

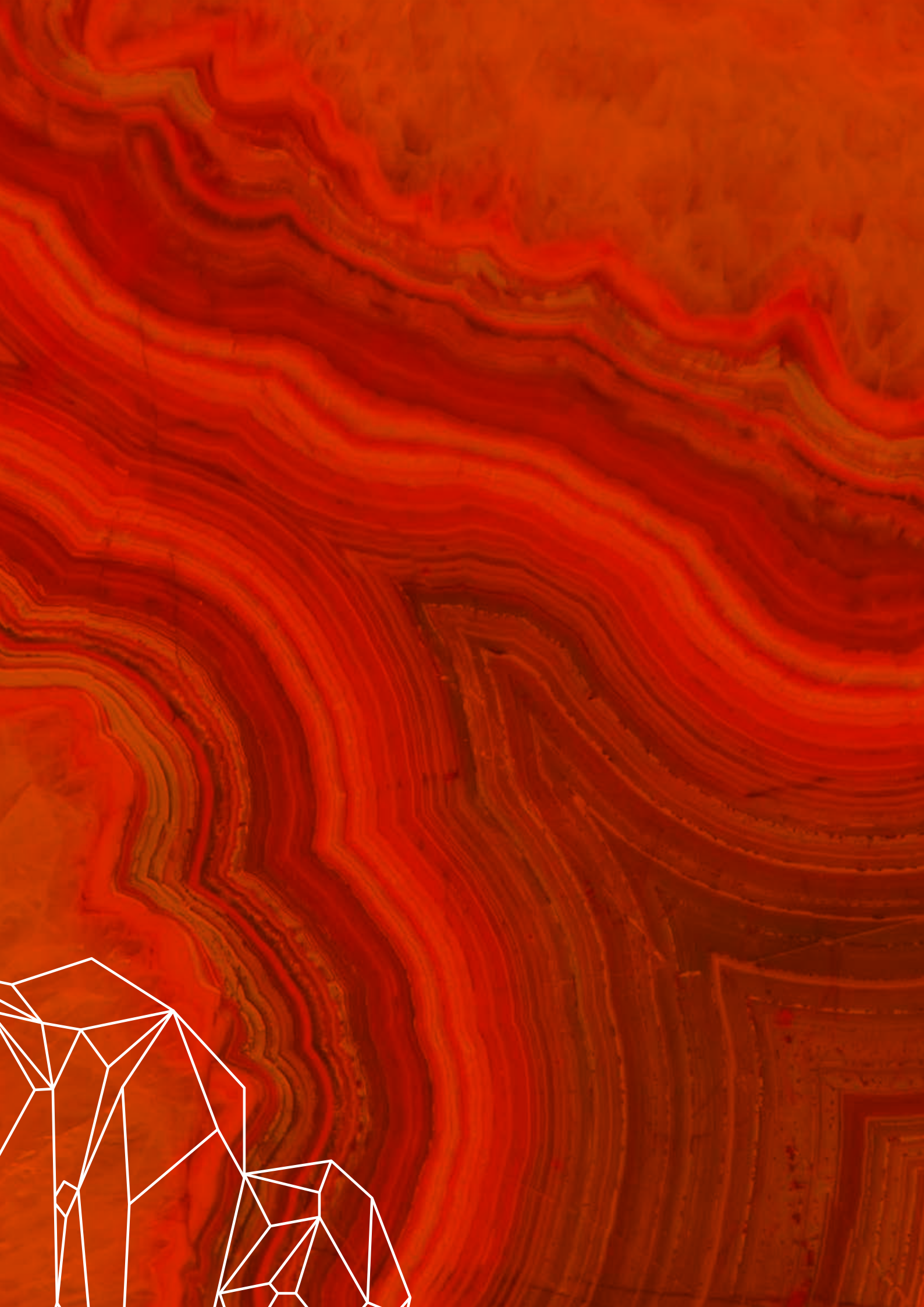


Perth USAsia Centre

CRITICAL MATERIALS FOR THE 21ST CENTURY INDO-PACIFIC

Dr Jeffrey Wilson, Research Director, Perth USAsia Centre

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EXECUTIVE SUMMARY

Critical materials will play a key role in the economic future of the Indo-Pacific.

Used in high-technology applications across the scientific, digital, clean energy and defence industries, these minerals are essential for the ongoing modernisation and integration of the region's economies.

Major security and sustainability challenges mean contemporary value chains are not fit for purpose.

Most critical materials markets are characterised by high levels of monopoly, posing political risks for supply security to end-users. Current mining practices also pose major environmental risks, and their production sometimes contributes to social conflicts, forced labour and civil wars.

Governments, businesses and civil society have begun efforts to reform value chain governance.

These initiatives have done a lot to draw attention to the challenges facing contemporary critical materials industries. However, these efforts are yet to develop the new sources of supply required for secure and sustainable value chains.

Now is the time to invest in developing new Indo-Pacific critical materials networks

As critical materials will become increasingly important for the region's future, governments and businesses need to pioneer new models to secure reliable and sustainable forms of supply.

Australia will be an important partner in these efforts.

Its geologic endowment, reliable institutional environment and well-developed relations with key players mean Australia is an ideal critical materials supplier for the Indo-Pacific. While several new projects attest to the opportunities, more is required for Australia to fully realise its potential.

New strategies will be required to create secure and sustainable critical materials industries.

Governments and businesses need to recognise the distinct challenges facing critical materials, adopt a regionally integrated value chain perspective, and build international partnerships that link producers and consumers across the Indo-Pacific.

FOREWORD



Professor Gordon Flake, CEO, Perth USAsia Centre

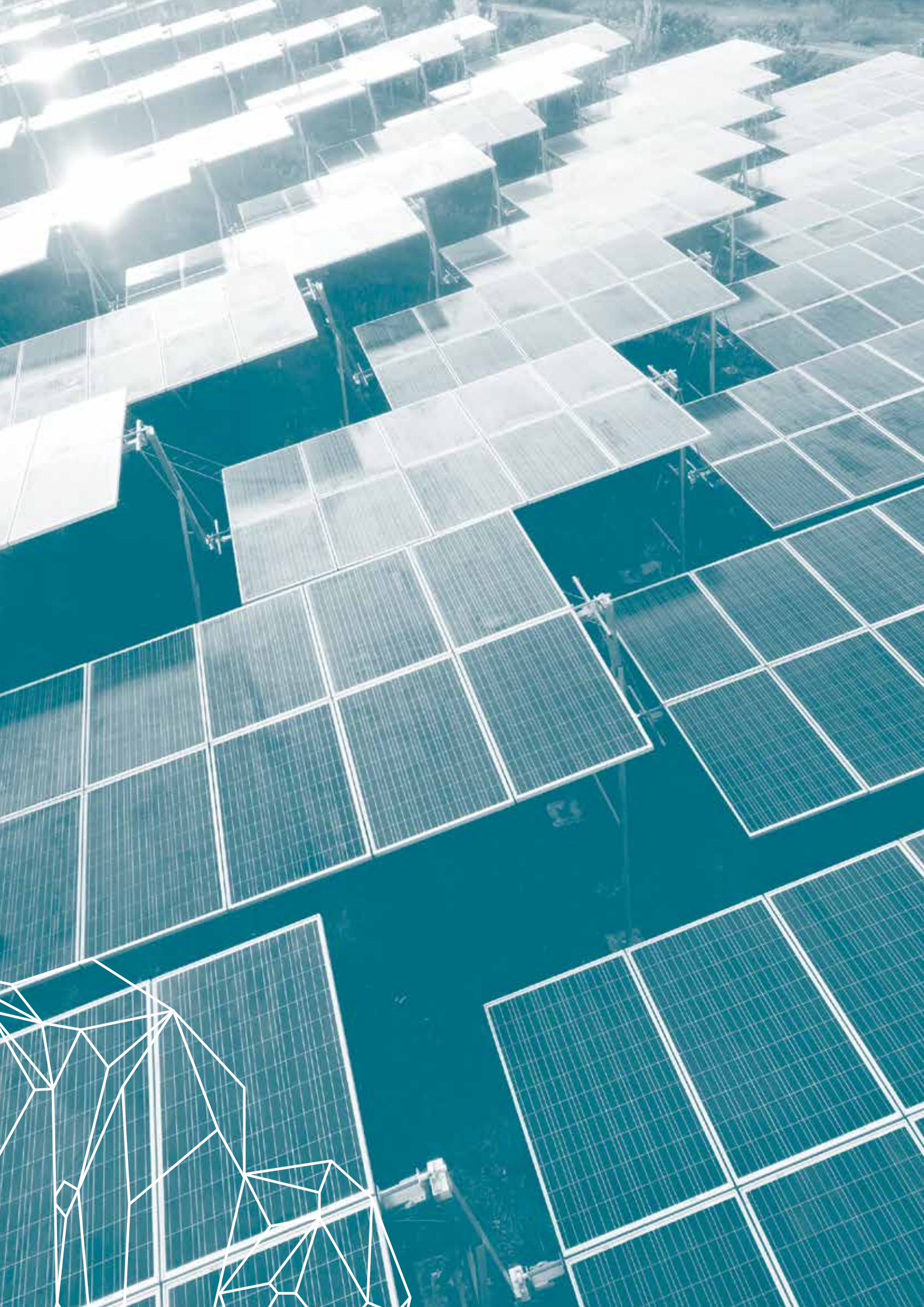
The work of the Perth USAsia Centre focuses on the Indo-Pacific, a region containing most of the world's leading and emerging economies. Strong relations between countries are crucial to the stability, security and prosperity of the region. In this report, Jeffrey Wilson explores how critical materials will play an increasingly important role in enhancing the economic integration and security of the Indo-Pacific.

The economic transformation of the Indo-Pacific has been one of the greatest developmental advances in world history. In only a few decades, its economies have urbanised and industrialised at a rapid pace, lifting hundreds of millions out of poverty. We are now seeing 'technological leapfrogging', with leading edge digital communications quickly disseminating through the region's economies and societies. Sustaining this digital revolution will be essential to maximise the Indo-Pacific's developmental potential.

Critical materials are important to this endeavour. These hitherto obscure materials are essential for a range of modern technologies, across the digital, scientific, advanced manufacturing and clean energy sectors. As the Indo-Pacific continues its developmental progress, they will be required in ever-greater quantities. Yet contemporary critical material value chains are neither secure nor sustainable. New approaches are required to ensure critical materials contribute to, rather than detract from, the economic advancement of the Indo-Pacific.

Western Australia has a key role to play. The state is richly endowed with critical material reserves, and has the expertise and relationships required to build world-class mineral processing industries. However, Western Australia cannot develop this industry on its own. International partnerships are required to establish the complex cross-border value chains essential for success and sustainability. Securing better critical materials supply must be a genuinely regional endeavour.

In this report, Jeffrey Wilson examines how governments and businesses in the Indo-Pacific can respond to the critical materials challenge. It analyses the economic, social, environmental and geopolitical challenges facing critical materials, and identifies strategies for developing 21st century value-chains that more effectively meet the needs of both producers and consumers. This report provides government and business leaders with a blueprint to ensure that critical materials contribute to a secure, sustainable and prosperous Indo-Pacific.



1. INTRODUCTION

Critical materials are essential for the economic development of the Indo-Pacific.

