A Logistics System Perspective

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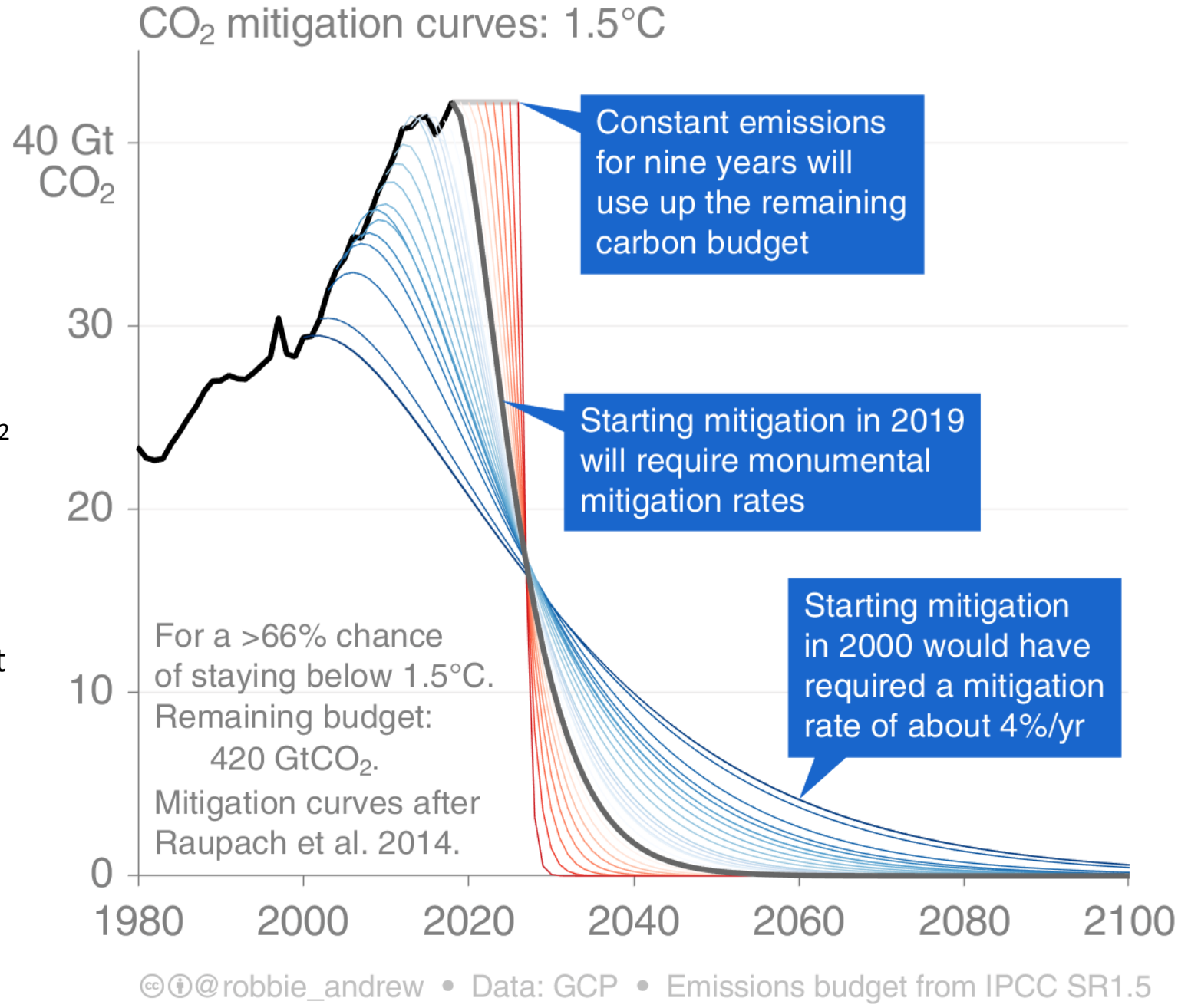
Mining is the Logistics Tail of Decarbonization

