

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

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

\$19.04 Billion

Annual carbon cost exposure at \$200/tCO₂

914 Assets

Global copper mines

56 Countries

Worldwide coverage

259 Assets

At critical/high risk

28.3%

Of assets vulnerable

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

Key Finding #1: Massive Financial Exposure

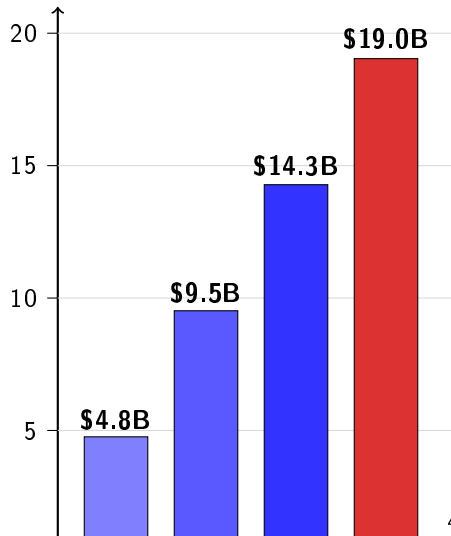
Carbon Cost by Scenario:

Scenario	Annual Cost
\$50/tCO ₂	\$4.76B
\$100/tCO ₂	\$9.52B
\$150/tCO ₂	\$14.28B
\$200/tCO ₂	\$19.04B

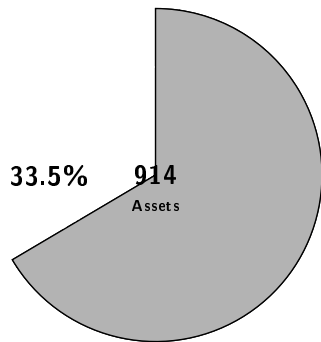
Key Metrics:

- \$14.28B swing between \$50 and \$200 scenarios
- Every \$10/tCO₂ = \$950M additional cost
- Top 10% of assets = 51.6% of exposure
- Median break-even: \$776/tCO₂

Annual Cost (Billions \$)



