SECURING CRITICAL MINERAL SUPPLY CHAINS IN THE INDO-PACIFIC

Photo: author at Mt Weld REE site, 2014

Critical Minerals Needs by Technology

	Copper	Cobalt	Nickel	Lithium	REEs	Chromium	Zinc	PGMs	Aluminium*
Solar PV	●	○	○	○	○	○	○	○	●
Wind	●	○	◍	○	●	◍	●	○	◍
Hydro	◍	○	○	○	○	◍	◍	○	◍
CSP	◍	○	◍	○	○	●	◍	○	●
Bioenergy	●	○	○	○	○	○	◍	○	◍
Geothermal	○	○	●	○	○	●	○	○	○
Nuclear	◍	○	◍	○	○	◍	○	○	○
Electricity networks	●	○	○	○	○	○	○	○	●
EVs and battery storage	●	●	●	●	●	○	○	○	●
Hydrogen	○	○	●	○	◍	○	○	●	◍

Notes: Shading indicates the relative importance of minerals for a particular clean energy technology (● = high; ◍ = moderate; ○ = low), which are discussed in their respective sections in this chapter. CSP = concentrating solar power; PGM = platinum group metals.

* In this report, aluminium demand is assessed for electricity networks only and is not included in the aggregate demand projections.

Source: International Energy Agency, The Role of Critical Minerals in Clean Energy Transitions

Identified Critical Minerals in Australia

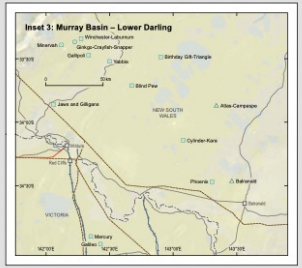
Critical mineral	On US list[6]	On EU list[7]	On Japan list[8]	On India list[9]	Australian geological potential[10]	Australian economic demonstrated resources (2020)[11]	Australian production (2020)	Global production (2020)[12]
High-Purity Alumina	✓[13]	✓[14]			Moderate	No data	No data	No data
Antimony	✓	✓	✓	✓	Moderate	125.2 kt	3.9 kt	155 kt
Beryllium	✓	✓	✓	✓	Moderate	No data	No data	240 t
Bismuth	✓	✓	✓	✓	Moderate	No data	No data	17 kt
Chromium	✓		✓	✓	Moderate	0	0	40,000 kt
Cobalt	✓	✓	✓	✓	High	1,495 kt	5.6 kt	135 kt
Gallium	✓	✓	✓	✓	High	No data	No data	300 t
Germanium	✓	✓	✓	✓	High	No data	No data	130 t
Graphite	✓	✓	✓[15]	✓	Moderate	7,970 kt	0	1,100 kt
Hafnium	✓	✓	✓		High	14.5 kt	No data	No data
Helium					Moderate	No data	4 hm^3	140 hm^3
Indium	✓	✓	✓	✓	Moderate	No data	No data	900 t
Lithium	✓	✓	✓	✓	High	6,174 kt	40 kt	82 kt
Magnesium	✓	✓	✓		High	Magnesite: 286,000 kt	Magnesite: 799 kt	Magnesite: 26,000 kt
Manganese	✓		✓		High	Manganese ore: 276,000 kt	Manganese ore: 4,800 kt	17,200 kt
Niobium	✓	✓	✓	✓	High	216 kt	No data	78 kt
Platinum-group elements	✓	✓	✓	✓	Moderate	107 t	0.522 t	380 t
Rare-earth elements	✓	✓	✓	✓	High	4,200 kt	20 kt	240 kt
Rhenium			✓	✓	Moderate	No data	No data	53 t
Scandium	✓	✓			High	30.34 kt	No data	No data
Silicon		✓[16]	✓	✓	High	No data	No data	8 kt
Tantalum	✓	✓	✓	✓	High	99.4 kt	0.1 kt	1.8 kt
Titanium	✓	✓	✓		High	Ilmenite: 274,000 kt Rutile: 35,300 kt	Ilmenite: 1,100 kt Rutile: 200 kt	Ilmenite: 12,000 kt Rutile: 1000 kt
Tungsten	✓	✓	✓		High	577 kt	<1 kt	84 kt
Vanadium	✓	✓	✓	✓	High	7,408 kt	0	86 kt
Zirconium	✓		✓	✓	High	Zircon: 79,300 kt	Zircon: 400 kt	Zircon: 2,000 kt

