SPECIAL REPORT

Developing Australia's critical minerals and rare earths

Implementing the outcomes from the 2023 Darwin Dialogue

John Coyne and Henry Campbell

September 2023

ASPI AUSTRALIAN STRATEGIC POLICY INSTITUTE

NORTHERN AUSTRALIA STRATEGIC POLICY CENTRE

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Contents

Executive summary

Rare-earth elements (REEs) and critical minerals are the world's building blocks for emerging and future technologies[1] and are essential to manufacturing, clean energy production, semiconductor production, and the defence and aerospace industries. Their supply and value chains are small relative to those of major commodities such as iron ore and coal, are highly concentrated around China,[2] are easily distorted, and are vulnerable to price fluctuations.

The current global supply is also inadequate, as global demand for these resources is expected to grow rapidly in the coming decades. Significant increases in global mining and refining capacity will be needed to meet that demand; the Organisation for Economic Co-operation and Development (OECD) estimates that 50 new lithium mines, 60 new nickel mines and 17 new cobalt mines will be required.[3] Diversifying and expanding supply is a strategic, economic and environmental necessity, and Australia's mineral reserves make it essential for the expansion of global supply.

In principle, supply chains convergent on single sources or single destinations are not resilient and create financial risks for market participants and economic risks for nations.[4] Supply-chain diversity is therefore essential. China has demonstrated its capacity to coercively wield its critical-minerals and rare-earths position and has inadvertently disrupted the global market when enacting domestic policy,[5] providing further evidence of the need to diversify global supply. Australia, like-minded governments and the private sector must collaborate to ensure competitive, secure, resilient REE and critical-minerals supply and value chains. But this is a complicated problem, requiring a nuanced and collaborative policy approach.

Government will need to adjust its approach to resolve these issues. For decades, successive Australian governments placed great confidence in economic liberalism: personal liberty, private property and limited government interference.[6] Neoliberalism has been particularly influential, eliminating price controls, deregulating capital markets, lowering trade barriers and reducing, especially through privatisation, state influence in the economy.[7] Three decades of economic prosperity have subsequently led to an almost religious belief in the ability of globalisation and market forces to solve economic problems. In this environment, business models have deliberately focused on offshoring, the centralisation of production, and just-in-time supply.[8]

But the market can't resolve this alone, especially as the market incentives that offshoring presents have resulted in the concentration of supply in China and developing nations. Those decisions have created economic and supply-chain vulnerabilities, accentuated by the global Covid-19 pandemic, a return of war to Europe and great-power competition.[9]

It's neither advisable nor desirable to abandon globalisation or the associated commercial practices that have contributed to market concentration. Success isn't about economic nationalism or protectionism, but ensuring that nations have a choice of suppliers that increases resilience. Policymakers must now identify what premium governments will pay for market-level risk mitigation, and for what goods.

This report—based on closed-door, invitation-only discussions at ASPI's new Darwin Dialogue, a track 1.5 meeting between Australia, Japan and the US—makes 24 recommendations for government and the private sector to support the development of viable, competitive alternative markets that offer products through supply chains secure from domestic policy disruptions and economic coercion.

Policy recommendations

The Australian Government should continue approaching the challenge of REEs and critical minerals with a clear understanding that it can't do everything. Instead, it should be concerned with what's most important to Australian national security and resilience. The recommendations below are what we believe are most important to Australia's national interests.

Geopolitical tensions and China's monopoly

1. The Australian, Japanese and US governments must work together, and closely with other partners and allies, to call out Beijing's coercive and anti-competitive actions, including through the World Trade Organization (WTO).
2. Australia, Japan and the US should recognise that they neither can, nor should, try to replace China's supply of REEs and critical minerals. Instead, through minilateralism, friend-shoring and nearshoring, they should focus on ensuring that there are viable and resilient supply chains in addition to those provided by China.
3. Beijing has been adamant and forthright about its non-benevolence in the REE and critical-minerals sectors. The Australian Government must be clear-eyed about protecting our technological developments in REE and critical-minerals processing. This will require the Department of Foreign Affairs and Trade to place a greater focus on mining-related intellectual property (IP) protection within the WTO and World Intellectual Property Organization frameworks.
4. The Australian Government should recognise that separating our economic and strategic relationships will be increasingly challenging.

Critical minerals and REEs investment and capital flows

5. The Australian and US governments should expand the Australia–US Taskforce on Critical Minerals membership to include Japan.
6. The Australia–US taskforce should consider the utility of establishing a joint fund with like-minded countries, including Japan. The new fund should focus on accelerating REE and critical-minerals mining and processing projects.
7. The Northern Australia Infrastructure Facility should prioritise funding of northern Australian REE and critical-minerals infrastructure projects, especially where the funding will serve to diversify supply chains.
8. The Department of Industry, Science and Resources (DISR) and the Office of Northern Australia should consider how to promote the further development of mineral hubs and industry clusters in northern Australia by the public and private sectors. The focus here should be on developing regional hubs to concentrate supply-chain developments, producing localised pockets of refinery capacity across the Northern Territory, Queensland and Western Australia.

Environmental, social and governance perspectives

9. The Australian private and public sectors must continue to lead in environmental, social and governance (ESG) compliance. DISR must work with industry to shape the future enhancement of international standards by championing continuous improvement, not simple compliance.

10. The Australian Government should continue to work with peak mining bodies and the not-for-profit sector to identify mechanisms to make careers and studies in mining and mining-related professions more attractive for students and younger workers.

11. The Australia–US taskforce should consider enhancing end consumers' understanding of supply-chain resilience and ESG compliance.

12. Geoscience Australia has identified 1,050 possible sites where critical minerals could be extracted from the waste of existing projects, including mine tailings, waste rock, smelter residues and related mine waste materials. The federal and state governments should incentivise projects that capitalise on that waste, where economically viable, to increase production, reduce waste and promote a circular economy.

Research and development and exploration

13. The Australian Government should establish a Cooperative Research Centre (CRC) for Mining Transformation. History has shown that, when done well, Australian CRCs create necessary push factors to support industry pull factors for innovation.

14. The Australian Government needs to further incentivise private-sector investment in R&D. Consideration should be given to tax incentives for those investing in this sector.

The role of government(s) and international cooperation

The Australian Government should do the following things:

15. Direct DISR to rapidly update our national mineral data and exploration. For example, much of the Northern Territory remains unexplored for REEs and critical minerals.

16. Direct DISR to enhance free and effective sharing of our national minerals data.

17. Develop less risk-averse financial support for the junior exploration sector and start-ups. This could be achieved through further funding being allocated to the Australian Critical Minerals Research and Development Hub focused on exploration.

18. Establish a national taskforce (comprising representatives of the federal, state and territory governments, peak bodies and academia) focused on cutting down and streamlining mining approvals so that moving to the production stage doesn't take an average of six years plus.

19. Focus all of Australia's mining-related CRCs on step-change discoveries.

International cooperation

20. REEs and critical minerals should be a G7 priority. The Japanese and US governments should further promote REEs and critical minerals by working together to get them onto the G7 agenda.

21. The Australian, US and Japanese governments should acknowledge that, while innovation comes largely from the private sector, entrepreneurs will go elsewhere without government facilitation.

22. The US, Japanese and Australian governments should consider prioritising multilateral approaches to investment in processing.

23. Like-minded countries, such as Japan, the US, Australia and India, should explore the potential of establishing a buyers' club for REEs and critical minerals. A buyers club could be used to coordinate members' policies to increase market power and negotiate better terms of trade.

24. The US Government should examine the lessons learned from the Japanese investments in the Darwin-based Ichthys facility and Lynas Rare Earths Ltd and use those lessons to inform the bilateral acceleration of supply-chain alternatives.

Background

Chinese-owned companies have dominated the world's supply of REEs and many critical minerals for decades (see box).[10] The rise of Chinese President Xi Jinping has blurred the lines between the country's private sector and government, providing Beijing with control of those markets.[11] Beijing has already used its near-monopolistic global supply-chain control for REEs to strategic advantage against the US and Japan.[12] In response, both countries have independently enacted policies to develop alternative supplies of critical minerals and rare earths, with limited success.

What are REEs and critical minerals?

