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Assessing the Impact of Fiscal Incentives on the Investment Feasibility of Geothermal Projects in Indonesia: A Value-at-Risk approach

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ABSTRACT

This study assesses the impact of fiscal incentives on the investment feasibility and risk profile of geothermal power projects in Indonesia. Geothermal energy is central to the country's clean-energy transition, yet high exploration costs, long development timelines, and limited fiscal support constrain private investment. To address these challenges, a quantitative analysis was conducted using an integrated Discounted Cash Flow (DCF) model and Value-at-Risk (VaR) analysis. A stochastic financial model for a 50 MW geothermal power plant was simulated over 1000 Monte Carlo iterations across five policy scenarios: Business-as-Usual (BAU), Value-Added Tax (VAT) removal, Land and Building Tax (LBT) removal, tax holiday, and a combined total incentive package. Results show that fiscal incentives improve project profitability while affecting financial volatility. The BAU case yields a mean Net Present Value (NPV) of – USD 8.4 million and an Internal Rate of Return (IRR) of 9.39%, whereas the Total Incentive scenario achieves + USD 0.38 million NPV and 10.03% IRR. The VaR analysis indicates reduced downside loss probability but greater dispersion of returns, suggesting a high-risk, high-return profile. Sensitivity results highlight power-plant EPC and drilling costs as dominant risk drivers.

Keywords: Geothermal Energy, Fiscal Incentives, Value-At-Risk, Investment Feasibility, Monte Carlo Simulation, Indonesia
JEL Classifications: Q42, Q48, G32, H25

1. INTRODUCTION

Geothermal energy, derived from the Earth's subsurface heat, is a renewable resource capable of producing electricity continuously regardless of weather conditions (IEA, 2022; Matek, 2014). Its baseload capability makes it a critical complement to intermittent renewable sources such as solar and wind (Anditya et al., 2015). However, geothermal development typically requires substantial upfront capital investment, long lead times between exploration and operation, and a high cost of capital, which together challenge its financial feasibility (IEA, 2024; Pambudi and Ulfa, 2024).

Indonesia, endowed with an estimated 23.6 GW of geothermal potential, recognizes this resource as a key pillar in its clean energy transition. Under the national roadmap toward Net Zero Emission (NZE) 2060, the Government of Indonesia (GOI) targets 22.7 GW of installed geothermal capacity generating 178 TWh annually, equivalent to 9.25% of the projected energy mix by 2060 (Dobson et al., 2025; MoEF, 2021; Muyasyaroh, 2024). The RUPTL 2025-2035 further sets renewable generation targets at 20.9 GW or 51.6% of total installed capacity, including 5.2 GW of additional geothermal capacity by 2025 (MEMR, 2021). Yet, as of 2025, only 2.7 GW—or roughly 11% of total potential—has been utilized, indicating a persistent investment gap despite abundant resources.

The underdevelopment of Indonesia's geothermal sector is driven primarily by high exploration risks, substantial upfront costs, and limited financial incentives (Adam et al., 2025; Tharom and Hadi, 2020). These challenges constrain investor confidence and delay project bankability. The uncertainty of subsurface resources during the exploration phase and the potential decline of reservoirs during exploitation contribute to significant financial risks, discouraging private sector participation (Dewi et al., 2022; Kassem et al., 2025). Effective risk mitigation and fiscal support are therefore essential to improve the economic viability of geothermal investments (Gehringer and Loksha, 2012).

To accelerate renewable energy deployment, the GOI has introduced a series of policy instruments, including tariff regulations and fiscal incentives. However, the reference electricity price for geothermal power plants (GPP) stipulated in Presidential Regulation No. 112/2022 does not yet reflect the true economic cost of geothermal development. This misalignment between tariff policy and project-level economics indicates the need for additional fiscal mechanisms to enhance investment feasibility. Furthermore, unlike the oil and gas sector—which already benefits from fiscal facilities such as exemptions from Value-Added Tax (VAT) and reductions or eliminations of Land and Building Tax (LBT) during the exploitation stage—the geothermal sector has not received comparable treatment. This regulatory asymmetry reduces competitiveness and limits the sector's growth potential. In addition, domestic VAT exemption on geothermal activities could increase the contribution of local content (*Tingkat Komponen Dalam Negeri*, TKDN), strengthening the competitiveness of domestic industries against imported products. Collectively, these policy considerations highlight the urgent need for a well-designed fiscal incentive framework to ensure a level playing field and support geothermal investment acceleration in Indonesia.

Several previous studies have analyzed geothermal project economics under uncertainty. Compernolle et al. (2019) examined the impact of policy measures on profitability using an economic Monte Carlo simulation model, while Lesmana et al. (2020) applied probabilistic financial modeling to evaluate investment risk. Hasyanita and Shimada (2023) found that direct funding and tax allowances significantly affect installed capacity growth. More recent works (Heryan and Sudrajad, 2024; Xiaojun and Hakam, 2024) explored carbon-trading mechanisms but did not isolate the effects of fiscal incentives. Despite these efforts, there remains a lack of quantitative assessment of how specific fiscal instruments influence project feasibility and financial risk in Indonesia's geothermal sector, particularly during the exploitation and utilization stages.

This study aims to assess the financial impact of fiscal incentive implementation on the feasibility of GPP investment projects in Indonesia. Using financial modeling and Value-at-Risk (VaR) analysis, the study evaluates and compares four scenarios: (1) A Business-as-Usual (BAU) scenario without fiscal incentives, (2) A VAT on domestic products not collected scenario, (3) LBT exemption scenario, and (4) Tax holiday scenario, along with an integrated combined incentive scenario. By quantifying how fiscal incentives alter the financial risk profile of geothermal projects, this study provides empirical evidence to guide Indonesia's renewable investment policy, supporting Indonesia's progress toward its NZE 2060 targets.

This study contributes methodologically by embedding fiscal instruments (VAT non-collection, LBT exemption, and tax holiday) directly inside a project-level discounted-cash-flow model and coupling it with a VaR analysis that reports NPVaR, IRRaR, and LCOEaR. This integration allows fiscal policies to affect taxable income and after-tax cash flows endogenously, while the VaR metrics quantify downside risk rather than only mean outcomes. We also introduce comparative risk–return mapping and scenario-specific tornado diagrams to identify the dominant cost drivers under each policy setting, implemented in a transparent Excel–Python workflow suitable for replication. Practically, the paper supplies decision-relevant evidence for MoF/MEMR: (i) Single measures (VAT/LBT) yield modest improvements with limited risk relief; (ii) A 10 years tax holiday provides the largest uplift in returns; and (iii) A combined incentive package crosses the commercial-feasibility threshold but entails higher return volatility—implying a policy trade-off between expected profitability and financial stability. The framework can be used as a screening tool to prioritize incentive mixes under Presidential Regulation No. 112/2022 and align geothermal deployment with Indonesia's NZE-2060 pathway.

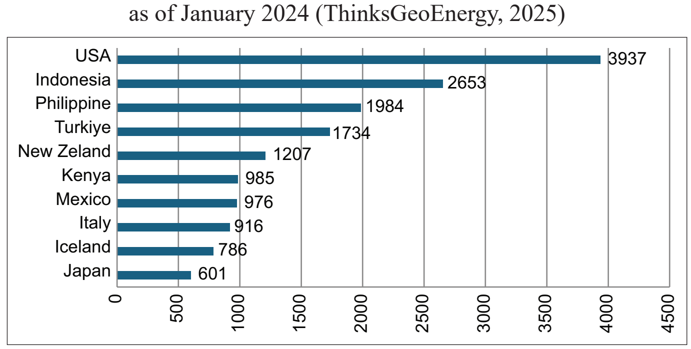
2. LITERATURE REVIEW

2.1. Geothermal Business Process in Indonesia

By the end of 2024, global geothermal power generation capacity reached approximately 16,873 MW, with 35 countries utilizing geothermal energy for electricity generation. Indonesia, with an installed capacity of 2,653 MW, ranks second globally in geothermal power generation, reflecting significant untapped potential (ThinksGeoEnergy, 2025). Figure 1 presents the top 10 countries by installed geothermal capacity.

According to the Best Practices Guide for Geothermal Exploration (International Geothermal Association, 2014), geothermal resource development typically follows eight stages: preliminary survey, exploration survey, exploration drilling, project review and planning, field development, power plant construction, commissioning, and operation. Indonesia adopts a similar framework in accordance with national geothermal laws and concession policies (Purba et al., 2019). The process begins with preliminary surveys or and exploration—carried out by the government, universities, or private entities—followed by tendering or direct assignments to state-owned enterprises. Business entities designated as geothermal permit holders then

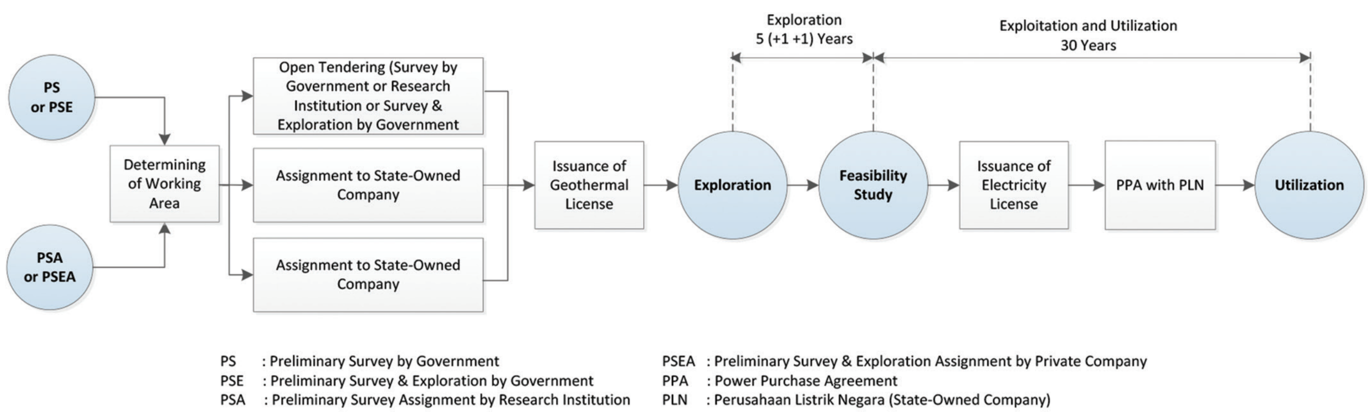
Figure 1: Top 10 geothermal power plant by installed capacity (MW) as of January 2024 (ThinksGeoEnergy, 2025)



Nomenclature

Abbreviation	Description	Abbreviation	Description
A	Amortization	NP	Net profit
BAU	Business-as-Usual	NPV	Net Present Value
CAPEX	Capital Expenditure	NPVaR	Net Present Value-at-Risk
D	Depreciation	NZE	Net Zero Emission
DCF	Discounted Cash Flow	O&M	Operating and Maintenance
EBT	Earning Before Tax	OPEX	Operating Expenditure
EBIT	Earnings Before Interest and Tax	LCOE	Levelized Cost of Energy
EBITDA	Earnings Before Interest, Depreciation, and Amortization	LCOEaR	Levelized Cost of Energy-at-Risk
FCF	Free Cash Flow	PD	Presidential Decree
GOI	Government of Indonesia	PLN	State Electricity Company
GPP	Geothermal Power Plant	PPA	Power Purchase Agreement
GSIF	Geothermal Sector Infrastructure Financing	PS	Preliminary Survey
GR	Government Regulation	PSA	Preliminary Survey Assignment
IRR	Internal Rate of Return	PSEA	Preliminary Survey and Exploration Assignment
IRRaR	Internal Rate of Return-at-Risk	PTA	Pre-Transaction Agreement
IPP	Independent Power Producers	SOE	State-Owned Company
JOC	Join Operation Contract	TH	Tax Holiday
LBT	Land and Building Tax	TI	Tax Incentive
MEF	Ministry of Environment and Forestry	USD	United States of America Dollar
MoF	Ministry of Finance	VaR	Value at Risk
MEMR	Ministry of Energy and Mineral Resources	VAT	Value Added Tax
MFR	Ministry of Finance Regulation	N	Project Lifetime
MW	Mega Watt	I	Interest rate/discount rate

Figure 2: Geothermal business process in Indonesia (author's compilation from geothermal regulations on geothermal)



sign a pre-transaction agreement (PTA) and, upon successful exploration and feasibility study submission, a power purchase agreement (PPA) with PLN. Permits are valid for 37 years, consisting of up to seven years for exploration and 30 years for exploitation and utilization. Figure 2 illustrates the geothermal business process in Indonesia.

