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Scenario-Based Evaluation of Economic Feasibility and Risk in City Gas Networks: A Case Study From East Java, Indonesia

Deddy Tricahyo Utomo and Cindy Dianita

Department of Chemical Engineering, Universitas Indonesia
Lingkar Street, Pondok Cina, Beji Sub-district, Depok City, West Java, 16424, Indonesia

Corresponding author: dedikristanto@upnyk.ac.id

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ABSTRACT - This study aims to evaluate the economic feasibility and develop optimization scenarios for a natural gas distribution network intended for household use. The case study employs existing gas pricing and consumption data from East Java Province to support realistic economic modeling. The analysis examines how three important factors the number of customers, the price of gas, and how much gas is used affect key economic measures: net present value (NPV), internal rate of return (IRR), payback period (PP), and benefit-cost ratio (BCR). The research methodology includes secondary data collection, simulation of six different scenarios, and sensitivity analysis to examine the critical factors influencing project viability. Simulation results indicate that the scenario assuming a 25% increase in both gas selling price and gas consumption yields the most favorable economic performance, with an IRR of 14.21% and a payback period of less than seven years. The novelty of this study lies in its integrated use of scenario-based economic modeling, sensitivity analysis, and international benchmarking with comparable industries. Unlike conventional feasibility studies that focus solely on regional expansion, this research underscores the strategic role of pricing and consumption patterns as key determinants of financial sustainability in residential gas networks. The findings from the sensitivity analysis reveal that gas selling price has the most significant impact on economic performance, followed by gas consumption rate. These insights reinforce the importance of pricing adjustments and consumption optimization in enhancing the financial and operational sustainability of natural gas distribution networks. The study concludes with strategic recommendations for operators and policymakers to advance efficient and resilient gas-based energy infrastructure.

Keywords: natural gas network, optimization scenarios, internal rate of return, payback period, sensitivity analysis.

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INTRODUCTION

Natural gas is increasingly acknowledged as one of the cleanest and most efficient fossil energy sources, playing a central role in the global transition toward a low-carbon energy system. Compared to coal and petroleum-based fuels, it generates significantly lower carbon emissions and delivers higher thermal efficiency, establishing its position as a key transitional fuel in many national energy strategies (IEA 2023; EIA 2023). The international effort to mitigate climate change, as outlined in the Paris Agreement, has led countries including Indonesia to reduce their dependence on high-emission energy sources. In this context, natural gas presents a viable and adaptable solution that supports greener energy transitions while safeguarding economic growth and social development. The United Nations Environment Programme (UNEP 2022) further highlights its importance in reducing carbon intensity during the interim phase toward full renewable energy adoption.

Responding to these global objectives, the Indonesian government has set a target of achieving a 23% share of new and renewable energy in the national energy mix by 2025, as mandated in the National Energy Policy (ESDM 2019). One of the key strategies to achieve this target is the expansion of residential natural gas distribution networks. This initiative is designed to reduce dependence on subsidized liquefied petroleum gas (LPG), improve national energy efficiency, and reinforce energy security (Purwanto et al. 2023).

Nevertheless, the advancement of Indonesia's natural gas infrastructure faces persistent challenges, including declining production from aging gas fields, limited exploration of new reserves, and the high capital investment required for pipeline development (Bambang 2007). According to the IEA (2023), national gas production has remained stagnant despite growing domestic demand, underscoring the need for more effective utilization of existing resources, particularly in the household sector.

From both technical and economic perspectives, natural gas offers distinct advantages over other fossil fuels. It features lower greenhouse gas emissions, delivers improved combustion efficiency, and enables efficient distribution through pipeline networks, which provide continuous, safe energy delivery while eliminating the need for gas cylinders (EIA 2023). Low-pressure pipelines for household use reduce transportation costs and contribute to reduced government subsidies (ESDM 2023). As such, household gas infrastructure is considered a strategic initiative to lower consumer energy costs and ease the fiscal burden on the state.

