

19 September 2023

Ford Gets on Board with Landmark Recycling Agreement

NEED TO KNOW

- Recycling plant – Ford, UK Government involved
- Positive drill results at Makuutu – infill drilling continues
- Key minister in Uganda supports licensing of project

Hugely significant agreement for magnet recycling; Ford and UK Government on board: Ionic Rare Earths' (IXR) magnet recycling business has executed agreements with Ford, Less Common Metals (LCM), and the British Geological Survey (BGS) to create a UK-based rare earth supply chain from recycled magnets. IXR's recycling technology will be used to produce traceable rare earths from spent magnets and swarf. These rare earths will be supplied to LCM for alloy production to be converted to permanent magnets for ultimate use by Ford in electric vehicle (EV) production. The UK Government has supported the agreement with two separate grants totalling £2m.

Promising drill results at Makuutu: Exploration results from outside of the current resource show promising results, with 43 out of the 45 holes assayed to date containing clay-hosted rare earths. An additional 31 holes are being assayed. Infill drilling continues within the resource, with the goal of upgrading the resource category to Indicated.

Minister lends support to approval of Mining Licence: The Ugandan Government has approved and gazetted its updated Mining and Minerals Regulations, an important precursor to the grant of the Mining Licence Application (MLA). Uganda's Minister of Energy and Mineral Development has indicated her support for the licensing of the project.

Investment Thesis

Essential elements for the modern economy: IXR is progressing toward becoming an integrated and significant producer of critical and strategic rare earths (REEs), which are essential to green energy and modern technologies. IXR's flagship Makuutu Rare Earths Project in Uganda is well positioned to produce high-value heavy rare earths (HREEs) as a long-life, low-cost asset.

Downstream magnet recycling: IXR's Ionic Technologies subsidiary (100%) has developed processes for separating and recovering REEs from mining ore concentrates and recycled permanent magnets (NdFeB). The proprietary technology efficiently recovers high-grade magnet rare earth elements from diverse magnet grades, contributing to the production of high-performance magnets vital for sectors such as EVs and wind turbines.

Long-term supply chain partnership opportunities: IXR is poised to develop new Western supply chains, integrating mining, refining, and recycling. It has two opportunities in the emerging Western REE supply chain to become a circular producer: it is studying a US refining plant and developing a magnet recycling program in the UK, positioning IXR as a leader in magnet REE recycling.

Valuation: \$0.10/share (unchanged)

Our IXR valuation is unchanged at A\$0.10/share, fully diluted. Our valuation is based on IXR's Makuutu Project, using a discount rate of 12%. We have applied a 75% risk weighting, and assume a lower head grade than what is being forecast in the project's later stages.

Risks

Key risks include delays in the grant of the Mining Licence, an increase in development capital costs; technological risks with processing REEs; and country risks with operating in Uganda.

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Mining and Energy

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Ionic Rare Earths Limited (ASX: IXR) is focused on developing its flagship Makuutu Rare Earths Project in Uganda into a significant long-life, low-cost supplier of high-value critical and heavy rare earths. It also plans to become a refiner and recycler of sustainable and traceable magnet and heavy rare earths.

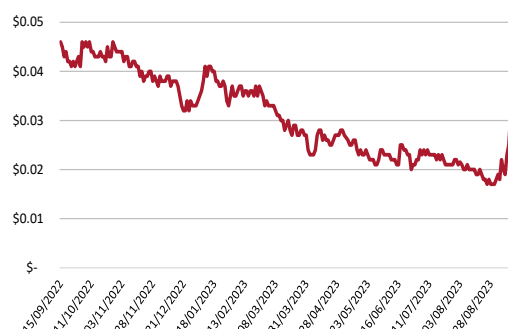
<https://ionicre.com.au/>

Valuation	A\$0.10 (unchanged)
Current price	A\$0.026
Market cap	A\$103m
Cash on hand	A\$11.1m (30 June 2023)

Upcoming Catalysts/Newsflow

3Q2023	Approval of the Mining Licence Application
4Q2023	First product from Makuutu Demonstration Plant
1Q2024	Secure project funding for Makuutu
CY2024	Commence construction of Makuutu

Share Price (A\$)



Source: FactSet, MST Access.