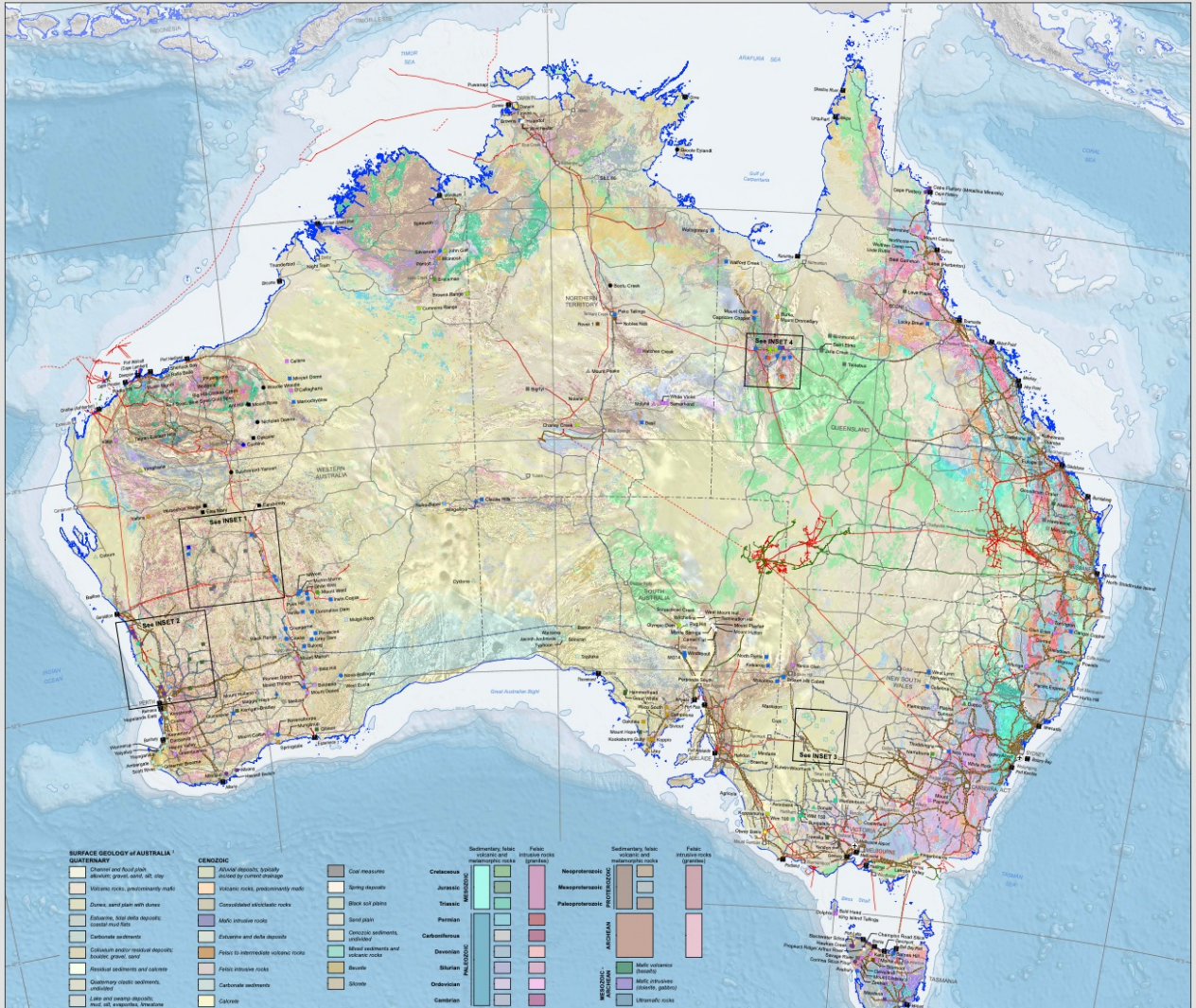
Source: Department of Industry, Science, Energy and Resources, Critical Minerals Strategy

