ESG Stranded Assets Analysis

Carbon Transition Risk in Copper Mining

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Research Emerging Topics

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Quantifying Climate Transition Risk Across 914 Global Mining Assets

Project Overview

Research Questions:

- Which copper mining assets become unprofitable under carbon pricing?
- What is the total financial exposure to carbon costs?
- How are emissions trending over time (2021-2024)?
- Can we predict stranded asset risk using machine learning?

Scope:

- 914 mining assets globally
- 56+ countries analyzed
- 51,184 monthly emission records
- 4 carbon pricing scenarios

Data Source:

Climate TRACE v5.2.0

- Satellite + AI emissions tracking
- Monthly data: Jan 2021 - Aug 2025
- Most comprehensive global emissions database

Methodology:

- Financial risk modeling
- Machine learning predictions
- Interactive web dashboard
- Scenario stress testing

The Problem: Carbon Pricing Impact

$19.04 Billion

Annual carbon cost exposure at $200/tCO$_2$

914 Assets	**56 Countries**	**259 Assets**	**28.3%**
Global copper mines	Worldwide coverage	At critical/high risk	Of assets vulnerable

Carbon pricing will destroy value. The question is: how much?

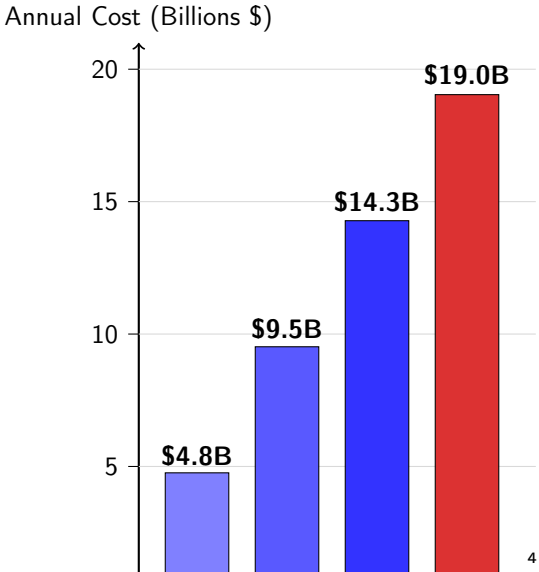
Key Finding #1: Massive Financial Exposure

Carbon Cost by Scenario:

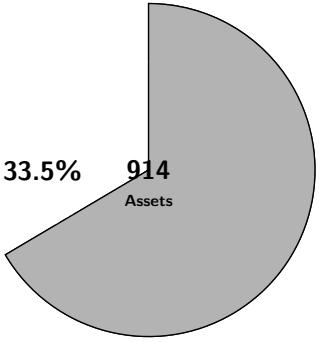
Scenario	Annual Cost
$\$50/tCO_2$	\$4.76B
$\$100/tCO_2$	\$9.52B
$\$150/tCO_2$	\$14.28B
$\$200/tCO_2$	\$19.04B

Key Metrics:

- \$14.28B swing between \$50 and \$200 scenarios
- Every $\$10/tCO_2$ = \$950M additional cost
- Top 10% of assets = 51.6% of exposure
- Median break-even: $\$776/tCO_2$