A critical mineral is a metallic or non-metallic element that is essential for modern technologies, economies or national security and that has a supply chain at risk of disruption. Geoscience Australia lists 26 critical minerals, ranging from graphite to magnesium.[13] See the appendix to this report for a complete list of Australia's critical minerals and further details. There are a number of additional minerals, such as copper (there are 3 tonnes of it in a 1MW wind turbine) and nickel, that aren't yet listed as critical.

REEs are a subset of critical minerals. They comprise 17 metals—15 elements from the lanthanide series and two chemically similar elements, scandium and yttrium. All have unique properties that make them vital for various commercial and defence technologies, including batteries, high-powered magnets and electronic equipment.[14] See Table 3 for a more detailed list.

There's growing recognition among the US and like-minded countries (including Australia, South Korea, Japan and India) that additional REE and critical-mineral supply chains must be developed without dependency on China.

But new supply chains won't just happen. Solutions will need to be driven by governments rather than left to market forces, and that will require significant resource contributions. Beijing's control over the market, and its coercive tactics, have distorted market forces and mean that industry can't resolve these issues alone. Government demand for these materials will also only continue to increase, as they're increasingly important to national objectives.

Australia's Department of Industry, Science, and Resources (DISR) released a critical minerals strategy in 2020[15] and established the Critical Minerals Facilitation Office.[16] In June 2023, the Albanese government released its Critical Minerals Strategy 2023–2030 to set out its vision to grow Australia's critical-minerals sector. These are steps in the right direction but need to be followed by close collaboration with the Department of Foreign Affairs and Trade and with Austrade to tap into their wealth of knowledge on promoting trade opportunities and act as facilitators. Their ability to connect buyers with sellers will be vital here.

Recent tensions in the Australia–China relationship have made diversifying REE and critical-minerals production even more pressing.[17] China currently produces 90% of the world's REEs, so like-minded countries can't shift its sector dominance overnight.[18] However, that dominance underscores the urgency for Australia and its partners to mitigate overreliance risks.

Beijing has realised that controlling the global market is a valuable economic lever. And it has used its dominant position in the marketplace coercively, adding a political risk that compounds the risk of overreliance on a single market. Chinese companies routinely adjust their domestic production quotas and subsidise REE prices to strategically flood the market to drive out competitors and deter new market entrants.[19]

As a result, Australian governments and their international partners must take more decisive action in the face of the increasing supply-chain risk.

US President Joe Biden has signed an executive order launching a comprehensive review of America's critical supply chains for strategically significant products and resources.[20] Among those are REEs, supplies of which the Biden administration says must be independent of foreign sources or single points of failure in times of national emergency.

Australia has the world's sixth-largest reserves of REEs.[21] However, they still need to be explored, and only two mines are in operation. Australia's critical minerals strategy for 2019 primarily focused on attracting foreign investment into new mining infrastructure.[22] However, the renewed focus on REEs' strategic and commercial importance should be a stark reminder that, as Luke Bowen has written on ASPI's *The Strategist* site, Australia needs to back itself on REEs instead of letting great-power competition lead the way.[23]

To address this issue, ASPI, with support from the Northern Territory Government, hosted a track 1.5 dialogue between Australia, Japan and the US: the Darwin Dialogue.[24] The dialogue brought non-government and government organisations together to create neutral ground to build a shared understanding of the challenge of the REE and critical-minerals industry.

This report is based on an analysis of the Darwin Dialogue sessions and the key themes discussed throughout the event.

The Darwin Dialogue

The inaugural Darwin Dialogue, held in April 2023, was a multi-day track 1.5 initiative. It involved 55 leaders and key players from Australia, Japan and the US, and senior representatives from the Netherlands and India attending as observers. The discussion focused on critical-minerals production and supply-chain security.[25]

The dialogue was broken up into seven thematic sessions:

1. Minilateral opportunities for strategic cooperation
2. Industry perspectives on REE and critical-mineral challenges
3. The Japan and ASEAN perspective
4. Current REE and critical-minerals investments and policy
5. The current and future state of critical-mineral and REE supply and demand
6. The geopolitical risk to REE and critical-mineral extraction and processing
7. Batteries, magnets and semiconductors.

Methodology

The Darwin Dialogue was undertaken under the Chatham House rule, which allows participants to use the information received. However, participants may never reveal the identity or affiliation of the speaker(s), nor that of any other participant. Consistent with the rule, there were two note-takers present throughout the dialogue. After the dialogue, their notes were merged. Subsequently, content and discourse analysis techniques were used to identify the dialogue's key themes.

In each of the dialogue's seven sessions, three speakers provided five-minute presentations on the theme of the session. Questions and discussions then followed the presentations.

Analysis

Analysis of the Darwin Dialogue content identified that six themes dominated discussions:

- Supply-chain vulnerabilities
- Geopolitical tensions and China's monopoly
- Critical-minerals and REEs investment and capital flows
- Environment, social and governance (ESG) perspectives
- R&D and exploration
- The role of government(s) and international cooperation.

Supply-chain vulnerabilities

Critical-mineral and REE supply chains feature significant vulnerabilities: they're dependent upon China, supply can't meet current or projected demand, manufacturers lack alternatives, and current market actors lack the necessary resources to invest in the sector. Increased strategic competition and recent events, such as Covid-19 and the Russian invasion of Ukraine, have also increased market-level risks and exposed supply-chain vulnerabilities.

Policymakers must now identify what premium governments around the world will pay for market-level risk mitigation, and for what goods. Substantial policy thinking and resources are needed to address these issues. For critical minerals and REEs, new initiatives will be needed to diversify supply and build supply-chain resilience.

Supply chains are the networks of businesses that contribute to transforming inputs into final outputs and eventually deliver them to consumers.[26] The global trend of trade liberalisation, which has accelerated over recent decades, along with technological developments, has had two deliberate impacts: offshoring and the centralisation of production to countries with lower labour costs where economies of scale can be achieved,[27] and increased economic specialisation.

Both trends make supply chains more complex at a time when countries such as Australia have placed greater emphasis on market forces, driven by the central consideration of return on investment. Complexity and interdependency aren't problems on their own. Interdependency as a rule ensures public- and private-sector policies focused on managing and mitigating potential risks or shocks: geopolitical (for example, a trade war), environmental (for example, a natural disaster), economic (such as a financial crisis), societal (such as a pandemic) and infrastructure-related (for example, a cyberattack).[28]

But, for critical minerals and rare earths, global production is now centred around China, despite our economic and strategic dependence upon these minerals. Australian, Japanese and US critical-minerals supply chains feature extensive vulnerabilities, which profit-driven private enterprises can't resolve on their own. Overconfidence in neoliberalism, the resilience of supply chains and risk mitigation has led to critical input dependency, geographical clustering, a lack of flexibility, and choke points (see box).[29]

Vanadium and the Russian invasion of Ukraine

Russia's invasion of Ukraine has severely disrupted global markets and supply chains, increasing the cost of energy commodities, certain agricultural products and critical raw minerals produced in Russia.[30]

Before the invasion, Russia accounted for 25% of global vanadium oxide exports, which are used to produce ferrovanadium—an additive in steel alloys with applications for the space industry, nuclear reactors and aeroplanes.[31] The addition of less than 0.1% vanadium per tonne of steel can result in a strengthening of 50%–100%,[32] making it a critical additive for various construction projects and manufacturing.[33]

In 2021, China produced 70% of global vanadium supplies and, alongside Russia, firmly controlled global supply.[34] Since the invasion, sanctions have limited Russia's access to the worldwide marketplace and distorted vanadium access, favouring China, which has expanded its broader trade relationship with Russia throughout 2022–23.

Vanadium is a listed critical mineral in Australia, and its global production centres around China, Russia, Brazil and Chile despite Australia having some of the richest vanadium deposits in the world.[35] Projects like Darwin-based Tivan are also employing innovative technology to achieve competitive advantages in vanadium processing that will help to diversify supply chain options. The current impact of the vanadium shortage has been global, affecting manufacturing countries such as the US, France and Germany, and there are no alternatives to vanadium in the aerospace industries.[36]

The 2023 Defence Strategic Review argues that a domestic missile industry and nuclear submarine capability are essential national-security objectives.[37] Both require reliable access to vanadium and other critical minerals, reinforcing the foundational relevance of critical minerals to government objectives.

