Cleantech Group

03 June 2025

Quadrature Climate Foundation

Innovating Mining for the Energy Transition: Interventions to Accelerate Global Ecosystems

Opportunities for philanthropic capital to accelerate global mining innovation ecosystems

Introduction and Methodology

Quadrature Climate Foundation's (QCF's) Transition Minerals Strategy supports the clean energy transition by advancing critical mineral solutions essential to clean technologies. Achieving net zero by 2050 requires rapidly scaling the responsible production of **copper, lithium, and nickel**, while minimising environmental and social impacts. To help meet this goal, QCF is exploring how **innovation can accelerate the supply of critical minerals in a just and equitable manner**.

Cleantech Group is supporting QCF in validating the concept of a **"Rock Warehouse" (RW)** mining innovation hub, designed to fill critical resource gaps for mining innovation as described in QCF's Transition Minerals Evidence Review. **Chile, Indonesia, South Africa, and Zambia** were selected as priority geographies for their mineral potential in copper, nickel, and lithium—key to the energy transition—and their sufficient base of innovation to enable ecosystem development. While the project confirmed the **viability of the Rock Warehouse model in at least one context**, it also highlighted the need for a **diverse set of interventions** to strengthen mining innovation ecosystems. These range from **localised efforts**—such as **artisanal & small-scale mining funds**, **mining-focused business accelerators**, or **research collaborations**—to more **systemic, national and regional initiatives**, like establishing **test-mine sites** in Africa or South America to catalyse broader and/or applied innovation.

This report presents the findings of the Rock Warehouse concept validation, consolidating insights from **23 interviews** with ecosystem stakeholders across the four countries, as well as global mining leaders—including BHP and Rio Tinto—and best-practice hubs in **Canada, the U.S., and Australia**. The analysis is further supported by **extensive secondary research, in-house knowledge** and proprietary data from **Cleantech Group's i3 database**, covering mining-related innovation and global investment flows.

QCF's mission and capabilities offer a chance to address **critical gaps** in the global mining innovation ecosystem. The report offers a **comprehensive overview of the global mining innovation landscape**, outlining key trends, capital flows, hardtech gaps, and emerging opportunities. It provides **detailed ecosystem analyses** of the four countries, identifying strengths, challenges, and **high-impact strategic recommendations** to advance mining innovation. While philanthropic capital plays a role across the recommendations, the report clearly defines where **philanthropy can lead**, and where **partnership with industry, government, or other stakeholders is critical**.

Contents

Global mining innovation urgently needs more disruptive (hardware) technologies and Global South representation

Insufficient support for early-stage innovation

- **Investors favour established mining scaleups**, creating funding challenges for early-stage innovations
- **Limited information-sharing creates misalignment** between industry needs and academic/startup innovation focus areas, requiring support to bridge these gaps
- **Expanded testing infrastructure** would **reduce adoption risk**, enabling implementation of promising but unproven technologies

Innovation concentrated in resource-rich nations

- **Majority of mining innovation occurs in wealthy nations**, creating opportunity gaps for resource-rich emerging economies
- Innovation enables **Global South countries to move up the value chain**, increasing domestic value retention and attracting investment
- **Whole-ecosystem approaches** developing local institutions and skills promote equitable economic gains
- **Philanthropy can help innovators** from developing ecosystems **access global innovation infrastructure**

Incremental rather than disruptive innovation

- Mining innovation ecosystem **disproportionately focuses on exploration**, neglecting other stages of critical mineral development — innovation in exploration is less disruptive and adaptable to software
- **Hardtech solutions for extraction, processing, and remediation remain underfunded** despite their transformative environmental potential
- **Water usage, energy consumption, and tailings management offer high-leverage intervention** points for sustainable mineral supply chains

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Global Scan: Ecosystem support is needed to enable Global South resource centres to respond to increased demand

Canada

- Top-12 positions in reserves, production of copper & nickel
- Mining Innovation Commercialization Accelerator Network (MICA): $112.4M Canadian mining innovation network to accelerate sustainable mining technologies

DR Congo

- Largest cobalt reserves, 4th largest copper producer
- Deep concern over conflict minerals, human rights abuses, highlighting severe political risks for investors
- DRC-Zambia Battery Council aims to transform both nations into battery manufacturers

Kazakhstan

- Ranks around 10-12th globally in copper production; major copper deposits in the eastern and central regions
- Local and international mining operators not currently engaging with innovation

USA

- Significant reserves in copper and lithium
- BIL and IRA allocated over $8.5B for critical mineral projects through various projects
- The US DOE: $75M for a Critical Supply Chain Research Facility

Indonesia

- World's largest nickel reserves and leads global production
- Nickel export ban coincides with major investments in domestic processing, with CATL, LG, Ford establishing local operations or procurement deals

Chile

- World's largest copper and lithium reserves; top 3 producer
- Established state-controlled partnership with SQM mining company to maintain majority control of lithium production
- Fundación Chile Expande programme connects innovators to mining industry, resulting in 190 contracts worth $US50m

Australia

- Largest lithium producer; top 10 in copper and nickel
- The Resources Technology & Critical Minerals Trailblazer: university consortium with $102M of funds ($67.6M from industry partners) to drive innovation in mining sector
- Australia's Critical Minerals Facility provides $4B AUD in loans, guarantees to support projects facing financing gaps

Brazil

- Major rare earths, graphite, and nickel production
- Several companies are advancing lithium exploration projects
- Mining Hub Brazil's M-Start initiative matches mining companies with startups to accelerate innovation

South Africa

- Massive ore reserves ($2.5T) with 16 commodities in global top 10
- Mandela Mining Precinct: PPP aimed at revitalising mining research, development and innovation
- $8.5B JETP partnership with major economies driving mining, energy, and transport decarbonisation

Zambia

- Africa's 2nd largest copper producer
- Zambia draws mining investment via geology, stability, mine privatisation
- The Lobito Corridor: US-backed rail project connecting DRC/Zambia's copper belt to Port of Lobito, reducing export times from 30+ to 9 days
- KoBold Zambia: Innovative copper mining with local partnerships

Priority geographies combine substantial reserves with untapped innovation potential in Chile, South Africa and Zambia which can be unlocked by targeted ecosystem support; Indonesian market could be difficult to engage productively

Chile

- **Critical Metals:** Cu, Li
- **Mining Innovation Ecosystem Maturity:** Developing ecosystem with strong research, government, but gaps in commercialisation
- **Strategic Importance:** Key supplier to Western & Chinese markets; deployment hub for mining tech, especially for US/Canada innovators
- **Cleantech Group Ranking:** 1

South Africa

- **Critical Metals**: Cu, Ni, Li
- **Mining Innovation Ecosystem Maturity:** Developing ecosystem with active stakeholders but coordination challenges
- **Strategic Importance:** Most established innovation hub in Southern Africa; gateway to mineral-rich neighbours like DRC, Zambia, Zimbabwe
- **Cleantech Group Ranking:** 2

Zambia

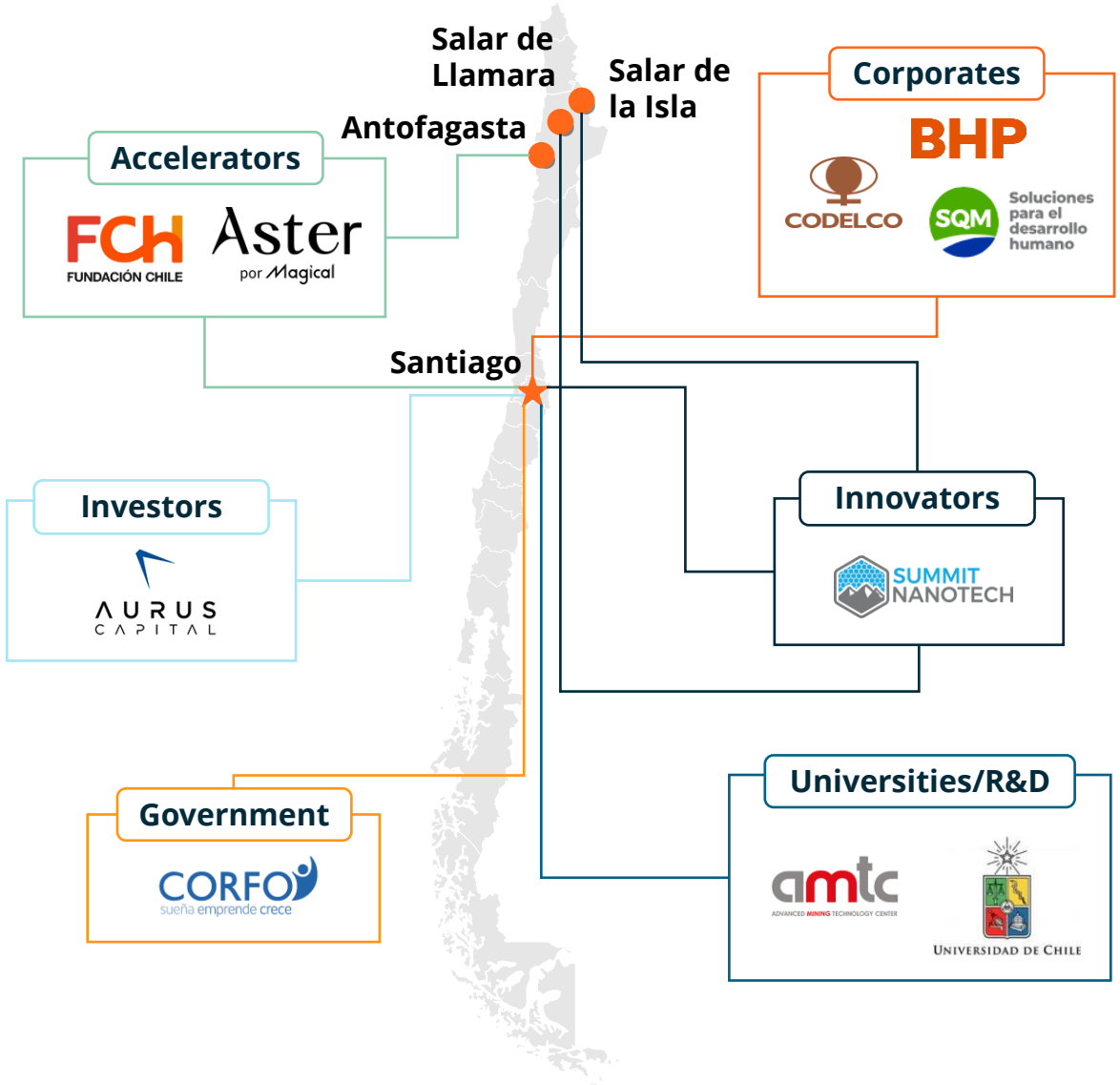
- **Critical Metals:** Cu, Ni, Li
- **Mining Innovation Ecosystem Maturity:** Emerging ecosystem with growth potential via initiatives like MineTech Hub, etc.
- **Strategic Importance:** Central to US-China critical metals competition; key node connecting Lobito Corridor (US) & Tazara railway (China)
- **Cleantech Group Ranking:** 2

Indonesia

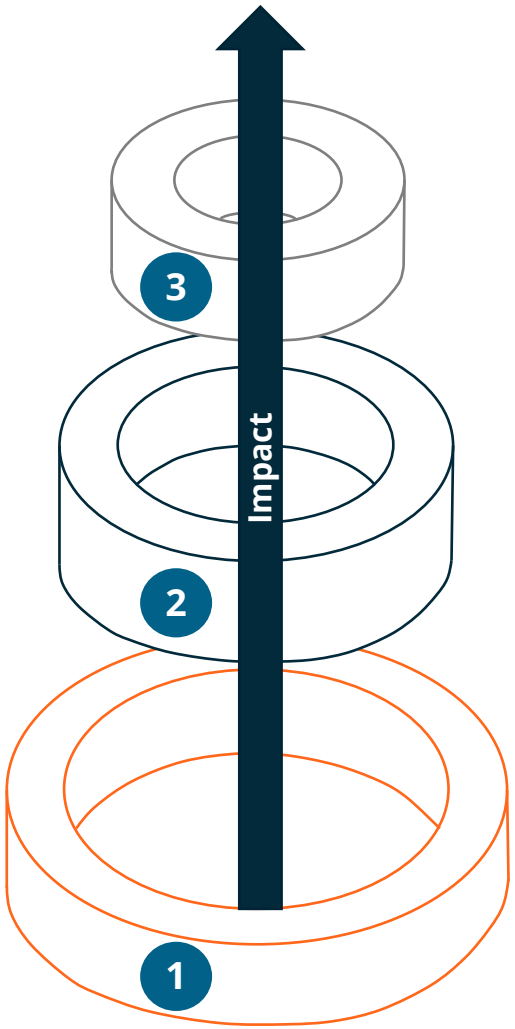
- **Critical Metal:** Ni (+60% of global supply)
- **Mining Innovation Ecosystem Maturity**: Emerging ecosystem dominated by Chinese interest
- **Strategic Importance:** Critical to global EV battery supply chain; China controls 75% of local refining capacity; price-setter for global nickel market
- **Cleantech Group Ranking:** 3

Chile ecosystem overview: high-potential mining innovation ecosystem with commercialisation challenges

- Chile is home to **some of the world's greenest copper production** powered by clean energy, due in part to corporate leaders like BHP
- Chile boasts excellent research institutions and universities supporting R&D (e.g. Universidad de Chile)
- **Public sector programmes** facilitated by CORFO are the backbone of mining innovation:
  - R&D Challenges: 7 R&D challenges have been developed with industry, including Li-ion battery reuse, low-carbon copper, and direct lithium extraction (DLE)
  - Plans to develop live lithium testbed in Northern Salars
- There is also growing interest to **build-up the mineral-rich north** (e.g. Antofagasta)
- **High competition** for the main source of public funding (CORFO) with startups and universities vying for limited grants amid bureaucratic processes
- **Lack of private finance** for innovators, especially at mid-TRL stage, is leading to a startup "valley of death"
- Foreign innovators from Canada, US seek out **grants, investments from their home country** and deploy on-site, thereby potentially displacing local innovators



Chile ecosystem support recommendations: transform technical excellence into market-ready solutions through validation and corporate engagement



