Vol. 7, No. 8, August 2026
E-ISSN:2723 – 6692 P-ISSN:2723– 6595
http://jiss.publikasiindonesia.id/

Risk-Based Feasibility Analysis of Battery Energy Storage System (BESS) Business Development Against Geopolitical, Technological, and Regulatory Threats: A Case Study of an Electricity Asset Management Company

Rakhmat Hidayat AB*, Muhammad Ahsin Sidqi
Institut Teknologi PLN, Indonesia
Email: rakhmat2310080@itpln.ac.id*, ahsin@itpln.ac.id

Keywords:
Battery Energy Storage System; Strategic Risk Management; Risk-Adjusted Return; Monte Carlo Simulation; Energy Transition

Abstract

This research aimed to formulate a risk-tested Battery Energy Storage System (BESS) business development strategy for the utility segment through the development of an Integrated Strategic Risk Management Framework. The study employed a mixed-methods approach with an exploratory case study design focusing on an electricity asset management company operating 762 power plants with a total capacity of 1,082 MW in remote, frontier, and outermost (3T) areas. Data were collected through interviews with five key informants, a review of internal documents from 2020 to 2025, relevant regulations (RUPTL 2025–2034, Minister of Energy and Mineral Resources Regulation No. 19/2025, and Presidential Regulation No. 112/2022), and industry reports from the IEA, BNEF, and Wood Mackenzie. The analysis was conducted in three stages: strategic analysis using PESTLE, Porter's Five Forces, VRIO, and quantitative SWOT; risk analysis using a probability–impact matrix and risk exposure calculations; and strategy–risk integration using risk creation and risk reduction analysis, the Risk-Adjusted Discount Rate (RADR), and a Monte Carlo simulation with 10,000 iterations. The results identified nine strategic risks, four of which were classified as critical, each with a score of 9, resulting in total risk exposure of IDR 765 billion relative to an investment of IDR 500 billion. The combination of Diversified and Integrated Risk Management, Service Differentiation, and 3T Niche Focus strategies generated an NPV of IDR 180–235 billion, an IRR of 26–30% at a RADR of 20%, a payback period of 4–5 years, and a 94.2% probability of achieving a positive NPV. This research operationalized the integration of risk and strategy in the context of BESS business development in emerging markets.

INTRODUCTION

The transformation (Zhu & Zhou, 2020) of the global energy system from dependence on fossil fuels toward renewable energy sources has placed decarbonization at the forefront of the global development agenda. The (Agency, 2023) affirmed that achieving the Net Zero scenario by 2050 requires halting approvals for new fossil fuel projects, while global renewable energy capacity additions reached approximately 510 GW in 2023. Increasing economic competitiveness has further strengthened this trend. (Lazard, 2023) reported that the Levelized Cost of Electricity (LCOE) for utility-scale solar power ranges from USD 24 to USD 96 per MWh, which in many regions is lower than the marginal operating cost of existing fossil fuel power plants.

The growing penetration of variable renewable energy sources creates a mismatch between electricity generation and demand profiles, commonly referred to as the duck curve in power systems with high levels of solar penetration (IRENA, 2022). Battery

Energy Storage Systems (BESS) have emerged as a flexible and responsive solution to address these challenges. Rather than functioning merely as passive energy storage, BESS can provide multiple grid services, including frequency regulation, voltage support, and rapid-response ancillary services with millisecond-level response times (Mahmoud & Ramadan, 2020a). Economies of scale driven by electric vehicle demand have reduced lithium-ion battery pack prices, which are projected to reach USD 108/kWh by 2025 (Veronika Henze, 2022), while (Mackenzie, 2024) projected that global energy storage capacity would increase fivefold by the end of the decade. In the commercial and industrial segments, BESS has also proven effective in reducing demand charges, which can account for 30% to 70% of total monthly electricity bills in the United States, thereby improving investment attractiveness (Dierauf et al., 2013).

However, the BESS industry remains highly vulnerable to geopolitical dynamics. The battery supply chain depends heavily on critical raw materials such as lithium, cobalt, nickel, and graphite, whose processing capacities are geographically concentrated; China controls nearly 90% of global processing capacity for several key materials (Bank, 2020) This concentration creates exposure to severe price volatility, export restrictions, and resource nationalism. From a technological perspective, the rapid evolution of battery chemistries—from nickel manganese cobalt (NMC) to lithium iron phosphate (LFP), as well as the commercialization of sodium-ion technologies and ongoing solid-state battery development—creates a risk of technological obsolescence that could prematurely reduce asset value (Chen et al., 2018; Ziegler & Trancik, 2021). From a regulatory perspective, the dependence of project feasibility on incentives, tariff structures, and market mechanisms makes policy changes a direct threat to BESS business models (Widiputranto et al., 2019).

In the Indonesian context, BESS plays a strategic role in supporting renewable energy integration across archipelagic power systems and remote, frontier, and outermost (terdepan, terluar, dan tertinggal [3T]) areas that are not adequately served by major transmission networks (Pratama et al., 2021). Indonesia's nickel downstreaming policy places the country in a distinctive position within the global battery value chain while simultaneously exposing it to potential international trade tensions (Siregar & Sitorus, 2022). These conditions place electricity asset management companies at a strategic crossroads, where substantial market opportunities coexist with significant operational, technological, regulatory, and geopolitical risks.

A review of the previous literature reveals a significant integration gap. Technical and operational studies have primarily focused on grid functions and capacity optimization ((Chen et al., 2018; Mahmoud & Ramadan, 2020b; Pratama et al., 2021), while economic studies have emphasized financial feasibility and cost structures (Lazard, 2023; Schmitz & Leoni, 2019; Widiputranto et al., 2019). Meanwhile, macro-level studies have highlighted supply chain and market risks (Woods, 2009). These perspectives have rarely been integrated into a unified decision-making framework. Consequently, business development functions oriented toward market opportunities may operate separately from risk management functions focused on loss mitigation, creating potential strategic blind spots in investment decision-making.