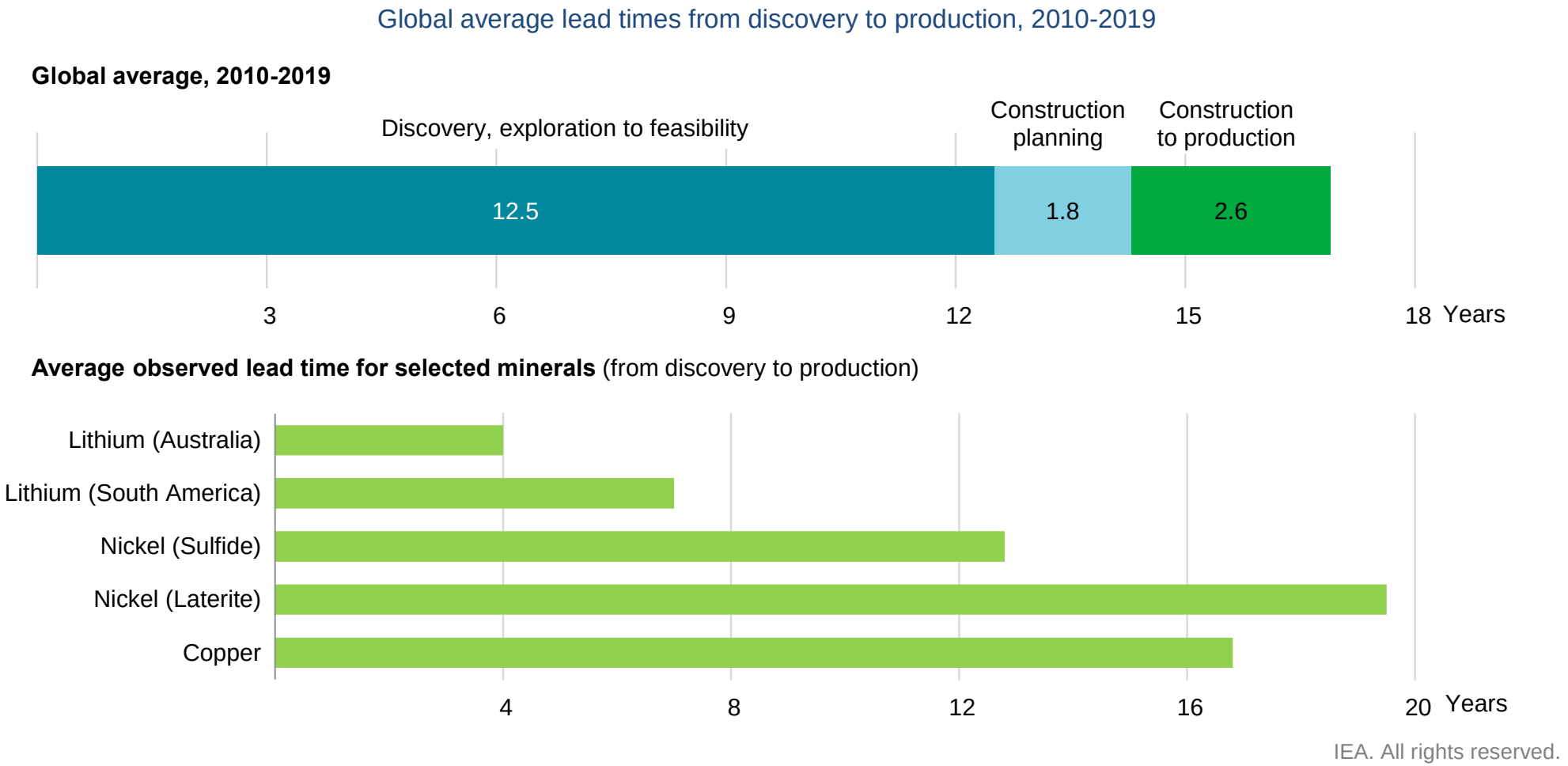
The Urgency

- “Carbon Budget” for 1.5°C
- Significant uncertainty in the 420GtCO_2
- Already missed the blue lines
- And the black one
- And two of the red ones!
- Mistake to think we have 7 years to act



Source: https://folk.universitetetioslo.no/roberan/t/global_mitigation_curves.shtml

