UNIVERSITY OF CAMBRIDGE

CSaP centre for science and policy

Centre for Science and Policy

Policy Workshop

The Future of critical minerals supply chains: risks, environmental impacts, and potential solutions

Summary report of the discussion held on 15 May 2024

Murray Edwards College, Cambridge

Prepared by Kavya Neeba (Policy Engagement Network Coordinator, CSaP)

Table of Contents

Introduction

The Centre for Science and Policy (CSaP), University of Cambridge, organised a Policy Workshop on the **Future of critical minerals supply chains: risks, environmental impacts, and potential solutions** in partnership with the Energy Interdisciplinary Research Centre at the University of Cambridge and the Department for Business and Trade (DBT). The event brought together stakeholders from academia, policy, and industry for a roundtable discussion under the Chatham House rule.

Background and purpose of the workshop

As technology evolves rapidly and the transition to clean energy accelerates, the world is increasingly relying on critical minerals (CM) for the future: lithium, cobalt, and graphite are needed for electric car batteries; silicon and tin for electronics; and rare earth elements for electric cars and wind turbines. Consequently, the demand for these minerals is expected to rise sharply, necessitating the development of resilient, diverse, and responsible value chains.

The workshop also aimed to explore potential solutions and leverage points, and to pinpoint the UK's capabilities to inform the government's rapidly evolving Critical Minerals Strategy.

The key questions addressed during the Policy Workshop were:

- What does existing evidence tell us about the footprint of mining (including refining and processing), including the impact on biodiversity? How do/could we measure the biodiversity impacts of mining and what are the challenges?
- What are the other key risks (current and anticipated) associated with the future of critical minerals supply chains and potential adverse impacts of mining?
- Where do evidence gaps lie regarding risks and impacts and what further research is needed in this space?
- What are the challenges and possibilities of moving towards buying sustainable critical minerals?

Setting the scene

Policy Perspective

The DBT participants gave a brief overview of the UK's Critical Minerals Strategy. Published in July 2022, under the 2019 to 2022 Johnson Conservative government, the Strategy set out an approach to improve the resilience of CM supply chains to safeguard British industries now and in the future, deliver our clean energy transition and protect national security and defence capability. The Strategy set out the A-C-E approach:

- Accelerating the UK's domestic capabilities
- Collaborating with international partners
- Enhancing international markets.

The Strategy refresh in 2023 outlined the Government's sustained commitment to securing the supply of CM, supporting the strategic development of the UK supply chains and boosting the circular economy.

The DBT participants emphasised that the Critical Minerals Strategy is a collaborative effort across multiple departments, not just DBT. The strategy includes ten delivery commitments spread across three main thematic areas. These areas are closely interconnected and do not exist in isolation. They form the foundations for how DBT and the Government organise themselves, ensuring that these interlinkages are represented in their work. Among the ten delivery commitments, the areas of the strategy most relevant to the policy workshop discussion are :

1. Circular economy
2. Boosting ESG (Environmental, Social and Governance) standards
3. Improving transparency and tracing the origin for CM

On the international collaboration front, the key objectives are to diversify and increase resilience of the CM supply chains, especially since the demand for CM is projected to grow exponentially.

The government seeks to support domestic companies in participating globally and to ensure that ESG standards underpin all of the UK's work.

It was noted that the UK has made significant progress in international collaboration, having signed eight mineral partnerships to date, all of which incorporate ESG standards. As the current ESG is filled with various standards and frameworks, a parallel priority for DBT is to support initiatives to streamline and enhance these existing standards while striving to understand what works well and what could be improved.

Participants noted that the complex landscape of critical minerals and their supply chains presents a significant systems dilemma for policy makers. From a policy perspective, DBT and other departmental bodies aim to integrate various aspects of this fragmented landscape to create a cohesive policy that forges strong connections between supply chains and development. The key is to identify emerging policy strands and understand where the UK can exert influence, prioritising actions accordingly.

Research Perspective

Two academic experts presented the research perspective. The intrinsic links between agriculture, mining, and human and social development were underscored. They emphasised the crucial role of mining in human and social progress and highlighted two key constraints that underpin discussions on CM: geography and politics.