Selected Australian Government Reports on Critical Minerals

Title	Organisation	Year
Outlook for Selected Critical Minerals: Australia 2019	Department of Industry, Science, Energy and Resources	2019
Australian Global Resources Statement	Department of Industry, Science, Energy and Resources	2020
Resources Technology and Critical Minerals Processing: National Manufacturing Priority Road Map	Department of Industry, Science, Energy and Resources	2021
Australian Critical Minerals Prospectus 2021	Australian Trade and Investment Commission (Austrade)	2021
Critical Energy Minerals Roadmap The Global Energy Transition: Opportunities for Australia's Mining and Manufacturing Sectors	Commonwealth Scientific and Industrial Research Organisation	2021
Critical Minerals Strategy	Department of Industry, Science, Energy and Resources	2022

Source: Compiled by author from government documents





Australian Government
Geoscience Australia

Australian Critical Minerals Map 2021

SCALE 1:7,000,000

0 125 250 375 500 625 750km

LAMBERT CONFORMAL CONIC PROJECTION
Central Meridian 134°E. Standard Parallels 18°S, 36°S
Geocentric Datum of Australia

This map shows the locations and status, as at 31 December 2021, of Australian operating mines, mines under development, mines on care and maintenance and resource deposits associated with critical minerals. Developing mines are deposits where the project has a positive feasibility study, development has commenced or all approvals have been received. Mines under care and maintenance and resource deposits are based on known resource estimations and may produce critical minerals in the future. The critical mineral deposits on this map may not be comprehensive for all commodities.

For the purposes of this map, critical minerals are defined as minerals and elements (solid and gaseous) that are vital for modern technology and whose supply may be at risk of disruption. The Australian critical minerals list comprises aluminium (high-purity alumina), antimony, beryllium, bismuth, chromium, cobalt, gallium, germanium, graphite, hafnium, helium, indium, lithium, magnesium, manganese, niobium, platinum group elements, rare earth elements, rhenium, silicon (high-purity quartz or silica), scandium, tantalum, titanium, tungsten, vanadium and zirconium. These commodities are coloured by mineral groupings on the map.

The map symbols are superimposed on a generalised surface geology map of Australia. The coloured areas represent rocks of different ages (see legend) exposed at the Earth's surface. The geology is superimposed on a greyscale background that represents the aeromagnetic response (0.5 vertical derivative of total magnetic intensity) of rocks at surface and at depth. In areas of younger basin and regolith cover (grey areas), the aeromagnetic data show the older geology continuing under this cover. In some areas, these buried rocks are prospective for undiscovered mineral deposits.

MINERAL DEPOSITS [1]

Commodity Type

- *Aluminium (High-purity alumina)*
- *Antimony*
- *Bismuth, +/- Cobalt, +/- Indium*
- *Chromium, +/- Cobalt, +/- PGE*
- *Cobalt*
- *Platinum Group Elements (PGE), +/- Cobalt*
- *Scandium, +/- Cobalt, +/- PGE*
- *Graphite*
- *Helium*
- *Indium*
- *Lithium, +/- Tantalum, +/- Niobium*
- *Magnesium*
- *Manganese ore*
- *Heavy Mineral Sands (HMS) - Titanium, Zirconium*
- *Heavy mineral sands - Titanium, Zirconium, REE*
- *Rare Earth Elements (REE)*
- *REE, Zirconium, Niobium, +/- Hafnium, Lithium, Tantalum, Gallium*
- *Rhenium*
- *Silicon (High-purity silica/quartz)*
- *Tungsten*
- *Titanium*
- *Titanium, Vanadium*
- *Vanadium*

Project status, as at 31 December 2021

- Operating mine
- Mine - under development
- Mine - care and maintenance
- Mineral deposit

ENERGY RESOURCES

INFRASTRUCTURE

Petroleum Fields and Pipelines [4]

- *Gas pipeline*
- *Gas pipeline (proposed)*
- *Oil pipeline*
- *Oil pipeline (proposed)*

Export Facility [5]

- *Resources export port*
- *Resources export airport*

TOPOGRAPHIC FEATURE

- *Coastline* [6]
- *Bathymetry contour (depth in metres)* [7]
- *Transmission Lines* [8]
- *Major road* [9]
- *Railway* [9]
- *Capital city* [9]
- *City/town* [9]

Compiled by Allison Britt, Mineral Resources, Advice and Promotion Section.
Cartography by Silvia Massomo, Communications Section, Geoscience Australia, Canberra, ACT.
It is recommended that this map be referred to as: Britt, A.F., 2022. *Australian Critical Minerals Map 2021 (2nd Edition)*, Scale 1:7 000 000, Geoscience Australia, Canberra.