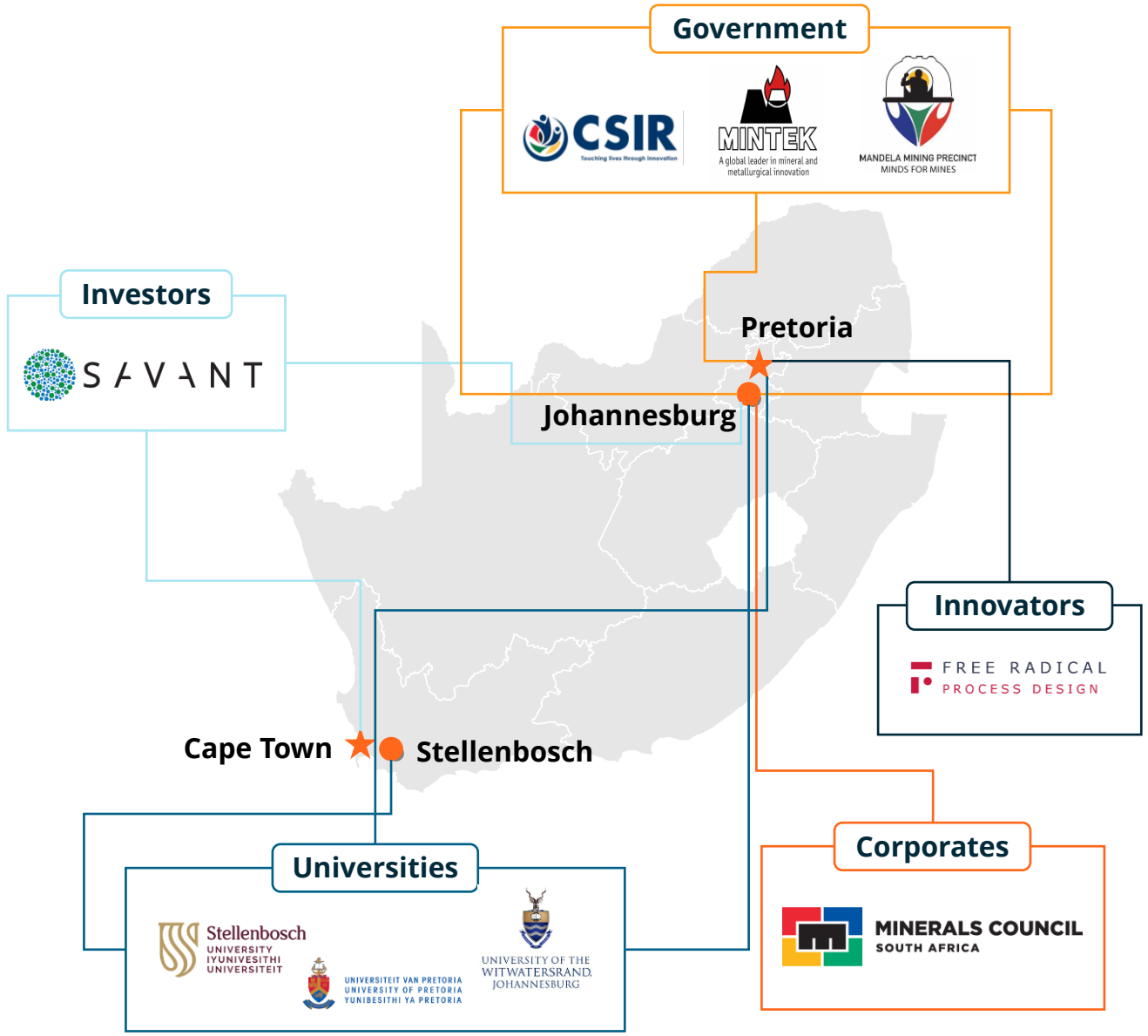
Intervention	Rationale	Partners
Establish a test mine	▪ Incentivise corporate adoption via validation ▪ Coordinate national piloting infrastructure ▪ Test mine must reflect ecosystem needs, not just single-company agenda	CORFO, SQM, CODELCO
Create a corporate matchmaking programme	▪ Improve startups' market access ▪ Leverage existing open innovation initiatives ▪ Need for facilitation and de-risking of pilots	expande, SQM, AURUS CAPITAL, BHP, CORFO, CODELCO
Create a mining-focused business accelerator	▪ Ensure product-market fit and business acumen to commercialise innovation ▪ Local innovation receives limited attention despite some existing effort	Aster por Magical, UNIVERSIDAD DE CHILE, CORFO

Multiplier effect:
Overcoming private financing gap hindering Chilean mining innovation

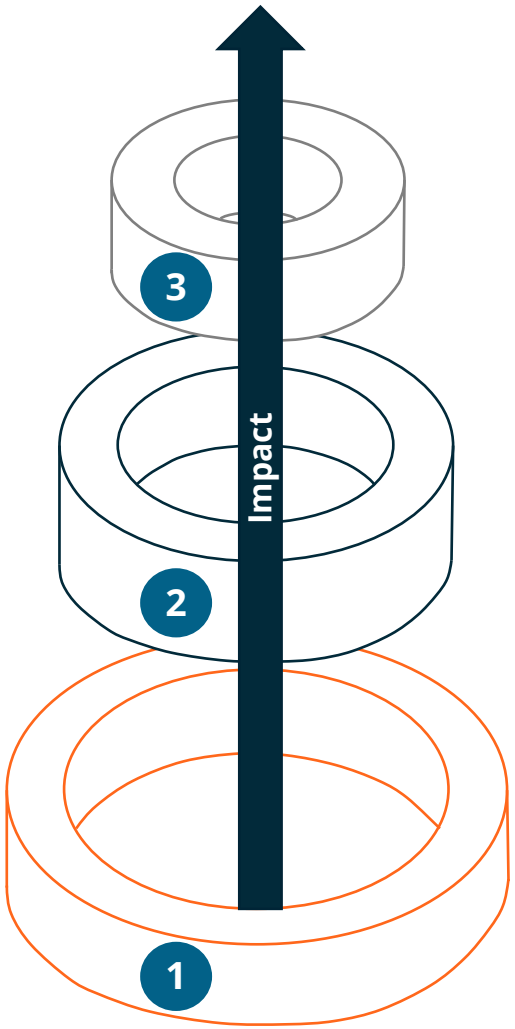
Multiplier effect:
Unlocking market access barriers faced by early to mid-stage innovators

South Africa ecosystem overview: active but fragmented mining innovation ecosystem with commercialisation bottlenecks

- Mining innovation landscape described as "confusing"—**engaged stakeholders but activities disjointed,** with redundant technology development, lack of coordinated activities between stakeholders, and stalled research
- **Strong manufacturing base for mining equipment**: Local OEMs participate in initiatives led by MEMSA and MMP to support localisation
- Excellent universities and research institutions like Wits (Digimine) and Stellenbosch, though **academic output struggles to connect to industry application**
- Entrepreneurial culture: availability of lab space and services, but SMEs face **challenges in piloting**
- **Corporate bureaucracy delays mining innovation**, with lengthy validation, complex approval processes, and slow decision-making stalling deployment
- Opportunity to **strengthen mechanisms connecting stakeholders**—current solutions (like TIA's Bridge Portal) contain valuable information but are underutilised



South Africa ecosystem support recommendations: bridge research-industry divide through silo dismantling, corporate partnerships and piloting



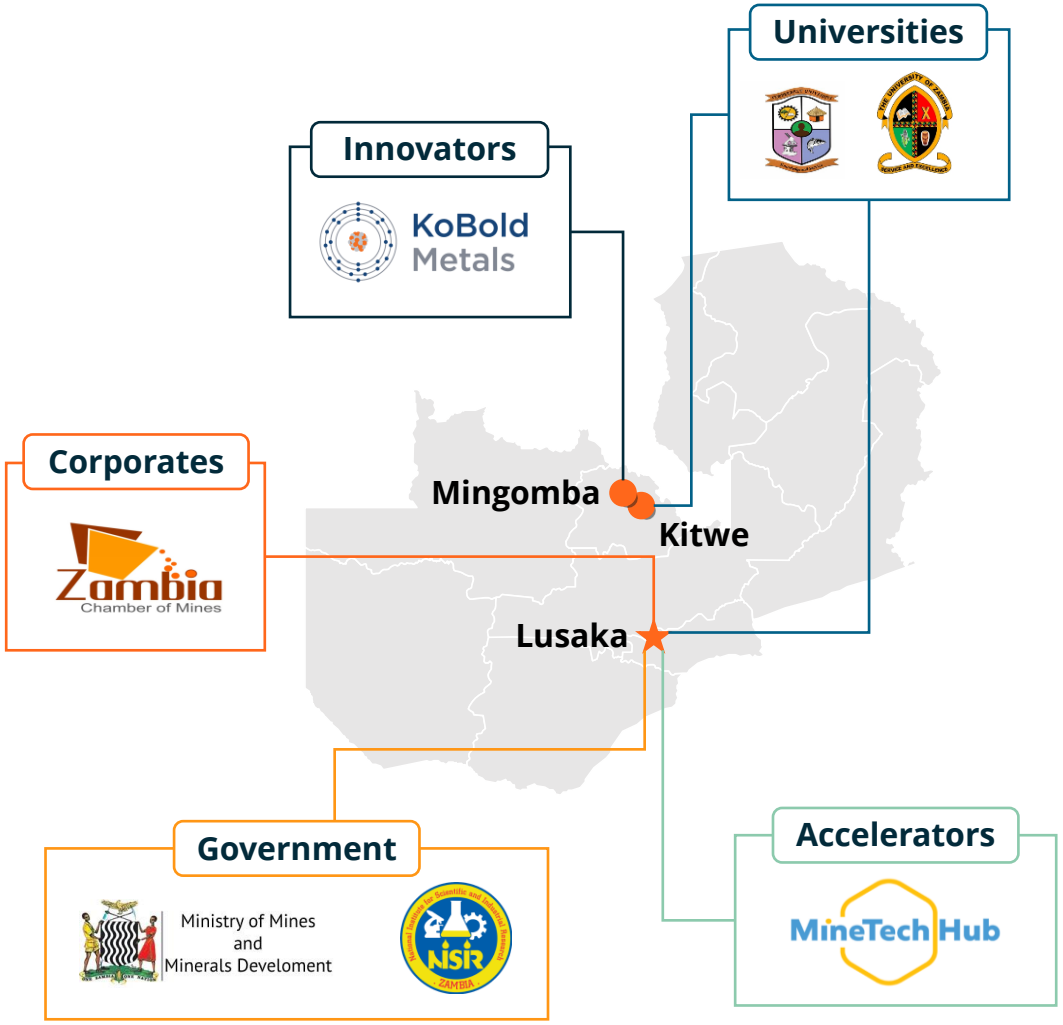
Intervention	Rationale	Partners
Establish a test mine	▪ Provide pilot, demonstration & validation opportunities ▪ Align siloed activity and drive stakeholder engagement ▪ Diversified funding insulates from mining market volatility and diverging interests	CSIR; Mandela Mining Precinct – Minds for Mines; MineTech Hub; Minerals Council South Africa
Create a corporate matchmaking programme	▪ Connect corporates with startups through structured pathways to overcome adoption barriers ▪ Enables partnerships where market forces alone fail	Valterra Platinum; SAVANT
Create a mining-focused business accelerator	▪ Bridge R&D to commercialisation gap by ensuring innovations are business-ready and meet industry needs	Mandela Mining Precinct – Minds for Mines; Minerals Council South Africa

Multiplier effect:
Creates market-ready innovation to overcome valley of death

Multiplier effect:
Establish a standard-bearer mining innovation ecosystem in Southern Africa

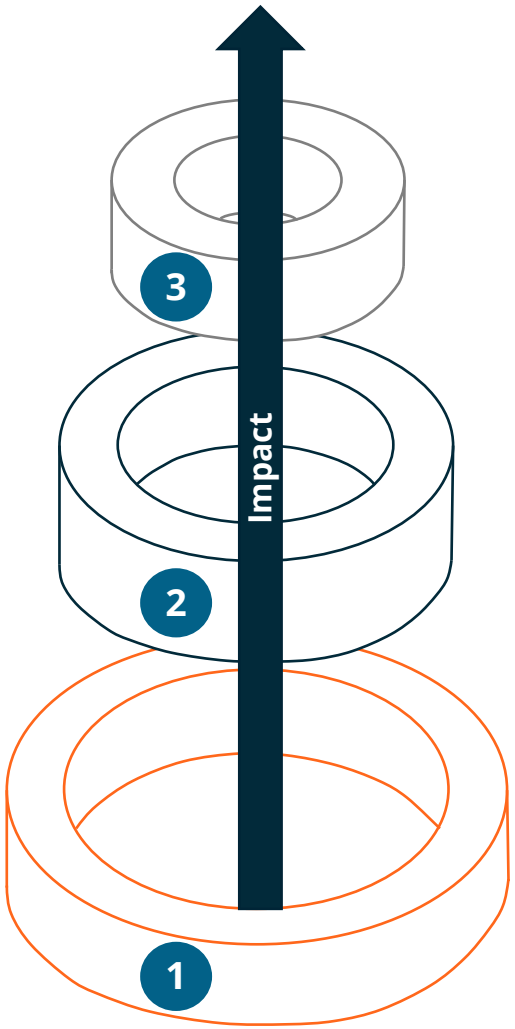
Zambia ecosystem overview: emerging and high-potential ecosystem depends on policy/regulatory deployment and enforcement

- Over half of Zambia's mineral potential remains unexplored, including lithium, cobalt, nickel, and graphite — positioning it as a **key frontier in transition minerals for clean technologies**
- Zambia is developed enough to absorb investment, yet early-stage enough that the right support could establish it as a **regional innovation hub with lasting impact**
- **Institutional infrastructure** in motion with UNDP MineTech Hub supporting industry-informed innovation, testing, and incubation (details on page 32)
- **Strong University Engagement**, with University of Zambia leading Critical Minerals Research Institute, while Copperbelt University's "UniPod" provides physical space to incubate ideas
- The **pro-business government's new Critical Minerals Strategy** focused on partnerships, value addition, R&D
- **Weak regulatory and policy enforcement remain a challenge**, as shown by the lack of data sharing by mining majors
- With over 600K artisanal miners[1], Zambia presents a major opportunity to embed **equity, safety, and environmental justice** from the start of mining innovation ecosystem development



[1] Artisanal and Small-Scale Mining (ASM) involves mineral extraction by individuals or cooperatives using minimal technology, often outside regulatory frameworks. ASM is a major source of global mineral production but is characterised by low safety, inadequate healthcare, and limited environmental protection.