Though often overlooked, critical materials are highly important for modern, technological societies. Comprising a range of speciality metals and minerals, they are essential input high-technology applications, across the scientific, electronic, clean energy and defence industries. With new digital communications technologies rapidly spreading across the Indo-Pacific, its economies have become increasingly dependent on secure supplies of these materials. As the global energy transition drives us towards cleaner and renewable sources of energy, demand for critical materials will only grow in coming years.

However, contemporary critical materials value chains are neither secure nor sustainable.

Critical materials only make up a small portion of international commodity trade, and production is often monopolised by a handful of countries. International markets are subject to political manipulation, threatening security of supply and leading to diplomatic conflict between producers and consumers. Poor institutional and governance frameworks also mean that exploitation of critical materials frequently has adverse social and environmental outcomes, contributing to forced labour, ecological destruction and civil wars. The value chains that produce critical materials are not fit for purpose for 21st century economies.

Government, business and civil society have all recognised the importance of new approaches to critical materials.

In recent years, efforts to develop better critical materials value chains have begun. Companies and civil society organisations have developed standards and monitoring schemes; while governments have launched strategies to encourage new sources of supply. While these initiatives are a positive start, they are yet to create reliable value chains. New strategies are required to ensure critical materials supplies that are secure and sustainable.

Australia has a key role to play in building new critical materials value chains.

It has a rich geologic endowment of critical materials, a reliable and transparent institutional environment, a technically sophisticated mining sector, and strong economic ties to major partners in the Indo-Pacific. Several Australian companies have taken this opportunity to launch new mining and processing projects. However, neither Australia nor regional partners have fully converted its critical materials potential into a key role in Indo-Pacific value chains.

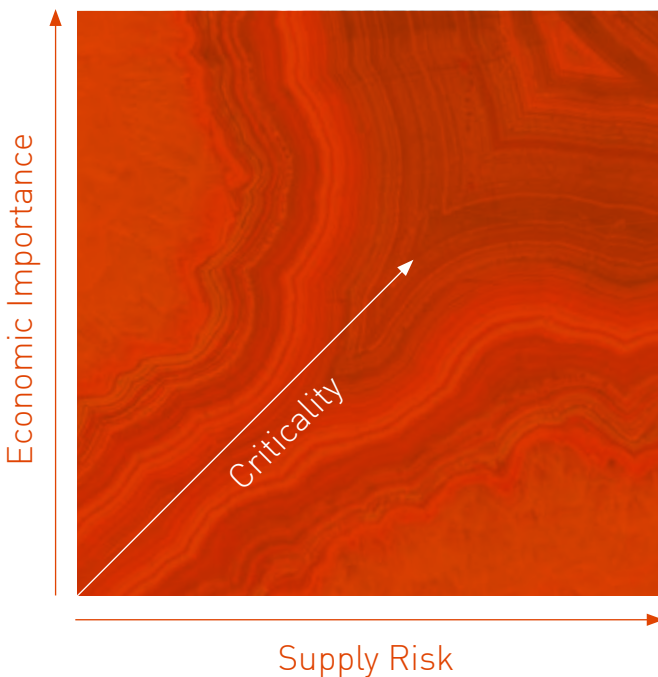
This report explores ways to develop more secure and sustainable critical materials for the 21st century Indo-Pacific.

It identifies the essential role of critical materials for modern economies, and the security and sustainability challenges facing contemporary value chains. It then reviews strategies for developing new industries, with a focus on Australia's potential to contribute to these efforts. It argues that for these efforts to be successful, governments, businesses and civil society will need to recognise the distinctive challenges facing critical materials, and build international partnerships that link producers and consumers across the Indo-Pacific.

2. WHAT ARE CRITICAL MATERIALS?

Critical materials are of existential importance for modern, technology-intensive societies. While all economies rely on raw materials – whether natural resources for industry, or energy to transform them into finished products – critical materials are a special category of outsized importance. This is because they pose unique risks to the security and sustainability of an economy. The commonly used definition identifies two distinct features¹: they have very high *economic importance* for the industries that consume them; and they are subject to heightened levels of *supply risk* that can interrupt physical availability and/or affordability (see Figure 1). This combination of economic importance and supply risk demarcates critical materials from other (non-critical) bulk commodities such as oil, gas or iron ore.

FIGURE 1 CRITICALITY MATRIX FOR DEFINING CRITICAL MATERIALS



Many factors affect whether a particular material should be classified as 'critical' or not.

In terms of economic importance, this includes whether a material is essential for the industries that use it, the existence of substitutes with similar or near-similar properties, and the extent to which resulting products are used across the industrial ecosystem. For supply risk, factors include whether a material is locally-produced or imported from abroad, the extent to which it is subject to monopoly or oligopoly by a small number of producers, and the prospect of political conflicts leading to an interruption of supply. These risk factors are inherently qualitative; and while they can be measured in relative terms, they are not easily quantifiable. For this reason, criticality is best conceived as a spectrum, with critical materials those that are subject to particularly high levels of economic importance and supply risk.

There is no universally agreed list of critical materials. As each country has its own distinctive geological endowment and industrial structure, whether a material is critical or not depends on the economy in question. For example, energy is not critical for hydrocarbon-rich Russia in the way it is for hydrocarbon-poor Japan, though both countries require energy for their transport and manufacturing industries. However, several governments have undertaken 'criticality studies', which review the use of raw materials across their economies and identify those which should be considered critical given their particular needs. Table 1 provides a summary of the thirty raw materials identified as critical by one or more of the five governments that have published criticality assessments: the EU, US, Japan, India and Australia.

TABLE 1 THIRTY CRITICAL MATERIALS

MATERIAL	PRINCIPAL USES	LIFE OF PROVEN GLOBAL RESERVES (YEARS)	GROWTH IN GLOBAL PRODUCTION 2007-17	VALUE OF INTERNATIONAL TRADE (USD MILLIONS)
Antimony	Flame retardants, specialty alloys, electronics	10	11%	173
Baryte	Medicine, fluorescent lighting, electrodes, glass, ceramics	38	-4%	595
Beryllium	Semiconductors, aerospace and defence components, spectroscopy		77%	21
Bismuth	Pharmaceuticals, non-toxic lead substitutes		146%	
Chromium	Specialty steels, pigments	16	55%	4043
Cobalt	Super alloys, speciality steel, magnets, lithium-ion batteries	65	77%	553
Fluorspar	Chemicals, glass, enamels	45	13%	500
Gallium	Electronics, lasers, photodetectors, thin layer photovoltaics		170%	
Germanium	Fibre and infrared optics, electronic and solar applications		34%	315
Helium	Cryogenics, controlled atmospheres	47	-8%	
Indium	Semiconductors, thin-film electroluminescent panels		41%	
Lithium	Batteries, specialist ceramics, optics, nuclear fuel cycle	372	72%	1741
Magnesium	Specialty alloys, batteries, electronics	289	80%	1861
Manganese	Specialty steels, batteries, fertiliser	43	38%	6956
Molybdenum	Specialty steels, super alloys, pigments	59	55%	2872
Natural Graphite	Composites, electronics, superconductors, large-scale fuel cells	225	17%	448
Nickel	Specialty steels, batteries, magnets	35	27%	2967
Niobium	Micro capacitors, superconductors, super alloys	67	42%	
Phosphate Rock	Fertiliser, industrial chemistry	266	79%	2833
Platinum Group Metals	Catalytic converters, electronic components, fuel cells	168	-11%	27353
Rare Earth Minerals	Magnets, catalysts, metal alloys, phosphors, energy storage, superconductors	923	5%	350
Selenium	Thin-film photovoltaics, alloys, glass, batteries	30	113%	165
Silicon Metal	Aluminium production, chemicals, electronics, photovoltaics		45%	2655
Tantalum	Microcapacitors, medical technology	85	-7%	912
Tin	Industrial and electronic solders, touch screen technologies	17	-3%	1356
Titanium	Pigments, carbides, specialty engineering, medical devices	131	16%	2569
Tungsten	Electronic applications, lighting, carbides, speciality alloys	34	6%	186
Vanadium	Superalloys, chemical catalysts, batteries	250	38%	399
Zinc	Anti-corrosion, polymers, semiconductors, hydrogen production	17	26%	11775
Zirconium	Refractory products, nuclear fuel cycle	46	29%	1350
TOTAL				74947

Source: Author's calculations, from USGS² and UN Comtrade Database³. Note: Comprises all critical materials identified for Europe, Japan, India, United States and Australia⁴. Some identified critical materials omitted as they geologically co-occur with other products on the list⁵.

While critical materials have diverse attributes, they share several common features.

First, they are widely used in specialised technology applications. They play a key role in the electronics, petrochemical, speciality metals, optics, batteries, composites and nuclear industries. A recent source of demand growth is consumer electronic devices, which use twelve different critical materials (Box 1). Another is the emergence of the clean energy technologies, where batteries and magnets make extensive use of these materials. Importantly, there is often a lack of viable substitutes⁶. For example, indium is an essential input for the manufacture of indium-tin oxide film, which is required for all touchscreen devices. Rare earth minerals are an essential component of high-performance magnets, which are in increasing demand from the clean energy industry. The societal penetration of consumer electronic devices has seen demand grow rapidly over the last decade (Table 1). As clean energy technologies achieve mainstream application in national energy systems, demand for critical materials continue to grow for many years to come.

BOX 1 CRITICAL MATERIALS IN CONSUMER ELECTRONIC DEVICES

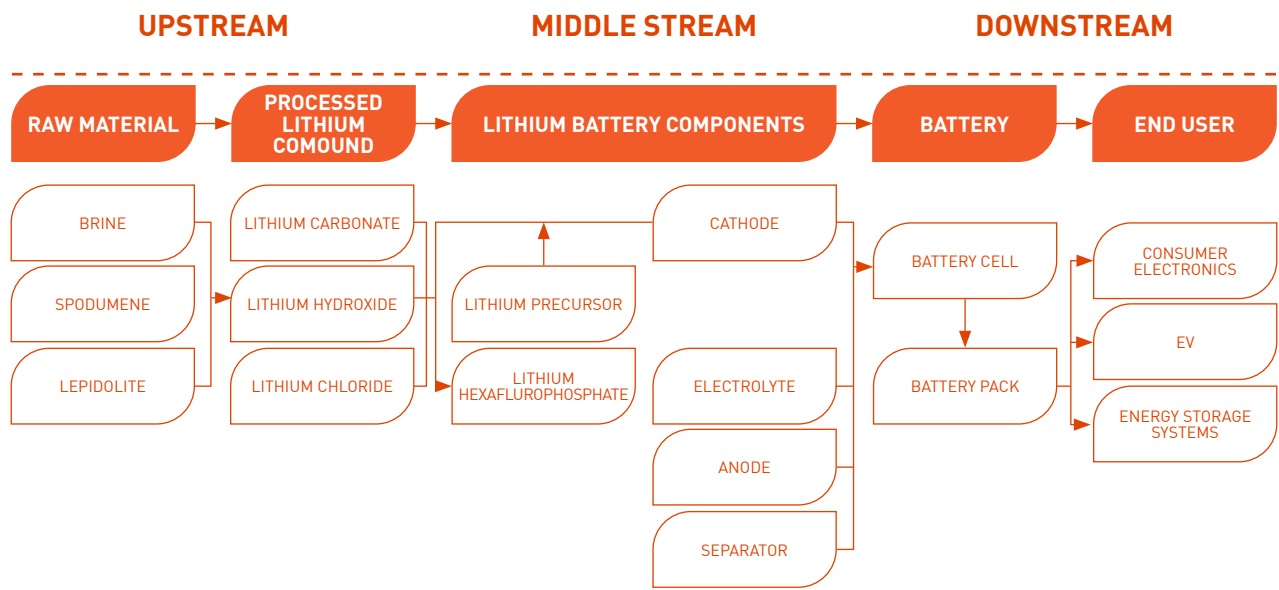
1. BERYLLIUM:
Semiconductors and connectors
2. COBALT:
Li-ion battery cathodes
3. GALLIUM:
LED display backlighting
4. GERMANIUM:
Semiconductors
5. GRAPHITE:
Li-ion battery anodes
6. INDIUM:
Conductive touchscreen coatings
7. LITHIUM:
Li-ion battery cathodes
8. PLATINUM GROUP METALS:
Semiconductors and electronic plating
9. RARE EARTH MINERALS:
LED display phosphors, speaker magnets
10. TANTALUM:
Capacitors and resistors
11. TIN:
Solder and coatings
12. TUNGSTEN:
Heat sinks and vibrators