REE and critical-mineral supply-chain vulnerabilities occur at both the public policy and company levels. It's challenging for policy movement along the REE and critical-mineral value chain to improve resilience from potential risks and shocks, despite the increasing likelihood of such outcomes. They're vulnerable to geopolitical risks, used in essential industries and critical (they can't be substituted easily; nor are alternative supply chains established).[38]

Australian critical-mineral and REE companies rely on establishing offtake agreements with customers that are able to process their goods.[39] Consequently, Darwin Dialogue participants noted that very little global supply of critical minerals is uncommitted, meaning that the sector is defined by high levels of vertical integration. While that can appear to be economically efficient, in practice it limits customers' options and diminishes corporate autonomy.

Geographical clustering of so much of the global critical-mineral and REE supply chain needs to be mitigated.[40] The policy aim here must be precise and realistic. It isn't to bifurcate trade or to force Chinese companies out of the market. Instead, the objective is to mitigate the impacts of geographical clustering of multiple levels of REE and critical-mineral production to provide a more resilient global supply chain. Further, it's essential to acknowledge that different minerals have different supply chains and unique vulnerabilities, which makes a one-size-fits-all solution unlikely.

Addressing this challenge will involve more than mineral exploration and mining. To start, more incentives are needed to address resilience at the company level. Regardless, a market-only-based solution seems unlikely, given the commercial risks involved. The change will require a concerted effort from the private and public sectors.

From the public sector, some effort must be made to incentivise this move for companies, which must also include putting a price premium on, at least in the short term, a resilient supply chain. It also means cooperation and collaboration between like-minded countries on moving along the process chains. For Australia, this must include support for the processing of REEs, components manufacturing (for example, batteries) and assembly.

The vulnerability is even more acute for Japan, the US, India and Europe. Most don't have sufficient reserves of critical minerals and REEs or the means to process them for their significant manufacturing requirements.

Global events, politically motivated or otherwise, have demonstrated a capacity to damage supply chains with little resiliency, especially when the chains are centred on single suppliers. Critical minerals and REEs are of fundamental importance to multiple industrial sectors, including health, green energy and defence, and it's imperative that serious structural weaknesses in their supply chains be resolved.

Geopolitical tensions and China's monopoly

Beijing's control over multiple stages of the REE and critical-mineral supply chain makes manufacturing's dependency on the materials a wicked problem. That dominance hasn't happened by chance but is part of a 25-year effort that's seen China's industry secure processing technology and capacity.

Critical minerals and REEs are firmly part of broader global competition. Their importance to national economies and defence industries, in combination with geostrategic tensions between China, the principal market entity, and the US and its allies, has had the effect of securitising them, as has China's demonstrated capacity and willingness to coercively exploit its position of dominance over the critical-mineral and REE marketplace.[41]

China is the leading producer of a significant number of critical minerals and firmly controls the global rare-earth supply. It's the leading producer globally of 29 different commodities,[42] including 13 of Australia's 26 identified critical minerals. Of those 13, China produces more than half of the global supply for 12 of them. It's also a very significant producer of the remaining minerals. The leading producers include several politically unstable nations (see Table 1). Chinese corporations also commonly own those foreign supplies, further expanding control over the marketplace. As highlighted by Ben Halton and Kim Beazley, there's great variance in individual countries' critical-mineral lists, even between Australia and the US.[43]

Table 1: Australia's critical minerals list, resources and production, with global comparisons

Australian listed critical mineral	Australian geological potential	Australian economic demonstrated resources (2021)	Australian production (2021)	World mine production (2021)	World leader[a]
High-purity alumina	Moderate	Aluminium oxide: 16.72 mt	0	No data	China
Antimony	Moderate	136.5 kt	3.4 kt	109 kt	China
Beryllium	Moderate	No data	No data	260 t	United States
Bismuth	Moderate	No data	No data	19 kt	China
Chromium	Moderate	0	0	41,400 kt	South Africa
Cobalt	High	1,582 kt	5.3 kt	165 kt	Democratic Republic of the Congo
Gallium	High	No data	No data	430 t	China
Germanium	High	No data	No data	140 t	China
Graphite	Moderate	7,970 kt	0	1,000 kt	China
Hafnium	High	14.5 kt	No data	No data	No data
Helium	Moderate	No data	4 hm^3	160 hm^3	United States
Indium	Moderate	No data	No data	920 t	China
Lithium	High	6,700 kt	55 kt	105 kt	Australia
Magnesium	High	Magnesite: 286,000 kt	Magnesite: 894 kt	Magnesite: 30,000 kt	China
Manganese	High	Manganese ore: 277,000 kt	Manganese ore: 4,900 kt	19,500 kt	Gabon
Niobium	High	216 kt	No data	75 kt	Brazil
Platinum-group elements	Moderate	247.7 t	0.470 t	380 t	South Africa
Rare-earth elements	High	4,260 kt	23 kt	240 kt	China
Rhenium	Moderate	157 t	No data	59 t	Chile
Scandium	High	36.65 kt	0	No data	No data
Silicon	High	No data	No data	8 kt	China
Tantalum	High	104.4 kt	0.1 kt	2.1 kt	Democratic Republic of the Congo
Titanium	High	Ilmenite: 273,800 kt; rutile: 33,800 kt	Ilmenite: 600 kt; rutile: 200 kt	Ilmenite: 14,400 kt; rutile: 600 kt	China
Tungsten	High	570 kt	<1 kt	79 kt	China
Vanadium	High	8,110 kt	0	110 kt	China
Zirconium	High	Zircon: 78,600 kt	Zircon: 500 kt	Zircon: 1,600 kt	Australia

a. World leader defined per *Mineral commodity summaries 2023*, US Geological Survey, online.
Source: Original table created by Geoscience Australia, online.

No international agreement exists on a definitive critical minerals list, and the list of the International Energy Agency (IEA) extends to 50 (See Table 4 in the appendix).[44] China is also among the top three producers of six out of 10 of the most production-concentrated critical minerals, meaning it's a particularly important producer of the materials with the least diversified supply chains.[45] Moreover, where China isn't the geographical producer of these metals, they may still be controlled by Chinese state-owned enterprises, as with cobalt in the Democratic Republic of the Congo.[46]

Former Chinese President Deng Xiaoping equated Chinese dominance in REEs to the Middle East's dominance over oil,[47] and China produces 62%–70% of REEs; the US is the second-largest producer (14%).[48] This significant gap is due to offshoring practices, and China's foresight; Deng Xiaoping was discussing REEs in 1987, saying 'There is oil in the Middle East, and rare earths in China.'[49] Australia and allied nations have started grappling with REEs' importance only in recent years.

China is consequently the principal global supplier and refiner of REEs,[50] and it's willing to use that dominance coercively. This most famously occurred in 2010 when China restricted REE exports to Japan in response to tensions over the disputed Senkaku Islands.[51] In 2011, it broadly cut export quotas for rare earths by 35% in a protectionist effort to advantage domestic industry.[52]

That prompted responses from the US, Japan and the EU, which disputed the policy as a breach of WTO obligations. In 2014, the policy was found to be inconsistent with WTO obligations.[53] However, as China reversed the restrictions, it saturated the global market and threatened international REE producers, principally the US Molycorp and Australian Lynas Corporation. Lynas's value plummeted, and Molycorp collapsed into insolvency (see box).[54] Valuable Molycorp assets were also transferred to the Chinese-linked Neo Materials.[55]

Lynas

Lynas Rare Earths is the only significant producer of separated REEs outside of China.[56] Lynas has received considerable support from the Japan Oil, Gas and Metals National Corporation (JOGMEC), which has underpinned its survival.[57]

JOGMEC's support for Lynas was catalysed by China's restriction of Japan's access to REEs in response to the 2010 diplomatic dispute with Japan over the Senkaku Islands.[58] Among other things, China's restrictions threatened Japan's domestic battery industry, which was valued at US$11.29 billion in 2020, in a coercive act of economic statecraft.[59]

Lynas operates in Australia and Malaysia, and in 2022 signed an agreement with the US Department of Defense to construct a heavy earths separating facility in Texas.[60]

The Lynas case study also illustrates the challenges of critical-minerals processing. Lynas operates its Mt Weld facility in Western Australia, but processes in Malaysia because it couldn't secure domestic licences.