The multi-stage and long-duration nature of Indonesia's geothermal licensing and development process substantially affects project risk and capital structure. Extended exploration periods delay revenue realization, while permit rigidity limits flexibility in investment timing. This reinforces the need for risk mitigation and fiscal support mechanisms to enhance project bankability and accelerate renewable energy deployment.

2.2. Fiscal Incentives and Policy Gaps in Indonesia's Geothermal Sector

Fiscal incentives are among the most influential policy instruments available to governments seeking to promote investment in capital-intensive renewable energy sectors such as geothermal. According to UNCTAD (2000), tax incentives constitute government provisions that reduce business costs or investment risks to stimulate sectoral growth. These incentives can increase post-tax returns and, consequently, influence firms' investment decisions (Botman et al., 2008). Comparative studies have demonstrated that countries with well-structured fiscal and financial frameworks—such as the Philippines, Kenya, and Iceland—have achieved faster geothermal market expansion (Brommer, 2025). Table 1 summarizes selected examples of international fiscal policies that have successfully encouraged geothermal development.

Globally, fiscal incentives take diverse forms, including tax holidays, investment allowances and credits, reduced corporate income tax rates, accelerated depreciation, and exemptions from indirect taxes within bonded or export-processing zones (Holland and Vann, 1998). In Indonesia, Siregar and Patunru (2021) identified several key fiscal instruments relevant to the geothermal sector. A tax holiday offers corporate income tax reductions for

Figure 3: Policy structure surrounding geothermal fiscal incentives in Indonesia (author's compilation from geothermal regulations on geothermal)

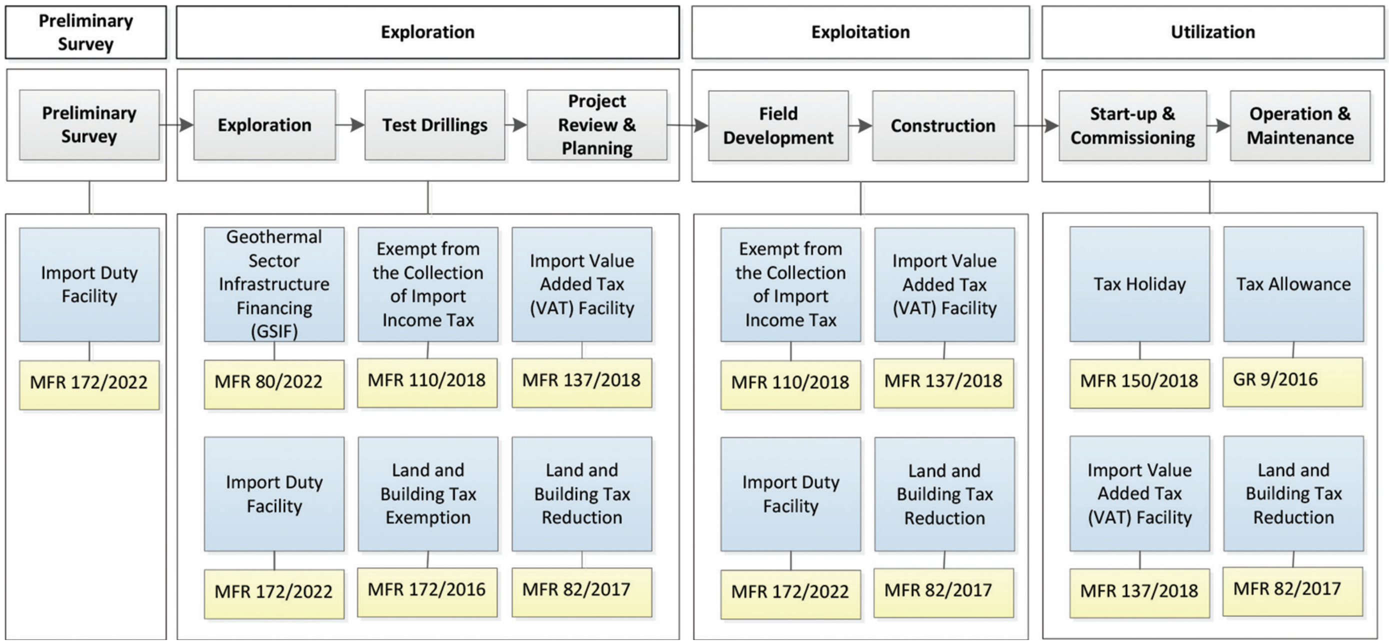


Table 1: Regulatory framework of geothermal development (Brommer, 2025)

Country	Subsurface access	License duration	PPA/Market structure	Tax and financial incentive
Iceland	Public, long-term	Up to 65 years	PPA or merchant	R&D funds, stable regime
Indonesia	Auctioned WKPs	30+ years	PLN PPAs with a cap	Tax holidays, import duty
New Zealand	Local councils	Varies	Liberalized	Few, but fast permitting
Kenya	Government controls	30 years	Set PPA tariffs	Steam-only biding
Mexico	Clear permit path	30 years	PPA/merchant	Tax breaks, dev banks
Philippines	DOE contracts	25-50 years	PPA/merchant	Tax holiday, Feed-in-tariff
Japan	Overlapping laws	Varies	Feed-in-tariff	Feed-in-tariff+subsidy

pioneer industries in strategic sectors, while a tax allowance provides net income deductions of up to 30% of total investment along with accelerated depreciation, reduced withholding taxes on dividends, and the ability to offset losses. Additional measures include import duty exemptions for capital goods and materials used in electricity generation, as well as exemptions from value-added and luxury taxes in bonded and free-trade zones. Together, these mechanisms aim to reduce the financial burden borne by project developers and improve after-tax cash-flow performance.

Indonesia's geothermal fiscal policy has evolved substantially since the early Joint Operation Contract (JOC) era under PERTAMINA in the 1980s. At that time, a risk-sharing mechanism between the government and private contractors was introduced, under which 34% of project risk was borne by the state through special tax adjustments. This arrangement resulted in an average annual capacity growth of 25.2% between 1983 and 1990—the highest in Indonesia's geothermal history. However, the transition from the JOC regime to the current licensing framework under the Geothermal Law shifted a greater share of financial obligations to private developers. Table 2 presents a comparative overview of incentive structures under the old and new regimes.

At present, the Government of Indonesia provides fiscal facilities across all stages of geothermal development. During preliminary surveys, developers may receive import-duty exemptions for

Table 2: Comparison of incentives between the geothermal sector and the oil and gas sector

Incentive	Geothermal		Oil and gas
	Old regime	New regime	
Import duty facility and import tax	34% all inclusive (PD 49/1991)	MFR 218/2019 MFR 115/2021 GR 49/2022	Cost recovery/ gross split GR 49/2022
Value-added tax exemption		-	
Tax holiday		MFR 69/2024	-
Land and building tax exemption in exploration stage		MFR 172/2016	GR 53/2017
Land and building tax reduction in exploitation stage		-	GR 53/2017

geoscience equipment. In the exploration phase, facilities include infrastructure financing through the Geothermal Sector Infrastructure Financing/GSIF (*Pembiayaan Infrastruktur Sektor Panas Bumi*, PISP) program, exemptions from import income tax and value-added tax, and reductions in land and building tax. During the exploitation and utilization stages, developers can benefit from tax holidays, continued import-tax exemptions, and further land and building tax reductions. These measures are summarized in Figure 3, which illustrates

Indonesia's fiscal incentive structure throughout the geothermal project lifecycle.

Collectively, these fiscal instruments are designed to lower upfront investment costs, enhance project cash-flow resilience, and improve the overall financial attractiveness of geothermal ventures. Yet, despite the presence of multiple fiscal mechanisms, empirical evaluations of their quantitative effects remain limited. Previous studies have rarely assessed how specific incentives alter key financial indicators—such as the Net Present Value (NPV), Internal Rate of Return (IRR), or risk exposure—of geothermal projects. Addressing this gap, the present alternative fiscal incentive designs on geothermal power plant investment feasibility in Indonesia.

Despite the various fiscal facilities summarized above, significant regulatory gaps remain between the geothermal and oil-and-gas regimes. The reference tariff under Presidential Regulation No. 112/2022 does not yet reflect actual geothermal project economics, requiring complementary fiscal support to restore investment competitiveness. In response, the Ministry of Energy and Mineral Resources (MEMR) and the Ministry of Finance (MoF) have identified several priority fiscal-incentive instruments for further implementation. These include VAT exemption on domestic geothermal goods and services, reduction or abolition of land-and-building tax during the exploitation stage, and clarification of corporate income-tax holiday provisions. Table 3 summarizes the status and rationale of these proposed instruments.

While fiscal policies reduce cost burdens, tariff mechanisms determine revenue structures — together shaping the project's overall financial feasibility. These fiscal-policy gaps provide the analytical foundation for the five incentive scenarios evaluated in this study: BAU, VAT removal, LBT removal, tax holiday, and total incentive.

2.3. Geothermal Tariff Policy

While fiscal instruments shape the cost structure of geothermal investment, tariff policy determines revenue potential and thus complements fiscal design in influencing project feasibility. Electricity tariff policy plays a central role in determining geothermal project profitability. The electricity purchase price from GPP has undergone multiple revisions, with the latest adjustment defined under Presidential Regulation No. 112/2022 on the Acceleration of Renewable Energy Development for Electricity Supply (Setiawan et al., 2022). Under this framework, PLN purchases electricity from independent power producers (IPPs) based on a ceiling price system, adjusted by location and resource enthalpy factors. Table 4 presents the current tariff structure for geothermal electricity.

The tariff is defined through two base prices: Base Price 1 (years 1–10) and Base Price 2 (years 11–30). The purchase price (P) is determined by the following general relationship (Susmanto and Hidayatno, 2024):

$$P = P_b \times I \quad (1)$$

Where P_b is the base price, and I = max $(1+0.25\times Y)$ with Y representing agreed escalation index (e.g., USPPI or 2%).

While this pricing mechanism provides revenue stability, the ceiling system often constrains project feasibility when high upfront costs and exploration risks are present. Consequently, fiscal incentives serve as complementary instruments that offset these revenue limitations, allowing developers to maintain financial viability within a fixed-tariff regime.

