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Selective CAPEX-to-OPEX Transformation in Electricity Infrastructure Asset Management: Financial Trade-offs and Governance Implications for PT PLN (Persero)

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Abstract

PT PLN (Persero) faces increasing pressure to expand and modernize electricity infrastructure while maintaining financial resilience, operational reliability, and technological adaptability. This study examines the strategic implications of selectively transforming infrastructure investment from capital expenditure (CAPEX)-based ownership toward operational expenditure (OPEX)-oriented arrangements. The study employed an integrated analytical design, combining documentary analysis, global benchmarking, financial scenario simulation, cost–benefit analysis, and regulatory assessment. The simulation assumes total investment requirements of Rp2,780 trillion for 2025–2034, a 2024 CAPEX baseline of Rp63.45 trillion, and the transfer of 70% of generation investment to Independent Power Producers while 30% of generation and 100% of transmission and distribution remain under PLN CAPEX. The results show a clear trade-off. Interest-bearing debt decreases by 6.75%, and the Debt Service Coverage Ratio increases by 3.8%, while OPEX rises by 24.88%, EBITDA declines by 36.99%, operating income by 7.63%, net income by 9.93%, ROA by 7.0%, and leverage increases by 48.1%. The cost–benefit analysis further shows that OPEX generates higher estimated ten-year benefits of Rp1,598.62 trillion than CAPEX at Rp726.45 trillion, whereas CAPEX produces a higher benefit–cost ratio of 17.01 than OPEX at 8.83. These findings indicate that OPEX should not be treated as a universal substitute for CAPEX. Instead, the optimal configuration is a selective portfolio in which OPEX or hybrid arrangements are applied to technologically dynamic and contractible assets, while strategically critical and long-lived infrastructure remains under direct ownership. The study contributes a contingent asset-governance perspective that integrates asset characteristics, financial consequences, risk allocation, and governance requirements in infrastructure investment decisions.

Keywords: CAPEX–OPEX transformation; strategic asset management; electricity infrastructure; servitization; cost–benefit analysis; risk allocation; PT PLN (Persero).

A. INTRODUCTION

Electricity utilities increasingly must reconcile three competing priorities: maintaining system reliability, financing infrastructure renewal, and adapting rapidly to technological change. For capital-intensive utilities, these pressures are especially significant because network expansion, asset replacement, digitalization, and energy-transition investments traditionally require substantial capital expenditure (CAPEX). At PT PLN (Persero), this challenge is reflected in the continuing need to expand and modernize electricity infrastructure while managing rising electricity demand, ageing assets, and financing constraints. The existing manuscript reports national electricity demand growth of approximately 6–7% annually, around 30% of distribution assets requiring renewal, and potential project cost overruns of 20–40%, accompanied by delays of up to 30%. Retain these figures as reported in the study, but explicitly identify the corresponding BPK and ESDM institutional documents in the final reference list. More broadly, ageing infrastructure, reliability requirements, and asset replacement have become central strategic concerns for electricity distribution systems (Alvarez-Alvarado et al., 2022; Shaghaghi et al., 2024).

These pressures are intensifying as electricity networks become increasingly digital. Smart grids, smart meters, supervisory control and data acquisition systems, predictive maintenance, advanced analytics, and Internet of Things technologies are changing both the technological architecture and investment logic of electricity distribution systems. Digitalization can improve asset visibility, reliability, maintenance planning, and resource allocation, but it also requires substantial investment and introduces

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risks of technological obsolescence (Monaco et al., 2024; Mortensen et al., 2024). Recent research demonstrates that electricity utilities must increasingly choose between conventional network reinforcement and digital investment alternatives whose effects on reliability, tariffs, and long-term system performance differ considerably (Leiva Vilaplana et al., 2025). Consequently, asset-management decisions are no longer limited to determining how much infrastructure to purchase; they increasingly concern which assets to own, which functions to contract out, and how to allocate financial and technological risks across organizational boundaries.

In this context, the shift from CAPEX-intensive asset ownership to operational expenditure (OPEX)-based arrangements has become strategically relevant. Such arrangements may include service contracts, leasing, subscription-based infrastructure, outcome-based contracting, and power purchase agreements. Conceptually, this transition relates to servitization, in which organizations shift from ownership-centered business models to service- and outcome-oriented arrangements (Vandermerwe & Rada, 1988; Baines et al., 2009; Kohtamäki et al., 2019). In Electricity and other infrastructure sectors, however, such transformation should not be interpreted as a simple accounting reclassification from CAPEX to OPEX. Rather, it represents a strategic decision concerning asset ownership, contract architecture, financing structure, technological risk, and organizational control. Previous research also cautions that servitization does not automatically improve financial performance; service-oriented transformation may increase flexibility while simultaneously generating new operational costs, organizational complexity, and profitability pressures (Gebauer et al., 2005; Neely, 2008/2009). This trade-off is particularly important for regulated utilities, where investment decisions affect not only corporate financial performance but also system reliability, public-service obligations, and long-term infrastructure resilience.

The existing literature provides several relevant but fragmented perspectives. Research on electricity asset management has examined ageing infrastructure, maintenance optimization, digitalization, and investment prioritization (Cambini et al., 2016; Mirshekali et al., 2024; Shaghaghi et al., 2024), while regulatory studies have highlighted the possibility of CAPEX bias and the risks associated with OPEX-intensive regulatory structures (Brunekreeft & Rammerstorfer, 2021). A separate stream of servitization literature explains how firms transition from asset ownership toward service ecosystems and outcome-based arrangements (Visnjic et al., 2017; Kohtamäki et al., 2019), whereas infrastructure-finance and public-private partnership research emphasizes contractual risk allocation and the role of private capital (Abednego & Ogunlana, 2006; Fleta-Asín & Muñoz, 2021; Nur et al., 2023). Accounting studies further demonstrate that the financial consequences of lease-based arrangements depend substantially on the contractual structure because IFRS 16-type arrangements may generate both right-of-use assets and lease liabilities rather than automatically producing an off-balance-sheet outcome (Morales-Díaz & Zamora-Ramírez, 2018; Górowski et al., 2022; Lopes & Penela, 2025). Nevertheless, these streams have rarely been integrated to explain how a state-owned electricity utility should evaluate a selective CAPEX-to-OPEX transformation across heterogeneous infrastructure assets.

This gap is particularly relevant to PT PLN (Persero). The strategic question is not whether CAPEX or OPEX is universally superior, but rather under what asset, financial, technological, and governance conditions an OPEX-oriented arrangement becomes preferable to direct asset ownership. This distinction matters because the financial consequences may move in opposite directions. The scenario analyzed in this study—transferring 70% of generation to Independent Power Producers while retaining 30% of generation and 100% of transmission and distribution under PLN CAPEX—produces precisely such a trade-off. The simulation reports lower interest-bearing debt and improved debt-servicing capacity, but simultaneously higher operating expenditure, lower EBITDA and profitability, and substantially higher leverage. The study's cost-benefit analysis similarly shows a higher benefit-cost ratio for CAPEX (17.01) than for OPEX (8.83), indicating that OPEX cannot be justified purely through conventional financial-efficiency ratios.

Accordingly, this study examines the strategic implications of selective CAPEX-to-OPEX transformation in PT PLN's electricity infrastructure asset management. It pursues four objectives: (1) to examine the strategic rationale and potential benefits of CAPEX-to-OPEX transformation; (2) to identify relevant international practices and lessons applicable to PLN; (3) to evaluate the financial, accounting, fiscal, legal, and governance implications of the transformation; and (4) to assess its economic implications through financial simulation and cost-benefit analysis. Rather than treating OPEX as an inherently superior alternative, the study adopts a contingent perspective in which asset characteristics, technological obsolescence, strategic control, financing flexibility, contractual risk allocation, and governance capacity determine the appropriateness of alternative asset-management arrangements. In doing so, the study contributes to the literature on strategic asset governance by linking servitization, infrastructure finance, electricity asset management, and contract governance within the institutional context of a regulated state-owned utility.

B. LITERATURE REVIEW

Strategic Asset Management in Electricity Infrastructure

Electricity infrastructure asset management involves more than maintaining physical equipment; it requires systematically allocating financial, technological, and organizational resources across assets with different lifecycles, criticality levels, failure risks, and replacement requirements. In electricity distribution systems, asset-management decisions must reconcile reliability objectives with lifecycle costs, investment constraints, and changing technological conditions (Alvarez-Alvarado et al., 2022; Shaghaghi et al., 2024). This makes investment strategy particularly complex for utilities because infrastructure assets typically have long economic lives, high sunk costs, and direct implications for public service continuity.

