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ASM
Australian Strategic Materials

REE WHITE PAPER

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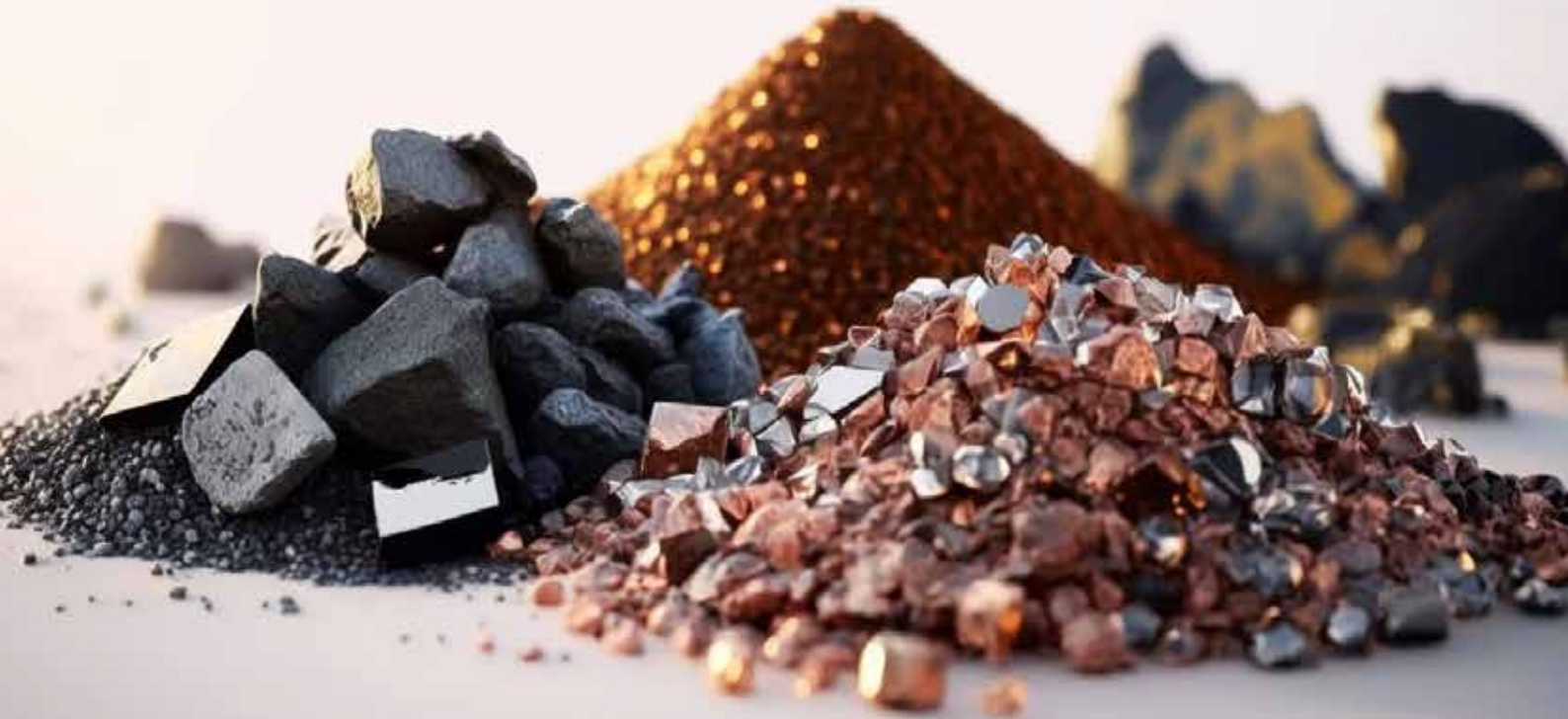


The REE revolution

by Rowena Smith

Rare earth elements (REEs) are playing a leading role in the globally shared ambition to build diverse, resilient and sustainable critical minerals supply chains. With a broad range of end uses – from clean energy technologies and semi-conductors to medical devices and defence applications – the relevance of REEs in supporting a sustainable and secure future cannot be overstated.

As demand for these materials continues to grow, the importance being placed on increasing production and enhancing processing capability is illustrated by the fact REEs appear on the official critical minerals lists of Australia, Canada, the EU, India, Japan, the Republic of Korea, the UK and the US. These strategically developed lists are driving activity within the resources sectors of the relevant jurisdictions and have been the basis for the policies and partnerships developing between those countries with the shared objective of mitigating risk within an existing supply chain dominated by a single jurisdiction.

