



# Mining more value: Assessing the fiscal and environmental implications of the Erdenet smelter project

DORJDARI NAMKHAIJANTSAN AND ZOLJARGAL NARANBAATAR

SEPTEMBER 2026

# Contents

|                                                         |           |
|---------------------------------------------------------|-----------|
| <b>Introduction</b>                                     | <b>4</b>  |
| <b>Part 1 - A mature mine at a strategic crossroads</b> | <b>6</b>  |
| - Erdenet overview                                      | 6         |
| - Mine-only scenario                                    | 9         |
| - Smelter scenarios                                     | 16        |
| - Financials: policy implications                       | 25        |
| <b>Part 2 - Environmental considerations</b>            | <b>26</b> |
| - Key challenge: sulfur dioxide                         | 26        |
| - Environmental planning and public disclosure          | 28        |
| - International experience and environmental standards  | 29        |
| - Environmental issues: policy implications             | 34        |
| <b>Conclusions</b>                                      | <b>35</b> |
| - Main findings                                         | 35        |
| - Recommendations                                       | 36        |
| <b>Annexes</b>                                          | <b>38</b> |
| - Annex 1. Methodology                                  | 38        |
| - Annex 2. Project sensitivity to key variables         | 42        |
| <b>References</b>                                       | <b>45</b> |

# Key messages

**Mongolia's ambition to add value to its copper resources is understandable, but value addition does not automatically translate into greater public value.** The proposed Erdenet smelter could support industrial diversification and create opportunities for downstream industries. However, copper smelting is capital-intensive, environmentally demanding and highly competitive.

## **1. The smelter increases value addition but does not add to project-level financial returns under the model assumptions.**

NRGI's modelling finds that continued mining and concentrate exports generate a higher project NPV than an integrated mine-and-smelter operation. The integrated scenario remains financially viable, but its NPV is USD 106.7 million compared with USD 152.3 million under the mine-only scenario. Higher sales revenue from processing is outweighed by substantially higher operating and capital costs. This does not mean downstream processing has no wider economic value. Potential benefits—including industrial diversification, employment, technology development and supporting industries—are not fully captured in the financial model and should be assessed separately.

## **2. A stand-alone smelter presents a particularly challenging commercial case.**

Under the assumptions tested, a stand-alone tolling smelter is not commercially viable. Treatment and refining charges generate about USD 3.4 billion in revenue, compared with approximately USD 9.0 billion in operating costs and USD 2.4 billion in capital expenditure.

## **3. Sulfur management is both an environmental and economic priority.**

High sulfur capture and effective sulfuric acid management are essential to the project's environmental performance. At the same time, the availability of markets for sulfuric acid affects project economics. The model finds that greater acid utilization improves project returns and government revenues, but even selling all acid does not make the integrated project financially stronger than the mine-only case.

## **4. Transparency should precede major investment decisions.**

Key information—including the feasibility study, investment assumptions, financing arrangements, environmental and social assessments, fiscal impacts and environmental performance indicators—has not been fully disclosed. This limits independent scrutiny and informed public debate.

## **5. Strong environmental oversight and public accountability are essential.**

The project should include transparent monitoring and reporting of sulfur dioxide emissions and capture rates, sulfuric acid management, environmental compliance and independent audits throughout its lifecycle.

**The key policy question is not simply whether Mongolia should add value to its copper, but whether the proposed form of value addition generates sufficient public benefits to justify its financial, fiscal and environmental risks.** The business case should therefore be transparent, independently scrutinized and regularly reassessed as market conditions change.

# Introduction

The Government of Mongolia (GoM) has announced that it is selecting a partner to build a copper smelter at Erdenet Mining Corporation,<sup>1</sup> the state-owned mining company that has produced copper concentrate since 1978.<sup>2</sup> Although the details of the partnership have yet to be disclosed, the project would represent a major milestone for the aging mine, which has faced declining ore grades, rising costs and governance challenges in recent years. With the global energy transition expected to drive higher demand for copper while new supply struggles to keep pace, copper prices have reached historically high levels. These favorable market conditions, together with increased resources and reserves resulting from additional exploration, have improved the mine's outlook and renewed interest in developing Mongolia's first domestic copper smelter.

The GoM has identified the construction of a copper smelter and refinery—a long-standing national ambition—as a strategic priority in its policy documents. It views the project as an opportunity to capture greater value from the country's mineral resources while stimulating the development of downstream industries.

If the GoM's most ambitious plans materialize, copper value addition could significantly reshape Mongolia's economy. It would move the country beyond mining into mineral processing, enabling the export of higher-value copper products. At present, with the exception of limited copper cathode production through SX-EW processes,<sup>3</sup> Mongolia exports copper primarily in the form of concentrate. More broadly, most of the country's mineral exports remain low-value ores and concentrates. Historically, inadequate power and transport infrastructure, as well as concerns about economic and environmental viability, have constrained the development of downstream processing.

Investing in a domestic smelter could therefore catalyze broader infrastructure development while supporting the growth of new industries. For example, long-standing plans to produce fertilizers using sulfuric acid generated during the smelting process could become viable. Together, these developments could increase value added in the economy, create new employment opportunities and diversify Mongolia's exports, reducing its vulnerability to commodity price shocks.

Developing a copper smelter at this stage, and in conjunction with the Erdenet mine, could also address several operational challenges. As the mine matures and ore grades decline, production costs continue to rise, including higher treatment charges for lower-grade concentrate processed by Chinese smelters. Over time, concentrate quality could fall below the thresholds accepted by existing smelters. Processing concentrate domestically could therefore help extend the mine's life while enabling more aggressive investment in exploration and the development of new mineral resources.

However, building a copper smelter raises several important policy considerations for the GoM. These include investing in supporting infrastructure, selecting appropriate technologies and strategic partners, designing effective environmental safeguards, assessing the project's fiscal benefits, allocating substantial public resources and managing public expectations.

These challenges are not unique to Mongolia. Many resource-rich countries are pursuing value addition as a strategy to maximize the benefits of their mineral resources. At the same time, such projects face growing public scrutiny over their economic benefits, environmental impacts and social risks. Transparency, access to information and meaningful public participation have therefore become essential components of effective value addition policies.

---

1 The proposed project includes an integrated copper smelter and refinery. For simplicity, this report refers to the integrated facility as the "smelter."

2 In June 2026, the GoM selected China Nonferrous Metal Industry's Foreign Engineering and Construction Co. Ltd (NFC) as its strategic partner for the proposed Erdenet copper smelter project. See, for example, Ikon.mn. "Three Chinese and one Swiss company shortlisted for copper concentrate smelting and processing plant." 25 February 2026.

3 Abbreviation of "Solvent Extraction – Electrowinning."

To date, publicly available information on Mongolia's proposed copper smelter remains limited and consists largely of media reports and general presentations. Key documents and project parameters—including the feasibility study, environmental and social impact assessments, investment assumptions, expected fiscal impacts and environmental performance indicators—have not been made publicly available.

Against this backdrop, the Natural Resource Governance Institute (NRGI) has undertaken this analysis to examine the key policy considerations associated with copper value addition in Mongolia. Its primary objective is to support informed and inclusive public debate by providing evidence-based analysis for policy-makers, civil society organizations, industry and other stakeholders.

The analysis focuses on the fiscal and environmental dimensions of developing domestic copper smelting and refining capacity, building on the priorities identified in NRGI's 2025 report on the opportunities and challenges associated with expanding Mongolia's copper sector.<sup>4</sup> That report concluded with several recommendations, including the need to “ensure detailed economic and financial analysis of new copper projects, especially downstream projects,” and to “revise environmental standards to make them comparable to those in leading countries, particularly with respect to sulfur dioxide capture.” This new report also builds on NRGI's broader work on the opportunities and risks associated with mineral value addition, including previous analysis of the conditions needed for equitable value addition.<sup>5</sup>

The report evaluates policy options for maximizing public benefits from copper sector development. It uses a financial model developed specifically to assess the costs and benefits of copper mining and processing under scenarios with and without domestic smelting capacity.<sup>6</sup> The analysis focuses on government revenues, including taxes and other fiscal instruments, as well as investment risks that could affect project returns, including those associated with sulfuric acid production.

In addition, the report examines the environmental implications of copper smelting and refining by comparing Mongolia's emerging regulatory framework with international standards and practices in major copper-producing countries. The report does not examine broader economic linkages, such as the development of downstream manufacturing, chemical industries, fertilizer production or the fabrication of finished copper products. Nevertheless, the fiscal and environmental considerations this report examines are among the most important factors that should inform decisions on investing in a domestic copper smelter.

The report is organized into two main parts. Part 1 examines the fiscal implications of three development scenarios: (1) a mine-only or business-as-usual scenario, in which Erdenet continues to produce and export copper concentrate; (2) a stand-alone smelter, which assumes a toll-smelting arrangement under which the smelter processes concentrate for a fee; and (3) an integrated mine and smelter, in which Erdenet owns and operates both the mine and the smelter. Part 1 begins with an overview of Erdenet Mining Corporation's current operational and financial position and discusses key considerations for extending the life of a mature mining operation. It then assesses the fiscal implications of each scenario and evaluates the principal risks associated with investing in a domestic copper smelter.

Part 2 examines the environmental dimensions of copper smelting, focusing on regulatory standards, international experience and their implications for Mongolia. The report gives particular attention to sulfur dioxide emissions and the management and utilization of sulfuric acid, which are among the most important environmental considerations associated with copper smelting.

The report concludes by summarizing the main findings and presenting recommendations for policy-makers and other stakeholders to support informed decision-making on copper value addition in Mongolia.

---

4 For details, see Dorjdari Namkhajantsan and Zoljargal Naranbaatar. *Copper Sector Expansion in Mongolia: Opportunities and Challenges*. NRGI, 2025.

5 For details, see Thomas Scurfield, Silas Olang and Matthieu Salomon. *Six Keys to Unlocking Equitable Value Addition in Mining*. NRGI, 2024.

6 The model is published on NRGI's website.

# Part 1 - A mature mine at a strategic crossroads

## Erdenet overview

Erdenet Mining Corporation is a wholly state-owned company that has produced copper concentrate as its primary product and molybdenum concentrate as a co-product since its establishment in 1978. Commonly known simply as Erdenet, the company has long been one of the pillars of Mongolia's economy, particularly during the country's political and economic transition in the 1990s. Erdenet is also the name of the city that developed around the mining operation. The mine is located in northern Mongolia.

Today, the company produces approximately 550,000 tonnes of copper concentrate and 5,000 tonnes of molybdenum concentrate annually, all of which is exported to China. Until Oyu Tolgoi—another major copper mine in southern Mongolia—began production in 2013, Erdenet was the country's sole producer and exporter of copper concentrate.

After nearly half a century of continuous operation, Erdenet is a mature mine facing declining ore grades. Nevertheless, the company continues to invest in exploration and has identified additional resources and reserves containing approximately 10 million tonnes of copper and 500,000 tonnes of molybdenum. According to the company, these resources could support mining operations for another 70 years.<sup>7</sup>

The GoM increased its ownership stake in Erdenet from 50 percent to 51 percent during the early years of the country's economic transition in the 1990s. Originally established as a joint venture between Mongolia and the Soviet Union, the company became wholly state-owned in 2019. This followed a brief period during which a Mongolian private company held the former Russian stake after acquiring it in 2016.

Because Erdenet is now wholly state-owned, the choice of fiscal instruments to maximize government revenue is less relevant than it would be for a privately owned mining project. However, investment decisions and operational risks have direct implications for citizens, as the state ultimately bears both the benefits and the liabilities. Whether the GoM will allow private ownership in the proposed smelter remains unclear. Such a move may prove politically sensitive given the brief period during which a private company held a stake in Erdenet before the government reclaimed ownership, citing irregularities in the transaction between the former Russian shareholder and the domestic buyer. If private investment is permitted, the financial viability of the smelter will become even more important, as investors are likely to seek government support if they consider the project commercially unviable.

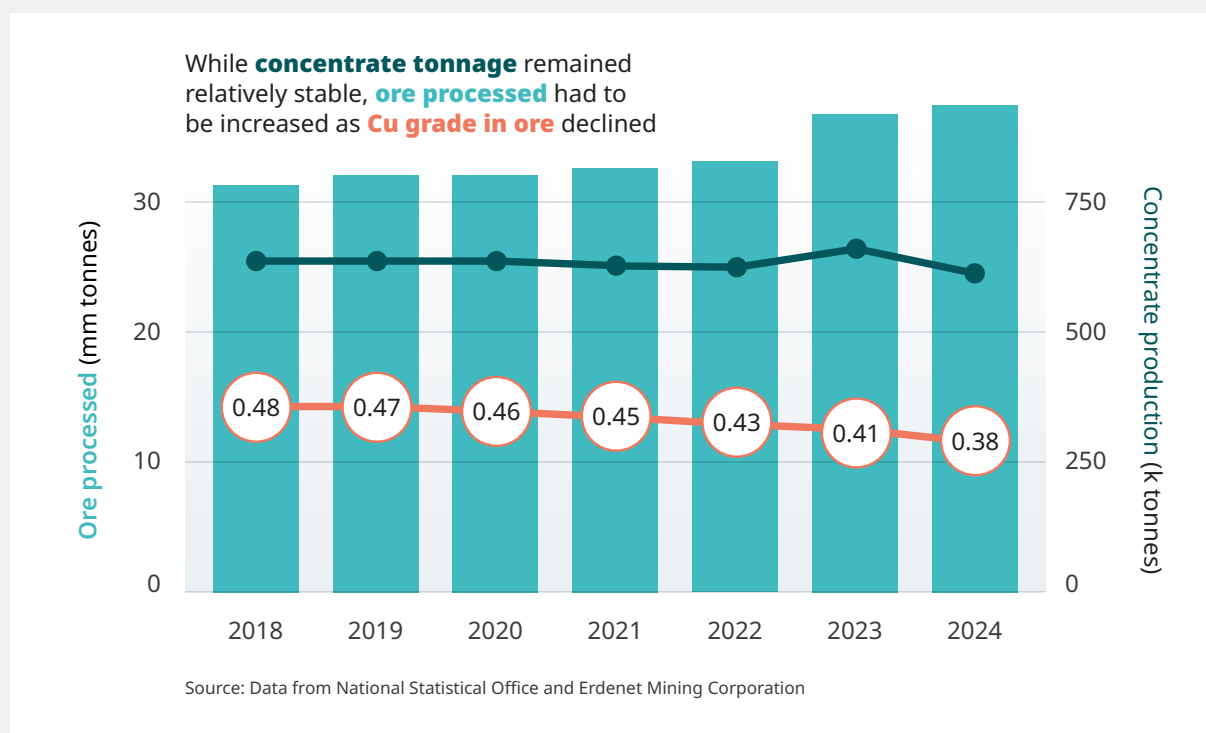
The mine directly employs around 7,000 people, including approximately 2,000 in managerial and administrative positions.<sup>8</sup> Erdenet remains the largest employer in Erdenet city and supports a wide range of local businesses and services, including suppliers, power and water utilities, healthcare providers, sports facilities and other social enterprises.

Production levels have remained relatively stable in recent years. Copper concentrate output, the company's primary product, ranged between 566,000 and 600,000 tonnes annually from 2018 to 2024. However, as Figure 1 shows, the copper grade of processed ore has steadily declined, requiring the company to process increasingly larger volumes of ore to maintain current production levels. This reflects the natural depletion of the deposit and is likely to place upward pressure on mining and processing costs over time.

---

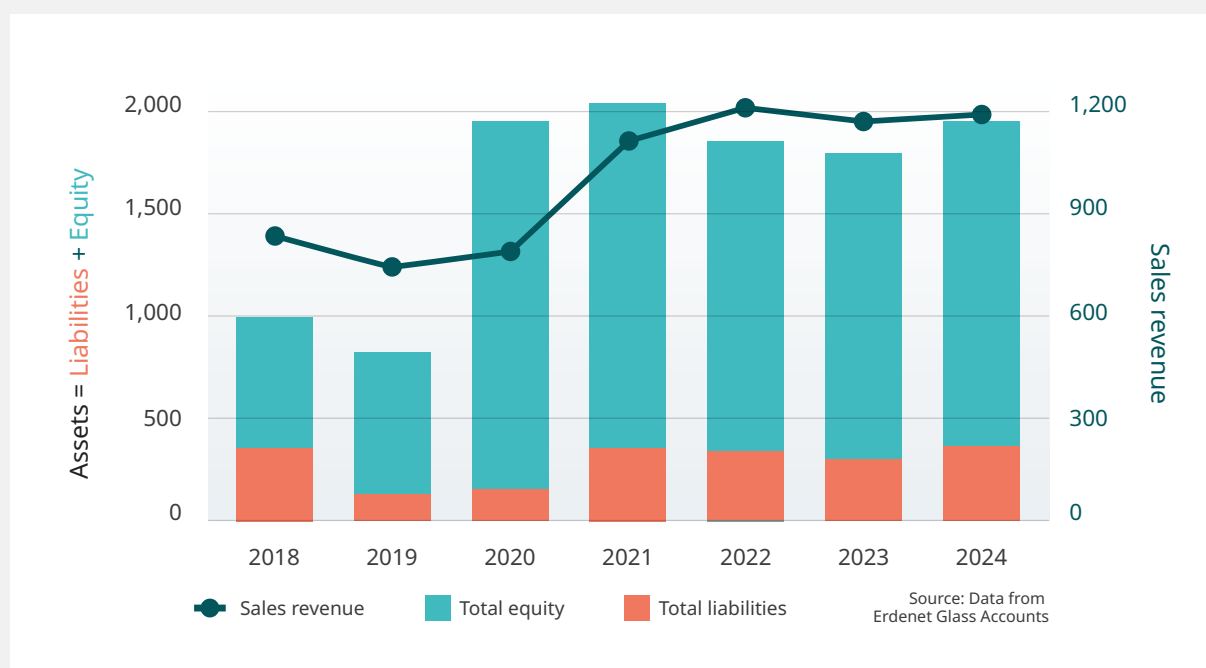
7 Erdenet Mining Corporation. "Geological Exploration." No date.