Addressing these gaps, this study aimed to: (1) analyze external environmental factors and internal capabilities to formulate BESS business development strategies for the utility-scale segment in Indonesia; (2) identify and prioritize key risks related to supply chains and geopolitics, technology and obsolescence, and regulation and licensing; (3) formulate an integrated strategic risk management framework; and (4) develop practical mitigation strategies and implementation recommendations. The novelty of this research lies in the development of an Integrated Strategic Risk Management Framework that uses high-impact risks as screening and testing variables for each strategic option, translates macro-level geopolitical risks into quantifiable enterprise-level risk priorities, and positions technological obsolescence as a strategic rather than merely operational risk.

This research contributes theoretically to the strategic management and risk management literature by integrating (COSO, 2017), the Resource-Based View (Barney, 1991), and (Porter, 1980) within the context of the energy transition. Practically, it provides strategic guidance for electricity asset management companies, a replicable investment evaluation model for the PLN Group, policy recommendations for regulators regarding hybrid tariffs and procurement mechanisms, risk-based project evaluation references for practitioners and investors, and a foundation for further academic research. Broader socioeconomic benefits include supporting the acceleration of the national energy transition, reducing dependence on fossil fuels, creating employment opportunities, strengthening energy security, and improving electricity service quality in 3T areas in support of community welfare and Indonesia's Net Zero Emissions target for 2060.

METHOD

Research Approach and Design

This research employed a mixed-methods approach with a predominantly qualitative design supported by semi-quantitative analysis. The qualitative approach was used to develop a comprehensive understanding of BESS strategic issues, industry dynamics, and stakeholder risk perceptions, while semi-quantitative analysis was applied during the risk assessment stage using a probability–impact matrix. The study adopted an embedded exploratory case study design focusing on an electricity asset management company operating 762 power plants with a total capacity of 1,082 MW in remote, frontier, and outermost (3T) areas. The research was conducted over six months and involved relevant internal and external stakeholders.

The study focused on formulating BESS business development strategies for the utility-scale segment and grid-connected systems in Indonesia. The analysis emphasized three high-impact risk categories: supply chain and geopolitical risk, technology and obsolescence risk, and regulatory and licensing risk. The study did not include battery cell-level technical validation or detailed power system network simulations.

Data Sources and Types

Primary data was obtained through semi-structured in-depth interviews with five key informants, consisting of senior management in the business development, corporate strategy, risk management, and technology units, as well as BESS experts from PT PLN (Persero) Pusat and practitioners of renewable energy associations. Secondary data is sourced from financial statements and internal company documents, regulatory documents, and international agency reports. Details of the research database are presented in Table 1.

Table 1. Research Database

Data Type	Source	Period
Financial statements	Company Internal	2020–2024
BESS project data	Nusantara IKN and PLTS project documents	2023–2025
Operational data	Company information system	2020–2025
Regulation	RUPTL, Minister of Energy and Mineral Resources Regulation 19/2025, Presidential Regulation 112/2022	2022–2025
Global industry	IEA, BNEF, Wood Mackenzie	2020–2025
Interview	5 Key informants	2025

Source: Processed from research data.

The validity of the data is maintained through source triangulation, namely the comparison of findings between informants from the perspective of regulators, corporates, and practitioners, as well as triangulation methods by verifying interview findings against secondary data from industry and policy reports. The framework and initial findings are then discussed through expert review with strategic and risk management experts.

Data Analysis Techniques

Data analysis was carried out gradually and iteratively following the three pillars of the framework that became the novelty of the research, as presented in Figure 1.

Figure 1. Integrated Strategic Risk Management Framework

Source: Author's construction.

Pillar I (strategic analysis) includes thematic analysis of PESTLE factors, structural analysis of Porter's Five Forces, capability assessment with the Resource-Based View based VRIO framework (Barney, 1991), capability gap mapping, and synthesis through quantitative SWOT to derive generic strategy options (Grant, 2020; Porter, 1980). Pillar II (risk analysis) refers to the COSO ERM framework (2017), specifically the risk assessment component and integrating risk with strategy, with a three-level assessment scale as presented in Table 2. The risk score is calculated as a multiplication of probability and impact, with a score of 9 categorized as critical, a score of 6 high, and a score of 4 moderate.

Table 2. Probability and Impact Assessment Scale

Scale	Probability	Impact
1	Low (<30%)	Loss <5% of project value
2	Moderate (30–60%)	Loss of 5–15% of project value
3	High (>60%)	Loss >15% of project value

Source: Processed from research data.

Risk exposure is calculated using the formula Risk Exposure = Investment Value × Probability × Impact, with a reference investment value of IDR 500 billion. Pillar III (strategy–risk integration) tests the resilience of each strategy option through risk creation analysis and risk reduction analysis, then assesses financial feasibility with a Risk-Adjusted Discount Rate (RADR) formulated as:

$$\mathbf{RADR = Rf + \beta \times (Rm - Rf) + Risk\ Premium}$$

with an Rf of 7% (10-year SBI), β of 1.2 (global BESS industry beta), and Rm of 15% (average yield of the Indonesian capital market), so that the CAPM component yields 9.6% which is rounded up to a 10% basic risk premium. Additional risk premiums are set specific to each strategy for geopolitical, technological, and regulatory dimensions. The durability of the results was tested through scenario analysis, sensitivity analysis, stress testing, and Monte Carlo simulations of 10,000 iterations. Throughout this article, the notation M refers to billion rupiah and T to trillion rupiah.