Further information can also be found on the Internet at:
http://www.ga.gov.au/scientific-topics/minerals/mineral-resources-and-advice
https://www.ga.gov.au/about/projects/resources/critical-minerals
https://www.industry.gov.au/about-us/what-we-do/critical-minerals-facilitation-office

Additional information on operating mines, developing mines or mines under care and maintenance on this map is available from the Geoscience Portal: http://portal.geoscience.gov.au/

Acknowledgements/Data Source :
[1] Critical Minerals and Mineral Deposits (Australian Critical Minerals Map 2021): © Commonwealth of Australia (Geoscience Australia) 2022. http://pid.geoscience.gov.au/dataset/ga/145250
[2] Commodity Export Facilities: © Commonwealth of Australia (Geoscience Australia) 2022.
[3] Electricity Transmission Lines (Foundation Electricity Infrastructure): © Commonwealth of Australia (Geoscience Australia) 2021. http://pid.geoscience.gov.au/dataset/ga/145249
[4] Oil and Gas Pipelines: ©Ports Petroleum Database. Data is correct as at December 2021.
GEODATA TOPO 1M 2001 (Coastline, State Borders):
© Commonwealth of Australia (Geoscience Australia) 2001. http://pid.geoscience.gov.au/dataset/ga/70614
GEODATA TOPO 10M 2002 (City/Town locations, Roads, Railways):
© Commonwealth of Australia (Geoscience Australia) 2002. http://pid.geoscience.gov.au/dataset/ga/60803
Surface Geology of Australia 1:1 million scale dataset 2012 edition
© Commonwealth of Australia (Geoscience Australia) 2012. http://pid.geoscience.gov.au/dataset/ga/74814
World Coastline and Bathymetric Contours Made with Natural Earth. Free vector and raster map data @naturalearthdata.com 2009–2021. https://www.naturalearthdata.com/downloads/10m-physical-vectors/

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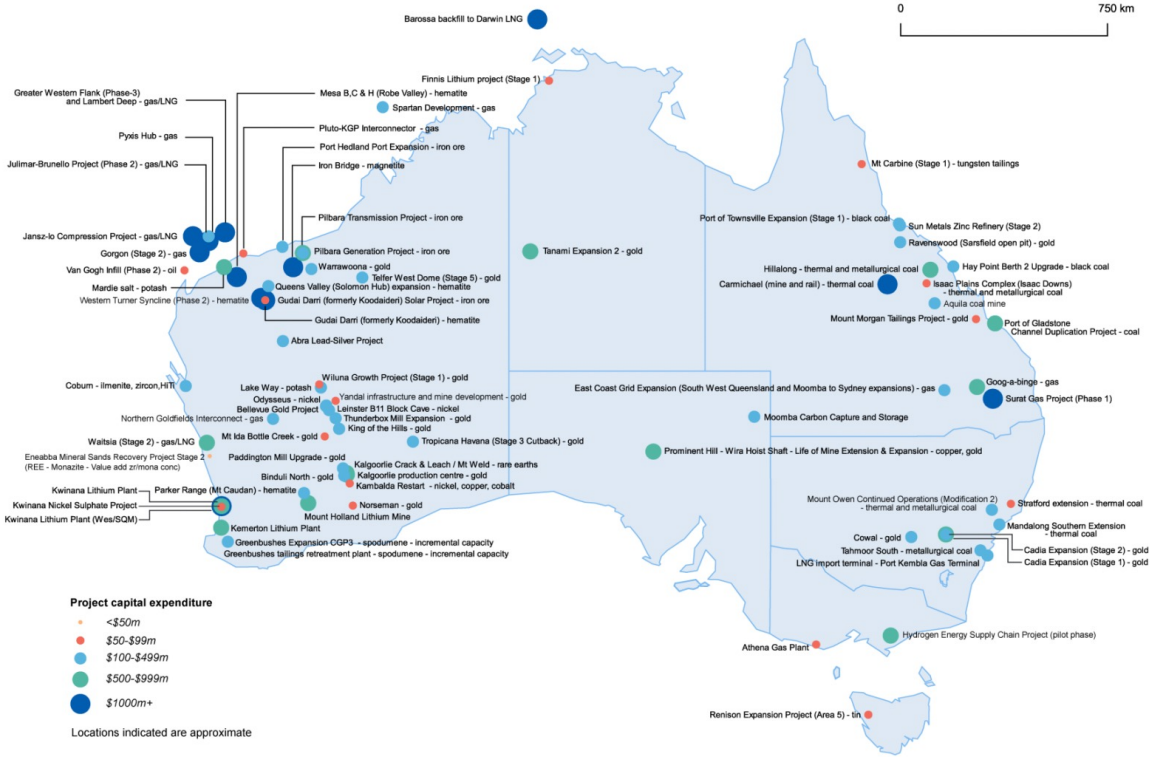
GA acknowledges traditional custodians of Country throughout Australia, and recognises their continuing connection to lands, waters and communities. We pay our respects to Aboriginal and Torres Strait Islanders' cultures, and to Elders past, present and emerging.