Key Finding #2: Risk Distribution



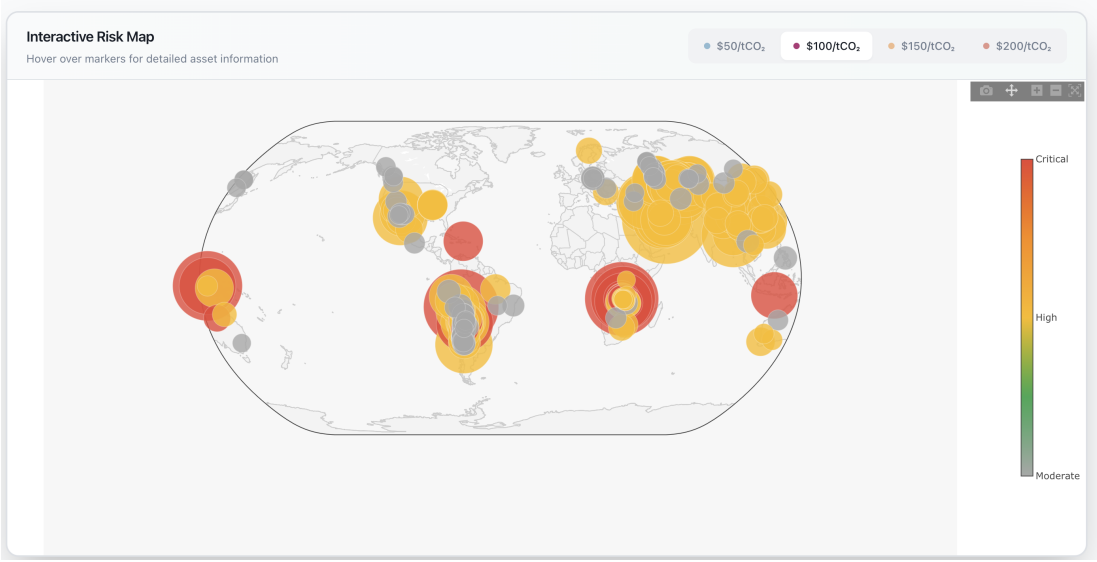
Risk at $100/tCO$_2$

Risk Level	Assets	%
Critical	21	2.3%
High	238	26.0%
Moderate	342	37.4%
Low	7	0.8%
Already Closed	*306*	*33.5%*
Total	**914**	**100%**

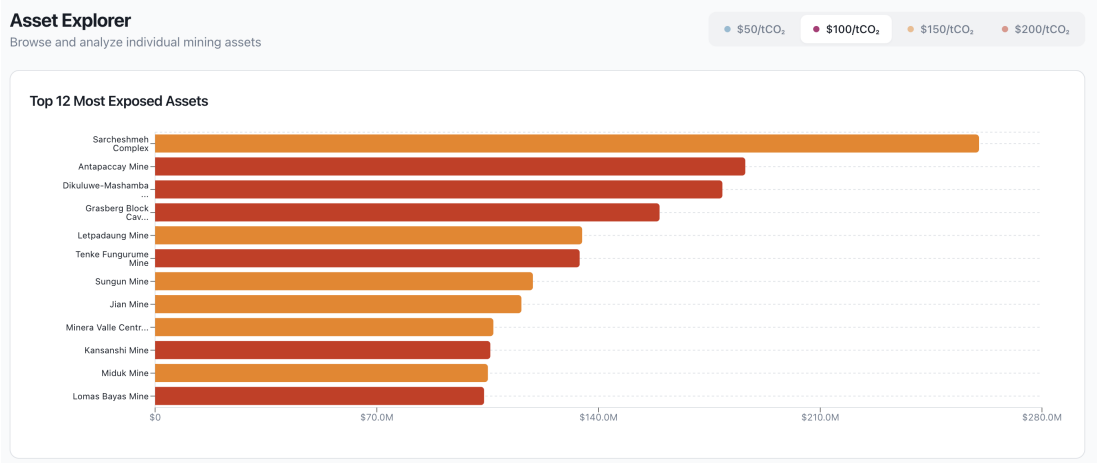
Key Insight

259 assets (28.3%) require immediate strategic intervention
(Critical + High risk categories)