In April 2023, an OECD policy paper identified China as the most restrictive exporter of critical minerals, increasing restrictions nine times between 2009 and 2020.[61] That restrictive pattern has continued since 2020; in 2022, Beijing threatened to limit rare-earth supplies to US defence contractors, including Lockheed Martin, over their involvement in US arms sales to Taiwan,[62] and in 2023 China again threatened to restrict global REE supply.[63]

China's virtual REE processing monopsony[64] was shown to present similar challenges at the Darwin Dialogue. Alongside being the largest producer of critical minerals, China is also commonly the largest consumer—even where it doesn't control production.[65]

Vast consumption requirements have underpinned China's domestic production and prompted it to pursue ownership over foreign-originating supply chains or pre-purchasing agreements for mine resources.[66] Very little production of many critical minerals is uncommitted and accessible, especially as global companies have adopted vertical integration strategies to guarantee their own supply.[67]

Pre-committed supply has inhibited the growth of a global minerals marketplace, reduced supply-chain resilience and profitability and maintained dependence on China as the largest customer. China's refinement capacity further reinforces this monopsony, making it currently inseparable from the supply chain, and it almost singularly possesses the refinery capacity for the critical minerals that will underpin the green energy transition: copper, cobalt, lithium (see box), rare earths and nickel.[68]

Case study: Lithium

Lithium, a critical mineral integral to batteries, is a perfect example of China's level of value-chain control. Lithium batteries are vital to phones, laptops and electric vehicles (EVs), and in 2021 China consumed 40% of globally produced raw lithium and produced EV batteries for BMW, Volkswagen and Tesla.[69]

Australian mines account for 47-54% of the global supply, while China's account for only 12.6%. But Australia doesn't refine significant quantities of lithium domestically, so China purchases and processes 96% of Australian lithium.[70] Similarly, Australia's largest lithium mine, the Greenbushes Mine in Western Australia, is operated by Talison Lithium, which is a subsidiary of Tianqi Lithium (51%), a Chinese mining company.[71] While Tianqi Lithium is no longer a state-owned enterprise it retains state affiliations - its founder and chairman of the board has strong links to the Chinese Communist Party and was a representative at the 13th National People's Congress.[72]

While foreign investment in Australian mining is essential and should be encouraged, critical minerals and REEs need to be protected and feed more diversified processing arrangements. In 1990, the Chinese Government declared rare earths to be a protected and strategic mineral, barring foreign investment and restricting foreign participation in joint processing ventures. The prohibition of Chinese ownership over strategically essential commodities, echoing Canada's forced divestment of Chinese ownership in lithium, is a national-security issue. However, it needs to be followed with strategies to increase investment from domestic sources and like-minded nations.

Chinese lithium companies Jiangxi Ganfeng Lithium and Tianqi Lithium are already the largest and third largest lithium-mining companies globally.[73] Government intervention is needed to lessen China's geoclustering advantages, which remain attractive to private enterprise, as is evidenced by Australian mining company Mineral Resources investing nearly $1 billion to acquire shares in two lithium refineries within China in early 2023.[74]

The Australian Government and like-minded nations must act to secure Australia's reserves for Australia's interests and develop domestic lithium-battery manufacturing and refinery capacity. Policy enactments similar to the 'Australia Made Battery Plan'[75] proposal should be encouraged, as should the government's $100 million investment into onshore mineral and chemical processing operations.

Similar investments by like-minded nations must also be encouraged, such as the South Korean Government's US$460 million investment into a Gwangyang facility that will refine Australian spodumene ore into lithium.[76]

Ultimately, removing China from critical-mineral and REE supply chains is neither advisable nor achievable. The ongoing diversification of REE supply chains demonstrates this, as Japan has invested extensively yet still relies on China for two-thirds of its rare-earth imports.[77] This is despite JOGMEC's investments into four critical-minerals exploration projects, financial assistance for eight critical-minerals projects globally, heavy investments into Vietnam's critical-minerals / rare-earths sector, and, principally, its significant investment (US$250 million) into Lynas.[78]

But supply-chain diversification and resiliency is achievable. The US and Japan are the largest markets outside of China for critical minerals and REEs, while Australia possesses the largest relevant mineral reserves. This provides the opportunity for a networked supply chain that would be far more resilient than a chain that depends on China.

Darwin Dialogue participants appreciated that a rebalance is an arduous task complicated by many factors. Still, these materials are too important to be monopolised and used coercively amid inter-state strategic competition.

Critical-mineral and REE investment and capital flows

Many at the Darwin Dialogue agreed that Japan, Australia, the US, India and the EU has good prospects for diversifying critical minerals and REEs. Many have already updated domestic policies with significant implications for critical minerals, including Japan's Economic Security Promotion Act (2022), Australia's Critical Minerals Strategy 2023–2030 (2023), the US's Inflation Reduction Act (2022), and the European Critical Raw Materials Act (2023).

Some participants likened the challenge to the diversification of oil supply in the 1970s and 1980s beyond Saudi Arabia and the Middle East. However, like the policy measures used then, solutions must be based on cost-effectiveness. In the current strategic environment, if capital investors believe the risks of private- and public-sector investment outweigh the benefits, action will be unlikely.

There are high barriers to market entry for those seeking to develop alternative REE and critical-minerals supply and value chains. Technical challenges relating to the metallurgical processing of REEs and critical minerals and their waste and by-products introduce risk.[79] The currently limited opportunity to negotiate offtake agreements (agreements to purchase minerals in the future) to markets outside China adds another layer of complexity.[80] Despite those challenges, plenty of big-thinking entrepreneurs in Australia, Japan, the US and India are willing to try. They must strive for sensible investments to avoid repeating the many historical misadventures that risk discouraging the positive momentum towards diversification at present. For example, as noted in the ASPI AUKUS critical minerals report, US$10–12 billion was lost from a combination of the New York, Australian and Canadian stock exchanges around the 2012 period from failed REE ventures[81].

Smaller companies currently dominate mining for REEs and some critical minerals; the market's exposure to dramatic price fluctuations makes the sector structurally non-resilient.[82] Australia's most significant REE companies include Lynas, Iluka Resources, Hastings Technology Metals and Arafura Rare Earths. They're capable companies pioneering the sector, but the scale of their financial resources is far smaller than those of their major counterparts. Their valuation demonstrates this: mining giant BHP's market capitalisation is A$227.91 billion, far greater than the combined market caps of Lynas (A$6.65 billion), Iluka (A$4.85 billion), Arafura (A$665.7 million) and Hastings (A$163.53 million).[83]

Smaller mining companies can't tolerate the same risks as the majors, creating difficulties in transitioning from exploring to production and in producing at scale. They can't rapidly develop projects of the size and at the desired speed for REE customers. Few rare-earths companies successfully transition from exploration to operations, and those that do still need help developing the infrastructure required for an at-scale operation. Even after overcoming these hurdles, there's still the threat of price fluctuations distorting the market, which has historically challenged Lynas.[84]

Preventing foreign investment in REEs and critical minerals in Australia, Canada and the US that's assessed as detrimental to national security is a necessary starting point for addressing this challenge. However, such defensively focused policies don't provide an alternative supply of capital to promote economic growth in a sector with many technical and commercial risks.

Developing new mining, processing and manufacturing facilities in Australia is a capital-intensive endeavour. It's here that Japan's investment in Lynas illustrates the kind of capital commitment that's required. But this burden need not be shouldered by a single nation. Australia's REE and critical-minerals endowment and mining expertise are a foundation for like-minded nations to cooperate and concentrate capital for supply-chain investments.

Risk tolerance for investments in this sector needs to be adjusted. For success, the mining industry, the finance sector and even governments need higher risk tolerance. Even the Northern Australia Infrastructure Facility (NAIF) hasn't been able to de-risk REE and critical-minerals projects adequately. Dialogue participants raised concerns that the NAIF often invests near the end of the capital-raising phase after other investors have taken on the risk. This isn't a sustainable model. Increased government risk tolerance should translate to more significant government equity in the sector and signal commitment to foreign investors. The commerciality of the sector will still matter, of course; tax breaks and subsidies can't prop up an industry indefinitely.