By the end of 2022, more than 700,000 household gas connections had been established nationwide (ESDM 2023). Energy consumption in the residential sector is projected to increase substantially by 2060, reinforcing the necessity of reliable and scalable distribution systems (Andi et al. 2025). However, the long-term sustainability of household gas networks remains uncertain due to multiple financial challenges ranging from volatile gas prices and limited customer bases to high upfront capital requirements and relatively low per-household gas usage (Parikesit et al. 2024).

Previous studies have primarily focused on evaluating the financial feasibility of regional gas infrastructure development (He et al., 2013; Biose et al., 2020). However, they often overlook critical factors such as tariff-setting mechanisms, customer behavior, and regulatory constraints, all of which significantly influence project viability. Moreover, few studies have explored international benchmarking and policy comparisons relevant to residential gas distribution networks.

To address these gaps, this study proposes an integrated analytical framework combining financial modeling, sensitivity analysis, and international benchmarking to assess the feasibility of household gas networks. The analysis identifies key parameters including customer growth, pricing strategies, and consumption rates and examines how their variations affect economic performance. By benchmarking against established operators such as Osaka Gas (Japan) and Engie Romania, the study also incorporates valuable insights into regulatory design, pricing policy, and infrastructure management practices applicable to the Indonesian context.

The objective of this study is to evaluate the economic feasibility of residential natural gas networks in East Java through scenario-based financial modeling, sensitivity analysis, and international benchmarking. It aims to identify the key variables that most significantly impact financial performance and to provide policy recommendations for the sustainable development of urban gas infrastructure in Indonesia.

METHODOLOGY

This study adopts a case study approach focused on the development and economic evaluation of urban gas distribution networks in East Java Province. The location was selected based on the availability of technical data, regulatory frameworks, and existing infrastructure, making it suitable for in-depth analysis. The research integrates empirical data with scenario-based simulations to assess the financial viability of expanding natural gas networks for both household and small business customers.

Primary data were gathered through a comprehensive review of official regulation and policy documents issued by key institutions such as the Downstream Oil and Gas Regulatory Agency (BPH Migas) and the Ministry of Energy and Mineral Resources (ESDM). Secondary data were obtained from reputable scientific journals and international energy reports, including those published by the International Energy Agency (IEA). This multi-source data approach provided a robust foundation for modeling and scenario development.

The analysis was conducted using six simulation scenarios designed to evaluate the sensitivity of economic indicators to variations in gas selling prices, customer numbers, and monthly gas consumption. These scenarios reflect potential policy interventions and shifts in end-user behavior. In all simulations, the gas purchase price was held constant at USD 4.72 per million British thermal units (MMBTU) for the duration of the project. The gas selling price varied by customer category: IDR 4,250/m³ for Household Category 1 (RT 1) and Small Customer Category 1 (PK 1), and IDR 6,000/m³ for Household Category 2 (RT 2) and Small Customer Category 2 (PK 2).

Average monthly gas consumption was assumed to be 15 m³ for households and 500 m³ for small business customers. The project lifespan was set at 30 years, consistent with typical infrastructure investment horizons. The estimated capital cost per household connection was approximately IDR 8,000,000, covering network procurement, installation, and commissioning. A discount rate of 10% was applied to reflect the opportunity cost of capital in the financial calculations.

Economic feasibility was assessed using four key financial indicators: Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PP), and Benefit-Cost Ratio (BCR). NPV was calculated as the difference between the present value of projected cash inflows and the initial capital investment; IRR represents the discount rate at which NPV equals zero; PP measures the time required to recover the initial investment; and BCR is defined as the ratio of total project benefits to total costs.

All simulations were conducted using dynamic spreadsheet models, enabling comparative analysis across scenarios. This methodological framework was designed to identify the most effective operational strategies and policy options for ensuring financial viability while promoting sustainable development of urban gas infrastructure development and expanding access to affordable energy for consumers.

RESULT AND DISCUSSION

Scenario simulation

This study developed six simulation scenarios, as shown in Table 1. Each scenario reflects variations in assumptions regarding the gas selling price, number of customers, and monthly gas consumption. These variables directly influence key economic indicators such as Internal Rate of Return (IRR), Payback Period (PP), and Benefit-Cost Ratio (BCR). Assessing these variables is essential, as nation natural gas production is stagnating - primarily due to declining and the limited discovery of new reverse (Bambang 2007; IEA 2023). These conditions underscore the need to optimize residential gas utilization to maintain energy security and ensure the viability of distribution infrastructure.