The occurrence of CM is highly concentrated in specific geographical areas, creating dependencies and vulnerabilities to supply shocks, sudden policy shifts, and geopolitical events. For instance, lithium, a mineral of great concern due to its high demand growth and lack of current substitutes, exemplifies this issue. Similarly, copper, essential for almost all clean energy technologies, is under significant pressure from declining ore quality.

The geographical concentration of CM exposes the supply chains to geopolitical tensions, increasing the risk of supply bottlenecks in the face of growing protectionist behaviour and trade restrictions. China dominates the processing of most critical minerals needed in low-carbon transition technologies, processing over half of all lithium, cobalt, and graphite and 90% of Rare Earth Elements. Similarly, Russia is the world's top supplier of battery-grade nickel, providing

significant uncertainty for future nickel supply. Cobalt relies on the Democratic Republic of Congo for 70% of supply, whose production has a high ESG (Environmental, Social and Governance) risk.

The social aspect of mining extends beyond mere social engagement, acceptance, or licenses to operate, stressing the crucial need for societal trust in the entire mining business. Citing the 2022 PWC World Mine Report, an academic expert stated that "Trust is a critical material" and underscored the necessity of establishing trust with all equity holders from the outset. They pointed out that a lack of trust between local communities and miners is consistently one of the industry's biggest failures and risks.

The independent Task and Finish Group report was a significant advancement in integrating industry and policy domains. However, the current need is for the UK to explore innovative methods to secure supply chains and address the mining industry's needs.

The implications of critical minerals mining on biodiversity were presented by an academic expert. The Living Planet Index has monitored several thousand populations of wildlife around the world and has seen a decline of about 70% of these in the last 50 years or so. This points towards a massive biodiversity crisis and the higher biodiversity extinction rate. This has led to the global plan for biodiversity - Kunming-Montreal Global Biodiversity Framework (GBF) which was signed in 2022. The Framework recommends governments to take urgent action to halt and reverse biodiversity loss to put nature on a path to recovery for the benefit of people and planet by conserving and sustainably using biodiversity and by ensuring the fair and equitable sharing of benefits from the use of genetic resources, while providing the necessary means of implementation.

Within the GBF and CM context, the academic expert noted how imperative it is to address the effects of mining on biodiversity, particularly within Africa. Africa contains around 30% of the world's mineral resources and is on the verge of an unprecedented mining boom (Edwards et al., 2013). The key problem Africa is facing is the overlap between mining areas and protected biodiversity areas, with more than a quarter of 4151 recorded mineral occurrences concentrated in three regions of biological endemism. As a result, there is a 41% increase in deforestation across 225 mines, resulting in 7.8% (4642) species being impacted by mining (See figure 1 and 2).

Mining activities have driven a 4% increase in deforestation, resulting in the substantial loss of nearly 300,000 hectares of forests over the past two decades. According to the International Union for Conservation of Nature (IUCN) Red List, several species are facing extinction due to mining activities. Eight percent of 4,600 species are significantly at risk from mining (Lamb et al 2024). The IUCN indicates that mining poses far more risks to species at risk of extinction than to those species that are not expected to go extinct imminently.

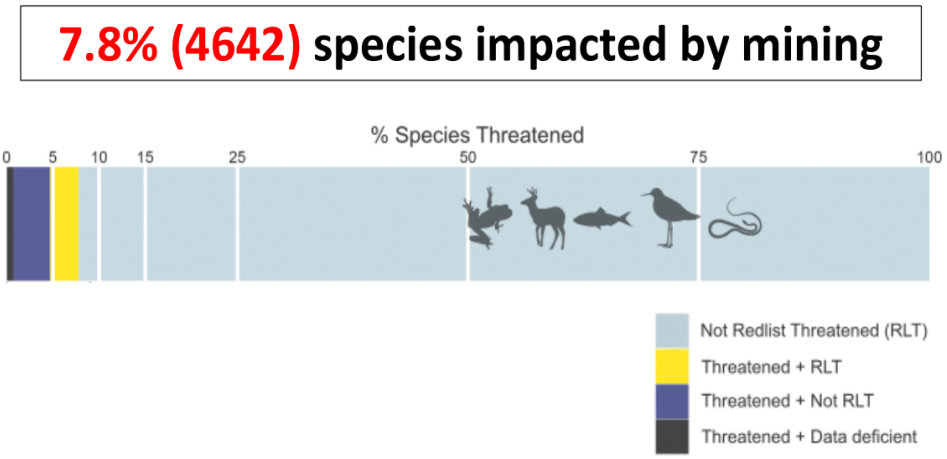

Fig 1: Impact of mining on species (Lamb et al., 2024, Current Biology 34, page 1–12)