2.4. Financial Obligations of Geothermal Development

In addition to taxation and tariff structures, geothermal developers in Indonesia must comply with a wide range of financial obligations imposed by multiple government institutions. These obligations represent a significant component of total project expenditure and have a direct influence on investment feasibility and cash-flow dynamics. As summarized in Figure 4, the financial obligations associated with geothermal development can be

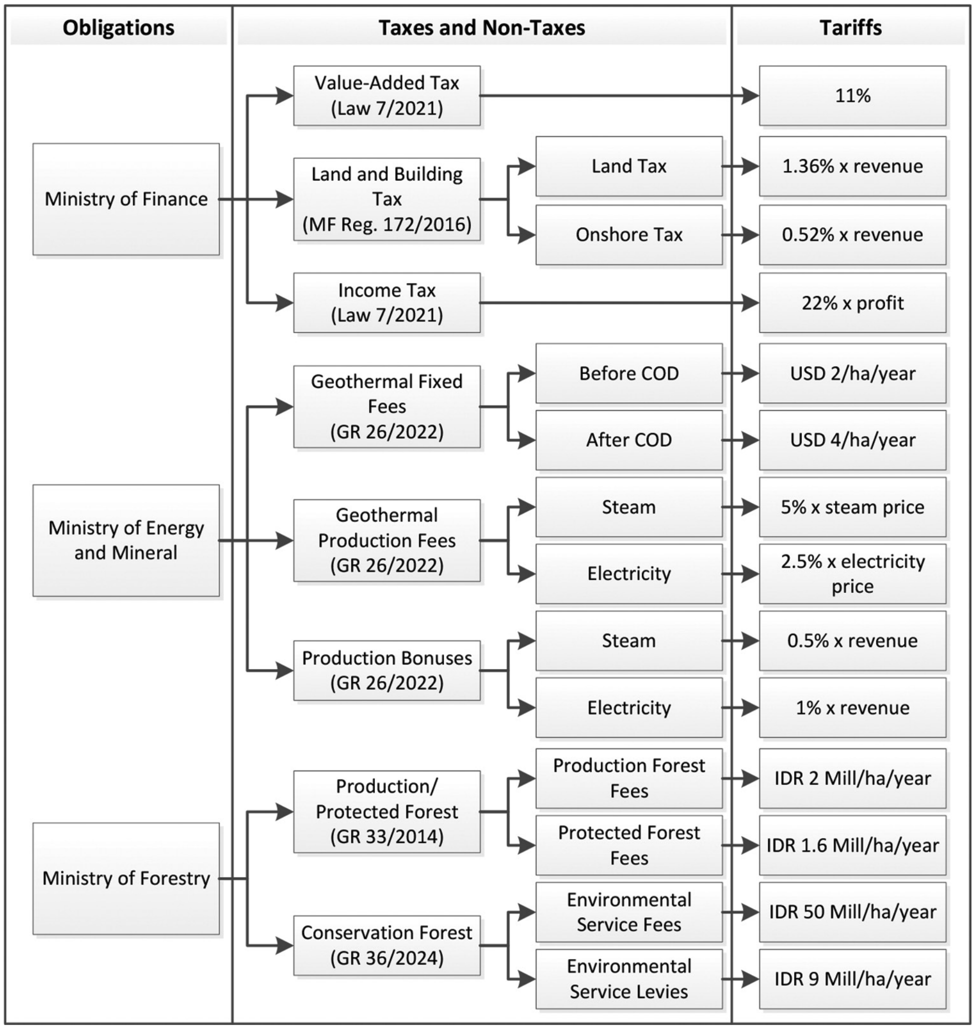
Table 3: Status and policy rationale of existing and proposed fiscal incentives for the Indonesian geothermal sector

Fiscal instrument	Implementation status	Policy rationale/relevance	Regulatory reference
Import duty and import tax exemption	Implemented	Already regulated for geothermal equipment importation	MFR 218/2019; MFR 115/2021; GR 49/2022
VAT on domestic geothermal goods and services	Not implemented	Needed to enhance local-content (TKDN) competitiveness vs. imported goods	Proposed revision to MFR 73/2010
Land and Building Tax (exploration phase)	Implemented	Already applicable for early-stage activities	MFR 172/2016
Land and Building Tax (exploitation phase)	Not implemented	Aligns geothermal with oil and gas fiscal regime; reduces operational burden	MFR 28/2016; GR 53/2017
Corporate Income Tax Holiday	Partially implemented	Applies generally to pioneer industries but lacks geothermal-specific regulation.	GR 69/2024; Law 7/1983 about Tax Income

Table 4: Electric power purchased from geothermal energy

Capacity	Ceiling price tariff (cent USD/kWh)		Java, Madura, Bali (F=1,00)	Sumatra, Kalimantan, Sulawesi (F=1,10)	Nusa Tenggara (F=1,20)	Maluku and North Maluku (F=1,25)	Papua and West Papua (F=1,50)
	1st to 10th Year	11st to 30th Year					
Up to 10 MW	(9.76×F)*	8.30	9.76	10.74	11.71	12.20	14.64
>10 MW up to 50 MW	(9.41×F)*	8.00	9.41	10.35	11.29	11.76	14.12
>50 MW up to 100 MW	(8.64×F)*	7.35	8.64	9.50	10.37	10.80	12.96
>100 MW	(7.65×F)*	6.50	7.65	8.42	9.18	9.56	11.48

Figure 4: Financial obligation of geothermal development in Indonesia (author's compilation from geothermal regulations on geothermal)



grouped according to the responsible ministries and agencies (Susmanto and Hidayatno, 2024).

From the fiscal perspective, the MoF administers the principal tax-related obligations, including VAT, LBT, and corporate income tax. These instruments form the core of Indonesia's tax system and apply to both exploration and production phases. Meanwhile, the MEMR regulates non-tax state revenues (PNBP), comprising geothermal fixed fees and production royalties that are levied according to project scale and production volume. In addition, developers are required to pay production bonuses directly to regional governments in geothermal-producing areas, ensuring that local jurisdictions share in the economic benefits of resource utilization.

The Ministry of Environment and Forestry (MEF) also plays a crucial role by imposing forest utilization fees and environmental service charges for projects that operate within protected or production forest areas. These levies aim to internalize the environmental externalities associated with geothermal operations and to ensure sustainable resource management. However, such fees can substantially increase the project's cost base, particularly for developments located in ecologically sensitive zones.

The multi-layered nature of these fiscal and non-fiscal obligations raises the effective tax burden on geothermal projects and may significantly reduce post-tax profitability. In practice, overlapping fees and taxes can diminish the financial attractiveness of geothermal investments, especially when combined with long development lead times and resource risks. Consequently, targeted fiscal incentives—such as exemptions or reductions in VAT, LBT, and income tax—become essential policy instruments to offset these obligations and maintain investment competitiveness.

A coherent fiscal policy framework that harmonizes the responsibilities of the MoF, MEMR, and the MEF is therefore critical for ensuring that the overall financial burden on developers remains aligned with national energy transition goals. By quantifying the effects of these financial obligations and simulating the relief provided by fiscal incentives, this study seeks to provide a clearer understanding of how Indonesia's fiscal architecture influences the financial feasibility of GPP development.

2.5. Methods for Assessing Geothermal Investment Feasibility under Uncertainty

Most feasibility assessments of geothermal projects rely on discounted-cash-flow (DCF) analysis using indicators such as NPV and IRR, sometimes complemented by sensitivity tests on capital and operating costs. Indonesian case studies (Lesmana et al., 2020; Rera et al., 2021; Timpal et al., 2023; Winofa et al., 2020) employ deterministic DCF models to evaluate project viability under varying tariffs, drilling and EPC costs, and financing structures. These studies consistently identify drilling and power-plant EPC costs as dominant financial drivers, while tariff ceilings and long lead times are shown to reduce investment feasibility.

To capture uncertainty more explicitly, several works introduce probabilistic or stochastic approaches. Lesmana et al. (2020) and Suryadi and Garniwa (2023) integrated Monte Carlo simulation into DCF frameworks to generate probabilistic NPV and IRR distributions, demonstrating that cost escalation and success ratios significantly affect project bankability. Compernolle et al. (2019) extended this probabilistic approach to a European context, showing that fiscal and regulatory mechanisms such as tax rebates or heat premiums can materially alter the risk–return balance of geothermal investments. Similarly, Fadhillah and Wilhelmus Adityatama (2024) and Prasad and Raturi (2022) examined the impact of tariff policies and financing structures using techno-economic simulations but did not directly quantify downside risk. Recent research has begun integrating robustness and exploratory modeling techniques to examine geothermal investment under deep uncertainty (Adam et al., 2025). These studies combine DCF modeling with Exploratory Modeling and Analysis (EMA) tools such as feature scoring and dimensional stacking to identify cost and success-ratio thresholds that preserve project feasibility across many futures. However, they still evaluate uncertainty mainly through spread or variance rather than formal risk metrics.

Across these streams of literature, fiscal instruments have been acknowledged as potential cost modifiers (Hasyanita and Shimada, 2023; Siregar and Patunru, 2021; Xiaojun and Hakam, 2024). Yet, most studies treat these incentives deterministically within the cash-flow structure, rarely quantifying how they alter the risk distribution of investment returns. This study bridges that methodological and policy gap by integrating fiscal-policy parameters directly into a project-level discounted-cash-flow (DCF) framework and coupling it with VaR analysis. The combined approach quantifies both expected profitability and downside financial exposure (NPVaR, IRRaR, and LCOEaR) across distinct fiscal-policy scenarios. To date, no published study has systematically assessed the financial impact of VAT non-collection, LBT exemption, and corporate income-tax holiday schemes on geothermal investment feasibility in Indonesia. By embedding these fiscal instruments within the cash-flow structure and evaluating their stochastic outcomes, this paper provides the first quantitative comparison of how such incentive configurations influence both project returns and financial-risk distributions. The results offer a more comprehensive basis for fiscal-policy design in Indonesia's geothermal sector and contribute a replicable framework for other emerging economies pursuing clean-energy investment under fiscal constraints.

3. METHODOLOGY

3.1. Research Framework

Assessing the feasibility of GPP investments requires an integrated analytical approach that combines technical, financial, and policy dimensions across the project life cycle. From a financial standpoint, valuation refers to the process of estimating the intrinsic economic value of a project based on expected future cash flows (Pinto et al., 2010). Geothermal projects are inherently capital-intensive, multi-phase, and exposed to high geological and regulatory uncertainty, making single-perspective evaluations (technical or financial alone) insufficient for policy analysis. An integrated framework enables simultaneous assessment of fiscal-policy mechanisms and project-level financial dynamics, thereby capturing the interaction between policy incentives, cost structures, and investment risks. This is particularly relevant in Indonesia, where fiscal instruments—such as VAT non-collection, LBT exemption, and tax holidays—directly modify project cash flows and risk exposure.

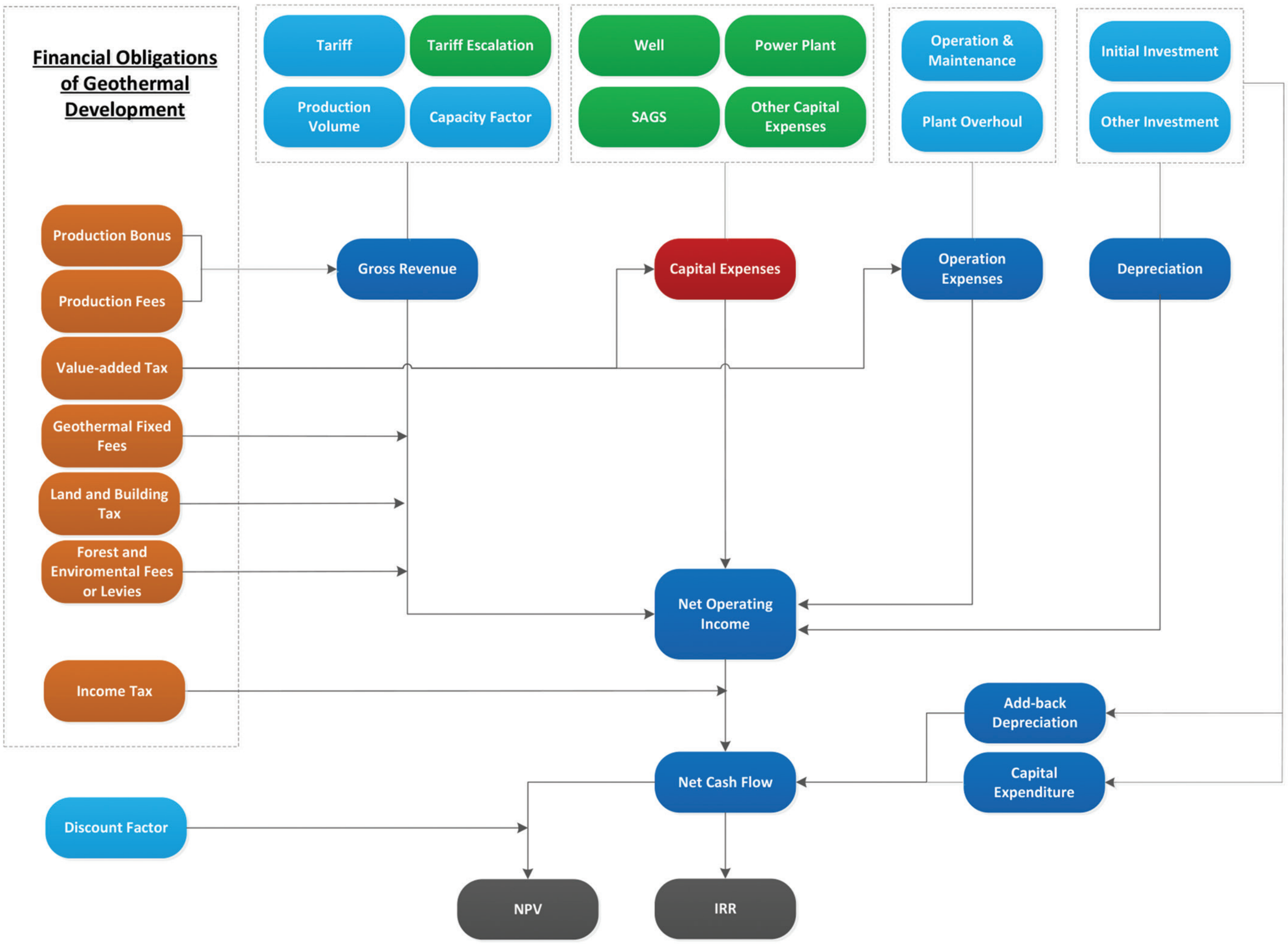
In this study, the integration of deterministic DCF modeling with stochastic VaR analysis provides a dual perspective: (1) To measure the impact of fiscal incentives on project feasibility (NPV, IRR, and LCOE) and (2) To evaluate financial-risk behavior across uncertain cost and policy VaR environments. This approach also identifies the dominant risk factors affecting investment performance under each fiscal-incentive scenario, thus linking economic outcomes with policy relevance. By combining technical, financial, and fiscal-policy layers in a unified modeling system, the study generates actionable insights for policymakers to design more effective investment-support mechanisms in Indonesia's geothermal sector.