8 Government of Mongolia, Glass Account Information. "Changes to approved employment plans." 2026.

**Figure 1.** Quantity and grade of ore processed, 2018–2024

The company's financial performance has improved significantly in recent years. Figure 2 presents trends in Erdenet's assets and sales revenue. The company maintains relatively low liabilities compared with its asset base, while the

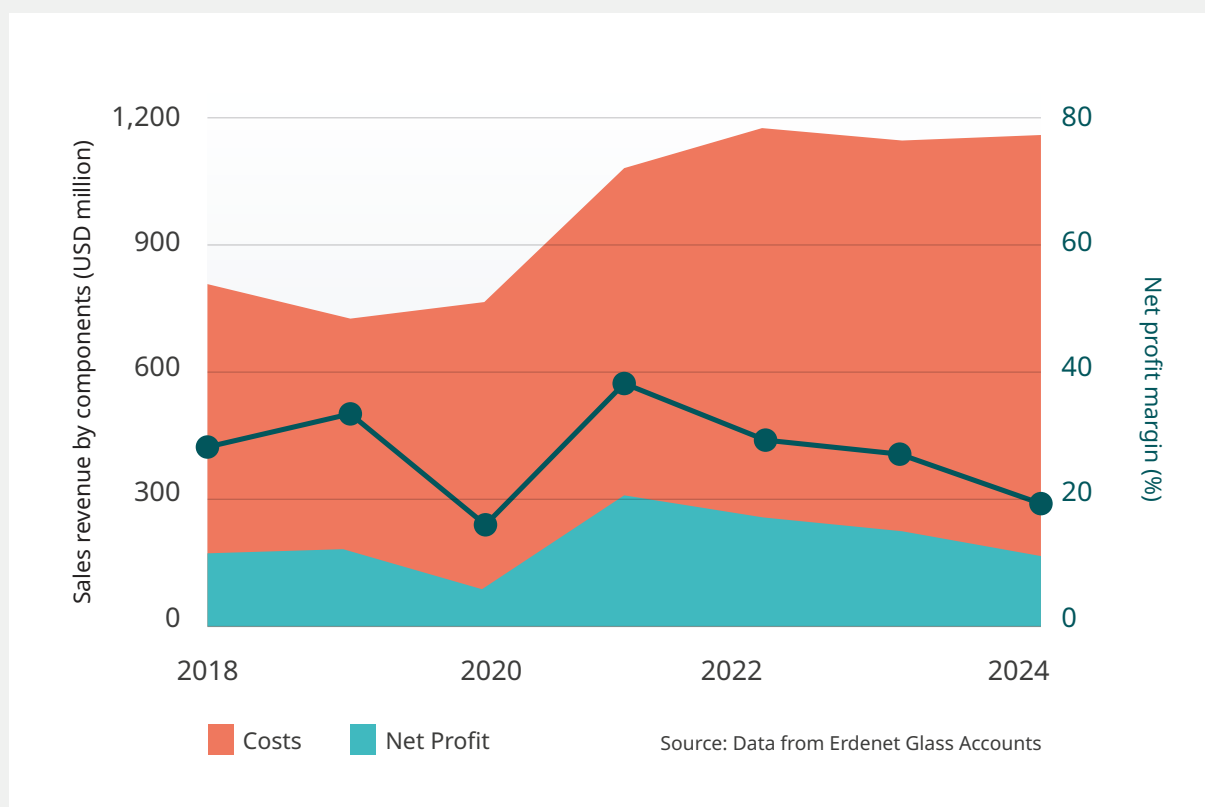
value of its assets has increased steadily. Given that production volumes have changed only marginally, the growth in sales revenue has been driven primarily by higher copper and molybdenum prices rather than by increased output.

**Figure 2.** Selected performance indicators for Erdenet, 2018–2024 (in USD million)

Erdenet has remained profitable in recent years, as Figure 3 shows. However, although sales revenue has increased, production costs

have also risen, resulting in a decline in the company's net profit margin from 29.1 percent in 2021 to 14.7 percent in 2024.

**Figure 3.** Sales revenue and net profits of Erdenet, 2018–2024

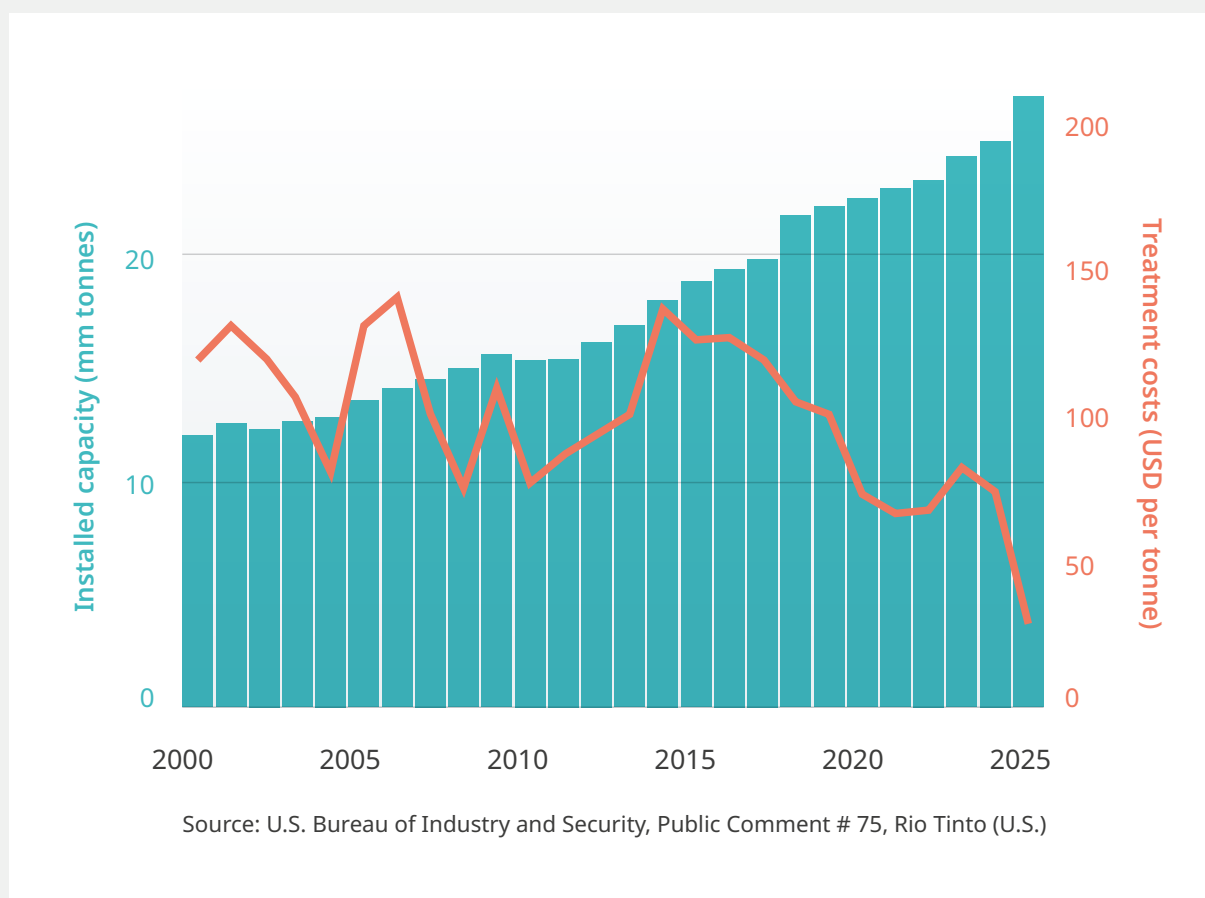


Overall, Erdenet remains a mature and operationally stable mining company that has benefited from historically high copper prices in recent years. With global copper demand expected to continue growing, the company's long-term outlook remains favorable. Moving further along the value chain through domestic processing of copper concentrate may therefore appear to be a logical next step and plans to develop Mongolia's first copper smelter are already underway.

However, copper smelting represents a new industrial activity for Mongolia and operates in a highly competitive global market characterized by thin margins. China alone accounts for around half of global refined copper production and continues to expand its smelting capacity.

As a result, treatment and refining charges (commonly known as TC/RCs)—the fees smelters charge mining companies to process concentrate—have declined sharply in recent years, with spot treatment charges falling to as low as negative USD 37 per tonne in 2025.<sup>9</sup> At such levels, smelters effectively pay mining companies for their concentrate in order to secure sufficient feedstock and maintain operations. This illustrates that, while value addition can create new economic opportunities, it also requires careful assessment of market conditions, commercial viability and investment risks. Figure 4 shows recent trends in global smelting capacity and treatment charges.

9 U.S. Bureau of Industry and Security. "Public Comment # 75. Rio Tinto (U.S.). Company Representative." 11 April 2025.

**Figure 4.** Copper treatment capacity and costs, 2000–2025

NRGI has identified six key considerations for countries pursuing mineral value addition, emphasizing the importance of assessing not only the potential benefits but also the associated costs and risks.<sup>10</sup> NRGI's previous report on Mongolia's copper sector similarly highlighted the need to evaluate both the fiscal and environmental implications of developing domestic copper smelting and refining capacity.<sup>11</sup>

The following sections evaluate the potential costs and benefits of constructing a domestic copper smelter. The analysis first examines Erdenet's future outlook under a baseline scenario in which the company continues to produce and export copper concentrate. It then compares this scenario with one in which Erdenet invests in domestic copper smelting capacity.

## Mine-only scenario

As a well-established mining operation with substantial remaining copper and molybdenum reserves, Erdenet could continue focusing on the production and export of copper and molybdenum concentrates while benefiting from favorable commodity prices. This section examines the business-as-usual scenario in which the company does not invest in domestic copper smelting and refining.

The financial analysis of the mine-only scenario is based on a set of assumptions relating to production, prices, costs and fiscal parameters. The key production assumptions are summarized in Table 1.

<sup>10</sup> Scurfield, Olang and Salomon. *Six Keys to Unlocking Equitable Value Addition in Mining*.

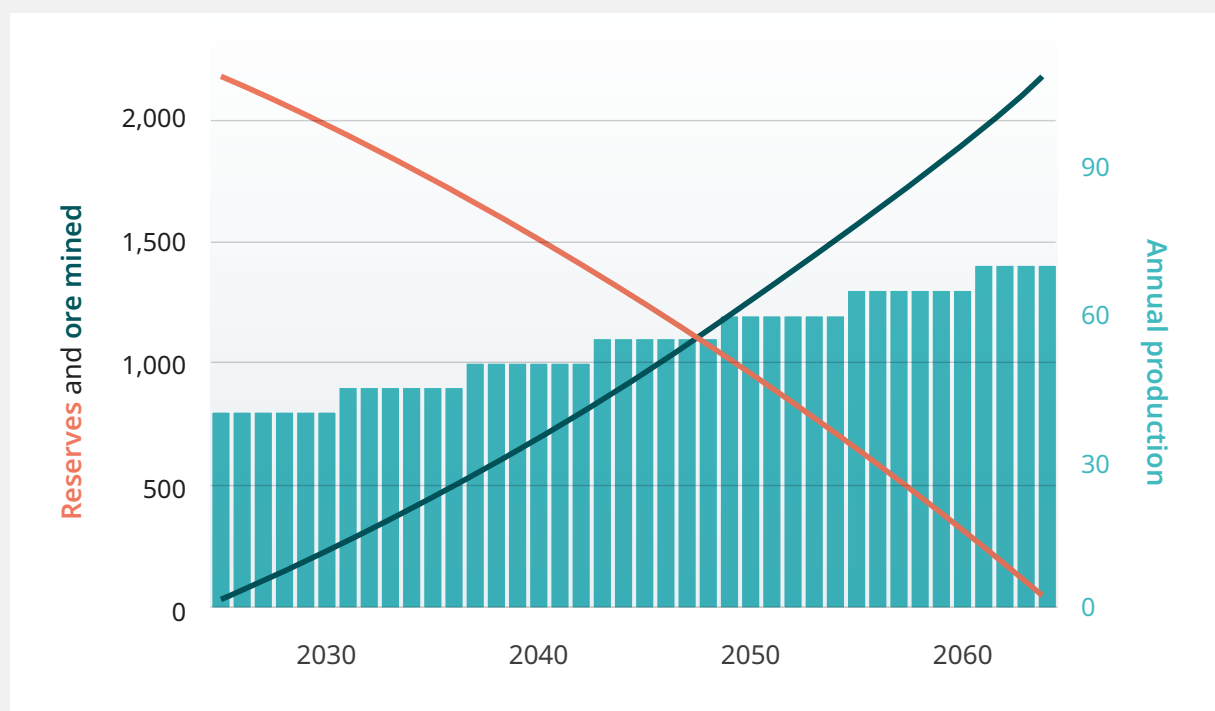
<sup>11</sup> Namkhajantsan and Naranbaatar. *Copper Sector Expansion in Mongolia*.

**Table 1.** Production assumptions for mine-only scenario

| Item                        | Value   | Units           |
|-----------------------------|---------|-----------------|
| <b>Timeline</b>             |         |                 |
| Reserves end year           | 2065    |                 |
| <b>Production</b>           |         |                 |
| Reserves                    | 2,216.4 | mm tonnes       |
| Head grade Cu               | 0.36    | percent         |
| Head grade Mo               | 0.01    | percent         |
| Concentrator capacity       | 40.0    | mm tonnes/year  |
| Concentrator upgrade period | 6.0     | years           |
| Concentrator upgrade        | 5.0     | mm tonnes       |
| Concentrate grade Cu        | 23.0    | percent         |
| Concentrate grade Mo        | 53.0    | percent         |
| Concentrate grade Au        | 0.3     | grams per tonne |
| Concentrate grade Ag        | 70.0    | grams per tonne |

Erdenet is assumed to continue operating its open-pit mine until the depletion of its remaining ore reserves of approximately 2.22 billion tonnes, which, under the model assumptions, occurs in 2065. A key assumption is that the concentrator

capacity increases from 40 million tonnes per year by 5 million tonnes every six years. The assumption reflects Erdenet's historical pattern of gradually expanding its milling capacity. Figure 5 presents the resulting production profile.

**Figure 5.** Reserves and production, 2025–2065 (in million tonnes)

Erdenet generates revenue from the sale of copper and molybdenum concentrates, with concentrate prices estimated on a netback basis. Netback pricing is appropriate because concentrates are intermediate products that are not traded on a transparent global exchange. Instead, concentrate values are derived from observable market prices for

refined metals after deducting the costs required to process, transport and deliver the material to the final market. These deductions typically include treatment and refining charges (TC/RCS), transportation costs and applicable taxes and fees. Table 2 presents the principal revenue and fiscal assumptions used in this scenario.

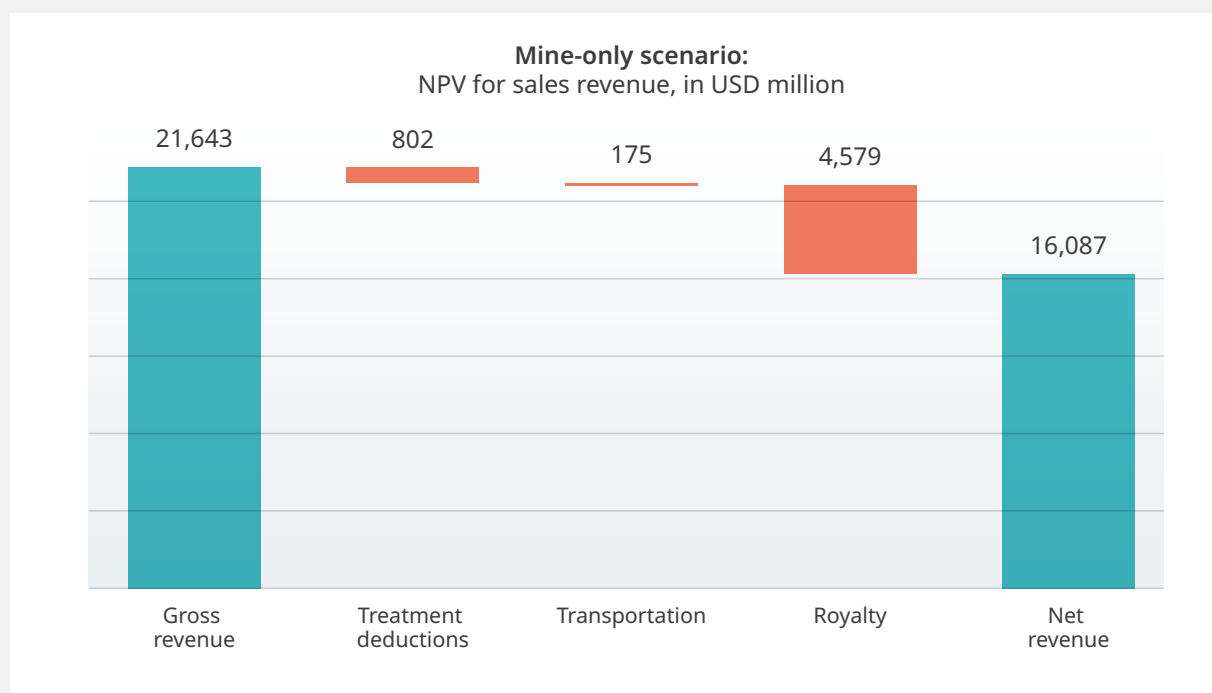
**Table 2.** Revenue and tax assumptions for mine-only scenario

| Item                                      | Value   | Units         |
|-------------------------------------------|---------|---------------|
| <b>Prices</b>                             |         |               |
| Inflation USD                             | 2.0     | percent       |
| Discount rate real                        | 7.0     | percent       |
| Copper                                    | 5.0     | USD per lb    |
| Molybdenum                                | 25.0    | USD per lb    |
| Gold                                      | 3,000.0 | USD per oz    |
| Treatment                                 | 50.0    | USD per tonne |
| Roasting                                  | 2.0     | USD per lb    |
| <b>Taxes</b>                              |         |               |
| Base royalty                              | 5.0     | percent       |
| Copper concentrate - marginal royalty     | 15.0    | percent       |
| Molybdenum concentrate - marginal royalty | 4.0     | percent       |
| Gold - marginal royalty                   | 5.0     | percent       |
| Silver - marginal royalty                 | 5.0     | percent       |
| Tax rate                                  | 25.0    | percent       |

Note: "Marginal" refers to the higher tier of an additional royalty

Although copper prices remain the primary driver of Erdenet's revenue, several additional factors influence the value received for copper concentrate. These include concentrate grade, treatment and refining charges, penalties for impurities such as arsenic and fluorine, transportation costs to smelters or export markets, and applicable cross-border taxes and fees.