Zambia ecosystem support recommendations: immediate impact through artisanal mining while building-up the innovation ecosystem in the medium-long term



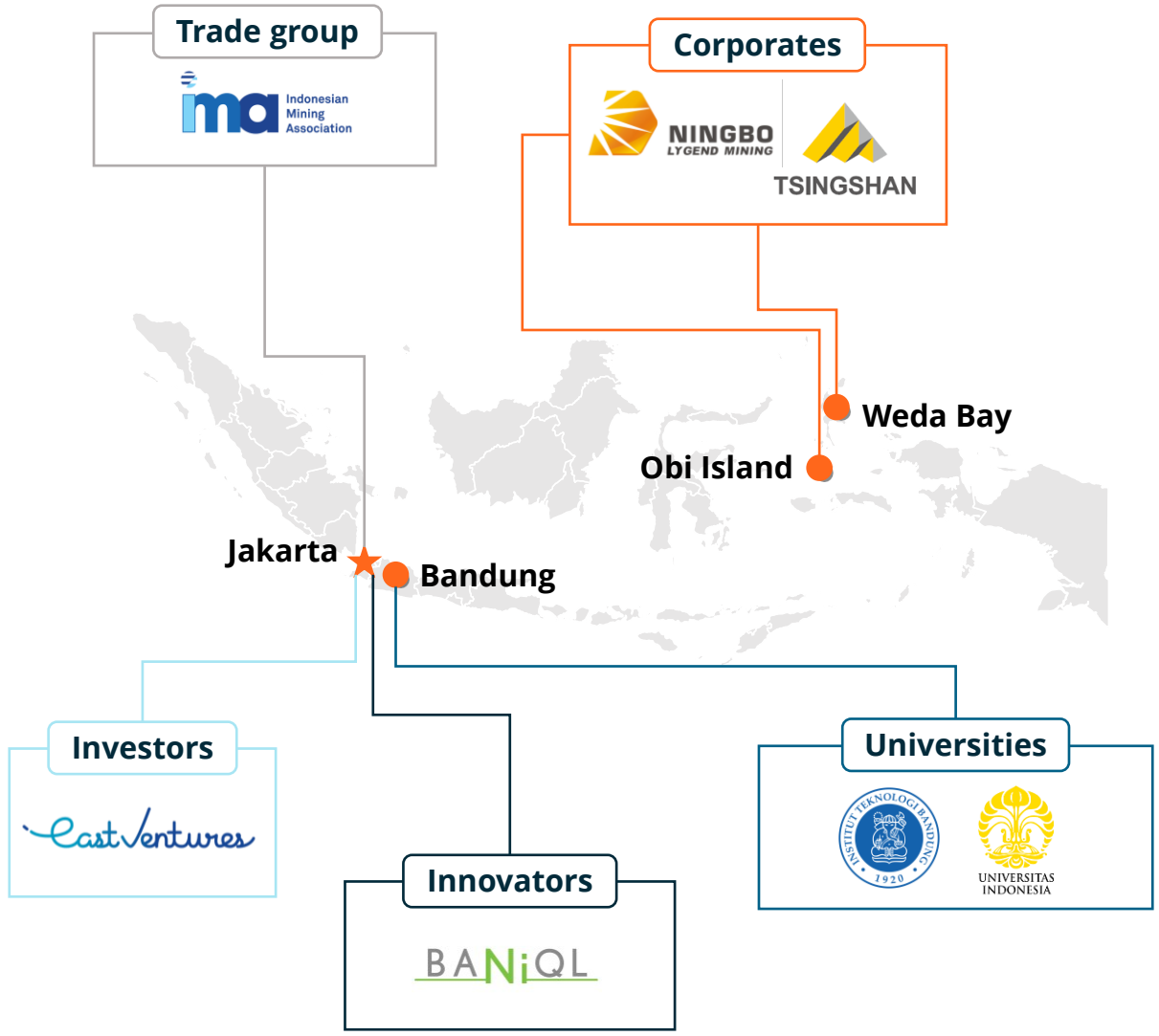
Intervention	Rationale	Partners
Establish a rock warehouse	▪ Leverage existing institutions while providing needed ESO infrastructure ▪ Physical hub in sync with government aims ▪ Guarantee equitable access across the ecosystem	Zambia Chamber of Mines; NSIR Zambia; Ministry of Mines and Minerals Development; MineTech Hub
Initiate collaborative R&D projects	▪ Strengthen research pipeline and industry-research links ▪ Funds pre-competitive research with potential to create value for entire sector	NSIR Zambia; KoBold Metals
Establish an artisanal & small-scale mining (ASM) fund	▪ Decarbonise artisanal & small-scale mining while boosting productivity and safety ▪ Address environmental, social indicators overlooked by markets	Ministry of Mines and Minerals Development; Zambia Land Alliance; MineTech Hub; WEAC

Multiplier effect:
End-to-end support across value chain, from incubation to mining adoption

Immediate environmental and social impact

Indonesia ecosystem overview: emerging mining innovation ecosystem dominated by Chinese interest

- Indonesia's critical minerals sector is expanding rapidly, but the **local mining innovation ecosystem is underdeveloped relative to its size**—despite being the world's largest nickel supplier, it lacks startup support, incubation, and local entrepreneurial infrastructure
- **Chinese firms** (e.g. Tsingshan, Lygend Resources) **lead the nickel value chain** via joint ventures and large-scale investments, shaping industrial development
- Nationalist bans on raw ore exports have created **new openings to build domestic capabilities**
- **Limited education infrastructure and bureaucratic hurdles** constrain human capital development and market entry – success often depends on high-level connections and top-down approach
- New government (2024) **actively seeking international investment** beyond dominant Chinese presence, but challenges for external stakeholder engagement remain high
  - Eramet: profitable nickel mining in Indonesia needs Chinese partners
  - Chinese stakeholders control over 75% of Indonesia's nickel refining capacity (C4ADS), limiting opportunities for non-Chinese players
  - Sustainability concerns around nickel mining are seen as a key reason why Western companies (e.g. Tesla) have hesitated to invest



Examining leading global minetech hubs shows success depends on strong industry engagement; diversified revenue streams essential for sustainability and long-term impact

Scope

Existing hubs include **non-profits, as well as those driven by commercial and strategic objectives** (e.g. leveraging legacy industries, creating value chains from natural resources, etc.)

Trade off between mission and financial sustainability: **regions with greatest need have lowest ability to pay**

Hubs like NewLab choose locations based on **public sector motivation** and ability to contribute resources

Initial Funding

Upfront cost of **$15m to $35m** depending on facilities

Public grants provided 30-100% of initial capital in examples

Path to financial sustainability typically 3-5 years

Physical facilities include workspace, lab space and equipment, test facilities

Revenue Streams

Member fees are main source of revenue for most hubs: tiered membership models with fees according to services used or ability to pay

Equity investments used by some but not all hubs, long timeline before returns

Government grants provide a small part of revenue

Workspace important to attract startups, but not a growth driver

Success Factors

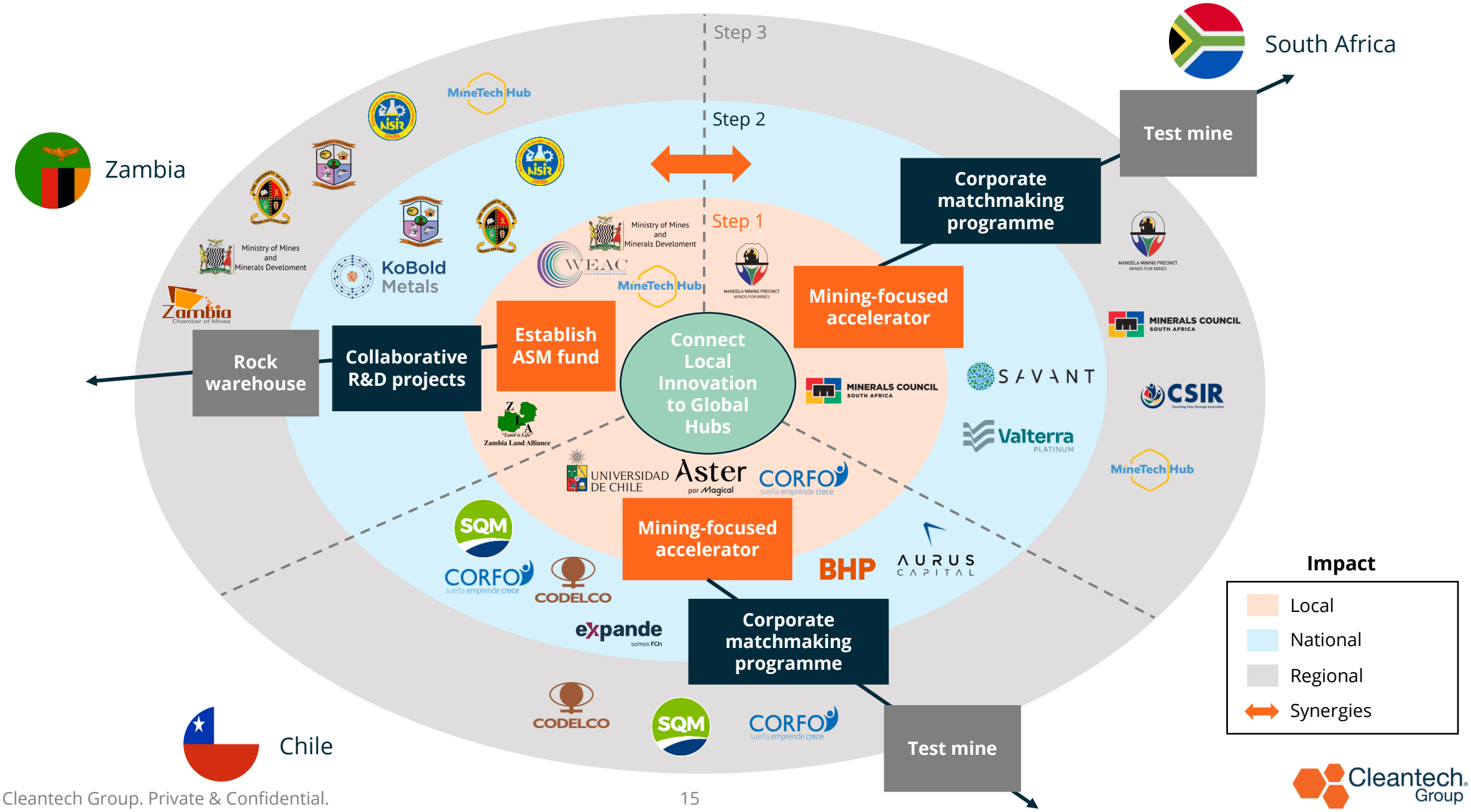
Diversified revenue streams optimise **financial and operational independence**

Industry involvement is critical: startups benefit from on the ground understanding/feedback; investors want to see industry on board

Facilitation of **interface between startups and industry** improves success rates

Easier to **involve regulators from the start** than bring them in later

Recommendations to leverage philanthropic capital for maximum impact, partnerships, and cross-country synergies



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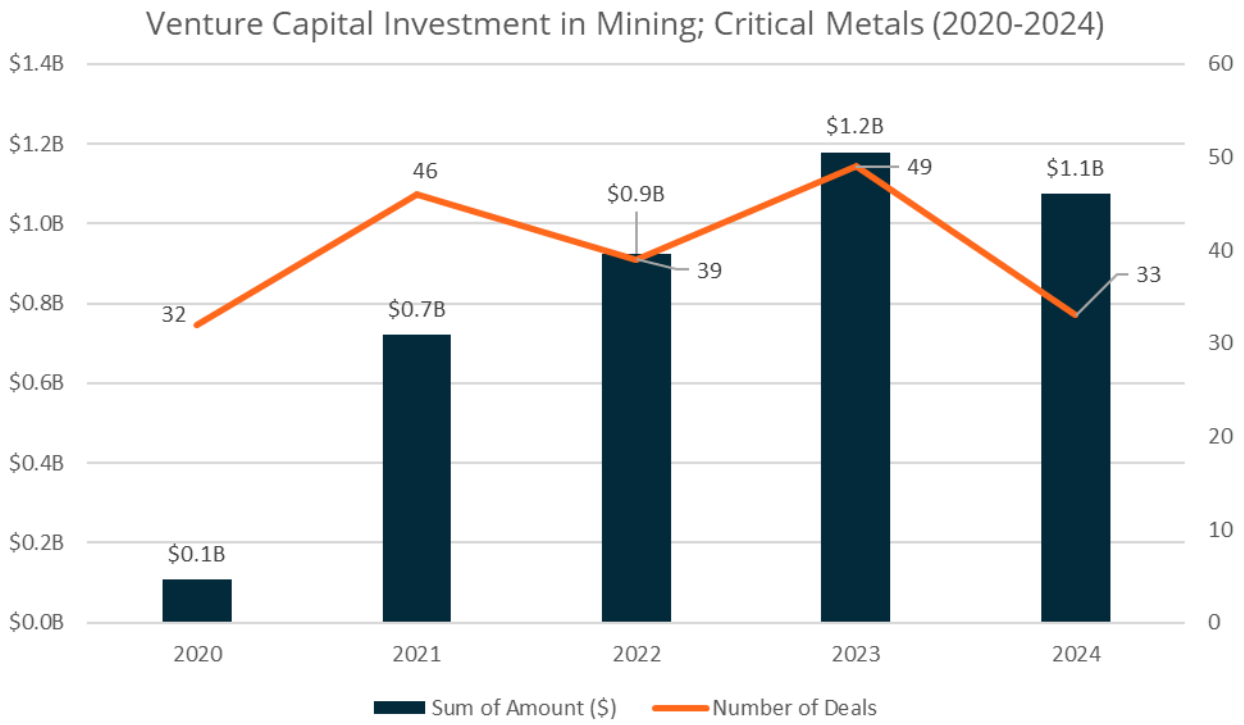
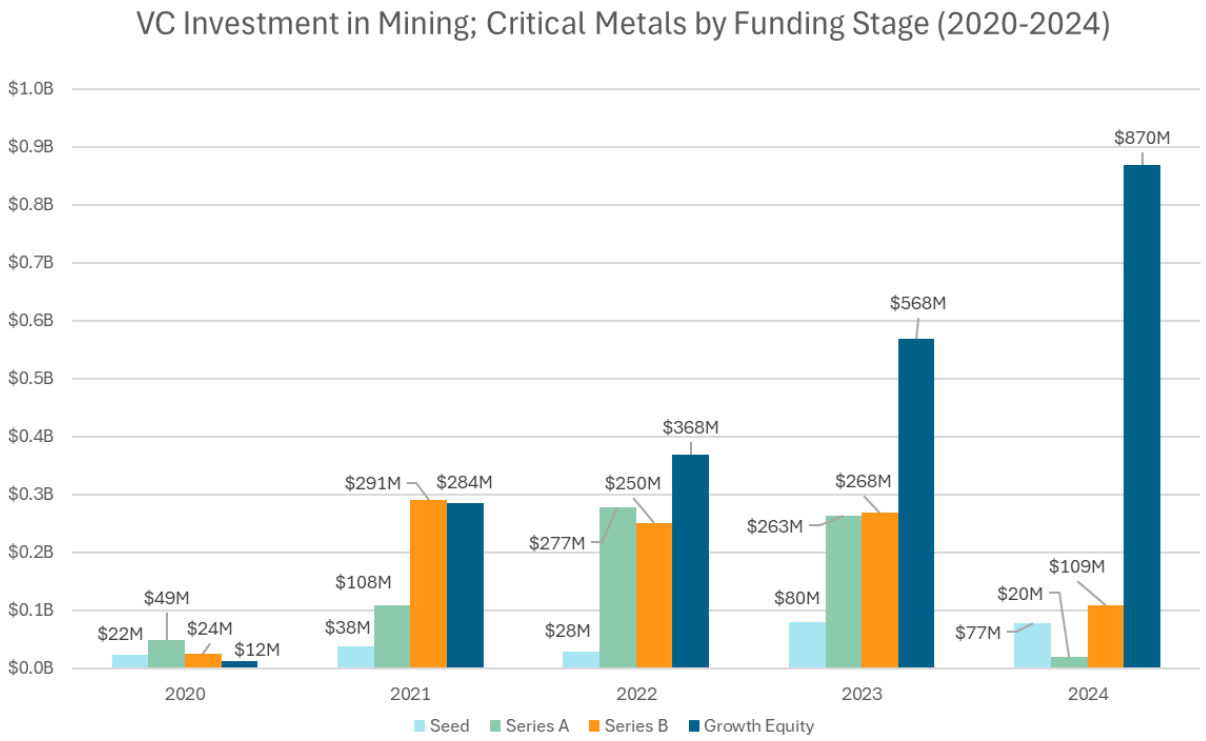
VC investment in mining & critical metals has expanded rapidly since 2020, but not reaching many critical solutions



