BLACK SWAN

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SECURITY OF CRITICAL MINERAL SUPPLY CHAINS IN THE INDO-PACIFIC: A VIEW FROM INDONESIA AND AUSTRALIA

Authored by Professor Allan Trench and Dr. Nugroho Adi Sasongko

DEFENCE AND SECURITY THROUGH AN INDO-PACIFIC LENS

UWA DEFENCE & SECURITY

THE UNIVERSITY OF WESTERN AUSTRALIA

BRIN BADAN RISET DAN INOVASI NASIONAL

UNIVERSITAS PERTAHANAN REPUBLIK INDONESIA

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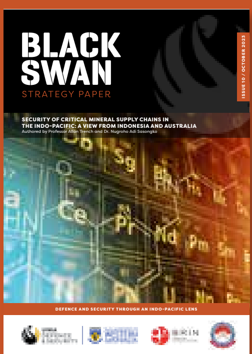


About the Black Swan Strategy Papers

The *Black Swan Strategy Papers* are the flagship publication of the UWA Defence and Security Institute (DSI). They represent the intersection between Western Australia and strategic studies – both of which are famous for their black swans. The series aims to provide high-quality analysis and strategic insights into the Indo-Pacific region through a defence and security lens, with the hope of reducing the number of 'black swan' events with which Australian strategy and Indo-Pacific security has to contend. Each of the Black Swan Strategy Papers are generally between 5,000 and 15,000 words and are written for a policy-oriented audience. The Black Swan Strategy Papers are commission works by the UWA DSI by invitation only.

This special edition of the Black Swan Strategy Paper is proudly in collaboration with Universitas Pertahanan Indonesia and The National Research and Innovation Agency (BRIN).

Executive summary

The Indo-Pacific region is set to play a more important role in providing the world with vital critical minerals. Future developments, notably in Indonesia and Australia, target the production of critical raw materials and an expanded footprint in downstream, value-added, mineral products as feedstock to new energy and advanced technological applications.

The critical minerals theme is well established, with long-run demand-side growth driven by cleaner energy and new technology applications, including defence technologies.

China has a strong position in critical minerals, notably in downstream processing. Supply chain diversification and security of supply are critical objectives for global manufacturers, who represent the principal consumers, especially in new renewable energy technologies, including batteries and, for example, electric vehicle production.

Strong resource endowment and mineral prospectivity in traditional mining jurisdictions such as Australia and Indonesia, coupled with the ongoing development of supportive government policies to encourage downstream value adding, look set to diversify supply chains globally. Complementary critical minerals legislation in the United States and Europe, which seeks clean supply chains in critical minerals from aligned free-trade partners, opens a pathway to new investment in mines and value-adding processing facilities.

Lithium, rare earths in Australia and nickel in Indonesia represent clear examples of the trajectory towards future critical minerals supply-side diversity. However, value adding can only be achieved where underlying global supply-side competitiveness exists in mineral endowment, capital availability, land access, energy costs, skilled labour, extraction technologies and environmental management. Demand-side support from manufacturers, in addition to governments, is required to avoid high-risk development strategies.

Policy recommendations

1. **A tiered approach to critical minerals assessment:** Some critical minerals have more economic potential and importance than others, which can be surfaced using a tiered approach to critical minerals list assessments. This approach will highlight those opportunities of most outstanding strategic value and those critical minerals where the market is thus far failing to solve for criticality, for example where certain critical minerals are produced as by-products. Each critical mineral market has vastly different microeconomics; for example, lithium versus cobalt. Further market-specific, in-depth value chain analysis is therefore required to formulate informed, prioritised and targeted policy and investment.
2. **Towards a time to shrink, not grow, the list of critical minerals:** Some critical minerals are now reaching a turning point, where supportive mineral policy, process technology development and favourable market dynamics have attracted significant investment towards sizeable new production. Lithium and nickel are thus among the first candidates for eventual removal from critical minerals lists globally. Even greater focus can be brought to finding market-based solutions for those minerals yet to 'breakout' and attract major new investments. Cobalt may be one such case, where opportunities exist in Indonesia and Australia as an example of potential future 'borderless', collaborative future investment feeding the battery supply chain.
3. **Critical minerals without borders:** Evolving minerals policies aimed at increasing the supply of critical minerals are principally targeted at the jurisdictional level, except for the Europe-wide approach adopted by the European Union. Cross-border opportunities abound, reflected in narratives that aim to encourage joint mineral developments 'without borders'. A shift towards assessing and encouraging cross-border developments, in parallel with in-country critical minerals developments, opens up greater possibilities for new critical minerals supply, notwithstanding the inevitable challenges of resource nationalism. Collaborative opportunities are enhanced where the comparative advantages of two or more jurisdictions can be leveraged within a mineral supply chain. A detailed assessment of the potential for greater collaboration between Indonesia and Australia in critical mineral supply chains is recommended with a view to creating greater value for both countries.

Introduction

Due to their rising economic importance in enabling technologies for the energy transition from fossil fuels to renewables and their ubiquitous use in electronic devices, critical minerals are one of the key frontiers of technological development.

Critical minerals, as a term, was first introduced by the US National Research Council to refer to a group of minerals, metals and non-metals considered essential for economic and technological development.[1] These minerals are crucial for producing a wide range of high-technology products, including electric vehicles, renewable energy systems, aerospace applications, defence applications and smartphones, and as key constituents to optimise performance within many other electronic applications. Critical minerals comprise only a small percentage of a material or consumer end-product by weight but are essential to its efficiency and performance.[2]

The term 'critical minerals' describes minerals important to a country's overall economy, or to key economic sectors, but vulnerable to supply disruptions, whether due to absolute global and/or local supply chain challenges, geopolitical issues, trade policy or other factors. As such, critical mineral lists differ by jurisdiction, often significantly.[3]

Critical minerals may be in limited supply and may come from a small number of countries and operating assets, making them vulnerable to geopolitical risks and trade disruptions. They are also challenging to substitute or recycle, making them even more strategic and valuable.

Some examples of critical minerals include lithium, cobalt, rare earth elements and platinum-group metals. However, the full spectrum of potential critical minerals across the emerging minor metals markets exceeds 40 in number.[4,5.]

As demand for high technology and clean energy production systems continues to grow, the importance of critical minerals will increase.

Governments and industries worldwide are paying increasing attention to the development and secure supply of critical minerals, including mineral policy interventions and direct investment.

Why critical minerals are so exciting – and so difficult

Critical minerals offer an exciting economic opportunity. They are essential to various emerging scientific applications, new technologies and industries, including renewable energy, electric vehicles, telecommunications, aerospace and defence. Wilson synthesises new demand growth as arising from:

- renewable energy, including batteries, electric motors and generators
- scientific applications, such as optics, medical and nuclear technologies
- digital technologies, including consumer and industrial electronics
- industrial applications, particularly specialty alloys and composites
- defence equipment, such as guidance systems, electronic warfare and space technologies.[6]

Demand-side excitement about the future growth potential for critical minerals has led to heightened interest in exploration for these minerals, mining and processing. Explorers often focus on the mineral potential for these minerals within established mining districts and jurisdictions. Exploration for critical minerals is therefore referred to as opening 'new search spaces' within what were previously considered mature exploration areas where it was thought most mineral deposits had been discovered.[7,8]

Excitement about the future growth of critical minerals demand has also led to an increased focus on thrifting and substitution strategies that aim to result in lessening the future overall requirements for critical minerals and allowing a partial switch to more abundant materials where feasible.[9]

Recycling technologies for critical minerals are also an active area of research and development.[10] However, as many critical minerals represent 'new' mineral markets, the stock of above-ground metals available for recycling cannot fulfil future demand needs.[11] Recycling tends to be product-focused, for example, on rare earth magnets and solar panels.

Recycling critical minerals takes two high-level forms, both referred to as scrap. First, the secondary recovery of the constituent minerals, typically as metals, from end-use products, known as 'old scrap'. Second, minimising and re-using waste products within the primary production process, known as 'new scrap'.

Recycling rates are generally meagre for critical minerals[12], given the newness of many applications. However, the level of re-use varies for each critical mineral and each end product.

Therein lies the opportunity for new major investments in critical minerals supply.

Specifically, within the Indo-Pacific region, mining jurisdictions such as Australia and Indonesia now have the clear potential to augment already established world-leading mineral commodity asset portfolios. Notably, the future opportunity lies in mining and value-added critical mineral products that provide feedstock to manufacturing, including, for example, along the batteries value chain and in renewable power technologies.[13]

As much as critical minerals present a compelling and exciting opportunity for new investment, they also pose many difficulties beyond that of mining bulk commodities, precious metals and base metals.