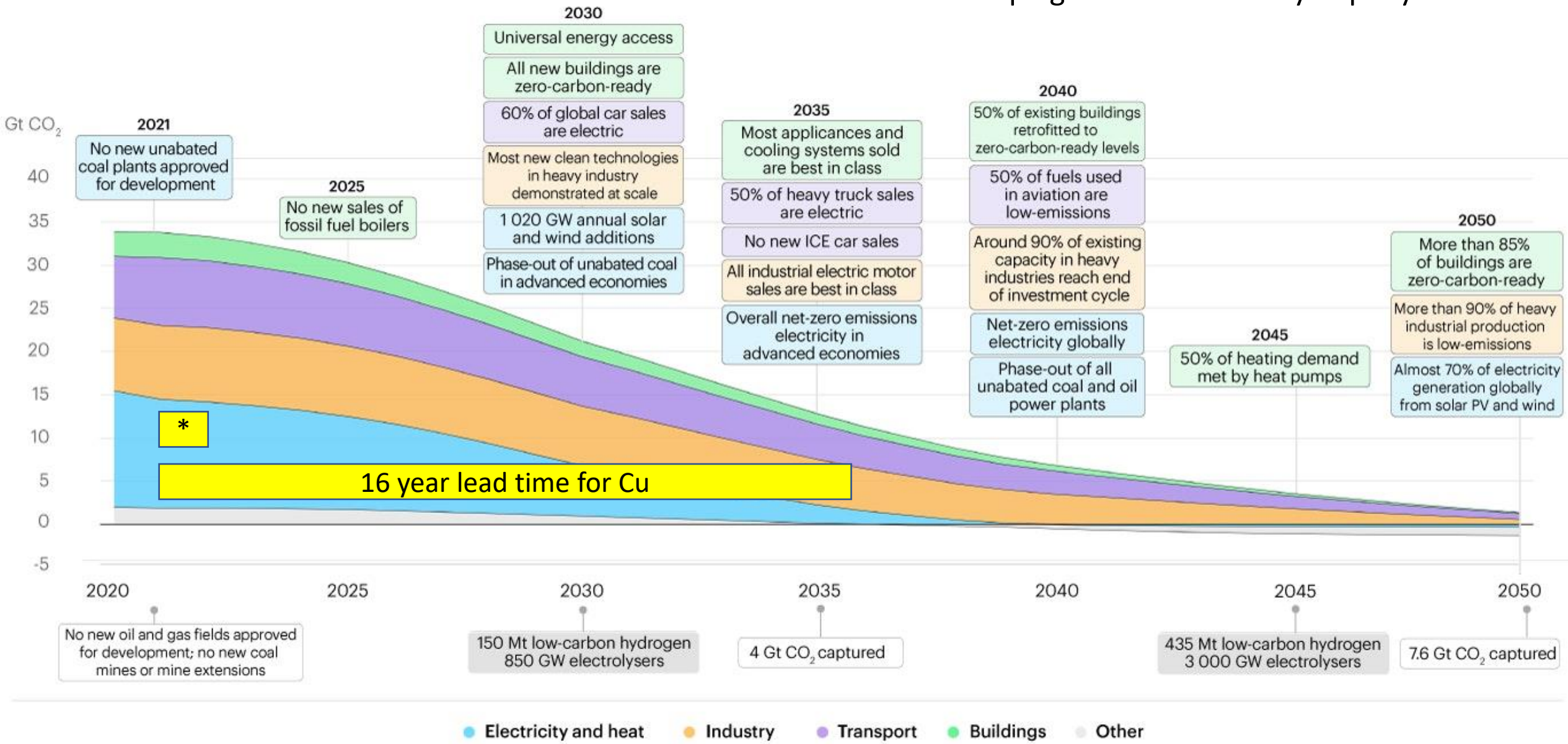
Project development lead times: Market tightness can appear much more quickly than new projects



Note: Global average values are based on the top 35 mining projects that came online between 2010 and 2019.
Source: IEA analysis based on S&P Global (2020), S&P Global (2019a) and Schodde (2017).

Source: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/reliable-supply-of-minerals