Financial Summary: Ionic Rare Earths Limited

IONIC RARE EARTHS LIMITED							IXR.AX
Year end June 30							
MARKET DATA							
Share Price	A\$/sh					0.026	
52 Week Low	A\$/sh					0.02	
52 Week High	A\$/sh					0.05	
Market Cap (A\$m)	A\$m					103	
Net Debt / (Cash) (A\$m)	A\$m					(11)	
Enterprise Value (A\$m)	A\$m					91	
Shares on Issue	m					3,946	
Options/Performance shares	m					157	
Other Equity	m					1,531	
Potential Diluted Shares on Issue	m					5,634	
INVESTMENT FUNDAMENTALS							
		Jun-21	Jun-22	Jun-23e	Jun-24e	Jun-25e	
Reported NPAT	A\$m	(2)	(5)	(5)	(6)	(2)	
Underlying NPAT	A\$m	(2)	(5)	(5)	(6)	(2)	
EPS Reported (undiluted)	¢ps	(0.1¢)	(0.1¢)	(0.1¢)	(0.1¢)	(0.0¢)	
EPS Underlying (undiluted)	¢ps	(0.1¢)	(0.1¢)	(0.1¢)	(0.1¢)	(0.0¢)	
P/E Reported (undiluted)	x	n/m	n/m	n/m	n/m	n/m	
P/E Underlying (undiluted)	x	n/m	n/m	n/m	n/m	n/m	
Operating Cash Flow / Share	A\$	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	
Price / Operating Cash Flow	x	(66.2)	(28.6)	(15.3)	(25.2)	(79.8)	
Free Cash Flow / Share	A\$	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	
Price / Free Cash Flow	x	(16.2)	(7.2)	(15.3)	(25.2)	(1.0)	
Book Value / Share	A\$	0.01	0.01	0.01	0.02	0.02	
Price / Book	x	4.99	2.12	2.35	1.55	1.58	
NTA / Share	A\$	0.01	0.01	0.01	0.02	0.02	
Price / NTA	x	4.99	2.12	2.35	1.55	1.58	
Year End Shares	m	3,392	3,943	3,946	5,477	5,477	
Market Cap (spot)	A\$m	88	103	103	142	142	
Net Cash / (Debt)	A\$m	11	27	10	59	(77)	
Enterprise Value	A\$m	77	76	92	84	220	
EV / EBITDA	x	n/m	n/m	n/m	n/m	n/m	
Net Debt / Enterprise Value		(0.1)	(0.3)	(0.1)	(0.6)	0.8	
PRODUCTION AND PRICING							
		Jun-21	Jun-22	Jun-23e	Jun-24e	Jun-25e	
CAPEX	\$AUD					(134)	
IXR REO Basket Price (excl. payability)	\$US/kg	51	77	88	96	101	
AUDUSD	:	0.75	0.73	0.70	0.70	0.70	
12-Month Relative Performance vs S&P/ASX Metals & Mining							
Profit & Loss (A\$m)							
		Jun-21	Jun-22	Jun-23e	Jun-24e	Jun-25e	
Revenue		-	-	-	-	-	
Expenses		(2)	(5)	(6)	(6)	(6)	
EBITDA		(2)	(5)	(6)	(6)	(6)	
D&A		-	(0)	(0)	(0)	(0)	
EBIT		(2)	(5)	(6)	(6)	(6)	
Interest		0	0	1	0	4	
Tax		-	-	-	-	-	
Underlying NPAT		(2)	(5)	(5)	(6)	(2)	
Exceptionals							
Reported Profit		(2)	(5)	(5)	(6)	(2)	
Balance Sheet (A\$m)							
		Jun-21	Jun-22	Jun-23e	Jun-24e	Jun-25e	
Cash		11	27	10	139	13	
Receivables		0	1	-	-	-	
Inventory		-	-	-	-	-	
PP&E		-	0	1	1	135	
Exploration		3	12	17	17	17	
Other		4	9	9	9	9	
Assets		18	49	37	166	174	
Creditors		0	1	-	-	-	
Debt		-	-	-	81	91	
Other		-	0	0	0	0	
Liabilities		0	1	0	81	91	
Shareholder's Equity		18	48	44	92	90	
Cashflow (A\$m)							
		Jun-21	Jun-22	Jun-23e	Jun-24e	Jun-25e	
Net Cash From Operations		(1)	(4)	(7)	(6)	(2)	
Capex		-	(0)	-	-	(134)	
Exploration		(3)	(9)	-	-	-	
Other		(1)	(2)	-	-	-	
Net Cash From Investing		(4)	(11)	-	-	(134)	
Equity		16	30	1	54	-	
Borrowings		-	-	-	81	10	
Dividend							
Net Cash From Financing		16	30	1	134	10	
Effects of FX		-	(0)	(0)	-	-	
Net Increase / (Decrease) in Cash		10	16	(5)	129	(126)	

Source: Company data, MST Access.