Critical minerals are challenging to process for many reasons. After the initial mineral deposit discovery step in the mining value chain, which remains a challenge, there is the ubiquitous issue of high-value minerals in that they often exist only in small concentrations within rocks. Furthermore, critical minerals are often closely associated with many other minerals of similar chemical and physical properties, making mineralogical separation both technically difficult and costly. Simple processing routes for critical minerals are unlikely to emerge given their close physicochemical properties, however improvements in processing efficacy will be realised over time as industry experience continues to develop.[14]

Next, the ores of critical minerals, for example, rare earth metals, can be very heterogenous between deposits. Consequently, the lessons learned from achieving physical and chemical mineral separation at one deposit may not be readily transferable to other deposits.[15] Mineral processing strategies for critical minerals can therefore be asset specific, adding to the difficulty and cost of 'cracking the code' for scalable extraction.

Further, the processing technologies to cost-effectively produce critical minerals are, in many cases, new and undergoing development and improvement through metallurgical research, such that industry knowledge about their implementation is still emergent.[16] The added technical risk from such unfamiliarity can lead to delays in completing economic feasibility studies, design engineering and financing. Supply chains can be opaque and complex, with intermediate products differing between assets, such that vertical integration to build dedicated downstream processing facilities is often required.

Critical minerals can be discovered in challenging remote locations, where the provision of both a reliable energy supply and cost-efficient inbound and outbound logistics, such as for chemical reagents for processing, and the cost-effective shipping of ex-mine bulk materials, can be problematic.[17]

As for all resource projects, many locations also have significant environmental and social impacts that must be managed to meet and exceed stakeholders' expectations.[18] Social issues are heightened where there is unfamiliarity with the processing of 'new' ores, and waste products from mining and processing must be safely managed. Research indicates that many major projects, even in mainstream commodity markets such as copper, face socio-economic challenges that require bespoke solutions for development.[19] A similar set of socio-economic challenges is ever present for critical minerals projects, from adequate water supply to competing land use, waste storage and engaging and achieving local communities' support.

Overcoming the numerous challenges requires a dedicated effort within each jurisdiction and a collaborative effort across the Indo-Pacific region, facilitated by supportive cross-border minerals policies and investment capable of catalysing new mine supply, minerals processing and manufacturing infrastructure.

CHAPTER 1
On the critical list: A global initiative

The rise and rise of critical minerals globally

As noted, the US National Research Council first introduced the term 'critical minerals'. The European Commission (EC) issued a similar report to the US in 2010 (regularly updated after that) on *Critical raw materials for the EU*, in which raw materials fundamental to Europe's economy, growth and jobs were outlined.

The breadth of materials considered critical has risen over time, despite efforts made to date to address the criticalities.[20] The first 2010 EC assessment identified 14 critical raw materials out of the 41 nonenergy, non-agricultural candidate raw

Figure 1: Total mineral demand for clean energy technologies by scenario, 2020 compared to 2040 (Source: IEA, 2021)[25]

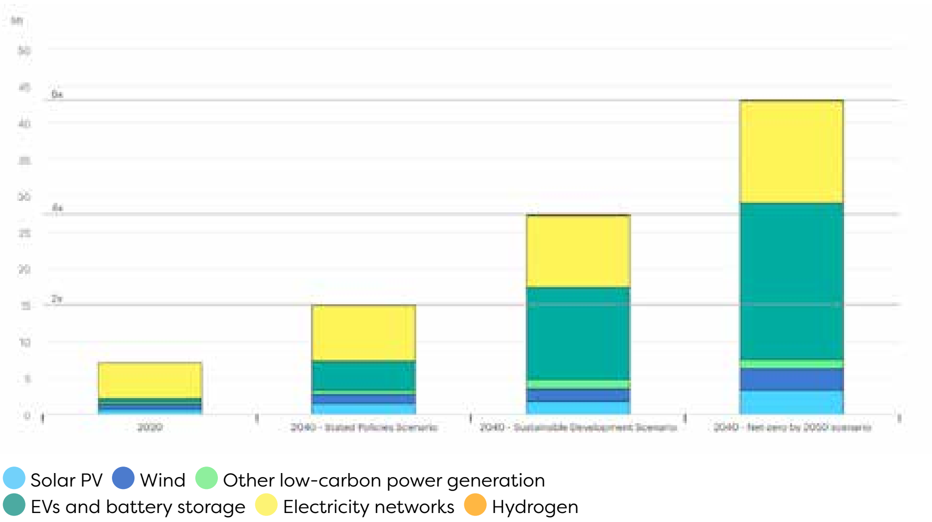
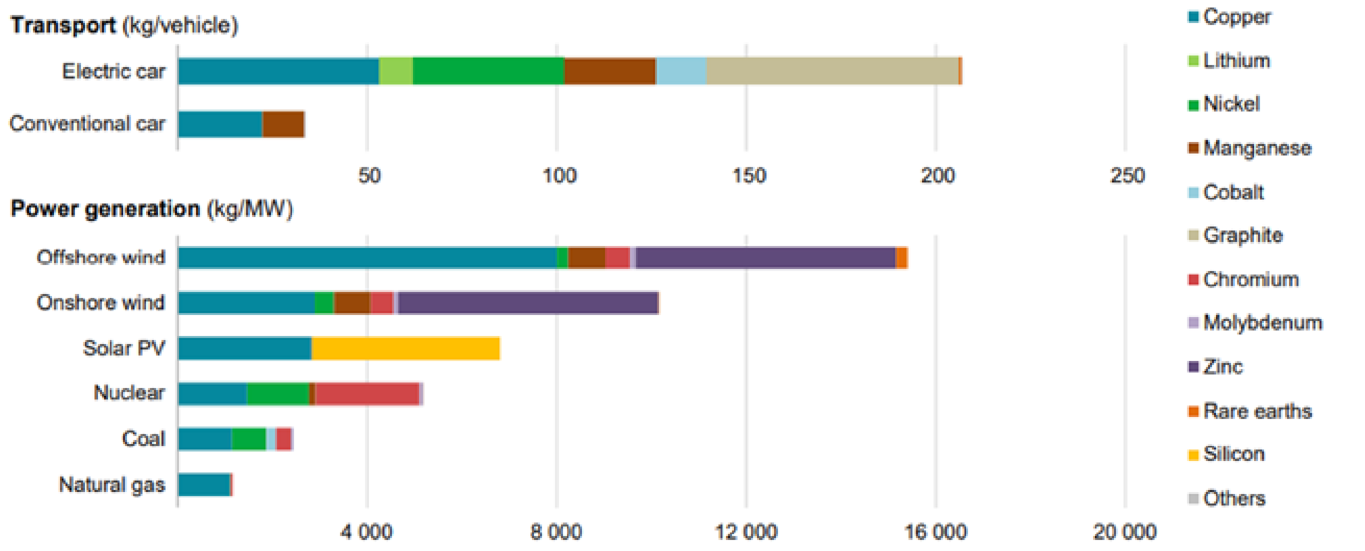


Figure 2: The rapid deployment of clean energy technologies as part of energy transitions implies a significant increase in demand for minerals (IEA, 2022)[25]



materials.[21] In the 2014 EC exercise [22], 20 raw materials were identified as critical out of 54 candidates. In 2017 the EC identified 27 critical raw materials among 78 candidates.[23] In 2020, the EC assessment covered 83 individual materials or 66 candidate raw materials. From this enlarged list, the EC report identified 30 as critical materials.[24]

One of the main drivers of the demand for critical minerals is the growing production of electric vehicles (EVs). EVs use large amounts of critical minerals such as lithium, cobalt, and rare earth elements, essential for producing batteries and electric motors. As the production and sales of EVs grows, the demand for these minerals will increase exponentially. Another driver of demand is the growth of renewable energy technologies, such as wind and solar power. These technologies require large amounts of critical minerals such as copper, nickel, and rare earth elements, which are used in producing wind turbines, solar panels, and other components.

The rise of critical minerals has led to growing concerns about supply chain risks, including geopolitical tensions, environmental impacts, and social issues such as child labour and human rights abuses. Many governments and companies promote responsible and sustainable sourcing practices for critical minerals, including developing certification schemes and due diligence frameworks.

Overall, the rise of critical minerals represents both an opportunity and a challenge for the global economy. While these minerals are essential for developing many high-tech industries, their production and supply chains pose significant risks that must be managed carefully to ensure a sustainable and equitable transition towards a more prosperous and low-carbon future.