Critical materials also play a key role in the defence materiel supply chain. Rare earth minerals are especially important for advanced military technologies, and are required to manufacture missiles, precision-guided munitions, laser targeting systems, radars, satellites, electronic warfare technologies, avionics systems, stealth technologies, sonar transducers and ballistic missile early warning systems⁷. Like civilian uses, there are few to no substitutes for critical materials in these military applications. Supply security is of such importance that the US Defense Logistics Agency actively monitors the availability of 170 different materials for military users, with those facing pronounced supply risks included in National Defense Stockpile program⁸.

Second, critical materials have especially complex value chains. Chemically, the desired elements are usually a minor component of the minerals in which they are found, and several critical materials often co-occur together. This requires extensive chemical processing to initially separate ores into individual oxides: in the case of rare earths, thirty-four distinct processing steps are required to separate bastnasite ore into its twelve constituent rare earth oxides⁹. These oxides then require further processing and manufacturing, often at different specialised facilities, to create useable products for industrial applications. Figure 2 illustrates the value chain that transforms lithium-bearing minerals into lithium-ion batteries through intermediate production stages. This is a considerably more complex value chain than for iron ore, which requires only simple crushing and screening before it is suitable for use in primary steel production¹⁰.



FIGURE 2 LITHIUM-ION BATTERY VALUE CHAIN



Source: Austrade¹¹

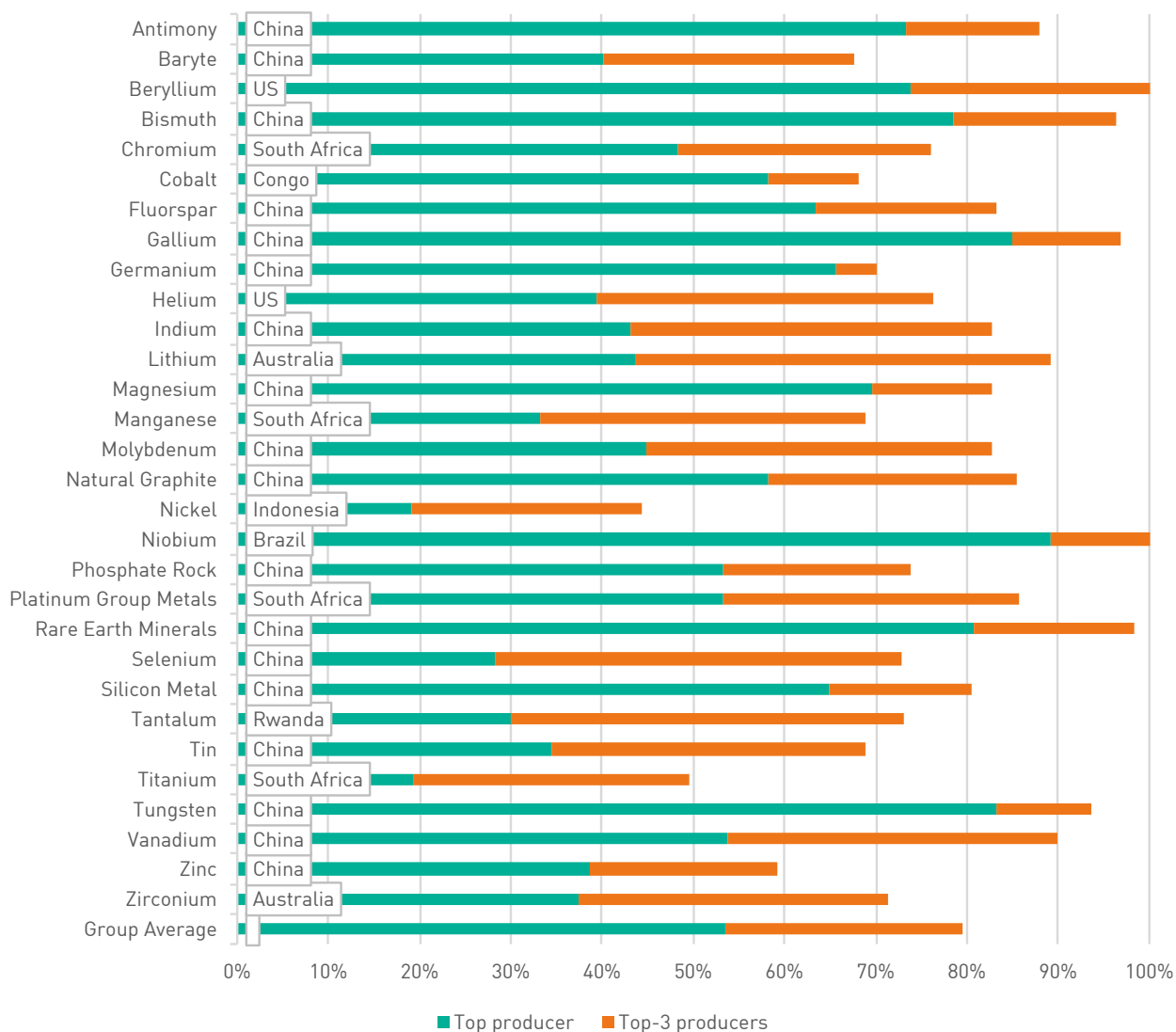
As a consequence, the economics of critical materials are very different to other bulk commodities. Mining projects do not function as standalone enterprises, but either require dedicated processing facilities close to mine sites, or vertical integration within the value chains of upstream manufacturers. Raw minerals and their intermediate products have special technical features that are calibrated to the value chains for which they are produced. The majority of value-adding is concentrated in the technology-intensive processing stages, with mineral extraction generally the least profitable stage in the value chain. While Australia is the world's largest producer and exporter of lithium ore, some 99.5 percent of the value in the resulting battery products is added offshore during chemical processing, cell manufacturing and product assembly¹².

Critical material reserves are only viable for commercial exploitation when integrated into the global value chains for technology products.

Compounding matters, the global market for critical materials is comparatively small. While essential in many civilian and military applications, they are usually only used in trace quantities of milli- or micrograms per unit. Global production volumes are therefore modest when compared to other bulk materials. In 2017, the collective value of international trade in the thirty critical materials was \$75 billion, though most individual materials were valued between a few hundred million to a billion dollars (Table 1). Despite the ubiquity of cobalt – which is present in every handheld electronic device with a lithium-ion battery – the international cobalt trade is worth only half a billion dollars. These markets are a fraction the size of the \$90 billion trade in iron ore, \$173 billion in natural gas and \$448 billion in oil¹³.



FIGURE 3 CRITICAL MATERIALS MARKET SHARE BY LEADING PRODUCERS, 2017



Source: Author's calculations, from USGS¹⁴

Third, critical material markets are characterised by a high degree of monopoly. The complexity of value chains, high investment overheads for processing facilities, and relatively small markets means only a handful of companies and countries participate in any one critical material market. As Figure 3 illustrates, for sixteen of the thirty critical materials a single country produces over half of global supply. On average, the top-three accounts for 79 percent of all critical materials production.

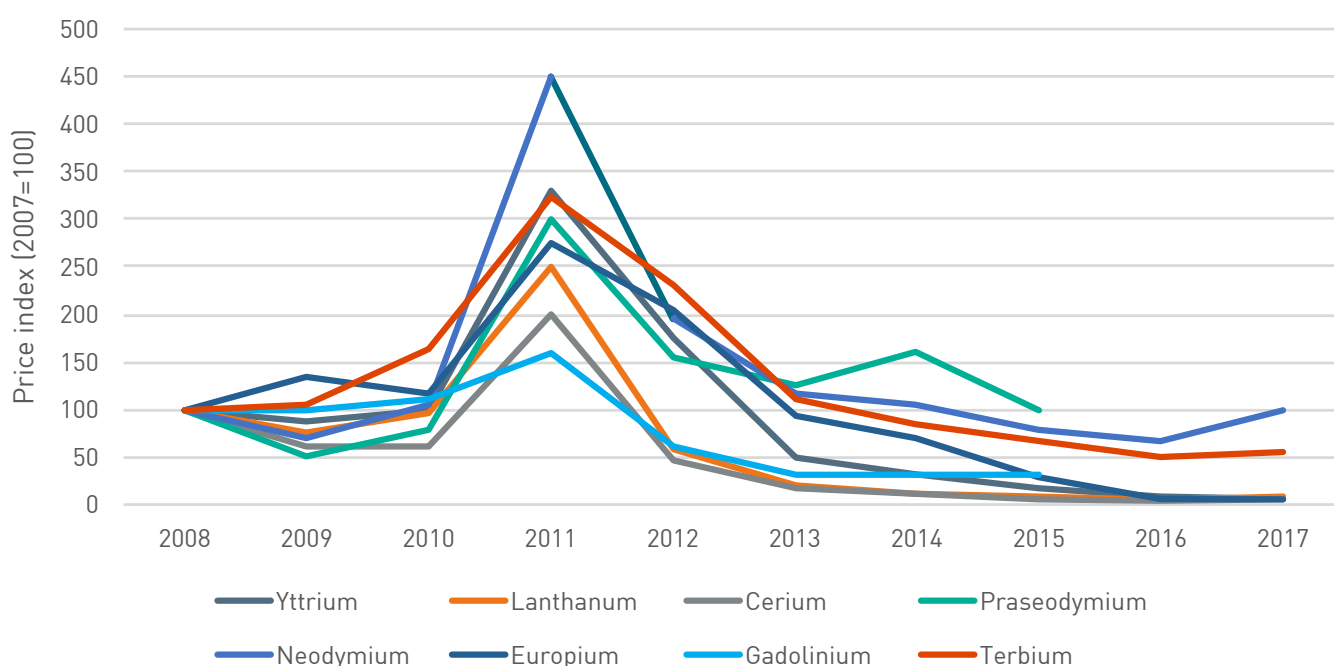
No other commodity market is subject to such extreme levels of concentration.