There's much that can be done by the Australian federal, state and territory governments. There are unnecessary challenges to REE and critical-minerals development that governments can address, including access to infrastructure development. As a starting point, greater intergovernmental cooperation on infrastructure development is needed to reduce the capital costs of REE and critical-minerals investment. This isn't an argument for a blank check approach but for a move to funding projects, on a prioritised basis, that focus on providing rail and road, power, and water infrastructure investments. Common user facilities might offer ideal solutions.

Australia's REE and critical-minerals mining sector targets underdeveloped and often underappreciated resources. As a result, the scale of investment is significant. However, the scale of emerging global demand requires substantial development of mines, refineries and downstream manufacturing. Unfortunately, excluding superannuation funds, Australia doesn't have direct access to enough domestic capital to address the challenge, necessitating foreign investment. Notably, that absence of capital also speaks to the investment appetite of the mining investment community, which has successfully focused on traditional commodities such as coal and iron ore to date.

Given the significant number of infrastructure megaprojects undertaken in the world in the past decades and the amount of capital investment in those projects, there appears to be no global shortage of investment capital. Government financing has a role; however, attracting investment capital from the private sector seems essential for infrastructure megaprojects other than a simple non-toll highway. To commit, private-sector stakeholders must perceive a compelling business case, including strategic alignment, a feasible investment amount, a clear and straightforward funding model (operational revenues), a persuasive return on investment and an acceptable level of risk.

The development of regional mineral hubs, while posing some technical challenges, is a strong example of what can be achieved. Developing the hubs can achieve economies of scale for mining projects, reducing transport costs. Furthermore, mineral hubs create opportunities for industry clustering. This isn't an argument for Australian governments to return to centralised economic planning. Instead, it's a means by which greater use and reuse of by-products, waste and energy, for example, can be achieved.

Finally, industry representatives made clear statements that there's no bureaucratic urgency in progressing approvals for mining. For example, it was reported that it takes some 74 months in Australia to get to production: that's far too long. It takes five or more years to get a lithium mine operational. It took 20 years for ANSTO to approve Australian Strategic Materials Ltd. Arguably, these circumstances should be driving rapid development and step-changes that need to translate across the Australian federal government bureaucracy.

ESG perspectives

A common thread across the Darwin Dialogue was ESG perspectives[85] on critical minerals and REEs. ESG is not and should not be an afterthought; it's crucial to maintaining the social licence to operate and to protecting the environment, and it offers economic opportunities.

The current Australian Government is committed to climate policy and transforming Australia into a renewable energy 'superpower'.[86] Climate policy was an early and important feature of the successful 2022 Labor electoral campaign,[87] and it was quickly followed by emissions reduction legislation.[88] The government's Critical Minerals Strategy 2023–2030 similarly made clear a heightened commitment to environmental outcomes and highlighted critical minerals' and REEs' roles in energy transition.[89]

Critical minerals and rare earths are vital components in the clean energy transition, including technologies such as wind turbines, solar panels and EV motors. Projections for net-zero emissions by 2050 indicate that critical-minerals demand will be 40 million tonnes by 2050, increasing from 8 million tonnes in 2020.[90] Demand for certain minerals is projected to grow nearly exponentially; for example, the demand for lithium is projected to increase 30 times to 2030, and over 100 times by 2050, compared to its 2020 base.[91]

Correspondingly, the IEA's conservative projections (a 10%–20% increase on today's value) of the value of energy-transition minerals project the minerals to be more valuable than coal, by US$70 billion, by 2040[92] and to reach coal's current market size by the 2040s and exceed it by the 2050s.[93]

The mining and processing of critical minerals and REEs to a high-ESG standard will be foundational to reducing emissions and transitioning to clean technology in the long term.

Government commitment reflects the fact that the ESG impacts of mining and REE processing are genuine concerns in some quarters of Australian society. For some, there's an irony that energy transition access and speed will rely on the ability to mine and process the necessary minerals. While building an effective circular economy may eventually reduce the need for some mining, they need to be pursued concurrently in the short and medium terms. Searching for commercially viable recycling solutions is proving problematic.

Neither the market's midstream manufacturers nor end consumers' commitment to ESG translates to paying more for products. The race to reduce costs in these supply chains has consistently been a critical factor.

A circular critical-minerals economy

Concurrent investment in a circular critical-minerals economy is both economically and environmentally prudent. It's also important to recognise that we can't maintain high ESG standards while mining unnecessarily when recycling provides a viable alternative.

Opportunities for a circular mineral economy in Australia have already been identified. Geoscience Australia has identified 1,050 sites where mine waste could be repurposed as a source of critical minerals.[94] Projects such as the Albemarle lithium hydroxide refinery in Western Australia are testing the value of this approach, processing the tailings of the Talison Lithium Greenbushes mine to produce aluminosilicates with potential applications in construction and transport. Circular projects increase economic efficiency, reduce waste and diminish the need for expansive storage facilities.[95] Industry-clustering initiatives similarly offer strong circular advantages, minimising waste and increasing profitability through recycling and sharing resources.

Direct government investment can go only so far. Policy incentives and private investment will be needed to develop the circular minerals economy. By 2050, it's projected that the energy transition will have developed a circular economy, reducing demand for new mines. This reinforces the need for broad investment to ensure that such opportunities can be realised at scale, including by backing innovation as a key pillar of corporate ESG commitments.

Social licence

The desire for the minerals for energy transformation has created demand, but there are enduring challenges from the 'not in my backyard' ethos. Australia continues to pioneer world's best practices for ESG compliance in mining and processing operations, but communities are generally resistant to mining in their vicinity or the construction of noisy wind turbines nearby. Further, we should be mindful of critics suggesting that turbines in certain areas could offer negligible net benefit to the environment if full life-cycle carbon footprints are factored in. This includes emissions from associated mining and manufacturing and the transportation, installation and maintenance of turbines.

There's also the separate need to negotiate agreements with Indigenous communities upon whose land these projects would be constructed. This is particularly true in the Northern Territory, as 78% of it's controlled under Indigenous land rights.[96] This shouldn't be considered an imposition, but a key mechanism in protecting both the environment and unique cultural connections to it.

These considerations are material and important, but so is the alternative. Overseas mining practices are often destructive to the environment and to impoverished communities, particularly in China and developing nations.[97] Australia as an ESG world leader has a capability and responsibility to improve the sector, utilising and further developing necessary legal mechanisms to do so.

Growing aversion to mining in Australian communities affects the availability of resources: capital and labour. Many younger Australians don't see an employment future in Australian mining.[98] They're turning away from careers in mine engineering and metallurgy. A stronger case needs to be made by both government and the private sector that mining and processing are critical to our future energy transition.

Australia must continue to maintain and advance international mining standards as a nation. Consumers must be encouraged to put a value on end-product ESG compliance across the breadth of global supply chains, especially for green technology. This approach is critical for the environment and the attraction of capital and labour.

R&D and exploration

In addition to capital, the fundamental building blocks for accelerating changes in REE and critical-mineral supply chains are exploration, research and development. Australia needs to conduct more research and capitalise on it more effectively.

According to the Harvard industry complexity review (which has a product–export focus), Australia is only the 91st most complex economy, declining from 55th most complex in 1995.[99] Australia spends 0.56% of GDP on research[100], but that research is clearly not translating into our overall economy. Australia generates relevant IP; for example, solar panels supplying 90% of the world are built in China using IP developed at the University of NSW. Overall, in the past two decades Australia developed 40,000 renewable-energy patents.[101]

But we don't capitalise on it. Some Darwin Dialogue participants argued that, as a nation, we're preoccupied with patents rather than being creative about accessing patented information. Australia needs to improve this to capitalise on the opportunities it creates.

Most Australian businesses are small enterprises, and consequently private enterprises' investment in R&D is minimal.[102] Some dialogue participants argue that greater creativity is needed in accessing patented information. This could enable greater economic complexity, which in turn would increase business investment in R&D.

From an industry perspective, there needs to be more REE and critical-mineral research and innovation occurring in Australia. ASPI's *Critical Tech Tracker* shows that, in the production of high-impact research, Australia's universities, labs and companies rank in the top five in mineral-processing technologies, but as a leading mining country Australia should be closer to number one or two.[103] This is part of the reason why Chinese companies produce more critical minerals and REEs than anyone else. The problem is more than just research funding, but one of people. Australia's university sector needs assistance attracting thought leaders and researchers and attracting the next generation of researchers and workers.