For molybdenum concentrate, roasting charges are deducted from metal prices to reflect downstream processing costs. Figure 6 presents projected sales revenue and the associated deductions under the mine-only scenario. Royalties represent one of the largest deductions from gross revenue and therefore have a significant impact on the company's net sales revenue.

**Figure 6.** Sales revenue and related deductions, 2025–2061

While production and commodity prices determine gross revenue, deductions such as treatment and refining charges, royalties and transportation costs determine net sales

revenue. Operating and capital expenditures are then deducted to estimate the company's profitability. Table 3 summarizes the assumptions used for these costs.

**Table 3.** Opex and financials assumptions for mine-only scenario

| Item                   | Value | Units            |
|------------------------|-------|------------------|
| <b>Operating costs</b> |       |                  |
| Labor                  | 4.17  | USD/tonne milled |
| Materials              | 3.06  | USD/tonne milled |
| Utilities              | 2.57  | USD/tonne milled |
| Fuel and transport     | 3.06  | USD/tonne milled |
| Other                  | 1.17  | USD/tonne milled |
| <b>Capital costs</b>   |       |                  |
| Capex sustaining       | 1.95  | USD per tonne    |
| Capex expansion        | 32.07 | USD per tonne    |
| <b>Financials</b>      |       |                  |
| Interest rate real     | 8.0   | percent          |
| Dividend payout ratio  | 70.0  | percent          |

As the mine matures and ore grades gradually decline, operating costs are expected to increase. At the same time, maintaining concentrate production requires periodic expansions of milling capacity, resulting in additional capital expenditure. Figure 7 presents the projected

operating expenditure (opex) and capital expenditure (capex) under the mine-only scenario. Operating expenditure includes labor, energy, fuel, materials, reagents and other operating costs, while capital expenditure comprises both sustaining and expansion investments.

**Figure 7.** Operating and capital expenditures, 2025–2061

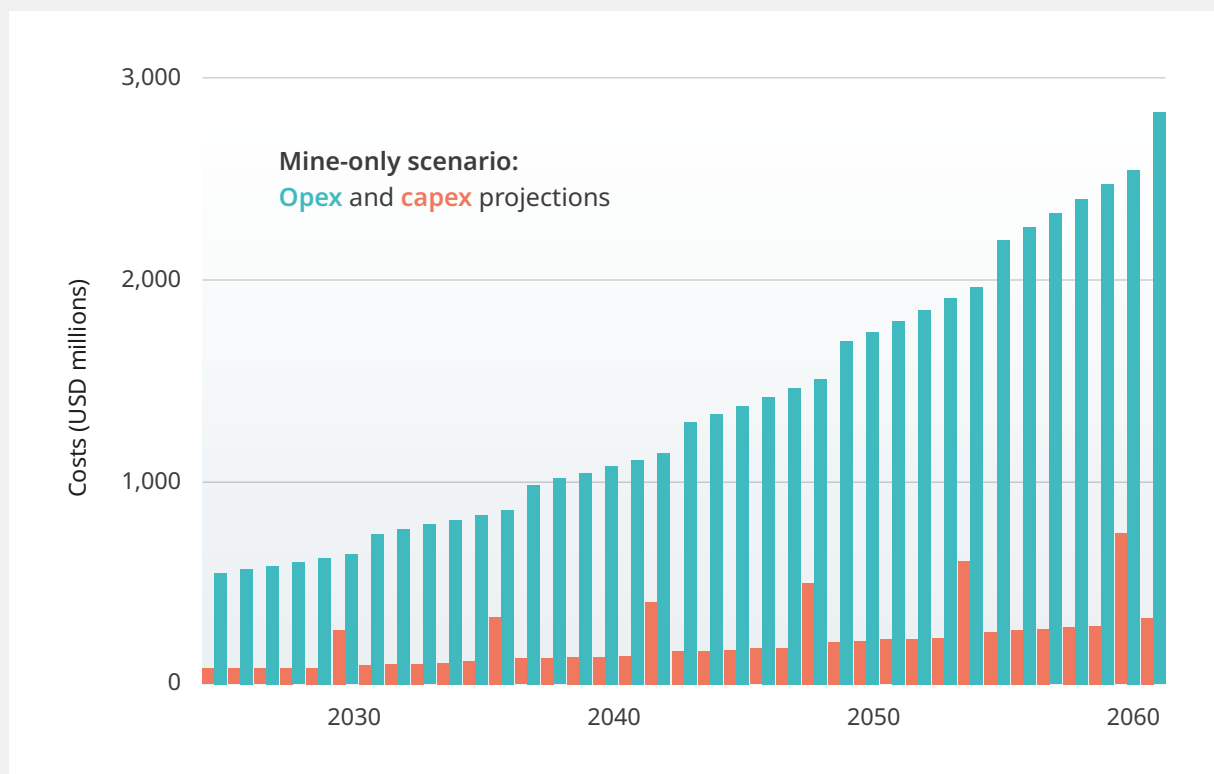


Table 4 presents the principal financial results for the mine-only scenario, in which Erdenet continues exporting copper concentrate without investing in domestic smelting capacity. Under this scenario, the operation generates substantial positive cash flows throughout the project life, with cumulative pre-tax cash flow of USD 24.5 billion. However, undiscounted net cash flow turns negative because large tax, royalty and dividend payments deplete the cash retained by the company. In net present value (NPV) terms, post-tax cash flows amount to USD 2.2 billion, while cash flow to equity reaches USD 4.1 billion. As the project generates sufficient internal cash to finance its operations and investments, no additional government equity contribution is required. Consequently, cash flow to equity is equivalent to dividends distributed to the state.

Government revenue is driven primarily by mineral royalties, particularly the additional royalty linked to copper prices, which contributes USD 15.7 billion in nominal terms. Corporate income tax provides a further USD 2.1 billion, while dividends from state ownership generate the largest fiscal benefit in present value terms at USD 4.3 billion. In undiscounted terms, dividends amount to USD 9.4 billion over the project life, reflecting the timing differences between dividend distributions and royalty payments.

Overall, the mine-only scenario demonstrates the substantial fiscal contribution of the existing concentrate export model and provides the baseline against which the financial and fiscal implications of downstream smelting investments can be assessed.

**Table 4.** Selected financials, mine-only scenario (in USD million)

|                           | NPV     | Total    |
|---------------------------|---------|----------|
| <b>Cash flows</b>         |         |          |
| Net cash flow             | 152.3   | -10.9    |
| Pre-tax cash flow         | 7,249.0 | 24,480.1 |
| Post-tax cash flow        | 2,159.1 | 803.7    |
| Cash flow to equity       | 4,056.8 | 3,824.5  |
| <b>Government revenue</b> |         |          |
| Base royalty              | 1,234.7 | 5,807.8  |
| Additional royalty        | 3,344.4 | 15,720.4 |
| Corporate income tax      | 976.0   | 2,148.2  |
| Dividends                 | 4,274.6 | 9,439.2  |

Project outcomes are inherently sensitive to changes in key assumptions, including commodity prices, operating costs, inflation and fiscal parameters. Understanding these sensitivities is important from both an investment and a public policy perspective. This section examines the effects of changes in royalty rates, while additional sensitivity analyses are presented in Annex 1.

Debate over mineral royalty rates has long been a feature of Mongolia's mining policy. Mongolia applies a base royalty of 5 percent on the metal content of concentrates and an additional royalty of up to 15 percent, depending on copper prices and the level of processing. Lower additional

royalty rates apply to processed metals, while higher rates apply to ore and concentrate.

The model results suggest that reducing, or even eliminating, additional royalties on copper increases both company returns and total government revenue, assuming all other variables remain unchanged. Although the model is simplified and does not incorporate tax-loss carry-forwards when calculating corporate income tax, the results indicate that excessive reliance on royalties may reduce the government's overall fiscal take by lowering project profitability and, consequently, corporate income tax and dividend payments. Table 5 summarizes the results.

**Table 5.** Impact of additional copper royalty on selected project results (in USD million)

| Item                | No royalty | 50% reduction | Current rate |
|---------------------|------------|---------------|--------------|
| NPV                 | 283.7      | 216.3         | 152.3        |
| Cash flow to equity | 7,932.6    | 5,990.4       | 4,056.8      |
| Government take     | 11,043.9   | 10,381.9      | 9,829.7      |
| Royalty             | 1,360.0    | 2,969.6       | 4,579.2      |
| CIT                 | 1,746.5    | 1,352.7       | 976.0        |
| Dividends           | 7,937.4    | 6,059.6       | 4,274.6      |

The mine-only scenario concludes with an assessment of project uncertainty using Monte Carlo simulation. Copper prices, inflation and real operating cost escalation are treated as stochastic variables, and their effects on key project outcomes - including NPV, cash flow to equity and government revenue - are evaluated over 1,000 simulation runs. Figure 8 presents the simulated distribution of project NPV. The results indicate a 100 percent probability of a

non-negative NPV, suggesting that the project remains economically viable under all simulated scenarios. This outcome is expected for an established mining operation with relatively limited development risk. Nevertheless, the analysis illustrates considerable uncertainty in project value, with simulated NPVs ranging from approximately USD 17.4 million to USD 475.7 million and clustering around a mean of USD 164.5 million.

**Figure 8.** Projected net present value

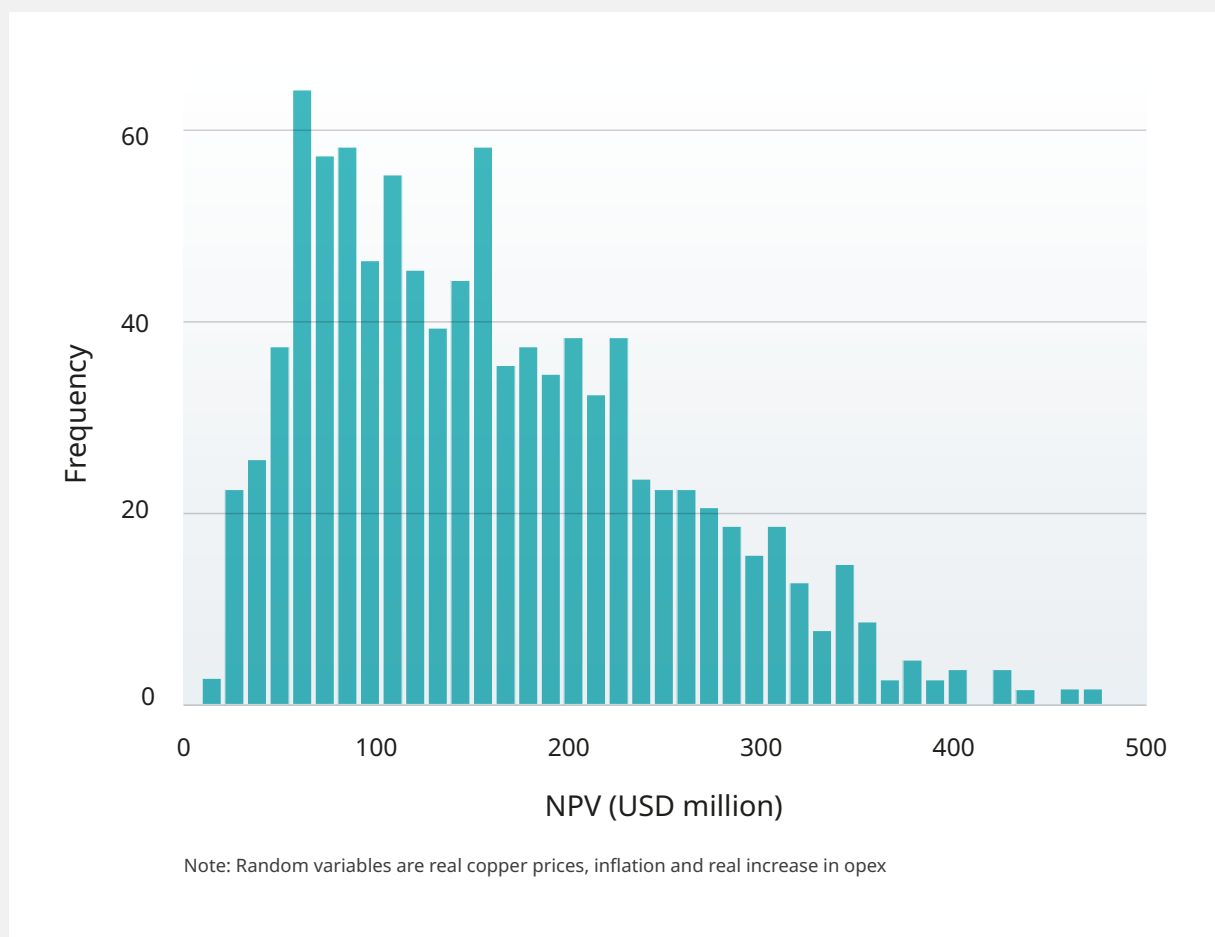
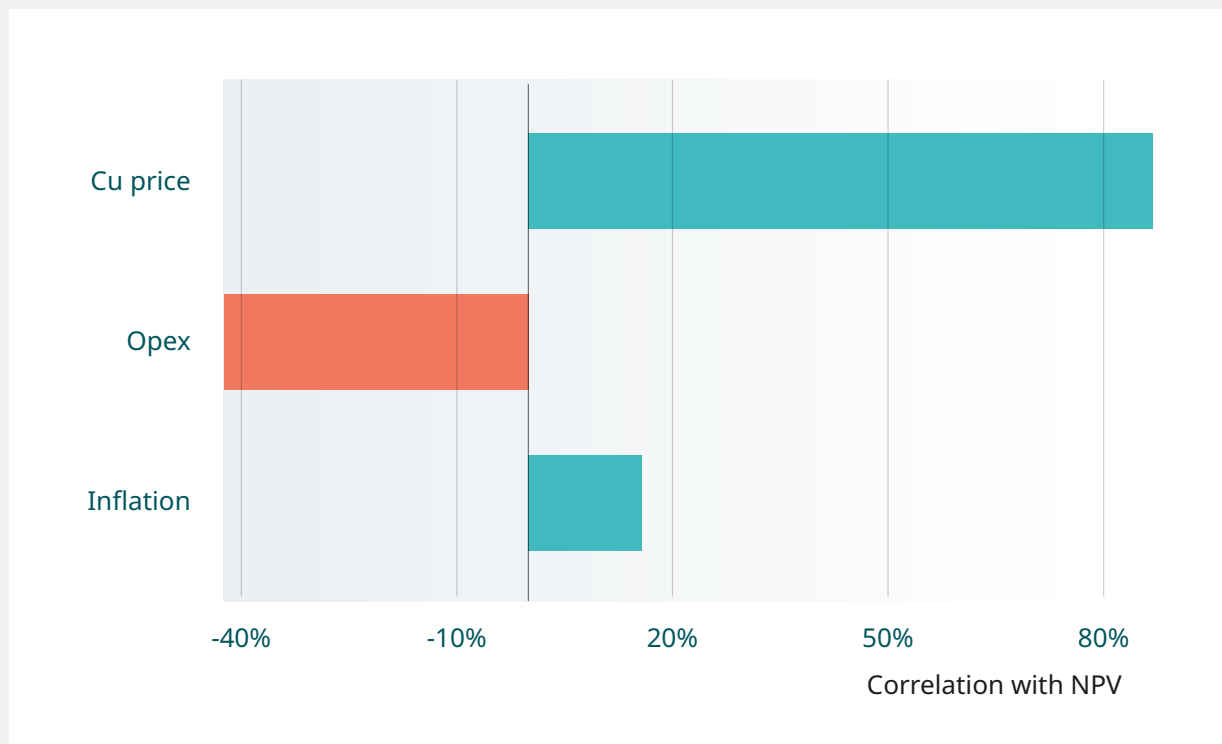


Figure 9 shows the relative influence of the three stochastic variables on project NPV. Copper price is the dominant driver, exhibiting a strong positive Pearson correlation of 87.2 percent with project value. In contrast, real operating cost escalation has a moderate negative correlation (-42.6 percent), indicating that higher operating costs reduce project value.