Scenario 1 explores the impact of a substantial increase (50%) in gas selling prices, while keeping the number of customers and consumption levels constant. This scenario evaluates the effect of tariff adjustments as a strategy to enhance financial performance, aligning with ongoing policy discussions on energy pricing reforms in Indonesia. Under this scenario, the gas price increases from IDR 4,250/m³ to IDR 6,375/m³ for RT 1 and PK 1, and from IDR 6,000/m³ to IDR 9,000/m³ for RT 2 and PK 2.

Scenario 2 examines the effect of expanding the customer base by increasing the number of connections by 50%, reaching 15,000, while keeping gas prices and consumption level unchanged. This case study simulates a government-led infrastructure expansion initiative aimed at broadening access to natural gas. The scenario assesses whether network scale alone can justify the investment in the absence of increased consumption or adjusted pricing.

Scenario 3 models a 50% increase in gas usage resulting from behavioral changes and the adoption of gas-powered household appliances, including water heaters. Household consumption rises from 15 m^3/month to 22.5 m^3/month, while small customer usage increases from 500 m^3/month to 750 m^3/month. This scenario captures the potential revenue impact of shifting end-user behavior without expanding the customer base or modifying tariffs.

Scenario 4 combines a 25% increase in both the gas selling price and the number of customers, while maintaining constant consumption levels. In this case, prices for RT 1 and PK 1 increase to IDR 5,313/m^3, and for RT 2 and PK 2 to IDR 7,500/m^3, with the customer base growing to 12,500. This hybrid approach evaluates the combined effects of pricing flexibility and moderate network expansion on financial outcomes.

Scenario 5, identified as the most financially favorable, assumes a 25% increase in both gas selling price and consumption, while the number of customers remains constant. Monthly consumption for RT categories increases to 18.75 m^3, and for PK categories to 625 m^3. This scenario highlights strategies that optimize revenue per connection, including targeted pricing policies, demand-side management, and consumer education initiatives.

Scenario 6 simulates a 25% increase in both the number of customers and gas consumption, with keeping gas prices held constant. This reflects organic market growth driven by rising demand and customer expansion, aligned with broader demographic trends and energy transition objectives.

Economic analysis

The simulation results are summarized in Table 1. Among the six scenarios, Scenario 5 provides the strongest financial performance, yielding an IRR of 14.21% and a payback period of 7 years. This outcome illustrates that a balanced strategy combining modest tariff adjustments with increased household gas usage can significantly enhance project profitability without requiring large-scale infrastructure expansion. These findings directly support the study objective of identifying cost-effective and sustainable approaches for city gas network development in Indonesia.

In contrast, Scenario 2, which focuses solely on increasing the number of customers, results in the lowest IRR at 1.01%, with a payback period of 25 years. This suggests that expanding the customer base alone is insufficient to justify the high upfront investment required for new connections, particularly when average gas usage remains low.

Scenarios that alter only one variable either price or consumption demonstrate modest improvements, but none match the profitability of Scenario 5. These findings reinforce the importance of pricing strategies and consumption behavior as more influencial levers than network size in determining the financial feasibility of city gas projects. This interpretation aligns with He et al. (2013), who found that pricing mechanisms significantly affect the long-term sustainability of urban gas network.

However, unlike He et al. (2013), this study employs an integrative approach that quantifies the combined effects of pricing, consumption and consumer base expansion across six simulation scenarios. As such, it contributes a novel methodological framework for policymakers to evaluate investment viability more comprehensively.