Interactive Dashboard: Overview



Interactive Dashboard: Asset Analysis



Interactive Dashboard: Geographic Risk Mapping

Company Portfolio Analysis

Analyze carbon exposure by parent company

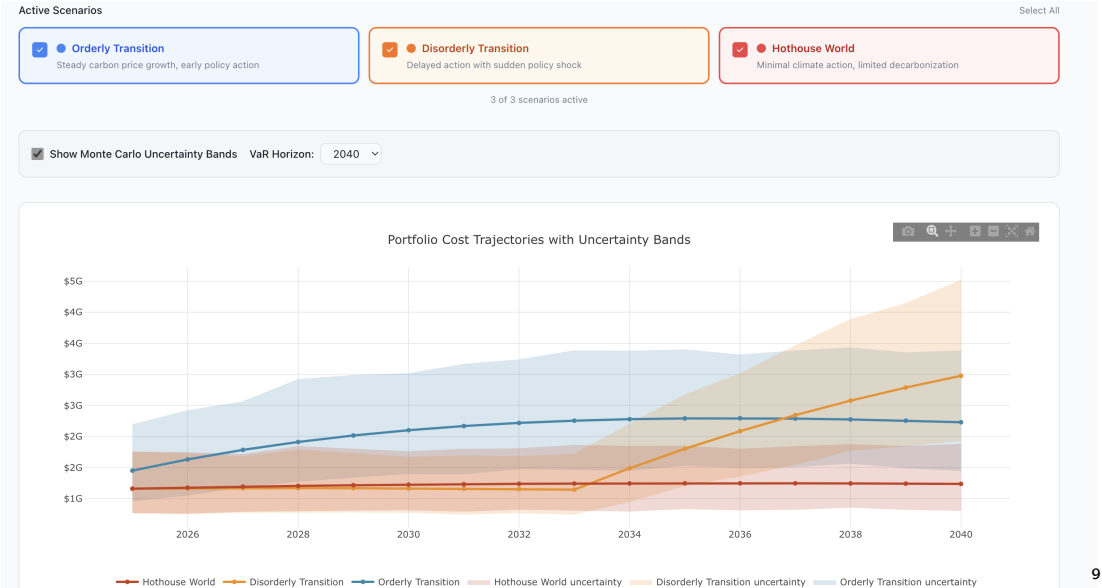
$50/tCO₂ | $100/tCO₂ | $150/tCO₂ | $200/tCO₂

Top 25 Companies by Exposure

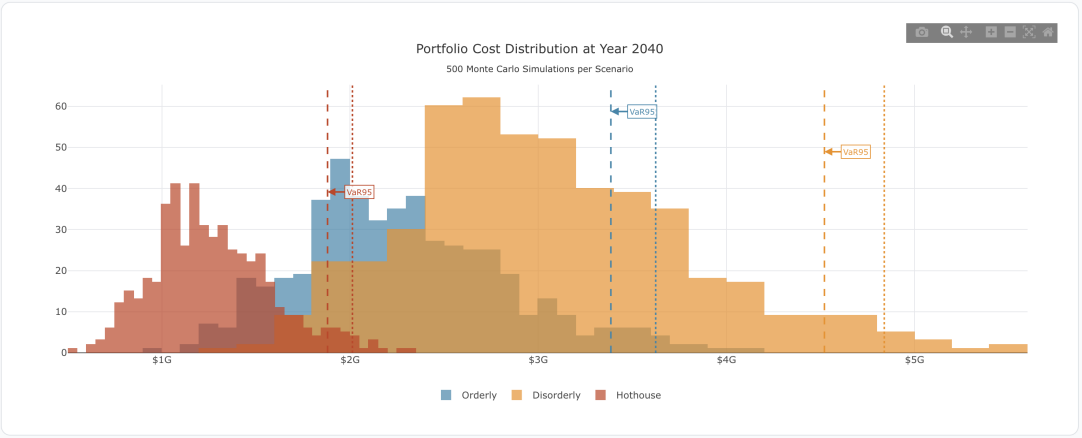
Export

Company	Mines	Total Emissions	Exposure @ $100/tCO₂	Carbon Intensity
FreePort-McMoran Inc	11	4,858,750.02 tCO₂	$485.9M	0.0104
Government of Iran	3	4,844,845 tCO₂	$484.5M	0.0240
Qatar Investment Authority	11	2,318,213.002 tCO₂	$231.8M	0.0445
Kazakhmys Holding LLP	4	2,262,216.04 tCO₂	$226.2M	0.0056
The Vanguard Group Inc	14	2,091,091 tCO₂	$209.1M	0.0045
Zijin Mining Group Co Ltd	10	1,641,364.428 tCO₂	$164.1M	0.0158
Eurasian Resources Group SARL	5	1,400,075.296 tCO₂	$140.0M	0.0092
First Quantum Minerals Ltd	5	1,384,564 tCO₂	$138.5M	0.0097
Glencore PLC	2	1,345,730 tCO₂	$134.6M	0.0455
Government of Poland	6	1,203,982.002 tCO₂	$120.4M	0.0128