Strong demand-driven outlook of critical minerals

The clean energy transition contributes to a significant increase in demand for critical minerals. The global demand for critical minerals is about to is about to increase significantly, as shown in Figure 1. The vertical axis is used to depict the quantity of future mineral demand that will result from different, policy-led, green energy scenarios. According to The International Energy Agency (IEA), in response to the Paris Agreement, mineral demand will increase by two to four times in 2040 compared to 2020. A faster green energy transition would require up to sixfold growth under a net zero emission scenario by 2050.

Both electric vehicles and clean energy power generation infrastructure require a more significant component of critical minerals in construction per vehicle and in energy output than traditional technologies, typically of a fivefold to tenfold increase.[25]

In addition to their importance in technology industries, critical minerals are essential for national security and defence. For example, rare earth elements are used in various military applications, including missile guidance systems, night vision goggles and other advanced technologies.

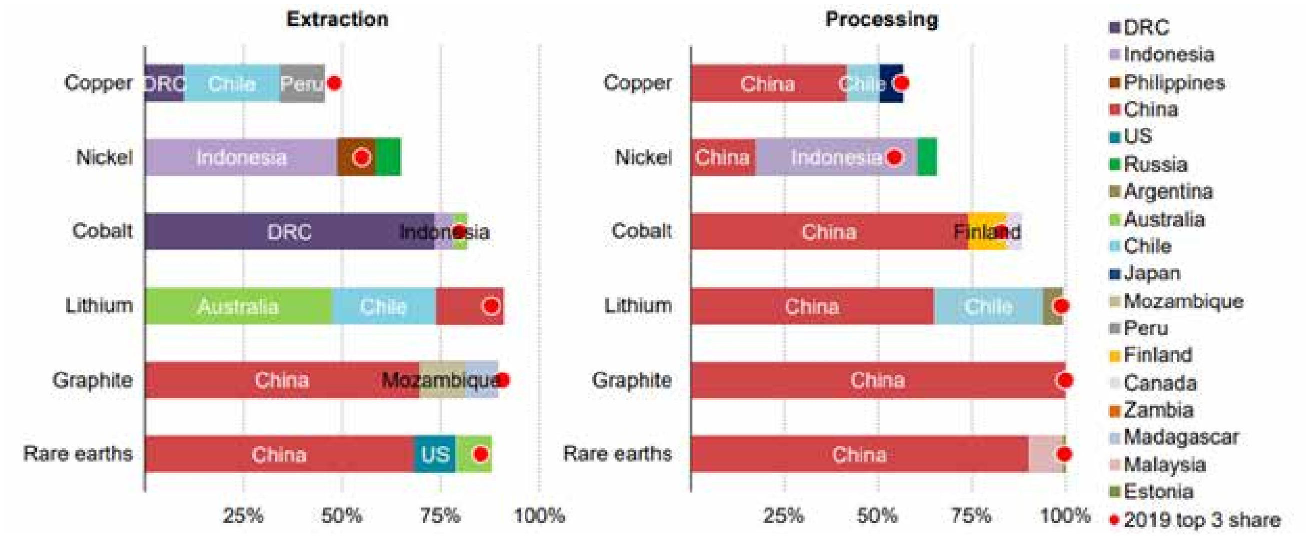
Given their importance, there has been growing concern about the availability and security of critical minerals. Many countries are now actively seeking to secure their supplies of these minerals through domestic production, strategic partnerships and other means including recycling.

The outlook for critical minerals is strong, driven by the ongoing growth of technological uses, renewable energy, and defence. However, their availability and production remain a concern, and continued efforts will be needed to ensure a secure and sustainable supply.

China is leading in the downstream supply of critical minerals

The geological endowment of critical minerals is global. Compared to oil and gas deposits, for example, where the giant hydrocarbon accumulations are located in only a relatively small number of countries, the geographic spread of critical minerals endowment, including the many minor metallic elements, is distributed.

Figure 3: Share of top-three production of minerals and fossil fuels[25]



Source: IEA analysis based on S&P Global, USGS Mineral Commodity Summaries and Wood Mackenzie.

However, the distribution of global critical mineral endowment and global critical minerals extraction are materially different. The extraction of specific critical minerals is typically concentrated in just a few countries.

For example, in cobalt and lithium, the relative shares of minerals extraction are strikingly concentrated. In 2021, over 70% of cobalt mine production originated from the Democratic Republic of the Congo (DRC), with the Russian Federation (5.0%) and Australia (4.2%) as the next largest producers (BP, 2022).[26] In lithium, the relative mine production shares are similarly highly concentrated. The top three lithium mine producers in 2021 were Australia (52%), Chile (24.5%) and China (13.2%) .[26]

Further, the subsequent downstream processing of critical minerals is again located in only a few countries[25], with China to the fore.

China is the world's leading producer and supplier of many critical minerals, including rare earth elements, lithium and graphite. The country's dominance in critical minerals is partly due to its installed capacity in processing, ability to source critical minerals feedstock and low production costs.[27]

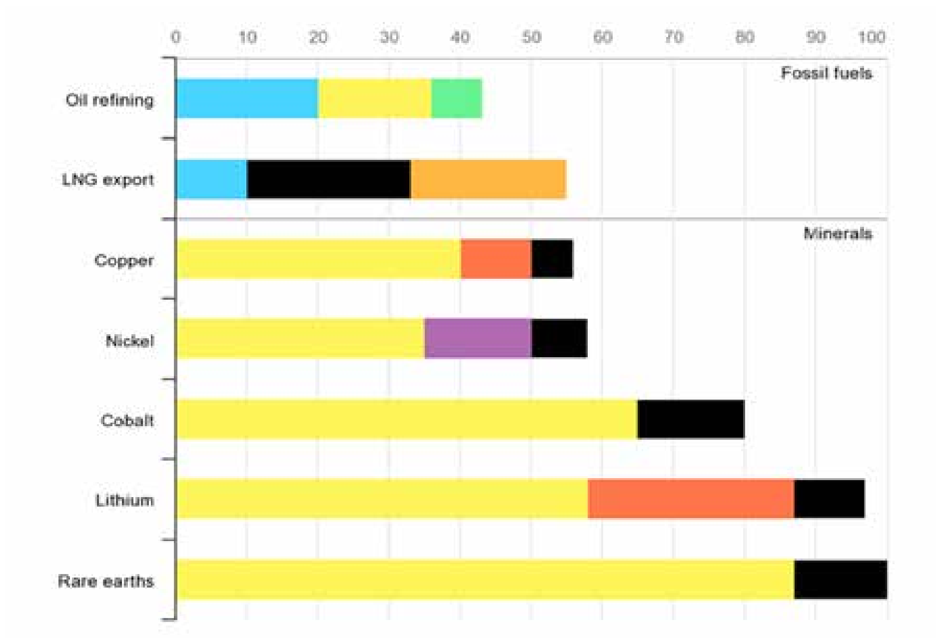
China's control over the critical minerals supply chain has raised concerns, particularly in the United States, about the potential for supply disruptions and geopolitical risks. In response, many countries are seeking to diversify their critical minerals supply chains and reduce dependence on China.

To address these concerns, many countries are exploring new sources of critical minerals, including new mineral exploration, but also deep-sea mining, urban mining and recycling. These efforts aim to reduce reliance on China.

However, it should be noted that China's dominance in the critical minerals sector is not absolute. Other countries such as Australia, Canada, and the United States have reserves of critical minerals and are increasing production to meet global demand. Additionally, some countries are forming strategic partnerships and alliances to secure critical minerals supply and reduce geopolitical risks.