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Landmark Recycling Agreement: Ford Gets Involved; UK Govt Provides Funding

Refresher on IXR's recycling business and strategy

Ionic Technologies (IXR's 100% owned magnet recycling subsidiary in the UK) has developed IP and processes for separating and recovering REEs from mining ore concentrates, swarf (cuttings and shavings) and recycled permanent magnets. This proprietary technology provides a flexible solution for extracting high-grade rare earth elements from varying magnet grades. It has the potential to provide magnet rare earth oxides (REOs) for the production of modern high-performance magnets, which are integral to sectors such as electric vehicles (EVs) and wind turbines. The recycling business is an important component in IXR's strategy, and potentially the first to generate revenue.

Demonstration recycling plant in Belfast – grant received September 2022

In September 2022, Ionic Technologies received a £1.72m (~A\$2.9m) grant from the UK Government to build a demonstration-scale magnet recycling plant in Belfast, UK. The facility will recycle waste magnets and scrap to produce high-purity REOs, suitable for use in rare earth permanent magnets employed in EVs and offshore wind turbines. IXR expects to produce ~10t of magnet REOs across CY 2023 and CY 2024 as part of the demonstration plant program.

Latest production progress from the demonstration plant

In the June quarter, Ionic Technologies made substantial progress, initiating commissioning, and generating its first magnet REOs at the Belfast demonstration plant. The first batch (from process commissioning) of high-grade magnet REOs included:

- 4.2 kg of Nd₂O₃, grading at 99.7% and ~0.3% Dy₂O₃ (cumulative REO content of 99.99%)
- 0.6 kg of Dy₂O₃, graded at 99.8% (total REO content of 99.9%).

Landmark agreement – Ford gets involved; UK Government chips in

Ionic Technologies has secured a collaboration partnership with Ford and Less Common Metals (LCM) to develop a UK supply chain for recycled magnet rare earths to magnets.

IXR's recycling technologies will be used to produce high-purity REOs from spent magnets and swarf which will then be sent to LCM to produce alloys which are suitable for use in permanent magnets. LCM will then send the alloys to a permanent magnet manufacturer (ex-China) who will produce permanent magnets for the testing in Ford's EV-producing plants.

Final aim of agreement – IXR's recycling technology to contribute to magnets that satisfy Ford's standards

The majority of Ford's European Union (EU) production will come from its UK-based Halewood facility, which Ford plans will produce close to half a million units per annum by 2026.

The aim of the agreement is to ensure that IXR's rare earths recycling technology, once implemented into the rare earths production chain, will lead to a sufficiently high-quality permanent magnet product to satisfy Ford's needs for its EV-producing plants in Europe.

Each stage of the process from magnet recycling to EV testing will generate waste (magnets and swarf), including the magnets used in Ford's EV motors. IXR will recycle this material, thus completing a totally circular rare earth supply chain within the UK.

The verification by Ford of the quality of the magnets produced from IXR's recycled materials would be a significant validation of IXR's recycling strategy.

UK Government grants accelerate the process

IXR will receive approximately £750k in direct cash funding as a result of the grants from the UK Government. The grants represent a strong commitment for the UK government to IXR's recycling facility and, along with the agreement signed with LCM and Ford, accelerate the development path of the company's recycling strategy.

£1m towards the IXR-LCM-Ford partnership: The UK government will support the partnership between Ionic Technologies, Ford and LCM via a £1m grant, with Ionic Technologies announced as the major beneficiary and lead collaborator in the focus on delivering the UK's first domestic sourcing of separated high-purity magnet rare earth oxides (REOs).

A further £1m for recycling feasibility study: The UK government is supporting an additional £1m grant in funding a feasibility study into the construction and supply-side dynamics of a magnet rare earth recycling plant in the UK in collaboration with the British Geological Survey (BGS).