With a significant endowment of REEs and as an established global leader in the extraction and processing of raw materials, Australia has an essential role to play in the development of this geopolitically sensitive market.

Through engagement and agreements, Australia has taken positive steps to enhance cross-jurisdictional opportunities with countries including the US, Canada, the Republic of Korea, Japan, the EU and Vietnam. These enhanced relationships are looking to develop trade, investment and partnership opportunities within the critical minerals sector but there is still more to be done if we are to fully leverage this generational opportunity.

The 2024 Australian Federal Budget placed an emphasis on Australia's ability to 'add value' to its critical minerals endowment – providing incentives to do more processing activity on Australian shores. It is a commendable ambition and one that one that we should continue to strive for when specifically discussing REEs. But it will not come without its challenges. Delivering on this ambition will require investment and support in both project development and workforce capability.

Rowena Smith, Managing Director & CEO
Australian Strategic Materials

At Australian Strategic Materials (ASM), we are progressing the development of our Dubbo Project in New South Wales. Here we will extract, separate and refine light and heavy REE oxides. Our refining capability has been developed in partnership with Australia's Nuclear Science and Technology Organisation (ANSTO) over many years and represents sovereign technical knowhow and IP integral to the successful delivery of the project and broader growth of this sector.

I hope this publication – developed in partnership with Mining Journal – provides some insights into the compelling nature of the global REE opportunity and why Australia should be positioning itself at the forefront of the revolution.

"Australia has an essential role to play in the development of this geopolitically sensitive market."

What are rare earths?

While more obscure than other mined metals like gold or copper, rare earth elements (REEs) are a quiet achiever that are critical to most people's everyday lives. REEs are a group of 17 elements on the periodic table, comprising the lanthanoids, as well as scandium and yttrium.

The 15 lanthanoids comprise lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium, and occupy the numbers 57-71 on the periodic table. While related, each REE has its own unique chemical and physical characteristics.

REEs are split into two groups, light and heavy, with scandium being the only REE in neither category. The main differentiator is that heavy REEs have a higher atomic weight than light REEs. The light REEs are lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium and gadolinium, while the heavy REEs are terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium and yttrium.

However, consultancy CRU Group classifies europium, gadolinium, terbium and dysprosium as "medium" REEs. Some of the REEs aren't particularly rare but most aren't found in large commercial quantities. For instance, cerium is more abundant in the earth's crust than copper though global REE production pales in comparison with other commodities.

Rio Tinto CEO Jakob Stausholm recently pointed out that the global market for aluminium was 98 million tonnes, the world market for copper was 32 million tonnes, while the world market last year for lithium was 800,000 tonnes. Total global production of all 17 REEs in 2022 was estimated at just 280,000 tonnes.

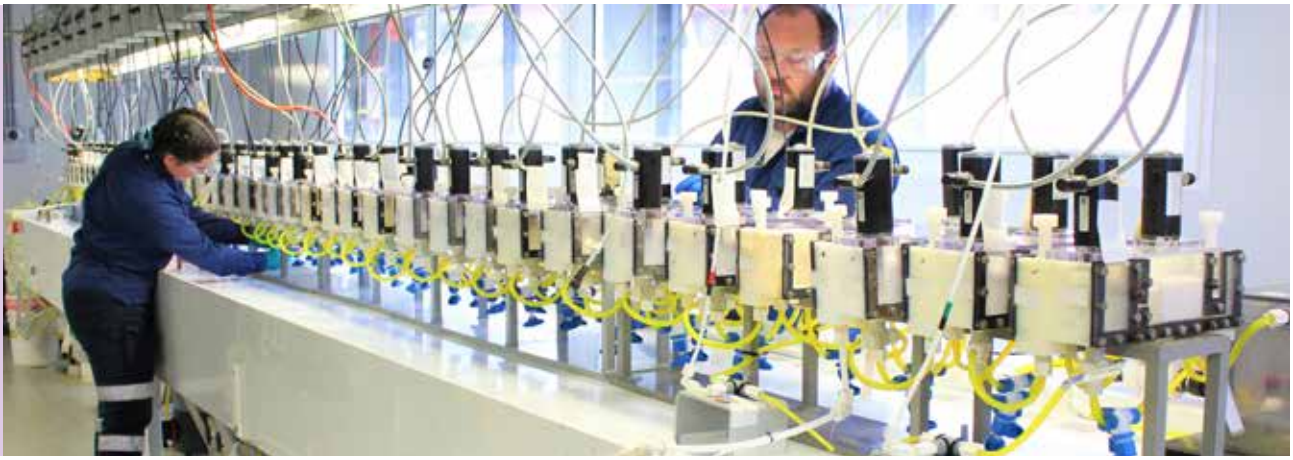
Swedish chemist Carl Axel Arrhenius first discovered the mineral ytterbite, or gadolinite, in 1787, which led to the discovery of REEs. It's said that during a visit to a feldspar mine in Ytterby, he found an unusually heavy dark material, which was sent to chemist Johan Gadolin in Finland for analysis. Gadolin managed to isolate a compound now known as yttrium, which kicked off a more than 100-year journey of the discovery of REEs.