Inflation has only a weak positive correlation with NPV because it affects both revenues and costs, resulting in a relatively small net effect on project economics. Overall, the analysis confirms that project uncertainty is driven primarily by copper prices, while operating costs play a secondary role and inflation contributes relatively little to overall variation in project outcomes.

**Figure 9.** Impact of some variables on NPV

Overall, the business-as-usual scenario demonstrates that continued production and export of copper concentrate remain economically attractive, generating substantial returns for both the company and the government. Project value is driven primarily by copper prices, while operating costs have a secondary influence. The analysis also suggests that a fiscal regime that relies less heavily on royalties could improve both project profitability and total government revenue. This scenario provides the baseline against which the integrated smelter scenario is evaluated.

## Smelter scenarios

The second scenario examines the addition of downstream copper processing facilities at Erdenet. For the purposes of this analysis, the term “smelter” refers to an integrated processing complex comprising a smelter, refinery, sulfuric acid plant and acid neutralization facilities. Two alternative configurations are evaluated. The first is a stand-alone smelter operating under a tolling arrangement, whereby copper concentrate

is processed on behalf of mine operators for a fee and the smelter does not purchase the concentrate. The second is an integrated mining and processing operation in which the smelter is added to the concentrate production. The financial performance and fiscal implications of each configuration are assessed and compared with the business-as-usual scenario.

The two smelter scenarios share a common set of technical, operating and financial assumptions, which Table 6 summarizes. Both assume the construction of a 150,000-tonne-per-year copper cathode production complex, with an estimated capital cost of just under USD 1 billion. The analysis further assumes a three-year construction period, with operations commencing in 2029. Common assumptions also include sulfur recovery, operating and capital costs, electricity consumption, and sulfuric acid production and transportation costs. Another assumption is that not all of the sulfuric acid produced will be marketable. The surplus acid is assumed to be neutralized to produce gypsum, which requires storage.

**Table 6.** Assumptions for smelter scenarios

| Item                     | Value  | Units                     |
|--------------------------|--------|---------------------------|
| <b>Timeline</b>          |        |                           |
| Construction period      | 3      | years                     |
| Smelter start            | 2029   |                           |
| <b>Production</b>        |        |                           |
| Smelter capacity         | 150.00 | k tonnes cathode          |
| Sulfur in concentrate Cu | 34     | percent                   |
| Sulfur capture rate      | 97     | percent                   |
| <b>Operating costs</b>   |        |                           |
| Labor                    | 12.00  | mm USD per year           |
| Materials                | 40.00  | USD per tonne concentrate |
| Utilities                | 300.00 | kWh per tonne concentrate |
| Fuel and transport       | 15.00  | USD per tonne concentrate |
| Other                    | 25.00  | USD per tonne concentrate |
| <b>Capital costs</b>     |        |                           |
| Capex development        | 984.58 | mm USD                    |
| <b>Prices</b>            |        |                           |
| Sulfuric acid            | 80.00  | USD per tonne             |
| Electricity              | 0.08   | USD per kWh               |

The scenarios differ only in the commercial structure of the smelter. The first assumes a stand-alone tolling operation that processes third-party concentrate for a fee, while the second assumes an integrated mining and smelting operation in which the mine and smelter operate as a single business. Treatment and refining charges applicable to the stand-alone smelter are already incorporated in the mine-only scenario, where they are deducted from concentrate revenues to derive netback prices. In the stand-alone smelter scenario, these same charges become the primary source of operating revenue for the smelter.

## Stand-alone smelter

The first smelter scenario evaluates a stand-alone copper smelter operating independently from the mine. Under this arrangement, the smelter does not own or purchase the copper concentrate. Instead, it provides smelting and refining services to mine operators under a tolling arrangement. The mine operator retains ownership of the concentrate and the contained metals throughout the processing chain and receives the refined copper and other payable products. The smelter receives treatment and refining charges in return for processing the concentrate.

The tolling structure separates the economics of downstream processing from those of mining. The smelter's revenue therefore depends primarily on the treatment and refining charges it receives, while its costs consist of the operating and capital costs required to process the concentrate. The smelter does not capture the underlying copper price margin or the mining margin associated with the concentrate. For consistency with the mine-only scenario, the treatment and refining charges

used in the tolling arrangement are based on the same charges deducted from concentrate value when deriving the mine's netback price. In the stand-alone scenario, these charges are instead treated as revenue for the smelter. This approach allows the two activities to be separated while maintaining consistency in the economic value attributed to the processing stage.

Table 7 summarizes the financial results of the stand-alone smelter.

**Table 7.** Key financial results of a stand-alone smelter scenario (in USD million)

| Items                 | NPV       | Total     |
|-----------------------|-----------|-----------|
| Sales revenue         | 597.4     | 3,412.4   |
| Opex                  | 1,440.7   | 8,999.2   |
| Capex                 | 1,164.5   | 2,373.8   |
| Net cash flow         | 8.9       | 0.0       |
| Pre-tax cash flow     | (1,839.6) | (7,960.6) |
| Post-tax cash flow    | (1,839.6) | (7,960.6) |
| Cash flow to equity   | (2,109.0) | (8,300.5) |
| Pre-finance cash flow | (2,100.1) | (8,300.5) |

The financial results indicate that the stand-alone smelter is not commercially viable under the assumptions used in the analysis. Although the facility generates approximately USD 3.4 billion in treatment and refining charge revenue over the operating period, this is insufficient to cover the approximately USD 9.0 billion in operating costs and USD 2.4 billion in total capital expenditure. The resulting pre-finance cash flow is negative, with an NPV of approximately USD 1.8 billion below zero. The result reflects the relatively limited margin available to a tolling smelter, which earns processing charges but does not capture the value of the copper, gold, silver or other metals contained in the concentrate.

The result therefore suggests that, under the assumed capital and operating costs and treatment and refining charges, a stand-alone smelting operation would require either higher processing charges, lower costs, additional by-product revenues or other forms of commercial support to achieve financial viability.

Under these assumptions, the project would therefore be unlikely to attract private investment on a stand-alone, commercially financed basis. Private investors would require either substantially higher and more secure processing charges, lower capital or operating costs, higher plant utilization or additional sources of revenue to achieve an acceptable return.

If the government nevertheless seeks to establish a stand-alone smelter, some form of public support or risk sharing may therefore be required to make the project bankable. Such support could take the form of direct capital participation, concessional financing, guarantees, tax incentives, infrastructure support or long-term concentrate supply and processing arrangements. However, public support would transfer part of the project's commercial risk to the state and should therefore be assessed against the wider economic and strategic benefits expected from domestic copper processing.

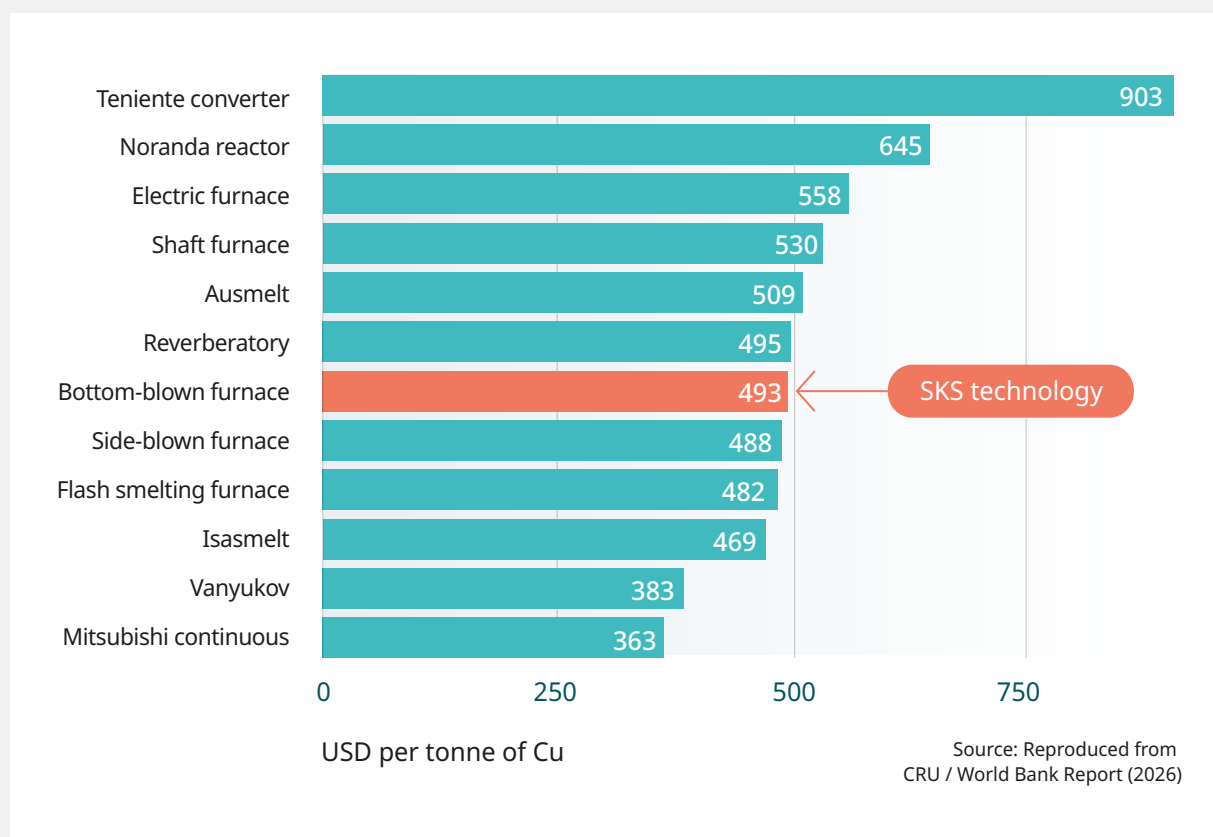
The stand-alone configuration also exposes the project to greater feedstock risk than an integrated mining and processing operation. The smelter would need to secure sufficient third-party concentrate to maintain high capacity utilization, potentially through long-term supply agreements or purchases from sources beyond the Erdenet mine. Its financial performance would consequently be sensitive to treatment and refining charges, concentrate availability, electricity prices, operating costs and capital costs. Under the assumed tolling arrangement, sulfuric acid and other by-products are treated as belonging to the concentrate owner, further limiting the revenue captured by the smelter. These factors suggest that the commercial case for a stand-alone facility depends not only on the technical feasibility of smelting, but also on the structure of concentrate supply, processing contracts and the allocation of by-product revenues and project risks.

The choice of smelting technology is another important determinant of the economics of a new facility. Different technologies can have substantially different capital and operating requirements, although the costs of a specific project will also depend on the characteristics of the concentrate, plant scale, site conditions, infrastructure and environmental requirements.

The GoM has indicated that the proposed facility would use SKS technology, a bottom-blown smelting technology developed in China. This choice is consistent with Mongolia's close economic and industrial links with China and the availability of Chinese engineering and construction expertise. Smelter projects in China can also benefit from lower construction and operating costs than comparable facilities in some other markets.<sup>12</sup> However, lower costs observed in projects in China do not necessarily translate directly into equivalent costs for a project in Mongolia, where differences in construction conditions, financing, labor, infrastructure and environmental requirements could increase the final cost.

Figure 10 compares global average cash costs across different copper smelting technologies. SKS falls under the "bottom-blown furnace" category in the figure, with a reported cash cost of approximately USD 493 per tonne of copper, placing it in the middle of the range of technologies shown. This is higher than the reported costs for Isasmelt (USD 469/t Cu) and flash smelting (USD 482/t Cu), but lower than those for Ausmelt (USD 509/t Cu), shaft furnace (USD 530/t Cu) and several older technologies. The comparison suggests that SKS is not among the lowest-cost technologies based on the global averages presented, but that its costs are broadly comparable with those of other established modern smelting technologies. These figures should, however, be interpreted as global technology-level benchmarks rather than estimates of the cost of an SKS facility at Erdenet. Actual costs would depend on the specific plant configuration, feedstock characteristics, scale, local construction and operating conditions and financing terms.

12 Kevin Brunelli and Tom Moerenhout. *Protecting Existing US and Allied Copper Smelting Capacity*. Center on Global Energy Policy at Columbia, 2026.

**Figure 10.** Average cash costs by copper smelting technology

The negative financial return should not be interpreted as evidence that downstream processing has no economic value to Mongolia. Rather, it indicates that the processing stage alone may not generate sufficient commercial returns to compensate private investors for the required capital expenditure and operating costs. The broader economic and fiscal benefits of domestic processing may therefore need to be assessed separately from the project's private financial return.

The next scenario examines whether integrating the smelter with the mine changes this result by allowing the project to capture both the mining and processing margins within a single operation.

## Integrated smelter

The second smelter scenario considers an integrated mining and processing operation in which a smelter is added to Erdenet's existing concentrate production.

Unlike the stand-alone tolling scenario, the integrated operation owns the concentrate and captures the value of copper and other payable metals across the full production chain, from mining and concentration through smelting and refining. The scenario therefore assesses whether downstream processing generates sufficient additional value to improve the project's overall financial and fiscal performance.

During the smelter construction period, copper concentrate is assumed to continue to be produced and sold, while molybdenum, the main co-product, continues to be produced and sold as concentrate throughout the analysis period.

Table 8 compares the key financial results for the integrated mine and smelter scenario with those of the mine-only scenario. The mine-only scenario generates the stronger financial performance, with an NPV of USD 152.3 million and a pre-tax cash flow NPV of USD 7.25 billion, while also requiring the lowest capital investment.

The integrated smelter scenario increases sales revenue, with the NPV of sales revenue rising from USD 20.67 billion to USD 22.23 billion. However, this additional revenue is accompanied by substantially higher operating and capital costs, with opex increasing from USD 10.97 billion to USD 12.41 billion and capex from USD 1.79 billion to USD 2.95 billion. As a result, the integrated scenario remains economically viable but generates a lower overall project NPV of USD 106.7 million, compared with USD 152.3 million under the mine-only scenario.

The NPV of pre-tax cash flow also declines from USD 7.25 billion to USD 6.3 billion. Although the integrated scenario generates higher post-tax cash flow, the additional value captured through downstream processing is insufficient to offset the substantially higher capital and operating costs. Under the base-case assumptions, therefore, integrating the smelter increases domestic value addition and total sales revenue but reduces the overall financial return of the project relative to continuing with mining and concentrate production alone.

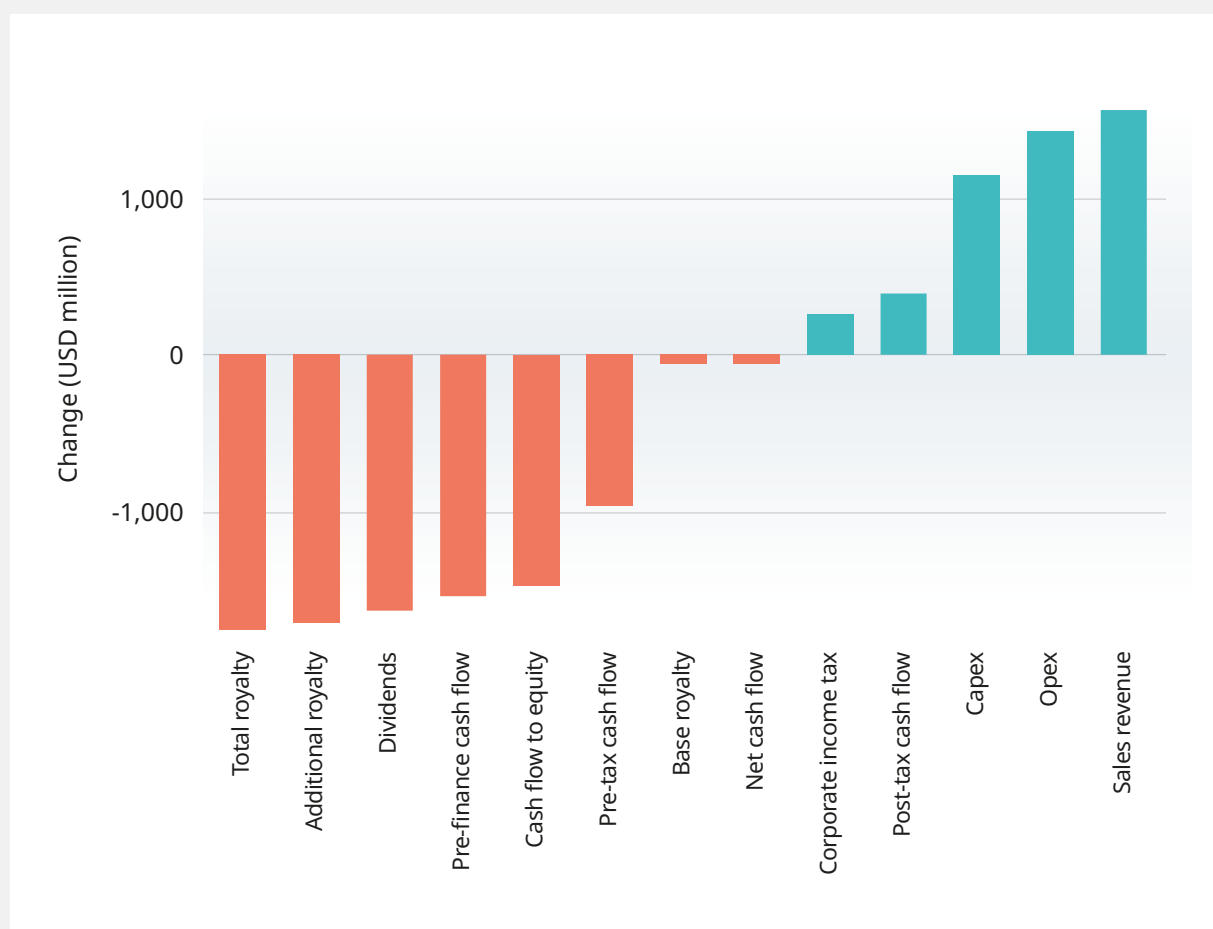
**Table 8.** Key project results under two scenarios (in USD million)

| Items                 | Mine only |          | Integrated smelter |           |
|-----------------------|-----------|----------|--------------------|-----------|
|                       | NPV       | Total    | NPV                | Total     |
| Sales revenue         | 20,665.9  | 97,337.4 | 22,234.9           | 107,130.7 |
| Opex                  | 10,969.1  | 63,165.1 | 12,409.8           | 72,164.3  |
| Capex                 | 1,785.2   | 9,692.2  | 2,949.7            | 12,066.0  |
| Net cash flow         | 152.3     | (10.9)   | 106.7              | (10.9)    |
| Pre-tax cash flow     | 7,249.0   | 24,480.1 | 6,299.6            | 22,900.4  |
| Post-tax cash flow    | 2,159.1   | 803.7    | 2,554.1            | 7,743.6   |
| Cash flow to equity   | 4,056.8   | 3,824.5  | 2,591.6            | 7,063.3   |
| Pre-finance cash flow | 4,285.4   | 3,928.0  | 2,753.1            | 84,219.5  |

The integrated smelter scenario captures additional downstream value from processing the mine's concentrate, but also requires substantial additional capital and operating expenditure. Figure 11 summarizes the resulting changes in key financial indicators relative to the mine-only scenario.