Traditional utility investment has generally been organized around asset ownership. Under this model, utilities finance network expansion, substations, transformers, equipment, and other infrastructure primarily through CAPEX and then recognize them as long-term assets. Such ownership can preserve operational control and provide long-term access to strategic infrastructure, but it also requires substantial upfront capital and exposes utilities to financing, depreciation, replacement, and technological-obsolescence risks. Electricity-sector regulation may further influence this choice because conventional regulatory frameworks can create incentives favoring capital expenditure over operating expenditure, generating what Brunekreeft and Rammerstorfer (2021) describe as CAPEX bias.

The increasing digitalization of electricity networks complicates this traditional investment logic. Smart meters, advanced sensors, communication infrastructure, predictive-maintenance platforms, cloud-based systems, and analytics technologies generally have shorter innovation cycles than conventional grid assets. Consequently, the economic life of a physical network component may differ substantially from the technological life of the digital systems attached to it. Recent research demonstrates that digital investments can improve network monitoring and reliability, but their economic attractiveness depends on system characteristics, investment costs, technological development, and the alternative value of conventional grid reinforcement (Monaco et al., 2024; Leiva Vilaplana et al., 2025). Predictive asset-management systems similarly allow utilities to prioritize replacement and maintenance spending based on asset condition and reliability consequences rather than relying exclusively on predetermined replacement cycles (Mirshekali et al., 2024; Mortensen et al., 2024).

Accordingly, the relevant strategic question is not whether to eliminate asset ownership, but whether different categories of electricity infrastructure require different ownership and contracting arrangements. Long-lived and strategically critical network infrastructure may continue to justify direct ownership, whereas technologically dynamic or highly contractible assets may offer greater potential for service-based arrangements. This distinction provides the first foundation for evaluating CAPEX-to-OPEX transformation as a selective asset-governance decision rather than a uniform financial policy.

From Asset Ownership to Servitization and OPEX-Based Arrangements

The conceptual logic underlying OPEX-oriented asset arrangements connects to the broader servitization literature. Servitization was initially conceptualized as the process through which firms increasingly create value by combining products with services rather than relying exclusively on product ownership and transactions (Vandermerwe & Rada, 1988). Subsequent studies extended this logic to product-service systems, outcome-based contracts, subscription arrangements, and digitally enabled service ecosystems (Tukker, 2004; Baines et al., 2009; Kohtamäki et al., 2019).

From the buyer's perspective, service-based arrangements change the organizational boundary between ownership and access. Instead of acquiring and retaining all productive assets internally, an organization may purchase the availability, functionality, capacity, or performance those assets generate.

Such arrangements can reduce initial capital requirements and redistribute selected lifecycle responsibilities to external providers. They can also accelerate technology adoption when replacement cycles are rapid or when specialized providers have superior technological capabilities.

However, servitization does not automatically generate superior financial performance. Gebauer et al. (2005) describe the service paradox, in which firms increase service activities without necessarily realizing the expected profitability benefits. Neely (2008/2009) similarly shows that the financial consequences of servitization can be mixed because service-based models may add operating costs, organizational complexity, and coordination requirements. Therefore, a move from ownership to service provision should not be evaluated solely on reduced upfront investment.

This issue is particularly relevant for electricity utilities. Service-oriented infrastructure arrangements may provide financial flexibility and technological adaptability, but they can simultaneously increase recurring expenses, dependence on service providers, contractual complexity, and exposure to long-term price escalation. The economic rationale for OPEX consequently depends on the relationship between the cost of ownership and the cost of securing equivalent infrastructure services over time. Digital servitization further strengthens this argument. Digital technologies increasingly enable remote monitoring, predictive maintenance, performance-based contracting, and continuous upgrading of infrastructure services (Kohtamäki et al., 2019; Paschou et al., 2020; Favoretto et al., 2022). In electricity infrastructure, such capabilities may make service-based arrangements more feasible for assets characterized by frequent technological change. However, digital connectivity also increases requirements for interoperability, cybersecurity, data governance, and coordination between utility operators and external vendors. OPEX transformation must therefore be understood as an organizational and governance transformation, not merely a change in expenditure classification.

CAPEX–OPEX Choice as a Contingent Asset-Governance Decision

The theoretical implication of the preceding literature is that CAPEX and OPEX should not be treated as mutually exclusive universal alternatives. Instead, the appropriate arrangement depends on the asset's characteristics and the institutional environment in which it operates. Several dimensions are particularly relevant. Technological obsolescence concerns how quickly an asset or technology loses economic or operational relevance. Assets with rapid innovation cycles may favour contractual access or service-based arrangements because specialized providers can partly absorb the risk of technological replacement. Conversely, infrastructure with long technological lives may provide greater economic justification for ownership.

Strategic criticality and control concern how essential an asset is to system reliability, security, and organizational autonomy. Electricity networks contain assets whose failure can directly affect national or regional service continuity. For such assets, direct ownership may offer stronger operational control even when externally provided alternatives appear financially attractive. Contractibility refers to the extent to which service outputs, performance standards, responsibilities, and contingencies can be specified and monitored contractually. Service arrangements become more feasible when outputs can be objectively measured through indicators such as availability, reliability, response time, service quality, or lifecycle performance. Where performance is difficult to specify or monitor, outsourcing may produce significant principal-agent and governance risks.

Demand and technological uncertainty influence the value of flexibility. When future capacity requirements or technological standards are uncertain, committing significant capital to long-lived assets can generate lock-in. OPEX arrangements may preserve greater adaptability, although this flexibility must be evaluated against long-term contractual commitments. Finally, risk-transfer capacity concerns whether an external provider is genuinely better positioned to manage technological, maintenance, financing, or operational risks. Transferring contractual responsibility does not necessarily eliminate risk. Poorly designed contracts can merely transform internal technical risk into vendor, price, performance, or dependency risk.

Accordingly, CAPEX-to-OPEX transformation can be conceptualized as a contingent decision: Asset Characteristics → Governance Choice → Risk Allocation → Financial and Operational Outcomes. This perspective differs from an assumption that OPEX is inherently more efficient. Instead, the optimal arrangement depends on whether the flexibility and risk-transfer benefits offset recurring operating expenditures, provider dependency, financing consequences, and reduced asset control.

Financial Consequences of CAPEX-to-OPEX Transformation

The financial consequences of CAPEX and OPEX arrangements operate through different mechanisms. CAPEX typically requires substantial upfront investment and generates depreciation over the asset's useful life. OPEX-based arrangements reduce or redistribute initial investment requirements but create recurring payments that affect operating expenses and profitability. Therefore, the transition may improve liquidity or reduce financing needs without necessarily improving EBITDA, operating income, or net income.

This distinction matters for the present study because its original simulation generates precisely these opposing effects. Under the existing scenario, the transformation reduces interest-bearing debt and improves the Debt Service Coverage Ratio but simultaneously increases OPEX and decreases EBITDA, operating income, net income, and ROA. The paper's empirical logic therefore does not support a simple claim that OPEX improves corporate financial performance. Instead, it demonstrates a financial flexibility–profitability trade-off.

Accounting treatment further complicates the distinction. Under modern lease-accounting standards, contractual payments labelled operational do not necessarily remain outside the statement of financial position. IFRS 16 and its Indonesian counterpart require many lease arrangements to be recognized through right-of-use assets and lease liabilities. Consequently, the balance-sheet effect depends on contractual substance rather than whether management informally describes an arrangement as OPEX. Research demonstrates that lease capitalization can materially affect assets, liabilities, profitability measures, and leverage ratios (Morales-Díaz & Zamora-Ramírez, 2018; Giner et al., 2019; Górowski et al., 2022; Lopes & Penela, 2025).

This distinction requires the analysis to differentiate among at least three arrangements as depicted in Table 1.

Table 1. Comparative Characteristics and Accounting Implications of CAPEX- and OPEX-Based Asset Arrangements

Arrangement	Primary economic character	Typical accounting implication
Direct asset ownership	PLN acquires and controls infrastructure	CAPEX, asset capitalization and depreciation
Lease/right-of-use arrangement	PLN obtains contractual control over use of an identified asset	Potential recognition of right-of-use asset and lease liability
Pure service/outcome contract or eligible PPA	PLN purchases service/output rather than controlling the underlying asset	Primarily operating/service expense, subject to contractual assessment

Source: Authors' Own Work, 2026

Therefore, CAPEX-to-OPEX transformation cannot be equated with off-balance-sheet financing. The accounting consequences must be evaluated according to the economic substance of each contractual arrangement.