Ytterbite contains eight stable REEs: terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium and yttrium. Cerite hosts cerium, lanthanum, praseodymium, neodymium, samarium, europium and gadolinium. The increased understanding of REEs, developed over many years, has enabled the expansion of their use.

Above:
The Dubbo Project site, NSW

280,000

Total estimated global production in tonnes of all 17 REEs in 2022



What are rare earths used for?

Above: Australia's Nuclear Science and Technology Organisation (ANSTO)

REEs have a wide range of uses and demand is only increasing as the energy transition gathers pace. In the late 1880s, German laboratory chemist Carl Auer von Welsbach became the first person to develop an industrial use for REEs when he invented a gas lamp, which paved the way for REEs to be used in cigarette lighters and car ignitions. In recent years, much of the focus has been on neodymium and praseodymium due to their use in permanent magnets used for electric vehicles (EVs) and wind turbines.

The strength of neodymium-iron-boron permanent magnets makes it the preferred type of magnet for battery and fuel cell EVs, generators of wind turbines, and many military weapons systems. A 3 megawatt wind turbine can contain up to 2 tonnes of REE permanent magnets. REEs play an important role in EVs, but unlike commodities like lithium, graphite and nickel, they aren't in the batteries themselves. Each internal combustion engine (ICE) car is estimated to contain 500 grams to 1 kilogram of REEs via its catalytic converter. A hybrid or EV uses anywhere from 500g to 4.5kg of REEs.

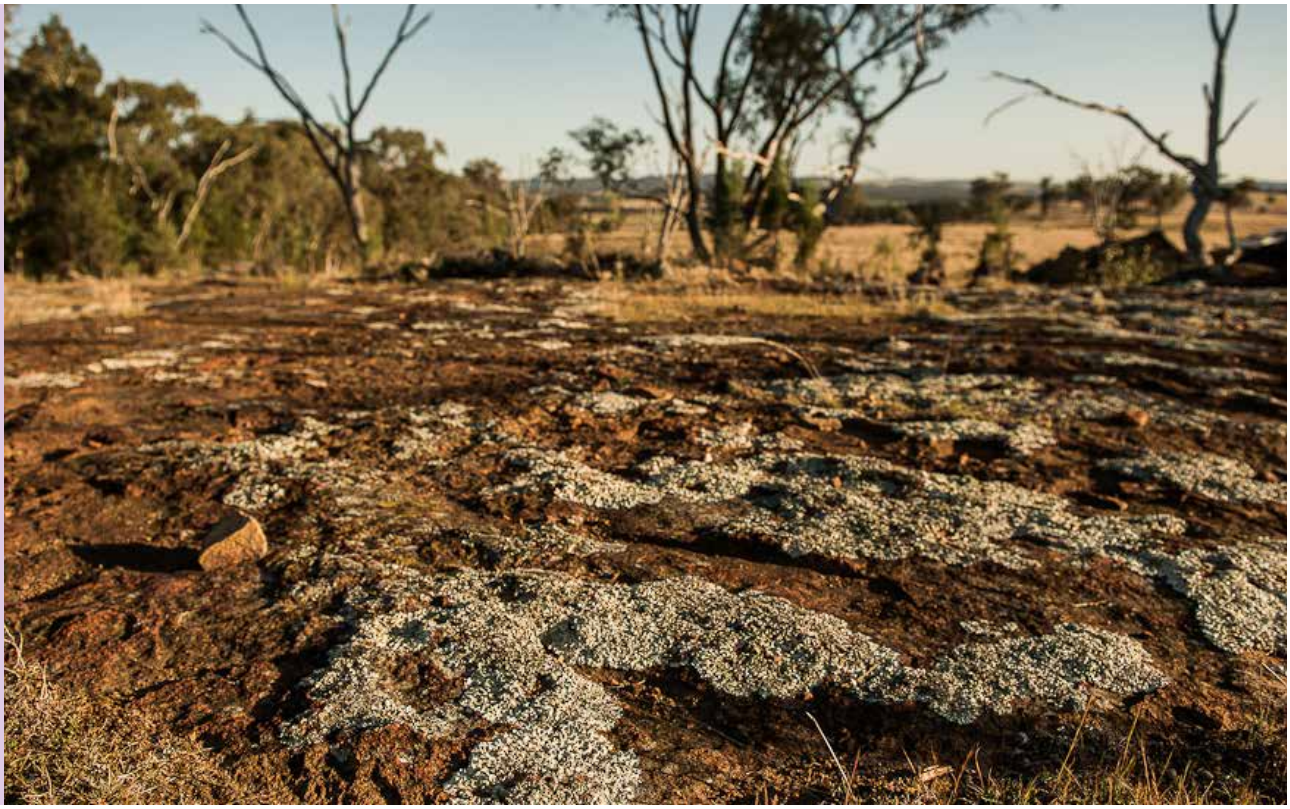
REEs are critically important to the defence sector, highlighting their strategic importance to major global players, including China and the US. Permanent magnets are essential components in the F-35 fighter jets and unmanned aerial vehicles, while lanthanum is used in night vision goggles and terbium is used in naval sonar systems.

