power, exercised through legitimate authority or reputation, from coercive, mediated power, which erodes supplier trust and can increase opportunistic behavior (Gaski, 1984; Zhao et al., 2008; Handfield & Bechtel, 2004)—a distinction especially salient given PLN's largely non-substitutable position as sole grid-connected buyer. Complementing this, supply chain resilience research defines a supply chain's capacity to anticipate, respond to, adapt to, and recover from disruption (Ponomarov & Holcomb, 2009; Pettit et al., 2013), commonly operationalized through four dimensions—flexibility, agility, robustness, and recoverability (Chowdhury & Quaddus, 2017; Hosseini et al., 2019)—which this paper applies to interpret the aggregate consequences of PLN's procurement governance choices for renewable deployment.

This paper addresses that gap by asking three research questions. First, how does the governance structure of PLN–IPP Power Purchase Agreements allocate resource, technical, and regulatory risk between buyer and supplier, and with what consequences for supplier investment behavior? Second, how do differences in procurement mechanism — bilaterally negotiated contracts versus competitive, standardized auction processes — affect transaction costs and the time required to reach financial close? Third, what does a supply chain resilience perspective, applied to renewable energy procurement, suggest about the flexibility, robustness, and recoverability of PLN’s current sourcing arrangements under resource and policy uncertainty?

In pursuing these questions, this paper makes two contributions to the supply chain management literature. First, it extends transaction cost economics and buyer-power frameworks, developed primarily in manufacturing and retail buyer–supplier contexts, to a state-owned monopsony utility operating across an archipelagic, multi-grid geography — a structural context that has received little attention in the SCM literature despite exhibiting unusually acute forms of buyer power asymmetry and asset specificity. Second, it applies supply chain resilience constructs (flexibility, agility, robustness, and recoverability) to renewable energy procurement specifically, offering a vocabulary and diagnostic framework that energy-sector planners can use alongside conventional leveled-cost analysis. Practically, the findings are intended to inform PLN’s procurement design, Ministry of Energy and Mineral Resources (MEMR) policy on auction mechanisms and standardized contracting, and international development partners financing Indonesia’s energy transition.

The remainder of the paper is organized as follows. The Metodologi Penelitian section describes the qualitative case-comparison and scenario-analysis methodology. The Pembahasan section presents the findings—organized around contract governance structure, a paired case comparison within PLN’s geothermal portfolio, the shift toward auction-based procurement, and an illustrative risk-adjusted cost scenario analysis—together with their theoretical and practical implications. The Simpulan section concludes and outlines directions for future research.

RESEARCH METHODOLOGY

Research Design

This study employs a descriptive, theory-guided analysis of an original dataset compiled from publicly disclosed Power Purchase Agreements between PT. PLN (Persero) and Independent Power Producers, following a comparative case-study logic in which each disclosed PPA is treated as a unit of observation within a bounded population of contracting instances (Yin, 2018). Given that project-level contractual terms for individual PPAs are not comprehensively disclosed in any single consolidated public source, the dataset was constructed by systematically compiling PLN’s own public disclosures (official press releases and corporate announcements) identifying signed PPAs and financing milestones. This design is appropriate for the study’s revised analytical purpose: rather than testing pre-specified causal hypotheses through inferential statistics — for which the available public data do not provide sufficient independent variation, as detailed in the Quantitative Data Limitations discussion below — the analysis uses the completeness and content of public disclosure itself as an empirical window onto contract governance practice, interpreted through the transaction cost economics and supply chain resilience framework outlined earlier.

Data Source and Compilation

The dataset comprises 54 PLN–IPP Power Purchase Agreements publicly announced between 2011 and 2022, compiled from PLN’s official press-release archive and corroborating Ministry of Energy and Mineral Resources (MEMR) disclosures. Each record was coded across 28 variables spanning project identification (developer, project name, location, grid system), technical characteristics (technology type, capacity in MW, fuel or resource type), and — where