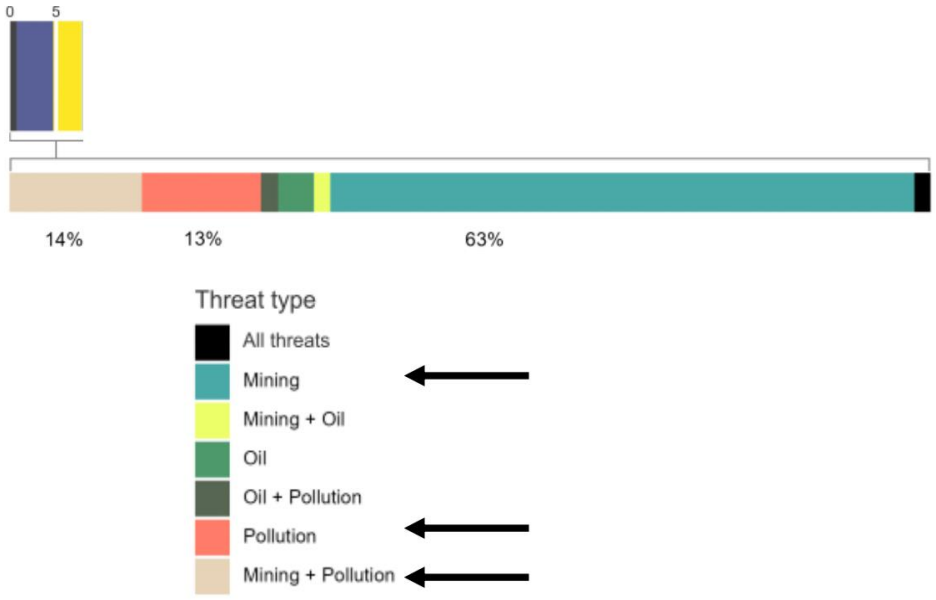

Fig 2: Impact of mining on Biodiversity Lamb et al., 2024, Current Biology 34, page 1–12)

The expert cited the Eden Project in Cornwall as an exemplary case of how informed co-creation of mining practices can leave positive legacies. The Eden Project transformed an open-pit clay mine, closed in the 1990s, into a profitable new sustainable business. It is now home to the largest indoor rainforest in the world, featuring over 1,000 plant species, Cornwall's first undercover ice rink, and a popular wedding, entertainment, and conference venue. Opened in 2001 at a cost of £140mln, the project used local mineral waste and compost to create soil for the biomes. Over the next 20 years, it generated an estimated £32.5bln for the local economy and now employs over 350 people.

Key Challenges Indentified

The discussion of the policy and research perspectives led on to the discussion of problem identification by participants. The key theme echoed by participants during the workshop was the complexity of the problems within the sector, owing to the presence of a wide variety of stakeholders at the national and international level as well as the often interconnected and mutually enforcing issues.

1. Lack of Data and Data Transparency

Participants identified the lack of publicly available data as the biggest concern. Despite significant monitoring of the environmental and social impacts of mining, data remains largely inaccessible to most academic and research stakeholders. Additionally, the existing data is often difficult to follow and inconsistent. One participant noted that most companies have only 20% visibility into their supply chains due to the lack of data, likening it to driving a car in the fog. Without clear data, supply chains lack transparency which makes them highly prone to disruptions.

Another participant observed that while mining companies frequently claim to follow ESG standards and regulatory protocols, concrete data to verify these claims is rarely available,

making it difficult to monitor and substantiate their assertions. It was also noted that data does exist but is often held by private consultants and third parties who collect data from individual mines and sell it at high prices.

The issue of data granularity was also highlighted. Participants noted that mining is often treated as a single process, but it consists of multiple steps, such as extraction, processing, and refining. To achieve clarity on the UK's CM supply chains and identify problem areas, it is essential to have detailed data on each step of the process.