Monopoly means that critical materials are subject to very high levels of supply risk. With a small number of countries accounting for the bulk of world production, adverse events can more easily lead to interruptions in international trade. Interruptions may occur for a variety of reasons, including social problems such as unrest or civil war, environmental factors such as extreme weather events or disasters at mining locations, and political conflicts where producing states withhold supply in order to extract concessions from consumers. Here, the outsized role of China – a country not typically considered a major resource exporter – is particularly noteworthy. China is the world’s largest producer of eighteen of the thirty critical materials, and a near-monopolist (over 70 percent market share) for five.

The security of global critical materials supply heavily depends on the reliability and affordability of Chinese exports.

As a result, critical materials markets are highly volatile. With only a small number of players in any one market, adverse events affecting a single producer can easily throw supply and demand out of balance. An instructive example occurred in rare earth minerals, which in 2010 were the subject of a trade dispute between China and Japan. While Chinese supply to Japan was suspended for only fifty-nine days, the dispute had a dramatic effect on global markets. Prices for rare earth oxides immediately spiked between 60 and 350 percent, before taking over a year to return to pre-dispute levels (Figure 4). This encouraged many new firms to enter the industry, who subsequently struggled to achieve profitability when prices collapsed below as excess supply entered the market¹⁵. Such volatile price cycles are harmful to both producers and consumers of critical materials, as they make it difficult to plan the long-term investment required for vertically integrated and complex global value chains.

FIGURE 4 RARE EARTH OXIDE PRICE VOLATILITY, 2008-17



Source: Author’s calculations, from USGS¹⁶

3. SECURITY CHALLENGES: POLITICAL, SOCIAL AND ENVIRONMENTAL

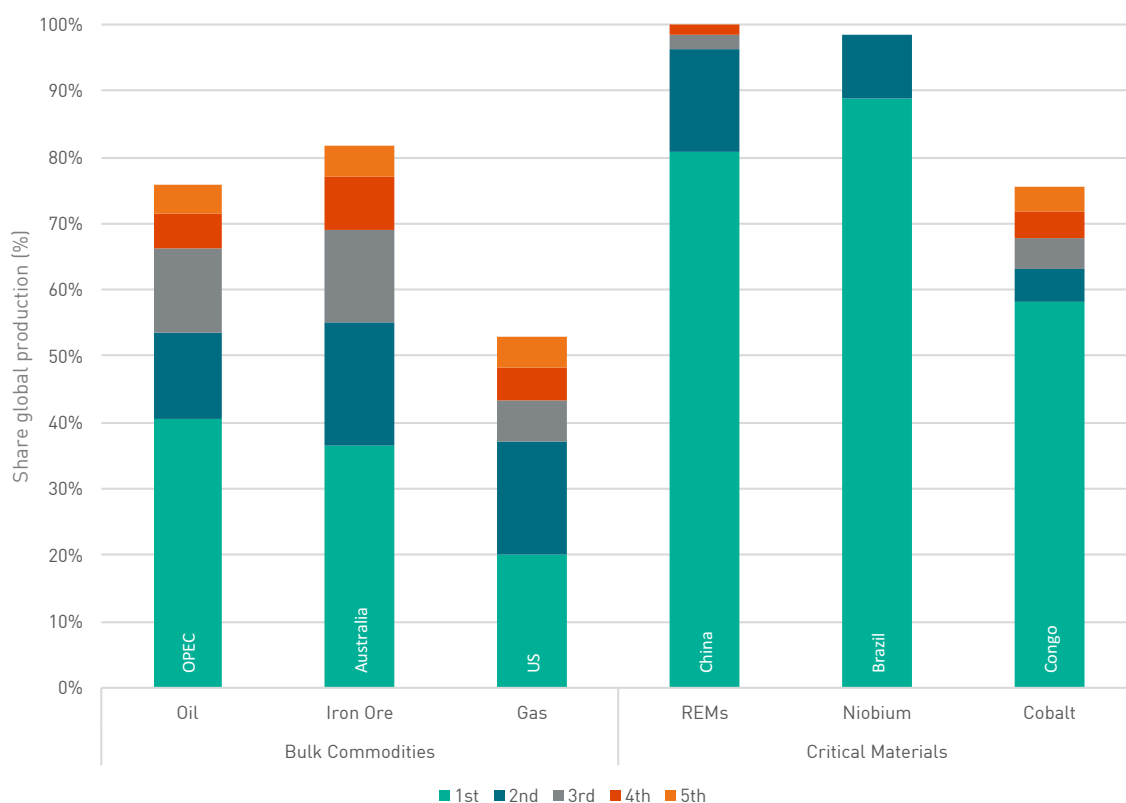
Ensuring the security and sustainability of critical materials value chains is of vital importance for the global economy. While critical materials are essential for the technologies that will define the 21st century, their value chains are far less robust than most other natural resources. Production is monopolised by a small number of countries, exposing markets to political and economic shocks that threaten insecurity and volatility. Many critical materials producers lack contemporary mining and processing technologies, posing environmental risks to local ecosystems and the communities that depend on them. Critical materials mining is also implicated in many social problems, including poor labour standards, the use of child and unfree labour, and in some cases social conflicts and civil wars.

Critical materials face a number of security challenges distinct from those affecting other bulk commodities.

Political risks are the most prominent security challenge. As scarce, essential and monopolised resources, critical materials have considerable value in international politics. Producing governments can use them as leverage in diplomatic exchanges, by placing conditions on which customers have access, on what regulatory terms, and at what price. While this can occur in all resource industries, it is highly pronounced for critical materials. As Figure 5 shows, they are far more monopolised than other bulk commodities, and there are often few or no alternates to buying from the world's dominant supplier. This grants the dominant supplier considerable power to dictate the terms for trade and investment, and potentially extract diplomatic side payments in exchange for allowing access. It also 'politicises' the operation of international markets, as trade and investment flows are influenced by political negotiations between governments rather than market dynamics.



FIGURE 5 TOP-5 MARKET SHARE FOR SELECT BULK COMMODITIES AND CRITICAL MATERIALS, 2017

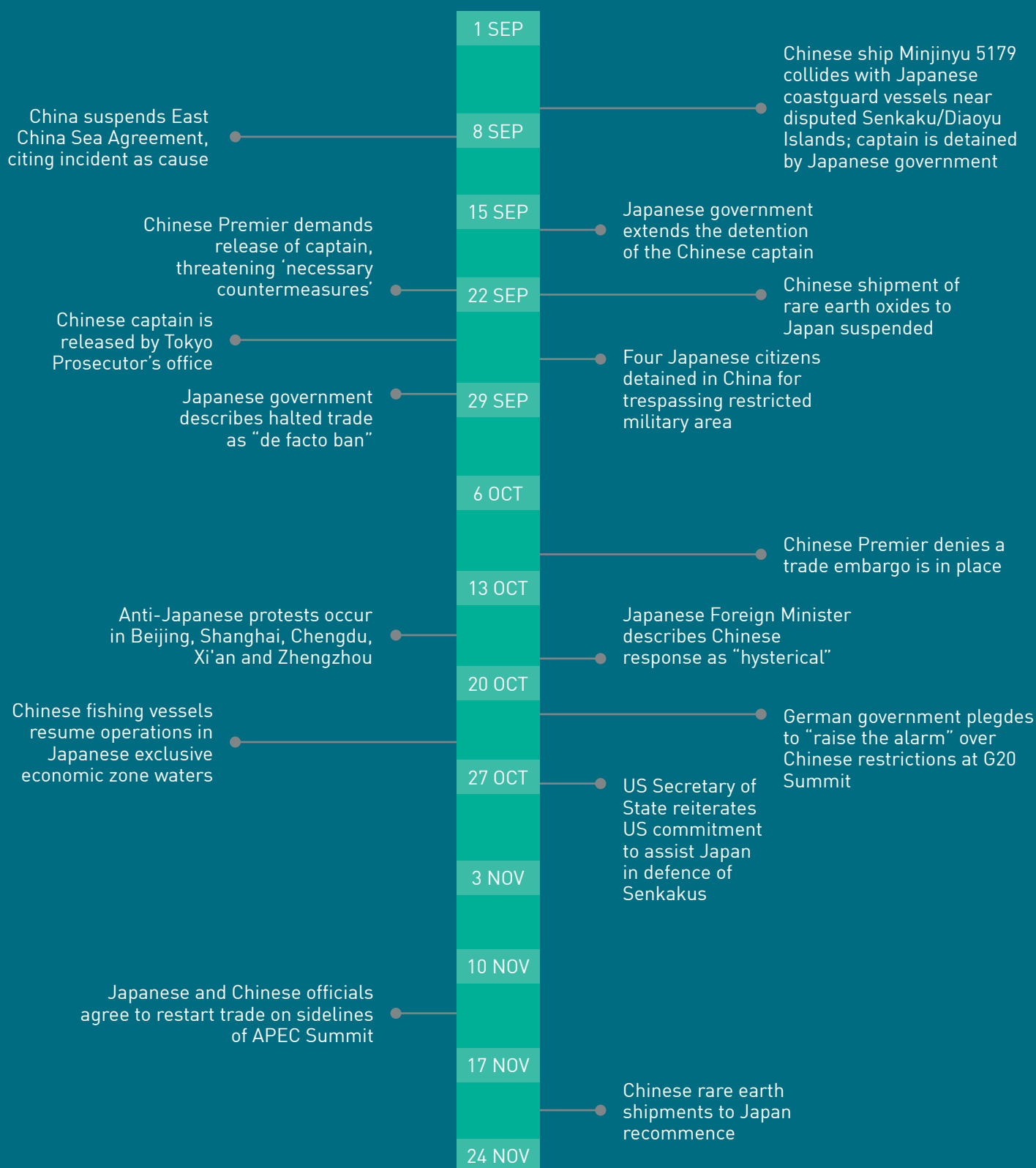


Source: Author's calculations, from BP and USGS¹⁹.

One of the most prominent political risks is posed by the use of the so-called 'resource weapon'. This is a type of economic sanction, where a resource-rich government withholds – or threatens to withhold – supply of a commodity in order to extract some kind of concession from a target. In situations where consumers are dependent on a particular supplier for a commodity, the resource weapon can have a powerful coercive effect.

Famous examples include the OPEC oil embargo of 1973¹⁷, and Russia's suspension of gas exports to Eastern Europe states on at least fifteen occasions during diplomatic disputes in the last decade¹⁸. Given the highly monopolised nature of critical materials markets, they make an ideal sanctioning instrument. The rare earth minerals dispute of 2010 was the first time critical materials were used as a diplomatic tool in an international dispute (see Figure 6).

FIGURE 6 TIMELINE OF CHINA-JAPAN RARE EARTHS DISPUTE, 2010



Source: Smith 2014²⁰ and Wilson 2017²¹

A more common political risk is the manipulation of international markets. In complex critical materials value chains, the majority of value-adding occurs in the processing and manufacturing stages of production. Host governments often attempt to capture a greater share of value through distortive policies that mandate a degree of local processing. These can include policies that limit the export of raw materials (such as export taxes, quotas, price controls and licensing schemes) and/or those that enforce local processing (including domestic market obligations of performance requirements for investors). While ostensibly designed as a developmental measure, these policies undermine cross-border value chains by distorting the operation of market mechanisms and deterring investment into the sector. They are also extremely widespread²². According to OECD data, in 2014 governments imposed 2663 export restrictions on industrial raw materials²³.