One important by-product of copper smelting is sulfuric acid. It is not a globally traded commodity in the same way as copper cathodes. Transporting sulfuric acid over long distances is expensive because of its corrosive nature and relatively low value per unit of weight, meaning that commercial markets are typically

regional and depend on nearby demand from industries such as mining, fertilizer production and chemical manufacturing. Mongolia's export opportunities may also be limited because both neighboring China and Russia have substantial domestic sulfuric acid production associated with their large metallurgical and chemical industries, reducing their reliance on imports under normal market conditions. Consequently, the long-term viability of a copper smelter will depend not only on achieving high sulfur capture rates but also on developing reliable domestic or regional markets for sulfuric acid or identifying alternative beneficial uses.

**Figure 11.** Change in key variables from mine-only to integrated smelter scenario

The integrated smelter scenario initially assumes that only 30 percent of the sulfuric acid produced can be sold, reflecting the limited domestic market for sulfuric acid in Mongolia. The remaining 70 percent is assumed to be neutralized through gypsum production, which is treated as having no commercial value. Given the importance of sulfuric acid utilization to smelter economics, the analysis examines how project performance changes as the share of acid sold increases.

As Table 9 shows, greater access to sulfuric acid markets improves the financial performance of the integrated project. As the share of acid sold increases from 20 percent to 100 percent, NPV, cash flow to equity and government take all increase, while capex remains broadly unchanged. However, even if all sulfuric acid can be sold, the integrated project remains less profitable than the mine-only scenario (NPV of USD 152.3 million), indicating that acid utilization alone is insufficient to offset the additional costs of downstream processing.

**Table 9.** Impact of change in sulfuric acid market (in USD million)

| Sulfuric acid sold | NPV           | Cash flow to equity | Government take | Capex           |
|--------------------|---------------|---------------------|-----------------|-----------------|
| 20%                | 105.61        | 2,543.28            | 6,675.68        | 2,949.70        |
| 30%                | <b>106.70</b> | <b>2,591.61</b>     | <b>6,735.50</b> | <b>2,949.70</b> |
| 40%                | 108.38        | 2,639.37            | 6,794.78        | 2,949.70        |
| 50%                | 110.06        | 2,686.95            | 6,854.23        | 2,949.70        |
| 60%                | 111.73        | 2,734.53            | 6,913.68        | 2,949.70        |
| 70%                | 113.41        | 2,782.01            | 6,973.23        | 2,949.70        |
| 80%                | 115.09        | 2,829.38            | 7,032.87        | 2,949.70        |
| 90%                | 116.76        | 2,876.73            | 7,092.49        | 2,949.70        |
| 100%               | 121.03        | 2,996.16            | 7,240.23        | 2,862.22        |

Copper price is a key determinant of project performance across both scenarios. Table 10 shows that higher copper prices increase NPV, cash flow to equity and government take for both the mine-only and integrated scenarios. Although the integrated project benefits from higher copper prices, it consistently generates lower returns than the mine-only scenario. At the base-case price of USD 5.0 per pound, for

example, NPV is USD 106.7 million compared with USD 152.3 million for the mine-only case. Even at USD 10.0 per pound, the integrated project's NPV remains lower. Higher copper prices therefore improve the economics of downstream processing but, under the assumptions tested, do not offset its additional investment and operating costs. Annex 1 presents other sensitivity analyses, including the impact of treatment costs.



**Table 10.** Impact of copper prices on key metrics for each scenario (in USD million)

| Cu price<br>USD/lb | NPV       |            | Cash flow to equity |            | Government take |            |
|--------------------|-----------|------------|---------------------|------------|-----------------|------------|
|                    | Mine-only | Integrated | Mine-only           | Integrated | Mine-only       | Integrated |
| 4.0                | 53.5      | 28.1       | 631.6               | 6.5        | 5,579.4         | 3,185.2    |
| 4.5                | 98.5      | 68.3       | 2,305.6             | 1,298.1    | 7,581.1         | 4,897.4    |
| 5.0                | 152.3     | 106.7      | 4,056.8             | 2,591.6    | 9,829.7         | 6,735.5    |
| 5.5                | 210.4     | 154.4      | 5,818.3             | 3,837.9    | 12,220.2        | 8,639.2    |
| 6.0                | 271.4     | 183.2      | 7,586.5             | 5,073.1    | 14,706.9        | 10,591.5   |
| 6.5                | 334.5     | 227.2      | 9,355.7             | 6,298.1    | 17,263.0        | 12,537.7   |
| 7.0                | 397.6     | 272.0      | 11,125.4            | 7,520.7    | 19,828.4        | 14,483.2   |
| 7.5                | 460.8     | 316.8      | 12,895.0            | 8,743.4    | 22,393.8        | 16,428.6   |
| 8.0                | 523.9     | 361.7      | 14,664.6            | 9,966.0    | 24,959.2        | 18,374.0   |
| 8.5                | 587.0     | 406.5      | 16,434.2            | 11,188.6   | 27,524.5        | 20,319.5   |
| 9.0                | 650.1     | 451.3      | 18,203.9            | 12,411.3   | 30,089.9        | 22,264.9   |
| 9.5                | 713.2     | 496.1      | 19,973.5            | 13,633.9   | 32,655.3        | 24,210.3   |
| 10.0               | 776.4     | 540.9      | 21,743.1            | 14,856.5   | 35,220.7        | 26,155.8   |

Overall, the analysis indicates that downstream copper processing does not improve the project's financial performance under the base-case assumptions. Although the integrated scenario generates higher revenues and increases domestic value addition, these gains are more than offset by the additional capital and operating costs of the smelter complex.

Higher copper prices and improved sulfuric acid utilization strengthen the economics of the integrated project, but neither is sufficient to make it financially superior to continued concentrate exports under the assumptions tested. The integrated project therefore remains financially viable but generates lower returns than the mine-only scenario.

## Financials: policy implications

The analysis demonstrates that downstream value addition does not necessarily translate into greater project value. Although integrating a smelter with the mining operation increases total revenues by capturing value from copper refining and sulfuric acid production, these gains are more than offset by the substantial capital and operating costs of the smelter complex. Under the base-case assumptions, the integrated project remains financially viable but generates lower returns than continued production and export of copper concentrate.

The results also show that the competitiveness of a domestic smelter depends on a combination of market and operational factors rather than a single variable. Higher copper prices, lower treatment and refining charges, and greater utilization of sulfuric acid all improve the financial performance of the integrated project. However, under the assumptions tested, these improvements do not by themselves make downstream processing financially superior to the mine-only scenario. A commercially viable smelter would therefore require favorable conditions across several dimensions simultaneously.

Sulfuric acid markets are particularly important. Increasing the proportion of sulfuric acid sold improves project returns, highlighting the importance of developing downstream markets alongside copper processing. Nevertheless, even under the optimistic assumption that all sulfuric acid can be sold, the integrated project continues to generate lower financial returns than the mine-only scenario. Sulfuric acid utilization can therefore strengthen the business case but is unlikely, on its own, to determine the overall viability of the smelter.

The analysis also has important fiscal implications. The mine-only scenario generates strong government revenues while requiring comparatively less capital investment. The results further suggest that fiscal policy can affect the government's overall revenue position through its impact on project profitability. In particular, a higher reliance on royalties may reduce corporate income tax and dividend payments and it weakens project returns in NPV terms as the timing of these revenue streams differs.

This highlights the importance of a balanced fiscal regime that captures an appropriate share of resource rents while preserving incentives for investment and continued project operations.

These findings are particularly relevant in light of ongoing efforts to develop domestic copper smelting capacity in Mongolia. Erdenet is currently negotiating the construction of a copper smelter, underscoring the importance of carefully evaluating both the financial and policy implications of such an investment. Beyond the financial assumptions examined in this study, the long-term viability of a domestic smelter will depend on its ability to secure sufficient concentrate from multiple mining operations. Erdenet's concentrate grade may decline in the coming years unless additional ore resources are identified and brought into production. As new copper projects are developed in Mongolia, the commercial success of a smelter will increasingly depend on its ability to process concentrates with different characteristics and impurity levels. Greater feed flexibility could improve capacity utilization, reduce supply risk and strengthen the long-term business case for domestic smelting.

At the same time, the financial results should not be interpreted as suggesting that domestic smelting lacks strategic value. Governments may pursue downstream processing to promote industrial diversification, employment, technology transfer, supporting industries and greater resilience of domestic supply chains. These broader economic benefits are not explicitly captured in the financial model and should therefore be considered alongside project-level financial returns when evaluating downstream processing policies.

Overall, the financial case for a domestic copper smelter in Mongolia remains challenging under the assumptions adopted in this study. Decisions on downstream processing should therefore be based on a broader assessment that considers not only project-level financial returns but also economic, industrial, environmental and strategic objectives. Part 2 complements the financial analysis by examining the environmental implications of copper smelting, paying particular attention to sulfur capture, sulfuric acid production and the management of sulfur-bearing by-products.

# Part 2 - Environmental considerations

## Key challenge: sulfur dioxide

The financial analysis presented in Part 1 evaluates the commercial viability of downstream copper processing. However, project-level financial indicators alone do not capture the full implications of constructing and operating a copper smelter. Like any major industrial development, a smelter generates significant environmental externalities that must be carefully managed. Of particular concern are sulfur dioxide (SO<sub>2</sub>) emissions, the production and management of sulfuric acid, and the handling of hazardous by-products. Environmental performance is therefore not only a regulatory requirement but also a key determinant of the long-term sustainability, social acceptance and investment attractiveness of a domestic added-value industry. Strong environmental performance can reduce regulatory and reputational risks

and help build investor confidence in the long-term viability of the project. The development of a smelter may also have important social and regional implications, particularly for employment and economic activity in Erdenet; however, these broader impacts are outside the scope of this analysis. In the context of natural resource exploitation, the Constitution of Mongolia emphasizes the protection of a healthy and safe living environment and explicitly guarantees citizens the right to obtain information about environmental impacts.<sup>13</sup> Information on the potential environmental risks associated with the proposed smelter, together with the mitigation measures planned by Erdenet and other stakeholders, is therefore not only essential for public accountability and the long-term sustainability of the project, but also a constitutional requirement that should receive the highest priority.



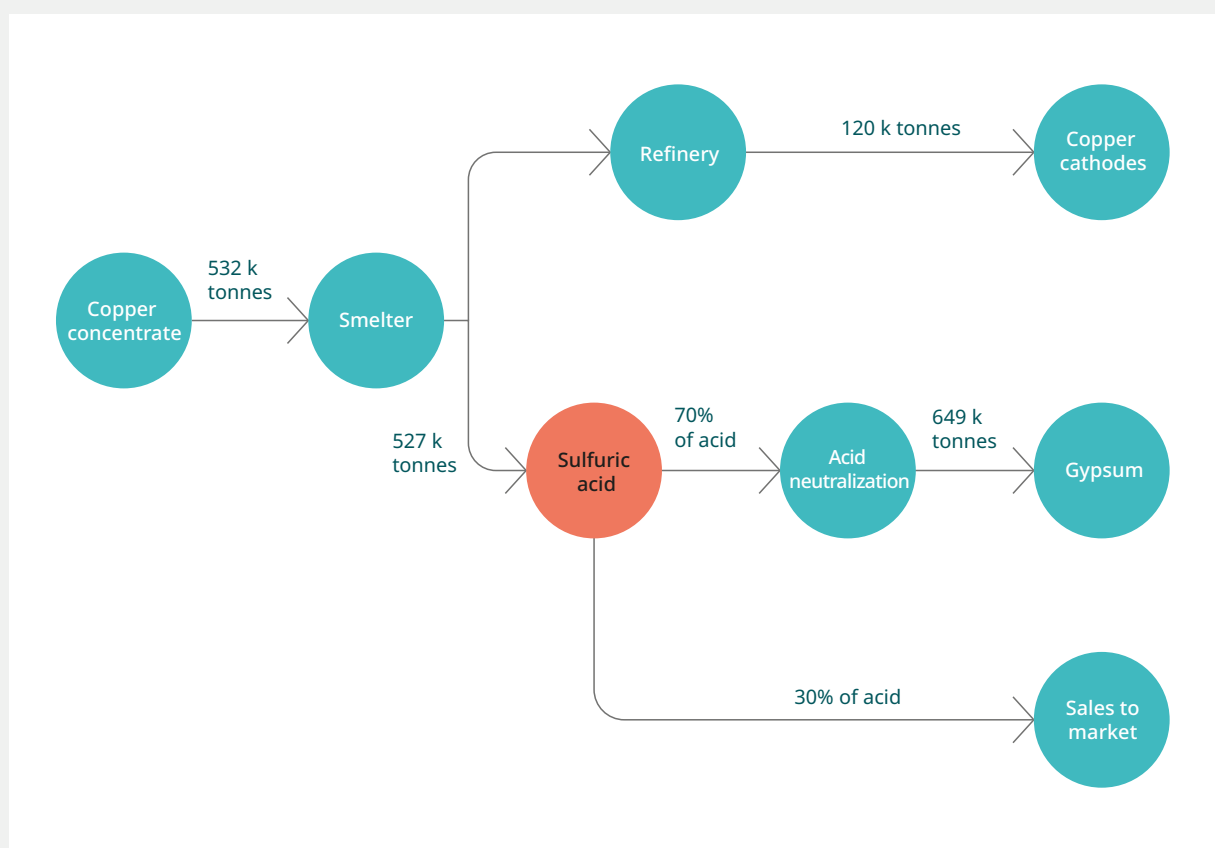
Erdenet copper mine dump - the city of Erdenet is located in the central part of Mongolia - photo by Pecold via Shutterstock

13 For details, see Article 6 of the Constitution of Mongolia.

Erdenet has extensive experience in environmental planning, management and reporting. Nevertheless, the introduction of copper smelting would present new environmental challenges for both the company and the surrounding community, given the proximity of the town to the mining and the planned processing sites. Among these challenges, sulfur management is particularly important. Copper smelters generate substantial

quantities of sulfur dioxide, which modern smelters are designed to capture and convert into sulfuric acid. However, the environmental and economic performance of the project depends not only on sulfur capture but also on the ability to utilize or market the resulting sulfuric acid. This could lead to additional costs to neutralize the acid and reduce associated risks. Figure 12 illustrates one potential sulfur management pathway based on the assumptions used in the financial model.

**Figure 12.** Sulfuric acid production, projection for 2029



For sulfur dioxide management, modern smelters are expected to capture more than 99 percent of emissions and convert the gas into sulfuric acid, making high sulfur capture rates a prerequisite for regulatory compliance and maintaining a social license to operate.<sup>14</sup>

Without a sustainable strategy for sulfuric acid utilization, sulfur management could become both the principal environmental constraint and a significant commercial challenge for downstream copper processing in Mongolia.

14 For example, the IFC and World Bank Group's *Environmental, Health and Safety Guidelines for Mining*, 2007, require 99.1% conversion for 1–4% SO<sub>2</sub> off-gas and 99.7% for above 5%, [documents1.worldbank.org/curated/en/605891489653831342/pdf/113559-WP-ENGLISH-Smelting-and-Refining-PUBLIC.pdf](https://documents1.worldbank.org/curated/en/605891489653831342/pdf/113559-WP-ENGLISH-Smelting-and-Refining-PUBLIC.pdf).