The geothermal DCF model shown in Figure 5 is adapted from Adam et al. (2025), which provides a comprehensive techno-economic framework widely used for project-level feasibility analysis. This model was selected because it represents the fundamental cost–revenue structure of geothermal power projects and reflects the key decision perspectives of both the government (through fiscal and regulatory parameters) and developers (through project-specific capital and operating expenditures). While the original framework captures the core financial mechanics of geothermal investment, it does not explicitly incorporate Indonesia's fiscal-policy instruments. Therefore, several modifications were made to align it with the national regulatory and taxation context—particularly by embedding tariff escalation, tax and non-tax obligations (e.g., VAT, LBT, and income tax), and production-based levies into the gross-revenue and capital-expense components. These additions ensure that the model realistically represents financial flows under Indonesian geothermal policy and enables systematic evaluation of fiscal incentives on investment feasibility.

The framework represents a system of cash-flow linkages where government-imposed obligations—such as VAT, LBT, income tax, and environmental fees—affect the project's net operating income and, consequently, its NPV and IRR. Each component reflects the interaction between fiscal instruments and standard project accounting flows, ensuring that the impact of policy incentives can be measured directly on financial outcomes.

Previous research has applied probabilistic or deterministic financial models to geothermal investment, yet with limited

Figure 5: Geothermal DCF model modified from Adam et al. (2025)



integration of fiscal parameters. Lesmana et al. (2020) and Compernolle et al. (2019) used Monte Carlo simulations to account for geological and market risks, while Hasyanita and Shimada (2023) demonstrated the influence of government incentives on installed-capacity expansion. However, these studies generally treated fiscal incentives as external modifiers rather than as embedded elements within cash-flow equations. In practice, fiscal mechanisms—such as tax holidays, land- and building-tax exemptions, and VAT-non-collection—directly influence taxable income, operational expenses, and after-tax cash flow, thereby determining the project's financial feasibility metrics.

To address this methodological gap, the current framework integrates the DCF model with a VaR module. The DCF model captures expected cash-flow performance under each fiscal scenario, while the VaR component quantifies downside financial risk by estimating the probability distribution of project NPVs under uncertainty. Through this integration, the model provides a comparative analysis of both the financial attractiveness and the risk resilience of alternative fiscal-policy designs. The detailed model equations, assumptions, and scenario specifications are presented in the following subsections.

3.2. Financial Model Formulation

The financial model forms the analytical basis for assessing the investment feasibility of a GPP project under different fiscal-policy scenarios. It represents all project-related cash inflows and outflows across the entire 30 years lifetime, incorporating both deterministic and policy-dependent parameters. The model evaluates the project's profitability through standard indicators, including NPV, IRR, and free cash flow (FCF). All financial results are expressed in thousand USD in the simulation outputs, which correspond to million-USD scale values at the project level.

Revenues are derived from the sale of electricity to the national utility (PLN) under a Power Purchase Agreement (PPA). The annual revenue (R_t) is calculated as the product of the electricity tariff and the total energy output exported to the PLN grid, as expressed in Equation (2) (adapted from Moeis et al., 2023). This formulation is consistent with standard practice in renewable-power project valuation models—originally developed for hydropower feasibility studies—and remains applicable to geothermal systems operating under similar tariff-based PPA structures in Indonesia.

$$R_t = T \times E_0 \quad (2)$$

where:
R_t = annual revenue (USD/year)
T = electricity tariff (USD/kWh)
E_0 = energy output supplied to the PLN grid (kWh/year)

To determine net operating results, the model sequentially estimates key income and cash-flow indicators, beginning from gross revenue and proceeding to net cash flow. FCF indicates whether the operation results in a positive cash flow (surplus) or a negative cash flow (deficit). To retrieve the net cash flow value, it is necessary to calculate Earnings Before Interest, Depreciation, and Amortization (EBITDA), Earnings Before Interest and Taxes (EBIT), Earnings Before Tax (EBT), and Net Profit as shown in the equation below. The relationships among these parameters are shown in Equations (3)-(7):

$$EBITDA = R_t – C_{OM} \quad (3)$$

$$EBIT = EBIT – D – A \quad (4)$$

$$EBT = EBIT – i \quad (5)$$

$$NP = EBT – T_{ax} \quad (6)$$

$$FCF = NP + D + A + C_i – CAPEX – CWC \quad (7)$$

where:
C_{OM} = operating and maintenance (O&M) costs (USD/year)
D = depreciation (USD/year)
A = amortization (USD/year)
i = annual interest expense (USD/year)
T_{ax} = total income and production taxes (USD/year)
C_i = other cash inflows (e.g., grants, subsidies)
$CAPEX$ = capital expenditures (USD)
CWC = changes in working capital (USD)

Fiscal incentives are incorporated directly into these equations by modifying relevant cost and tax components.

- A tax holiday reduces or eliminates the T_{ax} term in Equation (6) during the exemption period
- A land and building tax exemption reduces C_{OM} by excluding the corresponding property tax payment
- A VAT-not-collected policy reduces *CAPEX* by lowering the effective procurement cost of domestic goods and services.

Through these adjustments, each fiscal scenario alters the project's cash-flow trajectory and, consequently, its profitability metrics.

The project's NPV is calculated as the sum of discounted free cash flows minus the initial investment, as expressed in Equation (8):

$$NPV = \sum_{t=1}^{n} \frac{FCF_t}{(1+i)^t} - I_0 \quad (8)$$

where:
FCF_t = free cash flow in year t (USD/year)
i = discount rate (%)
I_0 = initial investment (USD)
n = project lifetime (years)

A project is considered financially feasible when $NPV > 0$.

The IRR represents the discount rate at which the project's NPV equals zero, as defined in Equation (9):

$$IRR = i_1 + \frac{NPV_1}{NPV_1 - NPV_2} \times (i_1 - i_2) \quad (9)$$

where:
i_1, i_2 = Two discount rates generating opposite-signed NPVs
NPV_1, NPV_2 = Positive and negative NPVs corresponding to i_1 and i_2, respectively

An investment is considered viable if $IRR > i$, where i is the chosen discount rate.

The financial model therefore captures how fiscal-policy changes—through adjustments in taxes, duties, and capital costs—alter the magnitude and timing of project cash flows. These outputs (NPV, IRR, and FCF) are subsequently analyzed under each fiscal-incentive scenario and used as input distributions for the stochastic VaR simulation presented in Section 3.4.

3.3. Levelized Cost of Electricity (LCOE) Estimation

The LCOE represents the discounted unit cost of electricity generation over the project's economic life. It captures the relationship between total lifecycle costs—including capital, operation and maintenance, and financing—and total electricity output. The LCOE is calculated using Equation (10) (Pagnini et al., 2024):

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + LCC_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \quad (10)$$

where I_t is annual investment, LCC_t is life-cycle cost, r is the discount rate, E_t is generated electricity, and is n project lifetime.

LCOE serves as a complementary indicator to NPV and IRR by expressing project competitiveness in terms of unit energy cost (USD/kWh). A fiscal incentive that lowers taxes or duties can reduce LCOE by decreasing total discounted costs. All cost and performance parameters used in this calculation are listed in Appendix 1 (Financial Assumptions**)** and Appendix 2 (Technical Assumptions). The detailed financial parameters used in the simulation, including tax rates, financing structure, and depreciation assumptions, are summarized in Appendix 3.

3.4. Uncertainty and Risk Factors

Geothermal investment projects are exposed to multiple sources of uncertainty that influence both cost and revenue performance throughout the project life cycle. These uncertainties originate from geological complexity, engineering execution, market price variability, and fiscal-policy implementation. To represent these risks quantitatively, key input parameters of the deterministic DCF model were assigned probability distributions and varied during the Monte Carlo simulation.

The main categories of uncertainty include capital-cost risk, operational-cost risk, production and performance risk, and fiscal-policy risk. Capital-cost risk reflects potential deviations in drilling, surface-facility, and infrastructure costs arising from geological and construction factors. Operational-cost risk captures variability in annual operation and maintenance (O&M) expenses and major overhaul requirements. Production risk accounts for fluctuations in capacity factor and well-success ratios that influence energy output. Fiscal-policy risk represents uncertainty in the implementation of tax incentives—such as income-tax holidays, VAT exemptions, and LBT reductions—over the project's duration.

In this study, stochastic uncertainty is operationalized through ±10% variations in selected cost parameters identified within the project's financial model. As summarized in Table 5, these parameters—covering well drilling, civil construction, EPC (engineering, procurement, and construction) activities, and O&M expenditures—are treated as random variables. Each variable follows a triangular probability distribution centred on its baseline value, with lower and upper bounds set at −10% and +10%. These variations propagate through the DCF structure, affecting both capital expenditure (CAPEX) and operating expenditure (OPEX) components, and ultimately influencing the financial indicators (NPV, IRR, and LCOE).

All stochastic simulations were conducted using Microsoft Excel integrated with Python (version 3.10) through the xlwings library, enabling dynamic linkage between the financial model and random variable generation. Each simulation consisted of 1000 Monte Carlo iterations for every fiscal-policy scenario. Ten cost parameters (as listed in Table 5) were modelled using independent triangular distributions centred on their baseline estimates. Independence among variables was assumed due to the absence of empirical correlation data from geothermal cost databases. Random sampling and iteration loops were executed in Python, while Excel computed project cash flows and financial indicators (NPV, IRR, and LCOE) for each iteration. This hybrid Excel–Python setup ensured computational transparency, reproducibility, and efficient processing of simulation results. The resulting datasets of simulated outputs were subsequently analysed within the VaR framework described in Section 3.5, which integrates the stochastic modelling results into a system-level representation of geothermal investment dynamics (Figure 6).

3.5. Value-at-Risk (VaR) and Risk Modeling

Investment in geothermal development entails considerable financial uncertainty arising from capital cost escalation, drilling success rates, tariff volatility, and fiscal-policy changes. To quantify these uncertainties, this study applies a Value-at-Risk (VaR)–based stochastic simulation. The approach estimates the probability distribution of key financial indicators—namely NPV, IRR, and Levelized Cost of Electricity (LCOE)—under different fiscal-incentive scenarios.

Figure 7 illustrates the overall system structure of the geothermal investment model, which integrates policy interventions, risk factors, and external drivers within a single DCF model. The central block represents the DCF model, which converts project inputs such as capital costs, operational expenses, and tax parameters into annual Net Operating Income and Net Cash Flow, serving as the basis for the calculation of NPV, IRR, and LCOE. Within this framework, three categories of variables interact dynamically. The red pathways represent risk factors that introduce stochastic variability into the simulation, primarily cost components sensitive to market or operational fluctuations—such as drilling and production well expenditures, power plant and surface facility construction (EPC) costs, and major overhaul expenses. These parameters are modeled as random variables with ±10% variation around their expected values to capture plausible uncertainty ranges.