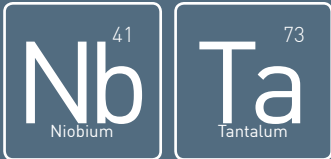

Less common – but considerably more problematic – are ‘resource wars’. These are armed conflicts whose political origins are at least partially connected to disputes over natural resources²⁴. Some resource wars occur due to scarcity, as governments use military means to capture control of valuable assets from adversaries²⁵. Civil wars are another type, which are fought for control of, and/or financed by revenues from, natural resource industries²⁶. Several critical materials are officially classified ‘conflict minerals’ due to their role in fuelling civil wars (Box 2). The most prominent example is the series of civil wars and insurgencies that have raged in the Democratic Republic of Congo (DRC) since the mid-1990s, where armed militias and government forces have repeatedly clashed for control of lucrative critical materials mines. The International Rescue Committee estimates the Second Congo War (officially 1998-2003) caused 5.4 million deaths, making it the deadliest global conflict since the Second World War²⁷. While the DRC is the most prominent example, critical materials are implicated in ongoing civil conflicts across many countries in Asia, Africa and Latin America today²⁸.



BOX 2 WHAT ARE CONFLICT MINERALS?

Conflict minerals are natural resources sourced from conflict zones and politically unstable areas. Their trade can both be a *catalyst* for conflict (as combatants fight for control of resources) and as a factor which *exacerbates* conflict (as a source of finance for armed groups). Their production often involves the use of child and/or unfree labour, and can support corruption and money laundering.

US and EU law formally defines four conflict minerals:

01  CASSITERITE (tin)	02  WOLFRAMITE (tungsten)	03  COLTAN (niobium and tantalum)	04  GOLD ORE
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Companies which trade in these minerals are legally required to undertake a due-diligence process to trace their supply chains, and ensure they respect human rights and do not contribute to conflict. The OECD has published best practice guidelines to assist companies in undertaking this due-diligence.

Two additional minerals – **cobalt** and **diamonds** – are also included in some definitions of conflict minerals. While not formally covered by EU or US law, their extraction is also frequently a factor in civil wars and conflicts in central and eastern Africa.

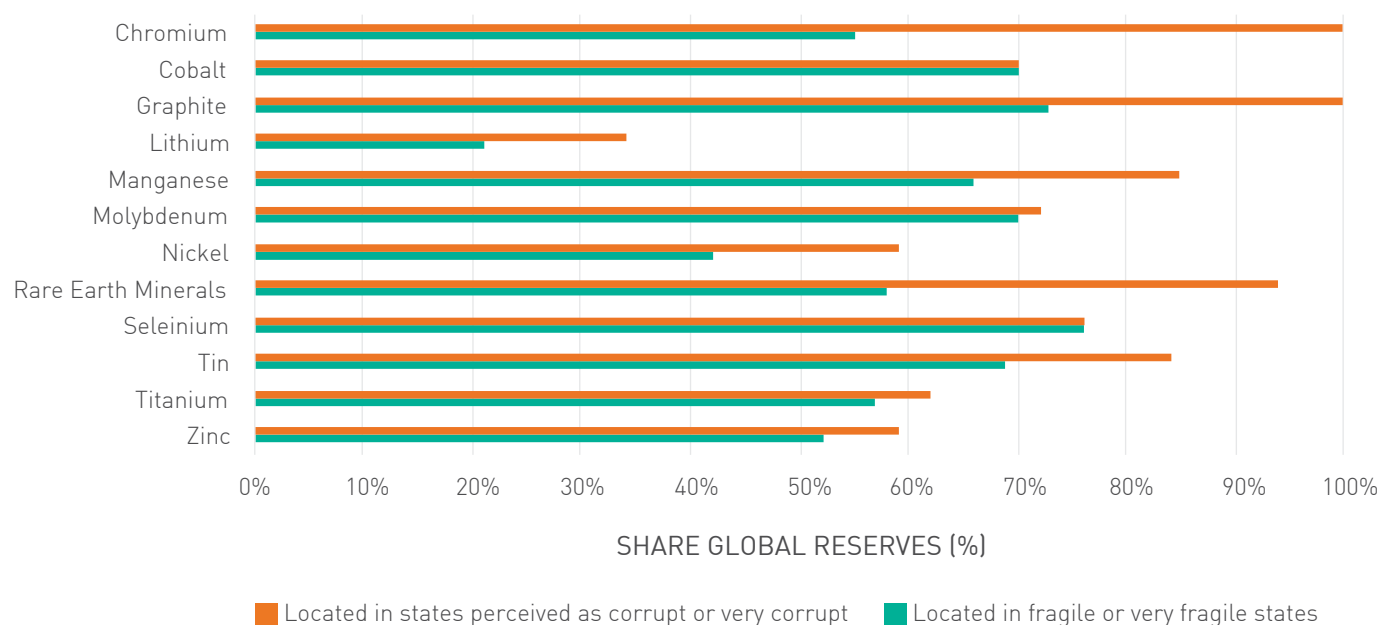
Complex social and environmental challenges also threaten the critical materials supply chain.

The countries that are rich in critical materials often have poorly developed political institutions, and fall towards the lower end of international rankings of political stability and corruption perceptions (Figure 7). These low rankings are indicative of under-developed regulatory regimes and poor-quality governance, which frequently leads to adverse social and environment impacts from mining activities.

Critical materials mining in these countries is presently economical due to these regulatory and institutional standards, which enable very low production costs. However, the environmental and social costs it imposes on mining communities are frequently devastating.

Poor social and environmental standards are subsidising the low price of critical materials for end-use consumers.

FIGURE 7 POLITICAL INSTABILITY IN CRITICAL MATERIALS-RICH COUNTRIES



Source: Church and Crawford 2018²⁹

Labour standards are a widespread concern. In the DRC's 150,000 artisanal mines, labourers work for as little as 65 cents a day with only hand tools, a lack of safety equipment, and minimal oversight³⁰. A lack of food for DRC coltan miners has seen a 77 percent drop in the endangered Grauer gorilla population, as workers are driven to hunt them for bushmeat³¹. The risks associated with artisanal mining extend to the general population, with doctors from the city of Lubumbashi discovering lead, cadmium and uranium, and cobalt levels in urinary concentrations to be five, four, and forty-three times higher than the general population³². Child labour is also widespread, with 40,000 children estimated to be working in artisanal mines in the DRC alone³³. Recent research from Verisk Maplecroft has identified three of the eight top tin producing countries were found to be at 'extreme risk' of child labour, while five were categorised as 'high risk' for forced labour³⁴.

Waste management is a key environmental and public health problem. The amount of critical materials used in final goods is only a tiny fraction of the raw materials that are mined.

For example, for every tonne of rare earth oxide some 2000 tonnes of waste are produced, some of which are radioactive due to the co-occurrence of uranium and thorium³⁵. Without adequate infrastructure, these toxic by-products are difficult to manage. The illegal dumping of waste produced by manganese mining in Xiushan, China has polluted waterways, affecting the drinking water of nearby towns and drastically reducing crop harvests. Many mining towns in Russia and South Africa that produce Platinum Group Metals are plagued by dust pollution, which initially coats houses and crops before making its ways into water supplies³⁶. The world's largest rare earths mine – Bayan Obo in Inner Mongolia, China – has accumulated a massive tailings dam known informally as the 'Baotou toxic lake'. Only ten kilometres from the upper waters of the Yellow River, and containing over 150 million tonnes of highly toxic and radioactive tailings, it has become an international *cause célèbre* for the social and environmental costs of critical materials mining³⁷.



These environmental and social problems often spill over into broader societal conflicts. Communities living near potential mining sites are often subject to violence and forced removal, causing discord between companies, governments and local populations. The *Salar de Atacama* salt flat in Chile is of great importance to the local indigenous Atacamas people, but is also part of the South America's 'lithium triangle', which holds 54% of the world's lithium resources³⁸. Disputes between mine operators and indigenous peoples have arisen over the share of profits returned to communities, displacement traditional lands, and the exacerbation of water shortages³⁹. These issues frequently occur across critical materials value chains. Tribal communities in South Africa's platinum districts have protested against the misallocation of royalty payments from large mining firms⁴⁰; while the expansion of the giant Carajas mine in the Brazilian Amazon has seen clashes with indigenous populations removed from cleared rainforest areas⁴¹.

The impact of these environmental and social challenges extend well beyond local mining communities and their countries.

Until recently, global companies in the electronics and technology sector had little knowledge of whether their critical materials were sourced from environmentally problematic and/or conflict-prone suppliers. As public awareness has increased, many companies and civil society groups have begun efforts to address these problems. These private-sector initiatives all aim to first trace value chains back to the origins, and then develop strategies to improve their environmental and social standards.

The most prominent private-sector initiatives include:

- **Kimberley Process** (2000)⁴² – a certification scheme designed to help companies and governments eliminate the production and trade of conflict diamonds.
- **Extractive Industries Transparency Initiative** (2003)⁴³ – a set of standards that requires countries to publish timely information about their resource governance, now adopted by 51 countries.
- **Responsible Minerals Initiative** (2008)⁴⁴ – a private-sector initiative which shares information, develops resources and provide third-party audits to ensure responsible sourcing of mineral products.
- **IRMA Standard for Responsible Mining** (2018)⁴⁵ – a set of corporate standards and associated certification scheme to ensure business integrity and social and environmental responsibility in mining projects.

Amongst tech companies, Apple has been a leader in ensuring that its value chains do not include conflict minerals. Since 2016, Apple has named its cobalt suppliers in annual *Supplier Responsibility Progress Reports*, and engaged with upstream companies to address environmental, labour and conflict standards⁴⁶. Both Amnesty International⁴⁷ (regarding labour standards) and the Enough Project⁴⁸ (for conflict minerals) have commended Apple as an industry leader in addressing social problems within the critical materials industry. Many other global tech firms – including Google, HP, IBM, Intel, Microsoft and Samsung – have adopted supply chain responsibility frameworks of some form⁴⁹.

While corporate-led responsibility frameworks vary in terms of ambition and implementation, they attest to an increased awareness of social and environmental imperatives.

However, tracing complex value chains is an arduous task. While companies may commit to improving supplier responsibility, the opaque structure of contemporary critical material value chains complicates these efforts. In many countries, raw materials from artisanal- and industrial-scale mines are combined in local trade networks, making it extremely difficult to undertake end-to-end audits of supply chains. The presence of corruption and local conflicts imposes further barriers to collecting reliable information on social and environmental conditions⁵⁰. Thus, while these private-sector initiatives are an important first step, substantively eliminating problematic supplies from the value chain is arguably beyond the scope of companies and civil society groups alone.

There is a pressing need for governments to support the development of new critical materials supply networks that enable transparent and traceable auditing from mine site to final production.

4. STRATEGIES FOR SECURING THE CRITICAL MATERIALS VALUE CHAIN

Fortunately, the challenges facing critical materials value chains are receiving attention. Critical materials are already an essential component of contemporary economies, and will continue to grow in importance as new digital and clean energy technologies diffuse around the world. Yet existing value chains are not up to the task. Political risks mean they do not provide the supply security needed by consumers in the technology sector; while social and environmental challenges mean they are failing to deliver developmental benefits for governments and communities in producing countries. Many governments have recently launched critical materials initiatives that aim to develop new value chains that better meet the needs of both consumers and producers.

