



Managing Risk, Delivering Shared Value

# Responsible Mining for the Energy Transition

May 2026



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**ChatGPT was used** in the course of this research to complement initial desk research and analysis. All AI references were verified for accuracy, and all language drafts were reviewed and further revised by the authors.



**Rocky Mountain Institute (RMI)** is an independent, nonpartisan nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to secure a prosperous, resilient, clean energy future for all. In collaboration with businesses, policymakers, funders, communities, and other partners, RMI drives investment to scale clean energy solutions, reduce energy waste, and boost access to affordable clean energy in ways that enhance security, strengthen the economy, and improve people's livelihoods. RMI is active in over 50 countries.



# Executive Summary



## THE NEED FOR RESPONSIBLE MINING STANDARDS

The energy transition requires a surge of mining for key elements that enable renewable energy and battery storage, creating economic opportunity accompanied by environmental and social risk.

### Key concerns associated with mining energy transition minerals



#### Environmental

- Waste and tailings management
- Water management
- Air quality and pollution
- Deforestation and associated climate and ecological impact
- Biodiversity impacts of mining
- Greenhouse gas emissions



#### Social

- Indigenous peoples' rights and Free, Prior, and Informed Consent (FPIC)
- Human rights and child labor
- Gender equity and gender violence
- Land rights, displacement, and resettlement
- Community health and safety
- Commitment to local economic development

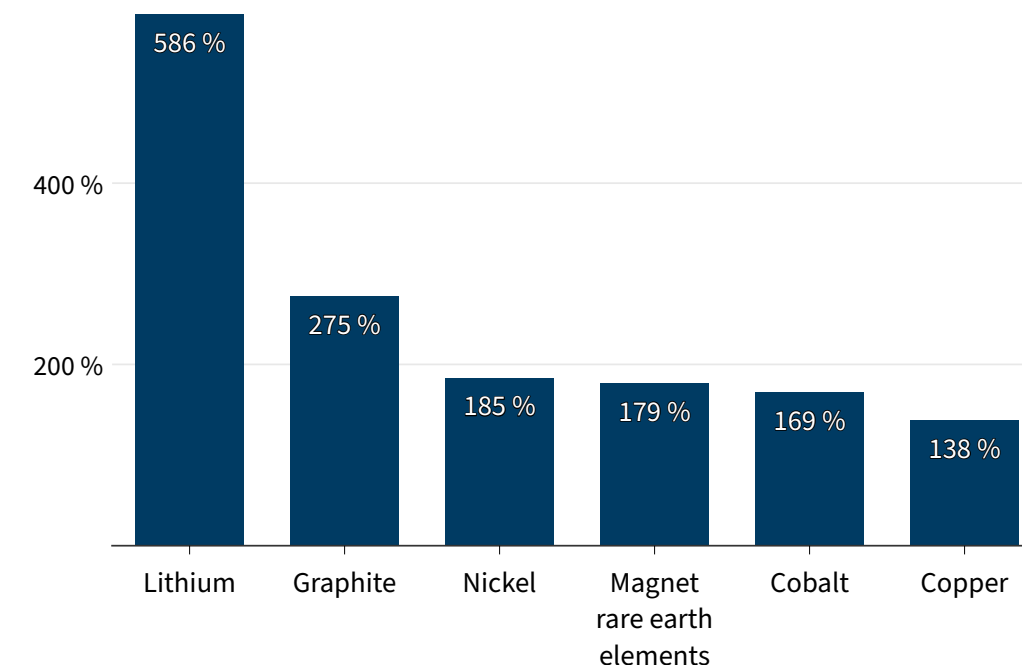


#### Governance

- Revenue and payments transparency
- Sourcing from conflict-affected and high-risk regions

Source: [Financing the Responsible Supply of Energy Transition Minerals for Sustainable Development](#); [Initiative for Responsible Mining Assurance](#)

### Expected increase in total demand for key minerals in 2040 from 2024 levels



Mineral demand considered from IEA's Announced Pledges Scenario (APS)

Source: [IEA Critical Minerals Data Explorer](#)

**Rigorous voluntary mining standards are helpful to address community, worker, and environmental concerns.** But the adoption of such responsible mining standards is hindered by poor understanding of its costs and benefits. **This work seeks to address this information gap so that the industry can build on a common fact base with:**

- Industry reported costs and accompanying cost assessment framework
- Improved benefit assessment framework



### OVERVIEW AND APPROACH

# A core focus of RMI's Battery Circular Economy Initiative (BCEI) is advancing responsible sourcing of battery raw materials.

To support this objective, RMI examined the costs and potential benefits associated with the [Initiative for Responsible Mining Assurance \(IRMA\)](#), given its growing adoption across the mining sector, and growing reliance on automakers on IRMA for upstream mining due diligence.

## IRMA's relevance to the responsible mining costs benefits study

Voluntary mining standards such as IRMA serve two important functions within the mining and battery value chain.

- First, they provide globally harmonized, implementation-focused frameworks for the mining companies that go beyond regulatory compliance. While national regulations establish enforceable minimum requirements, voluntary standards offer detailed guidance on operational practices and independent third-party verification.
- Second, these standards function as due diligence tools for downstream buyers seeking assurance of responsible sourcing. Automakers increasingly reference IRMA within their sourcing policies. Several major manufacturer – including [Ford](#), [Volkswagen](#), and [Mercedes-Benz](#) – require or encourage suppliers to undergo IRMA audits, and [11 global automakers](#) are members of IRMA's multi-stakeholder governance structure.

IRMA's mineral-agnostic and detailed requirements have been recognized by [automaker](#) and [civil society assessments](#) as among the most comprehensive available. Therefore, evaluating the audit and implementation costs at sites undergoing IRMA audits provides a practical lens for understanding responsible mining costs.

Given the IRMA process is mineral-agnostic, these costs would also be broadly transferable across commodities. Thus, the cost to implement IRMA is considered a proxy for the cost to implement responsible mining best practices at mine sites.

## Independent study informed by industry inputs

This analysis was conducted independently by RMI. It draws primarily on inputs from mining companies and buyers that have engaged with the IRMA process, supplemented by desk research.

IRMA facilitated introductions to relevant market participants, provided supplemental materials, and engaged in review of the methodology and the report. They did not direct the analytical process or conclusions.

Additional perspectives were gathered from investors who regularly assess mining-related due diligence practices, irrespective of their engagement with IRMA.

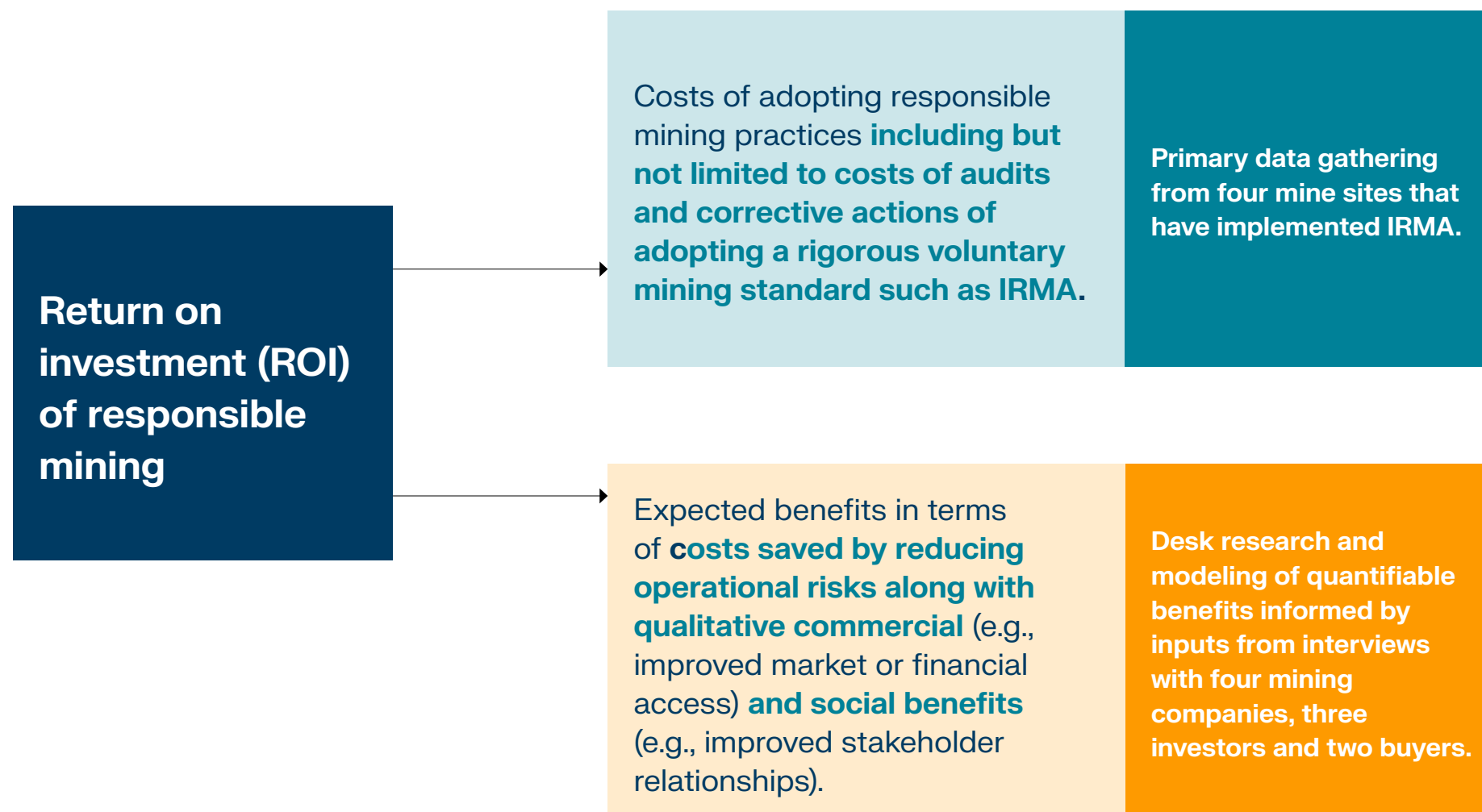




ANALYSIS GOAL

# A first-of-a-kind cost benefit assessment of responsible mining best practices implementation is needed to evaluate the return on investment.

This study weighs the costs of responsible mining at sites that have adopted a rigorous and comprehensive voluntary mining standard such as IRMA against expected tangible benefits from reduced operational risks and qualitative commercial or social benefits.





### ANALYSIS CONSIDERATIONS

# Costs and benefits data gathering

## Costs

The cost assessment relied on four case studies of IRMA implementation at mining sites. While the sample size is limited, it provides directional insights into the incremental costs associated with implementing responsible mining best practices.

Baseline conditions to evaluate incremental costs vary significantly across jurisdictions and companies, influenced by regulatory environments, existing internal sustainability practices, mine size and complexity, and company maturity. These differences have important implications. In regions with less stringent regulatory requirements, adopting responsible mining best practices may have greater incremental costs and a more noticeable budget impact than in regions with more stringent requirements.

However, where regulatory requirements are less developed, voluntary standards may also deliver greater value by strengthening governance systems, improving risk identification and mitigation, and enhancing transparency. The transparency and third-party verification embedded in responsible mining standards may also provide added assurance to downstream buyers, particularly in jurisdictions where due diligence and reporting requirements are less developed.

Accordingly, **the findings are not intended to be universally representative, but rather to initiate a more evidence-based discussion of responsible mining costs and offer directional benchmarks**. Expanding the dataset to include a broader range of sites across geographies and commodities represents a clear opportunity for future research.

## Benefits

The benefit assessment considered both **quantifiable and qualitative outcomes**, with benefit categories informed by stakeholder interviews. Quantifiable benefits focus on **potential avoided costs from reduced operational risks**, including delays and stoppages, catastrophic events, and fines and remediation. These estimates are based on desk research of environmental and social incidents affecting mining operations and their associated financial impacts. The dataset draws on publicly available incident databases and reported production losses, providing a broader cross-section of the mining sector than the primary cost data from the case studies.

This analysis is designed to support decision-making by comparing responsible mining costs against **downside risk exposure**. It does not establish a causal relationship between responsible mining standards and reduced incident rates. Given the relative nascency of comprehensive responsible mining standards such as IRMA, comparable datasets across sites that have adopted voluntary standards versus others are not yet available. Instead, the analysis uses a scenario-based approach, grounded in the premise that structured governance and risk controls are logically aligned with reduced operational risk.