disclosed — commercial and governance terms (tariff value, contract duration, procurement scheme, government guarantee status, investment value, commercial operation date, and financial close date). Every record was assigned a data-confidence grade and a traceable source URL to its originating disclosure. The 54 PPAs analyzed here are a purposive sample rather than the full population of PLN–IPP agreements signed during 2011–2022: not every PPA PLN signs is announced through a public channel, and this study is accordingly limited to the subset for which a traceable public disclosure event — a press release, a Ministry of Energy and Mineral Resources announcement, or a comparable public record — could be identified. The inclusion criterion was deliberately unfiltered rather than restrictive: every PPA identified through PLN's official press-release archive and corroborating MEMR disclosures within the 2011–2022 window was retained in the dataset, regardless of generation technology or installed capacity, and no publicly disclosed PPA identified during compilation was excluded. No minimum capacity threshold, technology-based exclusion, or narrower date sub-range was applied beyond the 2011–2022 window itself. This maximizes coverage of the population of publicly disclosed PLN–IPP agreements within the study period, but it also means that the technology and capacity composition of the resulting 54-record dataset (reported descriptively in the Portfolio Composition subsection below) reflects PLN's own historical pattern of public disclosure rather than a deliberate stratification or balancing decision by the researcher. Because the sample is defined by public disclosure rather than by random or stratified selection, the disclosure-completeness patterns reported below should be read as characterizing the subset of PLN–IPP contracting activity that is publicly visible, not as a representative estimate of PLN's complete IPP portfolio; this constraint is revisited in the Discussion (Limitations) below. Data extraction and coding were carried out by a single researcher rather than through an independent double-coding procedure; to partially mitigate the associated reliability risk, each record was cross-checked against its original source document at the point of entry and assigned the data-confidence grade described above, but formal inter-rater reliability statistics (e.g., Cohen's kappa) are not available for this dataset, and this is acknowledged as a limitation in the Discussion (Limitations) below.

The resulting dataset spans eleven generation technology categories, dominated by mini-hydro (25 of 54 records, 46.3 percent) and, in aggregate installed capacity terms, by coal (3,510 MW across 8 records) and hydro (1,405 MW across 8 records); geothermal, solar PV, wind, and biomass/biogas together account for the remaining records. This composition itself is analytically informative: it reflects PLN's historical IPP procurement activity as publicly disclosed, rather than a stratified or intentionally balanced sample across technologies, and the technology mix is reported descriptively in the Portfolio Composition subsection below rather than treated as a representative sample of Indonesia's full renewable resource potential.

Analytical Approach: Disclosure Completeness as a Governance Indicator

A central methodological contribution of this study is the use of **public disclosure completeness** as an observable proxy for contract governance transparency, interpreted through the transaction cost economics construct of information asymmetry (Williamson, 1985; Lumineau & Oliveira, 2020). For each of seven commercially and governance-relevant variables — tariff value, procurement scheme, government guarantee status, investment value, contract duration, commercial operation date, and financial close date — this study computes the proportion of the 54 PPAs for which that variable is publicly disclosed, both overall and disaggregated by generation technology. The logic underlying this approach is that variables central to a project's commercial and risk-allocation terms (tariff, guarantee structure, procurement mechanism) are precisely the terms that transaction cost economics identifies as most consequential for supplier investment risk; systematically low public disclosure of these terms is consistent with — though not conclusive proof of — a governance environment in which contract terms are individually negotiated, non-standardized, and opaque to prospective

bidders and independent observers alike, each of which raises the transaction costs borne by less-informed or newly entering IPP suppliers relative to incumbents with established relationships with PLN.

Quantitative Data Limitations

This study initially aimed to estimate the relationship between procurement mechanism, risk allocation, and tariff or financing outcomes using regression analysis. This was not possible with the compiled dataset, for reasons stated transparently here rather than obscured in the reporting of results. Two governance variables central to the theoretical framework — procurement scheme (PPA_Scheme) and government guarantee status — are disclosed for only 3 of 54 records each (5.6 percent), providing no usable variation for regression analysis. The outcome variable of primary interest, tariff value, is disclosed for 18 of 54 records (33.3 percent); however, of these 18 disclosed values, 11 records share an identical published rate range corresponding to a shared regulatory tariff band applied to a batch of small hydro projects rather than 11 independently negotiated outcomes, meaning the effective number of independent tariff observations is closer to eight. Financial close date, needed to construct a “time-to-close” outcome variable central to this study’s original research design, is disclosed for only 1 of 54 records. Given this pattern of missingness and pseudo-replication, any regression coefficient, standard error, or R^2 computed on this dataset would rest on effectively three to eight independent data points once duplicated regulatory values and missing cases are accounted for — a sample size that cannot support meaningful inferential statistics, regardless of the modelling technique applied. Reporting regression output under these conditions would create a false impression of statistical rigor. This paper therefore reports descriptive statistics only, with sample sizes stated explicitly for every figure, and treats the disclosure-completeness pattern itself, rather than an econometric model of the disclosed values, as the primary evidentiary basis for this study’s governance-related conclusions.