> ***"We're seeing more interest from the VC community in getting involved, including investors we hadn't heard of five years ago."***
>
> Pekka Santasalo
> Head of Growth & Ventures, Rio Tinto

- Total VC investment in mining and critical metals **increased nearly 12x** from 2020-2023
  - Timed alongside uptick for energy storage, EVs, batteries etc., recognising mining as a critical enabler for the global energy transition
- **Venture funding remains heavily skewed towards lower risk exploration** segments, and increasingly toward software-based technologies
  - Meanwhile, critical hardware & infrastructure-heavy solutions around processing, remediation, recycling **remain underfunded**
  - Systemiq and Breakthrough Energy's report on critical raw materials emphasizes the urgent need to accelerate innovation in mining and refining technologies in copper, nickel, lithium, and others to meet 2030 climate and industrial goals
  - Majors prefer incremental innovation which does not disrupt operations and CAPEX cycles
- While investment remained robust in 2024, this was primarily driven by a **few large growth-stage deals**
  - Capital is consolidating around a handful of mature startups considered 'safe' bets with large-scale commercial potential
- **Average (mean) deal size has grown dramatically** from $3.1M in 2020 to $33.3M in 2024

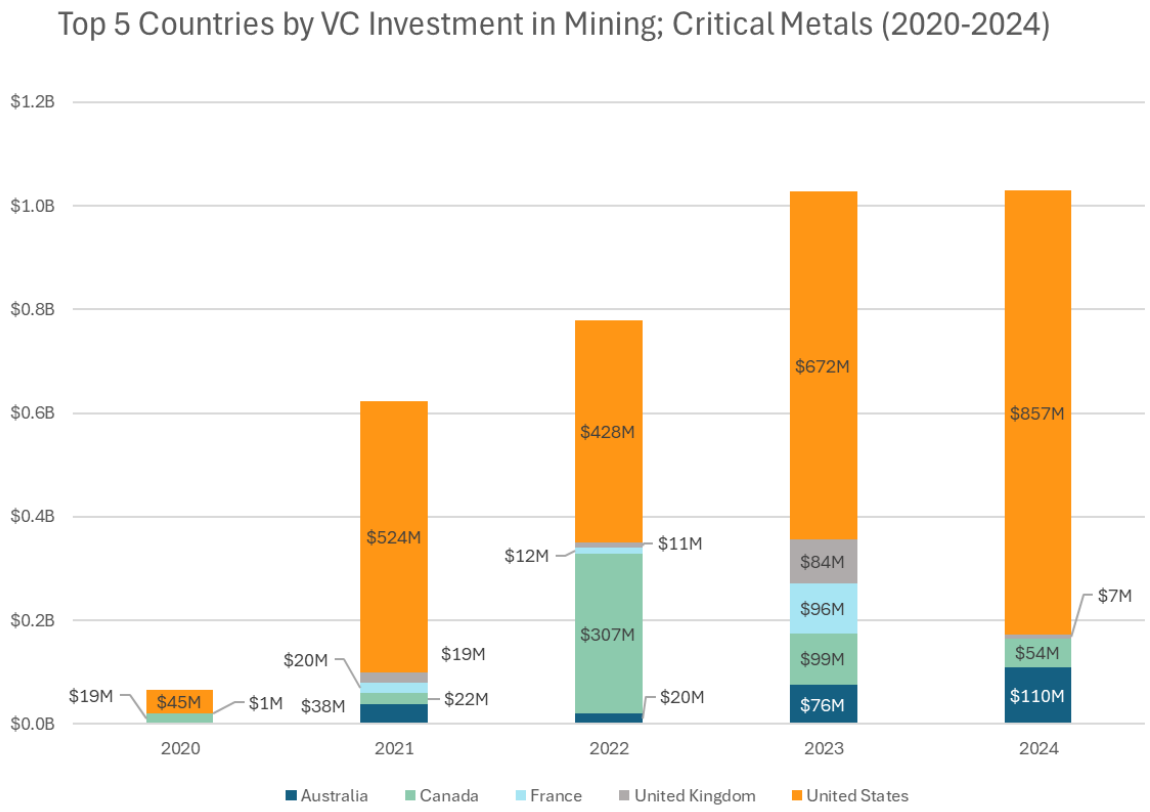
Despite funding growth, most VC investment going into established innovators, creating an early- to mid-stage gap



> ***"There's a clear lack of early-stage support for mining innovation, and short-term capital cycles aren't enough to back hard tech solutions that take years to scale."***
>
> Nic Allen
> Managing Partner, Savant

- Mining solutions face **long pathways to implementation**
  - Early R&D often stalls without testing materials or infrastructure—solutions struggle to move beyond lab without industry partnerships bridging TRL 2-6 gaps
  - **Market adoption requires demonstration at scale**, yet few facilities exist for full-system validation in relevant environments
- **Investors prefer established solutions** that have secured multiple rounds of financing and derisking
- **Growth equity** poured in significantly **after catalytic capital** (public / philanthropic) **de-risked** a few solutions
  - Examples of significant 2024 growth rounds include KoBold Metals ($491M), Lilac Solutions ($145M), and Fleet Space ($100M)
    - KoBold Metals secured a $20M seed round from Breakthrough Energy Ventures in 2019; their subsequent 2022 round closed at $192M (attracting +13 investors)
    - Lilac Solutions received initial seed funding from PRIME Coalition in 2018, followed by Breakthrough Energy joining their $20M Series A in 2020, which ultimately led to a $150M round with +11 investors
- **Series A and B investment declined significantly in 2024** after maintaining relative stability from 2022-2023
  - The decline may reflect broader market conditions (VC deployment in cleantech down from its 2022 peak) and critical metals or mining-specific challenges (subdued EV sentiment, saturation of mining leaders launching accelerators, CVCs, etc.)

Mining & critical metals VC funding is concentrated in wealthy mining nations notwithstanding global mineral production

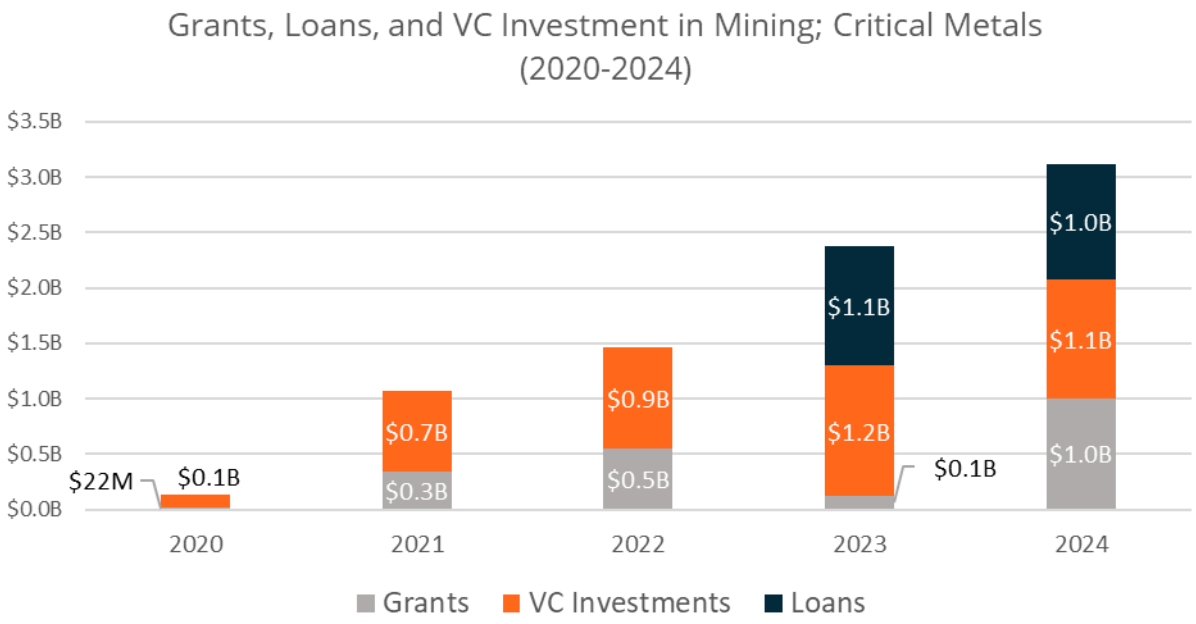


"For global mining innovation to thrive, we need a united network where ecosystems worldwide support each other's unique strengths. A united front means we achieve far more together."

Renu Kannu
National Robotics and Innovation Lead, AARP

- **U.S. dominates the global investment landscape** in terms of cumulative VC investment received by startups based in the country, totalling over $2.5B (2020-2024), more than 5x the amount received by second-ranked Canada ($500M)
  - Heavy push on policies (IRA) with substantial tax incentives and public funding to secure domestic supply chains for critical minerals
  - **Demand continues to be shaped by tandem policy support** for sectors depending on critical minerals, including energy storage and electric vehicles (battery minerals: cobalt, lithium, nickel etc.),
- Traditional mining powerhouses **Australia and Canada maintain consistent presence** in the top three, though at significantly lower investment levels than the U.S.
  - Slightly more conservative VC appetite compared to US around novel extraction / high-risk and infrastructure-heavy solutions
- **European presence** through France and UK **remains modest**, with VC investments of approximately $120-130M each over last five-years
  - Europe has a **general lack of large domestic mineral resources**, creating a **reliance on outsources & imported critical minerals** for renewable energy infrastructure and EV deployment
- **Innovations originating in the Global South are notably absent from the top VC investment** data, with funding overwhelmingly concentrated in Global North countries

Government funding is driving mining & critical metals innovation, leaving countries with fewer state resources at a disadvantage

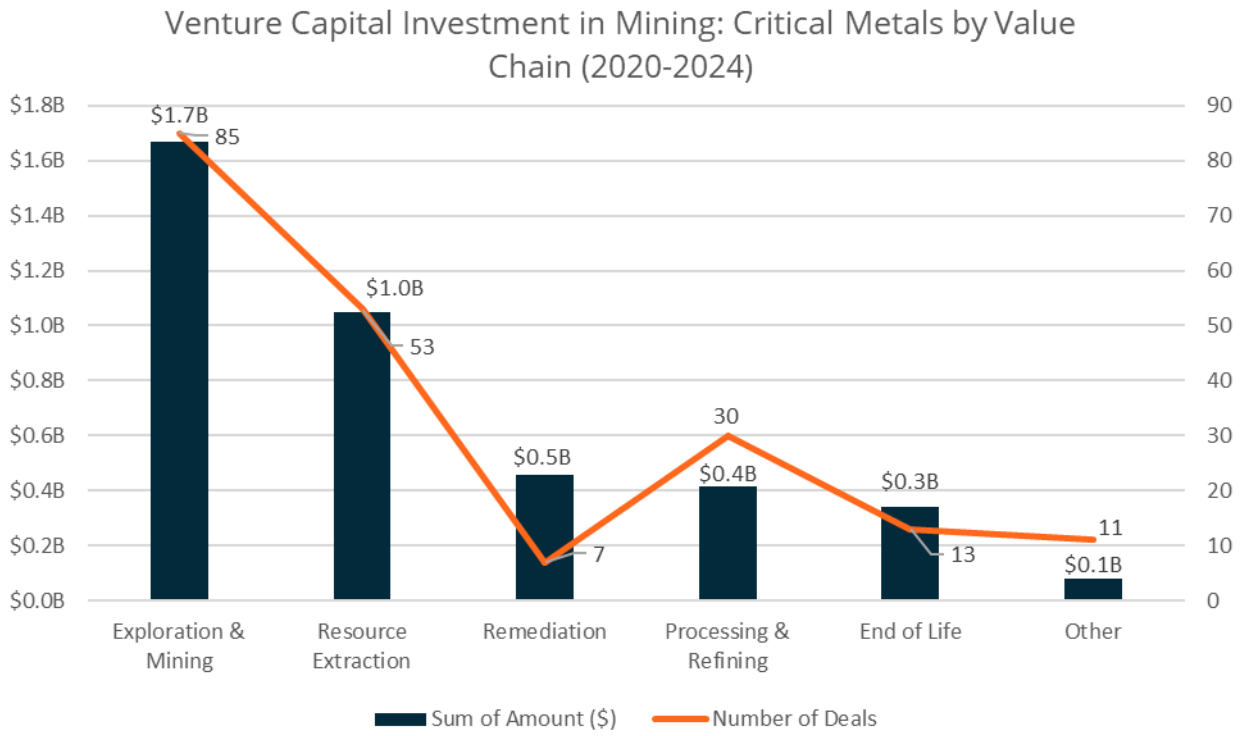


Example of Loans and Grants in Mining and Critical Metals

Year	Country	Type	Amount	Provider	Recipient	Element
2023	Australia, USA	Loan	$700,000,000	U.S. Department of Energy (DOE)	Ioneer	Lithium
2023	Canada	Loan	$375,000,000	U.S. DOE	Li-Cycle	Lithium
2024	Finland	Loan	$500,000,000	European Investment Bank; Export Credit Agency	Sibanye-Stillwater (Formerly "Keliber")	Lithium
2024	Brazil	Grant	$282,900,000	U.S. DOE	Vale	Iron, Nickel
2024	USA	Grant	$150,000,000	U.S. DOE	American Battery Technology Company	Lithium
2022	Canada	Grant	$20,000,000	Government of Canada	E3 Lithium	Lithium

- Mining & critical metals funding landscape extends beyond venture capital to include government grants & loans, with **public sector support exceeding private investment** in many leading innovation ecosystems
- The **U.S. DOE provides billions** in loans and grants **for critical metals development**, with similar programmes emerging in the EU and Canada
- Limited availability of data on Chinese financing, yet Financial Times reporting revealed **China has provided $57 billion in loans** from 26 state-backed institutions for mining and processing **copper, cobalt, nickel, lithium and rare earths** across developing nations over two decades

VC investment in mining & critical metals is heavily skewed towards exploration technologies, leaving value chain gaps



"There is a critical funding gap in mineral processing innovation, meaning we can find deposits but struggle to extract and process metals with efficient water and energy use."