Copies of this map may be downloaded from the Geoscience Australia website at:
http://pid.geoscience.gov.au/dataset/ga/145250
Or by contacting: Client Services, Geoscience Australia

Image 6.1: Location of projects at the committed stage, as at 31 October 2021



Source: Department of Industry, Science, Energy and Resources (2021)

https://www.industry.gov.au/sites/default/files/December%202021/document/resources-and-energy-major-projects-report-2021.pdf

Mining

Optimising Resource Extraction CRC (2010-2021)
- Improving feed quality
- Enabling mass separation
- Increasing extraction efficiency etc.

MinEx CRC
- New exploration tools to collect subsurface data.

Critical Minerals Accelerator Initiative
- AUD 200 million over 5 years
- Department of Industry, Science, Energy and Resources
  - feasibility studies
  - engineering design work
  - pilot testing
  - building demonstration plants

Critical Minerals Facility
- Up to AUD 2 Billion
- Export Finance Australia
  - Complements commercial finance
  - Extraction/processing for export
  - Completed feasibility study
  - Buyer commitment
  - Use of proven technology
  - Financial, technical and commercial cap.

- **Future Battery Industries CRC**
  - Battery market and value chain development
  - Battery supply chain integrity
  - Energy grid optimisation – with batteries
  - Transitional impact of batteries on society and the economy
  - Optimise battery industry ecosystems

Clean Energy Finance Corporation (CEFC)
- Projects that develop, commercialise or use renewable energy, low emissions or energy efficiency.
- Debt and equity offerings: aim to deliver a positive return across portfolio.
  - US$52 million in Pilbara Minerals: mine & process to produce raw material for lithium hydroxide.
  - US 1.5 million through Clean Energy Innovation Fund in Novalith for low carbon lithium production.