Risk Allocation, PPPs, and Contract Governance

The use of external providers, independent power producers, public-private partnerships, and long-term service contracts introduces a second theoretical dimension: risk allocation. Infrastructure partnerships are most effective when risks are allocated to the party best able to control, absorb, or mitigate them, rather than transferred away from the public or incumbent utility operator (Abednego & Ogunlana, 2006; Ng & Loosemore, 2007). This principle is highly relevant to PT PLN because IPP and service-based arrangements redistribute several risks simultaneously. Private partners may take on construction and financing risks, while PLN may retain demand, offtaker, regulatory, network-integration, and long-term contractual risks. The effectiveness of this arrangement therefore depends heavily on contract quality and institutional credibility. Evidence from infrastructure PPPs in developing economies shows that private participation depends on risk-sharing arrangements, institutional quality, revenue structures, and multilateral support (Fleta-Asín & Muñoz, 2021). Indonesian infrastructure research similarly emphasizes allocating risks according to each contractual party's capacity (Nur et al., 2023).

This perspective also challenges the assumption that outsourcing inherently lowers corporate risk. OPEX may reduce ownership exposure to technological obsolescence or maintenance requirements while creating other exposures, including vendor dependency, contract-renewal risk, service-price escalation, performance failure, and reduced operational control. Consequently, contract governance becomes an integral component of asset strategy. For PLN, this means that Service Level Agreements, measurable performance indicators, vendor-monitoring mechanisms, escalation procedures, termination provisions, cybersecurity standards, and multi-vendor strategies should be regarded not simply as implementation details but as governance mechanisms through which the theoretical benefits of risk transfer are realized. This is consistent with the original manuscript, which already emphasizes SLA design, vendor performance monitoring, multi-vendor arrangements, and Good Corporate Governance as prerequisites for successful implementation.

Cost–Benefit Analysis and Strategic Evaluation

Cost-benefit analysis provides an important financial basis for comparing alternative infrastructure strategies, but electricity-infrastructure decisions often generate benefits that a single financial ratio cannot adequately capture. Contemporary CBA approaches therefore require explicit specification of costs, benefits, time horizons, discounting assumptions, uncertainty, and sensitivity to critical parameters (Leiva Vilaplana et al., 2025). This consideration matters in evaluating CAPEX and OPEX because the two alternatives may produce different combinations of ownership value, liquidity, technology flexibility, operational expenditure, risk exposure, and residual asset value. A higher benefit-cost ratio therefore does not automatically imply strategic superiority under all conditions. The existing results illustrate this point clearly. The study reports an estimated ten-year benefit of Rp726.45 trillion under CAPEX and Rp1,598.62 trillion under OPEX, but the benefit-cost ratios are 17.01 and 8.83, respectively. Accordingly, CAPEX shows greater efficiency based on the reported CBR, whereas OPEX produces larger absolute benefits under the scenario assumptions. These findings reinforce the need to evaluate the alternatives multidimensionally rather than treating either expenditure model as universally preferable.

Conceptual Framework

Based on the literature, this study adopts a contingent asset-governance framework in which the suitability of CAPEX, OPEX, or hybrid arrangements depends on interactions among asset characteristics, governance requirements, and expected consequences.

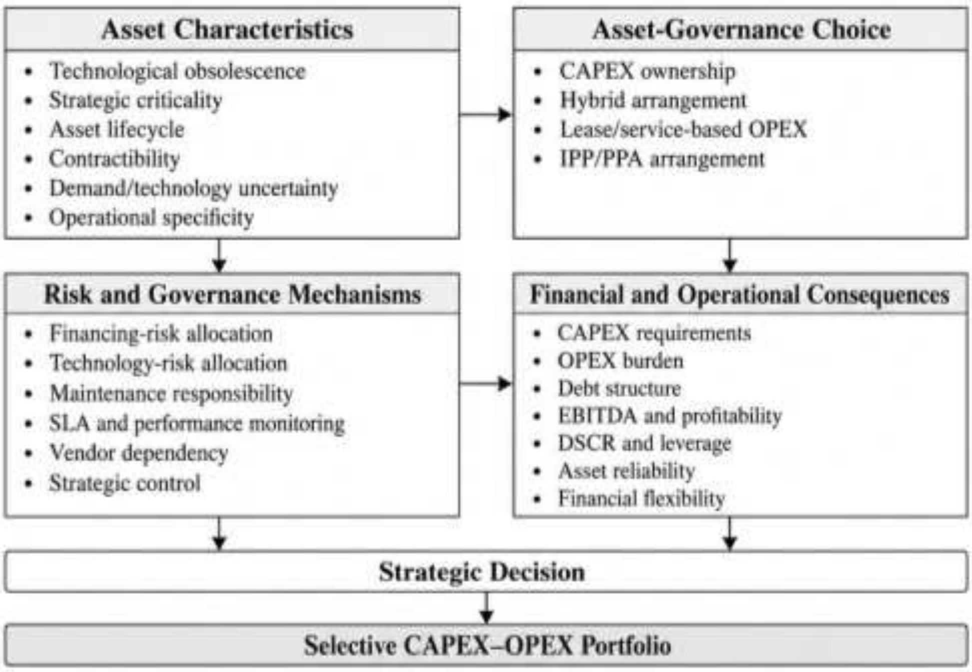

Figure 1. Contingent Asset-Governance Framework for Selective CAPEX–OPEX Transformation in Electricity Infrastructure

Source: Authors' Own Work, 2026

The framework implies that no universal CAPEX-to-OPEX optimum exists across all PLN assets. Instead, transformation should occur selectively where the value of flexibility, technological renewal, financing capacity, and risk transfer exceeds the economic and governance costs associated with recurring service payments and reduced direct control. This interpretation also aligns with the manuscript's findings, which conclude that the transformation should be selective and phased rather than a comprehensive replacement of PLN's asset-management model.

C. METHODS

Research Design

This study employed an integrated analytical research design combining documentary analysis, global benchmarking, financial scenario simulation, cost–benefit analysis, and regulatory assessment. The design evaluated the strategic implications of a selective transition from capital expenditure (CAPEX)-based asset ownership to operational expenditure (OPEX)-oriented arrangements within PT PLN (Persero). The analysis examined financial outcomes alongside asset characteristics, contractual arrangements, regulatory requirements, technological risks, and governance implications. The study followed five interrelated stages: literature and documentary analysis, global benchmarking, construction of the CAPEX–OPEX transformation scenario, financial simulation and cost–benefit analysis, and interpretation of accounting, fiscal, legal, and governance implications.

Unit of Analysis and Data Sources

The unit of analysis was PT PLN (Persero) at the corporate asset-portfolio level, with attention to investment allocation across generation, transmission, and distribution activities. The study did not examine individual projects, regional operating units, or distribution areas. The analysis relied exclusively on secondary and documentary data. The main evidence comprised PT PLN corporate and financial information, investment assumptions, government and regulatory documents, academic literature, and international benchmarking cases. The quantitative analysis used PLN's 2024 CAPEX baseline of Rp63.45 trillion and an estimated electricity-infrastructure investment requirement of Rp2,780 trillion for 2025–2034.

Table 2. Data Sources and Their Analytical Functions

Evidence Category	Main Information Used	Analytical Function
PT PLN corporate and financial documents	CAPEX baseline, financial position, investment requirements, financial indicators	Financial simulation and baseline construction
Government and regulatory documents	Electricity regulation, taxation, accounting, procurement, and institutional requirements	Regulatory, fiscal, legal, and governance analysis
Peer-reviewed academic literature	Asset management, servitization, digitalization, CBA, lease accounting, PPP, and risk allocation	Conceptual framing and analytical interpretation
International industry cases	Utility digitalization, predictive maintenance, and service-oriented infrastructure practices	Global benchmarking

Source: Authors' Own Work, 2026

Documentary Analysis and Global Benchmarking

Documentary analysis established the study's conceptual, financial, regulatory, and institutional basis. The literature covered strategic asset management, CAPEX and OPEX structures, servitization and service-based business models, electricity-network digitalization, predictive asset management, infrastructure financing, lease accounting, cost–benefit analysis, public–private partnerships, and risk allocation.

The regulatory analysis focused on accounting, taxation, electricity-sector regulation, and institutional governance applicable to PT PLN. Particular attention was given to differences among direct asset ownership, lease arrangements, service contracts, and power purchase agreements because these contractual forms may generate different financial and accounting consequences.

Global benchmarking used three cases: SP Group in Singapore, UK Power Networks, and Telstra in Australia. SP Group was examined in relation to smart-metering and distribution-network management, UK Power Networks in relation to analytics-driven asset management and predictive maintenance, and Telstra as a cross-sector reference for digitally enabled and service-oriented infrastructure management.