Table 1. Economic calculation for each scenario

Scenario	Gas Selling Price	Number of Customers	Monthly Gas Consumption	IRR (%)	Payback Period (years)
Scenario 1	Increase by 50%	Constant	Constant	10.5 %	9
Scenario 2	Constant	Increase by 50 %	Constant	1.01 %	25
Scenario 3	Constant	Constant	Increase by 50%	5.59 %	14
Scenario 4	Increase by 25%	Increase by 25%	Constant	6.24 %	13
Scenario 5	Increase by 25%	Constant	Increase by 25%	14.21 %	7
Scenario 6	Constant	Increase by 25%	Increase by 25%	3.45 %	18

Sensitivity analysis

Sensitivity analysis was conducted to evaluate the extent to which variations in key project variables namely, gas selling price, number of customers, and gas consumption rate affect the economic performance of the project. The objective is to identify which variables most significantly influence financial indicators such as the Internal Rate of Return (IRR), Net Present Value (NPV), and Payback Period (PP) (Parikesit et al. 2024). By understanding these sensitivities, stakeholders can better anticipate potential risks and optimize strategic decision-making.

In alignment with international best practices, the sensitivity analysis applied a ±10% variation to each of the key parameters. This modelling approach follows recommendations from global institutions such as the International Energy Agency (IEA 2023), the World Bank Group (2020), and the Asian Development Bank (ADB 2021)

The results indicate that changes in the gas selling price have the most pronounced effect on IRR and other financial metrics. A 10% increase in the gas price significantly enhances revenue, accelerates the payback period, and raises the overall project profitability. Conversely, a 10% price reduction adversely impacts all financial indicators, underscoring the pivotal role of tariff-setting policies in financial sustainability.

The gas consumption rate is the second most sensitive variable. Increased gas usage per customer improves revenue efficiency without substantially increasing fixed costs, thereby enhancing both IRR and NPV. This finding suggests that strategies aimed at promoting higher household gas consumption such as appliance subsidies or usage-based education can meaningfully improve project economics.

In contrast, increasing the number of customers has a relatively smaller impact on financial outcomes. Although this may lead to higher aggregate consumption, it also entails significant capital expenditure for new connections. As a result, the financial gains from customer growth are partially offset by the additional investment required, making this variable the least influential among the three.

Figure 1. illustrates the results of the sensitivity analysis, showing the response of IRR, NPV, and PP to ±10% changes in each variable. These findings reinforce the importance of prioritizing pricing and consumption optimization strategies over network expansion.

Compared to Biose et al. (2020), who evaluated pipeline projects in Nigeria, the results of this study show greater sensitivity to changes in consumption, likely due to Indonesia's lower average household gas usage and higher capital costs per connection. This further supports the need for consumption-based policies tailored to local context.