In the era of sophisticated electronic devices, the utilisation of elements belonging to critical minerals is vital for industry. As shown in Figure 5, China is currently supplying more than 80% of the world's need for cobalt; 60% of the world's need for lithium, copper, nickel; and more than 90% of rare earth metals.[25]

Figure 4: China leading in critical minerals supply (Source: IEA, 2021)[25]



China did not suddenly become the world's top producer of critical minerals, especially rare earth elements. From a supply dynamic perspective, China has only become a significant producer of critical minerals in the last 20 years. Until the late 1990s, the United States was a significant producer of critical minerals, particularly rare earths, mainly from California's Mountain Pass mining area. China's strength in downstream critical minerals processing is supported by a cost competitive labour market, by experience effects in using processing technologies, and a skilled workforce in the extraction, separation and purification of rare earths. Mineral processing costs in China are therefore typically lower than what other countries can achieve.[28] China also has a history of less stringent environmental standards. [29]

Rich global endowment and emerging project pipelines of critical minerals

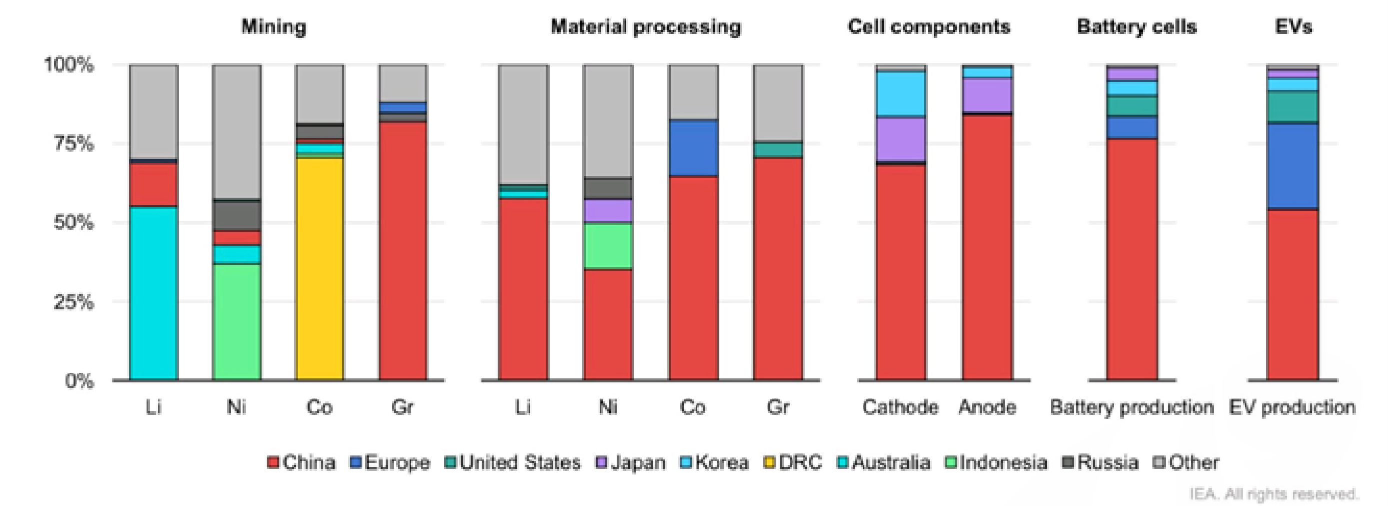
There is a rich global endowment of critical minerals, with many countries possessing significant resources. In addition to China, other countries with large endowment of critical minerals include Australia, Canada, the United States, Brazil and Russia.

These countries are also seeing an emergence of new critical minerals project pipelines as companies invest in exploration and development. For example, Australia is developing several new lithium and rare earth projects, while Canada is exploring new sources of lithium, cobalt, and graphite. The United States is also increasing its production of critical minerals, with projects underway to develop new sources of lithium, rare earth elements and other minerals.

Many of these projects are being developed to reduce resource dependence on China and secure a more sustainable supply of critical minerals. Additionally, some countries are forming partnerships and alliances to pool their resources and expertise in critical minerals development to create a more diversified global supply chain.

Australia and Indonesia are undoubtedly blessed in terms of their mineral endowment. For a large portion of the critical minerals identified, Australia is ranked among the top countries for lithium reserves and Indonesia for nickel reserves. For both these countries, there is more to come, for example with widespread, new, clay-hosted rare earth mineralisation being discovered in Australia [30] and multiple new lithium discoveries in Western Australia.[31]

Figure 5: Geographical distributions of the global EV battery supply chain (IEA, 2021)[25]



CHAPTER 2
Indonesia and Australia advancing along the critical minerals supply chain

Indonesia and Australia have a strong track record of mineral production. New opportunities in critical minerals are being advanced apace. Nickel in Indonesia and lithium in Australia are two rapidly evolving critical minerals success stories.

Indonesia is a leading producer of nickel, a key component in lithium-ion batteries used in electric vehicles. The country has ambitious plans to develop its nickel reserves and become a major supplier of battery-grade nickel to the global market, with significant production ramp-up underway. It is also developing its capacity to produce other critical minerals, including rare earth elements and cobalt.

Australia has grown lithium production rapidly, most notably in Western Australia, with the Northern Territory also being a significant development opportunity. Australia now leads the world in mining lithium, with new investments directed to mining and downstream value adding.[32]

Australia is also investing in research and development to support the growth of the critical minerals sector. For example, the country's Critical Minerals Facilitation Office is working to streamline regulation and facilitate investment in critical minerals projects. Australia is also exploring opportunities for collaboration with other countries, such as the United States, to promote the development of a more diversified and secure global supply chain for critical minerals.

Overall, the efforts of Indonesia and Australia to advance along the critical minerals supply chain reflect the growing recognition of the importance of these resources in the global economy.

Snapshot of Indonesia's current mineral exports and critical mineral supply chains

Indonesia is a significant player in the global minerals market and has a diverse range of mineral resources, including both traditional minerals such as coal, copper and gold, as well as critical minerals such as nickel, tin, cobalt and rare earth elements.

Nickel is one of Indonesia's most important minerals, accounting for around 15% of the country's total mineral exports. Indonesia is a major supplier of nickel to China, the world's largest metal consumer. Indonesia's nickel resources are also becoming increasingly important in producing battery-grade nickel used to manufacture electric vehicle batteries.

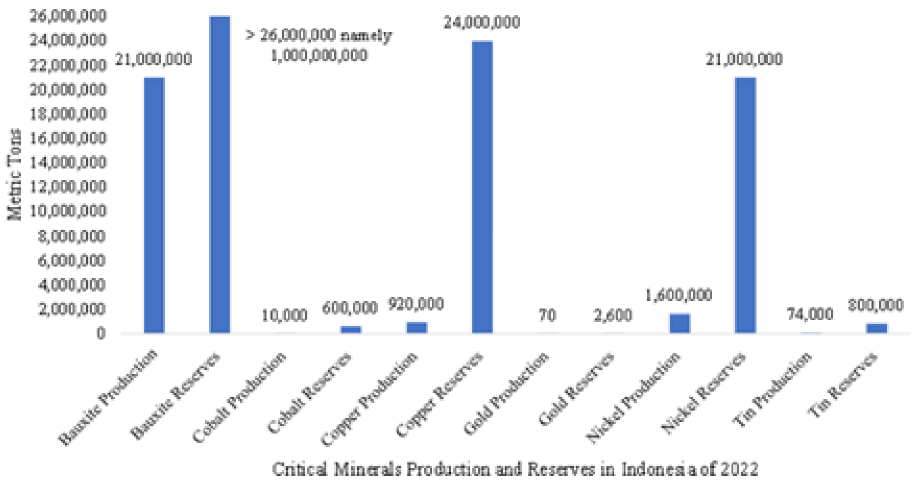
In addition to nickel, Indonesia is a major tin producer, accounting for around 30% of global production. Tin is a critical mineral used in the manufacture of electronics, and Indonesia's production is an important part of the global supply chain.

Indonesia also hosts significant occurrences of rare earth elements.[33] The country's rare earths endowment requires development. However, Indonesia has announced plans to increase its production and become a major supplier of these minerals to the global market.

Indonesia's mineral exports and critical mineral supply chains reflect its importance in the global minerals market and its potential to become a major supplier of critical minerals to support the growth of high-tech industries and renewable energy. However, like other countries, Indonesia also faces challenges in ensuring the responsible and sustainable development of its mineral resources, particularly regarding environmental and social impacts.

Indonesia is a country with abundant mineral wealth, making it one of the countries that play an important role in the supply of raw mineral commodities in the world. The results of mineral production are used to meet domestic and export needs. Factors that can affect sales of minerals are the amount of supply and demand both domestically and abroad, the level of mineral production, and the volatility of mineral commodity prices. Figure 6 and Table 1 shows the development of mineral export volume in Indonesia.

Figure 6 : Critical minerals production and reserves in Indonesia in 2022 [34]



Source: US Geological Survey, 2023

Table 1: Indonesian mineral exports

	Export quantity (in thousand tonnes)				
Minerals	**2016**	**2017**	**2018**	**2019**	**2020**
Bauxite ore	-	1,820	8,710	16,110	22,760
Nickel					
Nickel ore	-	4,940	20,070	30,190	-
Nickel matte	78.970	76.740	75.710	71.340	72.850
Ferro nickel (FeNi)	89.430	243.420	573.160	1,080.660	1,240.770
Nickel pig iron (NPI)	770.680	192.560	323.990	167.010	267.610
Copper cathode	146.220	173.270	148.080	176.320	197.530
Tin metal	62.880	78.070	83.020	67.060	65.040
Gold metal	0.074	0.071	0.074	0.065	0.045
Silver metal	0.290	0.241	0.206	0.226	0.265

Source: EITI (2021)

Resources and reserves

Indonesia is one of the countries that plays an important role in the global supply of mineral raw materials. Indonesia has significant resources and reserves of several critical minerals, including nickel, tin, and rare earth elements. Further exploration activities still need to be carried out so that currently estimated resources can increase to the status of mineral reserves.