RESULTS AND DISCUSSION

Historical Performance and Internal Capabilities

Revenue grew 19.0% CAGR with the largest contribution from the engineering services segment at 45%. Operating profit grew 31.8% CAGR with an operating margin of 57.5% in 2024, far exceeding the industry average of 25–35%. Free cash flow increased from IDR 165 billion in 2020 to IDR 400 billion in 2024 (Johnson et al., 2014).

The company's funding capabilities for the initial phase of BESS investment are considered very strong. Free cash flows average Rp245 billion per year as a source of internal funding, cash position of Rp630 billion, a DER ratio of 0.5 times which provides room for additional debt, and access to green financing through the Indonesia Sustainability Forum 2025 commitment worth Rp278 trillion. Thus, the initial stage of BESS development is not entirely dependent on external funding.

The 8 MW BESS IKN project uses a portable configuration of five LFP containers in two clusters, equipped with integrated PCS, switchgear, automatic extinguishing system, and real-time monitoring; this project validates the integration capabilities of utility-scale BESS that operates 24 hours a day non-stop and becomes the operational standard for future projects. The 50 MW Nusantara Solar Power Plant project with a BESS of 14.2 MWh consists of 114,420 625 MWp bifacial PV modules and 126 LFP packages, with a production of 92.8 GWh per year and an emission reduction of 104,864 tons of CO_2 per year, and is supported by a strategic partnership with Sembcorp. The de-dieselization program of 5,200 PLTDs has the potential to reduce fuel subsidies by up to Rp21 trillion per year while creating a large-scale BESS market in the 3T area.

The aggregate advantage score of 8.67 out of 20 shows a position of competitive capability with two sources of sustained competitive advantage, namely the experience of plant operations in the 3T area and the pioneering of the BESS IKN project. In contrast, the gap analysis identified five capability gaps as presented in Table 3, with three high-priority gaps.

Table 3. Gap Analysis Capabilities

Capabilities	Current conditions	Conditions required	Gap	Priorities
EMS/Software	Supplier dependent	Internal mastery	Height	1
Human Resources of BESS members	Limited	Multidisciplinary team	Height	2
Portfolio Scale	8 MW	≥100 MW	Height	3
System integration	Pilot project	End-to-end	Medium	4
Supply chain management	Single supplier	Global diversification	Medium	5

Source: Author's analysis.

External Environmental Analysis

Macro environment mapping with the PESTLE framework resulted in an average score of 4.33 out of a maximum value of 5, indicating that the external environment strongly supports the development of BESS.

Key factors in the political dimension include Presidential Decree 112/2022 as the foundation for the energy transition, the 100 GW solar power plant program with 320 GWh BESS which requires an investment of USD 140–210 billion, and nickel downstream with a production target of 260–270 million tons by 2026. In the economic dimension, the gap between the 6,000 MW target and the realization of 5 MW is a great opportunity, supported by Rp278 trillion in green investment from the Indonesia Sustainability Forum 2025 and Danantara's commitment of USD 1.4 billion for the 100 GW program. In the technology dimension, battery prices fell by 89% during 2010–2025, sodium-ion entered mass production in the first quarter of 2025, and mastery of EMS became a regulatory necessity as well as a source of excellence.

This condition puts the risk of the concentration of critical raw material supply and commodity price volatility at the highest score of 9, followed by trade policy with a score of 6 and logistics disruptions with a score of 4. The reduction of the nickel quota in 2026 to 260-270 million tons from the previous 379 million tons strengthens the urgency of securing supply.

Asset degradation becomes a significant long-term cost variable. LFP capacity decreased to 90% in the fifth year and 80% in the tenth year with a life cycle of 5,000–6,000, NMC to 85% and 70% with cycles of 2,000–3,000, while sodium-ions became 88% and 75% with cycles of 3,000–4,000. Using the exponential decay model at a rate of 15% obsolescence per year, the value of the threatened assets is calculated as Rp500 billion × (1 − e^(−0.15×5)) = Rp264 billion. This means that an investment of IDR 500 billion in one type of technology risks losing IDR 264 billion in five years if there is a technological shift.

In the regulatory dimension, the 2025–2034 RUPTL sets a BESS target of 4.3 GW with an additional 10.3 GW, allocates 73% of new capacity for IPPs, and requires an investment of IDR 2,967 trillion. The Minister of Energy and Mineral Resources Regulation 19/2025 on hybrid power plants defines the combination of technology with BESS at one point of interconnection, regulates the configuration of EBT+BESS, EBT+EBT+BESS, and EBT+BESS+non-EBT, determines procurement through direct selection by PLN, implements price ceilings and price floors, and requires EMS in every system with BESS. The supporting regulatory framework includes business licensing for the supply of electricity as stipulated in the Minister of Energy and Mineral Resources Regulation 26/2021 and domestic component level requirements based on Permenperin 16/2021 which stipulates incentives for local assembly and cell manufacturing targets after 2028, with the 2021–2030 RUPTL as its predecessor planning document. The absence of a hybrid tariff numerical figure is a major source of uncertainty; with an elasticity of 1.5, a tariff uncertainty of ±20% has the potential to change the IRR by up to 30% (ΔIRR = 1.5 × 20% = 30%).

The attractiveness of the industry is structurally rated low to moderate at a score of 1.2 out of 5. The intensity of competition was strengthened by the Sembcorp pipeline of more than 1.4 GWh, the Gamuda project of 400 MWh, the tender of 1,165 MW of Mentari Nusantara-I PLTS, and PLN's intragroup competition. The combination of a highly supportive macro environment (4.33/5) with low structural attractiveness (1.2/5) results in a strong strategic implication: excellence cannot be derived from an industry position, but must be sourced from internal capabilities, in particular differentiation through EMS and integrated services and a focus on 3T niches that are not dominated by global competitors.