The green pathways represent policy interventions, consisting of the removal of VAT and LBT, as well as the implementation of a tax holiday. These fiscal measures alter the effective tax burden and depreciation schedules within the cash flow model, directly influencing after-tax profitability and the project's overall financial exposure. Meanwhile, the yellow pathways denote external forces outside the immediate scope of policy evaluation—such as tariff levels, production output, and capacity factors—that remain constant across scenarios to isolate the fiscal-policy effects.

Collectively, this system configuration formalizes the causal relationship between policy levers, risk variables, and financial performance metrics. Each stochastic input is sampled through 1000 Monte Carlo iterations, producing probabilistic distributions of NPV, IRR, and LCOE from which the corresponding NPV-at-Risk (NPVaR), IRR-at-Risk (IRRaR), and LCOE-at-Risk (LCOEaR) are derived at a 95% confidence level. The results enable an integrated assessment of both profitability and downside financial risk, providing a quantitative foundation for comparing fiscal-incentive scenarios under uncertainty.

Table 5: Summary of key risk factors and distributions

Data parameter	Project phase	Unit	Baseline value	Variation range	Impact on model
Road and well pad construction	Exploration	USD/MW	110,000	±10% (triangular)	Affects CAPEX (Exploration Infrastructure)
Drilling – Exploration wells	Exploration	USD	7,000,000	±10% (triangular)	Affects CAPEX (Exploration Wells)
Additional road and well pad construction	Development	USD/MW	275,000	±10% (triangular)	Affects CAPEX (Exploration Wells)
Development drilling – Production wells	Development	USD	7,000,000	±10% (triangular)	Affects CAPEX (Exploration Wells)
SAGS EPC	Development	USD/MW	371,000	±10% (triangular)	Affects CAPEX (Steamfield Facilities)
Power plant EPC	Development	USD/MW	1,900,000	±10% (triangular)	Affects CAPEX (Power Plant Facilities)
Drilling – Make-up well and work over	Commercial	USD	6,500,000	±10% (triangular)	Affects OPEX (Operating Expenses)
O&M SAGS–PP	Commercial	USD c/kWh	1.50	±10% (triangular)	Affects OPEX (Commercial Maintenance)
Major overhaul cost	Commercial	USD	1,000,000	±10% (triangular)	Affects OPEX (Periodic Maintenance)

Figure 6: Distribution of NPV (in thousand USD), IRR, and LCOE under the Tax Holiday scenario

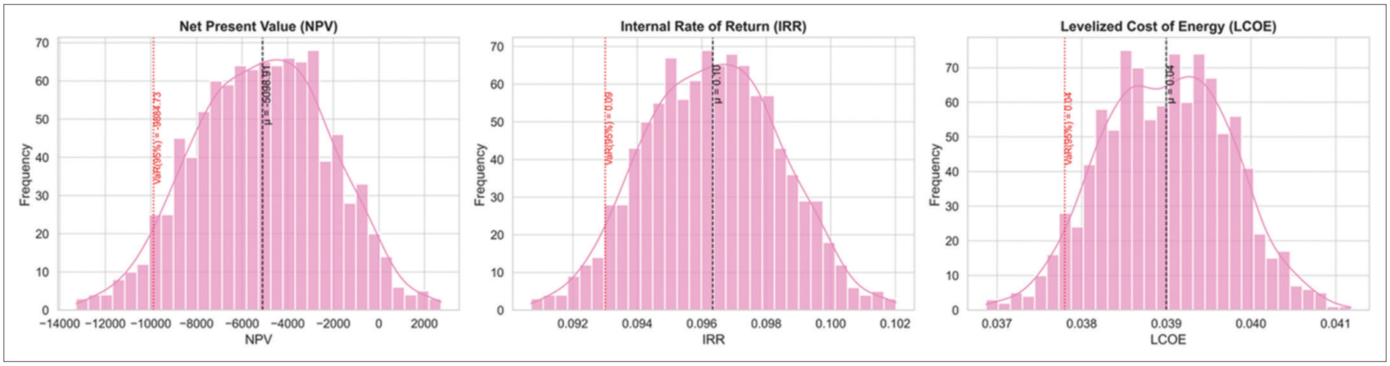
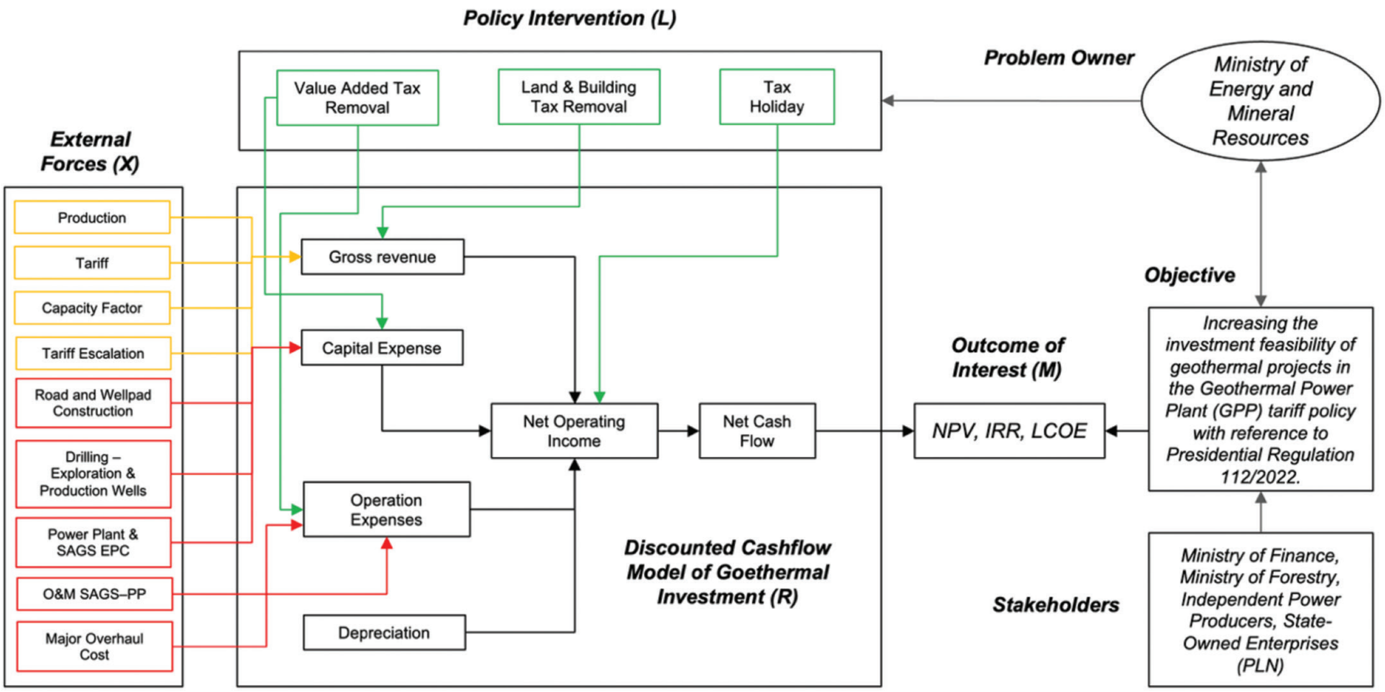


Figure 7: System diagram of fiscal-policy and risk interactions in the geothermal investment model



3.5.1. Conceptual basis

VaR represents the maximum expected loss over a specified time horizon at a given confidence level (α). In this study, VaR is adapted to project-finance metrics to evaluate the downside risk of investment outcomes. For each indicator X(NPV, IRR, or LCOE), VaR is defined as:

$$VaR = inf\{x \in \mathbb{R} : Pr(X \geq x) \leq 1 - \alpha\} \quad (11)$$

Where:
$Pr(X \geq x)$ = cumulative probability distribution function of X
α= confidence level (set at 95 percent% in this study).

A Monte Carlo simulation with 1000 iterations generate random draws for uncertain input variables—such as drilling cost, well success ratio, capacity factor, electricity price, and fiscal parameters (tax rate, VAT exemption, and LBT relief). Each iteration yields one set of financial outputs (NPV, IRR, LCOE), forming probability distributions for further analysis.

3.5.2. Net present value at risk

Following Ye et al. (2000), the NPV-at-Risk quantifies the threshold value of NPV that the project will exceed with a probability corresponding to the specified confidence level:

$$NPV_{aR} = \overline{NPV} - Z(\alpha)\sigma_{NPV} \quad (12)$$

Where $\overline{NPV}$ is the mean NPV, σ_{NPV} is its standard deviation, and $Z(\alpha)$ is the critical value from the standard normal distribution at confidence α. If $NPV_{aR}>0$, the project is financially acceptable with confidence 1−α; otherwise, it is considered infeasible.

3.5.3. Internal rate of return at risk

Analogous to NPV_{aR}, the IRR-at-Risk indicates the lower-bound internal rate of return that can be expected with a given confidence level:

$$IRR_{aR} = \overline{IRR} - Z(\alpha)\sigma_{IRR} \quad (13)$$

where $\overline{IRR}$ and σ_{IRR} are the mean and standard deviation of the simulated IRR distribution. An IRR_{aR} exceeding the project's discount rate signifies that even in pessimistic conditions, the investment remains financially viable.

3.5.4. Levelized cost of electricity at risk

To complement profitability analysis, this study introduces the concept of LCOE-at-Risk, representing the upper bound of the unit electricity cost under uncertainty:

$$LCOE_{aR} = \overline{LCOE} - Z(\alpha)\sigma_{LCOE} \quad (14)$$

A lower $LCOE_{aR}$ reflects stronger cost competitiveness and resilience to fiscal or operational uncertainty. Comparing $LCOE_{aR}$ across incentive scenarios reveals how fiscal policies influence not only expected cost levels but also the dispersion of cost risks.

The simulation framework was applied to a representative 50 MW geothermal power plant using the fiscal-policy configurations described above. The resulting probabilistic distributions of NPV, IRR, and LCOE across all scenarios are analyzed in Section 4, which presents the financial outcomes, sensitivity analysis, and policy implications. The full Python script used to execute the Monte Carlo simulations and Excel–Python integration is provided in Appendix 4. All visualization routines and Value-at-Risk calculations were implemented using Python, as documented in Appendix 5.

4. RESULTS AND DISCUSSIONS

The following section presents the financial simulation results of the 50 MW geothermal power plant. DCF model and sensitivity analysis for each fiscal-policy scenario: (1) BAU, (2) VAT removal, (3) LBT removal, (4) Tax holiday, and (5) Total incentive (combining all three fiscal mechanisms). Each scenario was simulated through 1000 Monte Carlo iterations to obtain probabilistic distributions of NPV, IRR, and LCOE. Mean (μ) and Value-at-Risk (VaR_{95}) statistics quantify expected performance and downside risk, respectively. All reported monetary values in this section are expressed in thousand USD for consistency with simulation outputs, equivalent to million-USD scale for the 50 MW project.

4.1. Business-as-Usual (BAU)

The BAU case represents project feasibility without fiscal incentives and serves as the benchmark for comparison. The simulation indicates a mean NPV (μ) of approximately – USD 8.436 million, with a VaR_{95} = – USD 12.905 million (Figure 8).

The mean IRR (μ) is 9.39 %, with a VaR_{95} = 9.08 %, while the mean LCOE (μ) is 0.0390 USD/kWh with a VaR_{95} = 0.0379 USD/kWh. The mean IRR (μ) of 9.39 % remains below the typical investor hurdle rate for high-risk energy infrastructure projects, which generally ranges from 10 % to 15 % in developing-country contexts (Climate Policy Initiative, 2015; IRENA, 2012; World Bank, 2019). This gap underscores the financial challenges of geothermal development without fiscal support.

4.2. VAT Removal Scenario

Introducing a VAT exemption on domestic goods and services reduces the effective project cost base by approximately 1.35 % of revenue. The simulation shows improvement relative to BAU: mean NPV = – USD 6.585 million, VaR_{95} = – USD 10.285 million (Figure 9).