Scenario Construction

The analysis was organized around four broad analytical areas. The first concerned student creativepreneurship practices, including venture characteristics, entrepreneurial motivations, and the use of digital platforms. The second concerned supporting conditions, including creativity, digital capability, social media utilization, peer and community interaction, mentoring, and institutional support. The third concerned constraints to venture continuity, including time-management difficulties, academic pressure, managerial limitations, financial constraints, and limited institutional integration. The fourth concerned institutional support, including entrepreneurship education, mentoring, incubation, access to institutional resources, academic arrangements, and perceived coordination among support mechanisms. These analytical areas were interpreted through the broader conceptual framework comprising individual capability, peer and network dynamics, and institutional support. They served as organizing categories rather than statistically defined latent constructs.

Data Analysis

The quantitative analysis used a selective CAPEX–OPEX transformation scenario. Total electricity-infrastructure investment requirements for 2025–2034 were estimated at Rp2,780 trillion, or about Rp278 trillion per year. PLN's 2024 CAPEX baseline was Rp63.45 trillion. The transformation scenario assumed that 70% of generation investment, approximately Rp44.45 trillion, was transferred to Independent Power Producers (IPPs) and represented as OPEX through electricity-purchase arrangements. The remaining 30% of generation investment, together with 100% of transmission and distribution investment (approximately Rp19 trillion), remained under PLN CAPEX. Two scenarios were therefore compared: a baseline CAPEX-oriented structure and a selective transformation scenario in which part of generation investment was transferred to IPPs while the specified generation, transmission, and distribution investments remained under PLN ownership.

Financial Simulation

The financial simulation assessed the effects of the transformation scenario on three groups of indicators: statement of financial position variables, income-statement variables, and financial performance ratios. The statement of financial position analysis included fixed assets, total assets, interest-bearing debt, equity, and total liabilities and equity. The income-statement analysis included OPEX, depreciation expense, EBITDA, operating income, and net income. Financial performance was evaluated using the Debt Service Coverage Ratio (DSCR), leverage, and Return on Assets (ROA).

Under the transformation scenario, fixed assets decreased by 2.94%, total assets by 2.52%, and interest-bearing debt by 6.75%, while equity increased by 0.28%. OPEX increased by 24.88%, depreciation expense decreased by 7.87%, EBITDA declined by 36.99%, operating income by 7.63%, and net income by 9.93%. DSCR increased by 3.8%, ROA decreased by 7.0%, and leverage increased by 48.1%. The simulation was interpreted as a scenario-based assessment of potential financial consequences under the specified assumptions.

Cost–Benefit Analysis

Cost–benefit analysis compared the economic implications of the CAPEX and OPEX scenarios over a ten-year analytical period. The analysis considered the total estimated benefits associated with the two approaches and their respective benefit–cost ratios. The CAPEX scenario generated estimated benefits of Rp726.45 trillion over ten years, while the OPEX scenario generated Rp1,598.62 trillion. The corresponding benefit–cost ratio was 17.01 for CAPEX and 8.83 for OPEX.

The cost–benefit ratio was expressed as:

$$CBR = \frac{Present\ Value\ of\ Benefits}{Present\ Value\ of\ \text{Costs}}$$

A ratio greater than 1 indicates that estimated benefits exceed estimated costs. The comparison distinguished between absolute benefit magnitude and benefit efficiency, allowing assessment of the financial implications of both alternatives from multiple perspectives.

Accounting, Fiscal, Legal, and Governance Analysis

The financial simulation and CBA were complemented by an assessment of accounting, fiscal, legal, and governance implications. The accounting analysis examined asset capitalization, operating expenses, leases, right-of-use assets, and lease liabilities under PSAK 16 and PSAK 73. Lease-based arrangements were distinguished from pure service contracts and power purchase arrangements because their financial-statement consequences differ. Under PSAK 73, qualifying lease arrangements may require recognition of both right-of-use assets and lease liabilities.

The fiscal analysis examined the treatment of operating expenditure, depreciation, lease-related taxation, and documentation requirements. The legal and institutional analysis covered electricity-sector regulation, the participation of subsidiaries and private entities, IPP arrangements, PPAs, government support, and the role of RUPTL. Governance analysis focused on contract design, service-level agreements, vendor performance monitoring, risk allocation, multi-vendor arrangements, and Good Corporate Governance.

Analytical Integration

The final analytical stage integrated the results of financial simulation, cost–benefit analysis, global benchmarking, and regulatory assessment within the contingent asset-governance framework. The analysis considered four dimensions: asset characteristics, asset-governance choice, risk-allocation mechanisms, and financial and operational consequences. The strategic assessment therefore evaluated whether different infrastructure categories were more appropriately managed through CAPEX ownership, OPEX-oriented contracting, or hybrid arrangements. The analytical framework did not assume that CAPEX or OPEX was universally superior. Instead, the appropriateness of each arrangement depended on technological obsolescence, strategic criticality, asset lifecycle, contractibility, financing flexibility, risk-allocation capacity, and governance requirements.

D. RESULTS AND DISCUSSION

Global Benchmarking of CAPEX–OPEX Transformation Practices

The benchmarking analysis indicates that transitions from asset-intensive investment to service-oriented, OPEX-based arrangements have been implemented across the energy, electricity distribution, telecommunications, mining, and digital infrastructure sectors. The cases reviewed show that the primary rationale for such arrangements extends beyond expenditure reduction. Their strategic value includes lower upfront capital requirements, greater flexibility in infrastructure deployment, access to specialized technological capabilities, and the redistribution of selected investment and operational risks to external providers.

The original benchmarking evidence indicates reported efficiency improvements of approximately 15–40% across several industries adopting CAPEX-to-OPEX-oriented models. These arrangements may stabilize cash flow by reducing large upfront investment requirements and releasing financial resources for other strategic purposes. The transformation may involve leasing, Build-Operate-Transfer arrangements, subscription-based infrastructure, contract-based services, or other service-oriented models in which organizations obtain access to infrastructure functionality without necessarily acquiring full ownership of the underlying assets.

Digitalization appears as an important enabling condition. Electricity distribution companies increasingly use analytics, predictive maintenance, smart metering, and digital monitoring to improve asset utilization and reliability. Predictive asset-management approaches allow maintenance and replacement decisions to be prioritized according to asset condition and reliability requirements, including indicators such as SAIFI and SAIDI. At the same time, decisions between conventional network reinforcement and digital investment must account for differences in reliability benefits, tariff effects, investment intensity, and technological lifecycles.

Three benchmark cases provide relevant strategic insights. SP Group illustrates digitally enabled smart metering and distribution-network management. UK Power Networks provides a reference for analytics-driven asset management and predictive maintenance. Telstra provides a cross-sector example of cloud-based infrastructure management and remote monitoring within a service-oriented infrastructure model. Although their technological and institutional environments differ from PLN, the cases collectively indicate that OPEX-oriented arrangements become more viable when infrastructure performance can be specified, digitally monitored, and governed through contractual service standards. The benchmarking results therefore identify three recurring characteristics of OPEX-oriented transformation: reduced dependence on large initial investment, increased technological flexibility, and greater reliance on contractual governance. These characteristics provide the basis for examining which PLN asset categories may be more suitable for selective transformation.

Transformation Potential Across Infrastructure Asset Categories

The asset-mapping analysis shows that CAPEX-to-OPEX transformation potential varies across PLN's infrastructure portfolio. The original analysis identifies five asset categories with different potential arrangements and estimated efficiency implications: transmission networks and substations, transformers, heavy equipment and operational vehicles, smart-grid technologies, and renewable-energy infrastructure.

Table 3. Potential CAPEX–OPEX Transformation Across Infrastructure Asset Categories

Asset Category	Existing/Capital-Intensive Requirement	Potential OPEX-Oriented Arrangement	Estimated Effect Reported in the Study
Transmission networks and substations / supporting technologies	Network development and associated equipment	Subscription-based services or equipment rental for smart-grid, smart-meter, and IoT-related components	10–20% potential reduction in distribution maintenance costs
Transformers	Procurement and ownership; reported cost of Rp5–10 billion per unit	Usage-based rental or leasing	20–30% potential reduction in procurement and maintenance costs
Heavy equipment and operational vehicles	Direct procurement and maintenance	Leasing and condition-based maintenance	15–25% potential reduction in annual maintenance costs
Smart-grid technologies	Direct investment in smart meters and monitoring infrastructure	Cloud-based services and monitoring platforms	30–40% potential improvement in maintenance efficiency and technological advancement
Renewable-energy infrastructure	Reported investment requirement of Rp500 billion–Rp1 trillion	Energy-purchase arrangements through PPAs	40–50% potential reduction in initial investment costs

Source: Authors' Own Work, 2026

The reported estimates indicate that smart-grid and renewable-energy-related infrastructure have the greatest potential to reduce initial capital requirements, while conventional physical network assets show more limited transformation potential. In particular, smart-grid technology is associated with an estimated 30–40% improvement in maintenance efficiency and technological advancement, whereas renewable-energy investment through PPA arrangements is associated with a potential 40–50% reduction in initial investment requirements. Transformer leasing is associated with estimated savings of 20–30%, while heavy-equipment leasing and condition-based maintenance are associated with 15–25% lower annual maintenance costs.