Dr Anil Subramanya
Strategic Advisor, Amira Global

- **Exploration and mining** make up approximately 43% of deal flow and 42% of total amount invested between 2020-2024
- **The lion's share of investments went to predictive analytics software** and this trend appears to be continuing into 2025; other trending technologies include direct lithium extraction from brine and satellite-based exploration
  - Software solutions demonstrate an optimal risk/reward balance for VCs, offering lower technological risk while significantly enhancing exploration outcomes
- **Critical funding gap persists in sustainable mineral processing**, raising questions about how innovation ecosystems can support essential refining technologies
  - **Catalytic capital can play a crucial role in de-risking** first-of-a-kind refining technologies, which— when complemented by public funding packages—can help attract significant private investment
  - These technologies lack the commercial and investment backing enjoyed by other parts of the value chain

Contents

Chile's mining innovation ecosystem is developing with active stakeholder engagement and opportunities for partnership

Universities / R&D

Partnered with Start-up Chile for acceleration corridors; R&D in mining via AMTC (with Codelco)

Entrepreneurship & innovation pipeline; R&D for mining & geological engineering

Connected to University of Chile, and partnered with Codelco for mining tech

R&D centre backed by CORFO, uncovering new mining technologies

Innovators

Water-efficient chemical leaching to extract copper from sulphide ores

Eliminating mining industry waste and recovering valuable minerals

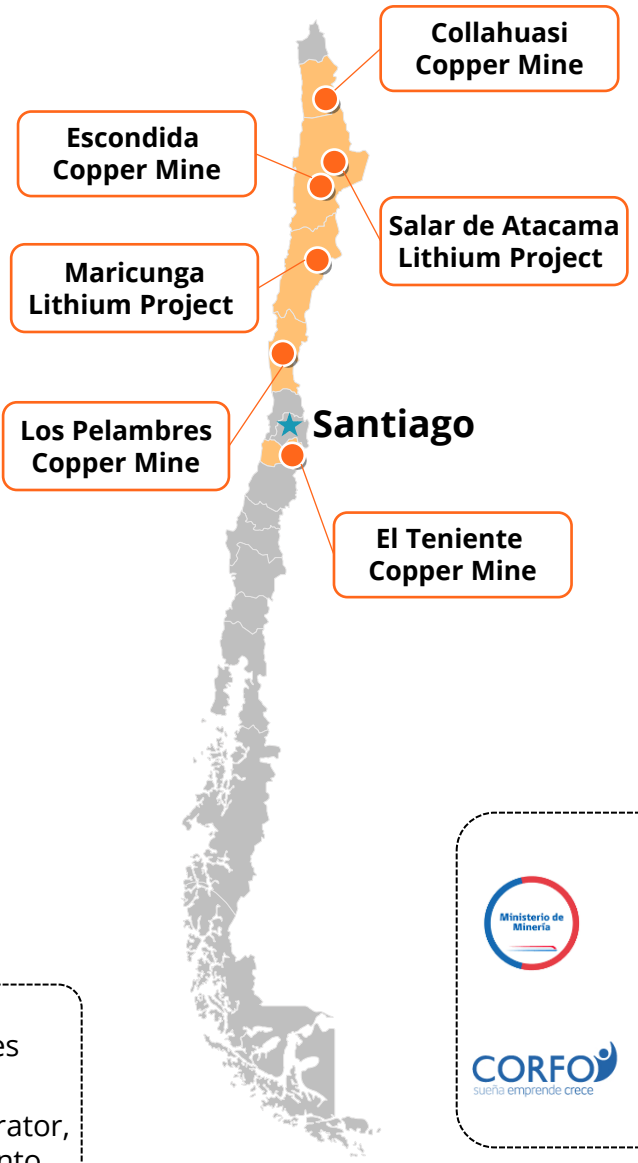
Developer of software for efficient mining activities

DLE technology that extracts lithium from salt brines while preserving aquifer integrity

Investors

Funding mining, critical minerals & materials technologies

VC arm of Fundación Chile; supports Aster mining accelerator, alongside Tailings Technologies initiative with BHP, Rio Tinto



Corporates

SQM Yodo arm partner with Lab4U for local mining talent programme

Leading in copper mining, and moving into Chile's lithium industry with SQM

Recognised as most innovative company (2023) in Chile's mining sector

Future of Smart Mining Program; partnered with Codelco to grow copper production

Expanding Escondida operations by $2B

Accelerators

Leading accelerator set-up by CORFO

Accelerator in Antofagasta directly focused on mining technologies

Public-private innovation hub; Expande specialised in mining technologies

Government

Mining policies for innovative, sustainable, national development

Agency promoting research and innovation

Government agency promoting production and economic growth

Generates and shares geology and mining information

Strong institutions and public support create a fertile ground for mining innovation in Chile

Context & Overview

- **Resource Power with Global Relevance:** Chile is the world's top copper producer and second-largest lithium producer
- **Strong Academic and Research Institutions:** Chile's skilled labour force and university partnerships are developing promising new technologies, but there remains untapped potential to commercialise these innovations
- **Government Support:** National Lithium Strategy is in place and public investment is seeding systemic change
- **Established Piloting Infrastructure:** Open innovation programmes like Expande & BHP Supplier Innovation Program allow SMEs to connect with mining companies and offer pilot & demonstration opportunities
  - Fundación Chile Expande programme has resulted in 190 contracts worth $50M
  - Chile hosts two mining tech pilot sites (controlled demo environments, not operational mines)
  - SQM Lithium Ventures also provides funding for innovators generally in Series A/B stages, though many investments are made in foreign startups
- **Industry-Leading Green Mining Practices:** Chile has some of the world's greenest copper, with 60-70% of mining electricity from clean sources; majors like BHP's high environmental standards influence production

CORFO's Role in Advancing Mining Innovation

CORFO, Chile's national economic development agency, drives mining innovation. It manages lithium extraction in the northern Atacama Salar through concessions and is planning a live test mine facility for technology demonstration and certification. Funded by lithium royalties generating hundreds of millions annually, CORFO has channelled $150M to a Cleantech Institute and funds industry-aligned R&D challenges targeting innovation for local implementation, including lithium (DLE and brine reinjection), low-carbon copper, and battery technology (lithium-ion battery reuse and metallic lithium components). Additionally, CORFO and Fundación Chile have invested $11M in Santiago's Startup Campus, a climate hub supporting high-potential startups.

Chile faces challenges in the commercialisation & financing of innovation, as well as slow corporate adoption

Challenges & Barriers

- **R&D to Commercialisation Gap:** Stakeholders noted that despite Chile's outstanding research and development, commercialisation often lags due to research misalignment with industry needs or limited business skills among technical founders, hindering scaling and investment
- **Private Financing Gap:** Investors favour established mining scaleups, creating funding challenges for early-stage innovations
  - Lack of strong private-sector-led VC funds specifically targeting mining innovation, with Aurus Capital being one of the very few active in this sector (though new investors are beginning to emerge)
  - Poor funding for overall R&D; Chile is among the lowest spenders in R&D compared to other OECD countries
  - Ecosystem's overreliance on CORFO funding creates bottlenecks as startups vie for scarce early-stage grants; universities and research centres face a similar challenge, also depending on CORFO without independent funding alternatives
  - Absence of mid-stage funding mechanisms (TRL 6-7) creates a "valley of death" for ventures in Chile; CORFO's early-stage focus leaves a gap for mid-to-late-stage financing that must be addressed through private investment or public mechanisms (including the potential creation of a national development bank, which CORFO is currently discussing)
- **Corporate Adoption**: Global mining majors (BHP, Anglo American) and local majors (Codelco, SQM) are actively involved in the ecosystem, but new technology adoption remains sluggish due to risk aversion and slow internal processes; there is a need for thorough technology validation, but pausing mine operations to test new tech is costly and can lead to production losses
- **Bureaucratic Processes:** Slow bureaucracy and permitting barriers can hinder innovation and market access for SMEs
  - CORFO is perceived as a bureaucratic organisation requiring extensive documentation that can drain away an SME's runway time
  - Complex permitting for new technologies (like direct lithium extraction) slows adoption
  - Need for better coordination between stakeholders such as universities, government, and companies

Chile can become a minetech leader by bridging commercialisation gaps, leveraging lithium royalties, and scaling value chain support

Potential for Growth & Innovation

- **Unlocking Lithium Royalties:** Partnering with CORFO to disburse millions in lithium revenue funds earmarked for regional development for critical metals and mining projects
- **Bridging the R&D-Commercialisation Gap:** Focus on initiatives that help transform technical excellence into market-ready solutions through validation and corporate engagement
  - Potential partnerships could include the Centro Avanzado de Tecnología para la Minería (AMTC) at Universidad de Chile or Centro de Investigación Científico Tecnológico para la Minería (CICITEM)
- **Focus on Value Chain Technologies:** Government programmes attracting local & international companies to develop Chile's lithium value chain from extraction to batteries via “Call for Specialized Producers of Lithium Products”
  - Addressing the critical funding gap in mineral processing innovation, which lags behind exploration
- **Specialised Support Services:** Developing tailored incubation and acceleration programmes with industry expertise to help startups navigate regulatory frameworks, funding options, and commercial scaling strategies

“Strengthening private-sector investment and bridging the R&D-commercialisation gap would make Chile a global leader not only in mineral production but also mining tech innovation.”

Amanda Hall

CEO of Summit Nanotech

South Africa's mining innovation ecosystem is developing; stakeholders are engaged but activities are disjointed

Universities

Stellenbosch University iYunivesithi yaseStellenbosch Universiteit — Partnered with Enaex Africa to fast-track robotics/AI for mining industry

University of Pretoria / Universiteit van Pretoria / Yunibesithi ya Pretoria — Mining Resilience Research Centre (MRRC): research collaboration for mining (design, rock engineering, etc.)

University of the Witwatersrand, Johannesburg — Wits Mining Institute (WMI) drives research, digital innovation, skills, and industry partnerships

Innovators

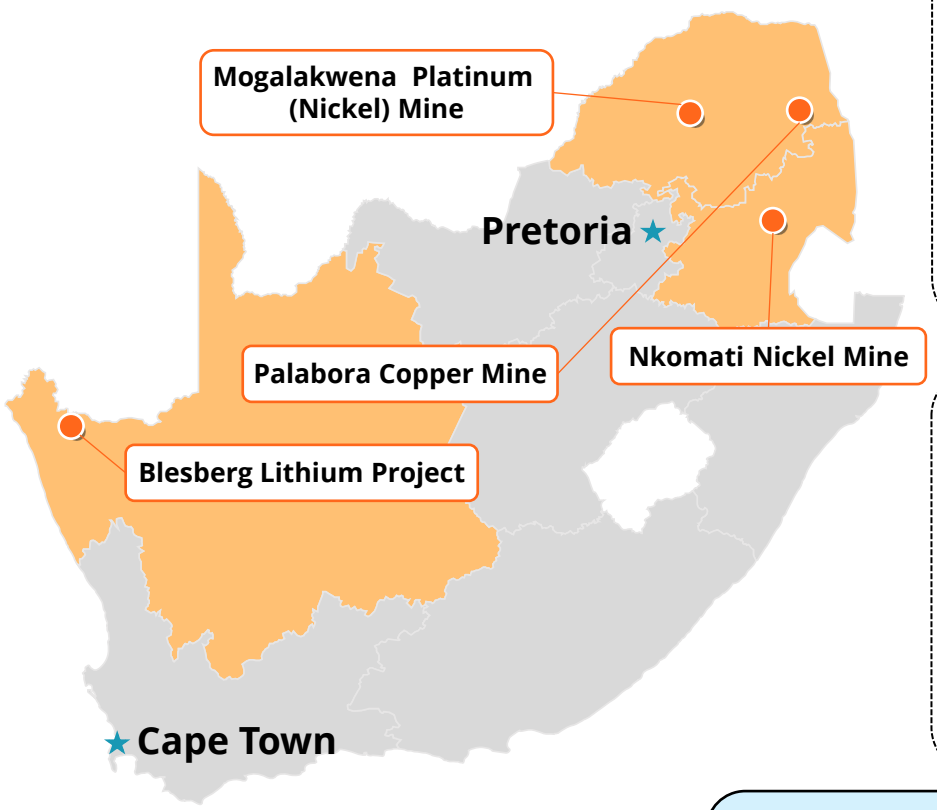
Trailblazer — Wastewater treatment tech focused mining, industrial water

Sperosens (safety through innovation) — Telemetry and sensor solutions for fire, dust and conveyor belts

Free Radical Process Design — Novel electrowinning technology used in copper + other industries

Investors

Savant — Deeptech-focused pre-seed/seed VC; invested in Trailblazer in 2023



Corporates

Valterra Platinum — World leading producer of PGMs in SA, owns Mogalakwena

ARM (African Rainbow Minerals) — Leading South African mining and minerals company; owns Nkomati

Minerals Council South Africa — Mining industry employers' organisation

ABB Epiroc — OEMs signed MoU to collaborate on solutions focused on trolley equipment

Accelerators

Prix EDF Pulse Africa — Mentorship and $10–20k grants for startups focused on low-carbon energy