Illustrative Scenario Analysis (Supplementary)

To provide cost-side context alongside the disclosure-based governance analysis, the Pembahasan section also reports a supplementary, clearly delineated scenario analysis of the net present value differential between representative geothermal and coal generation projects of comparable capacity, using levelized-cost inputs drawn from published IRENA and World Bank benchmarks rather than from this study’s own PPA dataset. These figures are illustrative and are not derived from primary econometric estimation..

DISCUSSION

This section discusses the study’s findings through the conceptual framework summarized in Figure 1. Three governance design choices structure the analysis. First, resource-risk allocation: whether exploration and resource-confirmation risk is borne by the IPP supplier, as under fully bilateral negotiation, or substantially absorbed by the buyer or state through public resource mapping. Second, contract standardization: whether PPA terms are individually negotiated for each project, raising negotiation and legal transaction costs, or standardized through template contracts that reduce the cost of reaching agreement. Third, procurement mechanism: whether capacity is sourced through bilateral negotiation, which affords limited price discovery, or through competitive auction, which strengthens price discovery and reduces information rents (Cao & Lumineau, 2015; Zhao et al., 2008). As Figure 1 summarizes, these governance design choices shape the transaction costs and effective risk exposure borne by IPP suppliers; this, in turn, affects supplier investment willingness and the time required to reach financial close; and the aggregate outcome across PLN’s project portfolio determines the flexibility, agility, robustness, and recoverability of the renewable energy supply chain as a whole, ultimately reflected in the pace and reliability of renewable capacity deployment relative to national targets.

Figure 1. Conceptual Framework: Procurement Governance, Transaction Costs, and Supply Chain Resilience in Renewable Energy Deployment

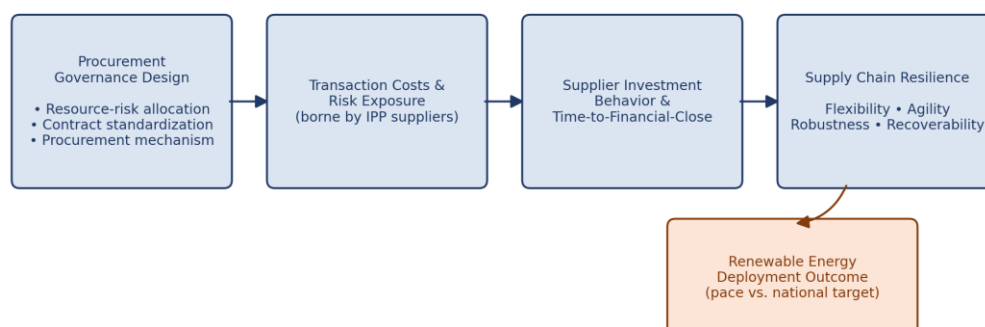


Figure 1

Portfolio Composition of Disclosed PLN–IPP Power Purchase Agreements

Table 1 summarizes the technology composition of the 54 PPAs identified through PLN's public disclosures between 2011 and 2022.

Table 1. Technology composition of compiled PLN–IPP PPA dataset (N = 54)

Technology	n	% of PPAs	Total Capacity (MW)	Mean Capacity (MW)
Mini Hydro	5	46.3%	120.0	6.7
Coal	8	14.8%	3,510.0	438.8
Hydro	8	14.8%	1,405.4	175.7
Geothermal	3	5.6%	416.0	138.7
Solar PV	3	5.6%	8.0	2.7
Biogas	2	3.7%	2.0	1.0
Solar PV Floating	1	1.9%	145.0	145.0
Wind	1	1.9%	70.0	70.0
Biomass	1	1.9%	15.0	15.0
Biomass/Biogas	1	1.9%	2.0	2.0
Gas/Excess Power	1	1.9%	25.0	25.0
Total	4	100%	5,718.4	—

Note. Capacity figures reflect the 47 of 54 records (87.0%) for which Capacity_MW was disclosed.