In addition, the assessment incorporates **qualitative benefits** identified through stakeholder engagement, including improved market access, access to capital, operational performance, and strengthened social license to operate.

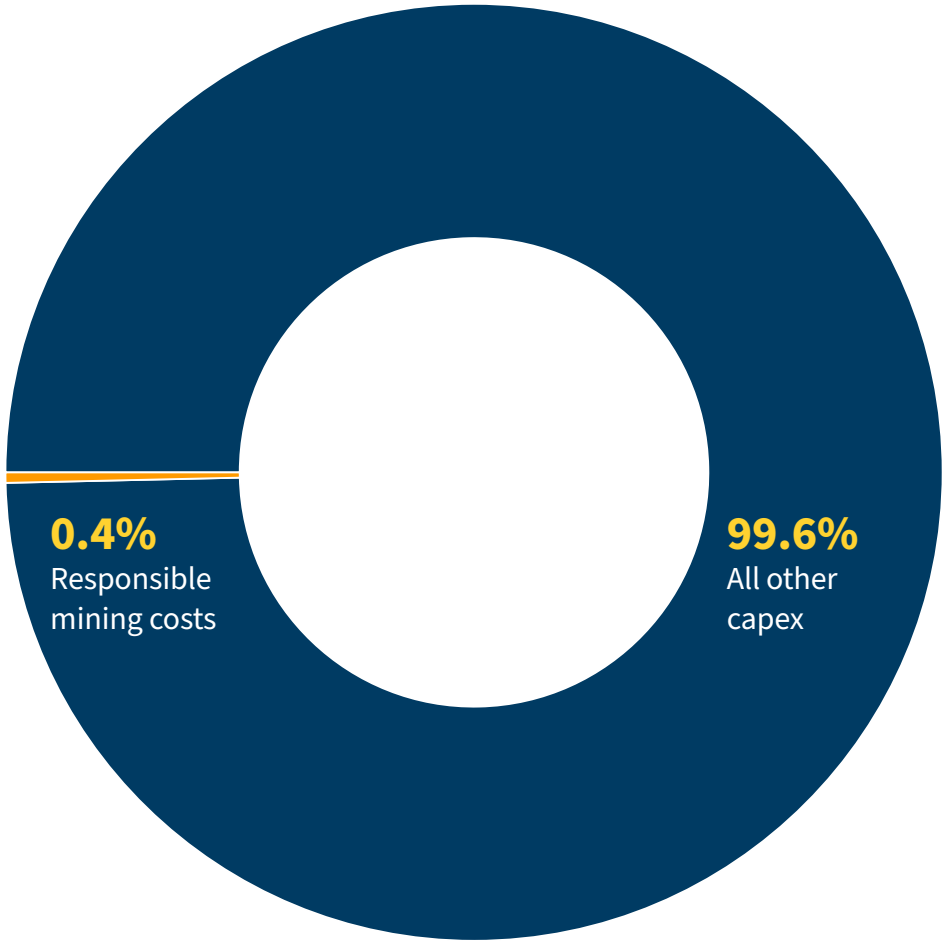


THE NEED FOR RESPONSIBLE MINING STANDARDS

Responsible mining costs average 0.4% of a project's up-front capital expenditure.

Responsible mining costs with respect to mining project capex

On an average ~\$1.18 billion capex project, responsible mining costs average ~\$4.1 million.



Responsible mining costs are **small compared to the up-front cost** of a mining asset.

Miners may already be investing in responsible mining practices. The **incremental portions for implementing a rigorous voluntary standard like IRMA with independent third-party verification and corrective actions is no more than two-fifths** of the overall costs of implementing responsible mining best practices.

Assurance costs tied to IRMA audits can vary depending on factors such as geography, location, scope of audit, mine type, and operational complexity.

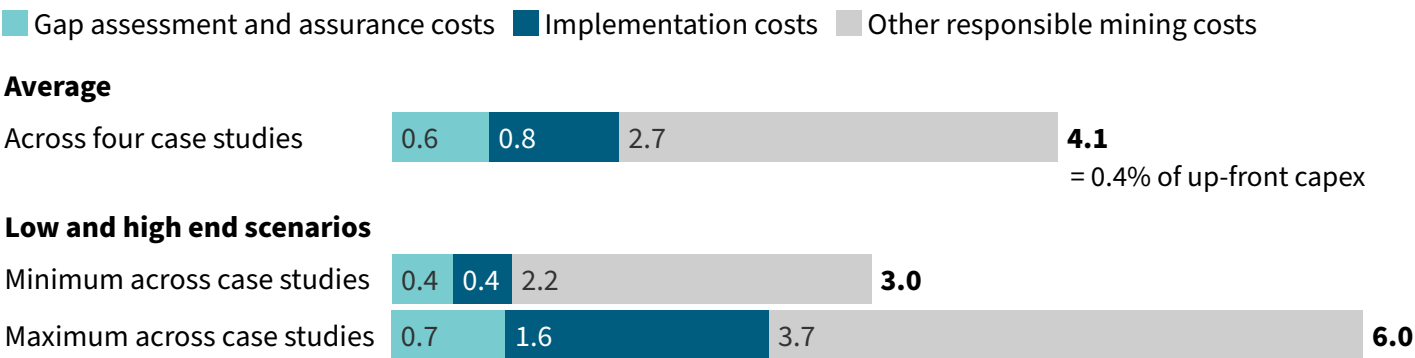
One avenue to reduce audit-related costs may involve minimizing on-site auditor engagement through more thorough pre-audit preparation. While this can lower direct audit costs, it would require additional effort and resources from the mining company during the preparation phase. As a result, overall gap assessment and assurance costs may not be materially reduced.

While responsible mining costs are a small share of capex, its significance depends on where and how decisions are made.

At the board level and the overall organization lens, these investments may be considered modest, but at the operational level where project team or sustainability budgets may be tightly managed, incremental expenditures may receive closer scrutiny.

Breakdown of responsible mining costs\*

In millions of dollars



\*Responsible mining costs may be influenced by factors not explicitly assessed in this study including regulatory stringency, company governance practices, operator type (junior versus mining major and jurisdictional context).

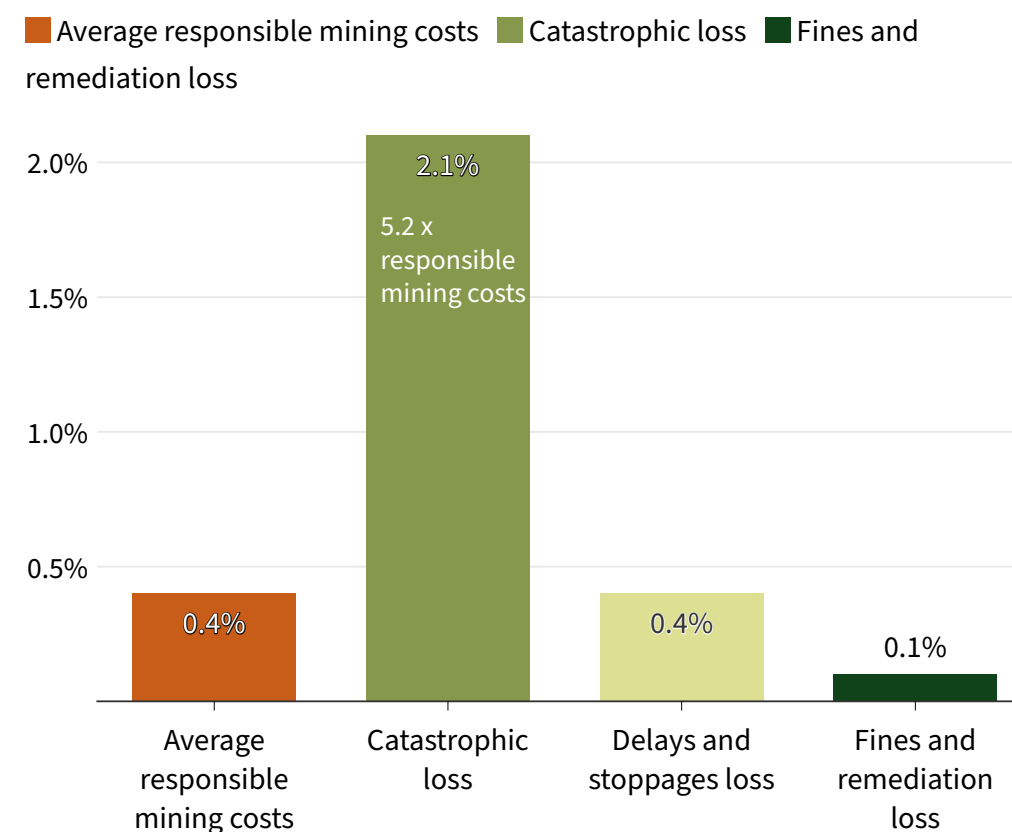


### ANALYSIS INSIGHTS

# Responsible mining costs are small relative to the possible loss exposure.

Average loss exposure can be up to approximately 5x responsible mining costs.

Average responsible mining costs versus financial impact of potential operational risks (probability-weighted)



#### Notes

1. Values normalized as percentage of capex for cross-site comparability
2. Operational risk incident data sources: Transition Minerals Tracker; Company reports; Business and Human Rights Resource Centre; News reports
3. Catastrophic loss reflects tailings dam failure scenarios and is relevant primarily to hard rock mines; delays and stoppages and fines and remediation are broadly applicable.

**Responsible mining practices** are designed to strengthen governance and operational controls, reducing unmanaged risks over the full life of a mine.

**The cost of implementing responsible mining is modest relative to the financial exposure from operational disruptions** caused by delays, stoppages, or catastrophic events. Operational delays and stoppages tend to be the more frequently encountered risk and can materially affect cash flow. Catastrophic losses may be less frequent but have more severe impact.\*

**Interviewees also detailed how responsible mining also delivers real value beyond quantifiable benefits.**

- Responsible mining practices reduce the risk of operational interruptions, and improve transparency and accountability which maintains or improves access to capital.
- A growing group of buyers are requiring mining companies to adopt responsible mining standards.
- Responsible mining drives increased collaboration among different teams within a mining company. Standardized process improves operational excellence
- Multi-stakeholder engagement, and robust and accessible grievance mechanism improve community dialogue
- Miners as well as producing regions are able to signal transparency and accountability to investors, buyers and civil society, thus building their social-license-to-operate.

\*Tailings failures can vary significantly by region and how those tailings facilities are built. In regions characterized by extreme rainfall, and/or there is high seismic activity, reports of tailings breaches can be more frequent



## CONCLUSION

**The cost-benefit assessment reveals responsible mining investments can be economically rational.**

### Analysis and stakeholder insights

- 1** Case studies show responsible mining costs are small when compared to up-front mining site investment.
- 2** Responsible mining costs are lower than the potential financial impact of operational risks such as delays and stoppages or catastrophic losses.
- 3** A small reduction in the probability of operational risk incidents can justify the cost of responsible mining practices.
- 4** Beyond impact to the company bottom line, responsible mining provides a boost to a mining company's social license to operate by improving affected community and civil society relationships while also improving market and capital access.

Responsible mining costs are useful investments for incorporating structured risk management and governance, while supporting a mining company's social license to operate.

Potential benefits outweigh costs and reach stakeholders through the end of the value chain — from the mining company to the consumer, including the end-product manufacturers, affected communities and workers, regional authorities, and civil society.

These data points support the adoption of responsible mining standards and practices.