Nickel: Indonesia is home to some of the world's largest nickel deposits, with estimated reserves of around 21 million metric tons in 2022.[34] The country's nickel endowments are concentrated in Sulawesi, where large deposits of nickel laterite ore are found. Nickel is a critical component in the manufacture of stainless steel, and its use in battery technology has been rapidly increasing due to the growth of the electric vehicle market.

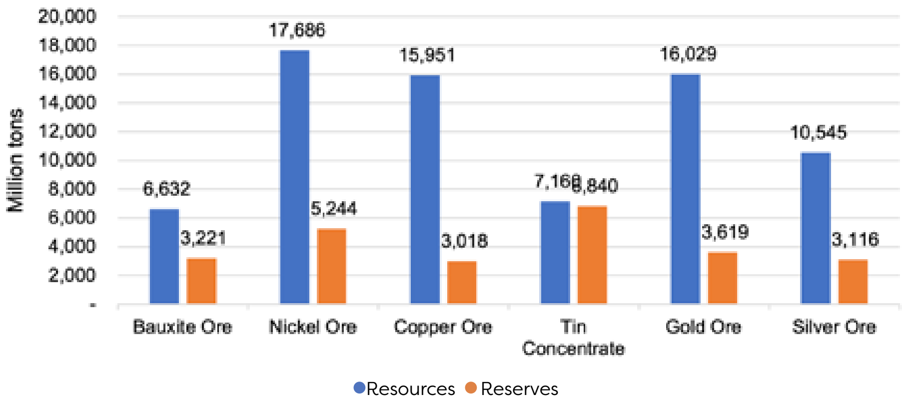
Tin: Indonesia is the world's largest exporter of tin, accounting for around 30% of global production. The country's tin resources are primarily in Bangka Belitung Islands and offshore deposits. Tin is a critical mineral in various industries, including electronics, automotive, and packaging.

Rare earth elements: Indonesia has significant potential for developing rare earth elements, with estimated reserves of around 2.8 million metric tons. The country's rare earth elements resources are primarily found in the Bangka Belitung Islands and other parts of the country. Rare earth elements are essential in various high-tech products, including renewable energy technologies and advanced electronics.

Other critical minerals found in Indonesia include bauxite, cobalt, copper, gold, manganese, silver, titanium and zircon. Indonesia's significant resources and reserves of critical minerals make it a potential key player in the global market, particularly as demand for them continues to grow in response to the increasing adoption of high-tech products and renewable energy technologies. The following are data on mineral resources and reserves in Indonesia in 2021.

↑ The management of the Indonesia Weda Bay Industrial Area is completing additional coal-fired power generation facilities with a capacity of 3 x 250 MW to support industrial activities there (Picture Taken on September 2023 by Dr Nugroho Adi Sasongko).

Figure 7: Indonesia's mineral resources and reserves in 2021 (USGS, 2023).[34]



Snapshot of Australia's current mineral exports and critical mineral supply chains

Australia is a major player in the global minerals market. In addition to traditional minerals such as coal, iron ore, and gold, Australia is also a significant producer of several critical minerals.

Lithium

Australia is the world's largest producer of lithium, a key component in manufacturing batteries used in electric vehicles and energy storage systems. The country's lithium deposits are primarily found in Western Australia, and Australian companies, in partnership with international lithium companies, are major suppliers of lithium to the global market.

The following key resource assets underpin the ongoing lithium expansion in Australia.

Pilgangoora – New spodumene-bearing pegmatite discoveries at Pilgangoora in the Pilbara Craton have led to new mining activity and processing facilities to produce a spodumene concentrate product for export. The Pilgangoora pegmatites were explored for lithium historically in the 1960s and for tantalum from 2007 to 2012. The Pilgangoora ore reserve as of 30 June 2022, including stockpiled material, was 159 million tonnes at 1.2% Li_2O, 101 ppm Ta_2O_5 and 1.0% Fe_2O_3. Downstream processing facilities for concentrate are being built in South Korea in a joint venture with POSCO, with the first 21,500 tonnes per annum train (of a 43 kilotonnes per annum lithium hydroxide monohydrate chemical facility scheduled to commence commissioning in late 2023) and the second 21,500 tonnes per annum train in 2024.

Mount Marion – Mount Marion is a mine and concentrator south of Kalgoorlie, Western Australia, managed by Mineral Resources Limited and Ganfeng, according to a 50/50 joint venture. The joint venture partners plan to expand production to 900 kilotonnes per annum spodumene concentrate.

Mount Holland – The Earl Grey deposit at Mount Holland has a resource of 189 million tonnes @ 1.50% Li_2O. The project is a joint venture called Covalent Lithium, held 50/50 between Wesfarmers Chemicals Energy & Fertilizers (WESCEF) and SQM. Construction of the spodumene concentrator was 70% complete as of the end of 2022, with the plant to produce feedstock for the Kwinana lithium hydroxide refinery.

Wodgina – Mineral Resources Limited and Albemarle have formed a joint venture to mine lithium in the Pilbara from Wodgina, but also to value-add to the spodumene concentrate through a lithium hydroxide plant of 50 kilotonnes per annum capacity located at Kemerton in the SW of Western Australia.

Kathleen Valley – Liontown Resources are advancing the project towards production. Unlike other lithium developments, mining will predominately be underground. A resource of 156 million tonnes @ 1.4% Li_2O is estimated. The Kathleen Valley asset has attracted the interest of lithium major Albermarle, who have lodged a takeover bid for Liontown Resources in 2023.

Finniss – Core Lithium is advancing the Finniss lithium project in the Northern Territory, favourably located near Darwin. Production of spodumene concentrate commenced in 2023. The BP33 deposit at Finniss has a resource estimated at 10.1 million tonnes @ 1.48% Li_2O. Feasibility work on the future downstream processing of Finniss production into lithium hydroxide in the Northern Territory is underway.

Rare earth elements

Australia is also a significant producer of rare earth elements, which are used in a range of high-tech products, including electronics, renewable energy technologies, and defence applications.[35] The country's rare earth elements resources are primarily found in Western Australia and the Northern Territory.

Significant new investment is taking place in Australia to develop not only new rare earth mining operations but also downstream processing facilities. Rare earths look well placed to follow the trajectory of lithium in Australia, with multiple production centres to be established. The long-term outlook also appears favourable, as new rare earth discoveries are being made in Australia hosted in clays, the geological source of significant rare earth production from China.

Australia has a range of rare earth deposits that could underpin a significant expansion of production beyond current levels. The enhanced level of current activity in advancing new projects merits summarising them below.

Mount Weld – Rare earth element (REE) mineralisation has long been known in Western Australia, notably at the giant, high-grade Mount Weld carbonatite deposit in the Laverton region of the Yilgarn Craton. The Mount Weld carbonatite was discovered in 1966 by a government airborne magnetic survey. Mount Weld has a long history of geoscientific and techno-economic study, ultimately resulting in the production of REEs following development by Lynas Rare Earths Limited and the opening of the official mine in 2011. Lynas is the only scale producer of separated rare earth outside of China. REE concentrate is produced at Mt Weld for processing in Malaysia. A Kalgoorlie rare earths processing facility in Western Australia is under construction to augment the Malaysian processing plant, strengthening the local supply chain. The material produced in Kalgoorlie will be further processed at the Lynas Malaysia advanced materials plant in Gebeng, Malaysia, or the proposed rare earth separation facility in the United States.

Eneabba – Eneabba is a Western Australian example of the sedimentary placer-type deposits of REE minerals that are well known in Australia and globally significant, occurring within heavy mineral sands mined for zircon, ilmenite and rutile. The REEs occur in minerals such as monazite and xenotime. In 2022, Iluka announced its final investment decision for Eneabba Phase 3, a fully integrated refinery for producing separated rare earth oxides. The investment decision was taken following the agreement of a risk-sharing arrangement with the Australian Government, including a $1.25 billion non-recourse loan under the $2 billion Critical Minerals Facility administered by Export Finance Australia. The first refinery production is expected in 2025.