The pattern is consistent with the asset-governance framework developed in this study. Assets subject to rapid technological change and higher obsolescence risk offer greater potential for externally provided or service-based arrangements, whereas the core network remains more dependent on direct PLN control. The results therefore do not support a uniform shift from CAPEX to OPEX. Instead, they indicate a differentiated portfolio in which ownership and service arrangements vary according to technological characteristics, strategic criticality, and operational requirements.

Financial Effects of the Selective Transformation Scenario

The financial simulation was based on an estimated investment requirement of Rp2,780 trillion for 2025–2034, equivalent to approximately Rp278 trillion per year, and PLN's 2024 CAPEX baseline of Rp63.45 trillion. The scenario transfers 70% of generation investment, approximately Rp44.45 trillion, to Independent Power Producers, while the remaining 30% of generation together with 100% of transmission and distribution investment, approximately Rp19 trillion, remains under PLN CAPEX. The simulation produces materially different effects across the statement of financial position, income statement, and financial ratios.

Table 4. Financial Effects of the CAPEX–OPEX Transformation Scenario

Financial Dimension	Indicator	Change
Financial position	Fixed assets	−2.94%
Financial position	Total assets	−2.52%
Financial position	Interest-bearing debt	−6.75%
Financial position	Equity	+0.28%
Income statement	OPEX	+24.88%
Income statement	Depreciation expense	−7.87%
Income statement	EBITDA	−36.99%
Income statement	Operating income	−7.63%
Income statement	Net income	−9.93%
Financial ratio	DSCR	+3.80%
Financial ratio	ROA	−7.00%
Financial ratio	Leverage	+48.10%

Source: Authors' Own Work, 2026

The statement-of-financial-position effects indicate reduced capital intensity in the simulated structure. Fixed assets decline by 2.94%, while total assets decline by 2.52%. Interest-bearing debt falls by 6.75%, reflecting lower financing needs associated with transferring part of generation investment to IPPs. Equity increases marginally by 0.28%. The income-statement effects move in the opposite direction. Electricity purchases from IPPs increase OPEX by 24.88%. Although depreciation expenses decline by 7.87%, the reduction in depreciation is insufficient to offset the increase in operating expenditure. Consequently, EBITDA falls by 36.99%, operating income decreases by 7.63%, and net income declines by 9.93%. The financial-ratio results further demonstrate the multidirectional nature of the transformation. DSCR increases by 3.8%, indicating improved debt-servicing capacity. In contrast, ROA falls by 7.0%, while leverage rises by 48.1%, largely due to the substantial decline in EBITDA.

These results reveal a clear financial trade-off. The transformation reduces interest-bearing debt and improves debt-servicing capacity, but these gains come with materially higher operating expenditure and weaker short-term profitability. The financial outcome therefore cannot be described as an unqualified improvement. Instead, the scenario shifts financial risk from upfront capital and debt commitments to recurring operating expenditure and profitability exposure.

Accounting and Fiscal Implications

The accounting analysis identifies an important distinction between direct asset ownership, lease arrangements, and pure service or energy-purchase contracts. Under PSAK 16, directly acquired infrastructure that satisfies capitalization requirements is recognized as a fixed asset and depreciated over its useful life. OPEX-oriented arrangements can reduce direct capital acquisition, but their accounting treatment depends on the contractual substance. For pure service arrangements and qualifying energy-purchase contracts that do not constitute leases, payments may be recognized principally as current operating expenses. This can reduce direct asset accumulation and provide greater flexibility in investment cash flows. However, this effect does not apply uniformly to lease arrangements. Contracts that provide the right to control the use of an identified asset may fall within PSAK 73 and require recognition of both a right-of-use asset and a lease liability. Consequently, an OPEX-oriented commercial arrangement does not necessarily produce an off-balance-sheet outcome.

Accounting results therefore depend on contract type. A service contract, PPA, and lease may all reduce conventional asset procurement, but they may generate substantially different effects on reported assets, liabilities, leverage, depreciation, and operating expenditure. This distinction matters for the financial simulation because the observed 48.1% increase in leverage cannot be interpreted independently of the contractual and accounting structure used to implement the transformation.

The fiscal analysis also identifies both advantages and compliance implications. Under the tax provisions examined in the study, recognized operating expenditures can reduce gross income in the period in which qualifying costs are incurred, whereas CAPEX-related deductions are generally distributed through depreciation. At the same time, OPEX arrangements introduce additional requirements concerning deductibility, documentation, auditability, and withholding-tax obligations.

For lease-related transactions involving land and/or buildings, the study identifies a 10% final income-tax treatment, while leases not involving land are associated with 2% Income Tax Article 23. These tax consequences show that the economic attractiveness of OPEX arrangements cannot be evaluated solely through gross expenditure comparisons; taxation and contractual classification shape their effective financial outcomes.

Legal, Institutional, and Financing Implications

The legal and institutional analysis indicates that private-sector participation in PLN's infrastructure development has an established regulatory basis. The study identifies Law No. 30 of 2009 on Electricity, particularly Article 4(2), as providing a basis for private-sector participation, while Presidential Regulation No. 4 of 2016 provides a framework for accelerated electricity-infrastructure development through PLN's own implementation, subsidiaries, or cooperation with private power developers. Within this framework, PLN may involve subsidiaries such as PT PLN Nusantara Power and PT PLN Indonesia Power or cooperate directly with IPPs. In the IPP structure examined in the study, private partners assume initial investment, financing, and construction responsibilities, while PLN operates as the electricity purchaser or offtaker through long-term PPAs. This arrangement frees up capital otherwise committed to generation investment and may allow resources to be redirected toward transmission and distribution reinforcement, reducing electricity losses, and preparing the grid for intermittent renewable-energy integration.

The study also identifies several mechanisms for financing diversification, including IPPs, public-private partnerships, PT SMI financing, Sukuk, IMBT structures, and deferred-payment arrangements. The RUPTL provides the planning framework for investment requirements, while government support and permitting arrangements contribute to investment certainty. Evidence from 1,371 PPP projects across 63 developing countries further indicates that private participation is associated with responsibility allocation to private partners, revenue structures, institutional quality, and support from multilateral development banks. Within the PLN context, this finding reinforces the importance of credible offtaker arrangements, contractual certainty, and institutional governance for mobilizing external investment. At the same time, increased reliance on external infrastructure providers introduces governance requirements that are particularly important for strategically critical electricity assets. PLN remains responsible for cybersecurity, system stability, vendor performance, contractual continuity, and accountability even when it transfers specific investment or operating risks externally. The transformation therefore shifts risk rather than eliminating it.

Cost–Benefit Comparison of CAPEX and OPEX

The cost–benefit analysis provides a second quantitative perspective on the transformation. Over the ten-year analytical period, the CAPEX scheme generates estimated total benefits of Rp726.45 trillion, equivalent to approximately Rp72.64 trillion per year. The OPEX scheme generates estimated benefits of Rp1,598.62 trillion, equivalent to approximately Rp159.86 trillion per year.

Table 5. Cost–Benefit Comparison Between CAPEX and OPEX Scenarios

Indicator	CAPEX	OPEX
Total estimated benefits, 10 years	Rp726.45 trillion	Rp1,598.62 trillion
Approximate annual benefits	Rp72.64 trillion	Rp159.86 trillion
Cost–Benefit Ratio	17.01	8.83

Source: Authors' Own Work, 2026

Although the OPEX scenario produces substantially greater absolute estimated benefits, the CBR results show the opposite ordering. CAPEX produces a CBR of 17.01, compared with 8.83 for OPEX. Under the study's ratio, every Rp1 trillion of cost under the CAPEX scenario corresponds to Rp17.01 trillion in estimated benefits, whereas the equivalent figure for OPEX is Rp8.83 trillion. This difference is central to the findings. OPEX produces approximately Rp872.17 trillion more absolute benefits over ten years than CAPEX, but CAPEX generates substantially greater benefit efficiency relative to its reported costs. Therefore, the financial evidence does not indicate that one arrangement dominates the other across all criteria.

The CBR results are particularly important when considered alongside the financial simulation. OPEX provides lower initial capital exposure and reduces interest-bearing debt but creates a considerably higher operating-cost burden. CAPEX, conversely, requires ownership and larger capital commitments but produces the stronger benefit-cost ratio under the assumptions applied in the study. The combined evidence therefore identifies two distinct dimensions of performance: capital and financing flexibility, where the transformation scenario provides advantages, and profitability and benefit-cost efficiency, where important disadvantages remain.