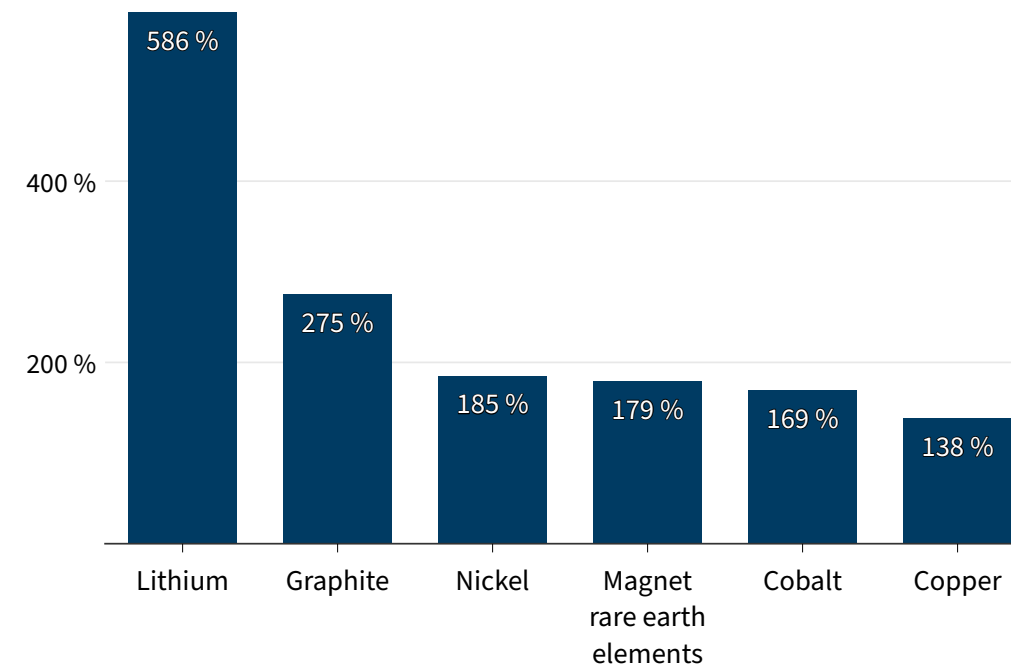
# 1. Introduction



## THE NEED FOR RESPONSIBLE MINING STANDARDS

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Expected increase in total demand for key minerals in 2040 from 2024 levels



Mineral demand considered from IEA's Announced Pledges Scenario (APS)

Chart: RMI Source: [IEA Critical Minerals Data Explorer](#)

## Key concerns associated with mining energy transition minerals



### Environmental

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### Social

- Indigenous peoples' rights and Free, Prior, and Informed Consent (FPIC)
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### Governance

- Revenue and payments transparency
- Sourcing from conflict-affected and high-risk regions

Source: [Financing the Responsible Supply of Energy Transition Minerals for Sustainable Development](#); Initiative for Responsible Mining Assurance



### THE NEED FOR VOLUNTARY MINING STANDARDS

# Rigorous voluntary responsible mining standards complement regulation and strive to improve implementation of best practices.

Regulatory frameworks define enforceable baselines for continuous due diligence. Rigorous voluntary standards are additional measures that provide deeper operational guidance and create incentives to go beyond the legal compliance baseline, which is consistent across jurisdictions. Independent third-party verification required by many voluntary standards can provide periodic evaluation of mining performance at the site.



#### REGULATORY COMPLIANCE REQUIRED

##### Mining regulations in producing countries

National/regional regulations applicable to operating mines and mining companies

Tend to be broad-based; define the minimum baseline for mining companies

##### Example

[US Federal Land Policy and Management Act of 1976](#); [Chile Law 19300](#)



#### REGULATORY COMPLIANCE REQUIRED

##### Importer regulations

National/regional regulations directing importing companies to implement due diligence mechanisms

Focus on procedural and institutional aspects of due diligence; reference other frameworks and standards.

##### Example

[EU Conflict Minerals Regulation](#); [OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas](#)



##### Voluntary standards

Not enforceable — voluntarily adopted by companies or projects to identify and mitigate risks and demonstrate responsible mining practices to diverse range of stakeholders including communities and workers, buyers, investors, local authorities, etc.

Focus on implementation of best practices, measurement and evaluation at site or company level.

##### Example

[Initiative for Responsible Mining Assurance \(IRMA\)](#); [IFC Performance Standards](#)



## THE NEED FOR VOLUNTARY MINING STANDARDS

**To address community, worker, and environmental concerns, rigorous voluntary mining standards must be designed to identify and address issues.**

While voluntary standards cannot replace enforceable regulations, it helps to establish practices for addressing environmental and social risks, harmonized across jurisdictions.





## MOTIVATION FOR THIS WORK

# Adoption of responsible mining standards is hindered by poor understanding of its costs and benefits.

Without responsible mining of minerals essential to the energy transition, there is an increased risk of mining harm to communities and the planet, and of conflicts that can lead to supply chain disruption.



### Cost-based objections

Missing quantification of responsible mining costs leads to a perception that compliance costs are too high.



### Missing holistic cost-benefit assessment

The costs of compliance should be weighed against quantifiable avoided operational risks *and* additional benefits such as improved relationship with affected stakeholders, and unquantifiable commercial benefits with improved market and/or financing access.



**This work seeks to address this information gap so that the industry can build on a common fact base with ...**

- Industry-reported cost assessment framework
- Improved benefit assessment framework



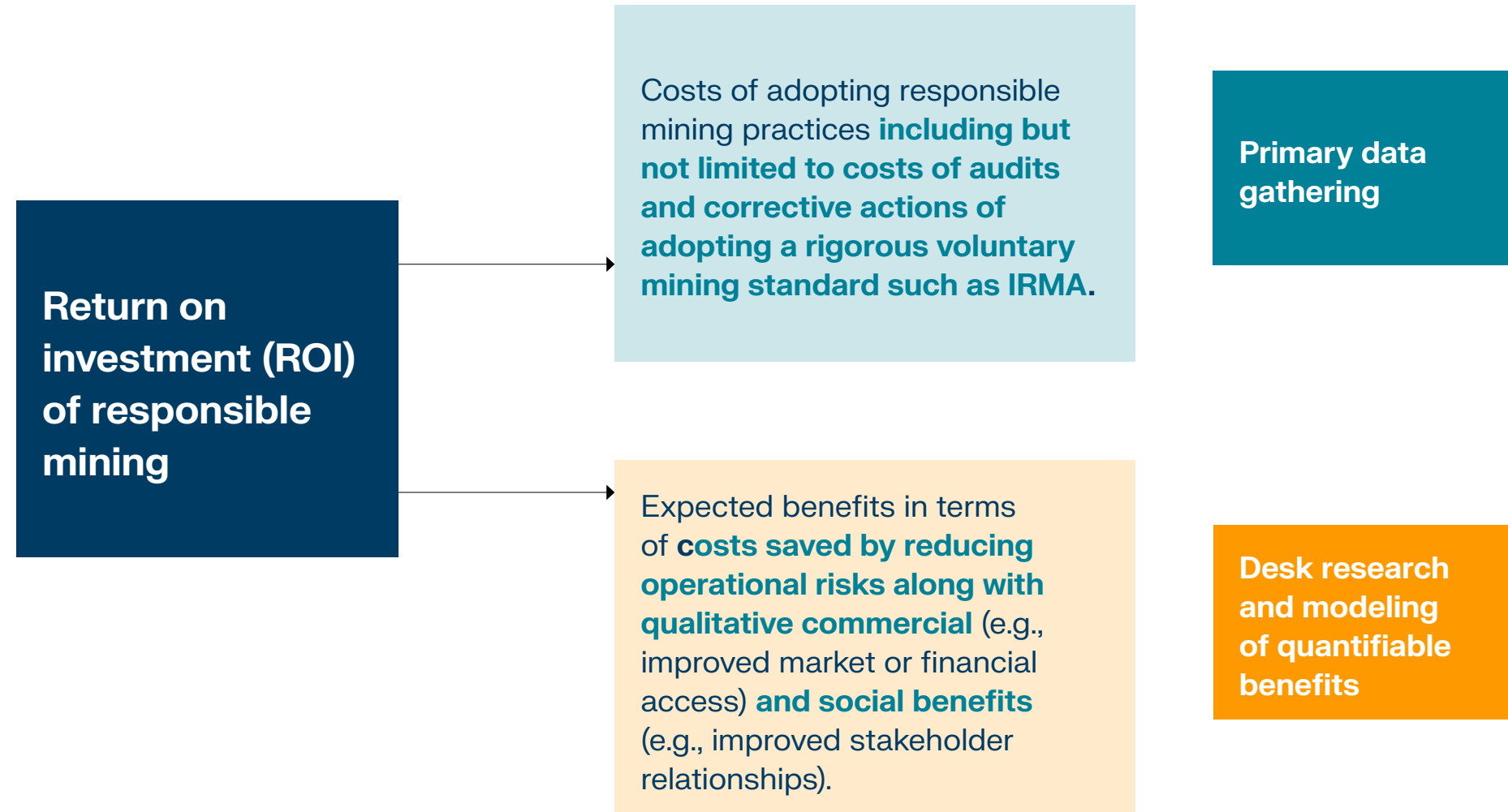
## **2. Cost Benefit Analysis Overview**



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VOLUNTARY SUPPLY CHAIN STANDARDS OVERVIEW

**Existing voluntary standards vary by commodity and scope of supply chain activities as well as in rigor, governance, and transparency.**

| A site can implement more than one standard                | Mining and on-site processing | Smelting and refining | Conversion to intermediates | Manufacturing | Reuse and recycling |
|------------------------------------------------------------|-------------------------------|-----------------------|-----------------------------|---------------|---------------------|
| Initiative for Responsible Mining Assurance                |                               |                       |                             |               |                     |
| International Council on Mining and Metal                  |                               |                       |                             |               |                     |
| Toward Sustainable Mining                                  |                               |                       |                             |               |                     |
| CERA 4-in-1                                                |                               |                       |                             |               |                     |
| International Finance Corporation                          |                               |                       |                             |               |                     |
| Responsible Minerals Initiative                            |                               |                       |                             |               |                     |
| World Gold Council                                         |                               |                       |                             |               |                     |
| Responsible Jewellery Council (Diamond, gold, silver, PGE) |                               |                       |                             |               |                     |
| The Copper Mark (copper lead, nickel, zinc)                |                               |                       |                             |               |                     |
| Aluminum Stewardship Initiative (aluminum)                 |                               |                       |                             |               |                     |
| Responsible Steel (steel)                                  |                               |                       |                             |               |                     |

Source: [BGR](#)



### COST ASSESSMENT APPROACH

# Automaker assessment identifies IRMA as most rigorous voluntary standard by benchmarking various standards on desired elements.

Given that responsible mining standards vary widely in scope and applicability, Mercedes-Benz developed a [Mining and Supply Chain Standards Guidance](#) to assist suppliers in identifying the appropriate standard for their purpose. Their assessment highlights the comprehensive and detailed nature of IRMA audits.

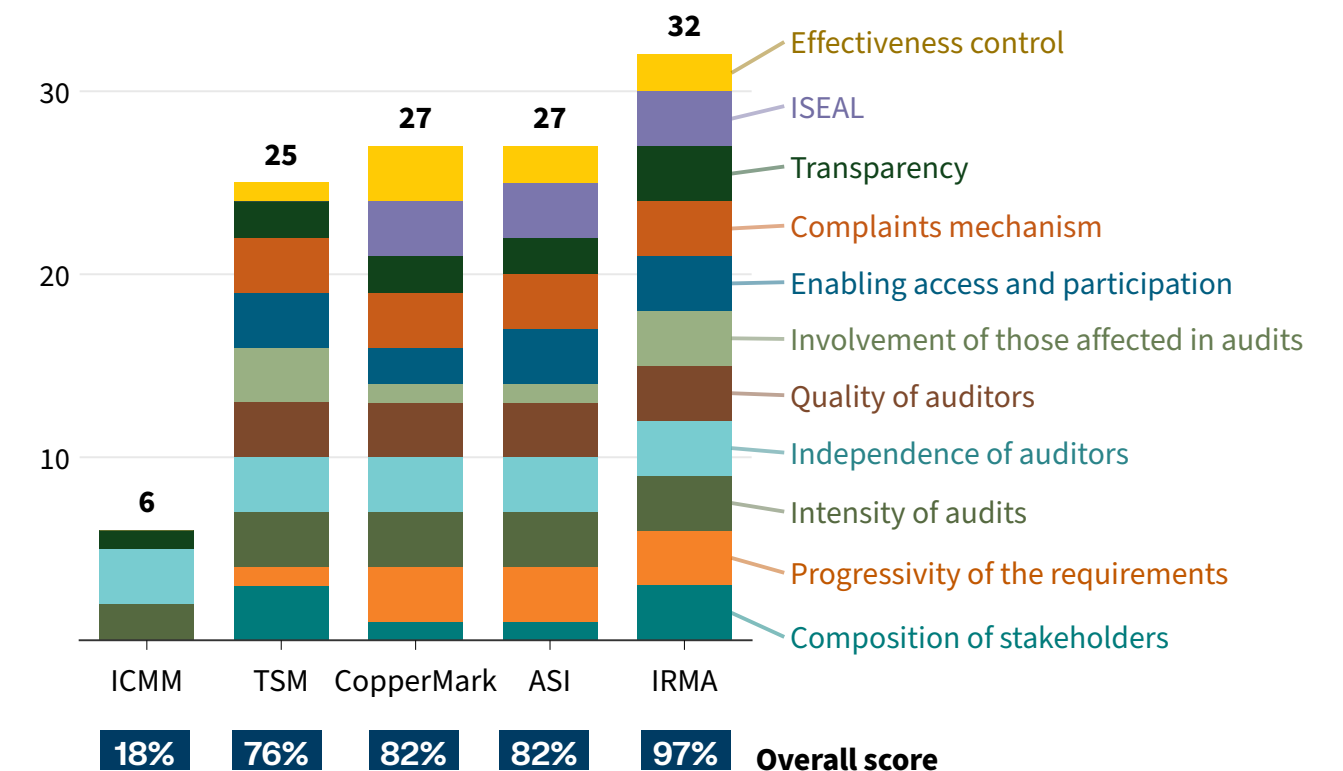
The Mercedes-Benz study articulates what Mercedes Benz considers as necessary for standards to serve as appropriate due diligence instruments.