Within the discourse on mining and biodiversity impacts, there is a pressing need to understand the different types of mines and the specific impact each type has on biodiversity. This poses a challenge in making comparisons, such as between the effects of land mining and deep-sea mining. A suggestion was made by one participant that the UK needs to develop a robust data infrastructure through the UK Critical Minerals Intelligence Centre (UKCMIC) to support itself and other countries in this regard.

2. Conflicting Timelines

Several participants stressed another key problem - the conflict between timelines with respect to mining, the growing demand and the 2050 Net Zero Target. One participant noted that an average copper mine takes 17 years from the discovery stage to the production stage, highlighting the need to understand why this is the case and also to understand the environmental and social elements to the problem. These long timelines pose a problem for the growing demand and for achieving the 2050 net zero target as without CM the growing demand for raw materials needed in renewable and clean energy technologies cannot be met.

Another key challenge is the conflict between the timelines that investors have in mind versus the mining companies. For investors, a long-term view often indicates five years which does not tally with the 17 years required to develop a mine. While public mining companies are held accountable, to an extent, by investors, the conflict in timelines poses a huge challenge for collective and collaborative action.

3. Negative public perception of the mining industry

Participants unanimously agreed that a lack of public trust and consequent negative perception of the mining industry is a deep-rooted problem that needs to be addressed urgently. Often the failures of the mining industry are highlighted in the public discourse. This negative reputation needs to be rectified and trust in the industry needs to be rebuilt in order to tackle some of the supply chain issues.

The lack of trust also stems from the lack of data and data transparency, which makes monitoring and evaluation difficult. Instead of working in silos, there is a need for academia, policy makers and the industry to work together to collect data to rewrite the existing perception of mining, which is very unrepresentative of commercial mining, argued one participant.

A participant brought to attention the anti-mining sentiments, especially within the younger generation and emphasised the need to spread awareness on the importance of mining as a societal choice we are making collectively. The negative perception of mining, they argued, often originates from it being associated with the worst parts of neo-liberal capitalism where the industry is perceived to be unregulated and exists outside of governance structures.

Another participant highlighted that one reason for the lack of trust is uncertainty about the origins of materials. With insufficient data transparency, it becomes challenging to verify whether metals originate from ethically managed mines. This opacity occurs because certain points in the supply chain aggregate and homogenise materials, obscuring their original sources. The participant stressed the importance of enabling consumers to trace the origins of products to enhance transparency and build trust. This transparency is crucial for ensuring ethical sourcing practices and promoting accountability throughout the supply chain.

4. Low Recycling Rates

Regarding the UK's domestic resources and supply chains, one participant highlighted that although the UK has a decent supply resource, a major hindrance is the very low recycling rates, especially for CM such as Rare Earth Elements, lithium, silicon, gallium, and tantalum. Another participant noted that current research suggests substitution as a solution within the 2050

framework is not feasible due to the industry's conservative nature, making it even more crucial to focus on recycling.

As most CM are often obtained as by-products or combined with other minerals, significant quantities are wasted due to inefficient mining processes. Low recycling rates for CM can exacerbate supply risks by maintaining a high industry dependence on virgin minerals and metals. This dependence could leave the UK industry exposed to supply chain disruptions for longer periods and hinder the creation of domestic and diversified closed-loop supply chains.

5. Closure of mines

Linked to the topic of the impact of mining activity on biodiversity and local communities, a key concern was raised regarding the improper closure and, in some cases, total abandonment of mines. The process of closing a mine is often poorly designed and not given sufficient consideration during the initial stages of mining projects.

Exploring new processes for mine closure is vital, as it can help mitigate biodiversity loss and support the affected communities. By developing well-thought-out mine closure practices, a system can be created that has a net positive effect on the environment and society, argued a participant.

The concern around the improper closure of mines was echoed by several other participants who noted how for mining to be truly sustainable, the industry must provide these natural resources without compromising the integrity of the environment or the wellbeing of local communities in the future. Well-planned and executed mine closures can help achieve this desired outcome. Underscoring the importance of this issue, another participant reported a research metric indicating that only 5% of all mines (approximately 16,000 mines) have been subjected to any ecological and other rehabilitation.