Quantitative SWOT Synthesis and Strategy Options

An internal score of 2.15 (S − W = 4.15 − 2.00) and an external score of 0.30 (O − T = 4.60 − 4.30) place the company in the quadrant of an aggressive growth-oriented strategy. A thin external score confirms that the magnitude of the opportunity is almost entirely offset by the magnitude of the threat, so growth can only be achieved if accompanied by a measurable risk mitigation program. The SWOT matrix produces four groups of strategy options, namely S-O in the form of service differentiation and 3T focus, W-O in the form of technology partnerships, S-T in the form of diversification and risk management, and W-T in the form of strengthening internal foundations. The six strategy options that were further tested were S1 (Service Differentiation), S2 (3T Niche Focus), S3 (Cost Leadership), S4 (Technology Partnerships), S5 (Diversified and Integrated Risk Management), and S6 (Strengthening Internal Foundations).

Strategic Risk Identification and Measurement

Risk identification is carried out through three approaches, namely thematic analysis of interviews of five key informants, analysis of regulatory documents and industry reports, and threat extraction from PESTLE and SWOT analyses.

Mapping the nine risks into the probability–impact matrix is presented in Figure 2. Four risks occupy the high probability and high-impact quadrants, namely R1, R2, R4, and R7, so they require immediate mitigation in the range of 0–6 months.

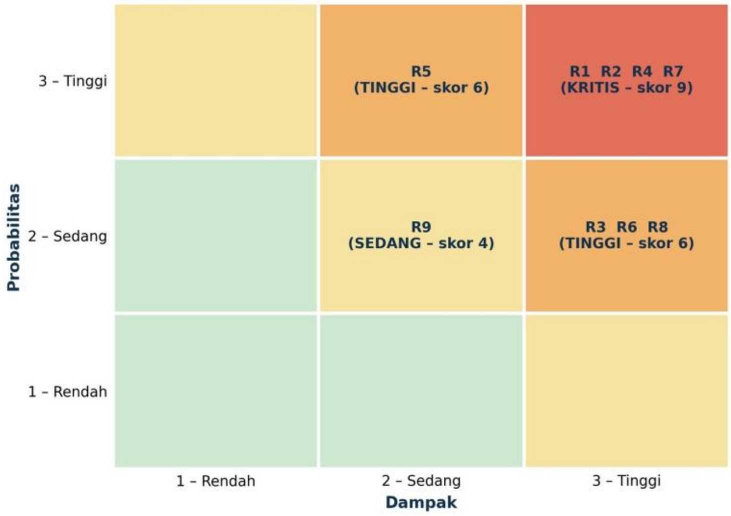

Figure 2. BESS Business Development Strategic Risk Map
Source: Author's analysis.

The total risk exposure of IDR 765 billion to an investment of IDR 500 billion shows that potential losses can exceed the value of the investment if several risks occur simultaneously. These findings are reinforced by a risk compounding analysis that identifies three mutually reinforcing combinations, namely R1 and R2 where supply concentration exacerbates price volatility, R4 and R6 where supplier dependency inhibits the adoption of new technologies thereby magnifying the risk of stranded assets, and R7 and R8 where both regulatory risks reinforce total revenue uncertainty. In the worst-case composite scenario, namely worsening geopolitical tensions, a 50% increase in lithium and nickel prices, a drastic shift to sodium-ion, the setting of hybrid tariffs too low, and the lifting of tax incentives, project costs rise by 40–60% and revenues fall by 30–50% so that the IRR slumps from 26% to below 10%. The probability of this scenario is low, which is 10–15%, but the impact is very high.

Risk Mitigation and Cost–Benefit Analysis

The mitigation framework is structured with a key strategy of reduction for all risks, supported by transfers for R1, R2, R3, R4, R5, and R9, avoidance for R6, and limited acceptances for R7 and R8. Mitigation plans are specific to each category. In the geopolitical and supply chain categories, activities include the identification of at least three alternative suppliers in 0–6 months with a budget of Rp2–5 billion, long-term contracts in 6–12 months worth Rp5–10 billion, sodium-ion pilots in 12–24 months worth Rp50–100 billion, localization of BESS assembly in 18–36 months worth Rp100–200 billion, and the establishment of a 10–15% cost buffer in 0–3 months worth Rp50–75 billion. In the technology category, activities include the preparation of a BESS technology roadmap worth IDR 500 million, modular design worth IDR 2-5 billion, internal EMS investment worth IDR 50-75 billion with a prototype target of 12-18 months and commercialization of 24-36 months, recruitment of 15-20 engineers worth

IDR 15-20 billion, and sodium-ion pilots worth IDR 50-100 billion. In the regulatory category, activities include the establishment of a policy advocacy team worth IDR 1-2 billion, the preparation of a hybrid tariff white paper worth IDR 500 million, participation in at least three policy forums worth IDR 2-3 billion, the development of an Energy as a Service business model worth IDR 2-5 billion, and the implementation of international safety standards worth IDR 2-5 billion.

In aggregate, the total estimated mitigation cost of Rp380-735 billion consists of Rp207-390 billion for the geopolitical and supply chain category, Rp119-205 billion for the technology category, and Rp54-140 billion for the regulatory category. The mitigation yield was positive for all critical risks, with the highest ratios at R4 (chemical transition) and R1 (CRM concentration). R7 mitigation is classified as the most cost-effective because the benefits are large and low cost, while R6 mitigation is neutral-positive as a long-term strategic investment.