Speaking in 2021, Defense Advanced Research Projects Agency director Stefanie Tompkins said REEs were absolutely critical to US defence, given their use in microelectronics ."Microelectronics are really sort of what make all of our different platforms and systems operate the way they do," she said. "But almost everything that really gives it the power and capability of a US defence capability will come from the microelectronics."

REEs including europium, yttrium and terbium are also found in everyday electronics including smartphones, computers, LED lights, televisions, computers and cameras. Apple alone uses nine different REEs – yttrium, lanthanum, praseodymium, europium, neodymium, cerium, gadolinium, terbium and dysprosium – in an iPhone, which accounts for everything from the battery to the screen to the phone's ability to vibrate.

They also have widespread medical use, including in x-ray machines (promethium and thulium) and cancer treatment (gadolinium and ytterbium). REEs are also used in the production of lasers, glass, ceramics, semi-conductors and fibre optic amplifiers. They are also used in the nuclear and oil sectors.

"Almost everything that really gives it the power and capability of a US defence capability will come from the microelectronics"



Where are REEs found?

According to the US Geological Survey, China has the largest known reserves of REEs. Other countries with known deposits of REEs include Vietnam, Brazil, Russia, India, Australia, the United States, Tanzania, Canada, South Africa and Thailand.

Due to an expected increase in demand for REEs, exploration has surged in the past two years, with Australia, Canada, Brazil and parts of Africa seeing increased expenditure.

The economics of an REE deposit depend on its composition and the quantity of high-value REEs it contains.

The major types of ores that host REEs include bastnaesite, monazite, xenotime and apatite. Deposits are generally either magmatic (hard rock) or sedimentary (clay), though REEs can also be found alongside uranium and phosphate.

According to investment firm MST Access, ionic adsorption clay (IAC) deposits in China and Myanmar are the world's main source of heavy REEs currently, estimated to account for 95-98% of global output.

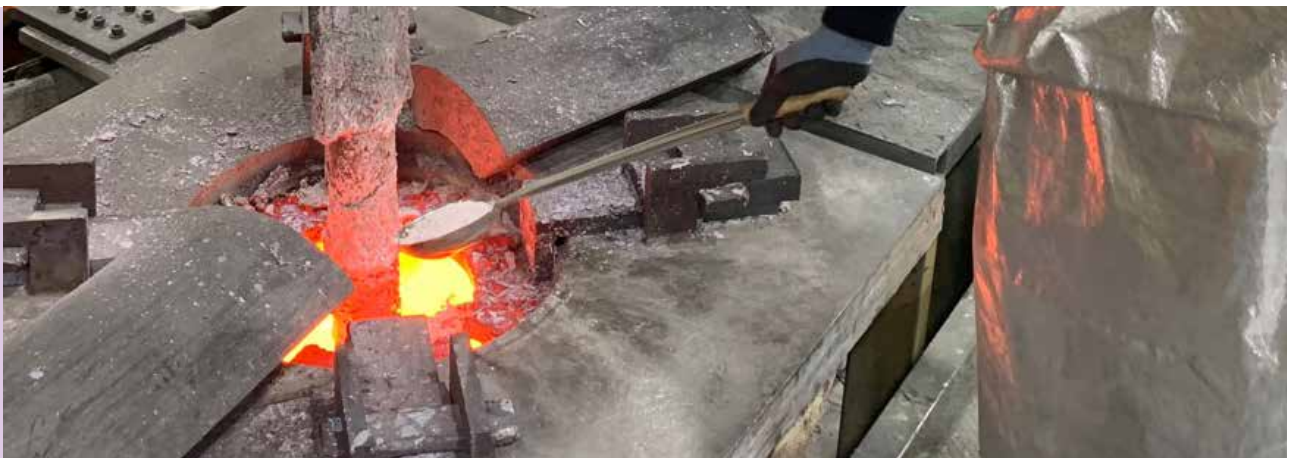
"Despite their low concentration of REEs, the clay deposits of south China are economic because the REEs can be easily extracted at low capital costs from the clays with weak salts and acids, and labour costs are low," MST said earlier this year.