It was agreed that mine closure is a complex multidisciplinary undertaking, requiring several years of planning and a coordinated effort from government and industry stakeholders, ideally right from the start of mining preparations It was also pointed out that local and community

stakeholders are often ignored at this planning stage, even though they 'inherit and have to live with' the closed mines and lands for years to come.

6. Risk of a two-tiered market

It was mentioned that it would be a good to see higher prices achieved for ESG products to incentivise better practices. However, a participant pointed out that there exists a risk that pushing for ESG standards/regulations will create a two-tiered market, where the standards are not brought up overall, but instead non-ESG friendly products are sold cheaply to markets that are not prepared to pay a premium, which does not have a net benefit overall on ESG.

Therefore, there is a real need for a global perspective and internationally agreed-upon frameworks and pricing standards. This approach would help avoid leaving developing and underdeveloped nations behind and prevent the creation of unscrupulous markets and supply chains.

7. Biodiversity monitoring and reporting metrics

It was noted that mining projects are not yet measured in true terms, which should include metrics for social and ecosystem services (including biodiversity) impacts to reflect their potential benefits for people, planet, and prosperity.

Several stakeholders expressed concern about the existing biodiversity monitoring metrics, emphasising the need to improve IUCN assessments. These assessments should be updated to identify which categories of mining are driving biodiversity loss and how they are doing so. This task requires the involvement of science experts, and there is a significant role for industry engagement in this process as well.

A participant emphasised the need for reporting metrics with an analytical backbone, remarking that metrics should be constructed holistically since biodiversity is just one aspect of a very complex system. They asked, "Can we make better use of modelled metrics for biodiversity?"

Another participant noted that existing metrics are quite intensive to measure and tend to be backward-looking, highlighting the fragmented landscape of biodiversity impact metrics. With

current metrics, it takes a long time to detect any signals regarding how biodiversity is faring. Despite mining posing a significant risk to biodiversity, there is little mention of mining in biodiversity frameworks, and it is only loosely referenced in several national frameworks. One participant argued that forward-looking, index-based metrics could be used to predict biodiversity changes and outcomes. Therefore, there is a need to better assimilate metrics to quantify the externalities and risks of mining on biodiversity.

8. Energy and Infrastructure constraints

The energy constraints for the production of CM pose another significant challenge, which is often disconnected from discussions around achieving the 2050 net zero target. A participant noted that the energy required to develop new renewable energy systems and transition to a circular economy is substantial and often overlooked by key stakeholders.

Building the new energy system will also result in initial CO2 emissions, as the first generation of any new clean technology must be built using fossil fuel-based energy. Consequently, the production of materials to support the energy transition will contribute to significant global cumulative life cycle emissions. A participant called for a shift in how we think about the energy needed to produce CM, highlighting the UK's dependencies on traditional and conventional technologies for energy production.

The urgency of addressing the energy constraints associated with CM production was highlighted. The uptake of low-carbon technologies needs to skyrocket further to meet global climate goals, especially since clean energy solutions are often much more materials-intensive during the construction phase compared to their conventional counterparts. The future net zero emission economy will depend on significant increases in electricity supply and demand.

Within the UK, this will require massive deployment of solar and wind power capacity, a major expansion of electricity grids and infrastructure, and substantial growth in the production of batteries, electric vehicles, and electrolysers for green hydrogen production. These developments underscore the need for a comprehensive strategy to manage the energy

requirements and environmental impacts of producing critical minerals essential for the transition to a sustainable energy future.

The key concern raised was that the rapidly escalating demand for CM stands in stark contrast to the extended timelines required to expand existing infrastructures under current circumstances. Participants noted that the permitting, exploration, and asset development phases alone can extend over one or two decades before production can even begin. Furthermore, there is insufficient investment being made currently to adequately meet future demand.

This mismatch highlights a critical challenge in the mining sector: the need for long-term planning and substantial investment to ramp up production of CM in time to support global transitions towards sustainable energy and technology.