## Environmental planning and public disclosure

Mongolia's environmental regulatory framework requires major industrial projects, including the copper smelter, to undergo a comprehensive environmental assessment before construction can begin. Another important legal requirement is that citizens should have access to key information on environmental aspects of these projects. The key stage of the assessment is the general environmental impact assessment (GEIA). The GEIA determines whether a detailed environmental impact assessment (DEIA) is required to proceed with the project. The DEIA identifies potential impacts, proposes mitigation measures, and includes an environmental management plan and an environmental monitoring program. Also, for large-scale projects, the project owner should prepare a baseline environmental assessment prior to the impact assessment. Together with permits and standards governing air emissions, water use, wastewater discharge, hazardous chemicals and waste management, these requirements are intended to ensure that environmental risks are identified, managed and monitored throughout the life of the project.

For the proposed Erdenet copper smelter, the GEIA and the DEIA have reportedly been completed as part of the regulatory approval process.<sup>15</sup> However, only limited information has been made publicly available, with the full reports missing from the environmental information database.<sup>16</sup> While conclusions from the GEIA and the minutes of the presentation of the DEIA to community members are available, the DEIA report itself is missing, with two chapters from the baseline study made available instead. The disclosed information nevertheless provides some insights into the project's principal environmental risks and the mitigation measures currently envisaged.

The baseline assessment report recognizes sulfur dioxide (SO<sub>2</sub>) emissions and acid mist as the principal air quality risks associated with copper smelting.

To address these risks, the project proposes capturing sulfur dioxide generated during smelting and converting it into sulfuric acid through an integrated acid plant, supported by 120-meter emission stacks and a system to enable continuous monitoring of atmospheric emissions. As discussed in Part 1, the ability to utilize or market sulfuric acid is important not only for environmental performance but also for the overall economics of the project.

The assessment also identifies measures to reduce impacts on water resources, soils, biodiversity, and occupational health and safety. Water demand is expected to be met through integrated treatment and recycling systems designed to minimize freshwater consumption. Topsoil would be removed and stockpiled before construction for later rehabilitation, while hazardous chemicals, including sulfuric acid, would be managed through dedicated storage facilities designed to prevent soil and groundwater contamination. Biodiversity offset measures are proposed to compensate for impacts on the surrounding forest-steppe ecosystem, alongside noise reduction and bird protection measures.

The baseline assessment further evaluates operational and natural hazards, including sulfuric acid leaks, furnace explosions, flooding, forest fires and lightning strikes. Proposed mitigation measures include drainage and fire protection infrastructure, hazardous chemical management procedures, automated toxic gas detection systems, and occupational health and safety measures for the plant workforce. Environmental monitoring would cover air quality, groundwater, soil quality and biodiversity, with annual reporting to the relevant authorities as required under Mongolia's environmental legislation.

While these measures are broadly consistent with international practice, the amount of information currently available to the public remains limited. Most disclosures consist of summaries rather than the full technical assessment.

---

15 Copper Processing Complex LLC. "Project Information." No date.

16 Ministry of Environment and Climate Change. "Report on Detailed Impact Assessment." 19 September 2023.

Particularly concerning is missing information on the smelter's sulfur dioxide capture rate and the DEIA's recommendation for the smelter. Given the scale of the proposed investment and its proximity to the Erdenet community, greater transparency would strengthen public confidence in both the project and the regulatory process. Greater disclosure of projected emissions under normal and stress conditions, sulfuric acid production and utilization plans, hazardous waste management, emergency preparedness, environmental monitoring methodologies and compliance reporting would enable a more informed public discussion of the project's environmental risks and the adequacy of the proposed mitigation measures.

The GoM's narrative is often vague and self-contradictory, which is a source of mistrust and could indicate poor planning and management. For instance, in terms of sulfur dioxide management, the plans seem to be shifting, from sulfuric acid and gypsum production to producing elemental sulfur and fertilizers. Therefore, continued public reporting not only for the smelter, but also for the related projects, and starting from the planning phases, will be essential for demonstrating commitment to compliance with environmental standards and maintaining public trust.

An important aspect of environmental stewardship is ensuring that communities living near mining or industrial facilities can exercise their right to participate in decisions that may affect their health, livelihoods and environment. Under Mongolia's environmental legislation, local communities are expected to participate in the environmental impact assessment process, with public consultations forming an important component of project approval. In the case of the proposed Erdenet copper smelter, documentation of the public consultation process is available online, including a record bearing the signatures of approximately 100 participants. However, the extent to which this consultation facilitated meaningful public participation is difficult to assess.

The published meeting minutes suggest that discussion of potential environmental impacts was limited, with relatively few questions concerning environmental risks. Instead, much of the discussion focused on the project's anticipated economic benefits. This highlights the importance of ensuring that public consultations provide communities with sufficient information and opportunities to engage substantively with the project's environmental implications before major investment decisions are made.

## International experience and environmental standards

### International standards and disclosure frameworks

In addition to complying with national environmental legislation, modern copper smelters are increasingly expected to operate in accordance with internationally recognized environmental, social and governance (ESG) standards and international good practice. These frameworks complement regulatory requirements by promoting sound environmental management, transparency, stakeholder engagement and continuous improvement throughout the life of a project.

Among the most widely recognized technical benchmarks are the Environmental, Health and Safety Guidelines for Base Metal Smelting and Refining, published by the International Finance Corporation (EHS Guidelines) in 2007.<sup>17</sup> The EHS Guidelines represent international good practice for the design and operation of base metal smelters and are widely applied by multilateral development banks and other international financial institutions when evaluating mining and metallurgical investments. They address the full range of environmental issues associated with copper smelting, including air emissions, sulfur dioxide capture, sulfuric acid production, hazardous waste management, wastewater treatment, energy efficiency, occupational health and safety, and environmental monitoring.

17 IFC and World Bank Group. *Environmental, Health, and Safety Guidelines for Base Metal Smelting and Refining*. 2007.

The EHS Guidelines emphasize pollution prevention rather than end-of-pipe treatment and recommend the use of modern smelting technologies capable of achieving very high sulfur capture rates (more than 99 percent) through integrated sulfuric acid plants and continuous emissions monitoring.

Building upon these technical standards, the Copper Mark has become the leading voluntary assurance framework for responsible copper production.<sup>18</sup> The framework applies not only to mines but also to smelters and refineries through an independent assurance process based on the Responsible Minerals Initiative's Risk Readiness Assessment, which covers governance, environmental, social and human rights issues. The current standard comprises 33 criteria applicable across mining and metal processing, including climate action, greenhouse gas emissions, water stewardship, waste management, pollution prevention, biodiversity, emergency preparedness, community health and safety, and sustainability reporting. Participating facilities undertake a self-assessment followed by independent third-party verification to demonstrate conformance with the standard.<sup>19</sup>

The Copper Mark is an example of standards and policies approaching environmental performance not only from the perspective of compliance with technical requirements such as emission limits but also from the angle of the effectiveness of environmental management systems. The standard requires operators to identify environmental risks, implement mitigation measures, monitor environmental performance, establish emergency preparedness procedures, engage with affected communities and publicly report environmental performance. Although the Copper Mark does not prescribe numerical sulfur dioxide emission limits, it requires participating facilities to identify and manage significant air emissions, implement effective pollution prevention measures, monitor environmental performance and demonstrate continuous improvement.

For copper smelters, this makes sulfur dioxide capture, sulfuric acid production and emissions monitoring central components of responsible environmental management.

Mongolia already has experience implementing international ESG standards in the mining sector. Oyu Tolgoi, the country's largest copper mining operation, has obtained the Copper Mark, demonstrating that Mongolia can successfully implement internationally recognized sustainability standards. The proposed Erdenet smelter could therefore build upon this experience while extending similar principles of environmental management, transparency and independent verification to downstream copper processing.

Other international initiatives, some of which Mongolia is a party to, also focus more on environmental and social issues. The Extractive Industries Transparency Initiative (EITI), which Mongolia joined two decades ago, was originally established to improve transparency in revenues and governance. But the 2023 EITI Standard expands disclosure expectations relating to environmental and social impact assessments, environmental monitoring, environmental obligations, rehabilitation and the implications of the global energy transition.<sup>20</sup> It also encourages reporting of greenhouse gas emissions using internationally recognized reporting frameworks. Together, the IFC and World Bank Group EHS Guidelines, the Copper Mark, the International Council on Mining and Metals (ICMM) Mining Principles<sup>21</sup> and the evolving EITI Standard illustrate a broader international trend in which responsible copper production is increasingly judged not only by regulatory compliance but also by environmental performance, independent assurance and transparent public disclosure.

Table 11 summarizes examples of selected international frameworks relevant to copper smelting.

18 The Copper Mark and other leading voluntary industry standards are being consolidated under one major standard, the Consolidated Mining Standard Initiative.

19 The Copper Mark. *Risk Readiness Assessment Criteria Guide*, 2023.

20 EITI. *EITI Standard 2023*.

21 ICMM. *Mining Principles*. 2023, updated December 2024.

**Table 11.** International standards and disclosure frameworks relevant to copper smelting

| Framework                              | Primary purpose                   | Key environmental relevance                                                                                                                                                                  |
|----------------------------------------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| IFC / World Bank EHS Guidelines (2007) | International good practice       | Technical guidance on air emissions, sulfur dioxide capture, sulfuric acid production, hazardous waste, wastewater management, occupational health and safety, and environmental monitoring. |
| The Copper Mark                        | Independent ESG assurance         | Independent verification of environmental management systems, pollution prevention, sulfur management, water stewardship, biodiversity, stakeholder engagement and public reporting.         |
| EITI (2023 Standard)                   | Transparency and governance       | Disclosure of environmental impact assessments, environmental monitoring, environmental obligations, rehabilitation, greenhouse gas emissions (encouraged) and public reporting.             |
| ICMM Mining Principles                 | Industry sustainability framework | Environmental stewardship, climate action, biodiversity conservation, water management, tailings governance and transparent sustainability reporting.                                        |

Sources: IFC (2007), Environmental, Health, and Safety Guidelines for Base Metal Smelting and Refining; Copper Mark (Risk Readiness Assessment v3.0); EITI Standard (2023); ICMM Mining Principles

Many internationally operating mining and metallurgical companies also maintain certification to ISO 14001, the international standard for environmental management systems. ISO 14001 provides a structured framework for identifying environmental risks, ensuring compliance with environmental regulations, monitoring performance and driving continual improvement. It therefore complements regulatory requirements and voluntary initiatives such as the EHS Guidelines and the Copper Mark.

Increasingly stringent standards governing sulfur dioxide emissions, hazardous wastes, arsenic management and water quality have substantially increased both the capital and operating costs of modern smelters. As a result, investment decisions increasingly depend not only on technical and economic considerations but also on the ability to achieve high environmental performance.

Table 12 summarizes selected international experiences and the principal environmental lessons relevant to Mongolia's proposed smelter.

## Country experiences

International experience demonstrates that environmental performance has become one of the principal determinants of whether copper smelters remain economically viable and socially acceptable.

**Table 12.** Selected country experience in environmental management of copper smelting

| Country       | Primary challenge                                                         | Response                                                                                                                         | Key lesson                                                                                              |
|---------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| Chile         | Historic SO <sub>2</sub> emissions, aging smelters and community concerns | Closure of Ventanas smelter; modernization of remaining smelters with high sulfur capture and stricter emission controls         | Environmental performance increasingly determines long-term social license to operate.                  |
| Peru          | Modernizing aging smelting infrastructure                                 | Investment in flash smelting technology, sulfur capture and sulfuric acid production (e.g., Ilo smelter)                         | Meeting modern environmental standards requires substantial long-term capital investment.               |
| Zambia        | SO <sub>2</sub> emissions and air pollution in the Copperbelt             | Construction of sulfuric acid plants, improved sulfur capture, environmental monitoring and community engagement                 | Technology alone is insufficient without effective monitoring, enforcement and transparency.            |
| China         | Rapid expansion of smelting while reducing pollution                      | Stringent emission standards (GB 25467-2010), continuous emissions monitoring, arsenic management and hazardous waste regulation | Expansion of smelting capacity has been accompanied by increasingly stringent environmental regulation. |
| United States | Hazardous air pollutants from copper smelters                             | Updated Clean Air Act requirements and EPA Copper Rule (2024)                                                                    | Environmental standards continue to tighten for existing facilities.                                    |

Sources: Compilation by authors based on national environmental legislation and public information

Chile, the leading copper producer, provides perhaps the clearest example of this trend. In 2023, the state-owned Ventanas copper smelter ceased operations following decades of sulfur dioxide pollution episodes, environmental concerns and increasing public pressure. At the same time, Chile has required substantial investment to modernize its remaining smelters by improving sulfur capture, sulfuric acid production and arsenic management.

Over the past three decades, Chile has invested more than USD 2 billion to modernize its copper smelters in response to increasingly stringent environmental regulations requiring sulfur capture rates of at least 95 percent for existing facilities and 98 percent for new smelters. These investments have focused on improving sulfur dioxide capture, sulfuric acid production, and reducing emissions of arsenic and particulate matter.<sup>22</sup>

Peru has largely focused on modernizing and operating a limited number of existing copper smelters rather than constructing numerous new facilities. This approach reflects the high capital costs of new smelting projects, increasingly stringent environmental requirements governing sulfur dioxide and other emissions, and intense international competition from large, efficient smelters in Asia. A notable example is the modernization of the Ilo smelter, which replaced older technology with flash smelting and modern sulfur capture systems. The project was undertaken to comply with Peruvian environmental regulations requiring sulfur dioxide capture of approximately 92–93 percent, while substantially reducing atmospheric emissions and improving energy efficiency.<sup>23</sup> Peru's experience demonstrates that achieving modern environmental standards requires major long-term investment in cleaner technologies rather than incremental operational improvements.

Zambia's Copperbelt illustrates the importance of combining technological improvements with environmental governance.

Investments in facilities such as the Mufulira smelter have significantly increased sulfur capture and sulfuric acid production, reducing sulfur dioxide emissions, from an average of 48 percent to about 94 percent. Nevertheless, environmental monitoring, community engagement and transparent reporting continue to receive considerable public attention, highlighting that investment in sulfur capture technology alone is insufficient without effective environmental management and public accountability.<sup>24</sup>

China presents another important example. Although it has become the world's largest copper smelting jurisdiction, it has simultaneously strengthened environmental requirements governing sulfur dioxide emissions, particulate matter, arsenic compounds, wastewater discharges and hazardous waste management. China's Emission standard of pollutants for the copper, nickel and cobalt industry (GB 25467-2010) establishes pollutant-specific concentration limits for both atmospheric emissions and wastewater discharges. Table 13, for example, illustrates selected limits applicable to copper smelters.

**Table 13.** China: atmospheric emission limits for copper smelters (in mg/m<sup>3</sup>)

| Pollutants                        | Limits |
|-----------------------------------|--------|
| Sulfur dioxide (SO <sub>2</sub> ) | 900    |
| Particulate matter                | 100    |
| Arsenic compounds                 | 0.5    |
| Lead compounds                    | 0.7    |
| Fluoride                          | 9.0    |

Source: GB 25467-2010, Emission standard of pollutants for the copper, nickel and cobalt industry

23 Fluor Corporation. "Ilo Smelter Modernization Project." No date.

24 Darius Muma, Bunda Besa, James Manchisi and Webby Banda. "Effects of Mining Operations on Air and Water Quality in Mufulira District of Zambia: A Case Study of Kankoyo Township." *Journal of the Southern African Institute of Mining and Metallurgy* 120, no. 4 (2020): 287–98.

The United States has similarly strengthened environmental regulation through the Clean Air Act and the 2024 amendments to the National Emission Standards for Hazardous Air Pollutants (NESHAP), requiring further reductions in hazardous metal emissions from copper smelters, particularly lead and arsenic.

Although regulatory approaches differ among countries, several common themes emerge. Modern copper smelters are expected to achieve high sulfur capture rates, effectively manage sulfuric acid and hazardous by-products, continuously monitor emissions, publicly disclose environmental performance, and maintain effective engagement with surrounding communities. These expectations increasingly influence financing, market access, public acceptance and the long-term sustainability of downstream copper processing.

International experience suggests that successful copper smelting requires more than compliance with minimum environmental standards. Increasingly, environmental performance is judged by a combination of high sulfur capture rates, effective sulfuric acid utilization, transparent environmental monitoring, independent verification and meaningful public disclosure. Designing Mongolia's proposed smelter to meet these expectations from the outset would reduce future regulatory risks, strengthen public confidence and improve the long-term sustainability of downstream copper processing.

Introducing technology-specific emission standards, continuous emissions monitoring systems, and internationally recognized environmental, social and governance (ESG) frameworks would strengthen environmental protection while enhancing the long-term competitiveness and credibility of Mongolia's downstream copper industry.

At the same time, environmental governance extends beyond technical compliance.

Although Mongolia's legal framework requires environmental impact assessments and public consultation, access to project information remains limited in practice. Key documents, including baseline environmental studies and the full DEIA, are not readily available to the public, making it difficult for independent experts and affected communities to assess the project's environmental implications. Similarly, while public consultations have been conducted, the publicly available records suggest that discussions focused more on anticipated economic benefits than on potential environmental risks and mitigation measures. As one of Mongolia's largest prospective industrial investments, the proposed Erdenet smelter presents an opportunity not only to adopt international environmental standards but also to establish new benchmarks for transparency, public participation and environmental accountability that could guide future mineral processing projects.