This isn't suggesting that the federal government hasn't been delivering initiatives. Australia's CSIRO continues to deliver innovation. Its establishment of a science diplomacy initiative aims to channel research into other countries (the US, India).[104] Australia's current REE and critical-mineral national investments policy must address various issues, including R&D. Much of the global mining industry is already struggling to get the skilled, semiskilled and unskilled labour it needs now, let alone to grow. Australia is no exception.

There's an emerging demand issue in the REE and critical-minerals sector. Chinese companies, on their own, can't meet projected demand. Some experts believe that the globe combined can't meet that demand.[105] This presents a global challenge requiring a global solution.

Global demand for REEs and critical minerals is growing, and more exploration and discovery are needed if Australia, as a nation, is to play a significant role in closing supply gaps. Exploration for new resources has been tapering off in Australia and has historically been highly concentrated in Western Australia.[106] Note also that exploration has been heavily skewed towards only iron ore and gold.

Further exploration across the country should result in newly discovered deposits and economic opportunity, while we should also recognise that the mining of such discoveries will be of limited value to a secure global supply without an exponential increase in diversified mineral-processing capabilities. Moreover, should Australia not take a sizeable stake in processing operations, the economic value to the nation would be marginal at best.

The Northern Territory has begun to significantly increase exploration, increasing funding by almost 30% in 2022, with nearly half of that funding (A$82.7 million) supporting critical-minerals exploration.[107] That model needs to be expanded and replicated by other jurisdictions to meet global demand. Australia and like-minded international partners, such as the US, need to focus on and finance exploration to meet growing mineral demand and consistently identify the most promising mineral deposits.

The role of government(s) and international cooperation

Australia

The governments of each country represented at the 2023 Darwin Dialogue are taking policy initiatives to deal with this challenge. While government assistance is required to mitigate REE and critical-mineral supply-chain vulnerabilities, the government must carry out that action carefully. Government can't solve all these problems; nor would we want it to.

This sector has a rare confluence of interests across government objectives, defence, renewables, the health industry and manufacturing. Australia must capitalise on the opportunity that this confluence presents by working with international partners to develop and process our critical-minerals and REE reserves for our strategic, environmental and economic interests.

The Australian Government already has many initiatives in this space, including:

- the Critical Minerals Facility: $2 billion; established in 2021[108]
- the Australian Critical Minerals Research and Development Hub: $50.5 million; announced in 2022[109]
- the Resource Technology and Critical Minerals Trailblazer Hub, led by Curtin University in partnership with The University of Queensland and James Cook University and industry partners: $50 million; established in April 2022 [110]
- the Modern Manufacturing Initiative: $1.3 billion;[111] this works alongside Export Finance Australia,[112] the NAIF[113] and the Clean Energy Finance Corporation[114]
- the Virtual National Critical Minerals Research and Development Centre: $50 million over three years.[115]

There should be no doubt that Australia, like Canada and the US, should continue to construct some legislative boundaries that preference national security and resilience over foreign investment. Canada began addressing the issue in 2022 by announcing that any foreign state-owned enterprise looking to purchase Canadian assets in the sector could be subject to a comprehensive review to ensure that the purchase is not 'injurious to national security'.[116] This practical national-interest test reverses the default towards investment and short-term company profit and instead prioritises Canada's security and sovereignty.

Australia continues to welcome foreign investment from China. In February 2023, the Foreign Investment Review Board (FIRB) approved China Baowu Steel Group's involvement in a $2 billion iron ore project in Western Australia (see box).[117] That's because such investments aren't directly injurious to national security or resilience. In contrast, the FIRB recommended an application from Yuxiao Fund to increase its stake in Northern Minerals, a REE player, from 10% to 19.9%,[118] but federal Treasurer Jim Chalmers blocked the proposed investment because of the importance of protecting these strategic assets.[119]

The Foreign Investment Review Board

The FIRB is a non-statutory body established in 1976 to advise the Treasurer and the government on Australia's foreign investment policy and its administration. The board's functions are advisory only. Responsibility for making decisions about the policy and proposals rests with the Treasurer. The Treasury's Foreign Investment Division administers Australia's foreign investment regulatory framework and supports the board's work.

The role of the FIRB is to:

- examine proposed investments in Australia that are subject to the *Foreign Acquisitions and Takeovers Act 1975* and supporting legislation and are covered by the foreign investment policy, and to make recommendations to the Treasurer and other Treasury portfolio ministers on those proposals
- provide advice to the Treasurer on the operation of the policy and the Act
- foster an awareness and understanding, both in Australia and abroad, of the policy and the Act.

The Australian Government released its new Critical Minerals Strategy 2023–2030 after the Darwin Dialogue. While the strategy references the issues highlighted in this report, it's arguably more like a 'description of what government is doing than a charter for a bold new direction'.[120] Initial industry feedback to ASPI highlights the limited capital investment available to promote 'crowd in'[121] private-sector investment. Moreover, the strategy is silent on the kinds of tax breaks needed to allow industry to be more globally competitive. Finally, it appears that the government has chosen not to adopt mandated processing in Australia.

In this situation, building high fences with domestic policy isn't, on its own, going to promote supply-chain resiliency. This sector is dominated by the 'minors', not the major mining companies. Yet, it serves other critical industry sectors: medical, aerospace and defence, advanced technology, and the auto industry. Here, it will be critical for the Australian Government to adopt an alternative model for working with the sector rather than what's been used successfully for iron ore and coal.

What's clear from participants at the Darwin Dialogue is that high-level cooperation between the private sector and state and territory governments is needed. Australia's federal, state and territory governments have an enormous appetite for solving the critical-mineral and REE supply-chain challenge. Still, they need more appetite to accrue the debt that they'll be likely to require for further investment. Therefore, Australia needs to target its niche in this sector strategically. In doing so, the public sector will need to play a significant investment role if the nation is to eventually realise the potential opportunities of moving along the value chain to manufacture green technology such as batteries.

Joined-up government efforts will be critical here. The state, territory and federal governments must work together to reduce the barriers, especially concerning building infrastructure and industry clusters (see box). These joint investments will reduce barriers to market entry and allow for industry clustering.

Middle Arm Precinct

The Northern Territory Government is undertaking master planning of infrastructure and services, engineering and rigorous environmental studies in an area on the Middle Arm Peninsula of Darwin Harbour, now called the Middle Arm Precinct.

This new precinct represents a strategic approach to creating a 'development-ready' location for investment, especially for renewables, low-emissions energy and fuels, advanced manufacturing, and low-emissions minerals processing. This work 'de-risks' investment by creating certainty for industries on the availability of infrastructure and services and a clear road map of the rigorous and efficient development approvals.

Middle Arm Peninsula is already home to the Santos Darwin liquefied natural gas (LNG) and the INPEX Ichthys LNG processing facilities; both companies are committed to net zero emissions. The precinct is designed to take advantage of the territory's natural advantages, including its strategic location and world-class solar resources. Almost all critical minerals required for manufacturing renewable energy components are available in the territory.

Plenty of evidence shows that Australia has been endowed with significant reserves of REEs and critical minerals. Many across the private and public sectors see the huge potential of the nation to become a major global miner and processor in the sector. There are also a smaller number with a vision for an Australia that moves further into downstream processing.

Beyond exploration and discovery, Australia's governments, especially the federal government, need to encourage projects at the feasibility stage. New mines are required, especially as many existing mines are reaching the end of their lives, and existing projects need to catch up with growing demand. Contributions from Victoria's mineral sands could prove vital to securing enough feedstock to ensure the viability of rare-earth processing operations elsewhere in Australia.

Many of those involved in the Darwin Dialogue agree that the federal government must reconsider how it approaches the question of 'red tape' and government facilitation. In short, it takes too long to establish new critical-minerals mines, mineral hubs and processing facilities. This isn't a suggestion that Australia should reduce its best practice approaches to ESG. Instead, we must find a mechanism to maintain those rigorous standards while reducing the time needed to obtain the appropriate clearances and standards.