"The IAC deposits are often enriched in high-value heavy REEs and, given chemical precipitate form, have a higher payability than mineral concentrates, providing a superior return."

The extraction of REEs from hard rock deposits employs conventional mining techniques such as open pit and underground mining.

While the extraction and processing of REEs found in hard rock deposits can be more capital intensive than that of their clay counterparts, hard rock deposits typically contain higher concentrations of REEs and often include both light and heavy REEs. This key combination is often a fundamental in making the development of such deposits economically viable.

Above:
The Dubbo Project



Where are REEs produced?

According to CRU, in 2023, China accounted for 68% of REE mine production, followed by the US (12%), Myanmar (11%) and Australia (5%). When it comes to the processing of REEs, the market is much more concentrated.

According to the International Energy Agency, China accounts for 90% of the global market, followed by Malaysia (9%) and Estonia (1%). That makes the REE market far more concentrated than just about any other global commodity market. China has enforced REE quotas since 2006 to manage the supply of REEs. China's Ministry of Industry and Information Technology's production quota for the first half of 2024 is 135,000t, up 12.5% year-on-year and comprising 125,000t of light REEs and 10,000t of heavy REEs. "The quota implies flat RE production half-on-half, but only after China issued a third batch of supply quota in December 2023," Goldman Sachs said.

It is split between two state-owned entities: China Northern Rare Earth Group (95,000t) and China Rare Earth Group (40,000t). "There are now just two Chinese rare earth mining companies, allowing for ease of quota management and price setting," Goldman Sachs said. "Our channel checks suggest that Chinese mine capacity is operating at circa 85-90%, implying some further growth is possible."

"In fact, recent announcements by the Baotou government in Inner Mongolia suggest that CNRE is doubling rare earths refining capacity (plus-110,000t per annum) and starting construction of an additional 15,000t of magnet capacity in 2024."

The Chinese government has banned the export of technology to extract and separate REEs and in December 2023, imposed a further ban of the export of technology to make REE magnets.

REE processing is complex and there are many steps before the ore that is mined winds up as a magnet. Generally, REEs are mined and processed into a concentrate before being sent for further processing REEs are then separated, via cracking and leaching, then made into oxide, refined into metal and then alloyed so they can go into a magnet.

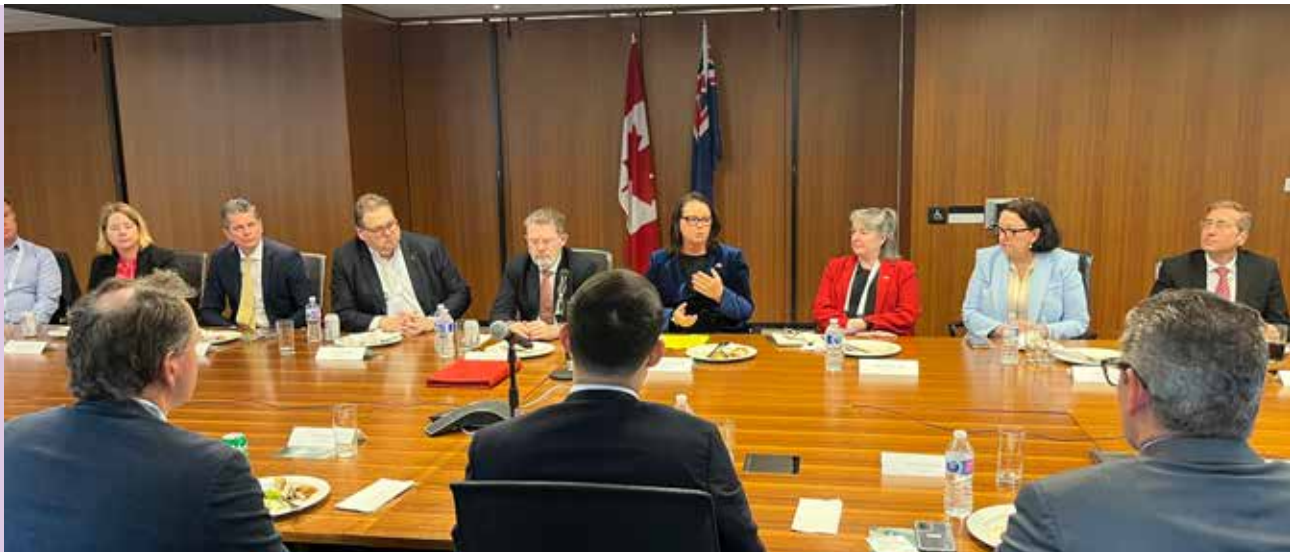
The process is capital and energy intensive, as well as highly technical. Permitting in Western nations can be challenging for any mineral deposit, let alone REEs, which have their own set of environmental challenges due to the chemicals involved and intensity of the processing required. Illegal and unregulated mining and processing in China and Myanmar has caused widespread environmental damage.