The Campaign Will Unfold Very Rapidly

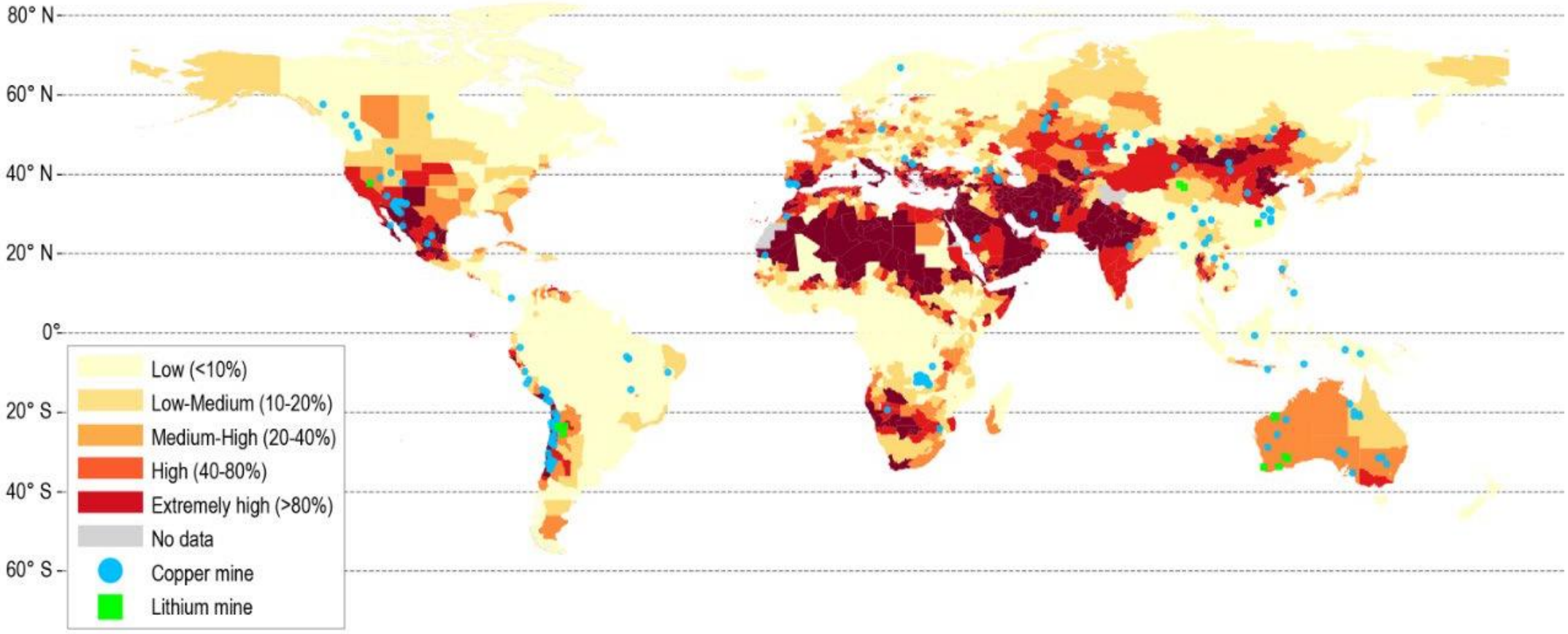


* time from start construction to first product for Tesla Giga Factory 1

Source: https://www.iea.org/reports/net-zero-by-2050

Unlike a military campaign, the logistics tail is also on the front line

Location of copper and lithium mines and water stress levels, 2020

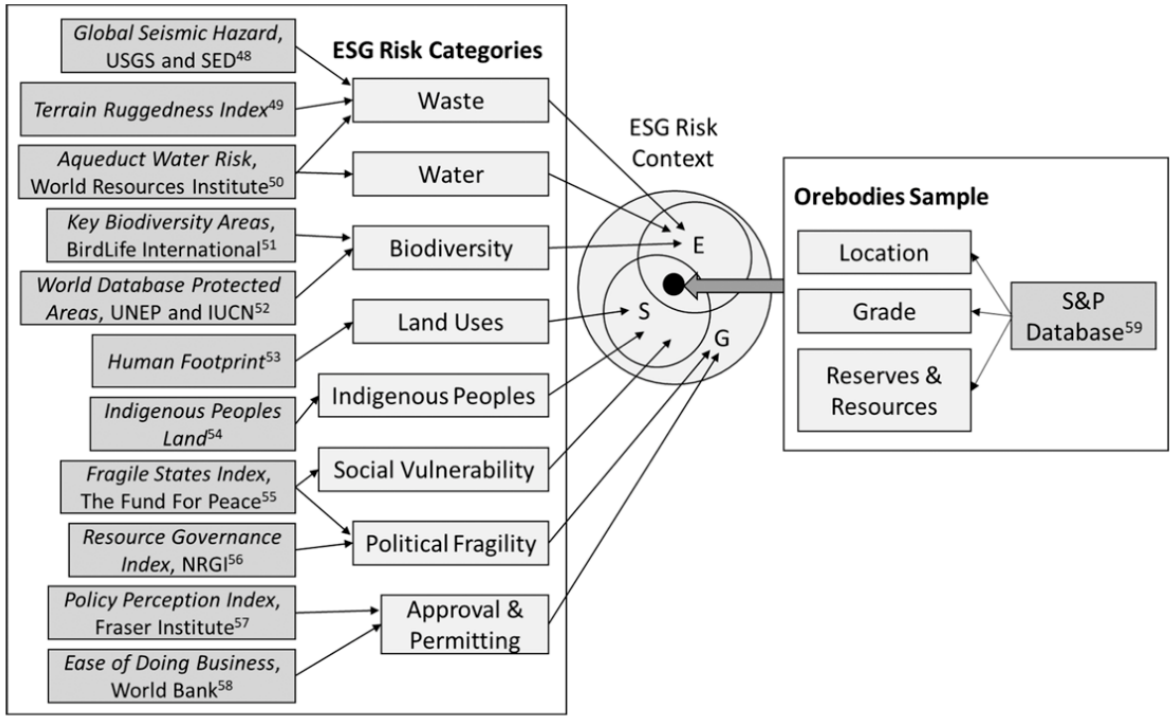


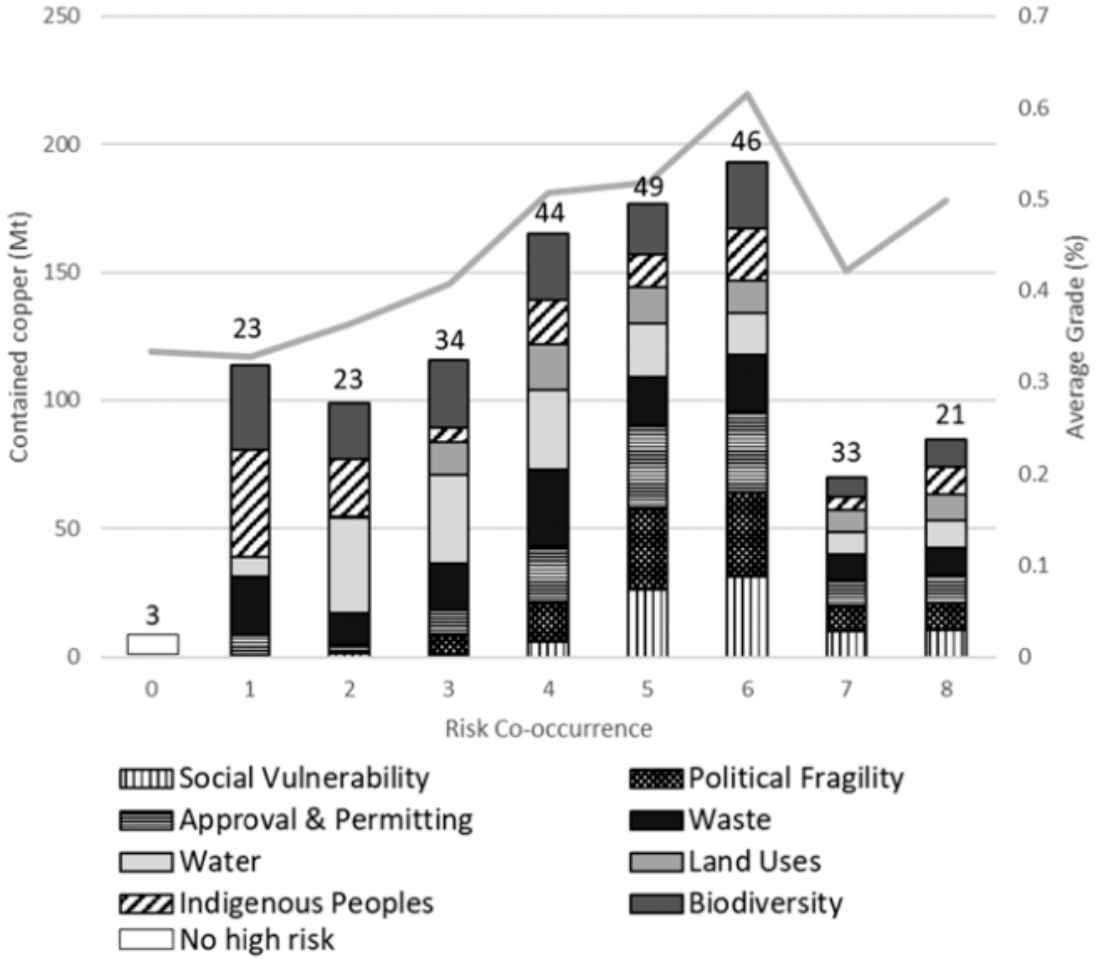
Note: The exact water stress levels vary by location. While we assessed the share of mines located in water stress areas according to granular regional representations (shown on the following page), we aggregated them at the sub-national level on the map for the sake of simplification. Water stress levels are as defined in the Aqueduct 3.0 dataset according to the ratio of total water withdrawals over the total available surface and groundwater supplies.
Source: IEA analysis based on WRI Aqueduct 3.0 dataset.

Source: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/reliable-supply-of-minerals

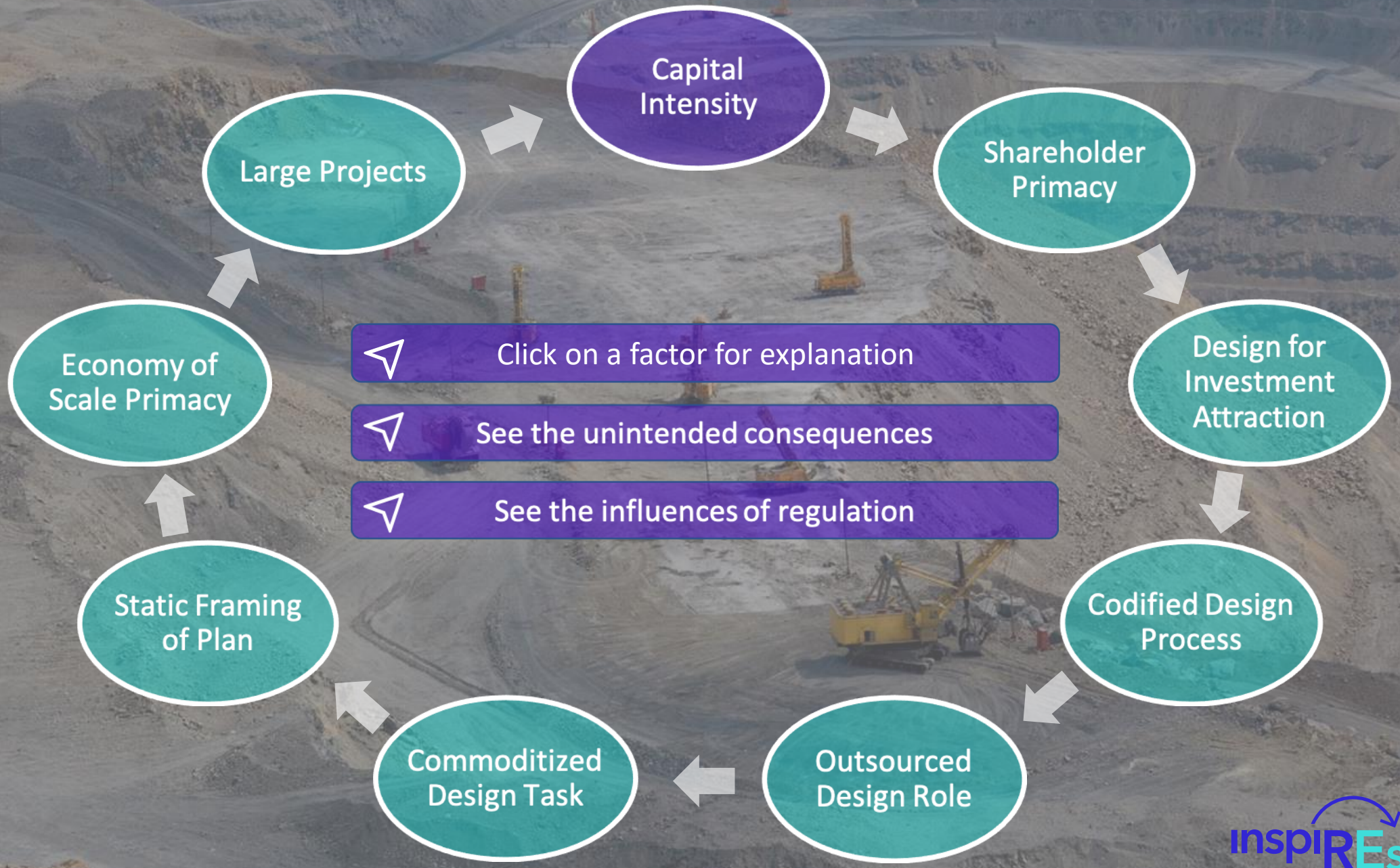
Source Risks: almost all of the largest untapped copper reserves are constrained by at least one price-insensitive risk