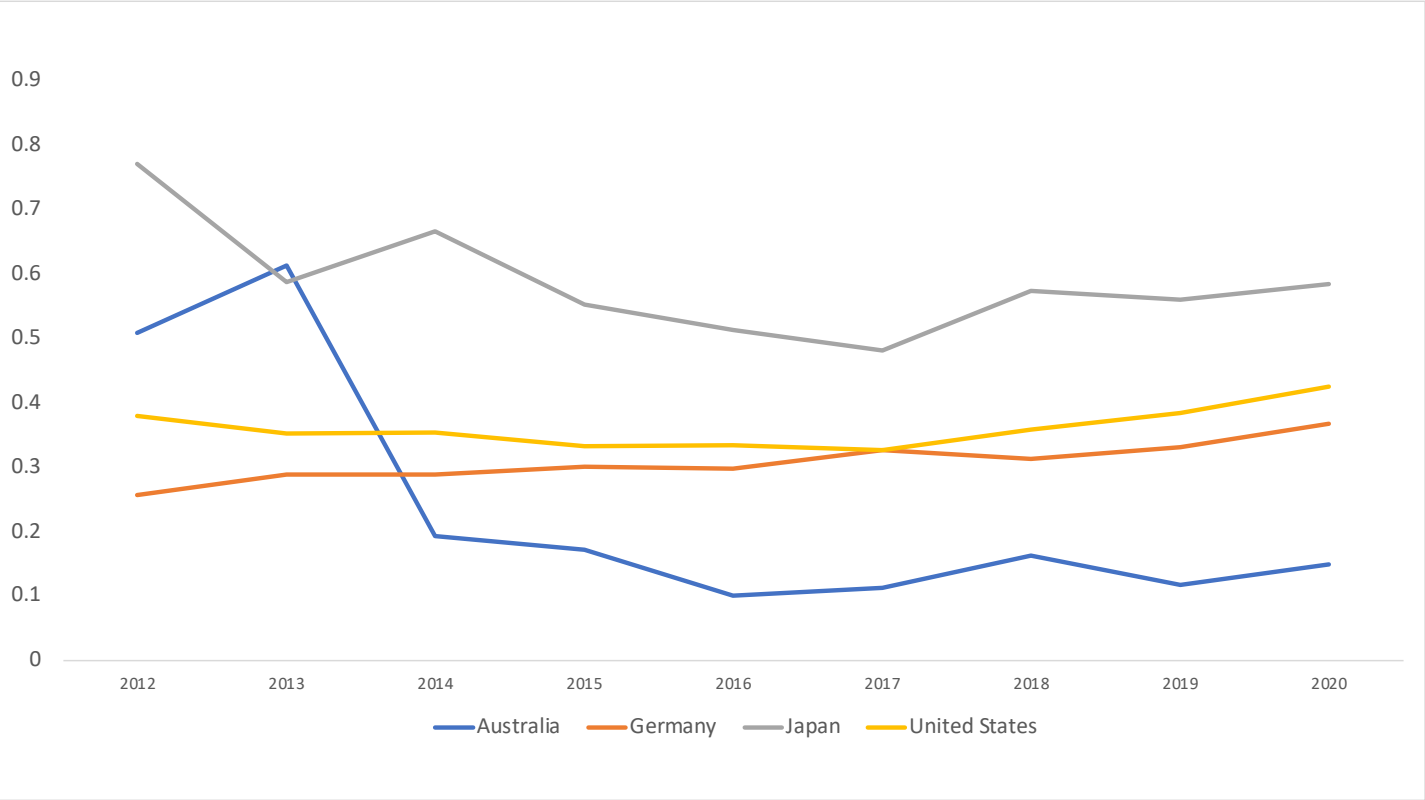
Processing

National Critical Minerals Research and Development Centre
- AUD 50 million over 3 years
- Tax offset on top of the applicable corporate tax rate for R&D
  - intellectual property in critical minerals processing
  - technical bottlenecks in strategic supply chains
  - collaborative research

Modern Manufacturing Initiative
- AUD 1.3 billion
- Pilot, demonstrate or scale up techniques and processes
- AUD 274+ million to critical minerals related products in 2020 & 2021, incl.,
  - Pure Battery Technologies: $119.6 million for nickel and cobalt battery material refinery
  - Australian Vanadium: $49 million for vanadium battery industry powered by green hydrogen
  - Arafura Resources: $30 million for Nolan's Project Rare Earth Separation Plant

Source: Compiled by author from government documents

Energy RD&D Budget per 1000 units of GDP



Source: Compiled by author from International Energy Agency, Energy RD&D Database