Figure 8: Distribution of NPV (in thousand USD), IRR, and LCOE under the BAU scenario

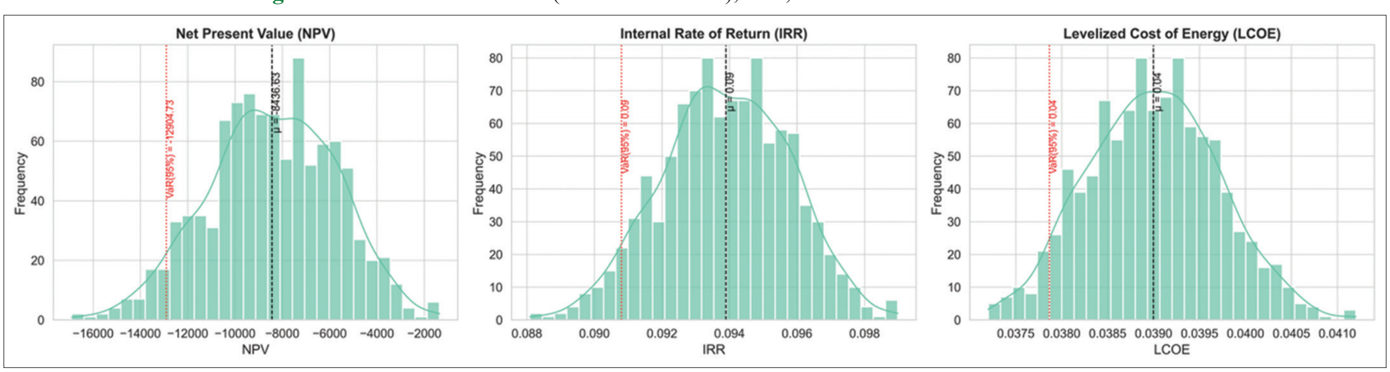
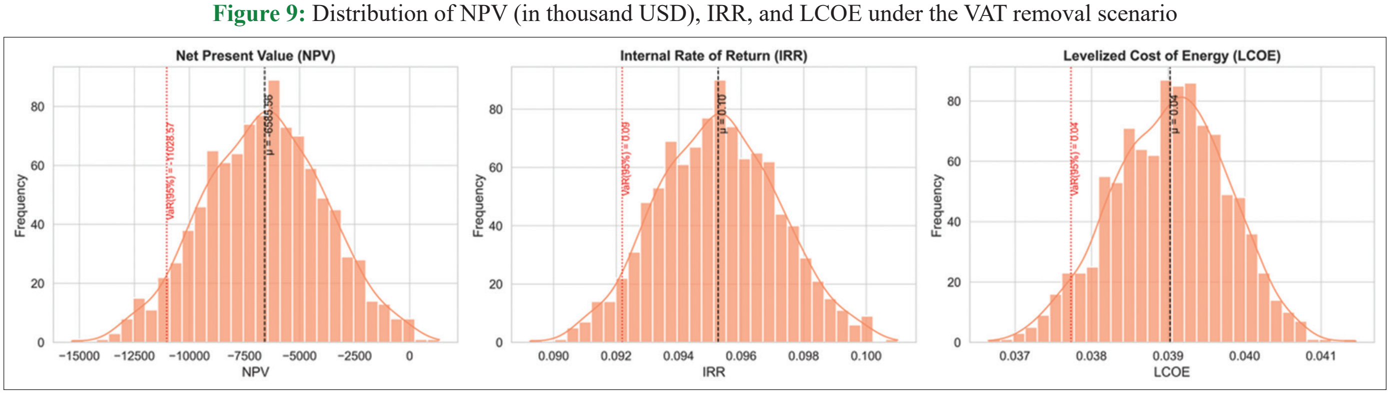


Figure 9: Distribution of NPV (in thousand USD), IRR, and LCOE under the VAT removal scenario



The mean IRR increases to 9.53 %, and VaR_{95} = 9.09 %, while the LCOE remains 0.0390 USD/kWh (VaR_{95} = 0.0377). The improvement, though modest, demonstrates that VAT exemptions enhance near-term cash flow during the early operating phase but remain insufficient to fully close the financial gap.

4.3. Land and Building Tax (LBT) Removal Scenario

The abolition of LBT—typically 1.36 % of onshore and 0.52 % of offshore revenue—further strengthens project viability. The simulation yields a mean NPV = – USD 5.689 million and VaR_{95} = – USD 10.190 million (Figure 10).

The mean IRR rises to 9.59 % (VaR_{95} = 9.09 %), and the LCOE stabilizes at 0.0390 USD/kWh (VaR_{95} = 0.0378). While the improvement is moderate, LBT exemption consistently enhances the project's long-term operating margin and investment stability.

4.4. Tax Holiday Scenario

A 10-year corporate income-tax holiday significantly improves financial outcomes during early revenue-generating years. The mean NPV improves to – USD 5.099 million with VaR_{95} = – USD 9.885 million, while the mean IRR increases to 9.63 % (VaR_{95} = 9.30 %) (Figure 6).

The LCOE remains around 0.0390 USD/kWh (VaR_{95} = 0.0378). Among individual policies, the tax holiday delivers the strongest boost to profitability, reflecting the significance of income-tax relief during the initial cash-flow recovery years.

4.5. Total Incentive Scenario

When all three fiscal incentives (VAT removal + LBT removal + tax holiday) are combined, the project's financial outlook becomes markedly more favorable. The simulation results show a mean NPV = + USD 0.378 million with VaR_{95} = – USD 4.470 million (Figure 11).

The mean IRR reaches 10.03 %, exceeding the lower bound of standard investor hurdle rates, and the LCOE drops slightly to 0.0390 USD/kWh (VaR_{95} = 0.0378). Under the combined fiscal framework, the project's IRR reaches 10.03%, finally meeting the lower bound of the typical 10–12% hurdle rate required by private investors.

4.6. Cross-Scenario Comparison

The comparative analysis across fiscal-policy scenarios highlights the progressive reduction of financial risk and improvement of project returns when fiscal incentives are introduced. To identify which cost elements contribute most strongly to output uncertainty, a sensitivity analysis was conducted using Spearman's rank correlation between stochastic inputs and simulated IRR outcomes.

Tornado diagrams (Figure 12) illustrate the Spearman rank correlations between each cost parameter and the IRR across all fiscal-policy scenarios. Negative correlation values indicate that an increase in the corresponding cost variable decreases project profitability, while higher absolute correlation magnitudes reflect greater sensitivity of IRR to that parameter. The results show that development-phase expenditures—particularly power-plant EPC, production drilling, and O&M costs—exert the strongest negative influence on project returns. In contrast, exploration-stage and commercial-stage factors, such as well-pad construction and overhaul costs, contribute less to overall risk. These findings imply that fiscal incentives primarily reduce tax-related financial

Figure 10: Distribution of NPV (in thousand USD), IRR, and LCOE under the LBT Removal scenario

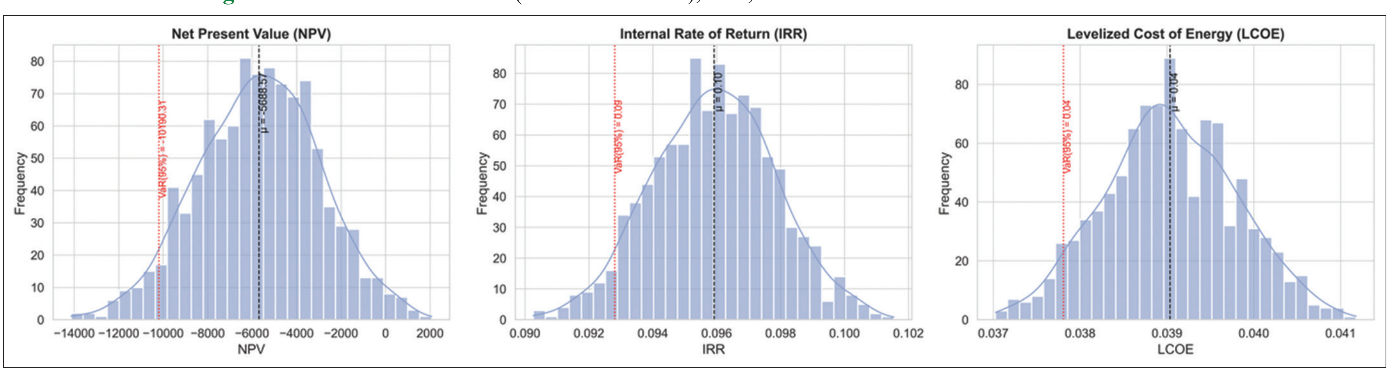
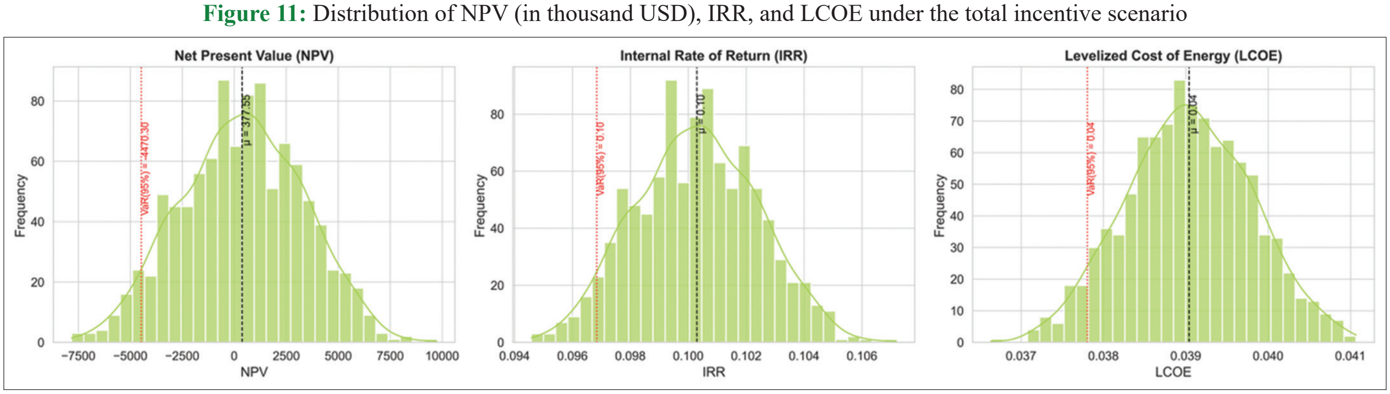


Figure 11: Distribution of NPV (in thousand USD), IRR, and LCOE under the total incentive scenario



burdens but do not directly mitigate the dominant technical-cost uncertainties. Therefore, complementary measures such as exploration-risk guarantees and concessional financing instruments are required to enhance the overall risk resilience of geothermal investment portfolios.

Distributional shifts across scenarios are captured in the ridgeline plots (Figures 13 and 14), which visualize the probability density functions of simulated NPV and IRR values. As fiscal incentives are gradually introduced—beginning with VAT removal, followed by LBT removal and the tax holiday—the curves shift rightward, indicating higher expected returns and a reduction in downside risk. However, under the combined Total Incentive configuration, the distributions broaden slightly, reflecting increased variability in financial outcomes alongside improved profitability. The IRR ridgeline (Figure 12) shows mean returns rising from $\mu = 0.0939$ (BAU) to $\mu = 0.1003$ (Total Incentive), while the NPV ridgeline (Figure 13) moves from strongly negative to positive territory. These results suggest that cumulative fiscal support enhances expected profitability but also amplifies overall volatility, underscoring the inherent trade-off between higher return and increased financial uncertainty.