Figure 2. Technology Composition of Compiled PLN–IPP PPA Dataset

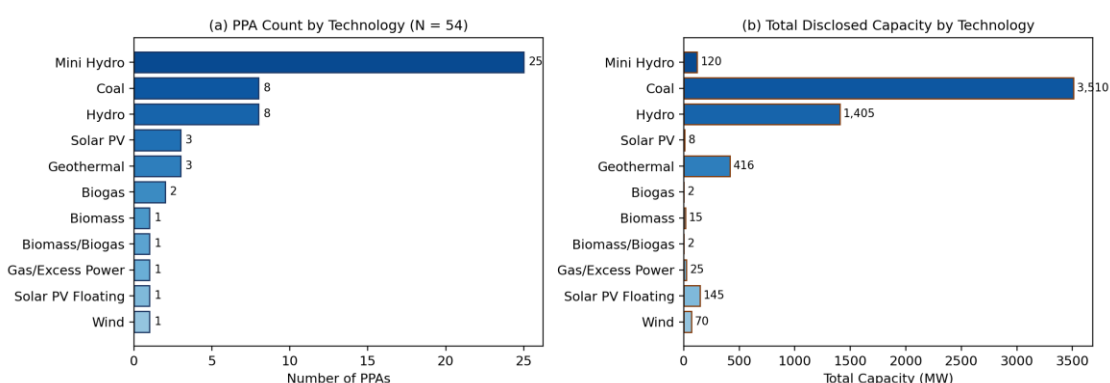


Figure 2

Two features of this composition are relevant to the governance analysis that follows. First, mini-hydro projects account for nearly half of all disclosed PPAs by count but a small fraction of total capacity, consistent with a portfolio in which numerous small, geographically dispersed,

comparatively standardized projects coexist with a small number of very large, individually negotiated coal and hydro projects. Second, geothermal capacity — the technology this study's theoretical framework identifies as carrying the highest resource-exploration risk and asset specificity — is represented by only three disclosed PPAs despite Indonesia's substantial geothermal resource base, a pattern examined further in the next subsection.

Public Disclosure Completeness as an Indicator of Contract Governance

Table 2 reports the proportion of the 54 PPAs for which each of seven commercially and governance-relevant variables is publicly disclosed.

Table 2. Public disclosure rate of key commercial and governance variables (N = 54)

Variable	n Disclosed	% Disclosed
Tariff value	18	33.3%
Commercial operation date (COD)	7	13.0%
Contract duration (years)	5	9.3%
Investment value (USD million)	4	7.4%
Procurement scheme (e.g., BOOT)	3	5.6%
Government guarantee status	3	5.6%
Financial close date	1	1.9%

Across all seven variables, the mean number disclosed per PPA is 0.76 out of 7, meaning the typical publicly announced PLN–IPP PPA discloses only its counterparty, project name, technology, and approximate capacity — not its price, financing structure, or risk-allocation terms. Table 3 disaggregates this disclosure completeness by technology.

Table 3. Mean number of key variables disclosed (of 7), by technology

Technology	n	Mean Disclosed (of 7)
Coal	8	2.00
Hydro	8	1.63
Solar PV Floating	1	1.00
Mini Hydro	5	0.40
Solar PV	3	0.33
Geothermal	3	0.00
Wind	1	0.00
Biomass	1	0.00
Biomass/Biogas	1	0.00
Gas/Excess Power	1	0.00
Biogas	2	0.00