At least 63% of global Cu reserves & resources are constrained by at least 4 risks.





Source: **Source Risks As Constraints to Future Metal Supply** Éléonore Lèbre, John R. Owen, Glen D. Corder, Deanna Kemp, Martin Stringer, and Rick K. Valenta *Environmental Science & Technology* **2019** *53* (18), 10571-10579 DOI: 10.1021/acs.est.9b02808



Capital Intensity

This is the starting point for our vicious circle.

Leaving aside the artisanal sub-sector, mining is universally assumed to be a capital-intensive business, both in the absolute sense of project capital expenditures, and in the relative sense by comparison with labour intensity.

The assumption of capital intensity shapes the business mindset of the industry.

Business strategy, as in most industries, seeks to increase relative capital intensity still further, for example through automation.

Take me back

Shareholder Primacy

Because of the absolute capital intensity of mine development, and the speculative nature of exploration, investors are pivotal in the mining industry.

Mining companies engage investors as if they were customers: how mines are designed and operated is influenced much more by investors than by metal buyers (or any other stakeholders for that matter).

Very few mining companies have been able to convince their investors that other stakeholders are not subordinate to them.

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Design for Investment Attraction

For the typical junior mining company, mine design is a process that cannot be completed without raising further equity or royalty-based investment.

Therefore, mine design is necessarily a multi-stage process aimed at identifying technical and other risks for potential investors.

Investors look for a single-point, adequately detailed design with credible costing.

Although feasibility studies are hypothetical designs, in practice once disclosed they become the design intent, which bolsters investor confidence.

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Codified Design Process

Although retail and generalist investment in mining has been declining for some years, investors are still protected by securities regulation that has a standardizing effect on the technical reports that arise from design.

The importance of investment attraction biases the design process towards the production of compliant technical reports.

Therefore, the design *process* has effectively been codified, even though the regulations only apply to its products and endorsements.

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Outsourced Design Role

Enabled by a *de facto*-standard design process and product, the design role has been contracted out to engineering companies.

A contributing factor to this shift has been the infrequency with which a typical mining company develops mines, which would leave an in-house design team under-utilized.

Infrequency of development, in turn, arises from the long mine-life needed to justify capital-intensive projects.

Take me back

Commoditized Design Task

The contracted-out design task has become transactional, even though engineering companies would prefer it to be relational.

Engineering companies compete for design projects, which biases the process towards an easily-estimated work package that does not exceed the needs of investment attraction.

These constraints prevent the designers from considering immature technologies and from including diverse stakeholders in decision-making.

Take me back

Static Framing of Plan

With “feasibility” requiring only a single design option to demonstrate, and with investors looking for uncertainty to be driven out, and with the design task being minimized through contracting-out, it is easy to see why the resulting mine plan rarely includes significant optionality.

A further disincentive to designing in flexibility is that its cost is visible but its value would have to be calculated with Real Options Valuation techniques, which are not understood by retail investors and not trusted by institutional investors. More flexible plans may also be disadvantaged in permitting processes.

Take me back

Economy of Scale Primacy

Because the mine plan and economic analysis are created with static framing, the principle that always wins is economy-of-scale.

The valuation of economy of scale results in the largest-throughput plans being the most attractive, because the strong net present value gives headroom for risk mitigation.