Financial Models and Risk-Adjusted Valuation

The financial model is prepared based on basic assumptions in the form of an initial investment of IDR 500 billion for BESS with a capacity of 50 MW, annual revenue of IDR 120 billion from basic revenue stacking, operational costs of IDR 30 billion including degradation, net cash flow of IDR 90 billion before mitigation costs, and a project life of 10 years. The revenue structure is sourced from BESS sales worth IDR 50–100 billion per project, EMS services IDR 10–50 billion per license, Energy as a Service IDR 20–50 billion per contract, frequency regulation IDR 5–15 billion per year, energy arbitrage IDR 5–20 billion per year, after-sales services IDR 5–10 billion per year, and technology licenses IDR 10–30 billion per year.

The determination of RADR per strategy is presented in Table 4, with risk premiums detailed according to geopolitical, technological, and regulatory dimensions.

Table 4. Risk-Adjusted Discount Rate per Strategy

Strategy	CAPM	Geopolitics	Technology	Regulation	Total premium	RADR
Q1: Service Differentiation	10%	2%	1%	2%	5%	22%
Q2: 3T Niche Focus	10%	2%	2%	1%	5%	22%
Q3: Cost Leadership	10%	4%	4%	3%	11%	28%
Q4: Technology Partnerships	10%	3%	1%	2%	6%	23%
S5: Diversification & MR	10%	1%	1%	1%	3%	20%
S6: Foundation Strengthening	10%	2%	1%	2%	5%	22%

Source: Author's analysis.

The lowest RADR is held by S5 at 20%, which reflects the best risk profile, while the highest RADR is held by S3 at 28% due to a combined risk premium of 11%.

If the mitigation benefits are taken into account as additional annual revenue, the feasibility of the three best strategies increases significantly: S5 earns an additional Rp12 billion per year so that NPV becomes Rp180–235 billion with an IRR of 26–30%; S1 received an additional IDR 15 billion per year so that NPV became IDR 120–155 billion with an IRR of 24–26%; and S2 received an additional IDR 10 billion per year so that the NPV became IDR

100–135 billion with an IRR of 22–24%. The reconciliation model shows an adjustment in the form of mitigation costs of −Rp60–100 billion, an increase in revenue from optimal revenue stacking of +Rp120 billion over ten years, and cost efficiency from corporate synergies of +Rp30 billion, so that the final NPV is in the range of Rp180–235 billion with a payback period of 4–5 years. The assumption verification confirms that the IDR 500 billion CAPEX is conservative on BNEF and industry data, while the assumptions of revenue, OPEX, project lifespan, and 20% RADR are considered valid.

Strategy Resilience Test

Cross-strategy comparisons show that S1 and S2 remain viable in the base case, optimistic, and pessimistic scenarios, but marginal in critical scenarios; S6 is feasible in the base case and optimistic, marginal in pessimistic, and not feasible in critical; S4 is marginal in the base case and only feasible in optimistic scenarios; while S3 is not feasible in all scenarios except marginal in optimistic scenarios. Only S5 survives very well in the first two scenarios while remaining viable in pessimistic scenarios.

The sensitivity analysis placed battery prices and electricity/hybrid tariffs as variables with very high influence but low level of control, EMS/software capacity as variables with high influence and high control, followed by critical raw material prices and government policies with high influence but low control, as well as the availability of expert human resources with moderate influence and high handling. Tornado analysis measured that a change in battery price of ±30% changed

NPV of ±60%, hybrid tariff change ±20% changed NPV ±40%, EMS capacity increase of 50% increased NPV 25%, and change in price of critical raw materials ±20% changed NPV ±20%. By implication, battery prices and tariffs require hedging and buffering strategies, while EMS capacity is the only high-value lever that is fully under the company's control so it deserves priority.

The results of stress testing for four stress scenarios are presented in Table 5.

Table 5. Results of Stress Testing S5 Strategy

Scenario	**Description**	**Impact of NPV**	**NPV**	**IRR**	**Status**
Geopolitics	US-China conflict, critical minerals embargo	−70%	IDR60 M	18%	Marginal
Technology	Sodium-ion replaces LFP in 3 years	−60%	IDR 80 M	19%	Marginal
Regulation	The rate is set at 30% below the base case	−55%	IDR 90 M	20%	Worthy
Composite	All scenarios occur simultaneously	−90%	IDR20 Billion	14%	Not eligible

Note: The impact is calculated from the NPV base case of Rp200 M.

Source: Author's analysis.

The Monte Carlo simulation of 10,000 iterations was run assuming normal battery price distribution (μ = USD 70/kWh; σ = USD 15/kWh) referring to BNEF (2025), triangular hybrid tariff (minimum 80; most likely 100; maximum 120) referring to the Minister of

Energy and Mineral Resources Regulation 19/2025, normal revenue (μ = Rp120 million; σ = Rp20 million), normal operating costs (μ = Rp30 million; σ = Rp5 million), and uniform degradation (minimum 15%; maximum 25%) refers to Chen et al. (2018). The results of the distribution are presented in Table 6.

Table 6. Monte Carlo Simulation Results 10,000 Iterations for S5 Strategy

Statistics	**NPV Distribution**	**Statistics**	**IRR Distribution**
Red	IDR215 M	Red	25,8%
Median	IDR210 Billion	Median	25,5%
Standard deviation	IDR85 Billion	Standard deviation	6,2%
5^{th} percentile	IDR70 Billion	5^{th} percentile	15,2%
95^{th} percentile	IDR360 M	95^{th} percentile	36,4%
NPV probability > 0	94,2%	IRR probability > RADR (20%)	87,6%
NPV Probability > IDR 100 Billion	82,5%	–	–
NPV Probability > IDR 200 Billion	51,3%	–	–

Source: Author's analysis.

The NPV distribution of the S5 strategy is skewed to the right, giving the potential for a large increase, with a probability of loss of only 5.8%. A comparison of the results of the simulation between strategies is presented in Table 7.