9. Cost of sustainability

The cost of producing CM sustainably and in line with ESG standards was a recurring concern among the participants. An industry representative raised the question, "Who is going to pay for sustainably and responsibly sourced critical minerals?" While there is an understanding within the industry of the need to produce ESG-friendly minerals, the issue of how the costs of sustainable production will be managed or who will account for them is often not acknowledged or discussed sufficiently. As a result, while the current market is thinking about environmentally conscious and sustainably produced metals and there is scrutiny, this is not currently reflected materially in prices for commodities. The participants agreed that interventions are needed at the market level, as mining companies are unlikely to hold themselves to this standard on their own.

This issue is particularly relevant in the African context, where there is a significant need to incentivise good mining companies to engage in and develop best practices and resources. Participants unanimously agreed that there are currently no market incentives that reward transparency. One participant mentioned that while some governments provide direct fiscal support, the UK government's approach includes both fiscal supports and the establishment and

enforcement of regulations. There is industry-wide acknowledgment that such an approach could have many unintended consequences, especially given that the market is not yet ready to deliver transparency. Participants emphasised the need for a carefully balanced strategy that encourages sustainable practices without disrupting the market or creating adverse effects.

Within the context of market mechanisms, a concern of standards versus compliance was raised. Even if the UK and other like-minded countries develop excellent ESG regulations, some countries might not adhere to them, finding them burdensome and focusing instead on profits. This disparity could further disincentivise companies and governments from adopting these standards, as they tend to opt for the easier, more profitable route.

This inconsistency presents another challenge for policy makers. Different standards and a lack of a uniform international standard can impede efforts to achieve net biodiversity gain. Policy makers must address this issue by striving for global alignment on ESG standards to ensure that efforts toward sustainability and biodiversity conservation are effective and widely adopted.

Key Solutions Proposed

1. Encouraging local and indigenous ownership

The importance of better understanding aspects of accountability and ownership of mines and minerals as a potential solution was discussed. "Do mining companies take ownership of the minerals and mines?" one participant asked. Another participant highlighted the need for a more robust regulatory framework to clarify ownership and to understand "who owns what."

They emphasised that a clearer regulatory approach to ownership could enhance accountability, ensuring that those responsible for the extraction and management of mineral resources are held accountable for their environmental and social impacts. This clarity could lead to more responsible mining practices and better compliance with ESG standards.

To combat and rectify the negative perception of mining, one suggested solution was to encourage indigenous co-ownership. As mineral and metal extraction is projected to soar in the

coming decades, indigenous peoples' exposure to mining industries is likewise expected to intensify. Indigenous co-ownership involves negotiated agreements where indigenous groups acquire an equity stake in the mining company operating on their land and embed themselves in the decision-making process. This approach ensures agency for indigenous peoples over their land and economic development that reflects their values and perspectives.

One participant noted that the global prevalence of indigenous co-ownership does not appear widespread or well-documented, citing Canada as an interesting example. Canada's campaign of economic reconciliation has significantly advanced natural resource infrastructure and energy projects across the country. Indigenous ownership and stakeholder involvement from the start can build substantial trust and credibility for these projects. It was also presented that 92% of global efforts to help biodiversity, and that are succeeding, are led by indigenous groups.

The recently concluded Canadian Indigenous Investment Summit was highlighted as a significant initiative showcasing how the integration of Indigenous knowledge and practices can enhance the sustainability and viability of investments.

Another participant added that indigenous ownership is often hard to operationalise. To integrate mining with the community and create a positive effect, more parties than just the mining companies are needed to create an overall sustainable landscape. Participants agreed that external actors are essential to ensure the impact of mining on biodiversity is managed properly.

They noted that post-mining landscapes are likely to be best co-designed by including third parties who will inherit the site later on. Involving people who will inherit the mining site in the design and post-closure processes ensures that their needs and perspectives are considered, leading to more sustainable and community-aligned outcomes.

Another major solution proposed was to encourage policy makers and industries to invest in local businesses and downstream actors. Working with downstream actors, such as smelters, provides a better understanding of supply chains. Smelters often operate on tight margins, with most profits going to the big mining companies. A participant noted that Western smelters struggle to be profitable because market structures are not viable for smelting.

A participant encouraged providing more fiscal support for these local actors to strengthen their position and viability. Investing in local businesses and downstream actors can help create more sustainable and transparent supply chains, ensuring that more of the economic benefits from mining activities are retained within the local community.

