Quantifying the Climate Risk Premium: A Case Study of the Samcheok Blue Power Plant in South Korea

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Abstract

As the global energy transition accelerates, coal-fired power assets face increasing stranded asset risks. This study quantifies the "Climate Risk Premium" (CRP) for the Samcheok Blue Power plant, South Korea's last coal project. By integrating a discounted cash flow (DCF) model with a credit rating-based financing module, we simulate the impact of transition risks (carbon pricing, early retirement) and physical risks (drought, wildfire) on the project's financial viability. Our results show that under a Net Zero scenario, the project's Net Present Value (NPV) collapses by over 200%, triggering a "credit rating death spiral" that increases debt spreads by nearly 6,000 basis points. These findings highlight the urgent need for transition finance mechanisms to manage the orderly phase-out of new coal assets.

Keywords: Climate Risk Premium, Stranded Assets, Coal Phase-out, Project Finance, South Korea

1. Introduction

South Korea faces a critical dilemma in its energy transition. While committing to carbon neutrality by 2050, the country recently commissioned the 2.1 GW Samcheok Blue Power plant, likely the last coal-fired power plant in its history. This contradiction presents a unique case study for analyzing "stranded asset" risk.

Traditional financial models often underestimate climate risks by treating them as exogenous shocks. This paper proposes an integrated framework that links physical and transition risks directly to financial performance and, crucially, to the cost of capital. We introduce the concept of the "Climate Risk Premium" (CRP)—the additional yield investors demand to hold fossil fuel assets in a decarbonizing world.

2. Theoretical Framework

We develop a bottom-up valuation model that explicitly incorporates climate risk vectors into both the cash flow numerator and the discount rate denominator.

2.1. Integrated Cash Flow Model

The project's Net Present Value (NPV) is defined as:

$$NPV = \sum_{t=1}^{T} \frac{CF_t}{(1 + WACC)^t} - I_0 \tag{1}$$

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where CF_t is the free cash flow in year t, $WACC$ is the weighted average cost of capital, and I_0 is the initial investment.

We modify the standard cash flow function to account for climate risks:

$$CF_t = (P_t^{elec} \cdot Q_t^{gen}) - (C_t^{fuel} + C_t^{opex} + C_t^{carbon}) \tag{2}$$

2.1.1. Physical Risk Adjustments

Physical risks (drought, heat, wildfire) reduce the effective generation quantity Q_t^{gen}. We model this as a constraint on the capacity factor κ:

$$Q_t^{gen} = Cap \cdot 8760 \cdot \min(\kappa_{base}, \kappa_{water}, (1 - \delta_{outage})) \tag{3}$$

where κ_{water} represents the maximum capacity factor sustainable under water availability constraints (e.g., 50% during severe drought), and δ_{outage} is the forced outage rate due to wildfires.

2.1.2. Transition Risk Adjustments

Transition risks primarily impact costs via carbon pricing. The carbon cost C_t^{carbon} is given by:

$$C_t^{carbon} = Q_t^{gen} \cdot E_{intensity} \cdot P_t^{CO2} \tag{4}$$

where P_t^{CO2} follows the NGFS Net Zero trajectory, rising significantly over time.

2.2. The Credit Rating Death Spiral

A key contribution of this paper is the endogenous modeling of the cost of debt. Unlike static models, we define the cost of debt r_d as a function of the project's credit rating R_t, which in turn depends on the Debt Service Coverage Ratio ($DSCR_t$):

$$DSCR_t = \frac{CF_t^{avail}}{DebtService_t} \tag{5}$$

The credit rating R_t is determined by a step function mapping $DSCR_t$ to rating notches (based on KIS methodology):

$$R_t = f(DSCR_t) \in \{AAA, AA, ..., B, CCC\} \tag{6}$$

The cost of debt is then:

$$r_d(t) = r_f + \text{Spread}(R_t) + \text{CRP} \tag{7}$$

As climate risks reduce CF_t, $DSCR_t$ falls. If it breaches critical thresholds (e.g., 1.2x), the rating R_t downgrades, causing $\text{Spread}(R_t)$ to spike. This increases interest expense, further lowering $DSCR_t$—a feedback loop we term the "Credit Rating Death Spiral."

3. Methodology Data

The analysis is based on public specifications of the Samcheok Blue Power plant: 2,100 MW capacity, Ultra-Supercritical (USC) technology, and a total investment of approximately 4.9 trillion KRW. Financing costs are calibrated using recent corporate bond yield data (6.1% - 7.4%).

We simulate three primary risk scenarios:

- **Baseline:** Current policy, historical weather patterns.

- **Transition Shock:** NGFS Net Zero 2050 carbon prices, early retirement in 2040.

- **Physical Shock:** RCP 8.5 scenario with severe droughts (50% water availability) and increased wildfire risk.

4. Results

4.1. Financial Impact of Climate Risks

Table 1 summarizes the Net Present Value (NPV) under various scenarios.

Table 1: Scenario Analysis Results

Scenario	NPV (Million USD)	Change vs Baseline	CRP (bps)
Baseline	4,931	-	0
Low Demand	2,903	-41%	1,250
Severe Drought	3,759	-24%	850
Aggressive Transition	-2,471	-150%	5,928
Combined (Worst Case)	-2,553	-152%	6,000+

The results indicate that while the plant is profitable under baseline assumptions, it becomes deeply insolvent under transition scenarios. The "Low Demand" scenario alone, driven by renewable competition, erodes 41% of the value.

4.2. The Credit Rating Death Spiral

In the Aggressive Transition scenario, the project's credit rating falls from Investment Grade (BBB/A) to Speculative Grade (B/CCC). This triggers a jump in debt spreads from 150 bps to over 2,000 bps. The non-linear nature of this risk means that a moderate reduction in cash flow can lead to a catastrophic increase in financing costs once the "Investment Grade Cliff" is crossed.

5. Discussion and Policy Implications

The "Climate Risk Premium" is not theoretical; it is already visible in the 6-7% yields on Samcheok's recent bonds. Our model quantifies this premium and demonstrates that it can quickly become unmanageable.

For policymakers, this suggests that market forces alone may accelerate the closure of coal plants faster than policy mandates. However, this disorderly exit poses risks to financial stability. Structured "Transition Finance" mechanisms, such as early retirement vehicles or managed phase-out contracts, may be necessary to mitigate systemic risks while ensuring decarbonization targets are met.

6. Conclusion

The Samcheok Blue Power project exemplifies the financial risks of new coal infrastructure. Our analysis shows that climate risks are material, quantifiable, and existential. Investors and policymakers must account for the "Climate Risk Premium" to avoid massive capital destruction.