The most prominent examples include:

- The EU's **Raw Materials Initiative** (2008)⁵¹. Reflecting the importance of critical materials to European technology firms, this three-pronged strategy aims to ensure fair and sustainable supplies from global markets; better develop critical materials industries within the EU, and promote efficiency within the value chain.
- Japan's **Strategy for Ensuring Stable Supplies of Rare Metals** (2009)⁵². Responding to risks associated with dependence on Chinese supply, this policy aimed to sponsor the development of new suppliers in third countries, promote recycling and the use of alternative materials, and maintain stockpiles of the most critical materials.
- The US Department of Energy's **Critical Materials Strategy** (2010)⁵³. Focused on critical materials for the energy sector, this aimed to strengthen the supply chain through interrelated research and international partnership initiatives.

- China's **Situation and Policies of China's Rare Earth Industry** (2010)⁵⁴. Recognising the environmental challenges facing the Chinese rare earths mining, this policy sought to rationalise the sector, modernise mining and processing technologies, and institutionalise environmental protection measures.
- India's **Critical Non-Fuel Mineral Resources for India's Manufacturing Sector: A Vision for 2030** (2016)⁵⁵. Recognising the importance of critical materials for the growth of India's nascent manufacturing sector, this strategy calls for upgraded institutional capacity, the promotion of local processing firms, and the development of international partnerships.
- Australia's **Critical Minerals Strategy** (2019)⁵⁶. Principally a producing rather than consuming economy, Australia's efforts have focused on identifying the critical materials in which it could contribute to value chains, and developing policy frameworks to attract investment, spur innovation and develop supporting infrastructure."

These initiatives promise a much-needed change in the way which critical material value chains are organised.

They not only reflect a growing awareness to the political, economic, environmental and social problems affecting these minerals, but also commit governmental resources to building more sustainable and secure alternatives.

Yet, given differences between these countries' endowments, needs and institutions, there is considerable variation amongst the approaches they have adopted. There are five distinct strategies that governments have employed to improve the security of value chains (Figure 8).



Lithium evaporation ponds, Salar de Atacama, Chile.
Source: NASA Visible Earth

FIGURE 8 SUPPLY SECURITY STRATEGIES FOR CRITICAL MATERIALS



Criticality studies are the simplest and lowest-cost strategy. These involve undertaking economy-wide surveys to ascertain the specific raw materials used by industry, and then investigate and measure the supply risks posed in their value chains. Many governments – including the US, EU, Japan, Korea, Australia, and India⁵⁷ – have either undertaken or sponsored criticality studies which identify the specific minerals posing supply security risks. These studies serve important informational functions: raising awareness amongst businesses and policymakers of critical materials risks, and enabling the design of targeted policy interventions. Their role is purely informational, however, and findings must be translated into concrete policies if they are to improve value chain governance.

Emergency stockpiling can insure against supply interruptions. Governments and/or the private sector purchase and store stocks of critical materials, which are released if imports become unavailable due to restrictions from foreign governments and/or a failure in supply chains. At present, only the US⁵⁸ and Japan⁵⁹ maintain critical materials stockpiles. Emergency stockpiles are of most relevance for strategic users in the defence sector, as they ensure that supply will continue to be available during a time of crisis. However, the cost of maintaining these stockpiles is high – the US National Defense Stockpile presently holds \$1.2 billion of critical materials – and are not a cost-effective solution for economy-wide needs beyond the defence sector. Moreover, while they provide temporary protection against supply interruptions, they do nothing to address the underlying problems that lead to interruptions in the first place.

Efficiency measures are widely used to offset a country’s exposure to critical materials risks. These reduce demand-side pressures by investing in R&D to promote more resource-efficient processing, improve the rate of critical materials recycling, and where possible develop substitute technologies. They also reduce environmental burdens by lowering the volume of raw materials needed. Every country with a critical materials strategy has included efficiency measures in its policy package, typically delivered through national research agencies and/or industry and university partnerships. The inherent limitation of efficiency measures is that they *lessen*, but cannot *eliminate*, the need for primary raw minerals.

As demand for critical materials grows in the 21st century, criticality studies, stockpiling and efficiency measure will prove insufficient to meet supply needs.

Investment promotion instead focuses on the supply-side. These efforts aim to support new producers entering the market, through sponsorship packages consisting of investment and/or offtake contracts. Investment promotion has the advantage of tackling the core problem facing critical materials – monopolised supply – at its source, by building more diversified value chains that include a broader set of firms and countries. However, due to the commercial risks in developing new critical materials mines, projects often require some form of financial subsidy from sponsoring governments. This is amplified in many of the countries with critical material reserves, whose weak governance frameworks additionally impose a high degree of political risk. For this reason, only the Japanese government⁶⁰ has included investment promotion in its critical material strategy. In the US, a proposed 2010 bill⁶¹ that would offer government loan guarantees to new rare earth mining projects failed to gain the support of Congress.

Diplomatic strategies can also be used to build political support for more secure value chains. In the wake of the rare earths crisis of 2010, consumer governments rapidly began such efforts. Japan primarily focussed on bilateral diplomacy with key suppliers, negotiating agreements to cooperate for the development of new mines with Australia, India, Kazakhstan, Vietnam and the US⁶². The US and EU favoured multilateral diplomacy, using the WTO to challenge Chinese restrictions on the export of several critical materials. Three WTO disputes have been raised against China over trade in twenty-one critical materials, of which two were resolved in the complainants' favour (with the third ongoing). Following the conclusion of these WTO cases, China has agreed to reform certain aspects of its export licensing and taxation policies for critical minerals (see Box 3).

These WTO cases were a landmark development for international trade law relating to natural resources. Never before had governments used the WTO to successfully resolve a trade dispute concerning raw materials. They have also set a precedent in defining what circumstances governments can restrict the export of raw materials for conservation and environmental reasons.



BOX 3 EVOLVING INTERNATIONAL TRADE RULES FOR CRITICAL MATERIALS

Given the importance of trade for the security of critical materials value chains, there have been several recent efforts to reform international trade rules for raw materials. These have principally made use of the Dispute Settlement Body (DSB) of the World Trade Organisation (WTO).

Three recent WTO disputes have concerned raw materials, all of which target Chinese policies on critical materials exports:

DS394/395/398:

Initiated by the US, EU and Mexico in 2009.

Concerns Chinese export duties, quotas, price regulations, licensing requirements and customs administration for bauxite, coke, fluorspar, magnesium, manganese, silicon carbide, silicon metal, yellow phosphorous, and zinc.

DS431/432/433:

Initiated by the US, EU and Japan in 2012.

Concerns Chinese export duties, quotas and licensing requirements for rare earth minerals, tungsten and molybdenum.

DS508/509:

Initiated by the US and EU in 2016.

Concerns Chinese export duties on antimony, cobalt, copper, graphite, lead, magnesia, talc, tantalum, and tin.

In all three cases, the complainants argued Chinese export restrictions constituted a restraint on trade prohibited under the *General Agreement on Tariffs and Trade* (GATT); and were designed to advantage Chinese critical materials processing firms over foreign competitors. They also argued the policies were in breach of product-specific commitments made by China in its Protocol of Accession to the WTO (2001).

China defended its policies as an allowable environmental protection measure. It cited a GATT provision – Article XX(g) – which allows governments to restrict natural resources exports if it is done for conservation purposes. China also argued the conservation rights implied by Article XX(g) overrode its product-specific commitments in the Protocol.

DS394 was resolved in 2012, and DS431 in 2014. In both cases, the WTO DSB ruled in favour of the complainants. It found that Chinese export restrictions functioned principally as an industrial rather than environmental protection measure, and were therefore not protected by Article XX(g). It also found product-specific commitments in China's Protocol overrode the general provisions of the GATT.

Following the completion of the cases, China undertook reforms to its trade policies for these critical materials to bring them into compliance with DSB rulings.

At time of writing, DS508 remains within the WTO dispute settlement process.

Source: Author's summary, from WTO⁶³.



These strategies are an important first step in developing more resilient critical materials value chains. They recognise that existing arrangements fail to provide security for either producers or consumers, and commit governmental resources to achieving better outcomes. However, these strategies alone are not sufficient to ensure secure and sustainable value chains. There is because of:

- **An emphasis on supply security, with less attention to social and environmental concerns.** Originating from consumer governments, these strategies all seek to improve the reliability of critical materials supply to industrial end-users. Yet notably absent are mechanisms for reforming value chain governance to deliver better social and environmental outcomes in the producing countries themselves. This agenda remains the preserve of private initiatives by corporations and civil society groups, who have less capacity to inculcate responsible governance arrangements.
- **Limited willingness of governments to incur financial costs.** The more impactful strategies – particularly investment promotion and stockpiling – impose financial costs on governments. While many have proven willing to undertake low-cost criticality studies, only the Japanese government has gone on to enact the full range of available policies. A broader commitment to reform, and the financial costs it entails, will be required for new value chains to be constructed.

- **A focus on raw materials supply, rather than an integrated value chain approach.** Most strategies aim to either secure raw critical materials at their source, or reduce consumers' exposure to raw material supply risks. Yet given the complexity of critical materials value chains, the security and sustainability of intermediate processing stages are equally important. Integrated approaches, which adopt a whole-of-value-chain perspective, will be needed to plan and create new critical materials industries.
- **The existence of reliable and competitive suppliers.** Despite these strategies being in operation for several years, most critical materials remain subject to very high levels of monopoly (Figure 3). It is imperative that new countries are brought into the market, to ensure the depth and diversity required for secure value chains. Finding reliable partners with appropriate governance frameworks, and developing packages for cost-competitive project development, will be critical in realising these ambitions.

5. AUSTRALIA AS A CRITICAL MATERIALS PARTNER

Australia has a key role to play in global efforts to build better critical materials value chains. The principal challenge facing critical materials consumers is to bring new suppliers into the market that are more secure and sustainable than existing options. Prospective entrants will need to meet several criteria.

- Politically, they will need to offer a secure and reliable source of supply, which can help diversify value chains and deepen international markets.
- Economically, they will need to possess the resource endowments and processing technologies required to offer cost-competitive products to downstream consumers.
- Institutionally, they will require robust and transparent governance frameworks that deliver strong social and environmental outcomes.

Australia is one of few countries that meets all the required criteria. Australia's critical materials potential rests on its world-class resource endowments. The unique geology of the Australian continent means the country is rich in many high-quality and easily exploited mineral resources.

Recent studies by the Australian Government have identified a number of critical materials with significant development potential (Table 2). Of the thirty critical materials identified in this report, thirteen are classified as having high developmental potential, and a further eight have moderate potential. Yet, many of these prospective critical materials industries are not presently active. Only half are currently produced at commercial scale; and Australia is the world's top supplier of only one (lithium).

While Australia has significant critical materials potential, it has yet to turn its geological endowment into a leading position in world markets.