Above:
ASM's Korean Metals Plant – Furnace

135,000t

China's Ministry of Industry and Information Technology's production quota for the first half of 2024

"Our channel checks suggest that Chinese mine capacity is operating at circa 85-90%, implying some further growth is possible."



Market dynamics

Goldman Sachs is forecasting a slight drop in demand growth from 10% in 2023 to 5% in 2024 and a modest 2024 surplus of around 4000t of neodymium-praseodymium. "We continue to forecast a slight surplus to balanced market over the medium term, but market deficits over the long run (2027 onwards) based on circa 7% demand growth per annum and our view that Chinese mine production growth slows due to declining grades," the bank said in February.

Unlike the lithium market, where recent price weakness has been driven by weaker-than-expected electric vehicle demand, prices of REEs are not solely driven by EV and battery markets due to their widespread usage. With many European nations putting future restrictions on the sale of ICE vehicles, demand for EVs is set to skyrocket in the next decade.

The composition of minerals in batteries is changing but Australian Strategic Materials managing director Rowena Smith says the REE sector is agnostic. "Rare earths are needed in electric vehicles regardless of the chemistry of the battery," she said.

Compared to other commodities, the opaqueness of the REE market and its pricing means that it is not as well understood or covered by the investment community, though that is beginning to change. Price reporting agency Fastmarkets announced in March that it was adding four REE metal and alloy prices in China and a new oxide price in Europe, in addition to the five RE oxide prices it launched late last year.

The move aims to increase market transparency as REE demand rises. Demand for REEs, particularly neodymium and praseodymium, is expected to rapidly increase as the world decarbonises. Goldman Sachs says the REE market still required strong growth outside China to meet growing demand after 2025. "We believe that over time a western world price index is required to disconnect from the China price, highlighting that REEs is the only global commodity where the price is directly set by China," the bank said.