Investing in African Mining Indaba / Development Partner Institute / BHP Xplor — $25K innovation grant, for early-stage mining innovation & research

GCIP — UNIDO climate accelerator; has supported mining innovators (GabResources, 2021)

Government

Mandela Mining Precinct, Minds for Mines — Public-private partnership to revitalise mining innovation

Department: Science and Innovation, Republic of South Africa — Launched minerals initiative (SACMMI), created Technology Innovation Agency (TIA)

IDC, Industrial Development Corporation — National development finance institution; key sectors include minerals

MINTEK, A global leader in mineral and metallurgical innovation — National mineral research & Innovation organisation

Department: Mineral Resources and Energy, Republic of South Africa — Mandated to ensure efficient regulation of mineral resources

CSIR, Touching lives through innovation — Future Production Mining Cluster connects researchers & industry for pilot projects

Cleantech Group

South Africa possesses significant untapped potential leveraging existing academic & industrial infrastructure

Context & Overview

- **Established Industrial Base for Mining Equipment:** South Africa possesses a well-established manufacturing sector for mining equipment
  - South Africa's industrial base, including local Original Equipment Manufacturers (OEMs) engaged in initiatives like the MMP, provides a strong foundation for developing and manufacturing new mining technologies domestically
  - As a recent example, local OEMs Hydro Power Equipment (HPE) and Novatek—participating in the MMP's Isidingo Drill Design Challenge—unveiled next-generation rock drills that are lighter, faster, quieter, and more energy-efficient
- **Government Strategy for Critical Minerals:** South Africa has a draft Critical Minerals Strategy led by Mintek
  - The strategy aims to position South Africa as a global supplier of critical minerals essential for clean energy technologies and the green transition, emphasizing local value addition and leveraging the country's mineral wealth to boost economic development
- **Increasing International Interest:** There is growing international interest in South Africa's mining sector from countries like Australia, Brazil, and Japan, presenting opportunities for collaborative development of innovation

The Backbone of Mining Innovation Ecosystems: Academic and Research Institutions

South Africa boasts excellent universities with a strong research base supporting mining innovation. The Mandela Mining Precinct (MMP), a public-private partnership managed by the CSIR and the Minerals Council, plays a central role in revitalising mining R&D to ensure industry sustainability. The University of the Witwatersrand (Wits) leads with its DigiMine laboratory, which focuses on transferring digital tech into underground environments. The University of Pretoria operates the Mining Resilience Research Centre, recognized for multidisciplinary research in mining and minerals engineering. Together, these initiatives drive cutting-edge research and collaboration.

Corporate risk aversion, structural silos, and scarce deep-tech funding are slowing innovation in South Africa's mining sector

Challenges & Barriers

- **Sluggish Corporate Adoption of Technology:** Technology adoption by major mining companies in South Africa is slow due to risk aversion, the need for extensive technology validation, and slow internal processes
  - Commercialisation remains a critical bottleneck with many innovators stalling between TRL 4-7 despite technical merit
  - A case in point: A South African startup with a proven and patented acid mine drainage technology saw progress stall for over three years with a major South African mining company—despite clear environmental benefits—due to multiple layers of approval, disengaged senior leadership, and a broader lack of corporate will, causing the startup to move abroad
- **Siloed Information Flow and Lack of Data Sharing:** There is a significant lack of information and data sharing within the South African mining innovation stakeholder community, often due to competitive concerns, leading to disjointed activities
  - Some examples include:
    - Redunant Technology Development: Stakeholders have reported cases where different actors (e.g. research centres or industry majors) have independently developed similar mining technologies without prior awareness of each other's efforts
    - Disconnect Between OEMs and Mining Majors: Local OEMs have created innovative mining technologies, but these struggle to gain traction with mining houses; potential explanations may include long sales cycles of mining majors, misaligned priorities, or insufficient engagement with industry needs
    - Stagnant Research: Research on ASM from a South African university remains confined to the institution, with limited pathways to practical application
    - Diverging Views on Key Barriers: Stakeholders interviewed lacked consensus on core challenges— for example, some cited regulatory red tape for startups as a major issue, while others saw it as irrelevant, highlighting a lack of common ground
  - While this coordination challenge is widely acknowledged by stakeholders across the ecosystem, clear solutions remain elusive; improving trust and fostering collaboration will be key to overcoming these silos
- **Challenges in Securing Funding for Deep Tech Startups:** It is very difficult to access the type of funding needed to make deep tech startups viable in Africa, including South Africa
  - Risk capital providers in South Africa may act more like banks than venture capitalists in how they value companies, making it harder for innovative ventures to secure investment

Targeted coordination, investment, and testing infrastructure can turn South Africa's entrepreneurial energy into scalable innovation

Potential for Growth & Innovation

- **Entrepreneurial Culture:** South Africa has a vibrant entrepreneurial culture, supported by the availability of lab space, research infrastructure, and a strong academic foundation for mining
  - While SMEs face challenges in accessing pilot facilities and scaling, this entrepreneurial energy—if better coordinated and supported—holds potential to drive innovation
- **Focus on Localisation:** There is a desire to see more technology localised in the country—an objective also reflected in the draft Critical Minerals Strategy
- **Need for Technology Validation Environments:** The halted national test mine project (2021–2023), developed by the MMP and funded by the Mineral Council, underscored the need for TRL-appropriate physical testing environments in mining
  - Although the project ended due to market factors—including the sale of the Royal Bafokeng Maseve's Mine and falling platinum prices—the initial testing was successful, offering cost savings for innovators compared to alternative testing environments
  - The mining community remains interested in reviving a future test mine site
- **Formalising Artisanal Mining:** Formalising artisanal mining could unlock economic potential through market access and improved equipment, while delivering environmental and social benefits; the Department of Mineral Resources and Energy supports this through its Small-Scale Mining Fund, which provides financial support for CAPEX, OPEX, and post-mining rehabilitation
  - Though this report did not assess South Africa's Small-Scale Mining Fund, it could inform Zambia, where stakeholders seek greater support for their larger ASM workforce

"The biggest challenge is the lack of information and data sharing. We need to prevent situations where we produce a mining technology, only to later find out that another company or mining house had done the same thing already."

Julie Courtnage

Executive Director of Mandela Mining Precinct

Innovation activity is beginning to take root in Zambia's emerging mining innovation ecosystem as new players and partnerships emerge

Innovators

KoBold Metals — US innovator whose tech discovered Mingomba; partners with local universities for talent

Metalex — Small-scale miner integrating innovation to improve sustainability and social outcomes

Universities

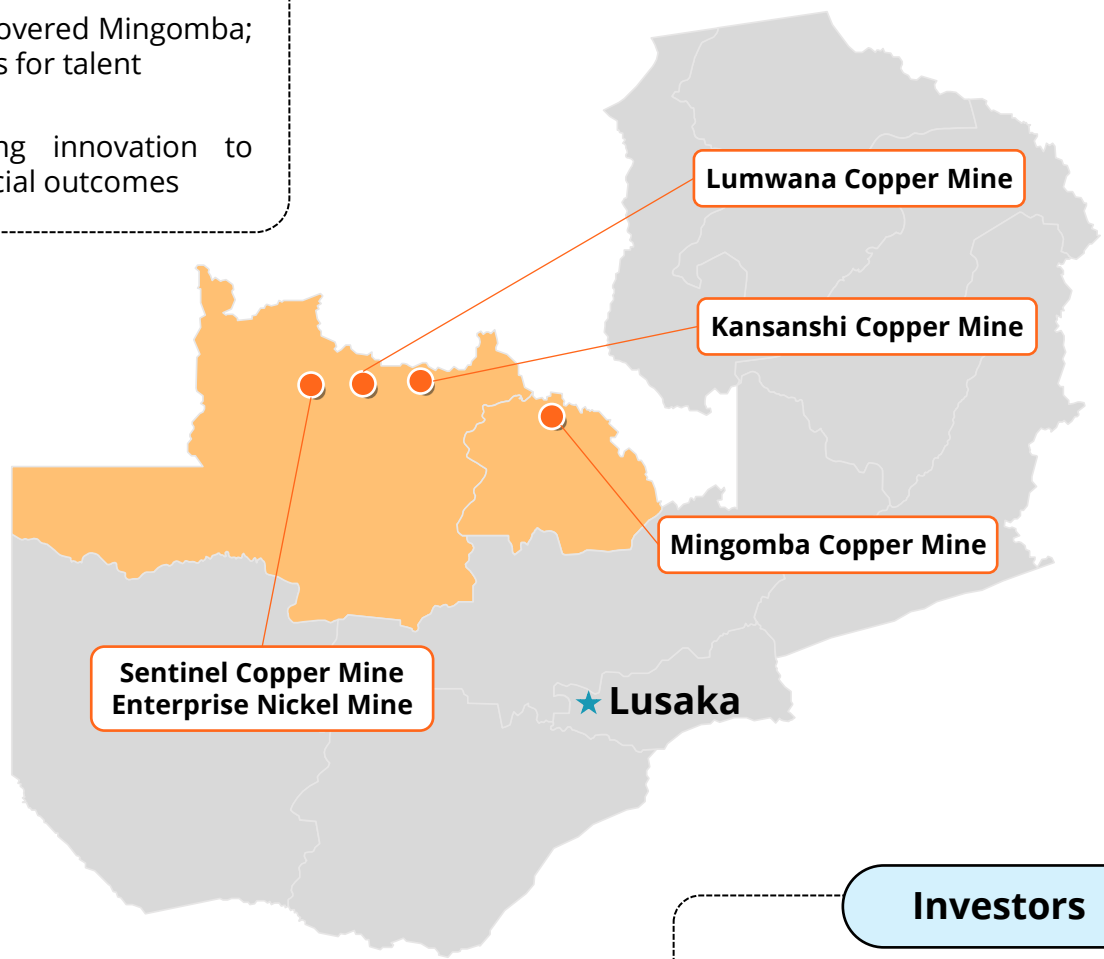
School of Mining & Mineral Science; MSc in Data Science & Geology (KoBold/Stanford partnership)

Top national university with School of Mines

Government

Ministry of Mines and Minerals Development — Responsible for Zambia's mineral resources

Responsible for strengthening R&D in science and tech; MineTech Hub partner



Accelerators

MineTech Hub — UNDP mining hub: $25k funding, 4-week bootcamp for African mining innovators

WEAC — Barrick Lumwana initiative to accelerate local business in mining supply chain

growthafrica — Has accelerated 32 startups, 20% in "Greentech"

Corporates

First Quantum Minerals — Sentinel, Kansanshi, and Enterprise mines

Barrick — Lumwana mine

Rio Tinto — Started exploration in 2021; partnership with KoBold

Zambia Chamber of Mines — Mining association with +20 members

Investors

ZCCM-IH — Investment portfolio of 18 companies, including Zambia's largest mines

Cleantech Group

Zambia's early-stage innovation momentum is supported by mineral wealth, policy reform, and academic engagement

Context & Overview

- **Untapped Mineral Potential:** Half of Zambia's mineral potential remains unexplored, with recent discoveries of lithium, nickel, graphite, and cobalt beyond its well-known copper reserves—positioning the country as a growing hub for critical minerals innovation
- **Emerging Innovation Initiatives:** Initiatives like the UNDP MineTech Hub (Timbuktu initiative), based at the NSIR in Lusaka, focus on accelerating mining innovations through industry consultation and partner with industry players to offer mine-site testing
  - The 10-year (2024-2034) MineTech Hub provides $25,000 to startups and received 350 applications from +21 African countries in its first call for applications (focusing on drones & data visualisation) and aims for pan-African impact and partnerships
- **Pro-Business Policies and Critical Minerals Strategy:** The Zambian government has implemented pro-business policies and introduced a new Critical Minerals Strategy focused on partnerships, value addition, and R&D
  - The strategy prioritises long-term ecosystem development through incentives for local processing, public-private R&D platforms, and infrastructure investments aimed at positioning Zambia as a regional hub for responsibly sourced minerals
- **Strong University Engagement:** The University of Zambia is leading the Critical Minerals Research Centre, and Copperbelt University (with UNDP) is launching "UniPod"—an on-campus hub offering design & prototyping facilities to incubate ideas for later acceleration at the MineTech Hub

Harnessing Zambia's Artisanal Mining Potential

Zambia's artisanal mining sector, estimated at around 600K miners, includes some operators whose activities are more sophisticated than often assumed. While most miners use basic tools, others employ more advanced machinery like trommels, crushers, and mills, enabling deeper and more efficient extraction. This evolving complexity creates opportunities for integrating innovative technologies tailored to artisanal practices, enhancing productivity, safety, and sustainability. Recognising this diversity within artisanal mining is key to designing effective formalisation strategies and supporting technological adoption that can transform the sector and improve livelihoods.

Zambia's mining innovation progress is limited by weak local linkages, regulatory uncertainty, and import dependence

Challenges & Barriers

- **Weakened Industry-Research Collaboration:** The privatisation of the mining sector around the turn of the century led international mining companies to collaborate with entities they have historically collaborated with, weakening collaboration with Zambian institutions
- **Limited Data Sharing:** There are ongoing issues with international mining companies not sharing geological data despite legal requirements
  - This lack of access to crucial data hinders capacity building within Zambian research institutions, limiting their ability to conduct meaningful analysis and develop relevant innovations
- **Regulatory Environment:** The regulatory environment has been described as a "Wild West" with a shorter average time from discovery to mining compared to North America, indicating less regulation—this can be both an advantage for speed and a disadvantage for environmental and social safeguards
- **Challenges for Local SMEs:** Local SMEs in the mining sector face challenges including a lack of capacity and business management skills, inability to meet product/service demand, limited access to financing, technological barriers to engage with mining corporates, complicated procurement processes, and a lack of human resources
  - Local suppliers often lack access to the electronic tendering systems used by mines and the digital literacy for online engagement
- **High Import Dependence:** 99% of mining equipment is imported, often from European countries, meaning R&D is often done elsewhere

Zambia can unlock innovation by investing in local production, deepening research-industry links, and creating shared spaces to accelerate hardtech solutions

Potential for Growth & Innovation

- **Localised Manufacturing:** Strong potential to localise innovation through manufacturing partnerships for selected components or equipment that can help reduce import dependence
- **Improving Existing Technology:** Focusing research and development on "light tech" and making incremental or modular improvements to existing, often old, mining equipment to enhance sustainability and efficiency is a low-hanging fruit
  - Mining equipment remains largely unchanged for decades, offering innovation potential to address energy inefficiency across industry
- **Rising Student Interest:** Universities note increasing student enrolments in mining programs, influenced by Zambia's national 3-million-ton copper production strategy by 2031
- **Leveraging Policy for R&D Funding:** There is strong desire to further support R&D (as reflected in the Critical Minerals Strategy and stakeholder consultations); potential solutions include exploring a tax incentive regime modelled after Australia or South Africa to unlock additional financing

"The mining industry is notoriously behind on hardtech. Creating a maker space for hardware innovation rather than software could transform how mining operates."