It evaluates voluntary mining and supply chain standards across 11 dimensions.

For each category a maximum of three points can be achieved. The maximum possible score is 33.

**Implication for the analysis:** Given the comprehensive requirements in the IRMA standard, evaluating the audit and implementation costs at sites undergoing IRMA audits provides a practical lens for understanding responsible mining costs. Thus, mining sites implementing the IRMA process were considered for the cost case studies.

### Mercedes-Benz guidance: Mining and supply chain standards



Source: [Mercedes-Benz](#)

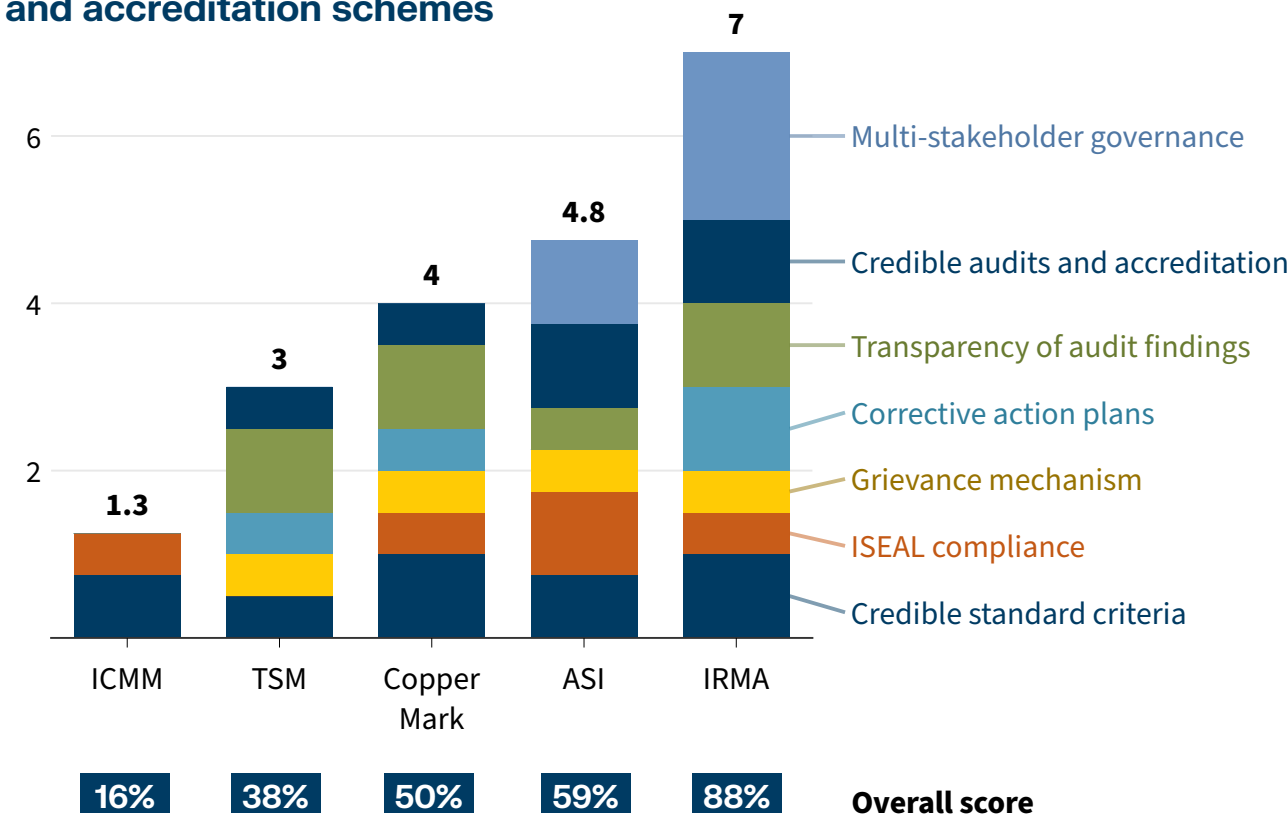


COST ASSESSMENT APPROACH

# Civil society assessment aligns on the rigor of IRMA standards.

A separate assessment developed by the Lead the Charge coalition arrives at similar conclusions. This assessment is intended to serve as a tool for automakers, and other automotive supply chain stakeholders, to make informed decisions regarding their use of these accreditation schemes for the mining sites, smelters, refiners, steel and aluminum plants, and other facilities in their supply chains.

## Lead the Charge assessment of third-party assurance and accreditation schemes



## Total points performance brand

| Total points    | Description                                                                                                                                                                    |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 8 points (full) | Robust standard that meets minimum criteria for effective governance, auditing and accreditation, and implementation of the criteria.                                          |
| 7 points        | Robust scheme overall that still has some shortcomings but still meets nearly all of the minimum criteria for governance, auditing, and/or accreditation against its standard. |
| 5-6 points      | Scheme has made notable progress in meeting most of the minimum criteria but has some significant shortcomings.                                                                |
| 3-4 points      | Scheme has made progress in some areas but fails to meet multiple criteria for effective governance, auditing, and/or accreditation against its standard.                      |
| Below 3 points  | Flawed scheme that fails to meet most of the minimum criteria for governance, auditing, and/or accreditation.                                                                  |



## ANALYSIS APPROACH

**Mining value chain participants contributed to the study by providing primary cost data and qualitative insights on benefits, guiding modeling and additional research.**



### 1. Study participants helped identify costs and benefits of responsible mining practices

Interviews with:

- 4 mining companies
- 3 investors
- 2 buyers



### 2. Cost case studies: Primary data mapped at mine sites and shared by participants

Mining participants shared data from four sites that implemented IRMA and other standards addressing specific areas of responsible mining:

- Costs of IRMA evaluation
- Common costs between IRMA and other certifications that address specific areas of responsible mining best practice (for instance tailings management requirements overlap between IRMA and Global Industry Standards for Tailings Management [GISTM] certification)
- Additional costs from internal policies or regulatory requirements



### 3. Quantified benefits: Desk research on operational risk incidents and impact

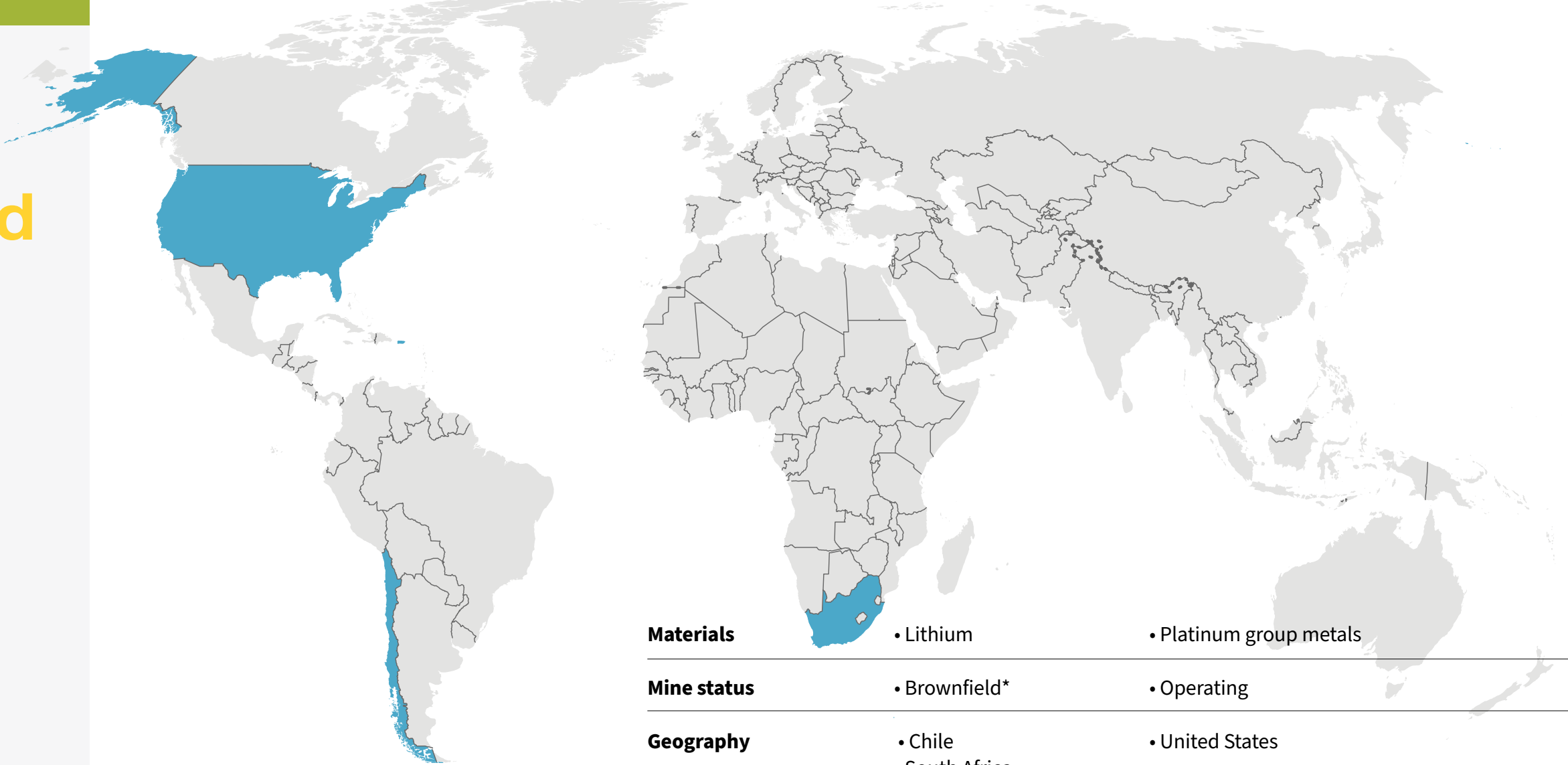
Supplemental desk research to gather additional inputs, based on initial insights provided in interviews:

- Financial impact of delays and stoppages, catastrophic incidents, fines and remediation costs
- Qualitative commercial and social benefits



COST ASSESSMENT APPROACH

Data were gathered from four sites for case studies, using the cost of IRMA implementation as a proxy for the cost of implementing responsible mining.



Together, these sources allow us to construct a representative cost profile for responsible mining practice implementation.

|                                        |                                                                                                                                                                                                         |                         |
|----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| Materials                              | • Lithium                                                                                                                                                                                               | • Platinum group metals |
| Mine status                            | • Brownfield*                                                                                                                                                                                           | • Operating             |
| Geography                              | • Chile<br>• South Africa                                                                                                                                                                               | • United States         |
| IRMA evaluation**                      | • Ongoing<br>• Aspirational IRMA75                                                                                                                                                                      | • Aspirational IRMA 100 |
| Responsible mining cost data gathering | • Company reported estimates of IRMA costs vs. other ESG/due diligence cost mapping, or<br>• Questionnaire responses from mining company providing detailed list of costs related to responsible mining |                         |

\* Brownfield projects refer to restarting operations at former mining sites.

\*\* Elaborated on in Appendix.