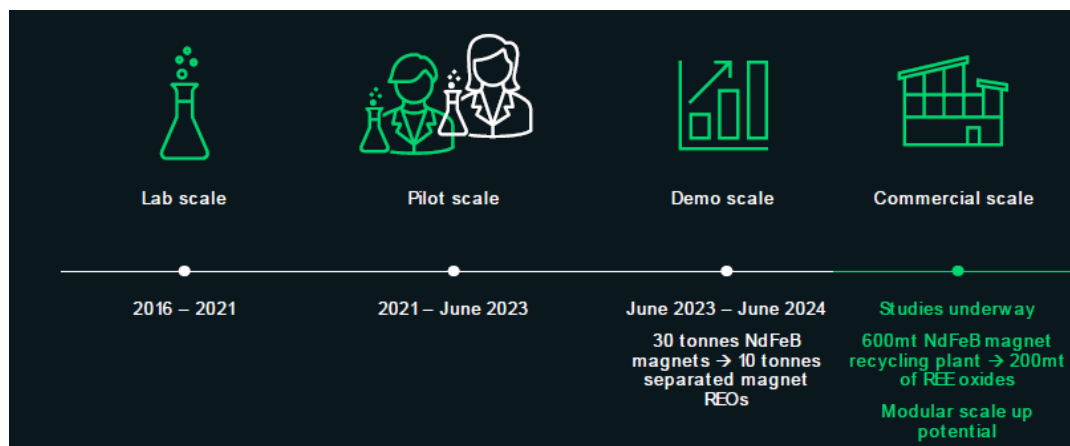
The two grants form part of a broader UK research program

The funding is part of the UK Government's circular critical materials supply chains (CLIMATES) program. This program committed £15m of government funding for cutting-edge research to strengthen the supply of critical materials, and is an important step towards the UK developing key battery materials recycling technology and assisting IXR to commercialise the first magnet recycling facility in Belfast.

IXR recycling fills a strategic need

The IXR recycling plant clearly contributes to meeting a strategic need for the UK, which, like the US, seeks self-sufficiency in regard to the production of rare earths-related products.

Figure 1: IXR's path to recycling commercialisation – getting ready to scale globally



Source: IXR.

Grant of Mining Licence Imminent: Mining Licence Regulations Gazetted; Minister Backs Approval

Mining licence regulations gazetted

IXR was advised in September 2023 that the Ugandan Government has approved and gazetted its updated Mining and Minerals (Licencing) Regulations 2023. This was an important precursor to the grant of the Mining Licence.

This is an important milestone for the Ugandan mining industry and has been a regulatory requirement for the grant of the company's MLA at Makuutu. The company has now finalised the MLA fee payment, which was the final item required by the Ugandan government, clearing the path to an expedited award of the Mining Licence at Makuutu.

The longer-than-expected time to update Uganda's mining regulations has led to extended timelines for their official gazetting and subsequently, the approval of Makuutu's Mining Lease Application (MLA) for RL 1693 (TN03834). However, IXR believes that the time and care taken in legislating Uganda's new mining regulations show that the government is intent on securing the right balance between growing the economy and ensuring sustainable mining practices.

Minister backs Mining Licence approval

The Hon Dr Ruth Nankabirwa Ssentamu, Uganda's Minister of Energy and Mineral Development, has backed the granting of the Mining Licence. She has stated that 'Uganda is committed to the development of its mining sector, in line with the Mining and Minerals Act 2022, and its 2040 Vision. Under this new framework, we look forward to granting approval of the mining licence application to Ionic Rare Earths. This is a flagship project to establish Uganda as a strategic partner in global supply chains for heavy rare earths'.