Market forces aren't going to, on their own, contribute to secure and competitive alternative REE and critical-minerals supply chains. It's equally clear that no single policy measure can be enacted by Australia's federal, state and territory governments. There is, however, much that can be done. The high fences needed are now in place in terms of the FIRB. Now Australia's governments will need to establish what they can do together and in partnership with other like-minded governments. Many options are feasible and affordable. A key question is how Australia accelerates and moves closer to closing the global REE and critical-mineral supply gap.

International cooperation

Resolving supply-chain threats to critical minerals will require cooperation between like-minded international partners, particularly Australia, Japan and the US. Opportunities exist to incorporate the subject into existing minilateral institutions, principally AUKUS or the Quad, and for bilateral partnerships, as demonstrated by Lynas. Australia's vast endowments of critical minerals and REEs make it a global focal point for mining and production. Still, Australia needs capital and domestic capacity to develop those resources independently.

The challenge of creating new resilient supply chains is more significant than any country outside of China can achieve. The REE and critical-minerals supply-chain dilemma is a highly strategic issue, so resilience will be likely only if the problem is handled as such, not as a strictly commercial issue. This approach requires close-minded cooperation between partners such as Australia, Japan and the US:

> Barely a week passes in which I am not contacted by an ambassador of a partner nation seeking to discuss access to Australian critical minerals and rare-earth elements.[122]

International agreements on REEs and critical minerals have been steadily increasing; the US and Japan signed a critical-minerals agreement in March 2023, agreeing to diversify supply chains; in May 2023, the US and Australia formed the Climate, Critical Minerals and Clean Energy Transformation Compact, which will include an intergovernmental Critical Minerals Taskforce to further bilateral collaboration.[123]

However, working together with so many different actors takes time to coordinate. The urgency of the challenge requires a focus on translating agreements into action.

Customers are willing to pay for an alternative supply chain for REEs and critical minerals when there's a guaranteed end product. But that's currently not a certainty, as most critical-minerals companies fail before producing market-level quantities.

Similarly, most consumers unfortunately don't make product choices based on the provenance of the supply chain. Neither do consumers make choices based on ethical consumption along the length of critical-minerals supply chains.

This presents significant problems in REEs and critical minerals, as like-minded governments must set standards for ESG and resilience. Moreover, there's a need for provenance ESG tracing for critical technology, including batteries. Like-minded countries must work together and incentivise and strategically communicate to final consumers that the end product, factoring in sovereignty and guarantees, is of greater value.

Regardless of demand, sovereign resilience is beyond the reach of one country and requires minilateralism. The dialogue was held in Darwin, as it's symbolic in demonstrating what can be achieved through bilateralism. INPEX's Ichthys facility provides 10% of Japan's LNG supply, providing depth in resilience in its national energy security.

REEs and critical minerals will play a key role in decarbonising national economies. However, as explained in the previous sections, that can no longer be separated from geopolitical tensions. Japan and, to some extent, the US have shown national foresight on this issue but, on their own, have yet to reduce their economic vulnerabilities. Australia is well positioned to play a globally significant role in partnership with Japan, the US and other like-minded nations. The combined impact of our natural endowment, mining expertise and investment security provides a firm base for cooperation.

Green transformation is key to any discussion of minilateral cooperation. However, it must be considered through multiple lenses simultaneously: decarbonisation, energy security, national security, resilience and economic growth.

Building diverse supply chains is critically important for Japan, and its domestic battery manufacturing depends on it. It already has a national strategy focused on investing ¥150 billion (around A$1.6 trillion) in critical minerals and REEs over the next decade.[124] It has also committed over ¥200 billion to green transformation over the next decade. Critical minerals and REEs are crucial to that transformation. JOGMEC has already played an essential role in demonstrating how to create resilient REE supply chains through its Lynas investment. Japan's private-sector companies, such as Idemitsu, have also played important roles in creating resilient vanadium and copper supply chains.

The US Government, too, has sought to address the challenge. The US Inflation Reduction Act was passed to make green energy more competitive with fossil fuels via tax incentives.[125] Ninety-five per cent of the Act focuses on clean-energy incentives, none of which can occur without critical minerals and REEs. Unfortunately, the Act's focus on 'America first' has had some unintended consequences. For Australia, the Act makes capital flow naturally into the US market, to the detriment of external investment.

The US and Australia signed the Climate, Critical Minerals and Clean Energy Transformation Compact in late May 2023.[126] The compact offers a framework for the US and Australia to collaborate on climate issues, clean-energy technology and critical-minerals supply chains. It discusses critical minerals mainly in the context of clean-energy technology.

The compact commits to using 'domestic financial instruments and incentives to foster greater integration of responsible, clean energy supply chains', which includes critical-minerals supply chains.[127] The compact says that the US and Australia will seek industry input on financial incentives, and it lists the US Export–Import Bank as one possible financing agency. Notably, a joint statement by US President Joe Biden and Australian Prime Minister Anthony Albanese said that Biden would ask Congress to add Australia as a 'domestic source' under Title III of the Defense Production Act, enabling Australian projects to access significant US Government funds.[128]

Underscoring the central role of critical minerals in the clean-energy transformation, Australia and the US are also establishing the ministerial-level Australia–US Taskforce on Critical Minerals, to be led by principals from the US National Security Council and Australia's DISR, with engagement from key stakeholders across industry and relevant government agencies. The taskforce will report to both governments, signalling the intent to deepen bilateral collaboration on the critical minerals and materials vital to clean energy and defence supply chains. The taskforce is also intended to work with industry leaders to develop and expand reliable, responsible and secure global access to critical minerals, strengthening the global supply by creating a shared energy industrial base.

While bilateral cooperation is essential, broader collaboration is needed. Beyond investments in exploration and infrastructure, international partnerships are necessary for financing, technology sharing (patents) and applications (technology, manufacturing). The absence of uncommitted supplies of REEs and critical minerals needs to be resolved, so minilateralism between a smaller group of partners seems a better suggestion.

While Australia should look to collaboration and cooperation with Japan and the US, other potential partners should be included in any minilateral response. For example, through mechanisms such as the European Critical Minerals Raw Materials Board, the EU could provide access to finance.

India has a vast market, a low-cost manufacturing base and ambitious plans to acquire critical minerals and REEs. Those strengths, combined with the advantages of Australia, Japan, Korea, the US and European partners, offer the perspective of competitive alternatives and more resilient supply chains.

While bilateral and minilateral collaboration should be given priority, we must be open to competition. Beijing's current policy settings have distorted global competition in this space. Nevertheless, there's a significant opportunity with little need for direct competition. Regardless of the possibilities, collaboration is tricky. There must be cohesive agreements to avoid unilateral policy measures deliberately or unintentionally creating roadblocks for like-minded countries.

Conclusion

The Darwin Dialogue brought together a diverse range of stakeholders from across countries, sectors and businesses. Of course, such a diverse range of participants meant an equally diverse range of perspectives. This report represents an analysis of those perspectives, not a consensus. Regardless, some pervasive themes emerged. The key ones are that REEs and critical minerals are essential to the economic, national and commercial security of all involved. The second is that the current global market presents a range of supply-chain vulnerabilities that market forces alone can't fix. The key discussion here was that there are not only vulnerabilities but also specific examples where disruption has occurred both unintentionally and to achieve nefarious outcomes. Despite the best efforts of those involved, current unilateral efforts haven't resulted in any meaningful change, and, without collective action, the problem is set to worsen.

For Australia, the mining industry has been vital to our national economy for decades, protecting us against recession. Our approach to mining has left our economy somewhat fragile beyond three-year cycles. The Harvard industry complexity review shows that our exported products are increasingly unsophisticated.[129]

The emerging REE and critical-minerals boom may give Australia renewed economic opportunity. However, by 2050 we may face a cliff: we may contribute to the energy transition, but then the circular economy will diminish the requirement for our materials. It's in Australia's interest to work collaboratively with like-minded countries to raise the capital needed for mine and processing development. And it's in Australia's long-term economic interest to be clear-eyed on our focus on moving further along the REE and critical-minerals value chain.