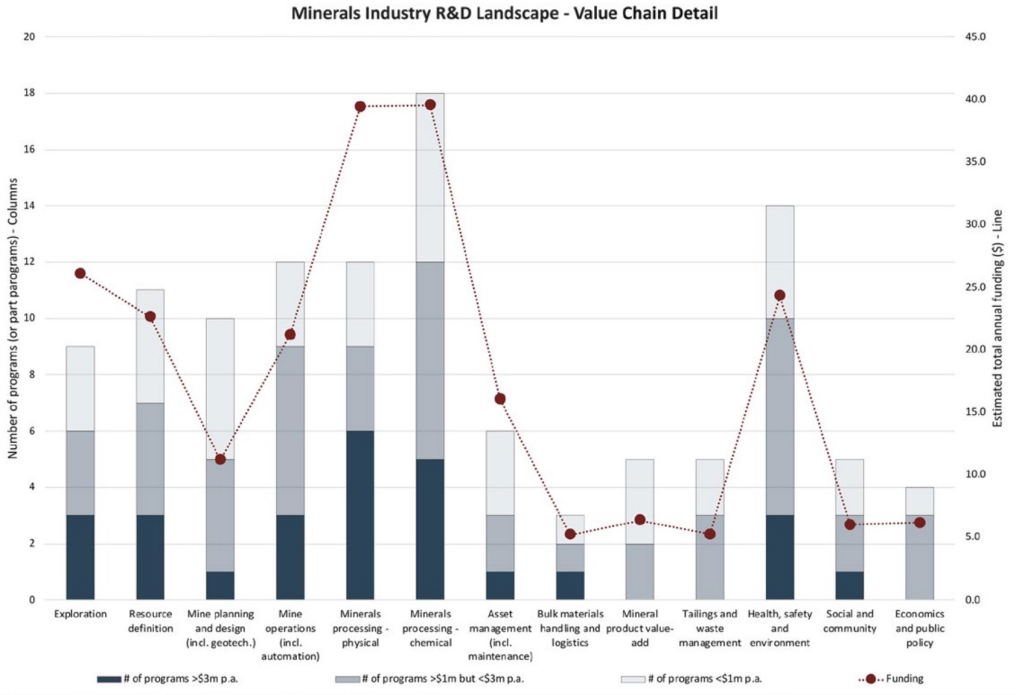


Figure 4: R&D landscape – value chain detail

- "65 significant R&D programs, with total annual funding of $229m per annum, identified.
  - Minerals industry export revenues of over $200b/annum
- "Overall R&D landscape:
  - majority of small-scale programs;
  - low focus on step-change innovation;
  - total funding lower than might be expected for such a critical industry."
    - 70% of programs with annual funding of less than AUD3 million.

Note: Dataset contains programs being conducted by or with Australian-based 'Research Service Providers' (RSPs), most notably Universities and CSIRO. It does not include R&D being conducted in-house by mining and METS companies, or by them with other organisations that are not RSP's.

Source: Andrew Jenkin, A review of the minerals industry R&D landscape in Australia, 2020

Opportunities for Australia-India cooperation

India's projected demand for critical minerals presents significant opportunities to increase cooperation with Australia.

India offers Australian critical minerals producers economies of scale for offtake arrangements, and a robust pipeline of manufacturing-led commercial innovation opportunities.

With its abundant critical mineral reserves and world-class mining expertise, Australia can assist India to achieve its industrial growth goals.

Australian companies and institutions can evaluate models to:

- supply processed minerals
- export services and technology for processing, refining, recovering and recycling critical minerals
- support mineral exploration and mining-related environmental management in India
- establish joint research projects across the value chain.

Austrade can assist with tailored introductions between companies and provision of market insights to businesses on both sides.

Indian firms are exploring investment opportunities in Australian mining and mineral processing assets.

The Indian government's critical minerals sourcing agency, Khanij Bidesh India Limited (KABIL), and the Australian Government's Critical Minerals Facilitation Office (CMFO), along with Austrade, can support investment facilitation.

There is also an opportunity for third country involvement in the value chain to enhance supply chain efficiency and resilience, and particularly to address capability gaps in intermediate mineral processing.

The Australia-India Joint Working Group (JWG) on critical minerals established under the bilateral memorandum of understanding (MOU) on critical minerals will support policy exchange and cooperation and facilitate linkages between business and research institutions.

RECOMMENDATIONS

1. Increase understanding of commercial opportunities and pathways to partnership
2. Identify and facilitate opportunities for Indian investment in Australian mining and mineral processing projects
3. Pursue mineral offtake partnerships
4. Seek government and industry partnerships with third countries to support supply chain resilience
5. Expand mining equipment, technology and services (METS) collaboration to drive productivity across the supply chain
6. Develop a critical minerals community of practice for collaborative knowledge sharing, research and development