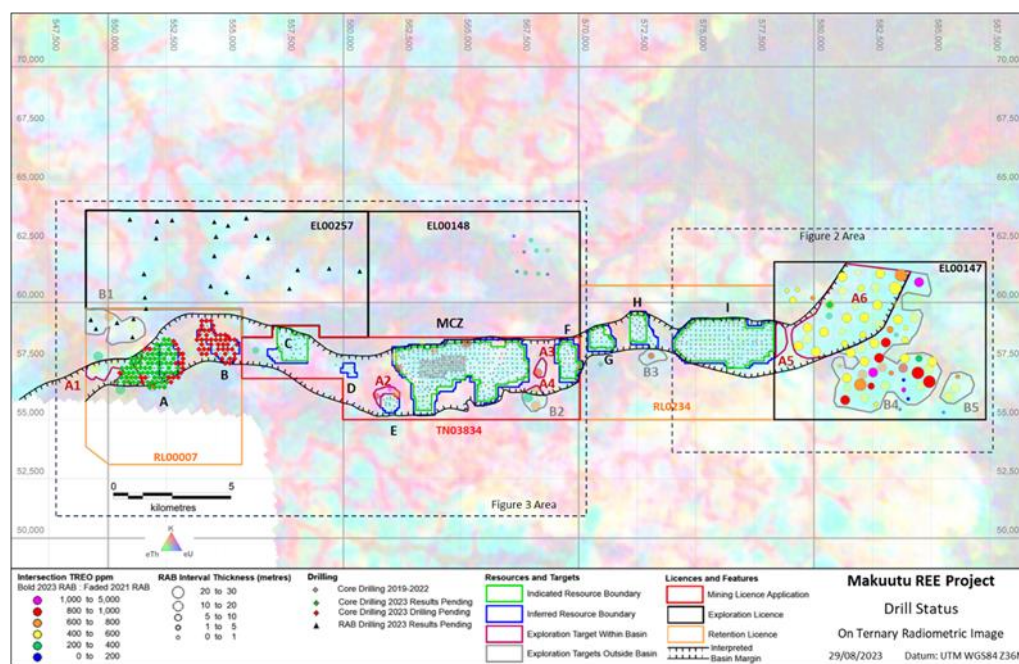
IXR expects the licence to be granted within days.

Excellent Exploration Results Pave Way for Resource Expansion

IXR has been conducting an expansive drilling campaign with three distinct pathways:

- drilling on EL00147, located at the eastern end of the extensive licence holding at Makuutu
- drilling on previously unexplored EL00257 to the north-west of the licence holding
- infill drilling the current Makuutu western resource to move the resource category to Indicated.

Figure 2: Makuutu project drill status plan showing location of recent Phase 5 RAB results and current core drilling program location



Source: IXR.

Exploration Licence EL00147 – strong results add to earlier drilling

This area was previously tested with 1km–spaced RAB holes in 2021. The aim of the 2023 program was to decrease the hole spacing to approximately 500-metre–spaced holes and determine broad trends and zonation of mineralisation.

EL00147 now has confirmed clay-hosted REE in 66 of 70 RAB holes drilled across programs in 2021 and 2023 (43 out of 45 in 2023), on a broad 500-metre spacing. This highlights the massive potential of this exploration target, with these new assays inferring considerable upside at Makuutu.

Results of the most recent drilling include:

- 3 metres at 1,337 ppm TREO from 13 metres
- 10 metres at 1,029 ppm TREO from 5 metres
- 11 metres at 1,013 ppm TREO from 6 metres
- 7 metres at 974 ppm TREO from 6 metres
- 24 metres at 967ppm TREO from 4 metres.

Further work planned on these areas includes metallurgical test work to determine potential rare earth extractions and core drilling to progress to a resource estimate.

Exploration Licence EL00257 – 31 assays pending

Results are pending for the remaining 31 RAB drill holes from the unexplored north-western licence EL00257.

RL00007 – resource infill program to increase resource confidence

Resource infill drilling on RL00007 (Makuutu western zone) is ongoing on the current MRE with the drilling designed to increase resource confidence from Inferred to Indicated status. To date, 78 holes (1,580 metres) have been drilled, and the company expects that the program will be completed in October.

Other Activities at Makuutu: Demonstration Plant Approved, Construction Commenced

IXR received approval from the Ugandan authorities to resume the construction of the Makuutu Demonstration Plant technical facility. We expect that this 780m² site will strengthen IXR's in-country technical ability for metallurgical testing and project validation, helping with project financing and collaborations.

Primary aims include elevating desorption heap stack heights to bolster capital efficiency and production capacity, while also focusing on refining desorption conditions to boost extractions and reduce impurities. Site preparations have advanced, and IXR expects that the facility will be erected within 3QCY23.

Figure 3: Demonstration plant earthworks progressing



Source: IXR.

Refresher on Three-Pillar Company Strategy

IXR has a three-pillar strategy which aims to supply a circular economy of sustainable and traceable magnet and heavy REE products for EVs, offshore wind turbines, communication, and key defence initiatives.