Conversely, more flexible concepts – where implementing innovations would be easier throughout the mine life – are undervalued by the methodology.

Take me back

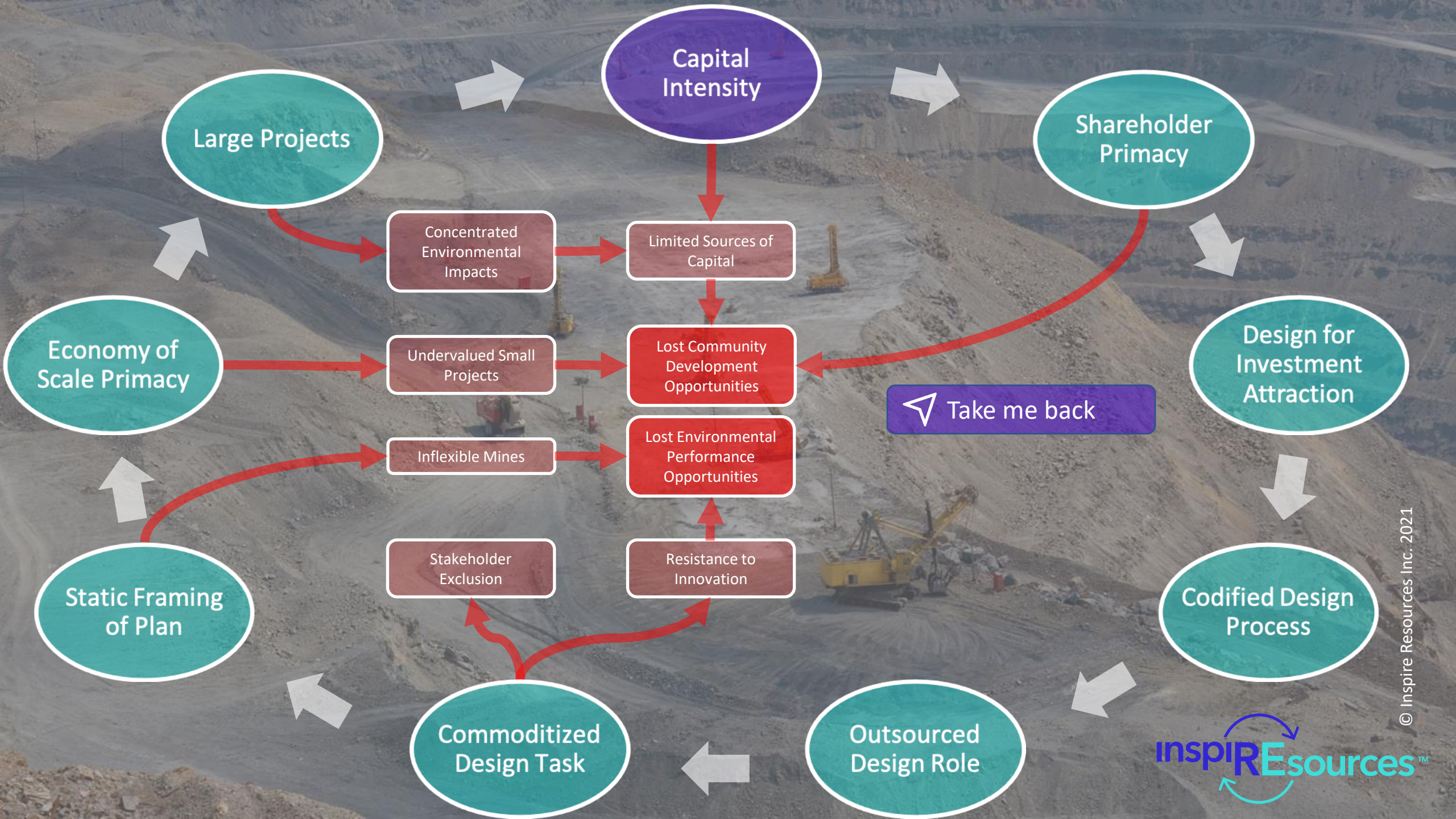
Large Projects

Ultimately the system delivers a strong preference for large projects (“tier 1 assets”). Unfortunately, large projects suffer from:

- Long development lead times
- Megaproject execution risks
- Large, concentrated waste problems
- Protracted permitting processes
- High-impact environmental risks
- Highly mobilized opposition
- Resource nationalism

They also require large capital investments, which closes the vicious circle.