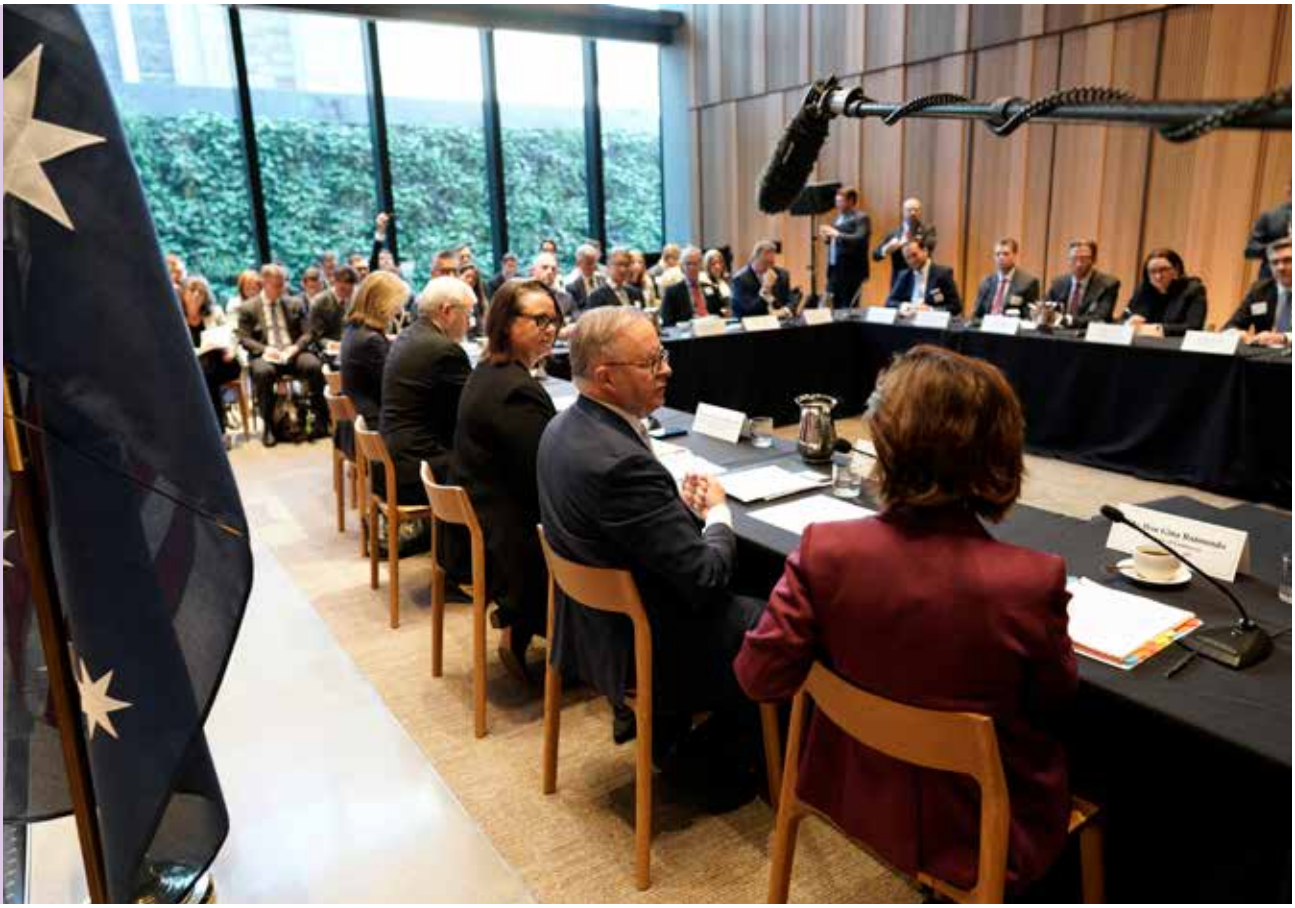
According to CRU, novel technologies, such as robots could significantly increase longer-term neodymium and praseodymium demand due to their reliance on REE-intensive components like motors and sensors. "Rare earths is its own story and it's solid and the demand is going to come," Smith said. "And there aren't that many projects that are actually going to be able to get there in time."

Above: Critical Minerals Session, PDAC 2024

7%

Demand growth per annum of neodymium-praseodymium

"We continue to forecast a slight surplus to balanced market over the medium term, but market deficits over the long run"



Growing strategic importance

Given China's dominance in the REE market, the race to secure supply has become more important to governments as the energy transition ramps up.

Eight countries have critical minerals lists (the US has two) with neodymium, dysprosium and terbium three of only seven minerals to appear on every list. Cerium, lanthanum and praseodymium appear on all but one list, while almost all of the other REEs are on at least five lists.

In November 2023, the European Union reached a provisional agreement on Critical Raw Materials Act, which will prioritise local supply, permitting and recycling. Given the US's large defence industry and budget, it has accelerated efforts to shore up REE supply outside of China.

The US Department of Defense (DoD) has allocated at least US$336 million from the Defense Production Act (DPA) Title III program to onshore REE processing, including US$258 million to Australia's Lynas Rare Earths for the construction of a heavy REE separation facility in Texas and US$30 million for an adjacent light REE separation facility, as well as US$45 million to MP Materials for the construction of a heavy REE separation facility and additional value-add processing capabilities in California.

Gracelin Baskaran, research director for energy security and climate change at the bipartisan Center for Strategic and International Studies in Washington, D.C., told Mining Journal it could take a long time for the US to build up its REE processing capabilities to the point where it substantially reduces its vulnerability to supply constraints. "The first DPA Title III award for a rare earths processing facility only went out in 2020," she said. "That's really recent. Think about the time it takes to build that, to get the operation up and running, and source the feedstock. Mining is a long-term game."

As the US hosts only 2% of the world's REE resources, Baskaran suggested it would have to look further afield.