Key Finding #2: Risk Distribution



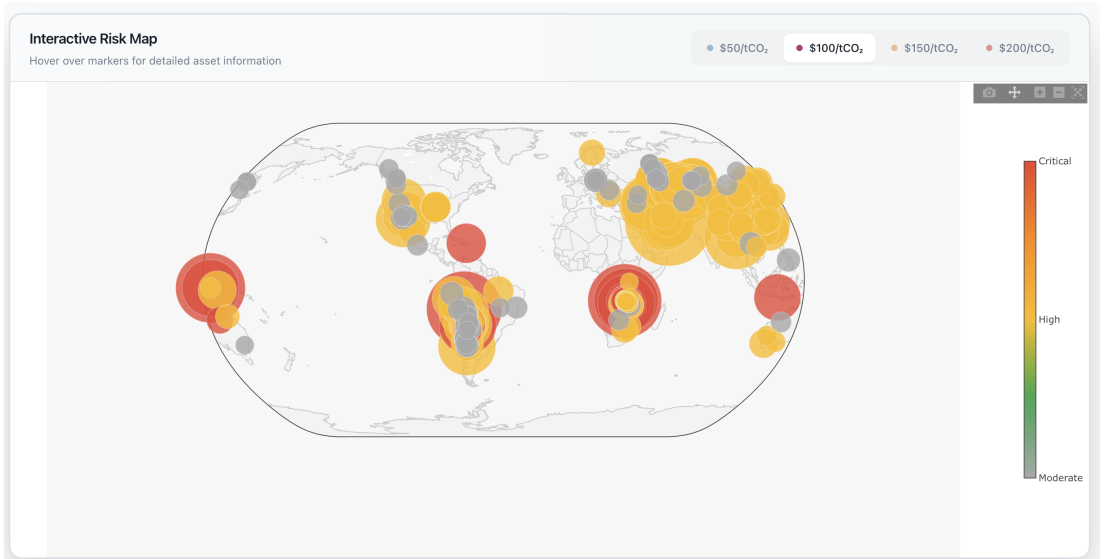
Risk at \$100/tCO₂

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



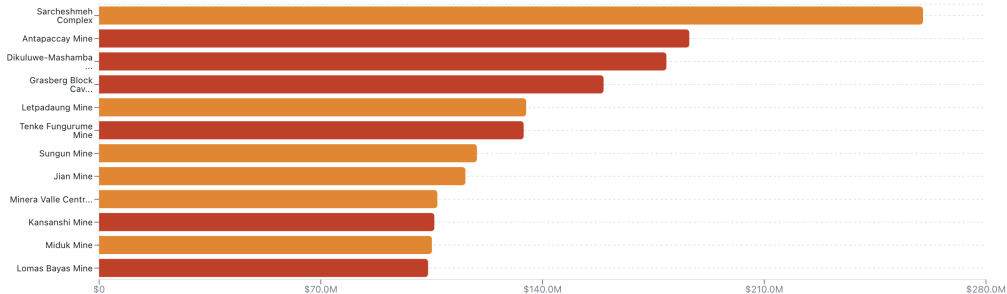
Interactive Dashboard: Asset Analysis

Asset Explorer

Browse and analyze individual mining assets

● \$50/tCO₂ ● \$100/tCO₂ ● \$150/tCO₂ ● \$200/tCO₂

Top 12 Most Exposed Assets



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

Interactive Dashboard: Scenario Analysis

Active Scenarios

Select All

☒ **Orderly Transition**

Steady carbon price growth, early policy action

☒ **Disorderly Transition**

Delayed action with sudden policy shock

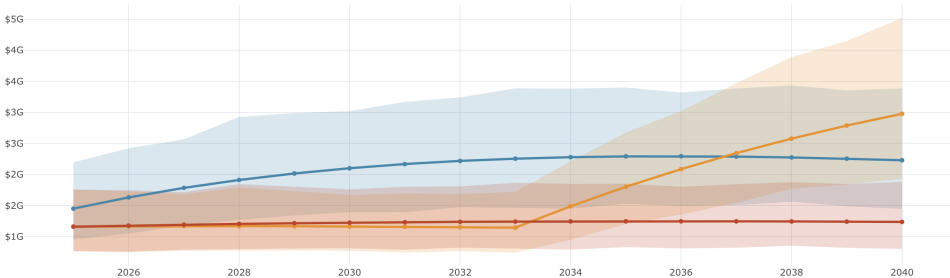
☒ **Hothouse World**

Minimal climate action, limited decarbonization

3 of 3 scenarios active

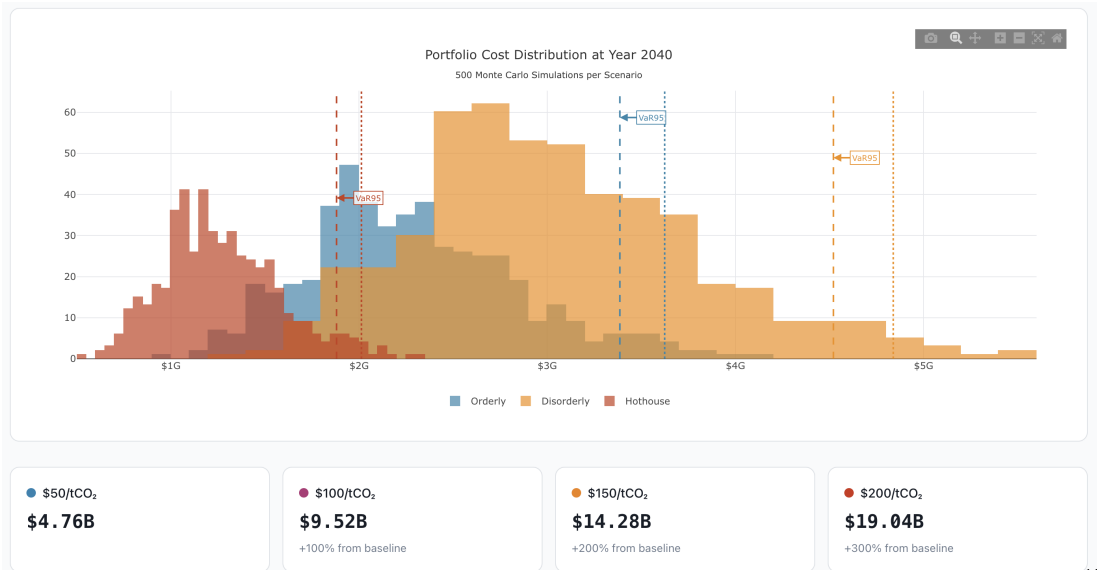
☒ Show Monte Carlo Uncertainty Bands VaR Horizon: 2040

Portfolio Cost Trajectories with Uncertainty Bands



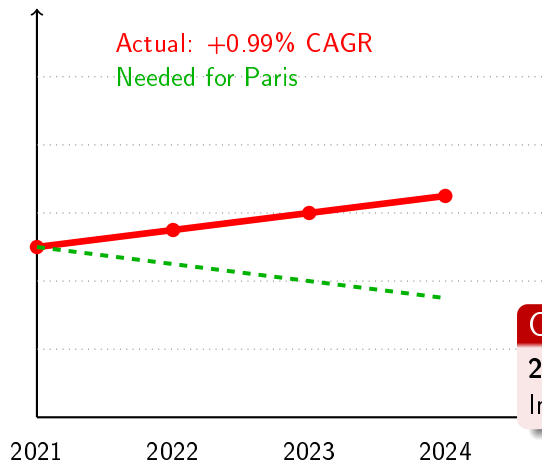
Hothouse World Disorderly Transition Orderly Transition Hothouse World uncertainty Disorderly Transition uncertainty Orderly Transition uncertainty

Interactive Dashboard: Risk Categories



Key Finding #3: Emissions Trending Upward

Emissions Index



Trajectory Analysis:

Trend	Assets
Deteriorating ($>10\%$ \uparrow)	202
Improving ($>10\%$ \downarrow)	119
Stable ($\pm 10\%$)	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

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**

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

Policymakers

- Predictable carbon price escalation

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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Assets Analyzed: 914 global copper mines