Integrated Results of the Selective CAPEX–OPEX Assessment

When the asset mapping, financial simulation, institutional analysis, and CBA are considered jointly, the results support a selective rather than universal transformation strategy.

Table 6. Integrated Assessment of the CAPEX–OPEX Transformation

Assessment Dimension	Principal Result	Strategic Implication
Capital requirement	Part of generation investment transferred externally	Lower direct capital commitment
Interest-bearing debt	↓ 6.75%	Reduced debt-financing requirement
DSCR	↑ 3.80%	Improved debt-servicing capacity
OPEX	↑ 24.88%	Greater recurring operating-cost exposure
EBITDA	↓ 36.99%	Significant profitability pressure
Net income	↓ 9.93%	Lower short-term earnings
ROA	↓ 7.00%	Lower reported asset-return performance
Leverage	↑ 48.10%	Higher financial-ratio pressure
Ten-year benefits	OPEX: Rp1,598.62 trillion; CAPEX: Rp726.45 trillion	Larger absolute benefit under OPEX
CBR	CAPEX: 17.01; OPEX: 8.83	Higher benefit efficiency under CAPEX
Technology flexibility	Strongest for rapidly changing technologies	Supports selective OPEX
Strategic control	Core network remains under direct PLN control	Supports continued CAPEX for critical assets
Governance requirement	SLA, vendor monitoring, multi-vendor management, risk controls	OPEX requires stronger contract governance

Source: Authors' Own Work, 2026

The strongest candidates for OPEX-oriented arrangements are therefore those characterized by rapid technological change, relatively high obsolescence exposure, measurable performance, and opportunities for transferring specific operational or financing responsibilities. Smart-grid-related technologies, monitoring platforms, selected equipment, and renewable-energy procurement arrangements fall most clearly within this category in the asset analysis. By contrast, long-lived core-network assets remain strategically associated with direct control. Overall, the results show that CAPEX-to-OPEX transformation redistributes rather than eliminates costs and risks. Capital intensity and debt requirements decline, but recurring expenditure and profitability pressure increase. External providers may absorb investment, technological, construction, or maintenance responsibilities, but PLN becomes more dependent on contract quality, vendor performance, and long-term service continuity. Accordingly, the empirical results support a portfolio-based configuration in which CAPEX, OPEX, and hybrid arrangements coexist according to asset characteristics and strategic requirements. This configuration is consistent with the quantitative evidence: the OPEX scenario provides greater absolute benefits and financing flexibility, whereas CAPEX retains a superior CBR and remains important for strategic infrastructure requiring long-term operational control.

Discussion

Selective CAPEX–OPEX Transformation as an Asset-Governance Strategy

The findings indicate that CAPEX-to-OPEX transformation should not be understood as a binary substitution between ownership and operating expenditure. Instead, it represents a portfolio-level asset-governance decision in which different infrastructure categories require different ownership, contracting, and risk-allocation structures. This interpretation is consistent with the heterogeneous transformation potential identified across PLN's asset categories. Technologies characterized by rapid innovation and higher obsolescence risk, such as smart-grid platforms, digital monitoring systems, and selected renewable-energy arrangements, are better suited to OPEX-oriented structures. In contrast, strategically critical and long-lived core-network assets remain more dependent on direct ownership and control. This finding extends the conventional CAPEX–OPEX debate by shifting attention from expenditure classification to the conditions under which ownership creates or destroys strategic value. Traditional CAPEX ownership remains economically rational where asset specificity, strategic criticality, system-security requirements, and lifecycle longevity are high. In contrast, OPEX-based arrangements become more attractive when technology changes rapidly, performance can be contractually specified, and external providers can manage maintenance, technological renewal, or financing risks more efficiently.

This pattern aligns with servitization theory, which explains the shift from ownership-oriented models to access-, service-, and outcome-based arrangements (Vandermerwe & Rada, 1988; Baines et al., 2009; Kohtamäki et al., 2019). However, the present findings also demonstrate that servitization in a regulated electricity utility differs substantially from service transformation in conventional manufacturing. PLNs must simultaneously preserve system reliability, national infrastructure control, financial resilience, and public-service obligations. Therefore, service-based arrangements cannot be adopted solely because they reduce initial capital expenditure. The results instead support a contingent asset-governance perspective. The strategic choice is not simply CAPEX versus OPEX, but rather the alignment among asset characteristics, contractual form, risk allocation, financial consequences, and governance capability. This helps explain why a hybrid portfolio is more appropriate than a uniform transformation across the entire infrastructure system.

Financial Flexibility Does Not Necessarily Translate into Higher Profitability

One of the most important findings is the divergence between financial flexibility and profitability. The transformation scenario reduces interest-bearing debt by 6.75% and improves DSCR by 3.8%, indicating stronger debt-servicing capacity. At the same time, OPEX increases by 24.88%, EBITDA declines by 36.99%, operating income falls by 7.63%, and net income decreases by 9.93%. ROA also declines by 7.0%, while leverage rises sharply by 48.1%. These results demonstrate that reducing capital commitment does not automatically improve corporate performance. Instead, the transformation changes the timing and location of financial pressure. Under CAPEX, the financial burden is concentrated in upfront investment, asset financing, depreciation, and long-term capital commitments. Under the transformation scenario, part of this burden shifts to recurring operating expenditure through electricity-purchase arrangements.

The decline in EBITDA is particularly significant. Because electricity purchases from IPPs are recognized as operating expenditure, the reduction in depreciation is insufficient to compensate for the higher recurring cost base. Consequently, the apparent advantage of lower direct investment is accompanied by weaker operating profitability. This result closely reflects the servitization paradox described in previous literature. Service-oriented transformation can provide flexibility and additional capabilities without necessarily generating superior profitability (Gebauer et al., 2005; Neely, 2008/2009). In the PLN context, the paradox takes a distinct form: outsourcing a portion of capital-intensive generation can improve financing flexibility while simultaneously putting greater pressure on operating earnings.

The finding therefore challenges simplistic managerial assumptions that OPEX is inherently more financially efficient than CAPEX. The relevant metric depends on the decision objective. If the primary concern is debt reduction and financing capacity, the transformation scenario has clear advantages. If the priority is EBITDA preservation, operating profitability, or cost efficiency, the results are less favorable.

This distinction is especially important for a utility facing simultaneous investment needs across generation, transmission, distribution, and digital infrastructure. Releasing capital may create room for strategic reinvestment, but recurring obligations under OPEX arrangements must remain financially manageable over the contract lifecycle.

The Cost–Benefit Paradox: Higher Absolute Benefits, Lower Benefit Efficiency

The cost–benefit results reinforce the multidimensional nature of the CAPEX–OPEX decision. The OPEX scenario generates estimated total benefits of Rp1,598.62 trillion over ten years, compared with Rp726.45 trillion under CAPEX. However, the benefit-cost ratio ranks them in the opposite order: 17.01 for CAPEX and 8.83 for OPEX. This divergence creates an important decision paradox. OPEX generates substantially larger absolute benefits, but CAPEX produces greater benefit efficiency relative to reported costs. The two alternatives are therefore superior according to different evaluation criteria. From a narrow financial-efficiency perspective, CAPEX performs better because each unit of cost generates a higher reported benefit. From a strategic perspective, OPEX may still be attractive when financing flexibility, technological renewal, risk transfer, and speed of deployment matter.

This finding supports Leiva Vilaplana et al. (2025) that electricity-infrastructure CBA should not be interpreted solely through a single ratio. Infrastructure decisions frequently involve reliability, flexibility, technological adaptation, risk exposure, and system-level externalities that conventional benefit-cost measures may not fully capture. The findings therefore suggest that the CBR should function as one decision criterion rather than the sole determinant of the transformation strategy. A CAPEX arrangement with a superior CBR may remain preferable for stable, long-lived, strategically critical assets. Conversely, a lower-CBR OPEX arrangement may remain strategically rational for assets with particularly high technological obsolescence risk, financing constraints, or flexibility requirements. This interpretation better explains the study's quantitative evidence than a universal claim that either CAPEX or OPEX is superior. The financial results instead point toward portfolio optimization, where asset categories are matched with the arrangement that best balances lifecycle economics, flexibility, control, and risk.

Accounting Classification Matters: OPEX Is Not Automatically Off-Balance-Sheet

The accounting analysis further demonstrates why CAPEX-to-OPEX transformation should not be treated as a simple change in expenditure classification. The financial consequences depend fundamentally on the arrangement's contractual substance. Pure service contracts and qualifying energy-purchase agreements may primarily generate operating expenses, but lease arrangements that provide control over identified assets may require recognition of right-of-use assets and lease liabilities under PSAK 73. As a result, some OPEX-oriented commercial structures can increase reported assets and liabilities rather than removing them from the balance sheet. This distinction is consistent with evidence showing that IFRS 16-type lease capitalization can materially alter leverage, asset values, and profitability measures (Morales-Díaz & Zamora-Ramírez, 2018; Giner et al., 2019; Górowski et al., 2022; Lopes & Penela, 2025).