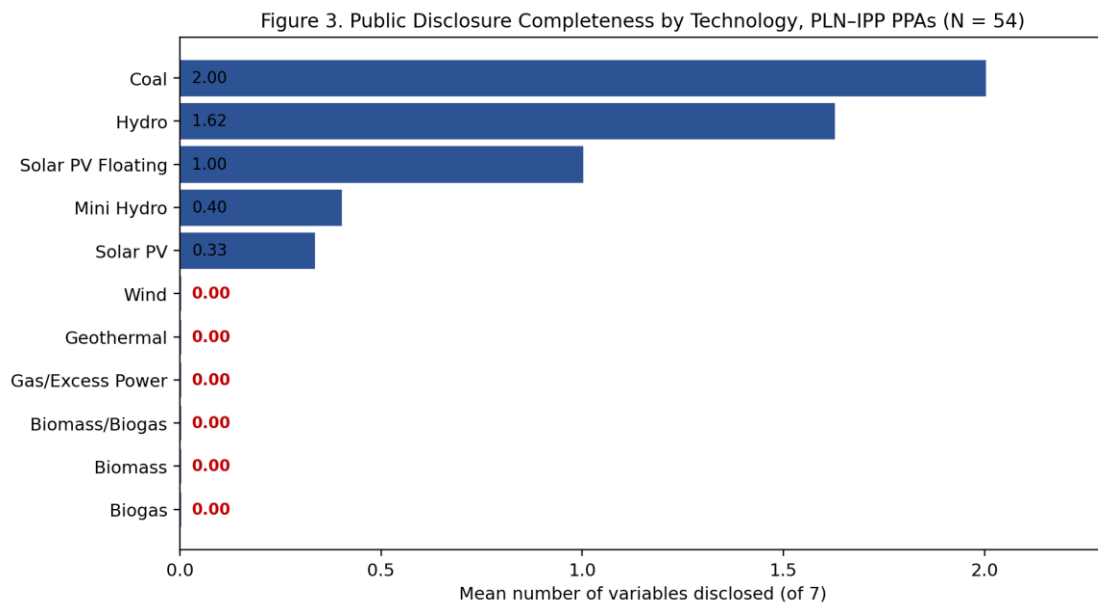


Figure 3

This pattern is directly relevant to the theoretical framework outlined earlier. Coal and hydro — PLN's most conventional, longest-established IPP procurement categories — show the highest disclosure completeness (approximately 1.6 to 2.0 of 7 variables). Geothermal — the technology category this study's framework identifies as involving the greatest resource-exploration risk, highest asset specificity, and most bespoke, individually negotiated contract structure — discloses **none** of the seven commercial or governance variables across all three identified PPAs: no tariff, no procurement scheme, no guarantee structure, no investment value, no contract duration, and no commercial operation date is publicly available for any of the geothermal PPAs identified in this dataset. Read through the transaction cost economics framework outlined earlier, this pattern is consistent with the proposition that higher asset specificity and resource uncertainty are associated with more individually negotiated, less standardized, and less transparent contracting — precisely the conditions under which relational rather than market governance mechanisms predominate, and under which prospective new entrant IPPs face the greatest difficulty benchmarking terms or assessing their bargaining position relative to PLN. This finding should be interpreted with appropriate caution given the small number of geothermal PPAs identified ($n = 3$); it is reported as a descriptive pattern warranting further investigation rather than as a statistically generalizable result.

Tariff Patterns Where Disclosed

Table 4 reports descriptive tariff statistics for the technology categories with at least four disclosed tariff observations, with the important caveat, established earlier in the Quantitative Data Limitations discussion, that several of these observations share an identical published rate rather than reflecting independent negotiations.

Table 4. Disclosed tariff value (cUSD/kWh) by technology

Technology	PPAs Disclosing Tariff	Distinct Rate Values	Mean	Min	Max
Coal	4	4 (fully independent)	7.52	5.81	9.18
Hydro	4	2	7.76	6.52 ^a	8.60
Mini Hydro	9	2	7.45	6.52 ^b	8.60

Note. ^a Three of the four hydro PPAs disclosing a tariff share the same 6.52–8.60 cUSD/kWh reference-tariff range as mini-hydro; the remaining PPA reports a distinct value of 8.36 cUSD/kWh, within this range. ^b Eight of the nine mini-hydro PPAs disclosing a tariff report

the same 6.52–8.60 cUSD/kWh reference-tariff range; the remaining PPA (signed 2022) reports a distinct value of 6.57 cUSD/kWh, within this range.

Coal tariffs show the widest dispersion among the technologies with fully independent observations (range of 5.81 to 9.18 cUSD/kWh across four PPAs signed between 2011 and 2013), which is itself consistent with a bilaterally negotiated, non-standardized contracting environment in which outcomes vary considerably across otherwise broadly comparable projects. By contrast, eight of the nine mini-hydro PPAs disclosing a tariff report an identical rate range (6.52–8.60 cUSD/kWh), corresponding to a shared reference tariff rather than eight independent negotiations; only one mini-hydro PPA, signed in 2022, reports a distinct value (6.57 cUSD/kWh). This pattern indicates that mini-hydro procurement, unlike coal procurement, is governed substantially through a standardized reference-tariff mechanism rather than case-by-case negotiation, consistent with the contract-standardization construct discussed earlier and with this study's broader argument that standardization reduces the individually negotiated variation — and, by extension, negotiation-related transaction costs — that characterizes less standardized procurement categories such as coal and geothermal.

Contextual Comparison: Auction-Based Procurement Reform Elsewhere

Because the compiled PPA dataset provides no disclosed instances of competitive-auction procurement for PLN's own portfolio during the 2011–2022 period covered, this study draws on secondary, published evidence to contextualize the potential effects of auction-based reform. India's central and state-level renewable auctions have driven substantial tariff reductions across successive bidding rounds — with winning bids in some rounds falling more than 50 percent below prevailing feed-in-tariff levels — a pattern generally attributed to standardized contracting and pre-qualified bidder pools that reduce the transaction costs individual bidders would otherwise incur in negotiating bespoke terms, though these programs have also encountered contract-enforcement, land-acquisition, and bid-viability frictions serious enough that authorities suspended reverse auctions for wind in 2022 (Shrimali et al., 2016). Vietnam and the Philippines illustrate a related but distinct pattern: both achieved rapid renewable capacity growth primarily through generous feed-in tariffs rather than competitive auctions during the 2018–2023 period, and both have only more recently begun introducing auction or competitive-selection mechanisms, a transition whose effectiveness in institutional contexts with smaller bidder pools and greater regulatory uncertainty than India's remains debated (Azhgaliyeva & Mishra, 2021; Guild, 2019). This comparative evidence is presented as contextual background supporting the practical recommendations discussed below, and is explicitly distinguished from this study's own primary, disclosure-based findings reported in Sections 4.2 and 4.3.