#### ANALYSIS APPROACH

# Considerations with costs and benefits data gathering

## Costs

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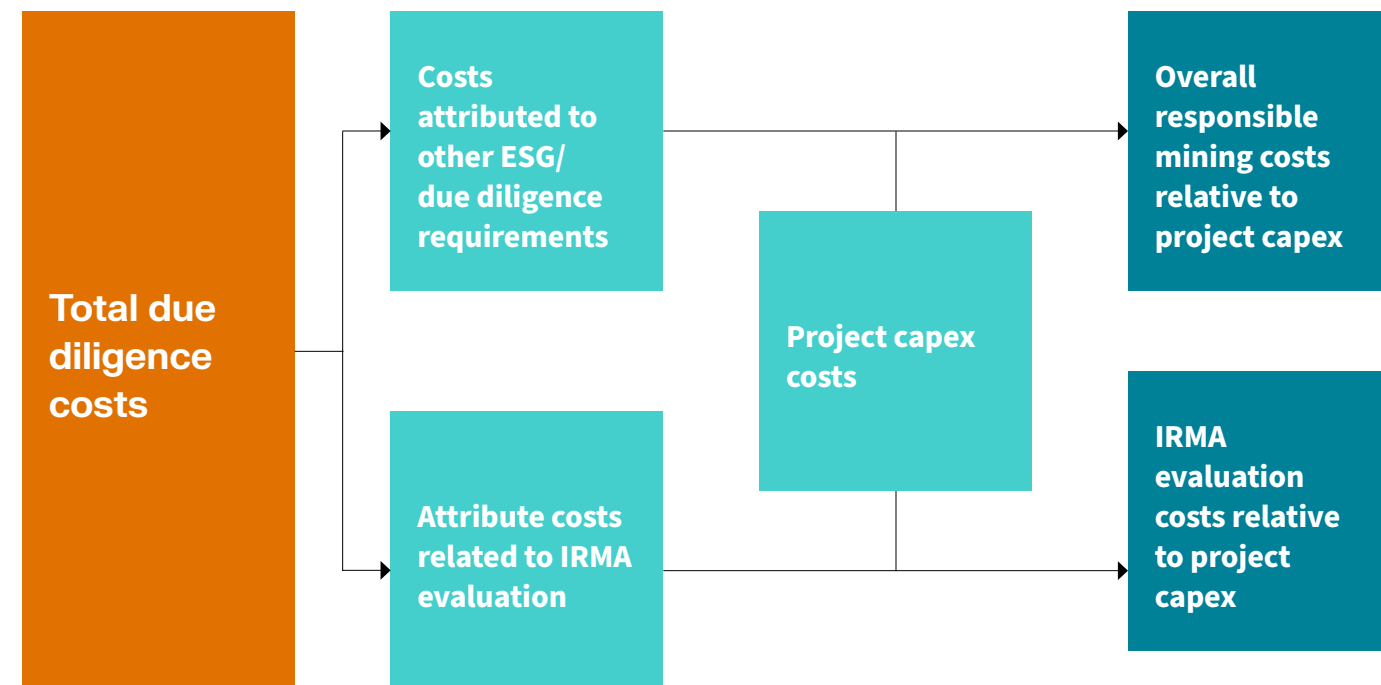


### COST ASSESSMENT APPROACH

**Responsible mining costs are reported relative to a mine's up-front capital investment (capex), and IRMA-specific costs are highlighted.**

### Objective

Provide stakeholders with a clear understanding of the overall cost associated with responsible mining practices, including indicative IRMA evaluation costs for brownfield or and operating sites. By normalizing these costs against a site's total up-front capital expenditure (CAPEX), the analysis enables comparisons across projects of varying scale.



### Outputs

- Relative additional cost of overall responsible mining, including IRMA costs
- Contribution of IRMA costs to responsible mining
- Top three cost drivers in responsible mining process

These costs were incurred over multiple years, including preparatory phases and audit cycles; to ensure comparability across varying timelines, they were discounted using a [geography-neutral rate of 7.18%](#).



COST ASSESSMENT APPROACH

# Cost categories definitions

Overflow text

| Cost category                      | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gap assessment and assurance costs | <p>Gap assessment and assurance costs include activities required to plan, implement, and evaluate responsible mining practices at a site, including both company-led efforts and IRMA audit-related costs.</p> <ul style="list-style-type: none"><li>• <b>Planning activities:</b> This includes company-led planning activities such as baseline environmental and social assessments, and gap assessments in preparation for IRMA audits.</li><li>• <b>Audit costs:</b> This includes fees for an initial IRMA audit to assess performance and an optional verification audit following corrective actions. Verification audits may be required to confirm improvements and update IRMA achievement levels. All four case studies included an initial</li></ul> | <p>audit and a verification audit in their audit cost planning.</p> <ul style="list-style-type: none"><li>• <b>Audit-related costs:</b> Legal review costs related to audit preparation and public disclosures, and auditor accommodation costs were also reported at some sites.</li></ul> <p>While some case studies reported IRMA surveillance audits, they are not treated as part of initial responsible mining investment costs. These are limited in scope and focused on reviewing material changes to ensure IRMA achievement level is maintained.</p> <p><b>Ease of quantification:</b> ●</p> |
| Implementation costs               | <p>This involves costs associated design and rollout of corrective action plans, and any technology or system upgrades undertaken <i>primarily to meet IRMA requirements</i>. It also covers staff time (HSEC, operations, community, procurement), training and capacity building, coordination with auditors and</p>                                                                                                                                                                                                                                                                                                                                                                                                                                             | <p>stakeholders, and internal management systems needed to comply with IRMA expectations. Staff costs are estimated from staff time allocations and salary data.</p> <p><b>Ease of quantification:</b> ●</p>                                                                                                                                                                                                                                                                                                                                                                                            |
| Other responsible costs            | <p>These figures represent the total non-IRMA responsible mining costs incurred to comply with regulatory requirements and other voluntary standards and frameworks, such as GISTM (Global Industry Standard on Tailings Management), HRDD (Human Rights Due Diligence), or other voluntary sustainability or certification frameworks adopted by the site, or internal company policy and practices such as waste management. Cost data reflect the once-off (implementation) and recurring (annual) costs of these frameworks, drawn from industry benchmarks and site-level disclosures.</p>                                                                                                                                                                    | <p>While many of these costs could be overlapping with IRMA given the efforts to harmonize IRMA with existing standards, mining companies typically distinguish between existing investments associated with internal policies or additional voluntary certifications from incremental IRMA-related costs. Therefore, in this study, other responsible mining costs are considered separately from IRMA-specific costs, reflecting the accounting and decision-making perspective gleaned from mining site case studies.</p> <p><b>Ease of quantification:</b> ●</p>                                    |

To enable cross-site comparability, these costs are normalized as a percentage of the site's project capex (total investment value)



BENEFIT ASSESSMENT APPROACH

**Benefits of responsible mining include reduced operational risks and commercial benefits.**



**Avoided losses**

Quantitative benefits assessed as financial impact of three types of incidents that can occur on a mine site:

- Catastrophic losses
- Delays and stoppages
- Fines and remediation

**Incident data was gathered from public databases. The scope was all mining sites globally.**



**Commercial**

Qualitatively assessed across the following categories:

- Market access and demand
- Financing
- Operational excellence
- Social license to operate

**These were surfaced in interviews and augmented through desktop research.**



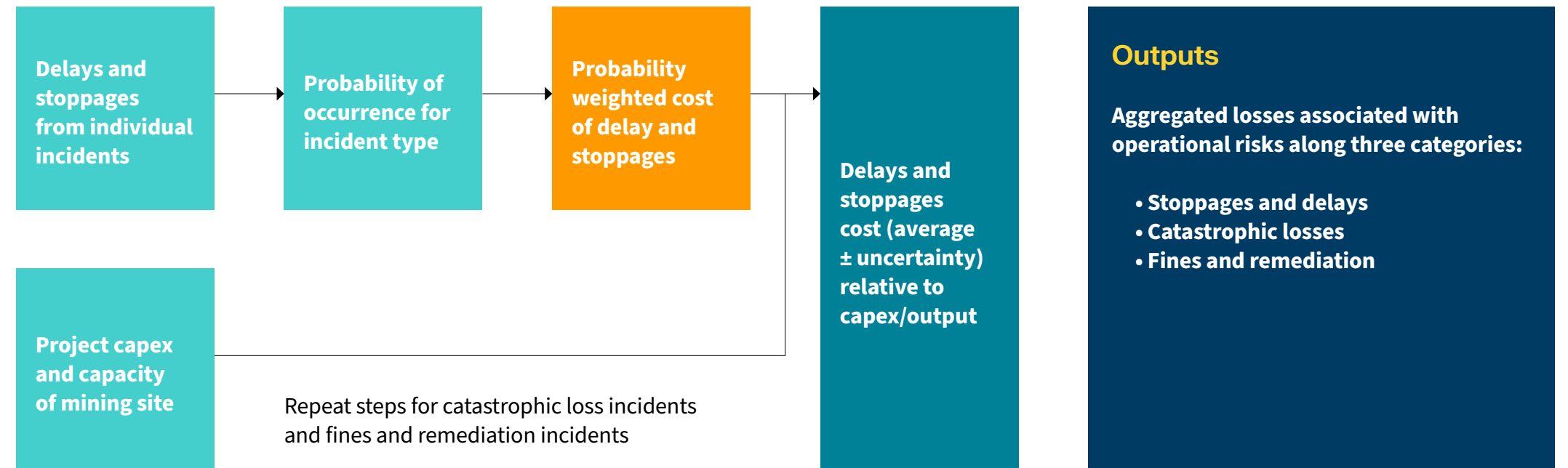


## BENEFIT ASSESSMENT APPROACH

**Operational risks and fine instances are collated, costs adjusted for size of mines and reported relative to up-front investment.**

### Objective

Use historical data of operational delays, losses, and fines to articulate the financial impact of operational risks, and benchmark against the cost of responsible sourcing.



Other potential benefits may include access to lower-cost capital, better market access, or insurance benefits. Quantifying these is beyond the scope of this analysis.



BENEFIT ASSESSMENT APPROACH

# Operational risks definitions

The avoided losses from operational risks are framed as benefits of responsible mining and compared to responsible mining costs.

| Operational risk category       | Description                                                                                                                                                                                                                                                                                                                                                                                                                                   | Ease of quantification |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|
| Production delays and stoppages | Environmental and social disruptions are translated into financial terms by gathering data on incident occurrences from publicly available databases and estimating the value lost per day or per curtailed project using academic <a href="#">research</a> .                                                                                                                                                                                 |                        |
| Catastrophic loss avoidance     | <p>A small number of low-probability events; major spills, tailings failures, or severe social conflicts, can generate catastrophic losses that dwarf routine fines or short-term stoppages. These include large-scale remediation and compensation packages, long-term production losses or permanent closure, and lasting reputational consequences.</p> <p>This does not include natural causes for these events or lawsuits.</p>          |                        |
| Fines and mandated remediation  | Captures the direct financial cost of non-compliance with environmental , social, and safety requirements. It includes: regulatory fines and penalties; mandated remediation, clean-up and compensation; and associated legal and advisory costs. Publicly available historical incident data and enforcement records are used to estimate typical and extreme costs by incident type. This does not include natural causes for these events. |                        |

To enable cross-site comparability, these costs are normalized as a percentage of the site’s project capex (total investment value).



BENEFIT ASSESSMENT APPROACH

# Commercial benefits definitions

| Benefit category | Description                                                                                                                                                                                                    | Ease of quantification                                                               |
|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Capital access   | Responsible mining performance can potentially influence a investors’ decision to provide financing due to lower perceived credit risk by lenders and investors.                                               |   |
| Reputation       | Enhanced reputational benefits which may result in stronger stakeholder relationships, and can contribute to a social license to operate.                                                                      |   |
| Market access    | Responsible mining standards can determine access to certain customers. For some, but not all buyers, this is a simple yes-or-no requirement: meet the standard and you can sell to them; fail and you cannot. |  |

These benefits are flagged as an area where evidence is yet to emerge and are qualitatively assessed rather than quantified.



BENEFIT ASSESSMENT APPROACH

# Operational risk definitions

The avoided losses from operational risks are framed as benefits of responsible mining and compared to responsible mining costs

| Operational risk            | Number of sites | Number of incidents | Minerals assessed           | Attributable concern                                                                                          | Geographies                              | Probabilities of risks used                                                                                              |
|-----------------------------|-----------------|---------------------|-----------------------------|---------------------------------------------------------------------------------------------------------------|------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| Fines and remediation costs | 8               | 17                  | Lithium                     | Water overextraction, water contamination, permitting and community complaints, indigenous community lawsuits | South America                            | <b>Value: 12.0%</b><br>Source: <a href="#">Analysis of the Regional Environmental Performance of Mining Corporations</a> |
| Catastrophic losses         | 4               | 5                   | Lithium<br>Nickel           | Tailings failings, spills, license revocation after environmental outcry                                      | South America, North America, and Asia   | <b>Value: 1.2%</b><br>Source: <a href="#">ksmproject</a>                                                                 |
| Delays and stoppages        | 6               | 6                   | Lithium<br>Nickel<br>Copper | Leaks, spills, community unrest, court injunctions                                                            | South America, North America, and Africa | <b>Value: 6.0%</b><br>Source: <a href="#">ERM Sustainability institute</a>                                               |

Sources for incidents: [Global violation tracker](#), [business and human rights centre transition minerals tracker](#), news reports, company filings

The categorization assumes limited overlap between incident types. For example, legal issues causing stoppages are recorded as a delay or stoppage incidents, while any resulting penalties are recorded as fines. Catastrophic loss events are the extreme form of operational risk, resulting in billion-dollar losses.