This implies that management should evaluate contractual architecture before estimating financial outcomes. Three transactions that may all be operationally described as "OPEX"—leasing equipment, purchasing infrastructure-as-a-service, and entering a PPA—may have materially different accounting effects. This is particularly relevant to the 48.1% increase in leverage observed in the simulation. Interpret the leverage effect alongside the contractual and accounting structures used to implement the transformation. Therefore, financial modelling should distinguish among lease-based, service-based, and offtake-based arrangements rather than treating them as a single homogeneous OPEX category.

Risk Transfer Requires Stronger, Not Weaker, Governance

A central strategic justification for OPEX-based arrangements is transferring selected risks to external providers. The study shows that IPP structures can shift initial investment, financing, and construction responsibilities away from PLN, while service and leasing structures can shift portions of technology, maintenance, and lifecycle responsibility. However, risk transfer does not eliminate risk. Instead, it changes the form of risk exposure. Capital and construction risks may decline while vendor dependency, service continuity, contractual rigidity, price-escalation exposure, cybersecurity risk, and performance risk increase. This finding is consistent with PPP literature emphasizing that infrastructure risks should be allocated to the party best able to manage them, rather than transferred indiscriminately (Abednego & Ogunlana, 2006; Ng & Loosemore, 2007; Nur et al., 2023). In the PLN context, the critical issue is whether an external provider can genuinely control the transferred risk and whether the contract provides sufficient mechanisms for enforcing performance.

The original analysis identifies several governance mechanisms that become particularly important under OPEX-oriented arrangements: detailed Service Level Agreements, dedicated vendor-monitoring functions, cost-time-quality KPIs, escalation mechanisms, contract review or termination provisions, and multi-vendor strategies. These mechanisms are not secondary implementation details. They are part of the transformation's economic logic. Without strong contract governance, provider dependency, performance uncertainty, and higher lifecycle costs may offset the theoretical benefits of flexibility and risk transfer. For electricity infrastructure classified as strategically critical or part of National Vital Objects, this governance requirement becomes even more important. PLN cannot fully transfer cybersecurity, operational reliability, system stability, and continuity of supply to external partners because it ultimately retains responsibility for electricity-system performance.

Strategic Implications for PLN's Infrastructure Portfolio

The combined results indicate that PLN should not pursue a uniform CAPEX-to-OPEX transition. Instead, the evidence supports a segmented asset strategy in which ownership and contracting structures differ according to asset characteristics. Assets characterized by rapid technological change, short innovation cycles, measurable service outputs, and high obsolescence exposure are stronger candidates for OPEX-oriented or hybrid arrangements. Smart-grid platforms, digital monitoring systems, selected operational equipment, and renewable-energy procurement structures fit this profile more closely.

Conversely, long-lived infrastructure with high strategic criticality, high asset specificity, and direct implications for system control remains more compatible with CAPEX ownership. The original asset analysis similarly concludes that core grid infrastructure should remain under direct PLN control while technologically dynamic assets offer greater transformation potential.

The resulting configuration is therefore best understood as a selective CAPEX–OPEX portfolio rather than a transition from one model to another. In such a portfolio, CAPEX preserves control and lifecycle efficiency for strategic assets, while OPEX provides flexibility and technological adaptability for selected asset categories. This portfolio logic is also consistent with the financial evidence. CAPEX produces the stronger benefit-cost ratio, whereas OPEX provides larger absolute benefits and greater financing flexibility. Neither arrangement dominates across all dimensions. The appropriate decision depends on the asset's strategic function and the relative importance of flexibility, profitability, control, and risk allocation.

Synthesis of the Discussion

The findings collectively show that CAPEX-to-OPEX transformation in electricity infrastructure is fundamentally a question of asset governance rather than expenditure substitution. Three conclusions emerge. First, the financial advantages of OPEX are conditional. Lower debt exposure and stronger DSCR come with substantially higher operating expenditure and weaker profitability. Second, economic evaluation produces conflicting signals. OPEX generates greater absolute benefits, whereas CAPEX produces a substantially stronger CBR.

Third, OPEX suitability depends heavily on asset characteristics and governance capacity. Technologically dynamic and contractible assets provide stronger transformation potential, while strategic core infrastructure remains more appropriate for direct ownership. The empirical evidence therefore supports a contingent model in which the optimal structure emerges from aligning asset characteristics, ownership form, contract design, financial consequences, risk allocation, and governance capacity. This finding underpins the theoretical contributions and managerial implications developed in the following sections.

Theoretical Contributions

This study contributes to the literature on strategic asset management, servitization, infrastructure finance, and utility governance in four ways. First, the study reframes CAPEX–OPEX transformation as a contingent asset-governance decision rather than a simple expenditure substitution. Existing discussions often treat CAPEX and OPEX as alternative financing or accounting arrangements. The present findings indicate that the appropriate choice depends on the interaction among technological obsolescence, strategic criticality, asset lifecycle, contractibility, financing requirements, and risk-allocation capacity. This extends the CAPEX–OPEX debate by positioning ownership structure as an asset-level strategic decision.

Second, the study extends servitization theory to the context of a regulated, capital-intensive electricity utility. Servitization literature generally emphasizes the shift from ownership to service- and outcome-based arrangements (Vandermerwe & Rada, 1988; Baines et al., 2009; Kohtamäki et al., 2019). The findings show that this logic operates differently in electricity infrastructure because strategic assets cannot be evaluated solely according to flexibility or cost. Reliability, national infrastructure control, regulatory obligations, system security, and public-service continuity constrain how far externally provided services can replace ownership. The study therefore introduces strategic criticality and infrastructure control as boundary conditions of servitization in utility settings.

Third, the study identifies a financial flexibility–profitability paradox in CAPEX-to-OPEX transformation. The scenario improves debt-servicing capacity, with interest-bearing debt decreasing by 6.75% and DSCR increasing by 3.8%, but simultaneously increases OPEX by 24.88% and reduces EBITDA by 36.99%, operating income by 7.63%, and net income by 9.93%. These results demonstrate that financing flexibility and operating profitability can move in opposite directions. This extends the servitization paradox identified in previous research by showing how it manifests in a capital-intensive electricity utility: transferring asset ownership and investment responsibility can relieve balance-sheet pressure while increasing recurring operating-cost exposure.

Fourth, the study contributes to infrastructure decision theory by demonstrating that economic attractiveness is criterion-dependent. The OPEX scenario generates higher absolute estimated benefits of Rp1,598.62 trillion over ten years, compared with Rp726.45 trillion under CAPEX, while CAPEX produces the substantially higher benefit-cost ratio of 17.01 compared with 8.83 for OPEX. This divergence suggests that strategic infrastructure decisions cannot be reduced to a single financial metric. Absolute benefits, benefit efficiency, financing flexibility, strategic control, and risk exposure may rank the same alternatives differently. These contributions support a Selective CAPEX–OPEX Portfolio Framework that matches asset-governance choices to the characteristics and strategic role of individual infrastructure categories. Rather than predicting that OPEX will replace CAPEX, the framework predicts coexistence among direct ownership, service-based arrangements, leases, PPAs, and hybrid structures within the same utility portfolio.

Managerial And Policy Implications

The findings have direct implications for PT PLN (Persero) and other capital-intensive utilities considering a transition toward more flexible asset-governance arrangements. The first implication is that PT PLN (Persero) should implement the CAPEX-to-OPEX transformation through asset segmentation rather than an organization-wide conversion. Evidence indicates that technologies characterized by rapid technological change and higher obsolescence risk are stronger candidates for OPEX-oriented arrangements. Smart-grid platforms, digital monitoring infrastructure, selected operational equipment, and renewable-energy procurement structures show greater transformation potential, while strategically critical core-network assets are better controlled through CAPEX ownership.

Accordingly, PLN should evaluate infrastructure assets using a structured screening mechanism.