- **Pillar 1: to develop its existing flagship project**, the Makuutu Rare Earths Project in Uganda, to be a long-term, low-cost supplier of high-value magnet and heavy REOs
- **Pillar 2: to develop a potential US-based rare earth refinery** to produce value-added, separated REOs and compounds and cement the company's place in new, ex-China rare earths supply chains
- **Pillar 3: to develop a downstream magnetic recycling business.**

Pillar 1: Flagship Makuutu Project – huge mineralisation with magnet + heavy rare earths

IXR expects its flagship project, the Makuutu Rare Earths Project in Uganda, to become a long-term, low-cost, and sustainable supplier of high-value magnet and heavy rare earth elements. The project has excellent existing infrastructure and is one of the largest known ionic adsorption clay (IAC) deposits outside of China, with the potential to significantly expand.

IACs are a known geology with well understood REE mineralisation and are a key source of global rare earths supply (particularly HREEs). Makuutu's Mineral Resource Estimate is 532 mt at 640 ppm TREO for 340,000t of contained TREOs, underpinning a potential for 50+ years of mine life.

Pillar 2: Rare earth refinery strategy critical to developing end markets

IXR is progressing the development of its own rare earths refinery in the United States to produce value-added, separated REOs and compounds. A scoping study is nearing completion, and the company is now finalising its preferred locations with an expected decision in CY2023. The refinery will produce all 15 rare earths plus scandium. It will play an important role in ensuring IXR will be a key partner and will provide a first-mover advantage in new Western REE supply chains that are still being developed. The refinery will offer IXR and potential downstream partners a unique opportunity to supply the market with critical and strategic separated REOs and compounds that cannot otherwise be obtained outside the Chinese supply chain.

Pillar 3: Recycling rare earth magnets to create a circular value chain

IXR's Ionic Technologies subsidiary has developed processes for separating and recovering REEs from mining ore concentrates and recycled permanent magnets. In September 2022, it received a £1.72m (~A\$2.9m) grant from the UK government to build a demonstration-scale magnet recycling plant in Belfast, UK. The facility will recycle waste magnets and scrap to produce high-purity REOs, suitable for use in rare earth permanent magnets used in EVs and offshore wind turbines.

IXR expects to produce ~10t of magnet REOs in 2023/2024 as part of the demonstration plant program.

IXR is progressing plans now for a UK recycling facility in Northern Ireland with dual market access to the UK and EU, plus links to the US.

Valuation: A\$0.10/Share, Fully Diluted (Unchanged)

Our valuation of IXR is A\$0.10/share, fully diluted, derived from our discounted cash flow (DCF) analysis of IXR's flagship Makuutu Project. We maintain a cautious valuation approach. Our assumptions include:

- Pricing assumptions which we believe are conservative, given the critical status of the Makuutu product basket
- a probability risk weighting of 75%
- a conservative head grade in the later years of the project.

Figure 4 summarises our valuation, using a discount rate of 12%. Our valuation assumes a A\$45m capital raise (60/40 debt to equity for IXR's share of capex) at A\$0.035/share (a 35% premium to the current share price), increasing the share count by 1.53bn.

Our valuation remains unchanged at A\$0.10 however we have revised a number of the components of the valuation:

- Increased the total capex for the project from US\$120m to US\$144m reflecting the continued pricing pressure in the global mining sector.
- Revised the shares issued in the capital raising for the project equity funding reflecting a lower assumed price for the issue.
- Offset by some fixed operating cost leverage for the expansions of Makuutu that we assume in our base case as IXR benefit from economies of scale.

Figure 4: Base-case valuation summary for IXR

Ionic Rare Earths Valuation				
	Discount rate	Risk weighting	AUD\$mn	AUD\$/sh
Makuutu (60%)	12.0%	75.0%	538	0.10
Total operating assets			538	0.10
Corporate/SG&A	12.0%		(30)	(0.01)
Net cash/(debt) (\$AUD)			59	0.01
Net Asset Value			566	0.10
Current Share Price				0.026
Upside				287%

Source: MST Access.

Our key assumptions

The critical assumptions for our valuation are shown in Figure 5. Our base-case NPV valuation is based on a mine plan consistent with Stage 1 DFS, but it assumes a final plant capacity of 15 Mtpa ROM throughput instead of the Definitive Feasibility Study's (DFS) 5 Mtpa. We consider this a reasonable assumption given the resource size (currently: 532Mt @640ppm) and anticipated demand.