Figure 12: Tornado diagrams showing sensitivity of IRR to major input variables under five fiscal-policy scenarios

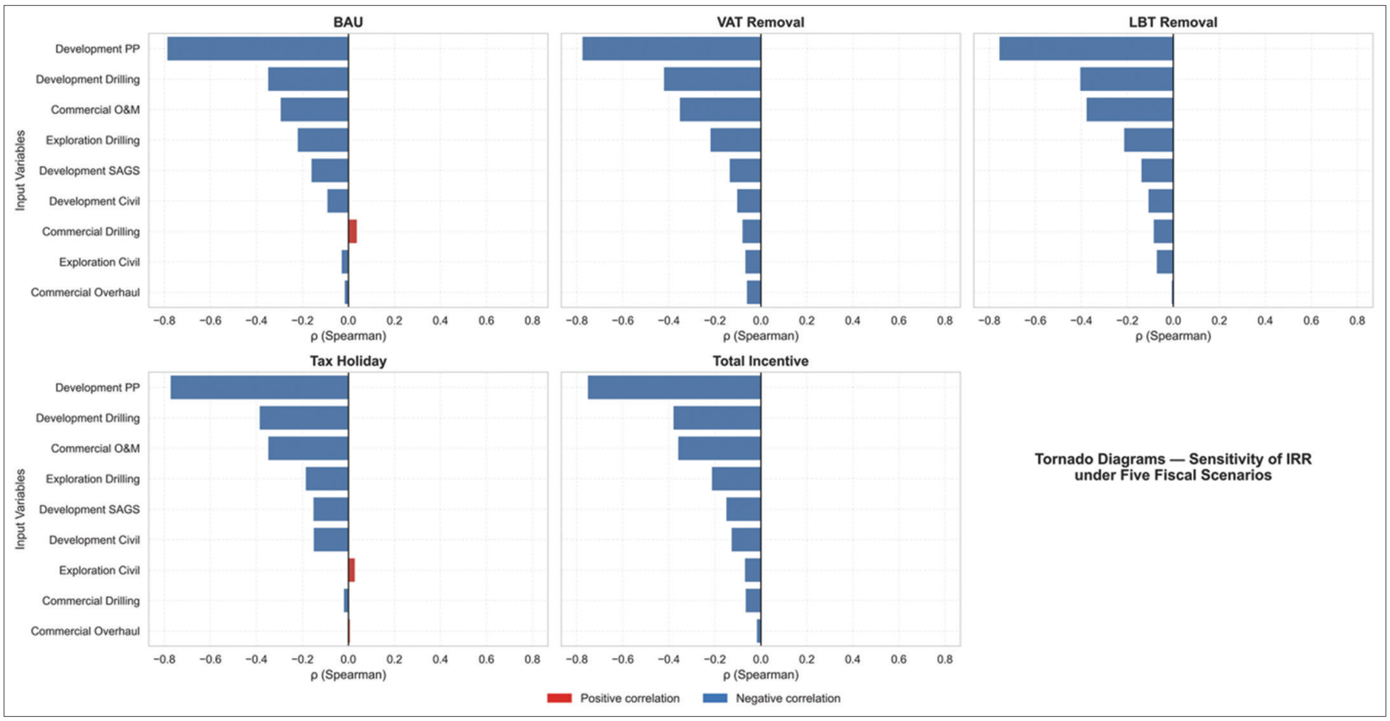


Figure 13: Ridgeline distribution of IRR across fiscal-policy scenarios (μ and VaR_{95})

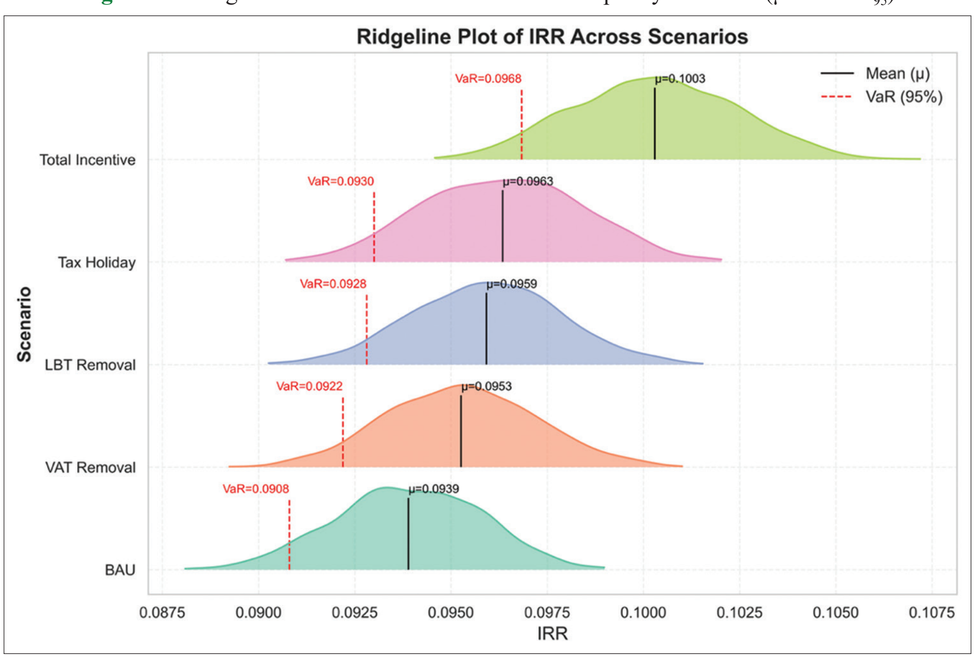
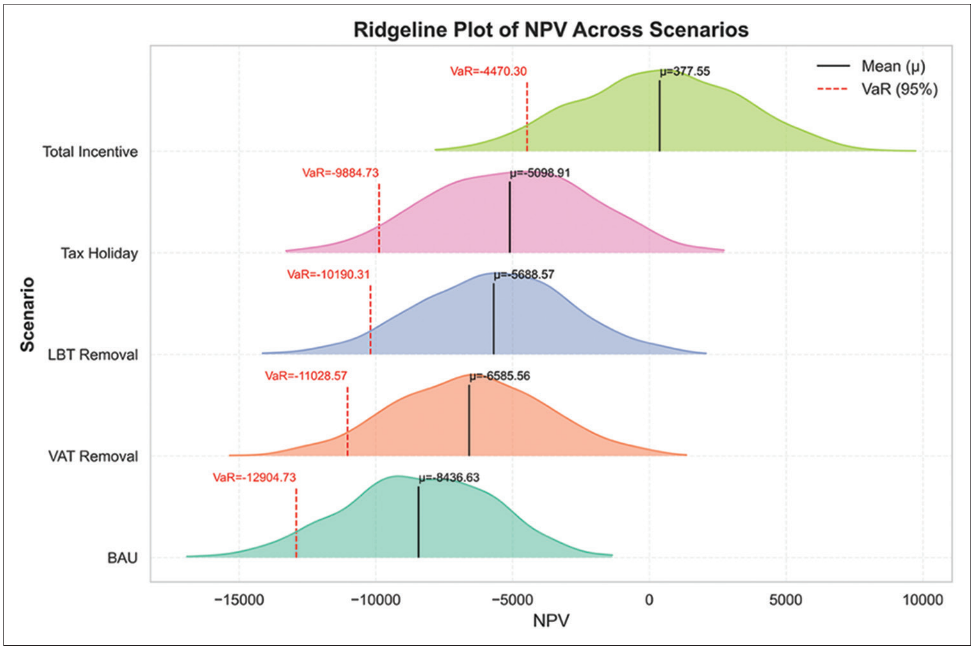


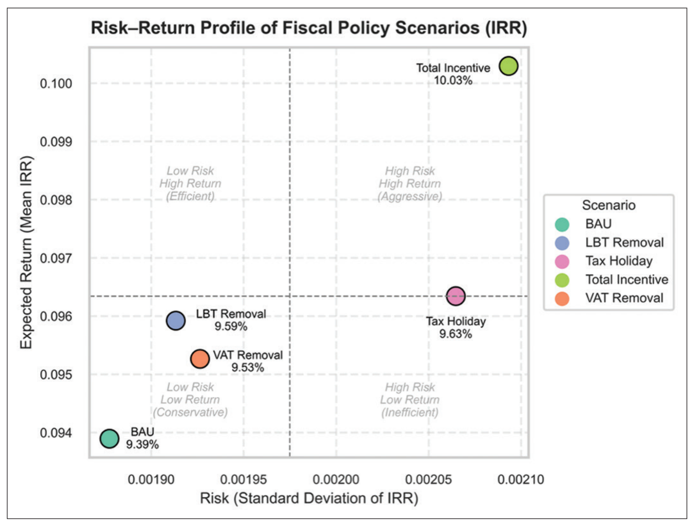
Figure 14: Ridgeline distribution of NPV (in thousand USD) across fiscal-policy scenarios (μ and VaR_{95})



The simulation results also indicate a significant improvement in downside financial performance, as reflected in the 95% Value-at-Risk (VaR_{95}) metrics. Across all fiscal-policy scenarios, the lower-tail risk of NPV improves from approximately – USD 12.9 million under the BAU condition to – USD 4.5 million under the Total Incentive configuration. Similarly, the IRR_{95} rises from 9.08% in the BAU case to 9.68% under the Total Incentive scenario, while the $LCOE_{95}$ slightly decreases from 0.0379 to 0.0378 USD/kWh. This rightward shift of the lower quantile values indicates that the probability of financial underperformance—defined as falling below breakeven NPV or minimum acceptable IRR—has decreased substantially, with downside risk reduced by nearly two-thirds. These findings confirm that fiscal incentives not only enhance expected profitability but also strengthen the overall risk resilience of geothermal investments.

The risk–return profile (Figure 15) illustrates the trade-off between expected profitability and volatility across fiscal-policy scenarios. The Total Incentive scenario exhibits the highest expected return (IRR = 10.03%) but also the greatest risk, reflecting increased variability due to the cumulative effects of multiple fiscal adjustments. This position in the upper-right quadrant characterizes a high-risk, high-return investment profile—attractive for risk-tolerant investors but requiring stable policy commitment to sustain confidence. Among the single-policy cases, the tax holiday scenario offers a relatively balanced outcome, providing a noticeable increase in expected return (9.63%) for a moderate rise in risk. In contrast, the VAT and LBT removal scenarios show smaller profitability gains with slightly lower volatility, indicating a more conservative improvement. The findings highlight that fiscal incentives can partially substitute for high tariffs, enabling the government to promote investment without overburdening PLN or end-users. Overall, these results confirm that combining fiscal incentives amplifies both upside potential and exposure to uncertainty, underscoring the importance of aligning incentive design with investor risk appetite and policy consistency.

Figure 15: Risk–return map of fiscal-policy scenarios based on IRR mean and standard deviation



4.7. Discussion and Policy Implications

The results of this study align with and extend the findings of prior techno-economic analyses of Indonesian geothermal projects, such as Xiaojun and Hakam (2024) in the International Journal of Energy Economics and Policy, who assessed a 60 MW Organic Rankine Cycle (ORC) geothermal plant using RETScreen modeling with carbon credit integration. Their study reported IRRs ranging from 20.7% to 35.7% and NPVs between USD 97–237 million under varying carbon price and tax-holiday scenarios. While both studies demonstrate that fiscal or environmental incentives are critical to achieving commercial feasibility, the present work offers a novel contribution by quantifying the downside financial risks through a VaR approach and by disaggregating the individual effects of VAT removal, LBT exemption, and tax holiday on project viability. Unlike the carbon-pricing incentives examined in Xiaojun and Hakam (2024), these fiscal instruments directly modify the project's cash-flow structure within Indonesia's existing taxation framework, offering policy-specific insights relevant to the Ministry of Finance and MEMR.

From a policy standpoint, the findings indicate that developers derive the most immediate financial benefit through improved after-tax returns and reduced upfront costs, enhancing project bankability. The government, meanwhile, gains indirect advantages through accelerated geothermal deployment, alignment with the national NZE 2060 target, and potential reductions in long-term fossil-fuel subsidies. However, these benefits also imply a short-term fiscal trade-off, as revenue from VAT and LBT collections decreases. To maximize systemic efficiency, fiscal incentives should therefore be coupled with performance-based criteria—such as local-content requirements or production milestones—to balance public expenditure with national development outcomes.

The empirical findings of this study are also consistent with Hasyanita and Shimada (2023), who examined the long-term drivers of geothermal capacity expansion in Indonesia using a national and provincial ARDL model. Their results indicate that direct funding and feed-in-tariff (FiT) policies exert a positive and statistically significant impact on geothermal capacity growth, while tax allowances showed mixed or even negative effects due to delayed implementation and investor uncertainty. These findings support the current study's conclusion that direct fiscal interventions, such as VAT and LBT exemptions and income-tax holidays, can yield more immediate financial leverage compared to indirect allowances. Furthermore, by embedding these incentives directly into a stochastic financial model, the present study extends their econometric approach into a project-level risk domain—quantifying not only expected profitability but also the downside exposure (NPVaR and IRRaR) under different fiscal-policy settings. This integration provides a bridge between macro-level policy analysis and micro-level investment risk modeling, offering a more actionable framework for fiscal design in Indonesia's geothermal sector.