TABLE 2 DEVELOPMENTAL POTENTIAL FOR CRITICAL MATERIALS IN AUSTRALIA

Development potential	Mineral	Production (thousand tonnes)	Australia share world production	Australia share world economic resources
High potential	Chromium			NA
	Cobalt	5.5	4.4%	16.6%
	Gallium			NA
	Germanium			NA
	Indium			NA
	Lithium	14.0	40.3%	11.4%
	Manganese	3200.0	7.3%	12.2%
	Niobium			0.6%
	Platinum Group Metals	0.7	0.2%	0.0%
	Rare Earth Minerals	140.0	11.1%	2.9%
	Tantalum	0.2	16.6%	75.7%
	Titanium	1700.0	13.8%	19.0%
	Zirconium	600.0	25.0%	66.5%
Moderate potential	Antimony	5.5	4.2%	9.3%
	Beryllium			NA
	Bismuth			NA
	Natural Graphite			NA
	Helium	4.0	2.5%	NA
	Magnesium	120.0	1.4%	4.0%
	Tungsten	0.1	0.1%	11.2%
	Vanadium			11.1%

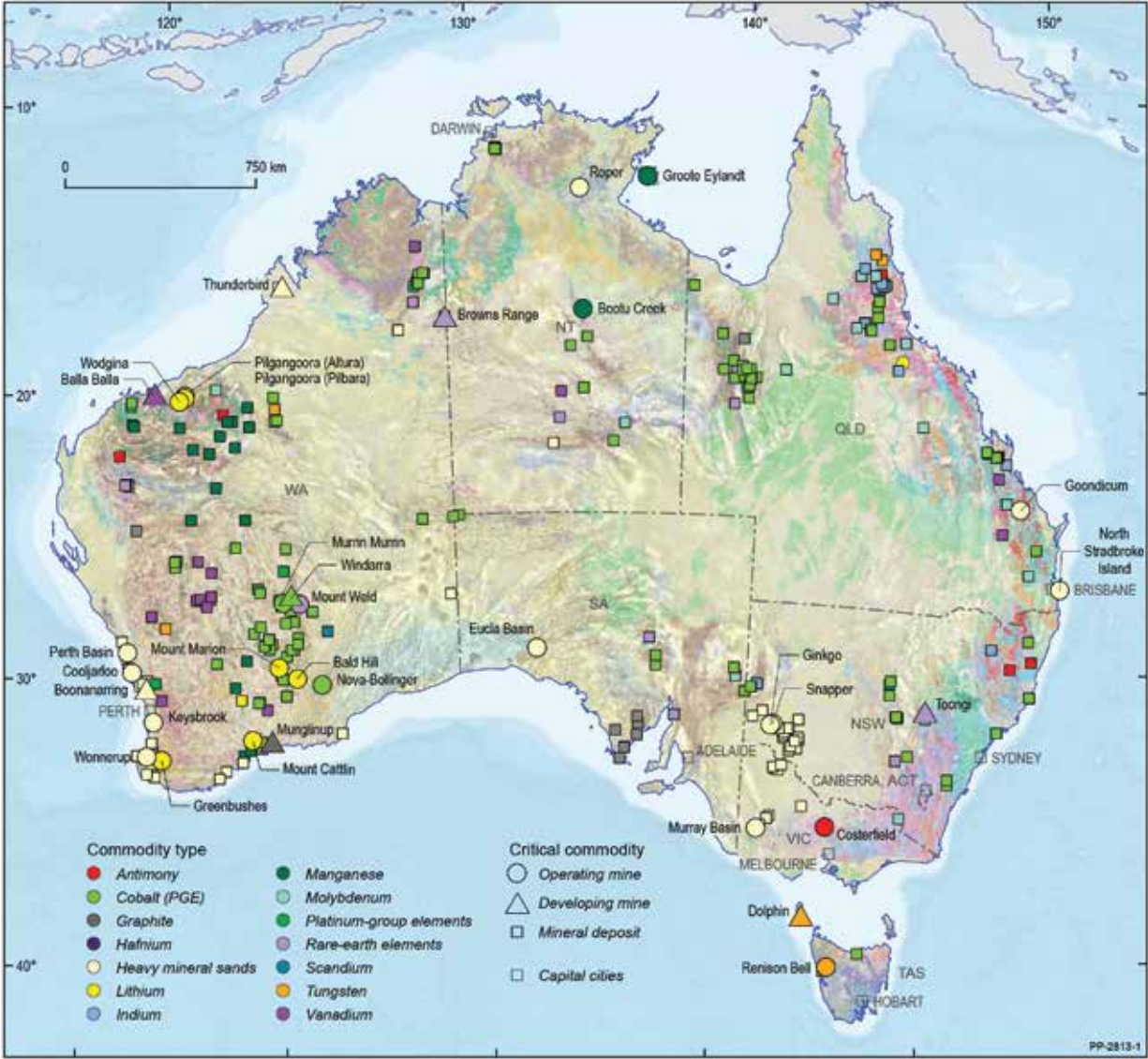
Source: Commonwealth of Australia and author's calculations from USGS⁶⁴

Australia's value proposition as a critical materials supplier extends well beyond its in-ground resources.

It also possesses a large and sophisticated mining sector, with the engineering and business capacity to execute large resource developments. Minerals and energy are a key component of the Australian economy, accounting for 7.5 percent of GDP and some AUD 173 billion of exports annually⁶⁵. It is a world-leading exporter of many bulk mineral commodities, including bauxite, coal, copper, iron ore, natural gas and several base minerals.

Its mining sector expanded rapidly during the recent China-driven 'global resource boom', with AUD 283 billion of foreign investment flowing into the sector in the decade to 2017⁶⁶. As a result, Australia has world-class technical capacity in its mining, engineering, mining services and business development ecosystems. Reflecting these advantages, several new critical materials projects have been launched in Australia in recent years (Box 4).

MAP 1: MAJOR CRITICAL MINERAL OPERATING AND DEVELOPING MINES IN AUSTRALIA



Source: Commonwealth of Australia⁶⁷

BOX 4 NEW AUSTRALIAN PRODUCERS OF CRITICAL MATERIALS



MONAZITE

LYNAS CORPORATION:

A rare earths producer, with special capacity in neodymium and praseodymium (NdPr). The company operates three assets: the Mt Weld rare earths mine near Laverton Western Australia, a co-located concentration plant, and the Lynas Advanced Materials Plant (LAMP) in Kuantan, Malaysia. The LAMP facilities allow the production of semi-processed rare earth oxides, making Lynas the only integrated mining and processing rare earth supplier outside China. Oxide production has steadily grown since commencing in 2012, and totalled 17.7 thousand tonnes in 2017-18. Lynas' growth has been supported by long-standing relationships with Japanese partners Sojitz and JOGMEC, who represent approximately 60 percent of current sales. It also exports to customers in China, Vietnam, South Korea, Europe and North America. Lynas' NdPr products are suitable for permanent magnets used in electric motors, where demand will increase with the dissemination of clean energy technologies.



SPODUMENE

PILBARA MINERALS:

A lithium-tantalum producer, based in Pilgangoora in the Pilbara region of Western Australia. Pilgangoora is one of the most significant hard rock (spodumene) lithium projects in the world, a distinctive source of lithium from the brine-based producers that presently dominate global markets. Construction commenced in January 2017, and the first 'on spec' concentrate production began in August 2018. Pilbara Minerals is supported by a strategic partnership with Korea's POSCO, which includes a long-term offtake and funding agreement, with the additional opportunity to participate in a downstream processing joint-venture in Korea. It also has offtake relationships with three Chinese partners: Ganfeng Lithium, General Lithium and Great Wall Motor Company. These partners mean Pilbara is well positioned to contribute to lithium battery value chains for the emerging electric vehicles industry.

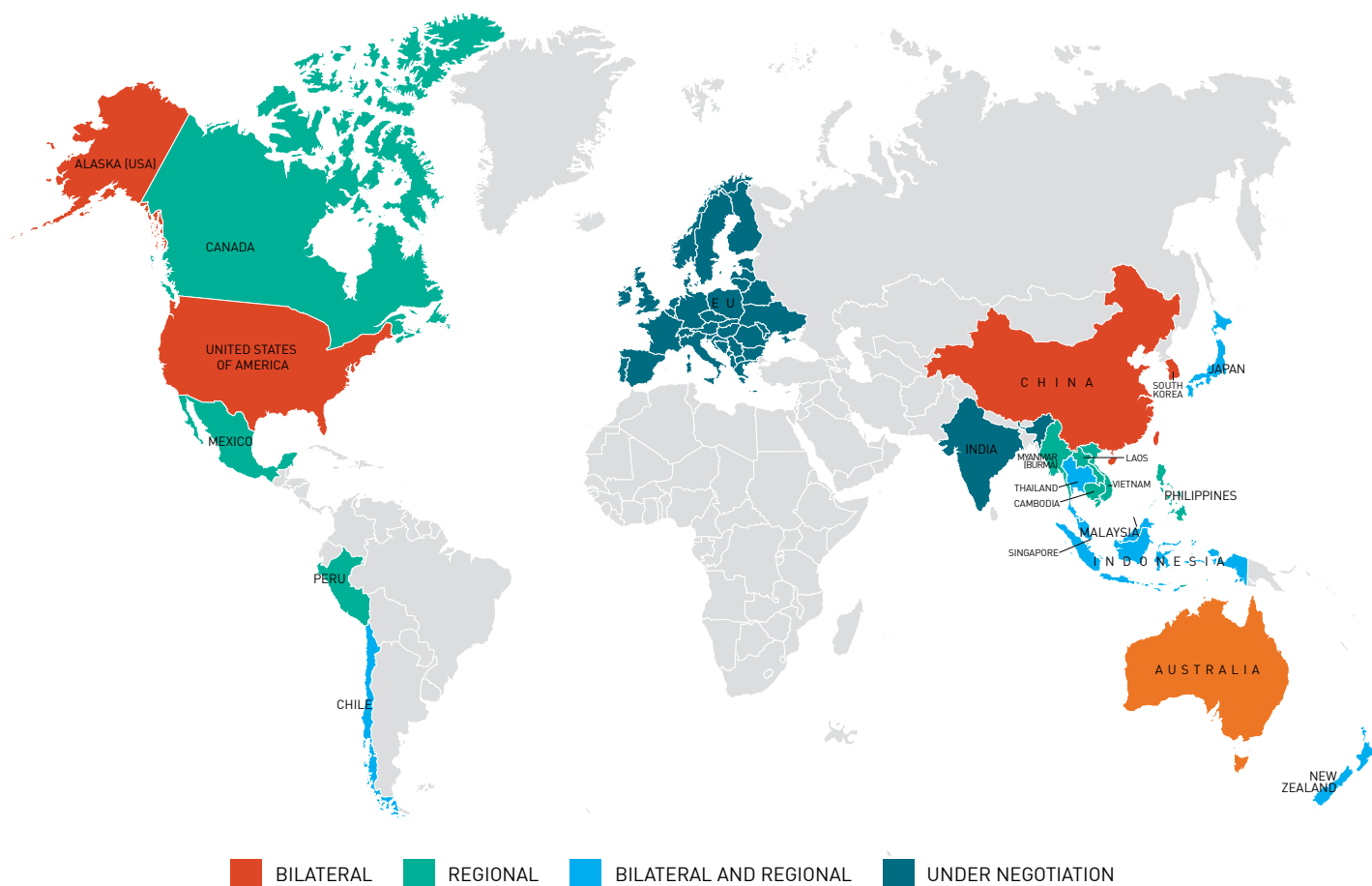


XENOTIME

NORTHERN MINERALS:

A heavy rare earths producer, focussed on the production of dysprosium (Dy). Its Browns Range project in northern Western Australia comprises several mines sites and a pilot processing plant, capable of producing mixed rare earth carbonates. A proposed full-scale expansion will include processing facilities to produce both individual rare earth oxides and DyFe metal. Browns Range is significant as the world's first – and presently only – operational heavy rare earth producer outside China. Northern Minerals secured a Memorandum of Understanding with Sumitomo Corporation of Japan to consider a formal offtake agreement, and is presently engaged with other potential offtake partners to support its full-scale expansion. Substituting dysprosium for neodymium greatly improves the performance of permanent magnets, and is in demand from the electric vehicle and wind turbine industries.