Table 7. Comparison of Monte Carlo Simulation Results Between Strategies

Strategy	**Mean NPV**	**Prob. NPV > 0**	**Mean IRR**	**Prob. IRR > RADR**	**Std. dev. IRR**	**Risk–return ratio**
Q1: Differentiation	IDR145 M	88%	23,2%	78%	5,8%	4,00
Q2: 3T Focus	IDR125 M	85%	22,8%	75%	5,5%	4,15
Q3: Cost Leadership	−Rp35 M	32%	14,5%	15%	8,2%	1,77
Q4: Technology Partnerships	IDR 5 Billion	52%	17,8%	35%	7,5%	2,37
S5: Diversification & MR	IDR215 M	94,2%	25,8%	87,6%	6,2%	4,16
S6: Foundation Strengthening	IDR 95 Billion	78%	21,5%	68%	5,2%	4,13

Source: Author's analysis.

The S5 strategy produces the highest return as well as the best risk-reward ratio of 4.16, followed by S2 of 4.15, S6 of 4.13, and S1 of 4.00. In contrast, S3 shows the worst profile with a ratio of 1.77 and a probability of a positive NPV of only 32%, which confirms that cost leadership strategies cannot be executed by companies that do not master the battery cell supply chain.

Integration of Strategy–Risk and Investment Decisions

The strategy resilience testing was carried out through two complementary analyses. Risk creation analysis showed that S1 worsened R6 (technology dependency), S2 worsened R7 (tariff uncertainty), S3 worsened R1, R2, and R4 simultaneously with a creation score of 4.3 out of 5, S4 worsened R1, R3, and R6 with a score of 3.7 out of 5, while S5 and S6 had the lowest risk creation score of 1.0. Risk reduction analysis of the nine risks resulted in an average score of 2.44 for S5, 2.22 for S1, 2.11 for S2 and S6, 2.00 for S4, and 1.11 for S3. The combination of the two analyses forms an integrated decision matrix as presented in Table 8.

Table 8. Integrated Decision Matrix

Strategy	NPV	IRR	Risk reduction	Risk creation	Net risk impact	Mitigation costs	Total score	Ratings
S5	IDR 180–235 M	26–30%	2,44	1,0	+1,44	Rs60–100 M	4,8	1
S1	IDR120–155 M	24–26%	2,22	1,5	+0,72	IDR 50–75 M	4,4	2
S2	IDR 100–135 M	22–24%	2,11	2,0	+0,11	IDR 30–50 M	3,8	3
S6	Rp75–110 M	19–22%	2,11	1,0	+1,11	Rp40–70 M	3,7	4
S4	−IDR 20 to IDR 15 M	16–19%	2,00	3,7	−1.70	IDR 80–120 M	2,2	5
S3	−Rp50 to −Rp25 M	12–15%	1,11	4,3	−3.19	Rp100–150 M	1,5	6

Source: Author's analysis.

The evaluation of the effectiveness of control reinforces the urgency of internal improvement. The controls over R2, R3, R6, and R7 were rated as low effectiveness, while controls over R1, R4, R8, and R9 were moderately effective; the highest gap is found in R1, R2, R6, and R7. The control design effectiveness score is still below target 4 out of 5 for all controls, namely supplier diversification of 2.5, volatility buffer 2.0, modular technology 2.0, EMS development 1.5, policy advocacy 1.5, and revenue stacking 2.0, so the gap ranges from 1.5 to 2.5 points. In the operational effectiveness dimension, all controls have not been implemented so that improvement priorities are set sequentially on the development of internal EMS (0–24 months), the formation of policy advocacy teams (0–12 months), supplier diversification (0–18 months), and the adoption of modular technologies (6–24 months).

Testing of investment decision criteria is presented in Table 23. All quantitative criteria are met.

Table 9. Testing Investment Decision Criteria on S5 Strategy

Criteria	Minimum score	S5 Reach	Status
NPV	> IDR100 M	IDR 180–235 M	Fulfilled
IRR	> RADR (20%)	26–30%	Fulfilled
Payback period	< 5 years	4–5 years	Fulfilled
Profitability index	> 1.2	1,36–1,47	Fulfilled
ROCE	> 15%	22–26%	Fulfilled

Criteria	Minimum score	S5 Reach	Status
NPV probability > 0	> 80%	94,2%	Fulfilled

Source: Author's analysis.

In the qualitative criteria, conformity with PLN's mandate, conformity with 3T advantages, and management support are considered very adequate, while human resource readiness, technological readiness, and regulatory support are still in a moderate status, requiring recruitment, EMS development, and advocacy. Thus, the recommended investment decision is GO with the main strategy of S5 combined with S1 and S2, accompanied by four requirements, namely the implementation of risk mitigation as planned, the completion of internal EMS development within 24 months, active policy advocacy, and the achievement of a minimum scale of 50 MW in three years.

Implementation is carried out through a five-stage stage-gate mechanism, namely scoping (0–6 months), feasibility (6–18 months), development (18–30 months), execution (30–48 months), and operation (48–168 months), with gate criteria requiring positive NPV and IRR above RADR at Gate 2, cost suitability ±10% and schedule ±3 months at Gate 4, as well as ROI above 15% in the third year and ESG compliance at Gate 5. Continuous control is carried out through a risk appetite statement with an NPV parameter of at least IDR 100 billion, an IRR of at least 22%, a maximum payback of 5 years, a minimum reliability of 99%, and zero safety incidents, as well as through the Early Warning Indicator in the form of less than three active suppliers, an increase in the battery price index of more than 20% in three months, a decrease in LFP market share below 70%, tariff regulatory status that has not been finalized for more than 12 months, the proportion of projects without internal EMS above 50%, and significant changes in incentive policies. Monitoring is carried out monthly by the risk team, quarterly by risk management, semi-annually by the board of directors, and annually by the board of commissioners.