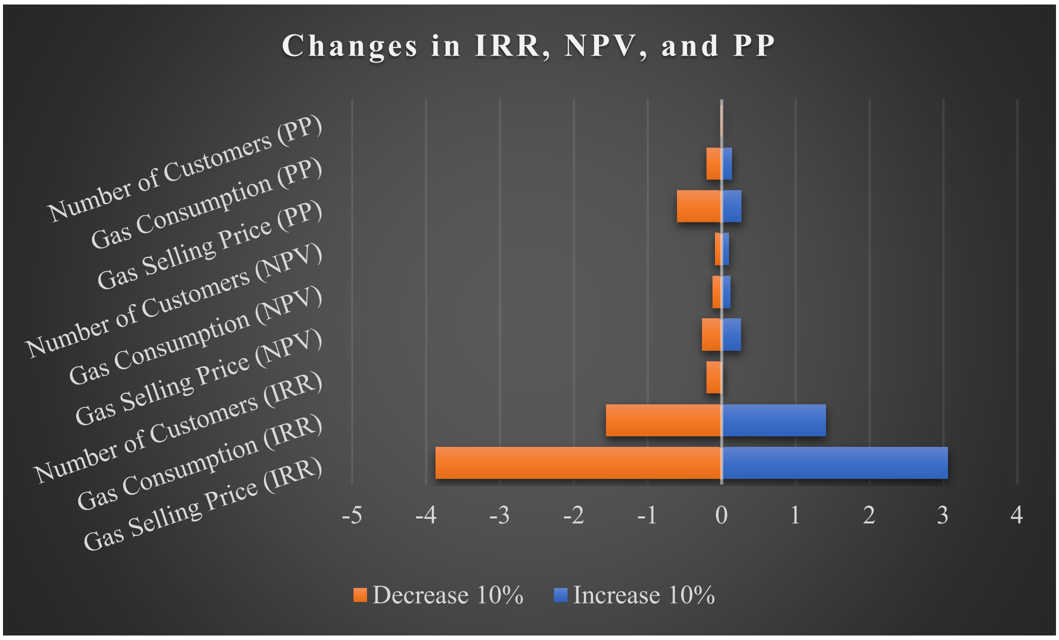

Figure 1. Changes in IRR, NPV, and PP with ±10% variations in gas selling price, number of customers, and gas consumption

Benchmarking of gas network operators

Benchmarking was conducted to compare the management strategies and operational performance of urban gas network operators in Indonesia with those in other countries. The aim of this exercise is to derive actionable insights that can enhance the sustainability, efficiency, and financial viability of Indonesia's gas distribution systems. The benchmarking emphasizes several key dimensions, including regulatory frameworks, pricing mechanisms, infrastructure development, and technological integration.

This study examines on two international operators with well-established gas distribution networks: Osaka Gas (Japan) and Engie Romania. These companies were selected due to their strong track records in managing urban gas infrastructure, as well as their adoption of advanced technologies and policy models that support efficient service delivery and financial sustainability.

A comparative analysis reveals that both Osaka Gas and Engie Romania operate under more flexible regulatory environments than Indonesia. For example, gas pricing in Japan and Romania follows a combination of market-based and regulated structures, allowing operators to adjust prices more dynamically in response to fluctuations in costs and demand. In contrast, gas prices in Indonesia are tightly regulated by BPH Migas, which limits the financial agility of domestic operators.

Another key distinction lies in infrastructure development. In Japan and Romania, infrastructure is primarily developed by private sector entities under government oversight. In Indonesia, by contrast, development is largely managed by State-owned enterprises (SOEs), such as PGN and Pertamina, which often receive direct budgetary support and subsidy mandates. This arrangement introduces operational and financial constraints that may hinder long-term efficiency and scalability. Furthermore, the national legal framework remains fragmented and lacks effective integration between central and regional policies, posing challenges for investor confidence and timely project execution (Winarsih 2022). These institutional rigidities underscore the need for comprehensive policy reform to support a more adaptive and investment-friendly environment in Indonesia's natural gas sector. Lessons from international benchmarks suggest that legal and regulatory flexibility is critical to enabling market responsiveness, improving operational efficiency, and accelerating network expansion

From a technological perspective, both international operators have implemented smart metering systems and energy efficiency technologies to optimize consumption and reduce operational losses. These tools not only improve customer service but also enhance real-time monitoring and revenue assurance. In Indonesia, such technologies are not yet widely adopted, presenting a significant opportunity for modernization and digital transformation.

Moreover, consumer categorization in Japan and Romania is more granular and consumption-based, enabling tailored pricing and service models. For instance, Osaka Gas classifies consumers into categories ranging from under 20 m^3/month to over 1,000 m^3/month, while Engie Romania uses electricity-equivalent brackets in megawatt-hours (MWh). In contrast, Indonesia applies broader consumer categories (e.g., RT 1, RT 2, PK 1, PK 2), which may limit pricing precision and reduce the effectiveness of cross-subsidization mechanisms.

Overall, this benchmarking highlights that financial and operational success in urban gas networks is not solely determined by technical capacity or gas pricing. Managerial flexibility, pricing mechanisms, technology adoption, and regulatory alignment all play critical roles. Learning from international best practices can support Indonesian operators and policymakers design more adaptive and sustainable models for household gas distribution.

The comparison results underscore the vital necessity of integrating Indonesia's gas network policies with global best practices. Specifically, implementing more flexible pricing models, encouraging greater private sector involvement in infrastructure development, and accelerating the adoption of smart technologies are crucial steps toward improving economic viability and operational robustness. By implementing a more flexible regulatory and pricing framework, Indonesia may substantially enhance the sustainability of its domestic gas network, reduce fiscal constraints, and bolster investor confidence.