Appendix

Table 2: Detailed Australian critical minerals: global production, production leaders, and Australian total reserves

Australian critical minerals	Global production (mt)	China's Production (mt)	% of global production	Australian production (mt)	% of global production	Global leader or 2nd largest producer	% of global production	Australian ore reserves (mt)[a]
Aluminium[b]	140,000	76,000	54%	20,000	14%	Australia (2nd)	14%	1,560,000,000 bauxite; 1,160,000 high-purity alumina
Antimony	110,000	60,000	55%	4,000	4%	Russia (2nd)	18%	19,500,000
Beryllium	280	70	25%	–	–	United States (1st)	64%	–
Bismuth	20,000	16,000	80%	–	–	Laos (2nd)	10%	–
Chromium	41,000	0	0%	0	0%	South Africa (1st)	44%	–
Cobalt	190,000	2,200	1%	5,900	3%	Democratic Republic of the Congo (1st)	68%	613,000
Gallium	550,000	540,000	98%	0	0%	–	–	–
Germanium								–
Graphite	1,300,000	850,000	65%	–	–	Mozambique (2nd)	13%	5,000,000
Hafnium[c]	–	–	–	–	–	–	–	–
Helium	160	1	1%	4	3%	United States (1st)	38%	–
Indium	900	530	59%	0	0%	South Korea (2nd)	22%	–
Lithium	130,000	19,000	15%	61,000 (1st)	47%	Chile (2nd)	30%	4,563,000
Magnesium (compound)	27,000	17,000	63%	2600	10%	Australia (2nd)	10%	–
Magnesium (metal)	1,000	900	90%	0	0%	Russia (2nd)	5%	–
Manganese	20,000	990	5%	3,300	17%	Gabon (1st)	23%	120,000,000
Niobium	–	–	–	–	–	Brazil	90%	58,000
Platinum-group elements[d]	400,000	–	–	–	–	South Africa (1st)	55%	51
Rare-earth elements	300,000	210,000	70%	18,000	6%	United States (2nd)	14%	3,110,000
Rhenium	58,000	2,500	4%	0	0%	Chile (1st)	50%	–
Scandium	–	–	–	–	–	–	–	11,650

Silicon	8,800	6,000	68%	50	1%	Russia (2nd)	7%	–
Tantalum	2,000	78	4%	57	3%	Democratic Republic of the Congo (1st)	43%	49,800
Titanium (ilmenite)[e]	8,900	3,400	38%	660	7%	Mozambique (2nd)	13%	70,700,000
Titanium (rutile)[f]	590	0	0%	190 (1st)	32%	Sierra Leone (2nd)	22%	11,400,000
Tungsten	84,000	71,000	85%	0	0%	Vietnam (2nd)	6%	213,000
Vanadium	100,000	70,000	70%	0	0%	Russia (2nd)	17%	2,948,000
Zirconium[g]	1,400	140	10%	500 (1st)	36%	South Africa (2nd)	23%	29,200,000

a Data for Australian ore reserves from Geoscience Australia.[130]

b Aluminium statistics reflect alumina production calcined equivalent weights.

c Hafnium statistics are included in zirconium, as zirconium and hafnium are typically contained in zircon at a ratio of about 50 to 1.[131]

d Platinum-group elements inclusive of palladium and platinum.

e Note that titanium ilmenite accounts for roughly 90% of global titanium consumption. Ilmenite statistics from Geoscience Australia.[132]

f Rutile statistics from Geoscience Australia.[133]

g Zirconium reserves are reflective of zircon statistics from Geoscience Australia.[134]

Note: All figures have been rounded.

Table 3: Rare-earth elements

Rare-earth element	Applications
Cerium	Autocatalysts, chemical catalyst, glass polishing, metal alloys
Dysprosium	High-power, high-temperature magnets, lasers, data-storage devices, lasers
Erbium	Lasers, glass colourant, fibre optics, optical amplifiers
Europium	Nuclear control rods, phosphors
Gadolinium	Magnetic resonance imaging contrast agent, nuclear reactor rods
Holmium	Highest power magnets in existence, lasers, nuclear control rods
Lanthanum	Batteries, catalysts for petroleum refining, ceramics, glass, machinery
Lutetium	PET scanners, cancer therapies, electronics
Neodymium	Catalysts, high-power magnets for consumer technology (computers, phones, audio systems) as well as medical equipment and turbines, lasers
Praseodymium	High-power magnets, aerospace alloys, batteries, autocatalysts
Promethium	Beta radiation source, atomic batteries for spacecraft and guided missiles
Samarium	Cancer treatments, nuclear, high-temperature magnets
Scandium	Aluminium-scandium alloys, solid oxide fuel cells, ceramics, electronics, lasers, lighting, and radioactive isotopes
Terbium	Phosphors for lighting, high-power / high-temperature magnets
Thulium	Metallurgy, lasers, radiation source in x-ray machines
Ytterbium	Fibre-optic technology, solar panels, scintillators, catalysts
Yttrium	Catalysts, ceramics, lasers, metallurgy, phosphors, metal alloys, cancer treatments, satellites, and superconductors

Sources: Lynas Rare Earths, online; US Geological Survey, 'US Geological Survey releases 2022 list of critical minerals', news release, 22 February 2022, online; Australian Trade and Investment Commission, 'Australian Critical Minerals Prospectus', 2019, online.

Table 4: IEA critical minerals

No.	Critical mineral	Global production leader	% of global production
1	Aluminium	China	54%
2	Antimony	China	55%
3	Arsenic	China	39%
4	Barite	India	33%
5	Beryllium	United States	64%
6	Bismuth	China	80%
7	Cerium*	China	–
8	Cesium	China	–
9	Chromium	South Africa	44%
10	Cobalt	Democratic Republic of the Congo	81%
11	Dysprosium*	China	–
12	Erbium	China	–
13	Europium*	China	–
14	Fluorspar	Germany	69%
15	Gadolinium*	China	–
16	Gallium	China	98%
17	Germanium	China	Unknown
18	Graphite	China	65%
19	Hafnium	–	–
20	Holmium*	–	–
21	Indium	China	59%
22	Iridium (PGE)	South Africa	–
23	Lanthanum*	China	–
24	Lithium	Australia	47%
25	Lutetium*	China	–
26	Magnesium	China	63%–90%
27	Manganese	Gabon	23%
28	Neodymium*	China	–
29	Nickel	Indonesia	48%
30	Niobium	Brazil	90%
31	Palladium (PGE)	Russia	42%
32	Platinum (PGE)	South Africa	74%
33	Praseodymium*	China	–
34	Rhodium (PGE)*	South Africa	–
35	Rubidium	–	–
36	Ruthenium (PGE)	South Africa	–
37	Samarium*	China	–
38	Scandium*	China[a]	–
39	Tantalum	Democratic Republic of the Congo	43%
40	Tellurium	China	53%

41	Terbium*	China	–
42	Thulium*	China	–
43	Tin	China	31%
44	Titanium	China	38%
45	Tungsten	China	85%
46	Vanadium	China	70%
47	Ytterbium*	China	–
48	Yttrium*[b]	China	–
49	Zinc	China	32%
50	Zirconium	Australia	36%

PGE = platinum-group element; * = REE

a Detailed statistics for scandium production are unavailable, as it's often a by-product of other operations. However, China has the largest facilities and was the leading exporter of scandium and yttrium per *Statista* in 2020.[135]

b Both China and Myanmar are the global leaders in yttrium production, but a clear production leader is unknown. China notably has an outsized financial influence over Myanmar, which affords it increased access and control over Myanmar's resources, and was the leading global exporter of scandium and yttrium in 2020 per *Statista*.[136]

Notes: Many IEA-listed critical minerals are REEs. Statistics aren't available for all REEs, although China is known as the largest REE producer (70%). Iridium, rhodium and ruthenium are PGEs. South Africa is the largest producer of PGE's, excluding palladium.

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Acronyms and abbreviations

CRC	cooperative research centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DISR	Department of Industry, Science and Resources
ESG	environmental, social and governance
EU	European Union
EV	electric vehicle
FIRB	Foreign Investment Review Board
IEA	International Energy Agency
IP	intellectual property
JOGMEC	Japan Oil, Gas and Metals National Corporation
LNG	liquefied natural gas
NAIF	Northern Australia Infrastructure Facility
OECD	Organisation for Economic Co-operation and Development
R&D	research and development
REE	rare-earth element
WTO	World Trade Organization

Developing Australia's critical minerals and rare earths

Implementing the outcomes from the 2023 Darwin Dialogue

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