The implementation roadmap is prepared in three phases as presented in Table 10, with a total investment need of Rp1-1.2 trillion.

Table 10. Three-Phase Implementation Roadmap

Phase	Period	Key focus and targets	Budget
Phase 1: Building the foundation	2026–2027	Internal EMS development (operational prototype, Rp50–75 M); recruitment of 20 expert human resources (Rp15 billion); diversification of 3 suppliers (Rp5–10 M); BESS 3T pilot project in 3 locations (15 MW, Rp150 M); volatility buffer of 10–15% (Rp50–75 M); advocacy team (Rp1–2 million); international safety standards (Rp2–5 M)	Price: $273–382 million
Phase 2: Measurable expansion	2028–2029	BESS 3T expansion of 50 MW (Rp500 M); commercialization of EMS in 10 projects (Rp100 million); adoption of modular technology 100% of new projects (Rp10–20 M); sodium-ion exploration (Rp50–100 M); localization of assembly ≥30% of components (Rp50–100 M); advocacy of final tariffs (Rp2–5 million); 3-project EaaS model (Rp20–30 M)	IDR 732–855 M

Phase	Period	Key focus and targets	Budget
Phase 3: Market leadership	2030–2034	BESS 3T market share 30%; total portfolio ≥100 MW; 50 MW C&I expansion; commercial-scale sodium-ion adoption of 10–20 MW; regional expansion of 1–2 ASEAN countries; EMS leadership with 50% of the domestic market and licenses to more than 20 customers.	–

Source: Author's analysis.

The targeted portfolio composition is 30 MW in the 3T segment, 20 MW in the utility-scale segment, and there is no allocation in the commercial and industrial segments in 2028, which will grow to 60 MW, 40 MW, and 20 MW in 2034, so that the total portfolio increases from 50 MW to a minimum of 100 MW. Diversification is pursued in four dimensions, namely geographical (3T and urban), technology (LFP and sodium-ion), segment (3T, utility, and CSI), and revenue (multi-source).

The findings of this study expand the results of previous studies on three aspects. First, if Pratama et al. (2021) and Mahmoud and Ramadan (2020) stop at the affirmation of the technical role of BESS in network stability and EMS optimization, this study brings these findings into the realm of strategic decisions by placing EMS mastery as the highest priority weakness (priority gap 1, design effectiveness score of 1.5 out of 5) as well as a leverage of NPV valued at +25%. Second, if Widiputranto et al. (2019) identified regulatory risk as a qualitatively major barrier, this study measured it explicitly through the elasticity of $\Delta IRR = 1.5 \times 20\% = 30\%$ and placed R7 as a critical risk with an exposure of Rp105 billion. Third, if the IEA (2023) and Wood Mackenzie (2024) expose the risk of supply concentration at the macro level, this study reduces it to the micro level of the company in the form of measured exposures and geopolitical risk premiums that make up the RADR.

The most notable finding was the contrast between the PESTLE score of 4.33 out of 5 and the industry's attractiveness of 1.2 out of 5. This contrast explains why the cost leadership strategy (S3) failed across the test: with maximum supplier bargaining power (5/5) and product commoditization, the price-based strategy actually increases exposure to R1, R2, and R4 simultaneously, resulting in a risk creation score of 4.3 out of 5, a RADR of 28%, and a probability of a positive NPV of only 32%. In contrast, strategies that structurally reduce risk (S5) obtain the lowest RADR of 20%, so that the reduction in the cost of capital itself is a source of value creation. In other words, in industries with low structural appeal, risk management is not just a supporting function but a direct component of returns.

Theoretically, this study makes four contributions. First, the formulation of a three-pillar Integrated Strategic Risk Management Framework that connects strategic analysis, risk analysis, and strategy–risk integration in a single decision flow. Second, the expansion of the Resource-Based View through the identification of the 3T region's operational experience as a context-specific sustained competitive advantage. Third, the operationalization of the principle of integrating risk with strategy from COSO ERM (2017) into measurable instruments in the form of risk creation and risk reduction scores. Fourth, adaptation of RADR through the addition of BESS-specific risk premiums for geopolitical, technological, and regulatory dimensions.

Practically, the results of the study provide BESS investment guidance for research object companies, business development blueprints for PLN Group, policy formulation input for regulators, project evaluation references for energy industry players, and theoretical frameworks for academics. This study has limitations in the form of a single case study design, a risk assessment that is partly sourced from five key informants, and a financial model that relies on the assumption of battery prices, tariffs, and capital costs for the 2025 period, so the generalization of the findings needs to be done carefully.

CONCLUSION

This study concludes that the business development strategy for utility-scale BESS in Indonesia can be effectively formulated through the simultaneous assessment of the company's external environmental attractiveness and internal capabilities. PESTLE analysis yielded a score of 4.33 out of 5, indicating a highly supportive macroenvironment, whereas Porter's Five Forces analysis produced an industry attractiveness score of 1.2 out of 5 due to strong supplier bargaining power, high capital intensity, and a single-offtaker structure. VRIO analysis identified two sources of sustained competitive advantage, namely operating experience across 762 plants with a total capacity of 1,082 MW in the 3T areas and the company's pioneering role in the 8 MW BESS IKN project. These capabilities were supported by strong financial performance, with revenue of IDR 3.25 trillion and net profit of IDR 159 billion in 2024, as well as a revenue compound annual growth rate (CAGR) of 19.0%. The quantitative SWOT synthesis positioned the company in the aggressive quadrant, with S–W and O–T coordinates of 2.15 and 0.30, respectively. A strategic risk management framework can be integrated into decision-making through a three-pillar model that identifies nine strategic risks, with category weights of 24 for geopolitical risk, 21 for technological risk, and 19 for regulatory risk. Four risks were classified as critical, each with a score of 9: critical raw material supply concentration (R1), price volatility (R2), battery chemistry transition (R4), and hybrid tariff uncertainty (R7), with total risk exposure of IDR 765 billion. Mitigation programs requiring investments of IDR 380–735 billion were found to be cost-effective because they could reduce risk exposure by 50–80%. The integration of risk into investment decisions was operationalized through a 20% risk-adjusted discount rate (RADR), a stage-gate mechanism, a risk appetite statement, and early warning indicators (EWIs).