5. CONCLUSIONS

This study evaluated the impact of fiscal incentives on the financial feasibility and risk profile of GPP projects in Indonesia. By integrating a DCF model with a VaR analysis, the research quantified both expected returns and downside risks across multiple fiscal-policy scenarios. Simulation results demonstrate that fiscal incentives play a decisive role in improving the financial viability of geothermal projects. Under the BAU conditions, the project's NPV is strongly negative and its IRR remains below standard investment benchmarks. Incremental policy measures—such as VAT and LBT exemptions—deliver measurable but modest improvements, while a 10 years tax holiday yields a larger positive effect on project returns. When combined, the Total Incentive scenario achieves a positive NPV (+USD 0.38 million) and an IRR slightly above 10%, meeting the lower bound of commercial feasibility.

The VaR results show that fiscal incentives improve mean performance and reduce the probability of extreme losses, yet they also increase the overall dispersion of returns—indicating higher volatility in financial outcomes. This finding is reinforced by the risk–return analysis, where the Total Incentive scenario occupies the high-risk, high-return quadrant, implying amplified profitability potential accompanied by greater exposure to uncertainty. Meanwhile, the tornado analysis confirms that drilling and EPC costs remain the dominant risk drivers, underscoring the need for complementary measures such as exploration-risk guarantees, concessional financing, and cost-sharing mechanisms to mitigate technical and financial exposure.

It should be noted that the simulation in this study represents a medium-scale geothermal project (50 MW), where economies of scale moderate the capital cost per MW. For smaller-capacity plants—typically < 50 MW—the capital intensity is considerably higher, which may reduce project feasibility even under current incentive structures. Therefore, future research should explore additional fiscal measures tailored for small and modular geothermal developments, including extended tax-allowance schemes, investment grants, and differentiated tariff mechanisms (e.g., flat feed-in tariffs or escalation-based rates).

In conclusion, a well-calibrated combination of fiscal incentives—supported by consistent regulatory frameworks and targeted risk-mitigation instruments—can substantially enhance geothermal investment attractiveness and accelerate Indonesia's transition toward its NZE 2060 target. Future work should extend this analytical framework by incorporating carbon-credit pricing, blended-finance structures, and portfolio-level optimization under deep uncertainty to support robust energy-transition policy design.

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APPENDICES

Appendix 1: Financial assumptions

Data	Unit	Value
Electricity price	USD/kWh	Years 1-10: 0,0941 Years 11-30: 0,0800
Exploration stage	**Unit**	**Value**
Geoscience survey	USD	350,000
Land acquisition	USD	638,710
Permit	USD	500,000
Civil construction	USD	6,050,000
Exploration drilling	USD	21,000,000
Feasibility study	USD	1,000,000
Development stage	**Unit**	**Value**
Land acquisition	USD	2,554,839
Civil construction	USD	15,125,000
Development drilling for production wells	USD	49,000,000
Development drilling for injection wells	USD	13,000,000
EPC-SAGS	USD	20,405,000
EPC-Power plant	USD	104,500,000
Management and overhead	USD	7,000,000
Commercial/Utilization Stage	**Unit**	**Value**
Major overhaul	USD/3 year	1,000,000
Work over	USD/4 year	1,000,000
Make up well drilling	USD	6,500,000

Appendix 2: Technical assumptions

Data	Unit	Value
Development capacity	MW	50
Capacity factor	%	90
Decline rate	%	3
Exploration well success ratio	%	67
Development well success ratio	%	80
Number of explorations well in PSEA phase	Well	1
Number of explorations well in GBP phase	Well	3
Number of exploitations well	Well	4
Number of reinjections well	Well	3
Number of make up well	Well	4

Appendix 3: Financial parameter

Data	Unit	Value
Loan percentage	%	70
Equity percentage	%	30
Interest rate	%	7.3
Upfront fee	%	1.5
Production bonus	% of revenue	0.5
Value-added tax	% of revenue	1.35%
Land and building tax after COD	% of revenue	1.88%
Production fees	% of revenue	2.5
Income tax	%	22
Income tax holiday with holiday	Year	6
Depreciation period	Year	8
Loan period	Year	15

Appendix 4: Python code for Monte Carlo simulation

```
# ==== Core Libraries ====

import xlwings as xw

import numpy as np, pandas as pd, random, time, subprocess

from numpy.random import triangular

from tqdm.notebook import tqdm

# ==== Simulation Settings ====

SEED = 42

random.seed(SEED)

np.random.seed(SEED)

num_sim = 1000

# ==== Triangular Distribution Bounds (±10%) ====

bounds = dict(min=-0.1, mean=0.0, max=0.1)

# ==== Excel Recalculation (macOS Safe) ====

def force_excel_recalc():

   script = ‘’’

   tell application “Microsoft Excel”

     activate

     calculate full

   end tell

   ‘’’

   subprocess.run([“osascript”, “-e”, script], capture_output=True)

# ==== Monte Carlo Simulation Function ====

def run_simulation(excel_file, scenario_name):

  wb = xw.Book(excel_file)

   sht = wb.sheets[‘Assumption’]

   results = []

for _ in tqdm(range(num_sim), desc=f” {scenario_name}”,
ncols=85, colour=“green”):

   # --- Random sampling of 9 cost parameters (±10%) ---

   rates = {name: triangular(bounds[“min”], bounds[“mean”],
   bounds[“max”]) for name in [
```

```
    'exploration_civil_rate', 'exploration_drilling_rate',

    'development_civil_rate', 'development_drilling_rate',

    'development_sags_rate', 'development_pp_rate',

    'commercial_OM_rate', 'commercial_overhaul_rate', 'commercial_drilling_rate'

]}

for k, v in rates.items():

    sht.range(k).value = v

# --- Trigger Excel recalculation ---

force_excel_recalc()

time.sleep(0.05)

# --- Read outputs (NPV, IRR, LCOE) ---

npv = sht.range('L29').value

irr = sht.range('L30').value

lcoe = sht.range('L31').value

results.append([*rates.values(), npv, irr, lcoe])

df = pd.DataFrame(results, columns=[

    'Exploration Civil','Exploration Drilling','Development Civil','Development Drilling',

    'Development SAGS','Development PP','Commercial O&M','Commercial Overhaul','Commercial Drilling',

    'NPV','IRR','LCOE'

])

df['Scenario'] = scenario_name

wb.close()

df.to_csv(f"df_{scenario_name.replace(' ', '_')}_results.csv", index=False)

return df

# ==== Run All Scenarios ====

scenarios = {

    "BAU": "Simulasi_PLTP Single Flash_BAU.xlsx",

    "VAT Removal": "Simulasi_PLTP Single Flash_Penghapusan VAT Tahap Eksploitasi dan Pemanfaatan.xlsx",

    "LBT Removal": "Simulasi_PLTP Single Flash_Skenario Penghapusan PBB Tahap Eksploitasi dan Pemanfaatan.xlsx",

    "Tax Holiday": "Simulasi_PLTP Single Flash_Skenario Tax Holiday.xlsx",

    "Total Incentive": "Simulasi_PLTP Single Flash_Total Incentive.xlsx"

}

df_all = pd.concat([run_simulation(v, k) for k, v in scenarios.items()], ignore_index=True)

df_all.to_csv("df_all_scenarios.csv", index=False)
```

Appendix 5: Visualization and value-at-risk analysis

```
# ==== Visualization Libraries ====

import matplotlib.pyplot as plt

import seaborn as sns

import pandas as pd

import numpy as np

from scipy.stats import gaussian_kde, spearmanr

from matplotlib.lines import Line2D

import matplotlib.patches as mpatches

sns.set_theme(style="whitegrid", context="paper", font_scale=1.2)

plt.rcParams.update({"figure.dpi": 300, "savefig.dpi": 600})

# ==== Load Combined Results ====

df_all = pd.read_csv("df_all_scenarios.csv")

scenarios = df_all["Scenario"].unique()

palette = sns.color_palette("Set2", len(scenarios))
```

A: Multi-Panel Histograms (NPV, IRR, LCOE)

```
variables = ["NPV", "IRR", "LCOE"]

titles = ["Net Present Value", "Internal Rate of Return", "Levelized Cost of Electricity"]

for scn in scenarios:
```

```
    df_scn = df_all[df_all["Scenario"] == scn]

    fig, axes = plt.subplots(1, 3, figsize=(18, 5))

    for ax, var, title in zip(axes, variables, titles):

        sns.histplot(df_scn[var], bins=30, kde=True, color="skyblue", ax=ax)

        ax.axvline(df_scn[var].mean(), color='black', linestyle='—', lw=1)

        ax.axvline(df_scn[var].quantile(0.05), color='red', linestyle=':', lw=1)

        ax.set_title(f'{title} — {scn}")

plt.tight_layout()

plt.savefig(f'Fig_MultiPanel_{scn.replace(' ', '_')}.png", dpi=600)
```

B: Ridgeline Plots (μ and VaR95)

```
confidence = 0.95

for metric in ["NPV", "IRR", "LCOE"]:

    fig, ax = plt.subplots(figsize=(9, 6))

    y_shift, gap = 0.0, 1.0

    for color, scn in zip(palette, scenarios):

        subset = df_all.loc[df_all["Scenario"] == scn, metric].dropna()

        kde = gaussian_kde(subset)

        x_vals = np.linspace(subset.min(), subset.max(), 300)

        y_vals = kde(x_vals)/kde(x_vals).max() * gap * 0.8

        ax.fill_between(x_vals, y_vals + y_shift, y_shift, color=color, alpha=0.6)

        ax.vlines(subset.mean(), y_shift, y_shift + gap*0.7, color="black")

        ax.vlines(np.percentile(subset, (1-confidence)*100), y_shift, y_shift + gap*0.7, color="red", linestyle="--")

        y_shift += gap

ax.set_yticks(np.arange(0, len(scenarios)*gap, gap))

ax.set_yticklabels(scenarios)

ax.set_title(f'Ridgeline Plot of {metric} Across Scenarios")

plt.tight_layout()

plt.savefig(f'Fig_{metric}_Ridgeline_MeanVaR_withYAxis.png", dpi=600)
```

C. Sensitivity Analysis (Tornado Diagram)

```
input_vars = [

    'Exploration Civil','Exploration Drilling','Development Civil','Development Drilling',

    'Development SAGS','Development PP','Commercial O&M', 'Commercial Overhaul','Commercial Drilling'

]

tornado_data = {}

for scenario in scenarios:

    df_scn = df_all[df_all["Scenario"] == scenario]

    tornado_data[scenario] = pd.DataFrame({

        "Input Variable": input_vars,

        "Spearman Rho": [spearmanr(df_scn[v], df_scn["IRR"])[0] for v in input_vars]

}).sort_values(by="Spearman Rho", key=np.abs, ascending=False)

fig, axes = plt.subplots(2, 3, figsize=(18, 9), sharex=True)

for ax, (scenario, df_corr) in zip(axes.flatten(), tornado_data.items()):

    sns.barplot(x="Spearman Rho", y="Input Variable", data=df_corr,

            palette=["#d73027" if r>0 else "#4575b4" for r in df_corr["Spearman Rho"]],

ax=ax)

ax.set_title(scenario)

plt.tight_layout()

plt.savefig("Fig_Tornado_IRR_2x3_AllXAxisLabels.png", dpi=600)
```

D. Risk–Return Scatter Plot (IRR)

```
summary = (

    df_all.groupby("Scenario")["IRR"]
    .agg(["mean","std"])
```

```
    .rename(columns={"mean":"Expected Return","std":"Risk"})
    .reset_index()
)

fig, ax = plt.subplots(figsize=(7,5.5))

sns.scatterplot(data=summary, x="Risk", y="Expected Return", hue="Scenario", s=180, edgecolor="black", linewidth=1)

ax.axvline(summary["Risk"].mean(), ls="--", color="gray")

ax.axhline(summary["Expected Return"].mean(), ls="--", color="gray")

ax.set_title("Risk–Return Profile of Fiscal Policy Scenarios (IRR)")

plt.tight_layout()

plt.savefig("Fig_RiskReturn_IRR_Final.png", dpi=600)
```