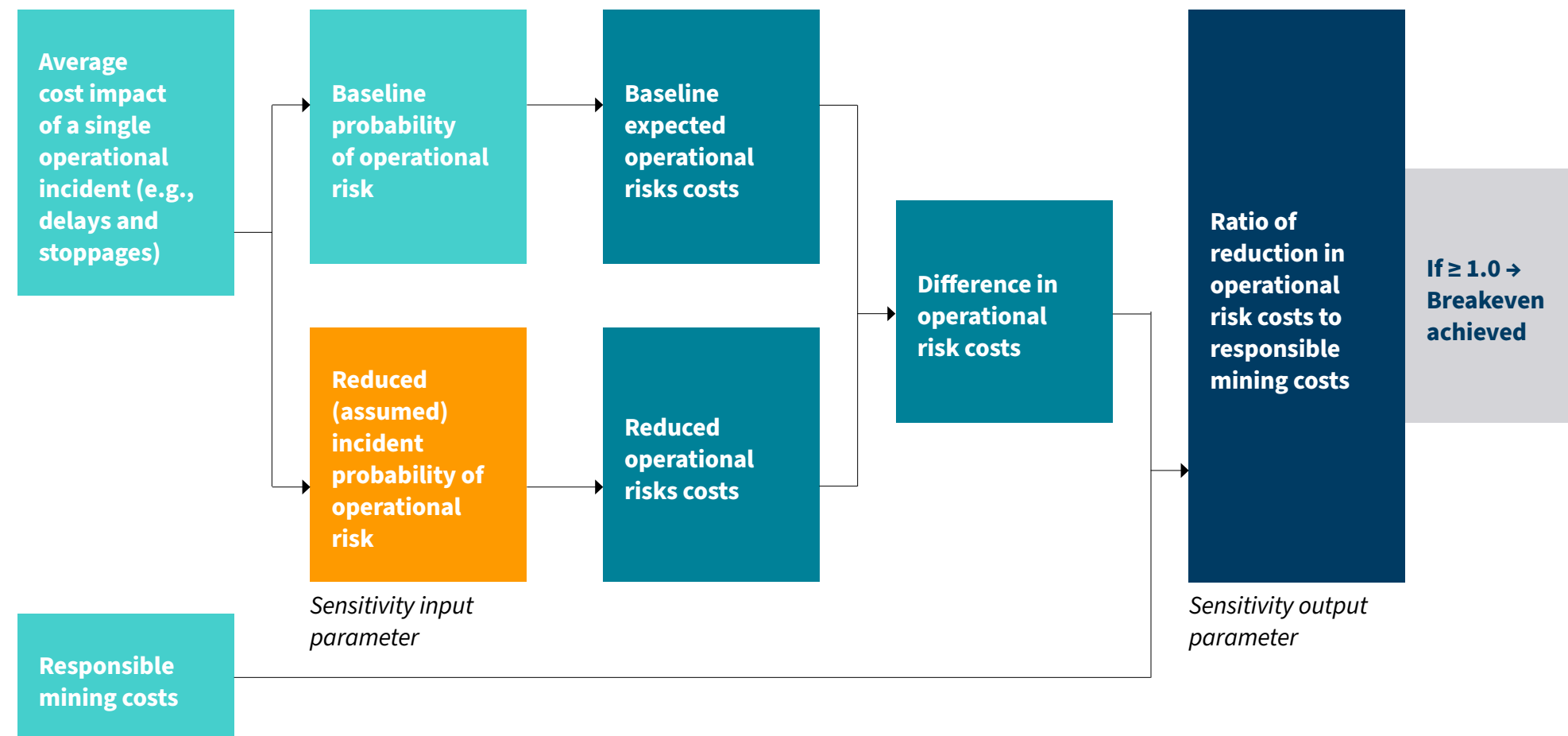


### BREAK-EVEN SENSITIVITY ANALYSIS

# Required risk reduction to break-even responsible mining costs.

## Objective

A sensitivity analysis was performed to evaluate whether modest improvements in risk outcomes are sufficient to justify the costs associated with responsible mining. These improvements can be expected with structured risk management and governance, the guiding principles of responsible mining standards.



**This break-even sensitivity analysis** does not attempt to empirically prove that implementing responsible mining best practices reduces incident rates. It considers plausible risk reduction scenarios to evaluate whether modest improvements in risk outcomes — consistent with structured governance and independent oversight — are sufficient to justify the cost.



## **3. Analysis results**



RESPONSIBLE MINING PROCESS FLOW AND COSTS

**A mining site's responsible mining costs are driven by internal policies and compliance, in addition to meeting voluntary IRMA requirements.**

Drivers

**Internal policy or compliance requirements**

**Examples, not exhaustive:**

- Adhering to local regulations
- Health and safety certifications
- Tailings management

**IRMA requirements**

**Examples, not exhaustive:**

- Free, Prior, and Informed Consent
- Accessible, functional grievance
- Tailings management

Activities

**Activities required solely for internal policy and/or compliance**

**Overlapping activities between internal policy, compliance, and IRMA requirements**

**Implementation activities solely for meeting IRMA requirements**

**Audits for independent, third-party verification**

Costs

**Other responsible mining costs**

**Costs associated with IRMA implementation\***

**Gap assessment costs**

Company-led assessment with baseline environmental and social studies, audit preparation efforts, etc.

**Implementation costs**

Improvements and corrective actions to address gaps, ongoing monitoring and stakeholder engagement, and management systems

**Assurance costs**

These are costs associated with independent third-party evaluation of a mining site's performance against IRMA requirements. Depending on site readiness and the targeted IRMA achievement level, the audit cycle may include more than one audit: an initial audit to assess baseline IRMA achievement level, followed by an optional verification audit to reassess IRMA achievement level after corrective actions have been implemented. Final audit results are publicly disclosed. All four case studies included both an initial audit and a verification audit in their assurance cost planning.

\*Additional details around costs are included in Cost categories definitions on [Page 26](#)

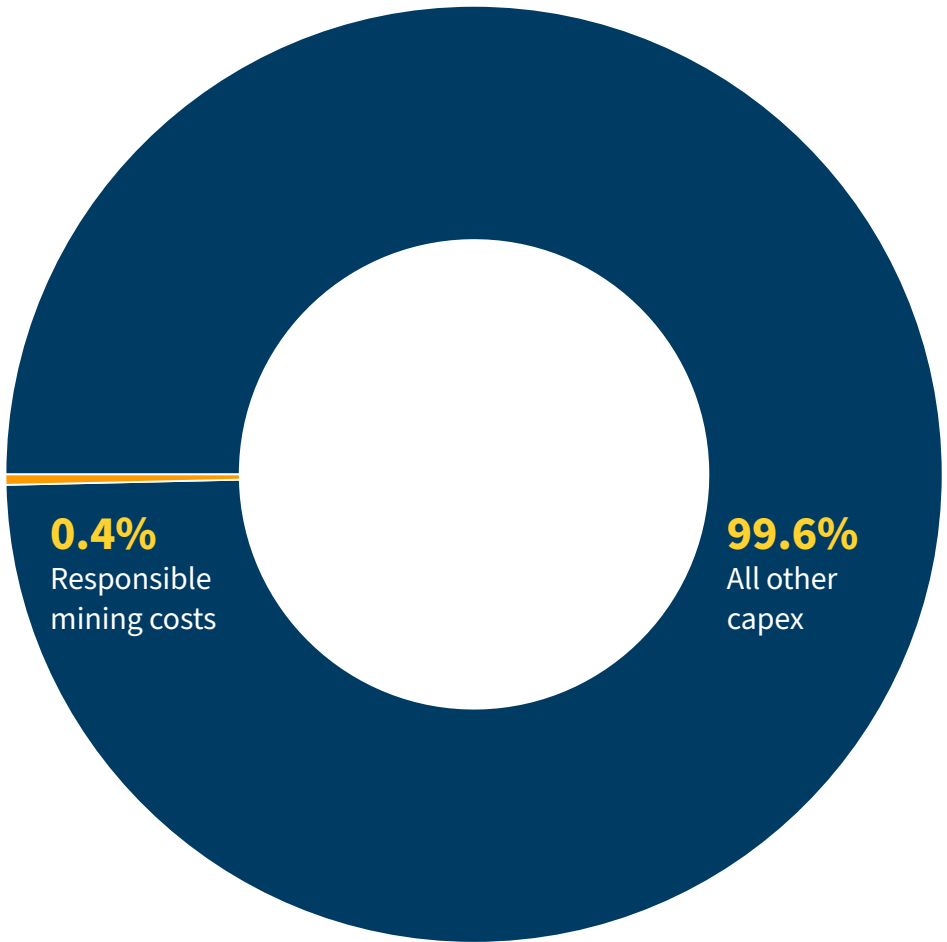


THE NEED FOR RESPONSIBLE MINING STANDARDS

**Responsible mining costs average 0.4% of a project's up-front capital expenditure.**

**Responsible mining costs with respect to mining project capex**

On an average ~\$1.18 billion capex project, responsible mining costs average ~\$4.1 million.



Responsible mining costs are **small compared to the up-front cost** of a mining asset.

Miners may already be investing in responsible mining practices. The **incremental portions for implementing a rigorous voluntary standard like IRMA with independent third-party verification and corrective actions is no more than two-fifths** of the overall costs of implementing responsible mining best practices.

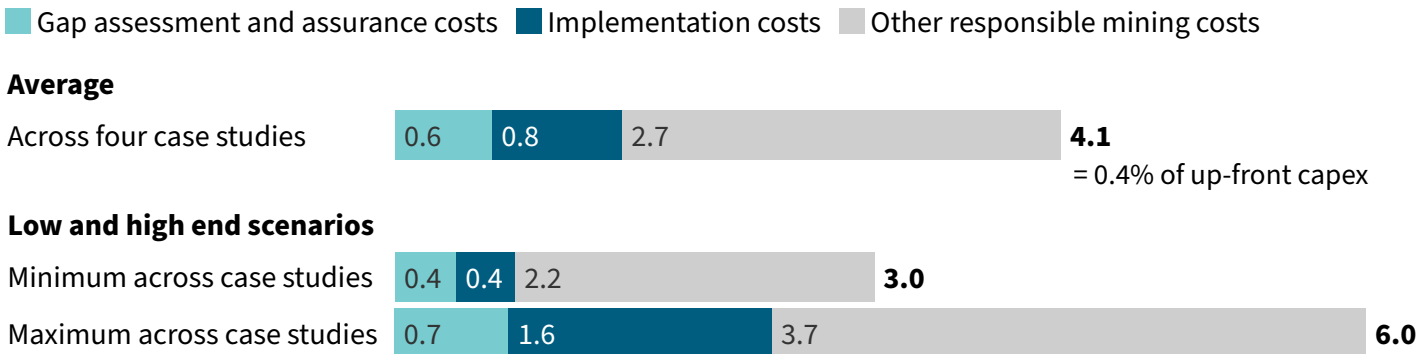
Incremental responsible-mining costs beyond the baseline can vary by operational stage; brownfield developments can face higher increments than operating mines because key requirements (ESIA updates, community engagement, etc.) may need to be established or strengthened for brownfield sites.

Assurance costs tied to IRMA audits can vary depending on factors such as geography, location, scope of audit, mine type, and operational complexity.

One avenue to reduce audit-related costs may involve minimizing on-site auditor engagement through more thorough pre-audit preparation. While this can lower direct audit costs, it would require additional effort and resources from the mining company during the preparation phase. As a result, overall gap assessment and assurance costs may not be materially reduced.

**Breakdown of responsible mining costs\***

In millions of dollars

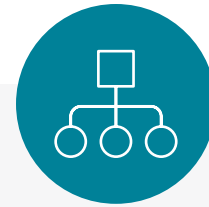


\*Responsible mining costs may be influenced by factors not explicitly assessed in this study including regulatory stringency, company governance practices, operator type (junior versus mining major and jurisdictional context).