Interactive Dashboard: Scenario Analysis



Interactive Dashboard: Risk Categories



$50/tCO$_2$

$4.76B

$100/tCO$_2$

$9.52B

+100% from baseline

$150/tCO$_2$

$14.28B

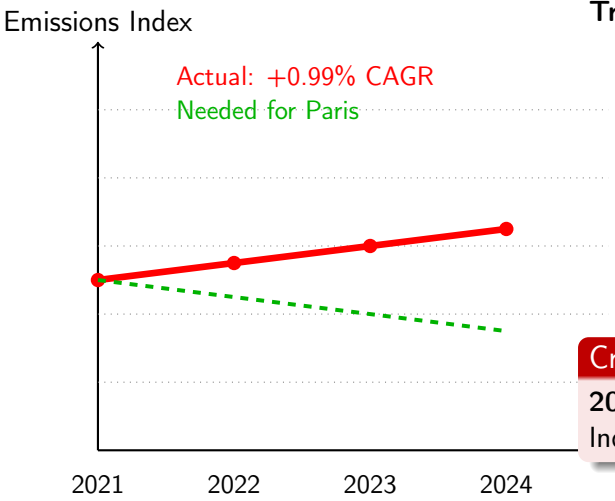
+200% from baseline

$200/tCO$_2$

$19.04B

+300% from baseline

Key Finding #3: Emissions Trending Upward



Trajectory Analysis:

Trend	Assets
Deteriorating (>10% ↑)	202
Improving (>10% ↓)	119
Stable (±10%)	208

Critical Problem

202 assets have worsening emissions
Industry moving *away* from decarbonization

Key Finding #4: Company-Level Exposure

Top 10 Companies by Carbon Cost

Rank	Company	$M @ $100
1	**Freeport-McMoRan**	**1,245**
2	**Codelco**	**1,123**
3	**BHP**	**987**
4	Rio Tinto	876
5	Glencore	845
6	Southern Copper	678
7	Anglo American	534
8	First Quantum	498
9	Antofagasta	445
10	Teck Resources	389
	Top 10 Total	**7,620**

Concentration

Top 10 companies = **80%** of industry exposure

Investor Implications:

- Major portfolio companies at risk
- ESG ratings will reflect exposure
- Shareholder pressure mounting
- Divestment risk for worst performers

Company Response Needed:

- Asset-level decarbonization plans
- Renewable energy investment
- Strategic divestments

Key Finding #5: Predictive Risk Modeling

Random Forest Model

Metric	Score
Accuracy	84.2%
Precision	79.3%
Recall	72.7%
ROC-AUC	0.87

Feature Importance:

- Carbon Intensity: 31%
- Capacity Factor: 24%
- Production Volume: 18%
- Temporal Trend: 12%
- Other factors: 15%

What This Enables:

Proactive Risk Management

Predict which assets will become stranded *before* they fail

Use Cases:

1. **Portfolio optimization**
   Divest high-risk assets early
2. **Targeted interventions**
   Focus capex on saveable assets
3. **Valuation adjustments**
   Price carbon risk into M&A
4. **Insurance pricing**
   Risk-based carbon insurance

Recommendations

Mining Companies

1. **Immediate audit**
   Assess 259 critical/high-risk assets
2. **Divest underwater assets**
   El Salvador, Sepon already unviable
3. **Decarbonization capex**
   Prioritize open pit electrification
4. **Renewable PPAs**
   Lock in green power for processing
5. **Enhanced disclosure**
   Asset-level carbon reporting

Investors & Lenders

1. **Portfolio stress testing**
   Model $150-200 carbon scenarios
2. **Engagement campaigns**
   Demand decarbonization plans
3. **Credit risk repricing**
   Adjust spreads for carbon exposure
4. **Thematic opportunities**
   Low-carbon copper as alpha source
5. **Voting actions**
   Support climate resolutions

Conclusion

The copper mining industry faces a $19B annual carbon crisis

28% of assets
at critical/high risk

Emissions rising
+0.99% CAGR

Cost multiplying
4x from $50 to $200

Massive value destruction unless industry acts now

This is not a distant threat. Carbon prices are already rising.

Thank You

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