Table 2. Summarizes the benchmarking findings across key regulatory and operational dimensions. Source: Osaka Gas (2023); Engie Romania (2023); Pertamina (2024); ESDM (2022); IEA (2023).

Indicator	Osaka Gas	Engie Romania	Gas Networks in Indonesia
Economic Feasibility and Pricing	Flexible gas prices following the market	Mixed gas pricing: market-based and regulated by the government	Gas prices are set by the government through BPH
Regulations and Policies	Private sector dominant; government as regulator	Private sector dominant; regulations ensure supply	Managed by SOEs; limited private sector
Gas Supply Sources	LNG imports and domestic network	Domestic production and imports from Eastern Europe	Natural gas from domestic wells
Infrastructure Development	Built by the private sector with government regulation	Built by the private sector with government regulation	Built by government; assignments to SOEs
Consumer Access	Extensive network coverage	Urban penetration is increasing	Limited to major cities; expanding gradually
Subsidies and Incentives	Minimal subsidies; green technology incentives	Household subsidies; clean energy tax incentives	Large subsidies for households and small customers
Technology and Efficiency	Smart metering, integration with green energy systems	Smart grid and advanced energy efficiency systems	Smart technologies not yet widely implemented
Customer Categories	A: 0-20 m³/month B: 20-50 m³/month C: 30-100 m³/month D: 100-200 m³/month E: 200-350 m³/month F: 350-500 m³/month G: 500-1000 m³/month H: >1000 m³/month	C1: 0-280 MWh/month C2: 280-2800 MWh/month C3: 2800-28000 MWh/month C4: 28000-280000 MWh/month	RT 1: 0-50 m³/month RT 2: 0-50 m³/month PK 1: 0-1000 m³/month PK 2: 0-1000 m³/month

CONCLUSION

Based on the results of the scenario simulations and sensitivity analysis, it can be conducted that the sustainability and economic feasibility of the natural gas distribution network project are significantly influenced by variables such as gas selling price adjustments and the optimization of customer consumption levels. The findings indicate that a strategy focused solely on increasing the number of customers —without corresponding adjustments to pricing or consumption—is insufficient to achieve acceptable profitability. This underscores the need for a holistic approach to ensure the long-term success of the project. Accordingly, a strategy that integrates moderate pricing policy adjustments, consumer education and outreach to encourage higher gas usage, and selective network expansion is essential to ensure both the viability and sustainability of the natural gas distribution initiative. Such an approach not only boosts revenue for operators but also reinforces the competitiveness and resilience of household clean energy programs. Furthermore, this approach supports the broader goals of energy efficiency and environmental sustainability, ultimately benefiting both end-users and the national energy sector.

The study also highlights the importance of regularly evaluating pricing structures, consumption patterns and market demand forecasts, given the evolving nature of the energy sector—driven by technological innovation, regulatory shifts, and global economic dynamics. Therefore, it is recommended that natural gas network operators adopt a scenario-based planning framework to proactively manage uncertainties and improve investment decision-making.

From a policy standpoint, government support is crucial in the form of adaptive pricing regulations, fiscal incentives for infrastructure development, and public education initiatives to promote broader and more efficient use of natural gas within the household sector. Through the synergy of forward-thinking policy and sound operational strategies, natural gas distribution networks can become a cornerstone of Indonesia's sustainable and inclusive energy transition.

GLOSSARY OF TERMS

Symbol	Definition	Unit
NPV	Net Present Value	IDR (Indonesian Rupiah)
IRR	Internal Rate of Return	%
PP	Payback Period	Year(s)
BCR	Benefit-Cost Ratio	Unitless (Ratio)
m^3	Volume of natural gas	Cubic meter (m^3)
MMBTU	Million British Thermal Units	Energy (MMBTU)
IDR	Indonesian Rupiah (currency)	Currency (IDR)
USD	United States Dollar	Currency (USD)
RT 1	Household Customer Category 1	m^3/month
RT 2	Household Customer Category 2	m^3/month
PK 1	Small Customer Category 1	m^3/month
PK 2	Small Customer Category 2	m^3/month
%	Percentage (used in increase/decrease of variables)	%
t	Time or year (for project duration/payback period)	Year (t)
r	Discount Rate	%

REFERENCES

Andi, J., Yusgiantoro, P., & Siagian, U., 2025, Development of energy system modeling in East Kalimantan's household sector with bottom-up approach for energy demand forecast in 2060. Scientific Contributions Oil and Gas (SCOG), 48(1). https://doi.org/10.29017/scog.v48i1.1732.