2. Adopting a global and long-term view

To tackle the multiple challenges faced by the CM supply chains, the UK needs to implement multiple strategies with a clear long-term vision. While the UK Critical Minerals Strategy is a step in the right direction, it was proposed that more concrete support should be provided to different mining companies to help them achieve the better standards and goals laid out in the Strategy. This support is especially vital for local UK mining companies, which struggle to compete globally against US companies without adequate financial investment. One participant mentioned the initiative for a global market system pilot led by the Cabinet Office—as a promising next step.

A global long-term view is also necessary to combat the risk of creating a two-tiered market that leaves low-income countries behind. Wealthier Western countries should be encouraged to transfer technological know-how to low and middle-income countries to help them maintain ESG standards and aid in their biodiversity conservation efforts. The green transition needs to be global and long-term, as pointed out by a participant who noted the 'short-termism' that exists in Western policies.

3. Addressing the data and evidence gaps

Participants unanimously agreed that the most urgent solution to a multitude of problems identified was to collect more data and make the existing available data public and accessible. A participant proposed that data on natural capital should be collected before mining starts, noting that such baseline data would be highly beneficial in understanding the impact of mining and other activities on biodiversity. There is also a need to use technologies like satellite data and

remote sensing data analysis in biodiversity conservation efforts to mitigate data deficiency and to track and understand the impact on biodiversity more clearly.

To facilitate this, one participant suggested that as one of the options the UK needs to build a solid infrastructure for data collection via the UK Critical Minerals Intelligence Centre (CMIC). This infrastructure would not only help the UK but also assist other countries in managing and understanding critical mineral supply chains and their environmental impacts. Additionally, the idea of anonymising data, given the sensitivity of the context, was raised by a participant to encourage transparency while respecting privacy and proprietary concerns.

4. Circularity of the three pillars of mining

Given the urgency to ensure circularity of different mining stages, one academic expert presented the 'cradle to cradle approach' as a potential solution to the challenges identified (refer to figure 3). Within the technical cycle, recycling, and minimising waste through higher efficiency in technological processes is required. Within the social cycle, the key is to involve local communities right from the outset. The environmental cycle should involve ecological rehabilitation interventions to manage the environmental and biodiversity impact. These three pillars, where all stakeholders co-design outcomes, becomes a nested circular process ensuring sustainability and shared benefits for all.

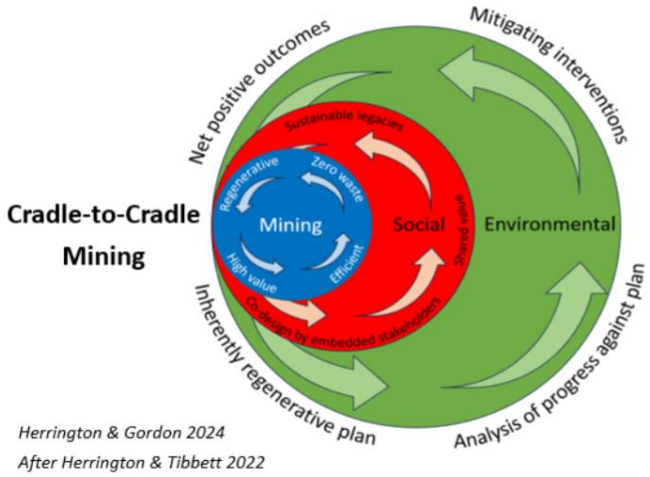

Fig 3: Circularity of 3 pillars

5. Addressing infrastructure and energy demands

There are significant infrastructure demands in the UK, especially concerning electricity networks. Record levels of new networks need to be built to meet these demands, noted one participant. The trade-off between biodiversity costs and the location and construction methods of infrastructure is complex and should be more widely discussed. Strategic stockpiling of components of clean energy is another potential solution to manage short-term fluctuations in the market and unforeseen disruptions in the supply chain.

This approach involves ensuring that key components for clean energy systems, such as batteries and solar panels, are stockpiled strategically. This can help mitigate risks associated with supply chain disruptions and market fluctuations, ensuring a more stable transition to clean energy without compromising biodiversity through hastily planned infrastructure developments.