Table 7. Strategic Screening Criteria for CAPEX–OPEX Asset Decisions

Decision Criterion	CAPEX More Appropriate When	OPEX/Hybrid More Appropriate When
Technological lifecycle	Technology is stable and long-lived	Technology changes rapidly
Strategic criticality	Direct control is essential	External provision does not compromise system control
Asset specificity	Asset is highly PLN-specific	Asset/service is standardized or transferable
Contractibility	Performance is difficult to specify	Output and SLA can be objectively measured
Obsolescence risk	Low	High
Capital requirement	Financing capacity is sufficient	Upfront capital requirement is constraining
Vendor market	Few credible providers	Competitive supplier market exists

Decision Criterion	CAPEX More Appropriate When	OPEX/Hybrid More Appropriate When
Risk-management capability	PLN can manage lifecycle risks efficiently	Provider has superior capability to manage selected risks
Financial priority	Lifecycle efficiency and ownership value dominate	Liquidity and financing flexibility dominate

Source: Authors' Own Work, 2026

Second, financial evaluation should go beyond reducing CAPEX. The simulation demonstrates that the transformation can reduce interest-bearing debt while creating substantial operating-cost pressure. Management should therefore evaluate at least five financial dimensions simultaneously: cash-flow requirements, debt capacity, OPEX exposure, profitability, and lifecycle cost. The 24.88% increase in OPEX and 36.99% decline in EBITDA in the scenario indicate that reducing capital expenditure without controlling recurring contractual payments can materially weaken operating performance. Third, PLN should implement the transformation through a phased portfolio strategy. PLN can transition assets with the strongest technological and financial rationale for OPEX first, allowing it to evaluate contract performance, financial consequences, vendor capability, and operational reliability before expanding the model. This reduces the risk of committing the organization to large-scale long-term contracts before the governance architecture has been tested. Fourth, treat contract management as a core asset-management capability. Every OPEX-based arrangement should be supported by a detailed Service Level Agreement defining service availability, reliability standards, response time, maintenance responsibilities, technology-refresh obligations, cost-adjustment mechanisms, cybersecurity requirements, data ownership, penalties, escalation procedures, and termination conditions. The original analysis already identifies detailed SLAs, periodic vendor evaluation, escalation mechanisms, and multi-vendor arrangements as necessary safeguards.

Fifth, PLN should avoid excessive vendor concentration. A multi-vendor strategy can reduce dependency on a single service provider, preserve bargaining power, encourage technological competition, and improve resilience where service interruption could affect critical electricity infrastructure. Vendor diversification is particularly important for systems connected to smart-grid operations, data infrastructure, monitoring platforms, and other digitally dependent assets. Sixth, conduct accounting assessments before contract approval, not after implementation. Commercial arrangements described operationally as OPEX may still generate right-of-use assets and lease liabilities under PSAK 73. Contract structures should therefore be jointly reviewed by asset-management, finance, accounting, tax, procurement, and legal functions before financial benefits are incorporated into investment decisions. Seventh, incorporate tax implications into lifecycle-cost evaluation. Immediate recognition of qualifying operating expenses may generate short-term tax benefits, but different lease and service structures carry different withholding and final-tax obligations. The study identifies a 10% final income-tax treatment for leases involving land and/or buildings and a 2% Article 23 withholding treatment for relevant leases without land. These effects should be incorporated into contract-level financial modelling rather than treated as administrative consequences after procurement.

Public policy should support neutrality between ownership and service-based investment structures. Regulatory arrangements that implicitly favor capital investment may discourage economically efficient service-based solutions, while indiscriminate encouragement of OPEX may create excessive contractual dependency. Policy should instead encourage lifecycle-value assessment, transparent risk allocation, financial sustainability, service reliability, and technological adaptability. For PLN, the strategic objective is therefore not to maximize OPEX or minimize CAPEX, but to develop an asset portfolio in which each financing and governance arrangement matches the economic life, technological characteristics, operational criticality, and risk profile of the underlying infrastructure.

E. CONCLUSIONS

This study examined the strategic implications of transforming selected infrastructure investments from capital expenditure (CAPEX)-based ownership toward operational expenditure (OPEX)-oriented arrangements within PT PLN (Persero). The findings demonstrate that the transformation should not be interpreted as a universal replacement of CAPEX by OPEX. Instead, the appropriate structure depends on asset characteristics, technological dynamics, financial objectives, contractual arrangements, and governance capacity. The financial simulation reveals a clear trade-off. Under the scenario in which 70% of generation investment is transferred to Independent Power Producers, interest-bearing debt decreases by 6.75%, and DSCR improves by 3.8%, indicating greater financing flexibility and stronger debt-servicing capacity. However, these improvements are accompanied by a 24.88% increase in OPEX, a 36.99% decline in EBITDA, a 7.63% reduction in operating income, a 9.93% decline in net income, a 7.0% reduction in ROA, and a 48.1% increase in leverage. The transformation therefore redistributes financial pressure rather than eliminating it.

The cost–benefit analysis produces a similarly differentiated result. The OPEX scenario generates estimated ten-year benefits of Rp1,598.62 trillion, substantially higher than the Rp726.45 trillion estimated under CAPEX. Nevertheless, CAPEX produces a stronger benefit-cost ratio of 17.01, compared with 8.83 for OPEX. These results indicate that absolute benefit magnitude and benefit efficiency do not necessarily point toward the same strategic choice. The asset-level analysis further shows that transformation potential varies across infrastructure categories. Smart-grid technologies, digital monitoring platforms, selected equipment, and renewable-energy procurement arrangements show greater potential for OPEX-oriented structures because they involve technological change, obsolescence risk, and opportunities for service-based delivery. In contrast, long-lived and strategically critical core-network assets remain more appropriately governed through direct PLN control.

The study therefore supports a selective CAPEX–OPEX portfolio strategy. CAPEX remains important where ownership, lifecycle efficiency, and operational control dominate, while OPEX or hybrid arrangements become more appropriate where flexibility, technological renewal, financing capacity, and risk transfer create greater strategic value. The effectiveness of these arrangements ultimately depends on contract design, accounting treatment, fiscal compliance, vendor governance, risk allocation, and institutional oversight. Accordingly, PLN's strategic objective should not be to minimize CAPEX or maximize OPEX. Instead, it should align each asset category with the governance and financing structure that best supports financial resilience, infrastructure reliability, technological adaptability, and long-term electricity-system sustainability.

Limitations and Future Research

This study has several limitations to consider when interpreting its findings. First, the financial simulation is based on specific assumptions, particularly the transfer of 70% of generation capacity to IPPs and the use of PLN's 2024 CAPEX baseline. The resulting financial effects are therefore scenario-dependent and may change under alternative transition proportions, financing conditions, electricity-purchase costs, or investment structures. Second, the cost–benefit analysis is deterministic. The model does not incorporate probabilistic uncertainty in key parameters such as financing costs, OPEX escalation, contract duration, discount rates, technology costs, or future electricity-purchase prices. Consequently, the reported CBR values of 17.01 for CAPEX and 8.83 for OPEX should be interpreted within the assumptions applied to the current analytical scenario rather than as universally stable estimates.

Third, the study is conducted at the corporate asset-portfolio level. It does not evaluate implementation feasibility across individual PLN regions, distribution units, generation projects, or specific infrastructure classes. Differences in network condition, asset age, electricity demand, reliability performance, geographic characteristics, vendor availability, and local operating environments may produce different CAPEX–OPEX preferences at the operational level. Fourth, the benchmarking analysis uses selected international and cross-sector cases. Although these cases provide relevant strategic lessons, differences in regulation, electricity-market structure, ownership arrangements, technology maturity, and institutional capacity limit direct transferability to the Indonesian electricity sector.

Future research should therefore extend the analysis in several directions. Scenario modelling should examine alternative CAPEX–OPEX compositions rather than relying on a single 70% transition assumption. Sensitivity analysis should test the robustness of financial outcomes against variations in electricity-purchase costs, financing rates, contract duration, OPEX escalation, depreciation assumptions, and technology costs. Probabilistic approaches, including Monte Carlo simulation, could further estimate the distribution of possible financial outcomes under parameter uncertainty. Future studies should also conduct asset-level and regional analyses to determine whether the transformation logic differs across substations, transformers, smart meters, digital platforms, renewable-energy procurement, operational vehicles, and other infrastructure categories. Such analyses would enable the development of an empirically validated asset-screening model for determining when CAPEX ownership, OPEX contracting, or hybrid arrangements are most appropriate.

Additional research is also needed on contractual architecture. The effectiveness of service-based infrastructure arrangements depends heavily on risk-sharing mechanisms, Service Level Agreements, vendor performance monitoring, cybersecurity provisions, price-adjustment mechanisms, termination rights, and technology-refresh obligations. Longitudinal research could examine how these contractual structures influence lifecycle costs, infrastructure reliability, provider dependency, and financial performance over time. Finally, future research should integrate financial outcomes with operational and public-service indicators such as SAIFI, SAIDI, outage duration, service reliability, network losses, technology adoption, and customer-service performance. This would enable CAPEX–OPEX decisions to be evaluated not only by corporate financial consequences but also by their contribution to the reliability and resilience of the electricity system.

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