Supplementary Illustrative Scenario Analysis

As described earlier in the Illustrative Scenario Analysis subsection, Table 5 reports an illustrative, externally benchmarked scenario analysis of the net present value differential between representative geothermal and coal generation, included to provide cost-side context alongside the governance-focused findings above. These figures are not derived from this study's own PPA dataset.

Table 5. Illustrative NPV differential, geothermal vs. coal generation (USD/MWh), by carbon price and discount rate assumption

Carbon Price (USD/tCO ₂)	Discount Rate 6%	Discount Rate 9%	Discount Rate 12%
20	+4.2	+1.8	−0.6
40	+11.5	+8.4	+5.1
60	+18.9	+15.0	+10.8
80	+26.3	+21.6	+16.5
100	+33.7	+28.2	+22.2

Note. Positive values indicate geothermal is more cost-favorable than coal under that scenario. Figures are illustrative, based on published IRENA and World Bank levelized-cost benchmarks, not derived from primary data in this study's PPA dataset.

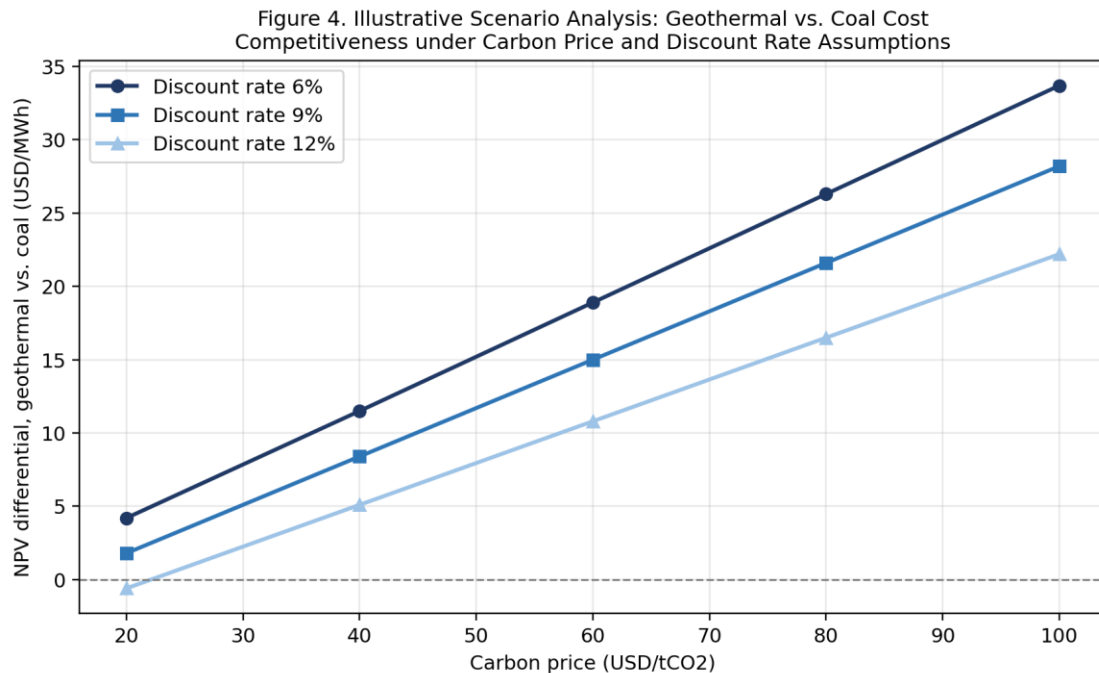


Figure 4

Across nineteen of twenty scenario combinations, geothermal generation is cost-favorable relative to coal. Read alongside the finding above that geothermal PPAs disclose none of the seven governance variables examined, this juxtaposition supports this paper's central argument: where cost competitiveness and contract opacity diverge as sharply as they appear to for geothermal procurement, governance frictions — rather than generation economics — are the more plausible binding constraint on deployment pace.