## Environmental issues: policy implications

The environmental performance of a domestic copper smelter will depend not only on compliance with Mongolia's environmental legislation but also on the adoption of internationally recognized standards, best available technologies and robust environmental governance. Effective sulfur management represents the project's principal environmental challenge and is closely linked to its financial performance through the production and utilization of sulfuric acid.

# Conclusions

## Main findings

Mongolia's ambition to increase domestic value addition through copper processing is understandable and widely supported. Copper demand is expected to remain strong over the coming decades, and developing downstream industries could bring financial benefits while contributing to broader industrial diversification, technological capabilities and employment. It could also generate social benefits, particularly for smaller cities such as Erdenet, which depends heavily on the copper mine and would face significant challenges if mining operations decline. However, international experience demonstrates that copper smelting is a highly capital-intensive, environmentally demanding and globally competitive industry. Successful projects depend not only on access to sufficient copper concentrate but also on economies of scale, efficient operations, reliable markets for sulfuric acid and strong environmental governance.

The financial modelling undertaken for this report suggests that, under the assumptions adopted, continued production and export of copper concentrate generate higher financial returns than constructing an integrated copper smelter. The integrated project is nevertheless financially viable under the base-case assumptions, generating revenues from copper cathodes and sulfuric acid that support the investment despite its substantially higher capital and operating costs. The analysis focuses primarily on the financial viability of the two scenarios, while also considering selected environmental implications of domestic smelting. It does not, however, assess the broader economic, social, regional or industrial development impacts that may arise from increased domestic value addition, and the potential importance of a smelter to communities such as Erdenet.

The analysis also demonstrates that sulfuric acid utilization is one of the most important determinants of smelter economics. Higher utilization improves both project profitability and government revenues, but it does not fundamentally change the investment case. The commercial viability of a domestic smelter therefore depends not only on copper production but also on the existence of sustainable domestic or regional markets for sulfuric acid.

The environmental assessment highlights that sulfur management represents the principal environmental challenge associated with copper smelting. Modern international practice requires sulfur dioxide capture rates exceeding 99 percent, continuous emissions monitoring, effective management of hazardous by-products and comprehensive environmental management systems. These standards substantially increase both capital and operating costs but are essential for maintaining public confidence and a social license to operate.

The review of Mongolia's environmental framework suggests that the legal basis for environmental regulation is broadly consistent with international practice. However, limited public disclosure of environmental assessments, sulfur capture targets, sulfuric acid utilization plans and environmental monitoring arrangements constrains informed public discussion. Greater transparency would strengthen both project governance and public confidence.

Overall, the report suggests that decisions regarding downstream copper processing should not be based solely on expectations of higher financial returns from value addition. Rather, they should reflect a broader assessment of industrial policy objectives, environmental risks, fiscal implications and long-term national development priorities.

## Recommendations

The analysis presented in this report suggests that decisions regarding domestic copper smelting should be guided by a comprehensive assessment of financial, environmental, industrial and governance considerations rather than by expectations of value addition alone. Based on the findings of this study, the following recommendations are proposed.

### 1. Ensure greater transparency before major investment decisions

Given the scale of the proposed investment and the public ownership of Erdenet Mining Corporation, the Government of Mongolia should make the principal project documents publicly available before final investment decisions are taken. These should include the feasibility study, the detailed environmental impact assessment projected capital and operating costs, financing arrangements, expected fiscal impacts, sulfur management strategy and environmental monitoring plans. Greater transparency would strengthen public confidence, improve policy discussions and allow independent experts to assess the assumptions underlying the project. Public disclosure would also help demonstrate whether the project meets Mongolia's broader economic, environmental and governance objectives.

### 2. Evaluate the smelter against broader national development objectives

The financial modelling indicates that, under the assumptions adopted in this report, continued concentrate exports generate higher financial returns than constructing an integrated copper smelter. If the government nevertheless decides to pursue downstream processing, the rationale should extend beyond project-level financial returns. Expected benefits such as industrial diversification, technology transfer, employment creation, development of supporting industries, regional development and improved domestic capabilities should be explicitly identified and, where possible, quantified. A transparent assessment of these wider economic and strategic objectives would provide a more robust basis for public investment decisions.

### 3. Prioritize sulfur management and environmental performance

Sulfur management should become one of the central design considerations for the proposed smelter. The project should not only demonstrate the expected sulfur dioxide capture rate but also present a realistic long-term strategy for sulfuric acid utilization. This should include projections of domestic demand, opportunities for regional markets, contingency measures during periods of low demand, and plans for gypsum and other by-product management. Environmental management should be aligned with internationally recognized good practice, including the IFC and World Bank Group Environmental, Health and Safety Guidelines for Base Metal Smelting and Refining, ISO 14001 (environmental management systems) and the Copper Mark. Environmental information—including sulfur dioxide emissions, sulfur capture efficiency, sulfuric acid production and utilization, environmental monitoring results and independent audits—should be publicly reported throughout the life of the project.

### 4. Strengthen fiscal and public investment assessment

Because Erdenet Mining Corporation is wholly owned by the state, any major investment ultimately represents an allocation of public resources. Before committing substantial public capital to downstream copper processing, policy-makers should compare the expected economic and fiscal returns with those of alternative investments, including mine expansion, exploration, renewable energy, transport infrastructure, education and other industrial development priorities. Even where private investment is attracted, this may not necessarily reduce the government's financial exposure, as policy support, infrastructure, guarantees or other forms of public assistance may still be required. Such comparisons would strengthen public investment decisions and improve the long-term management of Mongolia's mineral wealth. At the same time, future analysis should continue to assess whether the existing fiscal framework provides an appropriate balance between government revenue generation and maintaining incentives for long-term investment.

## 5. Build public confidence through continuous environmental oversight

International experience demonstrates that successful copper smelters rely not only on modern technologies but also on effective environmental governance and public accountability. Environmental oversight should therefore continue throughout the project's life cycle rather than ending with project approval. Regular disclosure of monitoring results, compliance reports, environmental incidents and independent audits would strengthen regulatory oversight while helping maintain the social license to operate, particularly given the proximity of the proposed smelter to Erdenet city.

## 6. Maintain flexibility as market conditions evolve

The economics of copper smelting are influenced by changes in copper prices, treatment and refining charges, sulfuric acid markets, technological developments and increasingly stringent environmental regulations.

Consequently, the business case for downstream processing should be updated periodically as new information becomes available rather than relying on a single set of assumptions. A flexible, evidence-based approach would reduce investment risk and allow policy decisions to adapt to changing market conditions while ensuring that downstream processing continues to support Mongolia's long-term economic and environmental objectives.

Overall, the proposed Erdenet copper smelter represents one of the most significant industrial investments currently under consideration in Mongolia. The findings of this report suggest that its success will depend not only on engineering performance or financial returns, but also on transparent governance, robust environmental management, realistic market assumptions and clearly articulated public policy objectives. Decisions on downstream copper processing should therefore be guided by rigorous evidence and careful evaluation of the long-term benefits, risks and trade-offs for Mongolia's economy, environment and citizens, with public discussions taking place on every detail of the project.



# Annexes

## Annex 1. Project sensitivity to key variables

The sensitivity analyses in this annex examine how key assumptions affect project outcomes. Tables present additional sensitivities for the mine-only scenario, with the exception of Table 18, which examines the sensitivity of both the mine-only and integrated mining and smelting scenarios to treatment and refining charges (TC/RCs). Table 14 presents the sensitivity of the project's NPV to different copper and molybdenum price assumptions. As expected, higher prices for both

metals improve project economics, although project value is substantially more sensitive to copper prices than to molybdenum prices. Holding the molybdenum price at USD 19 per pound, while increasing the copper price from USD 4 to USD 10 per pound, raises project NPV from approximately USD 42 million to USD 760 million. By comparison, holding the copper price at USD 4 per pound, while increasing the molybdenum price from USD 19 to USD 34 per pound, increases NPV from USD 42 million to USD 72 million. The project remains economically viable across all price combinations examined, with NPV ranging from USD 42 million to USD 803 million.<sup>25</sup>

**Table 14.** NPV sensitivity to copper and molybdenum prices: mine-only scenario (in USD million)

| Cu price (USD/lb) | Mo price (USD/lb) |       |       |       |       |       |
|-------------------|-------------------|-------|-------|-------|-------|-------|
|                   | 19                | 22    | 25    | 28    | 31    | 34    |
| 4                 | 42.5              | 48.1  | 53.5  | 59.7  | 65.9  | 72.0  |
| 4.5               | 85.3              | 92.0  | 98.5  | 105.8 | 113.1 | 120.4 |
| 5                 | 137.6             | 145.1 | 152.3 | 160.4 | 168.5 | 176.6 |
| 5.5               | 194.8             | 202.7 | 210.4 | 219.0 | 227.7 | 236.3 |
| 6                 | 255.6             | 263.5 | 271.4 | 280.4 | 289.3 | 298.3 |
| 6.5               | 318.2             | 326.4 | 334.5 | 343.5 | 352.5 | 361.4 |
| 7                 | 381.3             | 389.5 | 397.6 | 406.6 | 415.6 | 424.6 |
| 7.5               | 444.4             | 452.7 | 460.8 | 469.7 | 478.7 | 487.7 |
| 8                 | 507.5             | 515.8 | 523.9 | 532.9 | 541.8 | 550.8 |
| 8.5               | 570.7             | 578.9 | 587.0 | 596.0 | 604.9 | 613.9 |
| 9                 | 633.8             | 642.0 | 650.1 | 659.1 | 668.1 | 677.0 |
| 9.5               | 696.9             | 705.1 | 713.2 | 722.2 | 731.2 | 740.2 |
| 10                | 760.0             | 768.3 | 776.4 | 785.3 | 794.3 | 803.3 |

25 In all tables presented below, the shaded row or column denotes the base-case assumption.

Inflation and the choice of discount rate also influence project economics. Table 15 presents the sensitivity of project NPV to different assumptions for USD inflation and the real discount rate. Higher inflation assumptions increase project NPV across the range considered, while the effect of the real discount rate is more limited and reflects the timing

and composition of cash flows in the ongoing mining operation, including investment and operating cash flows occurring throughout the project period. Across the scenarios analysed, NPV ranges from USD 98 million to USD 201 million. The project remains economically viable across all combinations of inflation and discount rates considered.

**Table 15.** NPV sensitivity to inflation and discount rates: mine-only scenario (in USD million)

|               | Real discount rate |       |              |       |
|---------------|--------------------|-------|--------------|-------|
| USD inflation | 5%                 | 6%    | 7%           | 8%    |
| 0%            | 98.5               | 109.5 | 118.5        | 126.0 |
| 1%            | 118.9              | 128.2 | 135.6        | 141.7 |
| 2%            | 138.7              | 146.2 | <b>152.3</b> | 157.1 |
| 3%            | 157.9              | 163.8 | 168.4        | 172.0 |
| 4%            | 176.7              | 181.0 | 184.2        | 186.6 |
| 5%            | 194.9              | 197.7 | 199.6        | 200.8 |

One of the options the model considers is the expansion of milling capacity, which constrains the amount of ore that can be processed. The base-case assumption is an increase of 5 million tonnes of annual milling capacity every six years, up to a maximum milling capacity of 80 million tonnes. As Table 16 shows, the timing of capacity expansion has a significant effect on project outcomes. Reducing the expansion spread brings additional production and cash flows forward and generally increases project value.

However, accelerating all expansions into a single period requires substantially higher upfront capital expenditure, which can offset the benefits of earlier production. Under the assumptions tested, a one-year expansion spread generates the highest NPV of USD 204.2 million, compared with USD 152.3 million under the six-year base case.

**Table 16.** Impact of milling capacity expansion spread (in USD million)

| Expansion spread (years) | NPV   | Cash flow to equity | Government take | Capex   |
|--------------------------|-------|---------------------|-----------------|---------|
| 0                        | 149.2 | 3,907.4             | 9,107.1         | 1,245.1 |
| 1                        | 204.2 | 5,736.5             | 13,319.9        | 2,927.2 |
| 2                        | 175.9 | 4,907.1             | 11,699.4        | 2,556.6 |
| 3                        | 161.5 | 4,477.0             | 10,779.4        | 2,274.1 |
| 4                        | 156.2 | 4,238.2             | 10,304.7        | 2,069.2 |
| 5                        | 153.8 | 4,129.4             | 10,021.9        | 1,902.4 |
| 6                        | 152.3 | 4,056.8             | 9,829.7         | 1,785.2 |
| 7                        | 151.2 | 3,990.6             | 9,689.2         | 1,713.1 |
| 8                        | 150.2 | 3,967.5             | 9,576.5         | 1,638.2 |

Similarly, Table 17 examines the effect of different milling capacity expansion sizes. Larger capacity additions consistently increase NPV, cash flow to equity and government take, but require higher capital expenditure. However, the increase in project value is relatively modest

compared with the additional investment required. Increasing the expansion from the base-case 5 million tonnes to 9 million tonnes raises NPV from USD 152 million to USD 155 million, while CAPEX increases from USD 1,785 million to USD 2,142 million.

**Table 17.** Impact of milling capacity expansion tonnage (in USD million)

| Expansion (mm tonnes) | NPV   | Cash flow to equity | Government take | Capex   |
|-----------------------|-------|---------------------|-----------------|---------|
| 1                     | 149.8 | 3,929.7             | 9,268.0         | 1,364.2 |
| 3                     | 151.0 | 3,985.4             | 9,563.0         | 1,587.0 |
| 5                     | 152.3 | 4,056.8             | 9,829.7         | 1,785.2 |
| 7                     | 153.5 | 4,116.0             | 10,075.1        | 1,983.6 |
| 9                     | 154.7 | 4,203.3             | 10,302.5        | 2,142.0 |

Table 18 presents the sensitivity of project outcomes to changes in treatment and refining charges (TC/RCs). In the analysis, refining charges (RCs) are assumed to vary proportionally with treatment charges (TCs), such that a TC of USD 50 per tonne corresponds to an RC of 5 US cents per pound, while a TC of USD 80 per tonne corresponds to an RC of 8 US cents per pound etc. As expected, higher TC/RCs reduce the profitability of the mining-only scenario by lowering the net value received for copper concentrate. Conversely, lower TC/RCs increase both project NPV and post-tax cash flow.

For the integrated mining and smelting scenario, the effect of TC/RCs is relatively modest. In principle, once the smelter is operational, treatment and refining charges should have little influence because concentrate is processed internally rather than sold to

third parties. However, the model assumes a construction period during which the mine continues to export concentrate before the smelter commences operations. Consequently, TC/RCs continue to affect project returns during this transition period, resulting in a gradual decline in project value as treatment and refining charges increase.

The stand-alone smelter remains economically unviable across the full range of TC/RC assumptions. Although higher treatment and refining charges improve its annual post-tax cash flow by increasing processing revenues, the improvement is insufficient to recover the substantial capital and operating costs of the smelter. As a result, the project continues to require equity injections throughout its operating life, and changes in TC/RCs do not materially alter its overall financial viability.

**Table 18.** Impact of treatment (and refining) costs on project outcomes (in USD million)

| TC price<br>USD/tonne | Net present value |            | Post-tax cash flow |            |
|-----------------------|-------------------|------------|--------------------|------------|
|                       | Mining            | Integrated | Mining             | Integrated |
| 0.0                   | 175.4             | 112.1      | 2,577.3            | 2,646.4    |
| 10.0                  | 170.8             | 111.1      | 2,494.0            | 2,628.0    |
| 20.0                  | 166.2             | 110.0      | 2,410.4            | 2,609.5    |
| 30.0                  | 161.5             | 108.9      | 2,326.7            | 2,591.0    |
| 40.0                  | 156.9             | 107.8      | 2,242.9            | 2,572.6    |
| 50.0                  | 152.3             | 106.7      | 2,159.1            | 2,554.1    |
| 60.0                  | 147.6             | 105.6      | 2,075.4            | 2,535.7    |
| 70.0                  | 143.0             | 104.5      | 1,991.6            | 2,517.2    |
| 80.0                  | 138.4             | 103.4      | 1,907.7            | 2,498.7    |
| 90.0                  | 133.8             | 105.1      | 1,823.7            | 2,480.4    |
| 100.0                 | 129.3             | 104.0      | 1,739.7            | 2,462.2    |

## Annex 2. Methodology

### Copper mining

The financial flows of a copper mining project are shaped by production, revenue, costs, financing and government payments. The timing of these flows is also important, as mining projects can operate over several decades.

Production depends on factors such as ore grade, recovery rates, mining methods and processing capacity, while revenue is primarily determined by production levels and global copper prices. Project costs comprise capital expenditure (capex), operating expenditure (opex) and financing costs. Capex includes mine development, processing facilities, infrastructure, sustaining investment, equipment replacement and capacity expansion, depending on the stage of the project. Opex includes mining, processing, labor, energy, maintenance and administrative costs.

For an ongoing operation such as Erdenet, the financial structure differs from that of a greenfield mining project. The mine has been operating for decades, and much of its historical capital investment is therefore sunk. New investment is primarily associated with sustaining expenditure, capacity expansion and potential downstream processing. The operation may also finance new investments from internally generated cash flows, reducing its reliance on external financing.

Financial models evaluate the cash flows available to project owners using measures such as net present value (NPV) and internal rate of return (IRR). For an ongoing operation such as Erdenet, however, conventional project-level IRR may not provide a meaningful measure of the return on new investment because much of the historical capital expenditure is already sunk.