#### ANALYSIS INSIGHTS

**Although responsible mining cost is a small share of capital expenditure, its significance depends on where and how decisions are made.**



#### Decision context

- While responsible mining costs are small relative to overall capital expenditure, their significance can vary depending on where decisions are made.
- At the board level and from the overall organization lens, these investments may be considered modest but at the operational level, where project team or sustainability budgets may be tightly managed, incremental expenditures may receive closer scrutiny.
- This underscores the need for a thorough consideration of the benefits at both the site and enterprise levels.



#### Site-level context

- Responsible mining costs are influenced by several structural features, including company-specific internal practices, differences between junior operators and mining majors, size of mining operation, and variation in regulatory stringency across jurisdictions.
- In regions where regulatory frameworks are relatively well-established and enforced, adopting voluntary responsible mining standards may represent incremental enhancements. In contrast, in regions with less comprehensive regulations or weaker enforcement, it can drive more substantive improvements in operational practices and governance.
- These dynamics shape both the baseline level of compliance and the incremental value of responsible mining.



#### Cashflow perspective

- The cost structure of responsible mining is inherently mixed: ongoing activities such as audits and monitoring are opex-like, while many implementation activities are one time costs. Such system-level upgrades are typically front-loaded and capex-like.
- However, even the front loaded capex-like costs (e.g., gap assessments and system upgrades) are incurred over a few years. This reduces the financial burden over a single year.
- These costs should be understood as risk mitigation investments to proactively address social and environmental risks, supporting responsible outcomes, long-term operational continuity, and revenue cashflows.
- These costs should be benchmarked against a site's environmental and social risk exposure, which does not neatly align with opex or capex classification.

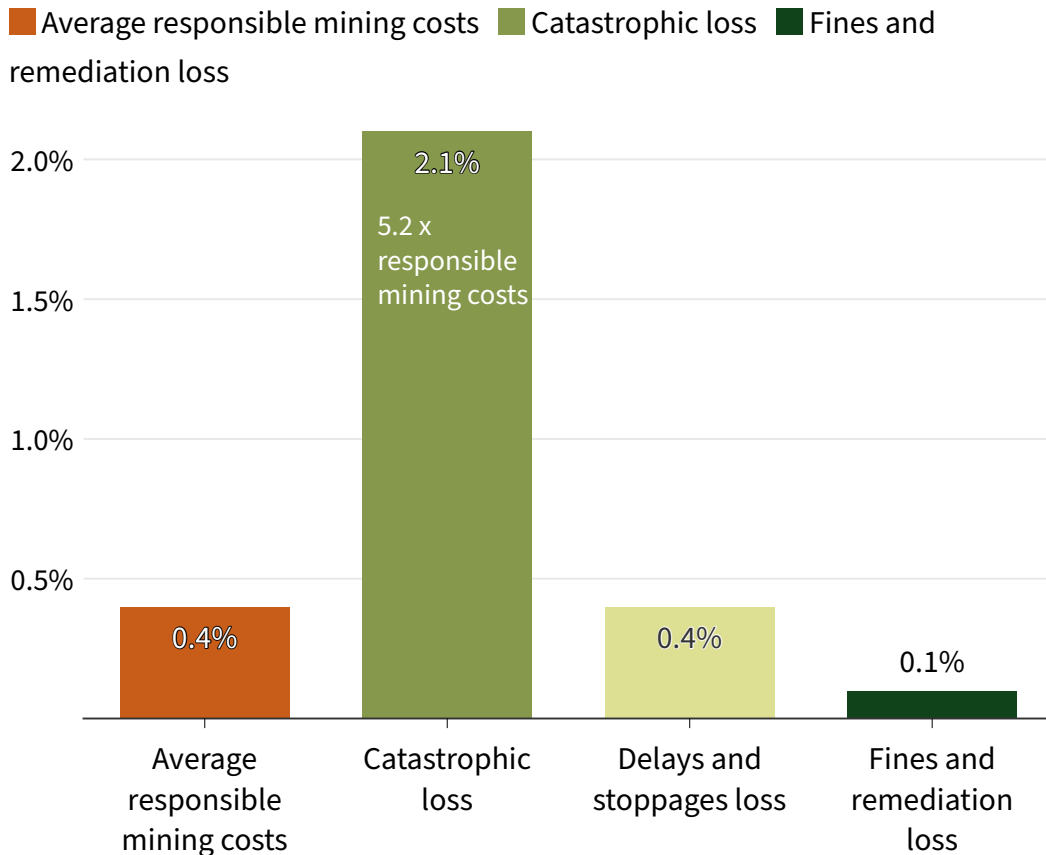


ANALYSIS INSIGHTS

# Responsible mining costs are small relative to the possible loss exposure.

Loss exposure can be up to approximately 5x responsible mining costs.

Average responsible mining costs versus financial impact of potential operational risks (probability-weighted)



Notes

- 1. Values normalized as percentage of capex for cross-site comparability
- 2. Operational risk incident data sources: Transition Minerals Tracker; Company reports; Business and Human Rights Resource Centre; News reports
- 3. Catastrophic loss reflects tailings dam failure scenarios and is relevant primarily to hard rock mines; delays and stoppages and fines and remediation are broadly applicable.

**Responsible mining practices** are designed to strengthen governance and operational controls, reducing unmanaged risks over the full life of a mine.

**The cost of implementing responsible mining is modest relative to the financial exposure from operational disruptions** caused by delays, stoppages, or catastrophic events. Operational delays and stoppages tend to be the more frequently encountered risk and can materially affect cash flow. Catastrophic losses may be less frequent but have more severe impact.\*

The analysis considers probability-weighted operational risk losses. If an incident occurs, realized losses can be an order of magnitude higher. Realized losses are estimated based on historical case studies of operational disruptions and tailings failures, including fines, remediation, legal costs and extended production stoppages

Financial impact of operational risk is assessed based on publicly reported enforcement incidents and cost of enforced actions. In case of delays and stoppages, impact is estimated based on loss of production.

\*Tailings failures can vary significantly by region and how those tailings facilities are built. In regions characterized by extreme rainfall, and/or there is high seismic activity, reports of tailings breaches can be more frequent

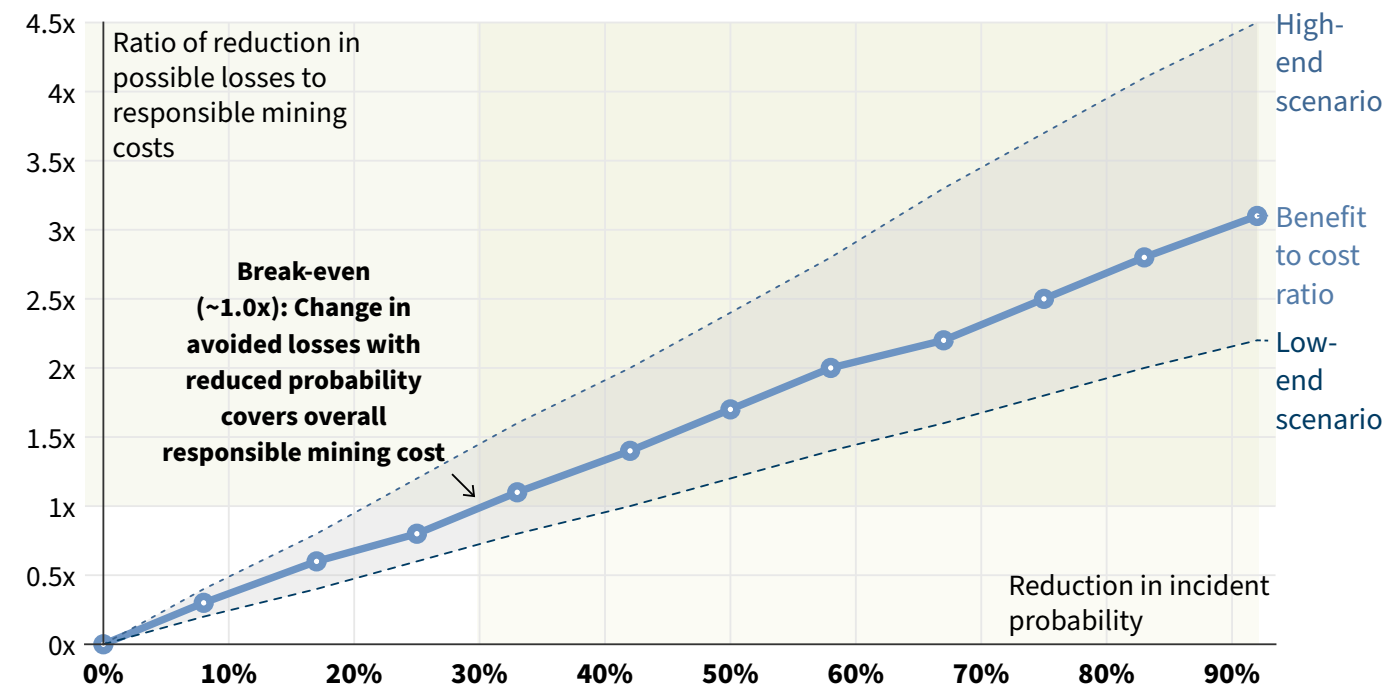


### ANALYSIS INSIGHTS

# A modest reduction in delay and stoppage risk justifies responsible mining investments.

The breakeven threshold will vary by project, as the severity of delays and stoppages differs depending on size of mine and commodity involved.

### Sensitivity analysis for delays and stoppage risk



**Note:** This break-even sensitivity analysis does **not** attempt to empirically prove that implementing responsible mining best practices reduce incident rates. It considers plausible risk reduction scenarios to evaluate whether modest improvements in risk outcomes — consistent with structured governance and independent oversight — are sufficient to justify the cost.

By comparing the responsible mining costs to reduction in possible losses as a function of incident probability, the sensitivity analysis helps to understand the extent of probability reduction that can justify responsible mining investment. It shows that if responsible mining reduces the risk of stoppage by one-third (from a baseline of 6% probability to 4%), the investment breaks even.

Stoppages and delays are the highest probability risk faced by mine sites and apply at both the individual site and portfolio level. The impact of this risk can vary by site, commodity, and size of the mine.

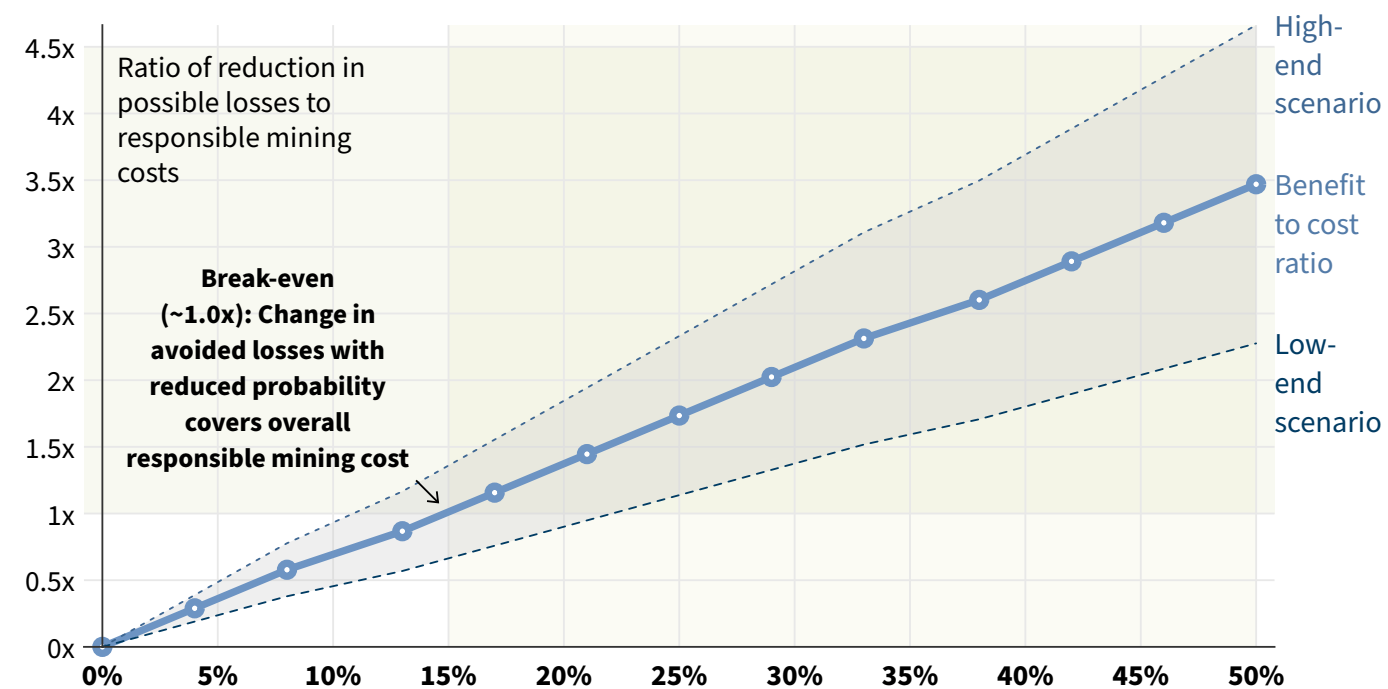
The costs of delays are associated with lost revenue from duration of stoppages due to social, environmental, or legal reasons, and [academic studies](#) exploring the financial impact of loss of mining production.