Browns Range – Northern Minerals Limited has been advancing the Browns Range project for over a decade. The project is notable for its heavy rare earth content and is particularly enriched in dysprosium. The REE mineralisation is associated with the Browns Range Dome in the Northern Tanami region within Western Australia and the Northern Territory. In 2022, Northern Minerals announced a strategic partnership with Iluka Resources, with Iluka making an initial investment of $20 million in Northern Minerals via a $15 million convertible note and $5 million share placements to provide the funding required to complete a definitive feasibility study. Under the partnership, REE concentrate produced from Brown's Range will provide feedstock for Iluka's Eneabba rare earth refinery in Western Australia.

Dubbo – Australian Strategic Minerals seek to develop the Dubbo project in New South Wales to produce a polymetallic suite of mineral products comprising rare earth, zirconium, hafnium and niobium over an initial 20-year mine life. The proposed on-site mineral processing route at Dubbo has been developed with the Australian Nuclear Science and Technology Organisation (ANSTO). Downstream processing is planned at a plant in Ochang Foreign Investment Zone in South Korea.

Clay-hosted rare earths – The discovery of widespread near-surface, regolith-hosted rare earth element mineralisation in the Esperance region of Western Australia and near the South Australia-Victoria state border presents an opportunity for the future development of a significant new sector. The recently discovered deposits have similarities and contrasts with geological features of ionic clay-hosted REE deposits in China, which are an established source of heavy rare earth element production, including dysprosium.

Active research is taking place to delineate those newly discovered deposits containing predominantly heavy rare earth in clays and to optimise the recovery and processing of clay-hosted rare earth.

Both rare earths and lithium appear on Australia's latest critical minerals list. Nickel does not appear on Australia's list of critical minerals where long-term production already exists, notably at BHP's Nickel West sulphide processing infrastructure in Western Australia, which commenced operations in the 1960s. In contrast, Australia's significant nickel laterite endowment, which also contains untapped cobalt resources as a co-product, has only seen one successful mine development at Murrin Murrin, owned by Glencore, also in Western Australia. Therefore, Australia has an opportunity to learn from Indonesia and the rise in nickel production from laterite deposits to become the leading global nickel producer.

Other critical minerals found in Australia include cobalt, nickel, tantalum, vanadium and titanium, with each having future potential to grow their contribution to the country's mineral exports.

CHAPTER 3
Mineral policy strategies: A growing global influence

Minerals policy regarding critical minerals is evolving rapidly. In 2022, for example, the United States passed the *Inflation Reduction Act* that specifically targets support for domestic critical mineral developments as part of a broader domestic clean energy strategy and global strategic sourcing initiative. The United States (US) and the European Union (EU) have recently developed updated policies focused on critical minerals. These policies aim to ensure the secure and sustainable supply of critical minerals, reduce dependence on a single supplier or region, and promote the adoption of responsible and sustainable mining practices.

The 2022 US *Inflation Reduction Act* was passed by the 117th United States Congress and signed into law by President Biden on August 16, 2022. The Act sets an agenda for reducing carbon emissions, lowering healthcare costs, funding the Internal Revenue Service, and improving taxpayer compliance. From a critical mineral's standpoint, the Act aims to encourage new investment in domestic manufacturing capacity and steer the procurement of critical supplies domestically and from free-trade partners. The policy focuses on federal funding for climate efforts, energy infrastructure, incentives for private investment and consumer incentives. Some USD$43 billion in IRA tax credits aim to lower emissions by making EVs, energy-efficient appliances, rooftop solar panels, geothermal heating and home batteries more affordable.

Many IRA tax incentives also contain scaling domestic production or domestic-procurement requirements. For example, to unlock the full EV consumer credit, a scaling percentage of critical minerals in the battery must have been recycled in North America or extracted or processed in a country with a free-trade agreement with the United States. The battery must have also been manufactured or assembled in North America.

Similarly, the European Union recently issued a major update to its critical minerals policy in the form of the *Critical Raw Materials Act*. Targeted minerals include nickel, specifically battery-grade products, lithium, cobalt and rare earth, among others.

On March 16, 2023, the European Union announced the *Critical Raw Materials Act*, intending to ensure the EU's access to a secure, diversified, affordable and sustainable supply of critical raw materials considered indispensable for a wide set of strategic sectors, including the net zero industry, the digital industry, and the aerospace and defence sectors. The Act sets out an agenda of clear priorities for action, creating secure and resilient EU critical raw materials supply chains; ensuring that the EU can mitigate supply risks; investing in research, innovation, and skills; protecting the environment through circularity and sustainability of critical raw materials; and leveraging international engagement to diversify the EU's imports of critical raw materials. The EU consider the following raw materials strategic: bismuth, boron (metallurgy grade), cobalt, copper, gallium, germanium, lithium (battery grade), magnesium metal, manganese (battery grade), natural graphite (battery grade), nickel (battery grade), platinum-group metals, rare earth elements for magnets (Nd, Pr, Tb, Dy, Gd, Sm and Ce), silicon metal, titanium metal and tungsten.

The US and EU policies emphasise the importance of responsible and sustainable mining practices and a focus on domestic sourcing where achievable. The US government has committed to supporting the adoption of best practices by the mining industry, including measures to reduce environmental impacts, ensure worker safety, and promote community engagement. The EU has developed a sustainable mining initiative focused on improving the environmental, social, and economic performance of the mining sector in Europe.

In summary, both the US and EU have developed policies focused on critical minerals that aim to ensure the secure and sustainable supply of these minerals, reduce dependence on imports, and promote the adoption of responsible and sustainable mining practices. These policies are expected to significantly influence the global supply chain for critical minerals in the coming years.

These recently updated critical minerals policy initiatives complement each other and collectively seek to bring forward investment in critical minerals supply chains, including, for example, across the 'Quad governments' of Australia, Japan, India and the US.[36.]

Indonesia's policy on critical minerals

Indonesia's nickel industry is an example of the impact of a supportive mineral policy targeting domestic downstream processing of critical minerals. The Indonesian Government is concerned that the economic returns from resource development should be returned to Indonesia. Indonesia is also working to improve the regulatory framework for the mining industry to ensure sustainable and responsible mining practices. The government has introduced a mandatory local content requirement (Tingkat Komponen Dalam Negeri / TKDN) for mining companies and has implemented stricter environmental standards through environmental impact assessment (Analisis Mengenai Dampak Lingkungan / AMDAL) as stated in recent Government Regulation (PP) Number 22 of 2021 about Implementation of Environmental Protection and Management.[37]

In accordance with Law (UU) Number 3 of 2020, Amendments to Law Number 4 of 2009 concerning Mineral and Coal Mining 38, article 106 states that Mining Business Permit (IUP) and Special Mining Business License (IUPK) holders are obliged to prioritize the use of local labor, goods and services within the country in accordance with the provisions of statutory regulations. That is, companies operating within the mining sector are to implement optimal levels of domestic components.

Indonesia's policy on critical minerals aims to add value to its mineral resources, create jobs and promote sustainable and responsible mining practices.