Above:
Critical Minerals & Industry Roundtable, Washington DC, October 2023

US$336m

The US Department of Defense (DoD) has allocated at least US$336 million from the Defense Production Act (DPA) Title III program to onshore REE processing

"What we need to start thinking about is what commercial diplomacy instruments can we deploy," she said. "It could be a combination of investment, DFC [US International Development Finance Corporation] de-risking and equity. It could be critical minerals agreements that let [partnering countries] benefit from the Inflation Reduction Act, tax incentives, etc."

In March, Australian Strategic Materials received a letter of interest from the US Export-Import Bank for up to US$600 million of debt financing for its Dubbo Project in New South Wales. It follows ASM's participation in Australian trade delegations to the US. Canada has its own strategy on critical minerals, which includes collaborating with countries including Australia.

In April, Canada's official export credit agency Export Development Canada issued ASM with a letter of interest for a direct lending funding package of up to A$400 million for Dubbo.

In Australia, the federal government is also pursuing initiatives to benefit from an expected rise in REE demand. The government recently doubled its Critical Minerals Facility (CMF) from A$2 billion to A$4 billion and provided a A$1.25 billion loan for Iluka Resources to develop a light and heavy REE refinery in Western Australia.

In March, the government announced it would provide a US$550 million debt finance package, via the CMF and Northern Australia Infrastructure Facility, to Arafura Rare Earths' Nolans REE project in the Northern Territory.

The 2024/25 federal budget, handed down in May, also included measures to promote the production of critical minerals, including REEs.

The initiatives included a 10% production tax credit totalling A$7 billion over the decade for all 31 critical minerals to drive local processing in Australia; A$10.2 million for prefeasibility studies to develop critical mineral common-user processing facilities; A$5.8 million for a critical minerals trade enhancement initiative; and A$1 million for a pilot educational program, to strengthen the capabilities of Australia's critical minerals sector to detect, prevent and mitigate foreign interference.

Australian Strategic Materials managing director Rowena Smith said government support was critical for the REE industry. "Most recently, the Australian government has put a lot of focus on making sure that the US and Australian government policies are really complementary and interfacing easily," she said.

"That's an absolutely essential step in getting the supply chains to work across these jurisdictional boundaries, but then also, that enables funding to flow across that supply chain so that Australia doesn't have to fund all of this capital-intensive midstream processing just because it's in situ in Australia."

A$7bn

Federal budget initiatives included a 10% production tax credit totalling over the decade for all 31 critical minerals to drive local processing in Australia

Below:
Critical Minerals US Trade Delegation, Washington DC, October 2023

Equities

The main publicly traded Western players in the REE space are Australia's Lynas Rare Earths and the US' MP Materials. Lynas has a hard rock REE mine, Mt Weld, in Western Australia, and processing facilities in WA and Malaysia. With US government support, it is seeking to build a processing facility in Seadrift, Texas. MP Materials owns the Mountain Pass mine and processing facility in California.

Lynas and MP recently revealed they had previously held unsuccessful merger talks, and billionaire Gina Rinehart has since bought substantial stakes in each company. UBS noted that while there were no operational synergies, a combination would potentially bring additional pricing power outside China and offer increased scale to pursue growth.

Belgian chemical company Solvay produces REEs via its La Rochelle plant in France, which is being expanded. Neo Performance Materials is the TSX's only listed REE producer and has facilities in China and Estonia.

Iluka Resources is primarily a zircon and rutile miner but produces REE-bearing minerals monazite and xenotime via its mineral sands operations. The company is building a A$1.8 billion REE refinery in Eneabba, WA, which will be commissioned in 2026. ASX-listed Australian Strategic Materials is already a producer of REE metals and alloys via its plant in South Korea. ASM is aiming to become the first company to turn ore from its Dubbo Project into metal via its "mine to metals" strategy.

Aside from Eneabba and Dubbo, the other advanced Australian projects, as listed in the government's Critical Minerals Prospectus, are Arafura Rare Earths' Nolans, Northern Minerals' Browns Range, Hastings Technology Metals' Yangibana, Astron Corporation's Donald and VHM's Goschen.

ASM managing director Rowena Smith said the projected demand growth in REEs meant there were room for all of those projects and more and industry collaboration would be key. "How do we work in partnership rather than in aggressive competition with each other?" she said. "Because we will all be stronger for this industry having more than just the one player."

"We will all be stronger for this industry having more than just the one player"

Above:
ASM's Korean Metals Plant Exterior

A$1.8b

Iluka Resources is building a A$1.8 billion REE refinery in Eneabba WA