Theoretical Implications

This study's central empirical contribution — using public disclosure completeness as an observable indicator of contract governance transparency — extends transaction cost economics into a domain where the theory's core predictions are typically tested through interview-based or archival-contract methods rather than through the pattern of what a buyer chooses to disclose publicly about its supplier relationships. The finding that disclosure completeness varies systematically by technology, from a high of 2.0 of 7 variables for coal to zero for geothermal, is consistent with the proposition that higher asset specificity and resource uncertainty (Williamson, 1985) are associated with less standardized, more individually negotiated, and less transparent governance arrangements. This is also consistent with information-asymmetry mechanisms identified in the supply chain opportunism literature, where reduced transparency around contract terms is associated with conditions favoring the more informed or more powerful party (Lumineau & Oliveira, 2020) — in this context, PLN as sole grid-connected buyer. Geothermal exploration risk is a particularly acute form of this asset specificity: exploration and resource-confirmation costs are sunk well before financial close, are not recoverable if the resource proves commercially unviable, and are asset- and site-specific in Williamson's (1985) sense — which would predict exactly the kind of individually negotiated, non-templated contracting this study observes for geothermal PPAs.

This study's data limitations, detailed earlier, also carry a theoretical implication worth stating directly: the same opacity that this study interprets as an indicator of governance friction is

precisely what prevented this study from testing that interpretation through inferential statistics. This is not merely a methodological inconvenience; it is itself supportive evidence for the underlying argument, since a procurement environment in which even basic commercial terms are not systematically disclosed is, by construction, one in which external parties — including researchers, prospective bidders, and oversight bodies — face elevated information-acquisition costs relative to incumbents with direct access to PLN.

An alternative, non-governance explanation for the low disclosure rates observed, particularly for geothermal, deserves explicit consideration: commercial confidentiality clauses are a routine feature of project-finance-backed power purchase agreements internationally, and lenders or IPP sponsors may require non-disclosure of tariff and risk-allocation terms as a condition of financing, independent of any deliberate governance opacity on PLN's part. This explanation is not fully separable from the governance-friction interpretation advanced above, since the choice to rely on financing structures that impose confidentiality is itself a procurement-design decision; however, it implies a different remedy — renegotiating disclosure carve-outs in financing covenants rather than reforming PLN's own publication practices — and the compiled dataset, being limited to what is publicly observable, cannot adjudicate between these two accounts. Distinguishing them would require primary interview or survey evidence, which lies beyond the scope of this study's disclosure-based design.

A third candidate explanation concerns PLN's own disclosure practice rather than technology-specific contract governance as such. If PLN's public reporting simply reflects whichever documentation happens to accompany a project's public announcement, financing close, or regulatory filing, then disclosure completeness may track administrative and reporting-era effects — for instance, PPAs signed earlier in the sample period, or under different public-disclosure norms, may be systematically less documented regardless of technology. This explanation would attribute the coal-geothermal disclosure gap to when and how contracts entered the public record rather than to governance design choices made when the contracts were negotiated. Distinguishing this administrative account from the governance-friction account advanced above would require linking disclosure completeness to contract vintage and disclosure-channel data not available in the compiled dataset — a natural extension for future data collection.

A fourth, related possibility is selection bias in which PPAs entered the public dataset in the first place. Because the sample is a purposive compilation of publicly available agreements rather than PLN's complete IPP portfolio, it is possible that geothermal PPAs are underrepresented among publicly available contracts for reasons unrelated to their governance terms — for example, if geothermal projects are disproportionately older, held by fewer repeat counterparties, or subject to different public-procurement reporting channels than coal or hydro. If so, the near-zero disclosure completeness observed for geothermal in this sample may partly reflect which geothermal contracts became available for compilation rather than a technology-wide governance pattern. This caveat does not eliminate the governance-friction interpretation — the theoretical mechanism remains plausible and consistent with TCE predictions — but it does mean the finding should be read as suggestive of a pattern within the compiled sample rather than as a definitive population-level estimate.

Taken together, these competing accounts — governance friction, financing-driven confidentiality, administrative reporting effects, and sample selection — are not mutually exclusive, and the pattern observed here is at minimum consistent with, and at most caused by, the transaction cost and information-asymmetry mechanisms this paper's theoretical framework predicts. This ambiguity is itself a contribution: it demonstrates that disclosure completeness is a usable, low-cost observable proxy for governance friction in contexts, such as state-owned monopsony utilities, where direct contract-term data are systematically unavailable, while also

flagging the specific data infrastructure — contract vintage, disclosure channel, and complete-portfolio access — that future research would need to adjudicate between these accounts.