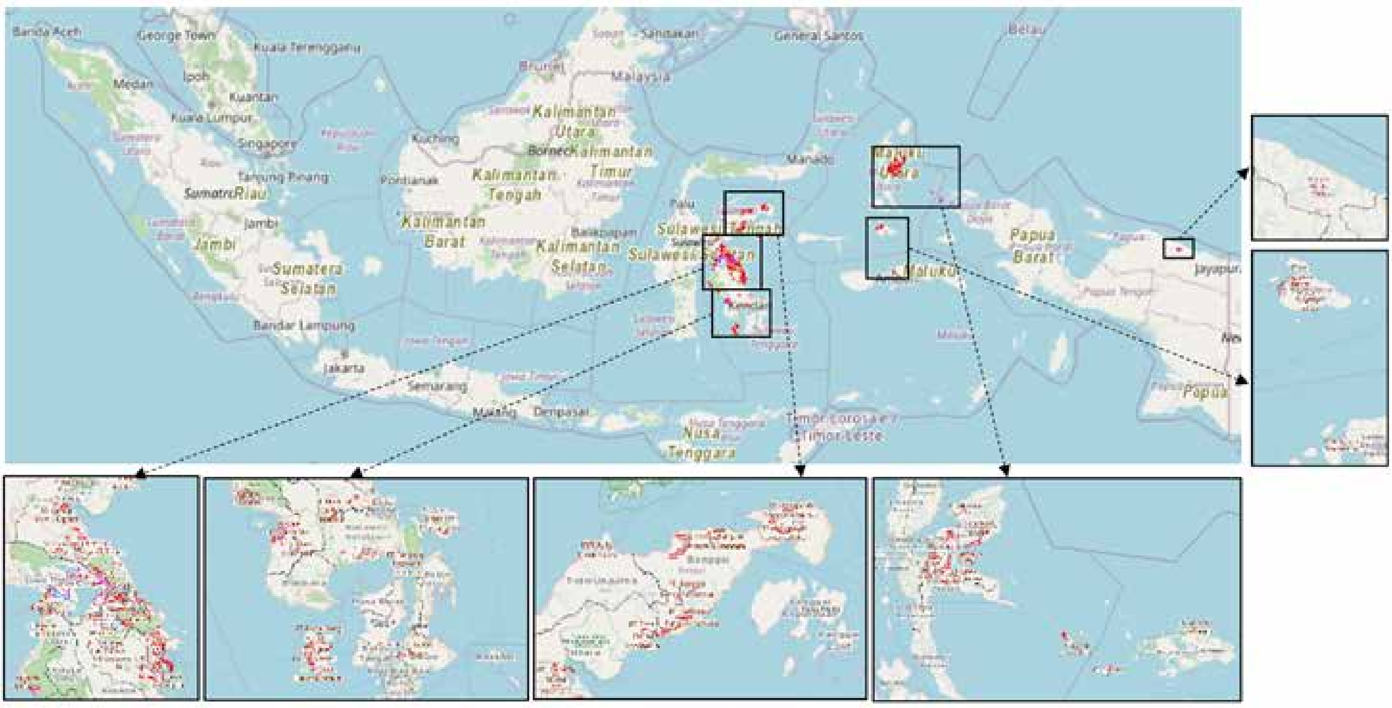
A series of policy adjustments have resulted in significant new downstream investment and therefore a move beyond upstream mining towards downstream value adding and metal production. Indonesia's policy, based on Indonesian mining law (2009), requires that special mining permit holders are required to process, refine or smelt their ore domestically unless exempted, 'not exceeding five years from the promulgation of the law', thus establishing the policy for an export ban on ores by 2014.[35] In 2012, Indonesia's Ministry of Trade issued a decree targeting a shift from being an exporter of metallic ores and concentrated to a country producing value-added finished metallic products. The decree followed a rapid rise during 2008-2014 in the export of copper (>100%) and nickel (>700%) ores. The 2012 'ore ban' added a 20% export tax on the shipping of these ores. Implementing the ban on exporting raw materials from Indonesia created excess capacity in refining hubs such as China.

In January 2017, the ore ban was eased, with exports of nickel laterites (of 1.7% Ni grade or lower), bauxite ores (of at least 42%) and copper concentrates allowed for up to five years but restricted to volumes decided by the Government. In 2020, a ban on the export of nickel laterite ores was reinstated two years earlier than previously scheduled. The new law again requires mining companies to increase the added value of minerals in mining business activities through domestic processing and purification of metal-bearing mining products. In March 2021, Indonesia established the Indonesia Battery Corporation (IBC) with equal shareholders from four state-owned enterprises operating in aluminium smelting, mining, oil and gas, and electricity (PT Indonesia Asahan Aluminum/Inalum), PT Antam Tbk (ANTM), PT Pertamina, and PT PLN). The Indonesian Government has included electric vehicle (EV) production in its National Masterplan for Industry 2015-35 and specified EV infrastructure development in its National Medium-Term Plan 2020-24.

Minister of Industry Agus Gumiwang Kartasasmita claims that the total number of smelters in Indonesia reached 91 units as of February 1 2023. However, the number of smelters in operation has reached 48 units.[39] This number includes nickel, steel, copper and aluminium smelters. The Ministry of Energy and Mineral Resources targets that by 2024 there will be 53 smelters operating, 30 of which will be nickel smelters. As shown in **Figure 8**, based on data from the Ministry of Energy and Mineral Resources, Indonesia now has 300 nickel Mining Business Permit (IUP) holders and 3 nickel Work Contract (KK) holders.[40]

Nickel mining business permits in Indonesia in 2022

Figure 8: Nickel mining business permits in Indonesia in 2022 [40]



Source: Ministry of Energy and Mineral Resources of the Republic of Indonesia, 2023

Indonesian nickel production has grown significantly faster than Australia's to become the world's largest producer, from having comparable production levels in the 1990s.[41]

Australia's policy on critical minerals

In consultation with industry, Australian Government policy has also been refreshed to target greater downstream processing of critical minerals. This includes direct government investment to bring forward selected new mines and downstream processing facilities to facilitate manufacturing, including in the battery supply chain. Future updates and enhancements to the Australian critical minerals policy are anticipated. To date, government actions have included de-risking projects through investment via the Critical Minerals Facility (CMF), the Critical Minerals Accelerator Initiative (CMAI), the Modern Manufacturing Initiative and attracting investment.

Austrade is the Australian Government's lead trade and investment facilitation agency. It supports the critical minerals sector by developing commercial partnerships that connect Australia with our trade partners and target markets. Austrade delivers specialised services to Australian critical minerals companies, including bespoke client engagement programs and targeted trade missions.[42,43] The Australian Government has developed a Critical Minerals Strategy, which aims to:

- encourage exploration and investment in critical minerals projects in Australia
- develop sustainable and responsible mining practices to ensure the industry's long-term viability
- promote the development of downstream processing and manufacturing industries in Australia to add value to the country's critical mineral resources
- strengthen international partnerships to secure critical minerals supply chains and promote trade.

Together, these initiatives seek to leverage the strong exploration potential of Australia, where a discovery track record continues, including in lithium and rare earth, where downstream investment is underway[44], and further new opportunities await discovery, including at-depth below near-surface cover rocks.[45,46,47]

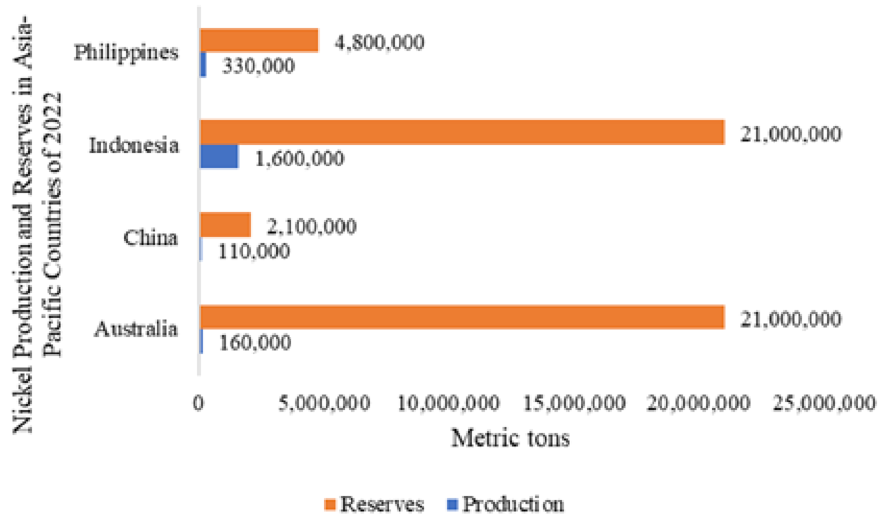
The growing global influence of critical minerals has led to the development of mineral policy strategies by governments around the world. These strategies aim to support the responsible and sustainable development of critical mineral resources while ensuring supply security for high-tech industries and renewable energy technologies.

At high level, key mineral policy strategies being implemented by governments include:

- **Diversification of supply:** A focus on diversifying critical minerals supply chains to reduce dependence on a single supplier or region. This can involve developing domestic resources and establishing new partnerships and trade agreements.
- **Investment in exploration and development:** Investing in the exploration and development of critical mineral resources, particularly in regions with high potential for these minerals. This can involve providing funding for research and development, as well as supporting the private sector in the exploration and development of new projects through co-funding of drilling and exploration surveys.
- **Promotion of responsible and sustainable mining practices:** To ensure that critical mineral resources are developed in an environmentally and socially responsible manner. This can involve the development of regulations and standards, as well as supporting the adoption of best practices by the mining industry.
- **Development of recycling and circular economy initiatives:** To reduce the reliance on the primary production of critical minerals. This can involve the support of research and development initiatives to implement new technologies and processes to recover critical minerals from waste streams and end-of-life products.