Ayo Sopitan

CEO of Metalex

Indonesia's mining innovation ecosystem is emerging under the influence of China's dominant role

Innovators

BANiQL — US-based innovator developing nickel and cobalt extraction with operations in Indonesia

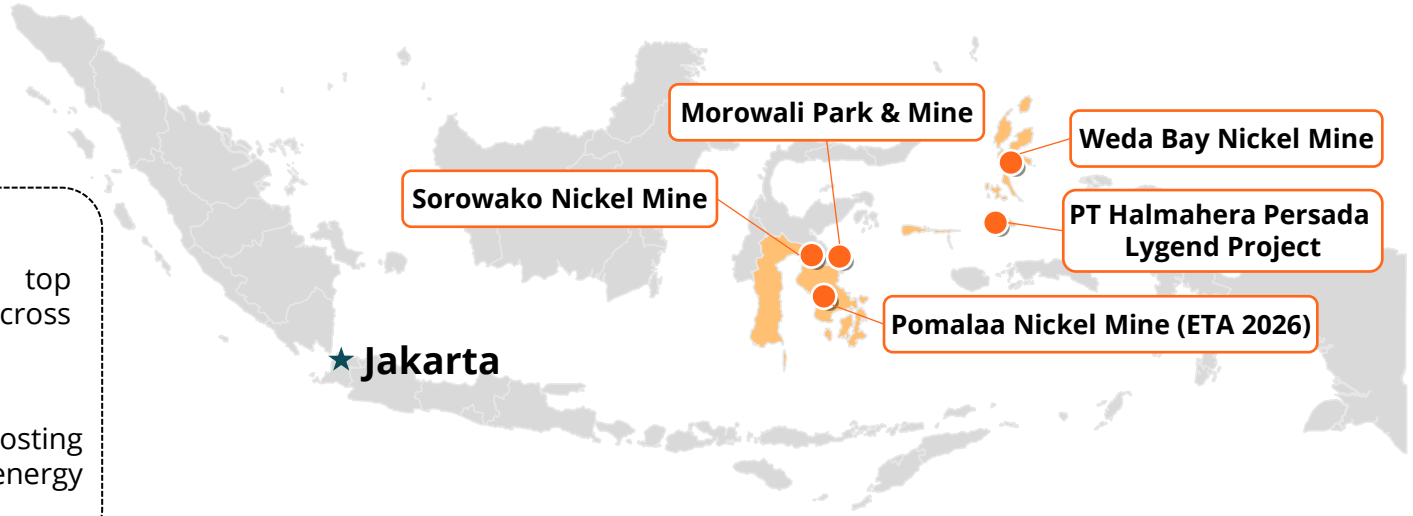
Other

Indonesian Mining Association — Mining association linking government and industry; coordinates sector-wide activities

Accelerators

instellar — Programmes include ImpactX accelerator, specialising in post-mining, mineral recovery

supernova ecosystem — Catalyst hub operating accelerator & impact fund supporting climate-focused startups



Corporates

TSINGSHAN — Major Chinese nickel producer & refiner; owns Weda Bay

NINGBO LYGEND MINING — Major Chinese nickel producer; owns Halmahera Persada Lygend

VALE — Owns Sorowako & Pomalaa; multiple partnerships with Chinese majors

eramet — Minority stake (~40%) in Weda Bay Mine

Universities

Institut Teknologi Bandung — Leading university with top mining faculty, partnering across public and private sectors

Universitas Indonesia — Indonesia's top university, hosting country's largest mineral & energy student summit

Government

Indonesian ministry overseeing national energy and mineral resource management

Investors

East Ventures — Leading Indonesian VC with over +20 cleantech investments

New Energy Nexus Indonesia — Investor & cleantech hub supporting more than 70 startups

Intudo Ventures — Indonesian-focused VC firm with 5 cleantech investments

INA Indonesia Investment Authority — Indonesia's sovereign wealth fund; mining among key sectors

Cleantech Group

As Indonesia pushes for domestic value-add, foreign investment & infrastructure still dominate the mining landscape

Context & Overview

- **Significant Nickel Resources:** Indonesia holds a dominant position in global nickel supply, accounting for 61% of the world's refined nickel in 2024, up from just 6% in 2015 (Macquarie) and projected to reach 74% by 2028
- **Chinese Dominance and Investment:** China dominates Indonesia's nickel and steel sectors through major investments and joint ventures with local partners
  - Chinese investments, facilitated by the Belt and Road Initiative (BRI), have brought new infrastructure like ports, roads, and airports to resource-rich areas, connecting them to the rest of Indonesia and the world, but local capacity development has lagged behind the pace of infrastructure growth
  - There are some exceptions to limited local tech transfer, such as the recent investment by China in the Bandung Technical Institute to establish a joint research laboratory for new energy materials and metallurgical engineering
- **Government Push for Local Value-Add:** Indonesia's nationalist policies have prioritised domestic value creation in the mining sector, particularly through a "downstreaming" strategy that prohibits the export of unprocessed ore
  - This policy, first introduced in 2014 and fully enforced by 2020, aims to develop local processing capabilities and capture more value locally

Indonesia Morowali Industrial Park Case Study

The Indonesia Morowali Industrial Park (IMIP), located in Morowali Regency, Central Sulawesi, is the global epicentre of nickel production. Established in 2013 as a joint venture between Indonesia's Bintang Delapan Group and China's Tsingshan Holding Group, the park plays a critical role in Indonesia's downstream nickel industry. It produces stainless steel, nickel pig iron, and EV battery materials—advancing the country's strategy to add value to its mineral resources following the 2014 export ban on unprocessed ores. While the park has significantly boosted local and national economies through job creation and exports, it has also raised environmental and social concerns.

Indonesia's mining innovation is constrained by foreign dependence, human capital, and top-down market structures

Challenges & Barriers

- **Heavy Reliance on Chinese Expertise and Technology:** Chinese operations in Indonesia often bring their own experts and technology, limiting local tech transfer and capacity building
  - Western companies (e.g. Eramet) find it "impossible" to profitably operate nickel projects without Chinese partners due to cost, technology, and expertise gaps
  - Equity concerns arise from value extraction without commensurate benefits for locals (example: per Carnegie Endowment for International Peace research, of ~43K IMIP workers, ~5,000 were Chinese—mainly managers—living segregated from the largely Indonesian workforce)
- **Limited Human Capital Development:** Indonesia faces significant challenges in developing the human capital necessary to drive innovation and economic growth
  - Indonesia has limited educational infrastructure, with only two leading universities (University of Indonesia and Bandung Technical Institute) for a large population, severely restricting human capital development
  - Academic research in Indonesia rarely pursues commercial applications, especially compared to institutions in the US
    - A study found that Bandung Institute of Technology (ITB) faces commercialisation challenges due to lack of exposure to entrepreneurship among faculty (especially outside business faculties), limited student interest in entrepreneurship, high startup costs (including employee salaries), external funding dependence, complex IP management processes, weak innovation ecosystem, and academia-industry communication gaps
- **Bureaucratic Hurdles and Market Entry Barriers:** Success in Indonesia often depends on high-level connections and a top-down approach to navigate the market

"The government needs to gain fairer benefits from the exploitation of natural resources in this country. Thus, (the government) will have more fiscal capacity for human capital investment especially in exploitation areas."

Khoirunurrofik
Lecturer, Faculty of Economics & Business, Universitas Indonesia

Human capital and international engagement can drive Indonesia's next phase of climate-aligned mining innovation

Potential for Growth & Innovation

- **Human Capital as a Strategic Lever:** Strengthening education and talent development is widely recognised as essential for intervention
  - Philanthropic capital aimed at entrepreneurship and capacity building initiatives at the university level can help bridge the research-to-commercialisation gap, enabling academic work to become market-ready and community-relevant
- **Political Realignment Creating New Space:** new Indonesian government (elected in 2024) has signalled a more pro-Western stance, actively courting international investors to diversify its partnerships beyond the dominant Chinese presence in the sector
- **Sustainability as a Market Opportunity:** Current mining practices rely on CO_2-intensive pyrometallurgy; there is clear room to support cleaner, climate-smart extraction technologies
  - Indonesia's active VC ecosystem has completed over 75 cleantech deals in the past 5 years—primarily in agriculture, food, energy, and transport; initiatives like the Climate Impact Innovations Challenge, backed by East Ventures and Temasek Foundation, have supported mining startups like BaniQL
  - While Indonesia's cleantech VCs could potentially be available for mining innovation, this requires a robust pipeline of innovative startups; universities and stakeholders must overcome spinout challenges and enhance commercialisation in mining innovation to attract investment

"From an entrepreneur's perspective, crucial resources such as research collaboration with universities, investment capital, and facilities for testing materials are often in short supply in Indonesia."

Eric Januar

Co-founder & COO of BANiQL

Geography prioritisation: Chile strongest candidate; Zambia & South Africa promising; Indonesia deprioritised due to limited ability to influence and more complex political landscape

	CRITERIA	COUNTRY EVALUATION				DETAILS
						
Cleantech Group Analysis	Mining Innovation Ecosystem	Medium	Medium	Low	Low	▪ Chile, South Africa: developing with diverse stakeholders ▪ Zambia and Indonesia: emerging with initial elements in place
	Government Critical Minerals Strategy	High	Medium	High	Medium	▪ Chile: National Lithium Strategy ▪ South Africa: Draft Critical Minerals Strategy led by Mintek ▪ Zambia: National Critical Minerals Strategy 2024-2028 ▪ Indonesia: “Downstreaming" policy to boost domestic processing
	Ability to Operate & Influence	High	Medium	Medium	Low	▪ Chile: Active ecosystem with CORFO support, but slow bureaucracy ▪ South Africa, Zambia: Interest exists but inefficiencies slow action ▪ Indonesia: China’s influence complicates direct engagement
World Bank Indicators	Political Stability	Medium	Low	Medium	Low	▪ Chile: 50th percentile, South Africa: 20th percentile, Zambia: 52nd percentile, Indonesia: 29th percentile
	Control of Corruption	High	Medium	Medium	Medium	▪ Chile: 80th percentile, South Africa: 45th percentile, Zambia: 37th percentile, Indonesia: 36th percentile
	Regulatory Quality	High	Medium	Low	Medium	▪ Ability of government to formulate & implement policies, regulation ▪ Chile: 77th percentile, South Africa: 44th percentile, Zambia: 33rd percentile, Indonesia: 61st percentile
Priority	Overall Country Priority Ranking					▪ Cleantech Group’s prioritisation based on potential to create positive impact in the ecosystem

Contents

Global mining hubs succeed when innovation goals align with financial sustainability and industry is engaged as core partners

Mission & Objectives

- Mission vs. financial sustainability: customers and regions with greatest need have lowest ability to pay
- Innovators need access to resources, capacity-building and industry connections to scale
- Operators such as NewLab select markets carefully according to availability of public sector resources, economic development need, and motivation to catalyse the ecosystem

> ***"Innovators, often being from outside the sector, don't fully appreciate risk perception in the mining industry. Innovation is highly disruptive to a business which has sunk significant CAPEX into existing value chains."***
>
> Dr Anil Subramanya
> Strategic Advisor, Amira Global

Success Factors

- **Industry** needs to see innovation working in real-world conditions (only a couple of locations worldwide where this can happen)
- **Startups** benefit from understanding and industry feedback gained from locating near to mining operations
- **Acceleration services** support startups to learn business skills which are essential to scale; these may be provided by an external partner
- **Venture Capital** investors want to see an industry partner on board
- **Involve regulators** in hub creation and development; more difficult to involve them once up and running
- **Facilitate interface** between startups and industry partners to articulate the benefits of innovation and plan pilot projects to demonstrate solution viability
- **Specialised expertise** required to navigate regulated assets

Successful mining hubs are characterised by high upfront investment and revenue stream diversification

Initial Funding

- **Upfront cost of $15m to $35m** depending on size and facilities; some hubs start with a smaller setup and expand incrementally as they grow
- **NewLab (Global):** public-private partnership funding provides 5-year runway (Brooklyn: +$30m PPP [$12m public])
- **AARP (Australia):** $28m initial investment via government grant

Delivery Model

- **Physical facilities** include workspace and equipment provision, test facilities
- **Services** include knowledge transfer, acceleration, workforce training, connection to pilot opportunities
- **Value chain**: exploration and extraction represent strongest deal flow and commercial prospects; most critical innovation needs lie in hardtech/ processing, which face funding gaps

Operating Model

- **Fee for service:** tiered membership models offering low cost for smaller companies & startups, with higher fees and more services for larger corporates
  - Mine operators pay for tech scouting and evaluation / due diligence
  - Corporates pay for scouting, pilot facilitation, access to test facilities and knowledge assets
  - Innovators and other technology-providers pay for site, testing access
- **Equity investments**: used by some but not all hubs, 5+ years to see returns
- **Government grants**: generally provide a small portion of revenue
- **Training courses:** as revenue diversification
- **Workspace:** attracts startups but not a growth driver

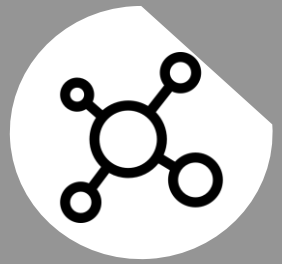
> ***"When mine operators can see, touch, and witness innovations working in real time in a live mining scenario, it significantly enhances buyer confidence and accelerates procurement decisions."***
>
> Don Duval
> CEO, NORCAT

Contents

Matching solutions to ecosystems: QCF can engage in different ways depending on local innovation needs

Pioneering Innovation Centre

- Establish *The Rock Warehouse*: a comprehensive mining innovation ecosystem, combining laboratory facilities, rock repositories, and collaborative workspaces under one roof where industry, academia, investors, and startups connect and collaborate to accelerate innovation
- Ideal for locations with significant mining potential but highly fragmented innovation ecosystems where no entity connects all elements and startup support facilities are insufficient



Complementary Hub

- Develops targeted facilities addressing specific ecosystem gaps rather than comprehensive services
- Appropriate for regions with some innovation elements but missing critical components like testing facilities, industry-start up connections, investment, etc.
- Focuses resources on solving the most pressing bottleneck (e.g., mine testing & scale-up facilities, investment and networking platforms, etc.) to maximise efficiency in partially developed mining innovation ecosystems