ANALYSIS INSIGHTS

# Catastrophic tailings failure risk reduction through responsible mining has outsized value.

## Sensitivity analysis for catastrophic loss risk



**Note:** This break-even sensitivity analysis **does not** attempt to empirically prove that implementing responsible mining best practices reduce incident rates. It considers plausible risk reduction scenarios to evaluate whether modest improvements in risk outcomes — consistent with structured governance and independent oversight — are sufficient to justify the cost.

**Tailings management is one of the key areas** of responsible mining practices. Catastrophic tailings failures may be low probability events but have significant impact. These are high-severity, high-cost events. The cost of tailings management associated with adoption of [Global Industry Standard on Tailings Management \(GISTM\)](#) was noted in all case studies and have been included as a part of responsible mining costs.

If responsible mining credibly reduces the likelihood of catastrophic events by one-fifth (from baseline 1.2% probability to 0.95%), the business case for investing into responsible mining is overwhelmingly positive.

Catastrophic tailings risk may seem rare at the site level,\* but portfolio exposure compounds for multi-asset operators. Implementing tailing management best practices that deliver modest probability reductions can deliver significant risk-adjusted value and enhance long-term resilience when considered across assets and over decades.

\*Tailings failures can vary significantly by region and how those tailings facilities are built. In regions characterized by extreme rainfall, and/or there is high seismic activity, reports of tailings breaches can be more frequent.



## 4. Insights



ANALYSIS INSIGHTS

**Stakeholders agreed that responsible mining also delivers real value beyond quantifiable benefits.**

**Key additional benefits**

**Market access**

A growing group of buyers are requiring mining companies to adopt responsible mining standards for regulatory compliance, due diligence, and continuity of supply.

Even in cases without guaranteed offtake, responsible mining helps miners keep options open for a differentiated market or improved access with future buyers.

**Capital access**

Responsible mining practices derisk against operational interruptions, signal transparency, and accountability, resulting in maintained or improved access to capital. Benefits are more visible when ESG risks are closely scrutinized (e.g., project finance, mid-tier miners, or first-time borrowers).

Responsible mining standards adoption might be a threshold requirement for development-focused investors such as development banks and impact investors.

**Operational excellence**

Responsible mining drives increased collaboration among different teams within a mining company. Standardized process improves operational excellence.

**Social license to operate**

Multi-stakeholder engagement and a robust and accessible grievance mechanism improve community dialogue.

Miners as well as producing regions are able to signal transparency and accountability to investors, buyers, and civil society – thus building their social license to operate.

Independent third-party verification enhances the assurance from miners and producing regions.

Such assurances can be particularly helpful in less regulated regions or for new mining entrants.



## CONCLUSION

**The cost-benefit assessment reveals responsible mining investments can be economically rational.**

### Analysis and stakeholder insights

- 1** Case studies show responsible mining costs are small when compared to up-front mining site investment.
- 2** Responsible mining costs are lower than the potential financial impact of operational risks such as delays and stoppages or catastrophic losses.
- 3** A small reduction in the probability of operational risk incidents can justify the cost of responsible mining practices.
- 4** Beyond impact to the company bottom line, responsible mining provides a boost to a mining company's social license to operate by improving affected community and civil society relationships while also improving market and capital access.

Responsible mining costs are useful investments for incorporating structured risk management and governance, while supporting a mining company's social license to operate.

Potential benefits outweigh costs and reach stakeholders through the end of the value chain — from the mining company to the consumer, including the end-product manufacturers, affected communities and workers, regional authorities, and civil society.

These data points support the adoption of responsible mining standards and practices.



# **5. Appendix**



# Key assumptions

| Area                     | Assumption                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Scope of analysis        | Results refer to a representative mine, not a specific asset.                                                                                                                                                                                                                                                                                                                                                                                                      |
| Company type             | This is based mainly on large, professionally managed operators, similar to major companies rather than junior ones.                                                                                                                                                                                                                                                                                                                                               |
| Parameterizing costs     | All costs are parameterized as % of project capex and \$/ton of site nameplate capacity to allow comparison across mines (in the same mineral group) and cost categories.                                                                                                                                                                                                                                                                                          |
| Incident data use        | Historical incidents observed for lithium, nickel, copper, iron, and platinum group metals and are used to set order-of-magnitude cost levels for each risk.                                                                                                                                                                                                                                                                                                       |
| Independence of benefits | The three quantified benefits are treated as additive and non-overlapping.                                                                                                                                                                                                                                                                                                                                                                                         |
| Role of IRMA             | Stakeholders emphasized the overlapping nature of responsible mining practices, and indicated neither costs nor benefits can be solely attributed to IRMA. This is also a logical outcome of detailed requirements in IRMA standards for implementing best practices while cross-referencing and harmonizing across existing practices (e.g., GISTM and ISO frameworks). The cost to implement IRMA thus serves as proxy for responsible mining cost case studies. |
| Responsible mining costs | Costs incurred over multiple years (including preparatory phases and audit cycles) are discounted using a geography-neutral rate of 7.18% to standardize comparability across projects and time horizons.                                                                                                                                                                                                                                                          |



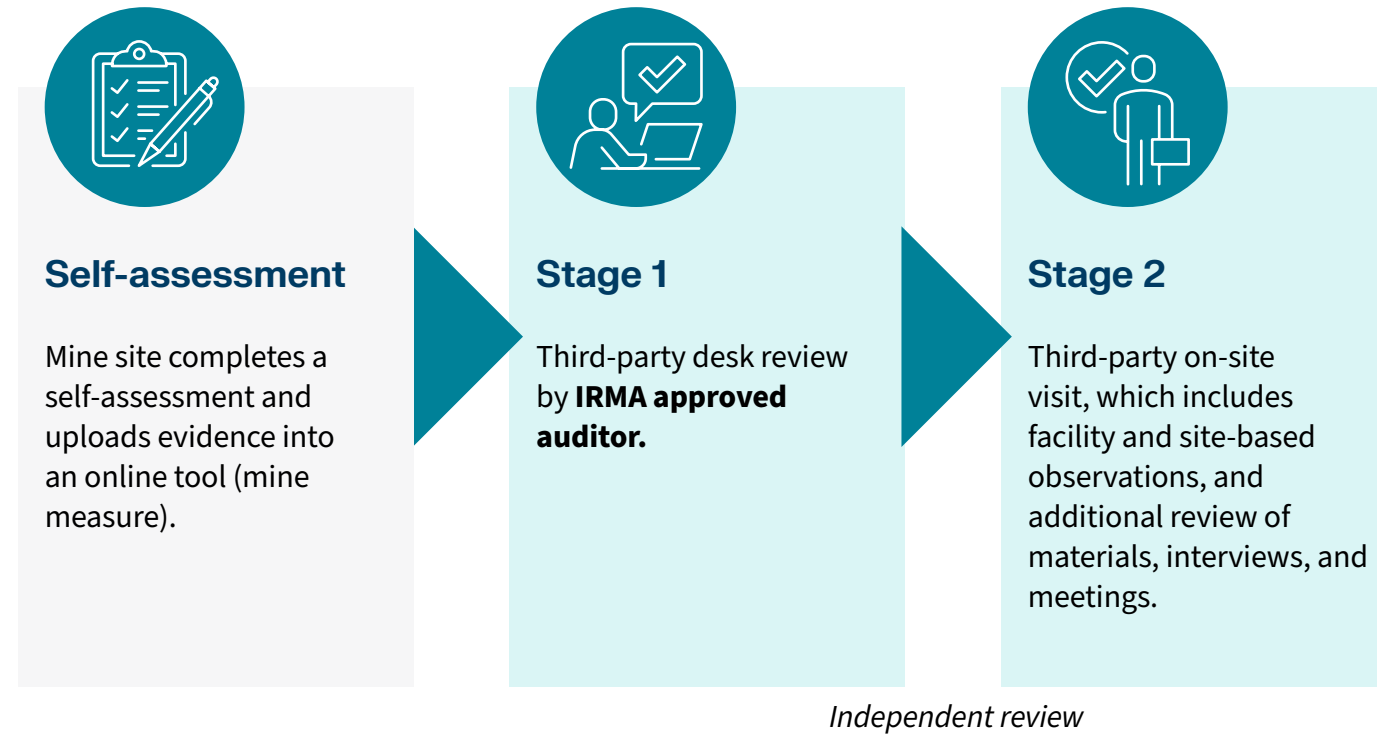
# Uncertainties

|                                   | What's uncertain                                                                                                                                                                                                                                                                       | Implication                                                                                                                                                                        |
|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Incident data coverage            | Few incidents have publicly disclosed financial costs; many events are under-reported or confidential.                                                                                                                                                                                 | Cost associated with ESG incidents are uncertain due to small sample size.                                                                                                         |
| Representativeness of cases       | Quantification relies on a small number of large, visible operators and incidents.                                                                                                                                                                                                     | May under- or over-state costs for juniors, very small mines, or very different operating contexts.                                                                                |
| Jurisdictional variation          | Enforcement strength, fines, and remediation requirements vary widely by country but that variation is not included in the model.                                                                                                                                                      | A single representative cost associated with ESG incidents may mask big differences between jurisdictions.                                                                         |
| Catastrophic loss parameters      | Catastrophic events are rare with limited data, but very high impact.                                                                                                                                                                                                                  | The catastrophic loss category is particularly uncertain; small changes in assumed frequency have big effects on results.                                                          |
| Responsible mining cost reporting | Responsible mining cost implementation costs come from only a few sites and companies. Sites can have significant variation in their efforts for audit preparation and baseline gap assessment. They may also hire external consultants to support preparation.                        | Actual costs for other operators may be higher or lower depending on existing systems and capability.                                                                              |
| Overlap with other standards      | Many IRMA adopters also follow other ESG/technical standards.                                                                                                                                                                                                                          | Unable to attribute risk reduction uniquely to IRMA versus broader good practice.                                                                                                  |
| Static lifetime view              | Costs associated with operational risks are expressed as percentage of capex, not modeled dynamically over time. Responsible mining costs are derived from case studies that reported these costs over a time period and were consolidated using net present value (NPV) calculations. | May understate the financial significance of operational risks or overstate precision in responsible mining costs, because the two are not modeled on a consistent temporal basis. |





# Cost of adopting rigorous and comprehensive standards like IRMA go beyond audits and include implementation and corrective action costs.



## Costs related to the process include:

- Audit costs
- Labor costs
- Costs for additional studies and systems for corrective actions

## Assessment results

**Certification body** makes a decision on whether a mine is fully, substantially, partially, or not meeting each of the IRMA standard requirements.

**Corrective action plans:** A mine may postpone the release of its audit results for up to 12 months while it implements corrective actions to reach a higher level and gain recognition for improved performance.



# IRMA compliance and cost implications

Companies included in this analysis reflect different stages of IRMA engagement:

- Aspirational IRMA 100 (full conformance across all IRMA requirements)
- Aspirational IRMA 75 (substantial alignment with IRMA criteria)
- Ongoing assessment (currently undergoing or maintaining IRMA audit cycles)

## IRMA 75

- Majority alignment with standard criteria
- Targeted system upgrades and gap remediation
- Enhanced monitoring, engagement, documentation

## IRMA 100

- Full compliance across all performance areas
- More comprehensive governance systems
- Deeper integration of human rights, environmental management, and transparency requirement

## Cost implications

- Higher attainment levels generally require broader and more sustained system upgrades and investment
- Aspirational targets involve phased investments over multiple years
- Cost intensity reflects both compliance ambition and baseline conditions at the site



**E.J. Klock McCook, Monkgogi Buzwani and Sudeshna Mohanty,**  
*Responsible Mining for the Energy Transition*, RMI, 2026,  
<https://rmi.org/insight/responsible-mining-for-the-energy-transition>.

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