Nickel production and reserves in Asia-Pacific countries in 2022

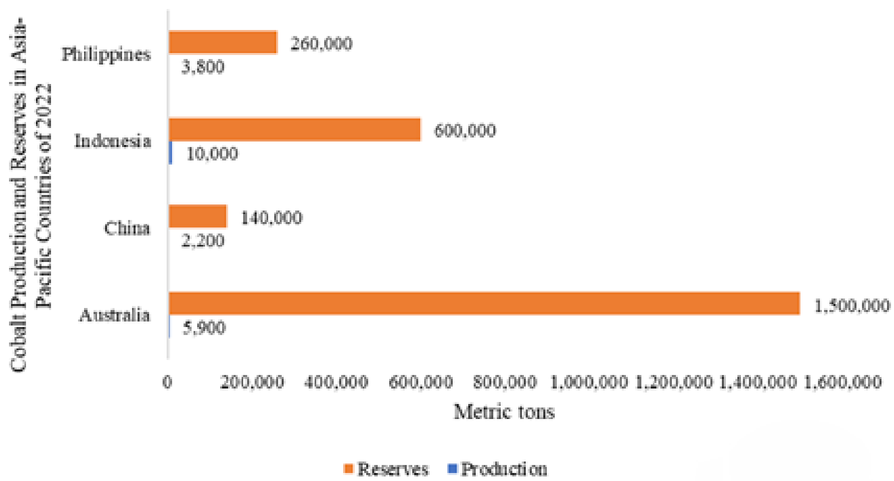
Figure 9 : Nickel production and reserves in Asia-Pacific countries in 2022[34]



Source: US Geological Survey, 2023

Cobalt production and reserves in Asia-Pacific countries in 2022

Figure 10: Cobalt production and reserves in Asia-Pacific countries in 2022[34]



Source: US Geological Survey, 2023

CHAPTER 4
Glimpses of 2030 and beyond

Here are some glimpses of what the critical minerals landscape might look like in 2030 and beyond.

- **Increased demand**: As the world transitions to a low-carbon economy, demand for critical minerals is expected to increase significantly. The growth in electric vehicles, renewable energy, energy storage technologies and the need for critical minerals in defence systems will drive this.
- **Shifts in supply chains**: The current supply chains for critical minerals are dominated by a few countries, including China and Russia, which has raised concerns about supply chain security. In response, there is likely to be a shift towards diversifying supply chains and developing domestic sources of critical minerals. Australia and Indonesia look set to benefit from greater supply chain diversification.
- **Technological advancements:** The development of new technologies, such as advanced battery chemistries, could change the critical minerals landscape by reducing reliance on certain minerals and increasing demand for others.
- **New discoveries and developments**: With the increased demand for critical minerals, there is likely to be a significant investment in the exploration and development of new mines and processing facilities. This will require significant capital investment and regulatory support to ensure responsible and sustainable mining practices.
- **Recycling and circular economies**: As the demand for critical minerals increases, and new metals production becomes embedded within the economy, there will be a growing need for recycling and the development of circular economies for these materials. This will help to reduce waste and ensure a sustainable supply of critical minerals.

↑ Processing Plant at Lithium Mine in Western Australia. Mechanical processing used to refine lithium spodumene concentrate.

An expanded role for Indonesia downstream in critical minerals

Indonesia has significant mineral resources, including some critical minerals such as nickel, cobalt, copper and rare earth elements. However, the country has traditionally focused on exporting these minerals in raw form with little value addition or downstream processing.

In recent years, there has been a growing recognition in Indonesia of the potential benefits of downstream processing and value addition in the critical minerals sector. By investing in downstream processing facilities and technology, Indonesia can capture a larger share of the value chain, create new jobs and develop a more diversified and resilient economy.

One area of particular interest for Indonesia is the production of nickel-based products for the growing EV market. Indonesia is one of the world's largest producers of nickel ore, which is a key input in the production of batteries for EVs. By investing in downstream processing facilities for nickel, such as nickel matte, battery-grade nickel sulphate, and precursor materials, Indonesia can tap into the growing demand for EV batteries and become a major player in the global supply chain.

An expanded role for Australia downstream in critical minerals

Australia has significant reserves of critical minerals, including rare earth elements, lithium, cobalt and others, which are essential to modern technologies such as electric vehicles, renewable energy systems and telecommunications equipment. As demand for these minerals grows, Australia has an opportunity to expand its role downstream in its production and supply chain where opportunities for cost-competitive new production can be established.

Downstream processing refers to the refining, manufacturing and recycling of critical minerals into products that consumers can use. By increasing its downstream capabilities, Australia can capture more value from its mineral resources and create high-paying jobs in advanced manufacturing industries.

To achieve this, Australia is investing in research and development in critical minerals and encouraging private sector investment in downstream processing facilities. The Australian Government could also further expand engagement with international partners to develop new processing and manufacturing facilities, employing new technologies and supply chain innovations that enhance the efficiency and sustainability of critical mineral processing.

In addition to creating economic benefits, an expanded role for Australia downstream in critical minerals could also strengthen the country's strategic position in the global supply chain for these essential materials.

Other Indo-Pacific key developments

Several countries in the Indo-Pacific region are also focusing on the development of critical minerals and the downstream processing of these materials. Here are some key developments:

- **Japan:** Japan has launched an initiative to secure a stable supply of critical minerals, which includes developing domestic resources and recycling materials. Japan has also invested in developing new technologies for the efficient and sustainable processing of critical minerals.
- **India:** India has identified critical minerals as a priority area for development and has launched several initiatives to increase domestic production and processing of these materials. India has also established partnerships with other countries, including Australia, to enhance its access to critical minerals.
- **China:** China is the world's largest producer and consumer of critical minerals and has significant downstream processing capabilities. China has also been investing heavily in developing new technologies for the processing and recycling of critical minerals.
- **United States:** The United States has identified critical minerals as a strategic priority and has launched several initiatives to increase domestic production and processing of these materials. The United States has also established partnerships with other countries, including Australia and Japan, to enhance its access to critical minerals.

Enhanced collaboration and new partnerships between countries will be essential to ensure a stable and sustainable supply of these essential materials.

CHAPTER 5
Conclusion

Critical minerals policies are reaching a new stage in their evolution. Some 15 years after the instigation of high-level critical minerals lists, a heightened level of government focus has emerged globally, typified by updated, supportive policies and direct government intervention to incentivise market-based solutions towards new production.

However, more can be done. Arguably, the various supportive, broad-based, critical minerals policies are now running ahead of the detailed mineral economics assessments needed for each critical minerals market to prioritise and bring forward future developments.

That is, rather than high-level judgement as to inclusion or exclusion in the list of critical minerals for a jurisdiction, attention must now turn to analysing and evaluating specific criticalities and growth opportunities within each respective critical mineral value chain, from mining to manufacturing.

In this context, we suggest three areas of mineral policy guidance to catalyse further and prioritise new investment.

- **A tiered approach to critical minerals assessment:** Some critical minerals have greater potential than others, which can be surfaced using a tiered approach to critical minerals list assessments, highlighting those opportunities of greatest strategic value and also those where the market is thus far failing to solve for criticality. One 'size' does not fit all. Therefore, the rational consequence is not to focus on the critical mineral list as a whole, but on each mineral as a specific criticality and/or opportunity. Each critical mineral market has vastly different microeconomics from the next, for example, lithium versus cobalt [48], and thus requires a market-specific, in-depth analysis of the value chain, intending to formulate informed, prioritised and targeted policy and investment.
- **Towards a time to shrink, not grow, the list of critical minerals:** Critical minerals lists have been getting longer as assessments are updated of the need for metals in new technology manufacturing globally. Some critical minerals are, however, now at a turning point, where supportive mineral policy, process technology development and favourable market dynamics have attracted material investments towards sizeable new production. While much remains to be done, the time when nickel, lithium and rare earth become less critical is foreseeable. Lithium and nickel are among the first candidates for removal from critical minerals lists, allowing the even greater focus to be brought to finding market-based solutions for those minerals yet to 'break out' via a wave of new investment. Cobalt looks to be one such investment case, where opportunities exist both in Indonesia and Australia as an example of potential future 'borderless', collaborative future investment.
- **Critical minerals without borders:** Evolving minerals policies aimed at increasing the supply of critical minerals are principally targeted at the jurisdictional level, with the notable exception of the Europe-wide approach adopted by the European Union. Cross-border opportunities abound, reflected in narratives that aim to encourage joint mineral developments 'without borders'. A shift towards further encouraging cross-border developments in parallel with in-country critical minerals developments opens up greater possibilities for new critical minerals supply, especially where the comparative advantages of two or more jurisdictions can be leveraged in the supply chain.

A comprehensive and coordinated approach is necessary to ensure the long-term viability and competitiveness of the critical minerals industry. Governments can play a key role in supporting exploration and development, downstream processing and manufacturing, responsible and sustainable mining practices, international cooperation, innovation and technology development, and recycling and circular economy initiatives.

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