IXR must fund its 60% share of the project, requiring US\$75m (~A\$112m). We assume a 60/40 debt-to-equity split (per company guidance) and an equity raising at a price of A\$0.04/share. The remaining three modules (2.5mtpa of additional processing capacity) will be self-funded through Makuutu's free cash flow.

Figure 5: Our Stage 1 DFS assumptions underpinning our base-case valuation

Assumptions (LOM)	MSTe
PROJECT ASSUMPTIONS (Real FY23)	
Project Ownership (%)	60%
Strip Ratio (waste : ore)	0.57
Mixed Rare Earth Carbonate (% REO)	>90%
TREO Average Recovery (%)	35.0%
Average REO Produced - ex. Scandium (tpa)	3,263
Mine Life (years)	35
Pre-development Capex - first module (US\$m) - for 100% (Real)	144
Major project capital - Incl. pre-development (US\$m)	303
Sustaining Capex (US\$m)	19
COST & FINANCING ASSUMPTIONS	
Discount Rate - Nominal (%)	12%
Inflation Rate (%)	2%
Capital Raised - IXR 60% Share (US\$m)	54
Debt to Equity Split of Capital Raised (%)	60:40
Debt interest rate	12%
Issued Price for Equity raising (A\$/share)	0.04
PRICING & EXCHANGE RATE ASSUMPTIONS	
USD/AUD	0.67
Average REO Price LOM (Real) (US\$/kg) - incl. Payability factor	86
Royalty Rate (%)	5%
Corporate Tax Rate (%)	30%

Source: MST Access.

Appendix 1: Understanding Rare Earths – the Metals and the Market

The rare earth elements (REEs) might colloquially be referred to as ‘industrial vitamins’ because, despite being used in small amounts, they play an important role in various industrial processes and are essential to enabling many modern industrial materials and technologies. The sources of the most valuable rare earths, heavy rare earths, are concentrated in China, which is driving efforts to diversify the supply chain for these essential elements.

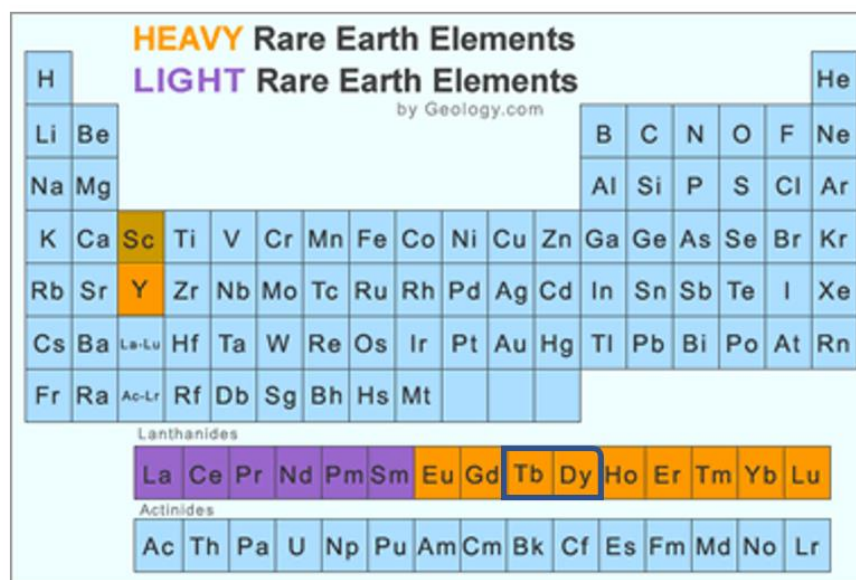
Definition of rare earths: what are they?

The REEs are a group of 15–17 metallic elements composed of the lanthanides on the periodic table, and sometimes also including scandium and yttrium (non-lanthanides) – see Figure 6. These elements, while sharing similar chemical properties, possess distinct physical and magnetic characteristics.

REEs are typically divided into two categories, light and heavy, based on their atomic weight and electron configurations. Heavy rare earth elements (HREEs) have a higher atomic weight compared to light rare earth elements (LREEs).

The REEs are typically abundant in the earth’s crust; cerium (Ce) is as abundant as copper, for example. However, because of their geochemical properties, the elements are rarely found in concentrated economic clusters (ore deposits). Typically, economically viable ore deposits will contain concentrations of many or all of the individual REEs.

Figure 6: Rare earth elements (REEs)



Source: Geology.com.