Asian Development Bank (ADB), 2021, Handbook on Infrastructure Economic Analysis. Manila: Asian Development Bank. https://www.adb.org/publications/infrastructure-economic-analysis-handbook.

Widarsono, 2007, Indonesia's natural gas: Production, reserves, and challenges. Scientific Contributions Oil and Gas (SCOG), 30(1). https://doi.org/10.29017/SCOG.30.1.972.

Biose, H., Dosunmu, A., & Nwaozuzu, C., 2020, Economic Impact Analysis of Natural Gas Pipeline Development in Nigeria. International Journal of Engineering Technologies and Management Research, 6(12), 35–45. https://doi.org/10.29121/ijetmr.v6.i12.2019.472.

BPH Migas, 2021a, Regulation No. 13/2021 regarding the gas selling price in Gresik Regency.

BPH Migas, 2021b, Regulation No. 4/2021 concerning the second amendment to Regulation No. 22/P/BPH Migas/VII/2011 on the determination of natural gas prices for households and small customers.

Brealey, R.A., Myers, S.C., & Allen, F., 2019, Principles of corporate finance (13th ed.). McGraw-Hill Education.

Directorate General of Oil and Gas, Ditjen Migas, 2013, Technical guidelines for the development of natural gas networks.

ECliST, 2021, Energy Outlook Indonesia 2021.https://www.eclist.org/energy-outlook-indonesia-2021

Energy Information Administration (EIA), 2023), Natural gas prices. https://www.eia.gov/naturalgas/.

Engie Romania, 2024a, Gas distribution network management in Romania. Engie Romania S.A. https://www.engie.ro/.

European Gas Hub, 2024b, TTF price index trends. https://www.europeangashub.com/

He, Y., Xia, T., Liu, Y., Zhou, L., & Zhou, B., 2013, Residential natural gas price affordability analysis A case study of Beijing. Renewable and Sustainable Energy Reviews, 28, 392–399. https://doi.org/10.1016/j.rser.2013.08.004.

International Energy Agency (IEA), 2023, LNG market analysis. https://www.iea.org/reports/lng-markets-analysis.

Kayis, B., 2008, Risk management in engineering projects. McGraw-Hill.

Ministry of Energy and Mineral Resources (ESDM), 2019, National energy general plan.

Ministry of Energy and Mineral Resources (ESDM), 2023, Energy sector performance achievements in 2023. Ministry of Energy and Mineral Resources, Republic of Indonesia.

Minister of Energy and Mineral Resources (ESDM), 2024, Regulation No. 14/2024 regarding the optimization of natural gas utilization.

Osaka Gas, 2023, Company profile and operations in Japan's urban gas distribution. Osaka Gas Co., Ltd. https://www.osakagas.co.jp/en/.

Parikesit, D., Amrozi, M.R.F., Rachmawati, F., Utomo, C., Hatmoko, J.U.D., Hermawan, F., Handayani, F.S., Safitri, E., & Hendrawan, V.S. A., 2024, Engineering economics: Case-based learning in projects. UGM Press.

Purwanto, Y.S. et al., 2023, Development of natural gas energy for low-carbon urban areas.

SNI ISO 31010:2016. Risk management Risk assessment techniques.

United Nations Environment Programme (UNEP), 2022, The state of the climate in 2022. https://www.unep.org/resources/report/state-climate-2022.

Winarsih, W., 2022, Legal framework on policy for natural gas development and utilization. Scientific Contributions Oil and Gas, 31(3), 47–56. https://doi.org/10.29017/scog.31.3.1016.

World Bank Group, 2020, Analyzing the Economic Viability of Energy Infrastructure Projects. Washington, D.C.: World Bank.