The most optimal and applicable strategy is a combination of Diversification and Integrated Risk Management (S5) as the primary strategy, reinforced by Service Differentiation (S1) and a 3T Niche Focus (S2). This combination resulted in an NPV of IDR 180–235 billion, an IRR of 26–30% at a 20% RADR, a payback period of 4–5 years, and a 94.2% probability of achieving a positive NPV based on a Monte Carlo simulation with 10,000 iterations. It also generated the highest risk-reduction score of 2.44, the lowest risk-creation score of 1.0, and an integrated decision score of 4.8 out of 5. The recommended investment decision is GO, supported by a three-phase roadmap for the 2026–2034 period and an estimated investment requirement of IDR 1.0–1.2 trillion. Thus, sustained competitive advantage in Indonesia's utility-scale BESS market can be achieved through a differentiated niche strategy implemented in conjunction with a measurable risk mitigation program rather than through capacity expansion alone. Further research is recommended to empirically validate strategy implementation after three to five years; expand the research scope to private independent power producers (IPPs) and other ASEAN countries; conduct techno-economic studies integrating power-system or grid simulations with laboratory validation (Laboratory, 2023); compare alternative battery chemistries; examine advanced regulatory frameworks for hybrid tariff mechanisms; and investigate sustainability issues related to battery waste management, recycling, and the circular economy.

REFERENCES

Agency, I. E. (2023). *Net zero roadmap: A global pathway to keep the 1.5°C goal in reach — 2023 update*. IEA. https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach

Bank, W. (2020). *Minerals for climate action: The mineral intensity of the clean energy transition*. World Bank.

Barney, J. B. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, *17*(1), 99–120. https://doi.org/10.1177/014920639101700108

Chen, X., Fan, Y., & Li, R. (2018). Optimization of battery energy storage system capacity considering degradation and replacement strategy. *Applied Energy*, *219*, 233–242. https://doi.org/10.1016/j.apenergy.2018.03.043

COSO. (2017). *Enterprise risk management---integrating with strategy and performance*. COSO.

Dierauf, T., Growitz, A., Kurtz, S., & Hansen, C. (2013). Weather-Corrected Performance Ratio Technical Report NREL/TP-5200-57991. *Technical Report NREL/TP-5200-57991*, (AprilNREL/TP-5200-57991).

Grant, R. M. (2020). *Contemporary strategy analysis* (10th ed.). Wiley.

Johnson, G., Scholes, K., & Whittington, R. (2014). *Exploring strategy: Text and cases* (10th ed.). Pearson Education Limited.

Laboratory, N. R. E. (2023). *Battery storage demand charge reduction analysis*. NREL. https://www.nrel.gov/docs/fy23osti/87081.pdf

Lazard. (2023). *Lazard's levelized cost of energy analysis—Version 16.0*. Lazard Ltd. https://www.lazard.com/research-insights/2023-levelized-cost-of-energyplus/

Mackenzie, W. (2024). *Global energy storage market outlook update: Q1 2024*. Wood Mackenzie Ltd.

Mahmoud, M. S., & Ramadan, H. S. (2020a). Review on battery energy storage systems for grid applications: Applications and management. *Journal of Energy Storage*, *29*, 101313.

Mahmoud, M. S., & Ramadan, H. S. (2020b). Review on battery energy storage systems for grid applications: Applications and management. *Journal of Energy Storage*, *29*, 101313. https://doi.org/10.1016/j.est.2020.101313

Porter, M. E. (1980). *Competitive strategy: Techniques for analyzing industries and competitors*. Free Press.

Pratama, H. D., Muslim, M., & Heryana, N. (2021). A study on the potential implementation of energy storage system (BESS) batteries in electric power systems in Indonesia. *ITS Engineering Journal*, *10*(2), F218–F223.

Schmitz, J., & Leoni, G. (2019). Accounting and auditing at the time of blockchain technology: A research agenda. *Australian Accounting Review*, *29*(2), 331–342. https://doi.org/https://doi.org/10.1111/auar.12286

Siregar, Y., & Sitorus, E. P. (2022). Challenges and opportunities for Indonesia's nickel downstream policy in the global battery supply chain. *Journal of Social and Political Sciences*, *26*(3), 209–224. https://doi.org/10.22146/jsp.69543

Veronika Henze. (2022). Lithium-ion Battery Pack Prices Rise for First Time to an Average of $151/kWh. *BloombergNEF*.

Widiputranto, D., Suryono, S., & Hartono, B. (2019). Analysis of the economic feasibility of using communal-scale energy storage batteries in Indonesia. *Journal of Electrical*

Engineering, *15*(4), 213–221.
Woods, M. (2009). A contingency theory perspective on the risk management control system within Birmingham City Council. *Management Accounting Research*, *20*(1). https://doi.org/10.1016/j.mar.2008.10.003
Zhu, K., & Zhou, Y. (2020). Digital transformation in the energy sector: Value creation through smart battery management system and data analytics. *Energy Policy*, *147*, 111875. https://doi.org/10.1016/j.enpol.2020.111875
Ziegler, M. S., & Trancik, J. E. (2021). Re-examining rates of lithium-ion battery technology improvement and cost decline. *Energy & Environmental Science*, *14*(4), 1635–1651. https://doi.org/10.1039/D0EE02681F