Support Existing Services

- Provides financial, technical, or other support to improve and/or expand established mining innovation initiatives
- Most effective in developing or maturing ecosystems where enhancements can accelerate existing programmes
- Leverages grants, expertise, and partnerships to strengthen and scale successful local programmes, improving their reach and impact without duplicating infrastructure

Cleantech Group

Chile: Transform technical excellence into market-ready solutions through validation and corporate engagement

Impact

	Description	Value to Ecosystem	Potential Partners
3. Establish a test mine	▪ Neutral innovation testing ground for pilots in a realistic operating environment ▪ Physical site (ex. lithium salars) equipped with industry-standard infrastructure ▪ Corporates can observe, scout, and validate promising mining technologies ▪ Builds on Codelco Tech's previous attempt, avoiding past single-company focus pitfalls	▪ Stakeholders value innovations tested in real-world conditions for improved validation and adoption ▪ Bridges the gap in scaling technologies to industrial readiness, accelerating adoption by risk-averse miners ▪ Overcomes corporate inertia by creating low-risk opportunities to witness innovation in action ▪ A national test mine would unify piloting infrastructure	CORFO sueña emprende crece SQM CODELCO
2. Corporate matchmaking programme	▪ Connects business-ready startups to mining companies committed to piloting technologies ▪ Provides access to corporate facilities and resources with potential for procurement ▪ Optional: add-on financing component from CVCs or VCs to support innovators who have outgrown CORFO's early-stage grants	▪ Innovators with promising technologies struggle to access markets due to the slow pace of corporates ▪ Adress permitting barriers by pairing innovators with industry partners to navigate regulations and provide compliant test environments ▪ Leverage Chile's existing open innovation initiatives (Expande, BHP Supplier Innovation) to address unmet needs in connecting startups with mining majors	expande somos FCh SQM AURUS CAPITAL BHP CORFO sueña emprende crece CODELCO
1. Mining focused business accelerator	▪ Provides comprehensive support (capacity-building, partnerships, funding) to improve innovators' growth and investment readiness ▪ Potential to organise international exchanges with global hubs to further test & develop ▪ Must engage corporates for maximum success	▪ Transform technically sound innovations into viable businesses by ensuring solutions address industry needs and building founders' market readiness and appeal ▪ Equips Chilean entrepreneurs with specialised mining industry insights and investor networks to overcome competitive advantage currently held by foreign startups	CORFO sueña emprende crece Aster por Magical UNIVERSIDAD DE CHILE

Cleantech Group

South Africa: Bridging research-industry divide through dismantling silos, corporate partnerships and piloting

Impact

	Description	Value to Ecosystem	Potential Partners
3. Establish a test mine	▪ Neutral innovation testing ground for pilots in a realistic operating environment ▪ Physical site (e.g., retired mine) equipped with industry-standard infrastructure ▪ Corporates can observe, scout, and validate promising mining technologies ▪ Leverage MMP/Mineral Council's past attempt; Mineral Council still has funding earmarked	▪ Bridges commercialisation gap by providing infrastructure to demonstrate in real-life conditions ▪ Overcomes corporate inertia by creating low-risk opportunities to witness innovation in action ▪ Promotes data sharing amongst relevant stakeholders to combat siloed information ▪ Establishes a central facility to enable coordinated interaction between mining stakeholders	MANDELA MINING PRECINCT MINDS FOR MINES MineTech Hub CSIR Touching lives through innovation MINERALS COUNCIL SOUTH AFRICA
2. Corporate matchmaking programme	▪ Connects business-ready startups to mining companies committed to piloting technologies ▪ Provides access to corporate facilities and resources with potential for procurement ▪ Can be established via operator-corporate partnerships (e.g., Savant–Sibanye Stillwater iXS) that identify startups, conduct due diligence, and validate industry fit	▪ Innovators with promising technologies struggle to access markets due to the slow pace of corporates ▪ SMEs benefit from receiving industry insights, which can enhance their offerings and market readiness ▪ VC investors typically require SMEs to have an industry partner, underscoring the importance of strategic partnerships for securing investment ▪ Potential to improve startup-corporate coordination	Valterra PLATINUM SAVANT
1. Mining focused business accelerator	▪ Provides comprehensive support (capacity-building, partnerships, funding) to improve innovators' growth and investment readiness ▪ Potential to organise international exchanges with global hubs to further test & develop ▪ Must engage corporates for maximum success	▪ Addresses technical-commercial gap by equipping founders with business & market skills needed to advance beyond R&D ▪ Integrates corporate feedback to ensure startups accelerated align innovation with industry needs	MANDELA MINING PRECINCT MINDS FOR MINES MINERALS COUNCIL SOUTH AFRICA

Cleantech Group

Zambia: Achieving immediate impact through artisanal mining while building-up the innovation ecosystem

Impact

	Description	Value to Ecosystem	Potential Partners
3. Establish a rock warehouse	▪ A shared ecosystem builder with lab space, equipment, and rock samples for innovators and researchers ▪ Helps de-risk innovation, attracts early-stage investment, engages corporates, & plants seeds for an incubator-style space ▪ UNDP Minetech Hub would be the ideal operator given existing network & infrastructure (e.g. test mine)	▪ Leverages existing institutions (ministries, universities, Chamber of Mines) while filling missing ESO infrastructure (startups, accelerators, investors) ▪ Improves industry-research collaboration by ensuring market-readiness aligned with corporate demand for potential adoption ▪ Physical mine tech hub in sync with government ambitions (e.g. Critical Minerals Strategy)	Zambia Chamber of Mines; MineTech Hub; Ministry of Mines and Minerals Develoment; NISIR Zambia; The University of Zambia; Copperbelt University
2. Initiate collaborative R&D projects	▪ Enable R&D partnerships between universities, research bodies, and mining companies ▪ Fund joint projects to co-develop sustainable mining technologies	▪ Unlock academic research by connecting it to real-world applications useful for Zambian mining network ▪ Support government R&D goals and critical minerals strategy through targeted partnerships ▪ Potential to tackle energy inefficiency in mining equipment through applied, collaborative R&D	NISIR Zambia; The University of Zambia; KoBold Metals; Copperbelt University
1. Establish an artisanal and small-scale mining (ASM) fund	▪ Equip artisanal miners with tools, equipment, and training to improve responsible mining & safety outcomes ▪ Connect artisanal miners with majors/juniors for value addition and market linkages	▪ Artisanal miners rely on outdated equipment, worsening environmental harm and safety risks ▪ Equipment fund supports government push to formalise sector and improve working conditions ▪ With over 600k artisanal miners, the fund offers high-leverage impact at national scale	Ministry of Mines and Minerals Develoment; MineTech Hub; Zambia Land Alliance "Land is Life"; WEAC

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Where philanthropy can lead: Filling market gaps and democratising assets

Establish an Artisanal & Small-Scale Mining (ASM) Fund: Philanthropic capital is uniquely positioned to take the lead where market forces struggle—by providing seed funding for tools, training, and capacity building for artisanal miners, demonstrating impact to attract further industry and government support, with philanthropic foundations spearheading initial fund establishment and industry and government partners gradually taking a larger role in scaling and market linkages

Establish a Rock Warehouse: Philanthropic capital can serve as catalytic funding to support infrastructure, laboratory equipment, and initial operational costs, thereby de-risking the ecosystem builder and attracting early-stage innovators. The philanthropic foundation would lead this initial phase by identifying a suitable operator to manage the initiative and actively coordinating the phased engagement of other key stakeholders, including universities, industry, investors, and public institutions before broader stakeholders scale it up

Connect Local Innovation to Global Hubs: Philanthropic capital can support top startups and researchers from emerging markets to access advanced infrastructure, expertise, and partnerships in world-class hubs like NORCAT (Canada) and AARP (Australia). This approach leverages existing state-of-the-art facilities to accelerate technology validation, foster cross-border collaborations, and drive rapid innovation across multiple countries without the need to build costly local hubs. It should complement, not replace, local ecosystem development, as it is less impactful in building local capacity, and its success depends on home deployment support and relationship building with local stakeholders

Where philanthropy can support: Catalysing innovation services and high-complexity shared assets alongside market players

Test Mine: Philanthropic capital can play a catalytic role by absorbing early-stage risks and helping to establish a test mine as a neutral, accessible site available to all stakeholders. However, sustained success will require industry and government to take a leading role in long-term development and governance

Corporate Matchmaking Programme: Philanthropy can play a catalytic role by seeding the initiative—ensuring that SMEs do not run out of capital during corporate pilot phases (as observed in South Africa)—and by supporting structured matchmaking activities such as curated forums and event spaces. The program would be implemented in collaboration with industry partners and a dedicated operator, such as a local deeptech venture capital firm, to ensure market relevance, sustained deal flow, and scalable outcomes

Mining Accelerator: Philanthropic funding can underwrite early-stage program development and capacity building, while industry leads mentorship, market access, and scaling support to accelerate mining innovation commercialisation

Initiate collaborative R&D projects: Philanthropic capital could fund joint R&D grants and support to convene partnerships between universities, research institutes, and mining companies, bridging early-stage funding gaps and accelerating technology co-development

Contents

The ‘mining innovation’ continuum: matching solutions to ecosystem maturity

Applied Innovation

- *Applied innovation* strategically **integrates existing technological solutions to address local challenges**, delivering key improvements in areas including operational efficiency, sustainability, and safety
- Given lower barriers of entry, applied innovation is **often utilised by emerging innovation ecosystems** while they develop local capabilities to capture greater value; it can also be used by **developing or mature ecosystems** where the cost-benefit calculation **favours integrating existing technology**

Strategic Innovation

- *Strategic innovation* involves deliberate strategies to **enhance competitiveness & leadership by advancing local capabilities**, moving Technology Readiness Levels[1] forward and driving transformation across the value chain
- Strategic innovation is generally **employed by developing innovation ecosystems** to leverage existing base of resources and skills to **achieve higher levels of value addition**, though it can be used by emerging ecosystems as complementary strategies to build local capabilities or by mature ecosystems to strengthen specific sectors

Pioneering Innovation

- In mature ecosystems, *pioneering innovation* thrives through corporates, capital, and research excellence—**creating novel technologies that establish global standards** while enhancing competitiveness & sustainability
- These established hubs act as innovation accelerators by connecting innovators, corporates, investors, and researchers in shared testing environments that facilitate technology validation and commercialisation
- To maximise global innovation, **mature ecosystems should create structured pathways for emerging economies** to access testing facilities, corporate networks, and research capabilities—an area where philanthropy can play a catalytic role in aligning incentives—while creating collaborative opportunities

[1]Technology Readiness Levels (TRL) is a 9-point scale measuring the maturity of clean technologies from concept (TRL 1) to commercial deployment (TRL 9)

Examples of global innovators operating across the mining value chain, including adjacent technologies and materials beyond the project's scope

Sale of Raw Materials to OEMS

Exploration & Mining | **Resource Extraction** | **Processing & Refining** | **Component Manufacturing** | **End-of-Life (EOL) Recycling & Re-use** | **Remediation**

End-to-End Services, from mining to recycling
*(*Excludes manufacturing)*
eraMET, RockTech Lithium Inc.

Lithium Mining & Processing, DLE & in-situ extraction from hard rock, clay & brine
ioneer, Summit Nanotech, ENERGY X, E3 Lithium, KELIBER, Schlumberger, Cornish Lithium, ALMA Energy

Exploration Tools
Identifying deposits with AI, geographic modelling, & data
PLOTLOGIC, ROCK MASS, EARTH SCIENCE ANALYTICS, MINERVA INTELLIGENCE, LUNASONDE, KoBold Metals, ideon

Process Optimisation
Monitoring software & remote sensors
MINVIRO, SHYFT, minesense, phaidra

Mining
Aluminum, copper, lithium, precision drilling, etc.
POTTER DRILLING, GA Drilling, Rio Tinto, IROX, PLATEAU ENERGY METALS, NOVAMERA, LEADING EDGE MATERIALS

tenova

Extraction, Refining, Manufacturing & Recycling
Decarbonising industrial processes
NTH CYCLE

Lithium Production
Membrane, electrochemical, & liquid-liquid salt extraction
Adionics, LITHIOS, Lithium de France, Lilac, MANGROVE LITHIUM

Recovery
e.g., metal ore, low-ore concentration rare earth elements, etc.
TORNGAT, geo40, BOTREE, Ceibo

Tailings Management
Recovering minerals from mine waste
TERRA CO2, EKS ElectroKinetic Solutions, GREENIRON, LIXIVIA, DISA, ENVICORE, INTASOL, NTH CYCLE, Blackstone Resources

Intermediate Processing
Manufacturing chemicals & inputs for components, *e.g., batteries, magnets, semiconductors, etc.*
LiEP Energy, GREEN LITHIUM, Novalith, H2Sonics, ecomet, TRAVERTINE

Magnets
Wind turbines
Niron Magnetics, AML, COREPOWER MAGNETICS, aml Advanced Magnet Lab, MagREEsource

Electrolysers and Fuel Cells
Green hydrogen & aluminum
10 LOG 9 MATERIALS, H GEN, upstart power inc., PAJARITO POWDER, H2Sonics, ecolectro

Semiconductors and Microchips
Photovoltaic & thermal solar panels
Silfab, Sinopont, YUZE

Battery Production
EVs and grid storage
CATL, ilika, WELION, BYD, Panasonic, Zeta ENERGY, LG Chem, GREATPOWER, SAMSUNG SDI, Natron Energy, SK innovation, KEDA, EVOLUTION ENERGY

Rare Earth Elements
Mine and industrial waste
Cyclic Materials, GEOMEGA, BOTREE

E-waste Batteries
Cobalt, aluminum, lithium, etc.
greenuion, ecomet, CYLIB, Cirba Solutions, PARASIS, (주)재영텍, Li-Cycle, call2recycle, PRINCENTON NUENERGY

EV Batteries
Cobalt, nickel, manganese, etc.
REDWOOD MATERIALS, Lithion, posco, ASCEND ELEMENTS, VEOLIA, northvolt, Primobius

Battery Disassembly & Re-use
Automated EV battery recycling to secondary energy storage batteries
POSH

Plasma Systems
Metal powders for battery components
6K

Soil Remediation
Contamination removal
GFL GREEN FOR LIFE environmental, medusoil, SoilSafe, KSM

Wastewater Treatment
Filtration & purification
GRADIANT CORPORATION, kmx technologies, OLOKUN MINERALS, suez environnement

Wellsite Reclamation
Restoring native landscapes
Climate Wells

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