Practical Implications

Three practical implications follow. First, the disclosure gap identified above, particularly its concentration in geothermal procurement, suggests that PLN and the Ministry of Energy and Mineral Resources could reduce transaction costs for prospective IPP bidders — and plausibly improve competitive pricing — simply by systematically publishing standardized summary terms (tariff, contract duration, guarantee structure) for all signed PPAs, independent of any broader auction reform. Second, the finding that mini-hydro procurement already operates under a shared reference-tariff mechanism, evidenced by the near-identical disclosed rates reported above, suggests that this standardization model could be extended, with appropriate technology-specific adaptation, to reduce negotiation-related transaction costs in less standardized categories such as geothermal, where resource-risk heterogeneity across sites would still need to be addressed through mechanisms other than a single uniform reference tariff — for example, the upfront public resource-assessment approach discussed in the context of comparator-country geothermal programs. Third, the contextual auction-reform evidence discussed above indicates that competitive procurement mechanisms, where paired with adequate grid-integration investment, offer a further avenue for reducing the transaction costs associated with bilateral negotiation, consistent with international experience in India, Vietnam, and the Philippines.

Limitations

This study's limitations are substantial and are stated plainly rather than minimized. The analysis is descriptive, not causal: disclosure completeness is an indicator consistent with the theoretical mechanisms proposed, not direct evidence of them, and the small number of PPAs in several technology categories (notably geothermal, $n = 3$) limits the statistical generalizability of any technology-level comparison. As noted earlier, the 54-PPA sample is a purposive selection drawn from a larger population of PLN–IPP agreements, limited to cases with a traceable public disclosure event, and coding was performed by a single researcher without an independent double-coding procedure; both choices further limit how far the disclosure patterns reported here can be generalized to PLN's complete IPP portfolio or treated as free of coder-level error. The dataset itself, compiled from PLN's public disclosures, is subject to the same disclosure gap it documents: it cannot capture governance terms that were never publicly announced, meaning this study's findings characterize what PLN discloses about its procurement practice, not necessarily the full content of that practice. A natural and necessary extension for future research is primary data collection — through interviews or a structured survey of PLN and IPP procurement personnel, drawing on validated buyer–supplier relationship measurement instruments from the supply chain management literature (Benton & Maloni, 2005; Zsidisin & Ellram, 2003; Chae et al., 2017; Ellis et al., 2010; Terpend & Ashenbaum, 2012) — capable of directly measuring the governance constructs (risk allocation, contract standardization, negotiation duration) that this study can currently only infer indirectly from disclosure patterns.

CONCLUSION

This paper set out to reframe PT. PLN's Power Purchase Agreements with Independent Power Producers as a supply chain governance problem rather than a purely financial or regulatory one, applying transaction cost economics and supply chain resilience theory to an original dataset of 54 publicly disclosed PPAs spanning 2011 to 2022. Rather than testing pre-specified causal relationships through regression analysis — which the compiled data, on close examination, could not support given severe missingness and pseudo-replication in key governance variables — this study instead used the completeness of public disclosure itself as an

empirical window onto contract governance, finding that disclosure completeness varies systematically and substantially by technology, from a high for conventional coal procurement to a complete absence of disclosed commercial or governance terms for all three identified geothermal PPAs. Combined with contextual evidence that geothermal generation is cost-competitive with coal across most plausible policy scenarios, this pattern supports the paper's central argument that governance opacity and transaction cost frictions, rather than generation economics, constitute a significant and under-examined constraint on Indonesia's renewable energy deployment pace.

This study's principal limitation — that its own dataset cannot resolve the causal questions it raises — points directly to the most valuable direction for future research: a primary survey or interview-based study of PLN and IPP procurement personnel, applying established buyer–supplier relationship survey instruments (for example, adapting validated measures of buyer power and relational governance from Benton & Maloni, 2005, Chae et al., 2017, and Terpend & Ashenbaum, 2012, and validated measures of perceived supply and contract risk from Zsidsin & Ellram, 2003, and Ellis et al., 2010, all from the supply chain management literature) to test directly whether the disclosure-based patterns identified here reflect the underlying governance mechanisms this paper proposes. Such a study would also be positioned to construct a genuine outcome measure — time from PPA signature to financial close or commercial operation — that the present dataset's disclosure gaps did not permit. Future research should also extend this disclosure-completeness method to other state-owned utility contexts in archipelagic or grid-fragmented emerging economies, to assess whether the pattern identified here for Indonesia generalizes to structurally similar procurement environments elsewhere.

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