Take me back


Capital Intensity
Large Projects
Shareholder Primacy
Concentrated Environmental Impacts
Limited Sources of Capital
Economy of Scale Primacy
Undervalued Small Projects
Lost Community Development Opportunities
Design for Investment Attraction
Take me back
Inflexible Mines
Lost Environmental Performance Opportunities
Static Framing of Plan
Stakeholder Exclusion
Resistance to Innovation
Codified Design Process
Commoditized Design Task
Outsourced Design Role
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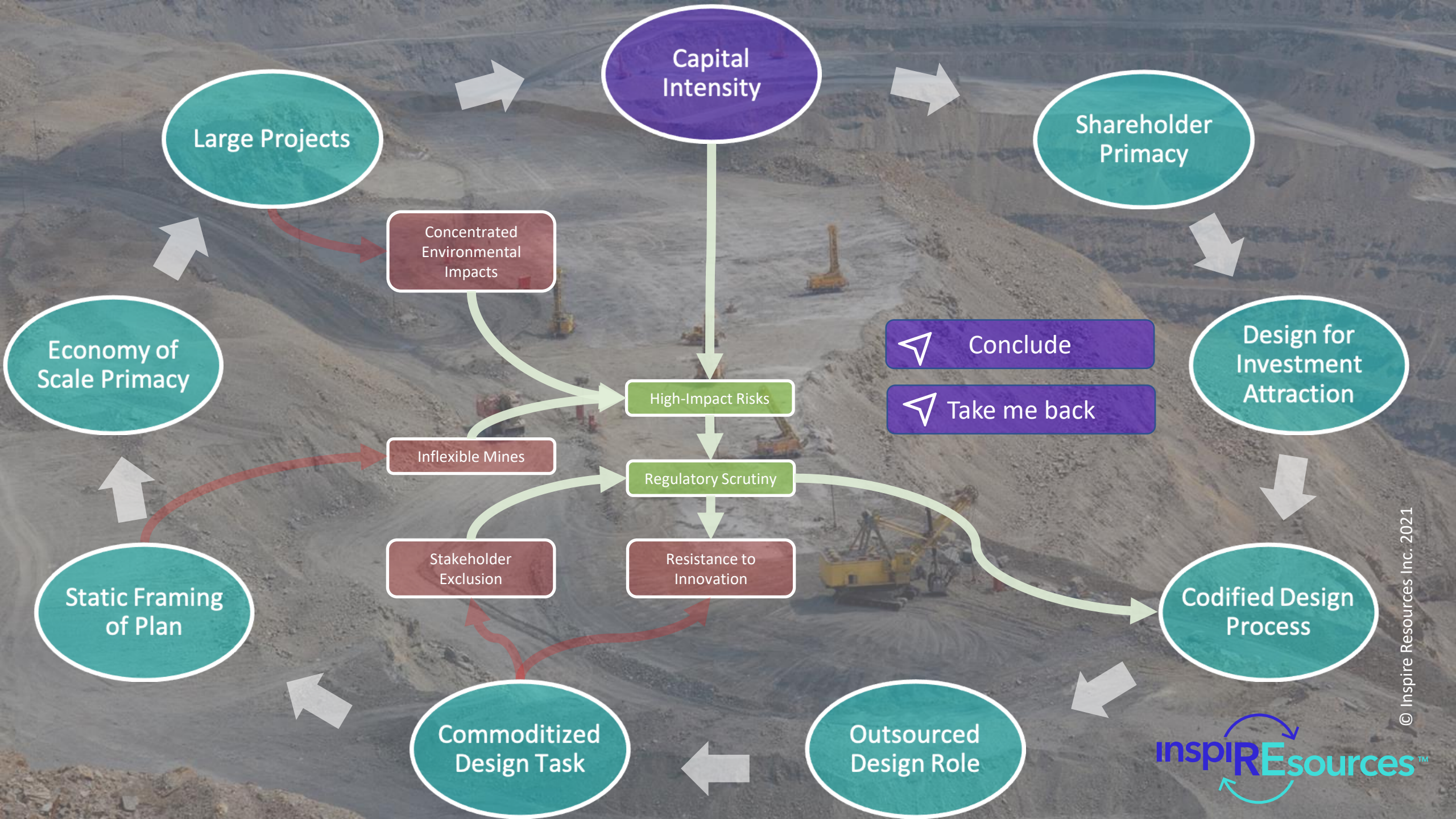
Capital Intensity
Large Projects
Shareholder Primacy
Concentrated Environmental Impacts
Economy of Scale Primacy
Design for Investment Attraction
Conclude
Take me back
High-Impact Risks
Inflexible Mines
Regulatory Scrutiny
Stakeholder Exclusion
Resistance to Innovation
Static Framing of Plan
Codified Design Process
Commoditized Design Task
Outsourced Design Role
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Conclusions

- Mining is the logistics engine of decarbonization
- Mining must grow supply while also decarbonizing itself
- There is a widening mismatch in demand-supply timescales
- To accelerate, mining must innovate in ESG
- The incumbent mining business model inherently limits speed and innovation
- This is an emergent characteristic of the system, not the fault of any one player
- We cannot address it unless we acknowledge that we are all part of it.

Some Ideas For Discussion

- What if the whole system were designed to go faster?
- Can we build a mine like a Giga Factory?
- How can investors, miners, engineers and regulators align their efforts?
- Are investors active or passive in ESG?
- Is there a need for business model change?

Please feel free to contact me

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