From the government's perspective, revenues may come from corporate income tax, royalties, dividends from state ownership and other payments. These flows are used to assess government take and the contribution of mining projects to public finances. In this analysis, the average effective tax rate (AETR) is used to assess the government's share of economic returns over the life of the project.

### Copper processing

Our analysis examines the addition of copper smelting and refining facilities to Erdenet's existing mining operations. Downstream processing can allow a country to capture additional value from its mineral resources, but it also requires substantial capital investment and introduces additional operational, market and environmental risks.

Value addition involves several stages of processing copper ore or concentrate into intermediate or final products, including smelting, converting, refining and, where applicable, casting into marketable products. The scale and technology of these operations vary widely, and processing facilities can require hundreds of millions or even billions of dollars in capital investment.

A smelter can be developed as a stand-alone business or as an extension of an existing mining operation. The revenue model differs between these configurations. Under a tolling arrangement, the smelter processes concentrate on behalf of the mine operator in return for treatment and refining charges (TC/RCs), while ownership of the concentrate and the resulting metal remains with the mine operator. TC/RCs therefore affect the value received by the mine for its concentrate. Where smelting is not integrated with refining, the primary product is typically blister copper or copper anode, which is then sold to a refinery for further processing. In an integrated mine-smelter-refinery operation, by contrast, the operator owns the concentrate and captures value through the sale of refined copper, such as copper cathode, as well as other payable products.

Capex for processing includes investments in smelters, refineries and supporting infrastructure such as power and water supply. These costs are typically high because of the scale, complexity and energy intensity of processing technologies. For tax purposes, capital expenditure is generally recovered through depreciation or other capital allowances over a prescribed period rather than deducted immediately. Opex includes energy, consumables, labor, maintenance and environmental compliance costs.

These expenses are sensitive to scale, technology choice and local input costs, including electricity prices. Financial flows from processing and value addition affect the overall profitability of copper projects and have important implications for government revenues. Domestic smelting and refining can create additional opportunities for value capture, employment, technology transfer and industrial development.

However, processing also requires substantial capital and operating expenditure and can generate significant environmental and operational costs. These trade-offs make it important for financial models to compare scenarios with and without domestic processing. Such comparisons allow policy-makers, investors and project developers to assess the financial and fiscal implications of downstream value addition.

**Figure 13.** Flow of cash in the model

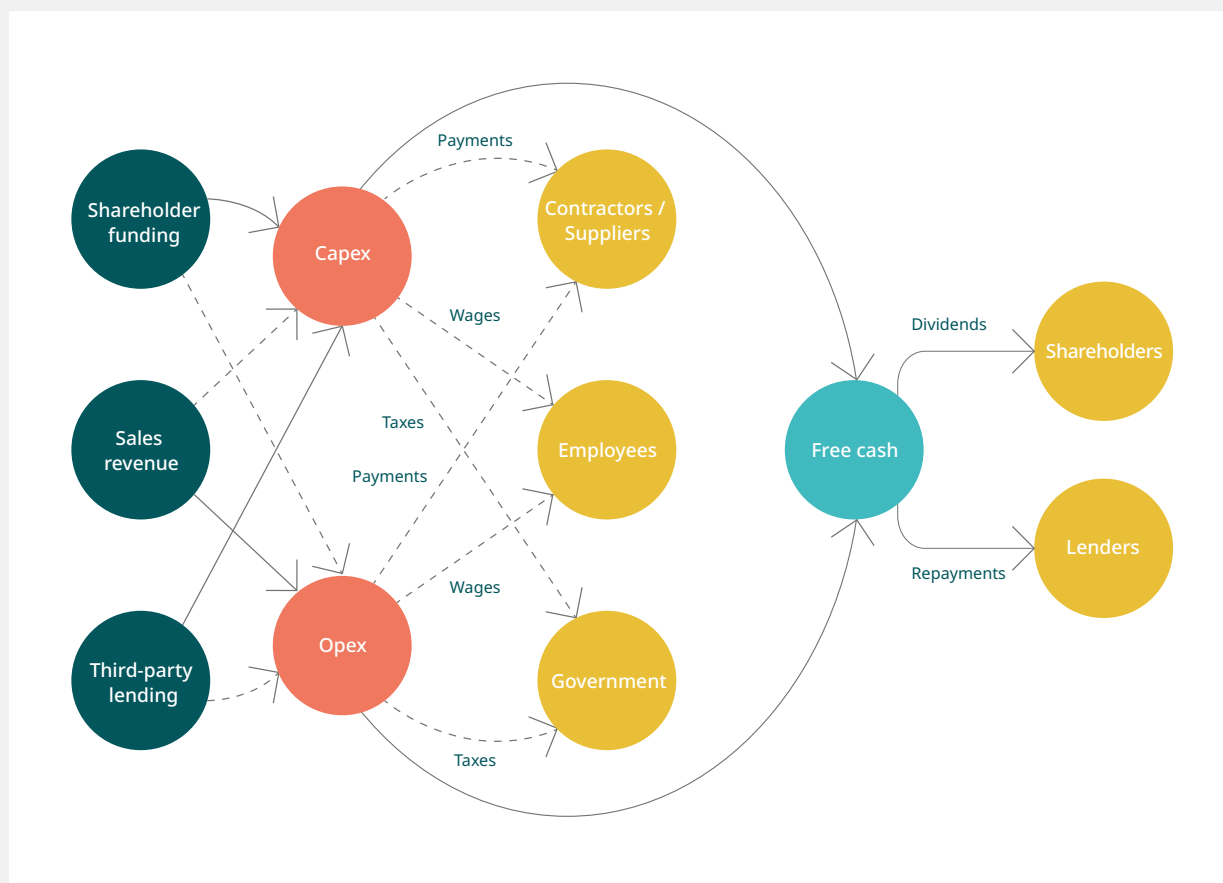
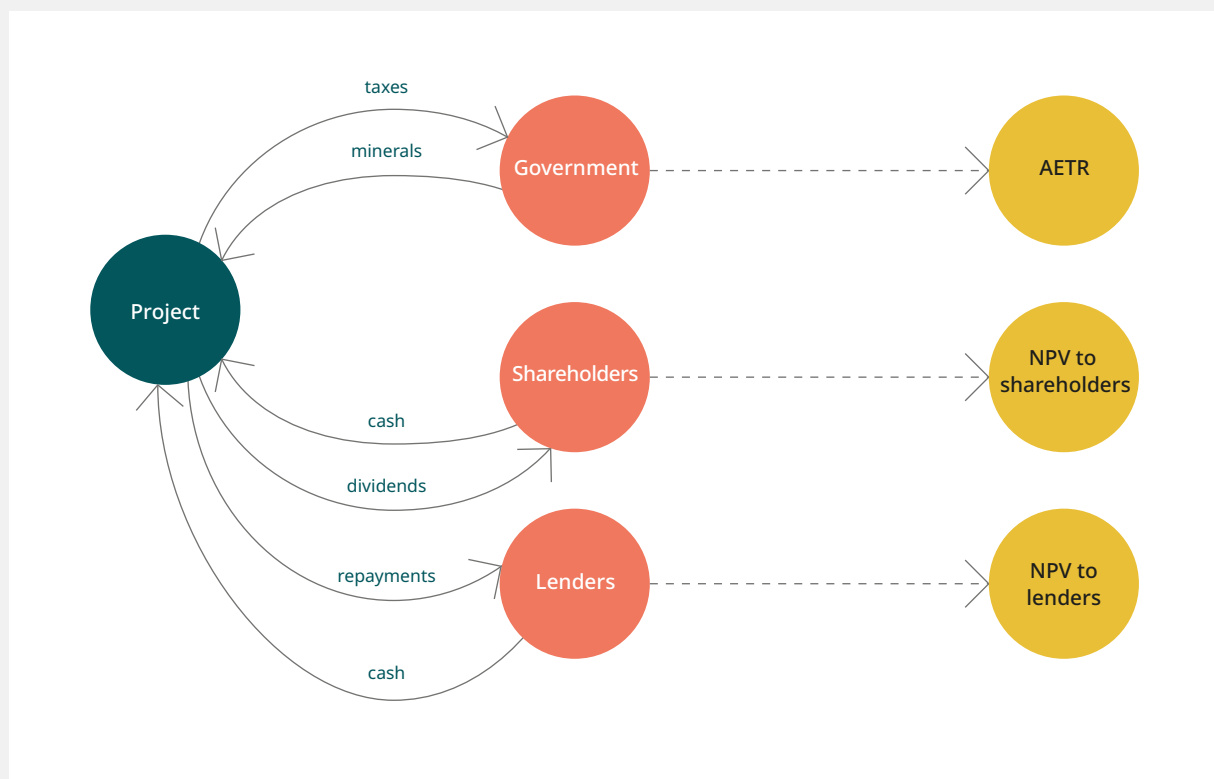


Figure 13 shows the general structure of cash flows in the model. Cash inflows comprise sales revenue, shareholder funding and third-party borrowing, while cash outflows include operating and capital expenditures. Cash is then distributed among project stakeholders through wages, payments to contractors and suppliers, debt service, taxes and dividends. The model can also be viewed from the perspective of three

key stakeholder groups: lenders, shareholders (or investors) and the government. Lenders provide financing and receive interest and principal repayments. Investors provide funding through shareholder loans or equity and receive interest or dividends, respectively. The returns to each group can therefore be assessed by comparing the timing and magnitude of their respective cash flows.

**Figure 14.** Flow of cash by stakeholders

From the government's perspective, the analysis is more complex because the government's primary economic contribution is access to mineral resources rather than a conventional cash investment. Mineral resources generally do not have an explicit cash value in the project model, and therefore no initial cash outflow is assigned to the government for the resource itself. Government returns, however, are received in the form of taxes, royalties, dividends and other payments. In this context, measures such as AETR can be used to assess the government's share of project economic returns. Conventional investor measures such as IRR may be less meaningful when there is no measurable initial cash investment against which government revenues can be compared.

### Data and sequence

NRGI has sought to use publicly available information to develop the financial model. Such information is often limited, particularly for mining and processing costs.

Where project-specific data are unavailable, the analysis therefore uses approximate estimates based on available information and comparable projects. The model is intended to identify key economic and fiscal relationships and sensitivities rather than to provide precise forecasts of project outcomes.

The analysis uses discounted cash flow modelling to evaluate the economics of copper mining and processing. We first modelled the mine-only scenario, in which the mine continues operating without a smelter until its reserves are depleted. We then modelled two downstream processing scenarios: a stand-alone smelter operating under a tolling arrangement and an integrated smelter added to the existing mining operation. The model provides insights into key policy trade-offs, including project profitability, government revenues and the incremental financial effects of downstream processing. It also allows sensitivity analysis of key risks, including changes in commodity prices, costs, capacity and fiscal parameters such as royalty rates.

# References

- Brunelli, Kevin and Tom Moerenhout. *Protecting Existing US and Allied Copper Smelting Capacity*. Center on Global Energy Policy at Columbia, 2026. [www.energypolicy.columbia.edu/publications/protecting-existing-us-and-allied-copper-smelting-capacity](http://www.energypolicy.columbia.edu/publications/protecting-existing-us-and-allied-copper-smelting-capacity).
- The Copper Mark. *Risk Readiness Assessment Criteria Guide*. 2023. [coppermark.org/wp-content/uploads/2023/10/RRA-v3.0-Criteria-Guide\\_2023.pdf](http://coppermark.org/wp-content/uploads/2023/10/RRA-v3.0-Criteria-Guide_2023.pdf).
- CRU Group and World Bank Group. *Technical and Economic Feasibility of Smelting and Refining in Developing Countries*. 2026. [egps.worldbank.org/sites/default/files/2026-06/P513669-ec1192fb-8eac-43db-ae73-bfb82401d3ae%20%281%29.pdf](https://egps.worldbank.org/sites/default/files/2026-06/P513669-ec1192fb-8eac-43db-ae73-bfb82401d3ae%20%281%29.pdf).
- EcoMetales Ltd. "Trends and Treatment of Impurities in Copper Mining." Presentation for Japan Organization for Metals and Energy Security (JOGMEC) International Seminar on impurities in copper raw material, 2018. [www.jogmec.go.jp/content/300358434.pdf](http://www.jogmec.go.jp/content/300358434.pdf). Accessed 2 July 2026.
- EITI. "EITI Standard 2023." [eiti.org/eiti-standard](http://eiti.org/eiti-standard).
- Erdenet Mining Corporation. "Geological Exploration." No date. [www.erdenetmc.mn/operations/geo-pros](http://www.erdenetmc.mn/operations/geo-pros).
- Fluor Corporation. "Ilo Smelter Modernization." No date. [www.fluor.com/projects/ilo-smelter-modernization-peru](http://www.fluor.com/projects/ilo-smelter-modernization-peru). Accessed 2 July 2026.
- Government of Mongolia, Glass Account Information. "Changes to approved employment plans.", 2026. [shilendans.gov.mn/organization/38753?ry=2025&group=5&for=69446&rf=1357&rm=12](http://shilendans.gov.mn/organization/38753?ry=2025&group=5&for=69446&rf=1357&rm=12).
- Government of Mongolia, Ministry of Environment and Climate Change. "Detailed Impact Assessment Report." 19 September 2023. [eic.mn/eia/index.php?menuitem=3&count=10&page=1&project\\_aimag=61&proponent\\_name=%D0%AD%D1%80%D0%B4%D1%8D%D0%BD%D1%8D%D1%82%20%D2%AF%D0%B9%D0%BB%D0%B4%D0%B2%D1%8D%D1%80&action=more&eiareport\\_id=8627](http://eic.mn/eia/index.php?menuitem=3&count=10&page=1&project_aimag=61&proponent_name=%D0%AD%D1%80%D0%B4%D1%8D%D0%BD%D1%8D%D1%82%20%D2%AF%D0%B9%D0%BB%D0%B4%D0%B2%D1%8D%D1%80&action=more&eiareport_id=8627).
- ICMM. *Mining Principles*. 2023, updated December 2024. [pimcore.icmm.com/website/publications/pdfs/mining-principles/mining-principles.pdf](http://pimcore.icmm.com/website/publications/pdfs/mining-principles/mining-principles.pdf).
- Copper Processing Complex LLC.. "Project Information" No date. [www.ifc.org/content/dam/ifc/doc/2000/2007-mining-ehs-guidelines-en.pdf](http://www.ifc.org/content/dam/ifc/doc/2000/2007-mining-ehs-guidelines-en.pdf).
- IFC and World Bank Group. *Environmental, Health, and Safety Guidelines for Base Metal Smelting and Refining*. 2007. [documents1.worldbank.org/curated/en/605891489653831342/pdf/113559-WP-ENGLISH-Smelting-and-Refining-PUBLIC.pdf](https://documents1.worldbank.org/curated/en/605891489653831342/pdf/113559-WP-ENGLISH-Smelting-and-Refining-PUBLIC.pdf).
- IFC and World Bank Group. *Environmental, Health and Safety Guidelines for Mining*. 2007. [www.ifc.org/content/dam/ifc/doc/2000/2007-mining-ehs-guidelines-en.pdf](http://www.ifc.org/content/dam/ifc/doc/2000/2007-mining-ehs-guidelines-en.pdf).
- Ikon.mn. "Three Chinese and one Swiss company shortlisted for copper concentrate smelting and processing plant." 25 February 2026. [ikon.mn/n/3lmb](http://ikon.mn/n/3lmb).
- Muma, Darius, Bunda Besa, James Manchisi and Webby Banda. "Effects of Mining Operations on Air and Water Quality in Mufulira District of Zambia: A Case Study of Kankoyo Township." *Journal of the Southern African Institute of Mining and Metallurgy* 120, no. 4 (2020): 287–98. [doi.org/10.17159/2411-9717/952/2020](https://doi.org/10.17159/2411-9717/952/2020).
- Dorjdari Namkhajantsan and Zoljargal Naranbaatar. *Copper Sector Expansion in Mongolia: Opportunities and Challenges*. NRG, 2025.
- Scurfield, Thomas, Silas Olang and Matthieu Salomon. *Six Keys to Unlocking Equitable Value Addition in Mining*. NRG, 2024. [resourcegovernance.org/publications/six-keys-unlocking-equitable-value-addition-mining#assess-feasibility-3](http://resourcegovernance.org/publications/six-keys-unlocking-equitable-value-addition-mining#assess-feasibility-3).
- U.S. Bureau of Industry and Security. "Public Comment # 75. Rio Tinto (U.S.). Company Representative." 11 April 2025. [www.regulations.gov/comment/BIS-2025-0010-0076](http://www.regulations.gov/comment/BIS-2025-0010-0076).

---

## About the authors

Dorjdari Namkhajantsan is Mongolia Manager and Zoljargal Naranbaatar is Program Officer at the Natural Resource Governance Institute.

---

## Acknowledgements

The authors thank colleagues across NRGi, in particular Cintia Roa Cabello, Thomas Scurfield and Amir Shafaie, for their helpful feedback and advice. We also acknowledge the support provided by the European Climate Foundation's Pooled Fund on International Energy.

---

## About NRGi

The Natural Resource Governance Institute is an independent, non-profit organization that supports informed, inclusive decision-making about natural resources and the energy transition. We partner with reformers in government and civil society to design and implement just policies based on evidence and the priorities of citizens in resource-rich developing countries. Learn more at [www.resourcegovernance.org](http://www.resourcegovernance.org)

---



Natural Resource  
Governance Institute