FIGURE 9 AUSTRALIA'S FTA PARTNERS, 2019



Source: DFAT⁶⁸.

Politically, Australia also offers a very reliable investment environment. A consolidated democracy, with strong political institutions and rule of law, it does not suffer the problems of corruption, transparency and political fragility that are present in most other critical materials suppliers. The Australian economy offers a reliable and low-regulation business environment, and presently ranks fourteenth out of 190 countries in the World Bank's Ease of Doing Business survey⁶⁹. Its regulatory framework for the mining sector is especially attractive for investors. Australian governments do not engage in many of the common forms of 'resource nationalism' – such as trade restrictions, foreign investment restrictions, state-ownership or performance requirements – that are common in most other mineral-rich countries⁷⁰. Western Australia, the country's principal resource province and home to the majority of its critical materials reserves, consistently ranks in the top-5 jurisdictions globally for its attractiveness to mining investors⁷¹.

Australia also benefits from longstanding and well-institutionalised economic partnerships with many of the key players in critical materials markets. Its network of free trade agreements (FTAs) is particularly important in this regard (Figure 9). Australia has bilateral FTAs with four of the world's major critical materials consumers – the United States, China, Japan and Korea – and is presently negotiating with India and the European Union. It also has strong trade links across the broader Indo-Pacific through regional agreements: including a plurilateral FTA with ASEAN, and membership of the recently established CPTPP. All of Australia's FTAs include regulatory provisions that protect critical materials value chains, including tariff eliminating, investment protections, and dispute settlement provisions. Its bilateral FTA with Japan also includes a path-breaking resources chapter, under which the governments have committed to cooperate to ensure a stable supply of minerals and energy⁷².

Australia's trade agreements provide a set of intergovernmental instruments that underwrite the security of its critical materials supply.

Finally, Australia offers opportunities to develop critical materials processing facilities. Historically, the Australian mining sector has specialised in supplying raw materials to metals processors in Asia, particularly to the Japanese, Korean and Chinese steel industries⁷³. However, given the complex value chains involved in critical materials production, there is scope to co-locate certain processing activities in Australia.

The most promising of these are in the lithium-ion battery value chain.

- Australia's existing battery minerals capacity – it currently produces 43 percent of world primary lithium supplies – could be leveraged as the foundation for lithium processing industries.
- Australia also possesses many related mineral industries (copper, nickel, cobalt, graphite, manganese and chemical precursors) required in the battery value chain.
- An initial phase would focus on moving 'one step up the value chain' to the processing of lithium hydroxide⁷⁴, where several Australian companies have already begun development efforts (Box 5).
- Longer-term, there are prospects for 'mid-stream' chemical processing for the production of cathodes⁷⁵.

BOX 5 LITHIUM PROCESSING PROJECTS UNDER CONSTRUCTION IN AUSTRALIA

ALBEMARLE CORPORATION:

A US-owned speciality chemicals company, Albemarle is developing a lithium processing plant in the Kemerton Strategic Industrial Area (KSIA) near Bunbury, Western Australia. The plant will process spodumene from the Greenbushes mine to produce lithium hydroxide and a sodium-sulphate by-product. Construction commenced in late 2018, with first production targeted in 2020 before achieving full production in 2025. The investment is valued at over AUD 1 billion. At completion, the plant will process 1 million tonnes of spodumene ore into 100,000 tonnes lithium hydroxide for battery cathode manufacturers.

TIANQI LITHIUM:

A Chinese energy materials company, Tianqi is currently developing its first overseas lithium projects in Western Australia. Located at Kwinana near Perth, its two-stage processing project at completion will produce 48,000 tonnes of lithium hydroxide from spodumene from the Greenbushes mine. First stage construction was completed in late 2018, with second stage work ongoing. The complete project is valued at approximately AUD 700 million. Tianqi's Australian processing plant complements a network of lithium mining, processing and battery manufacturing facilities in Sichuan, Chongqing and Jiangsu provinces, China.

TALISON LITHIUM:

A joint venture between Tianqi (51%) and Albemarle (49%), which operates the Greenbushes mine that supplies spodumene ore to the projects.

6. CREATING 21ST CENTURY VALUE CHAINS

There is pressing imperative to pioneer new approaches to critical materials in the Indo-Pacific. Existing value chains are not fit for purpose for 21st century economies. Raw materials are primarily sourced from production bases with problematic social and environmental results. Monopoly creates shallow and volatile markets, and exposes consumers to political, economic and defence supply risks. Critical materials have also been the subject of diplomatic disputes, politicising trade and undermining the reliability of international markets.

Indeed, these challenges are likely to intensify in coming years. As digital communications further penetrate into developing economies, and the renewable energy transition gathers pace, the demand for critical materials will only increase.

More secure and sustainable value value chains are essential for the Indo-Pacific to fully realise its economic potential.

This will require a step-wise change in how value chains are designed and governed. There is an immediate need to expand these networks by incorporating new raw material producers, which will offer greater diversity and augment market depth and reliability. These new producers must have more robust institutional and governance frameworks, so that better sustainable social and environmental outcomes are achieved. There is also a need for greater transparency within value chains, so that consumers can trace the origins of critical materials have confidence in the conditions under which they were produced and traded.

Australia fits the bill on all counts. It has world-class geological endowments of many critical materials, and a mining sector with the technical and business expertise to execute complex resource projects. It offers one of the strongest institutional environments of any resource-rich economy, ensuring transparency for consumers and reducing risk for investors. The Australian government also has strong political and economic relations with all the key players in critical materials value chains, which can serve as a foundation for building regional partnerships. That several companies have already begun developing projects in Australia is a testament to its strategic importance as a critical materials partner for the Indo-Pacific.

However, more is required if Australia is to realise its full potential. While Australian-based companies have made pioneering steps in the lithium and rare earth industries, the full breadth of its critical materials endowment remains significantly under-utilised. It also currently occupies only a peripheral role in regional value chains: while an important supplier of raw materials, it has yet to develop the intermediate processing industries that connect upstream mineral producers to downstream technology consumers.

Developing a broader set of critical materials industries will benefit both Australia and its partners in the Indo-Pacific.

For Australia, developing new critical materials value chains offers new major new economic opportunities, alongside a platform to strengthen its international links with key trade and investment partners in the region. For the Indo-Pacific, it promises the best opportunity to build secure and sustainable value chains that meet the needs of technologically-sophisticated economies.

To realise these opportunities, there are several steps that governments and businesses should take:

- 1 Recognise that critical materials are not 'just another commodity'.** Unlike other bulk materials, these industries have special and distinctive features. Security concerns, and the strategic imperative to build more diverse and reliable value chains, are one. Environmental and social sustainability is another, as consumers are becoming more concerned with the conditions under which goods are produced. Technological factors are also important, given the complexity of the value chains that convert raw materials into finished products. Developing critical materials industries requires grappling with a more complicated set of issues and challenges than is common in resource project development.

2 Building secure and sustainable value chains will require a long-term approach.

Despite surging demand from the digital and energy sectors, unprocessed critical materials currently trade at very low prices when compared to more-processed final products. These low prices are a direct consequence of poor social and environmental protections at the mining stage of the value chain. High-standard projects which deliver more sustainable outcomes are not likely, at least initially, to be able to fully cost-compete with existing producers. Consumers and investors must recognise that a price premium will be required to bootstrap new project developments, particularly during the start-up phase. Patience and longer time horizons will be required from investors and policymakers if high-standard projects are to successfully make it to market.

3 An integrated value-chain perspective needs to inform project development.

The technological complexity of critical material value chains means their economics more closely resembles that of a manufacturing than mining industry. The need for technical alignment from mining to finished products mean that individual projects do not 'stand on their own', but need to be functionally-integrated within regional networks. The resource development model commonly employed in Australia – which focuses on producing raw materials for commodity export markets at cost-competitive scale – is simply not calibrated to the economics of critical materials value chains. Building trade and investment ties between the up-, mid- and downstream stages of production will be an essential component of new project development. Equally important will be mechanisms for technical integration, such as standard setting, technology transfer and joint research and development efforts.

4 There is a clear role for government in leading change.

Corporate- and civil society-led initiatives have made some positive impacts, particularly over issues such as local mining governance and conflict minerals. However, the opaque nature of contemporary value chains imposes limits to what private-sector efforts can achieve. Moreover, given the geopolitical and defence issues in question, governments cannot leave the security of critical materials supply to the private sector alone. There is a clear need for producer and consumer governments to become more involved in reform efforts, which work to support and enable the private sector to develop new critical materials value chains. While initial steps have already begun, there is room to expand government efforts to better support the development of new mining and processing projects.

5 International partnerships will be essential if these efforts are to succeed.

No one country commands the entire critical materials value chain, with different nations contributing to mining, processing and manufacturing activities. Critical materials inherently involve interdependence between economies, and the need to jointly coordinate and manage industrial integration across borders. As a result, no one country can go it alone when it comes to developing critical materials industries. International partnerships can take many forms, including government-to-government economic agreements, business-to-business linkages through trade and investment, and government-to-business collaborations in the development of new projects. If efforts to build new critical materials industries are to succeed, governments and businesses will need to work with likeminded partners across the region to ensure that critical materials contribute to a secure, sustainable and prosperous Indo-Pacific.

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- 10 This description refers to high-grade hematite, which constitutes 96 percent of Australian iron ore exports. A small number of Australian iron ore mines produce magnetite, which requires a second stage of magnetic separation to remove impurities before export. See Geosciences Australia (2013), *Australia's Mineral Resource Assessment 2013*, Canberra: Geosciences Australia, p. 41.
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ABOUT THE AUTHOR

DR JEFFREY WILSON

Research Director, Perth USAsia Centre

He provides leadership and strategic direction in developing and managing the Centre's research programs across its publications, policy and dialogue activities. He specialises in how transformations in the regional economic architecture – including trade agreements, multilateral organisations and policy dialogues – are reshaping the contemporary economic and business environment of Asia. He has contributed to a range of national and international policy dialogues with the governments of the US, China, Korea, Indonesia, India, Singapore and Australia. He is the author of two books, over two dozen scholarly articles and chapters, and a wide range of policy analyses and reports for both Australian and international audiences.

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t @JDWilson08

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M265, 3rd Floor, Old Economics Building, The University of Western Australia, 35 Stirling Highway, Crawley WA 6009, Australia
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