Light rare earths (LREEs) – key to the clean energy transition

LREEs are more commonly found in nature than HREEs and are also more abundant in the earth’s crust. They are widely used in a variety of industrial and technological applications, such as catalysts, polishing powders, and glass additives. Of the LREEs, praseodymium (Pr) and neodymium (Nd) are of the most economic interest due to their critical role in rare earth permanent magnets (PMs). Lanthanum (La) and cerium (Ce) are typically the most abundant in economic LREE deposits but are very low value in comparison and are often discarded.

Heavy rare earths (HREEs) – driving value and strategic importance for Makuutu

HREEs typically have higher melting/boiling points and tend to be more magnetically and electrically active. They are also generally more costly than LREEs as they are rarer and harder to extract. Some HREEs are facing shortages, especially dysprosium (Dy) and terbium (Tb), due to high demand.

Ionic adsorption clay (IAC) deposits in southern China and Myanmar are the world’s primary source of HREEs today, producing over 95% of global products – some estimates are as high as 98%. This deposit type is informally referred to as ‘south China clays.’ Thick clay accumulations that host low concentrations of REEs – about 0.04%–0.25% (or 400–2,500ppm) total rare earth oxides (TREO) – form in tropical regions with moderate to high rainfall when REEs are leached by groundwater from granite bedrock.

Thick zones of clay-rich soils develop above the granites, and then mobilised REEs become weakly fixed (by ion adsorption) onto clays in the soils.

Despite their low concentrations 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. The IAC deposits are often enriched in high-value HREEs and, given chemical precipitate form, have a higher payability than mineral concentrates, providing a superior return.

Global rare earths market: demand, production, supply and pricing

REEs have a wide range of industrial applications, including in rare earth PMs (e.g. NdFeB magnets), catalysts, glass and ceramics, metal alloys, and electronics.

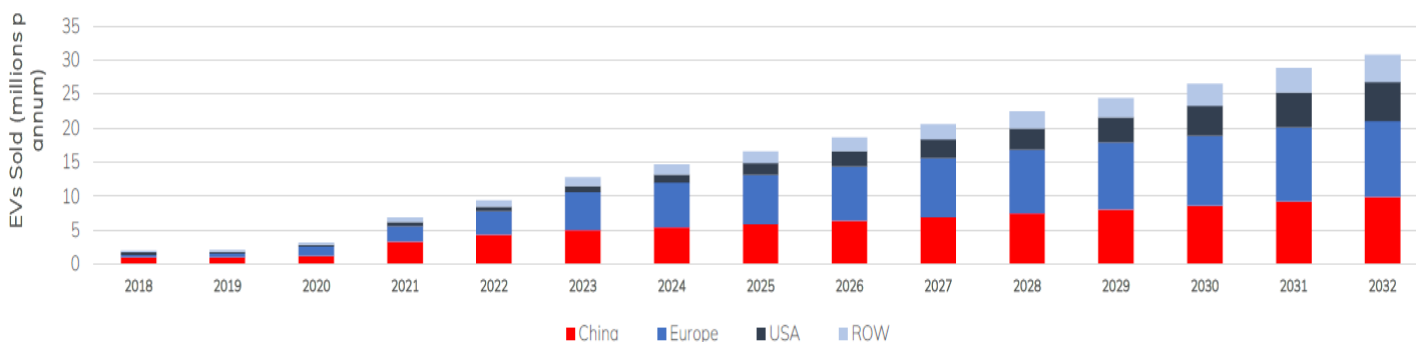
By volume, most rare earth consumption is driven by low-value end uses that consume La and Ce; catalysts, polishing powders, and metallurgical applications. This represents >40% of the end-use categories by volume for rare earths.

However, by market value, PM use is the most important and highest-growth end use for REEs. In 2019, approximately 5,000 tonnes of rare earth PMs were used worldwide in electric vehicles (EVs). This figure is expected to increase significantly by 2030, with estimates ranging from 40,000t to 70,000t of rare earth PMs on a global scale. This is due to growing EV penetration, with the global EV fleet forecast to grow 27% from 2020 (13m EVs) to 2030 (140m), and then 15% per annum to 2040 (565m) – see Figure 7.

Demand for rare earth PMs is further driven by the use of such magnets in wind turbine generators, with an expected addition of 235GW (25% CAGR) by 2030 (Figure 8).

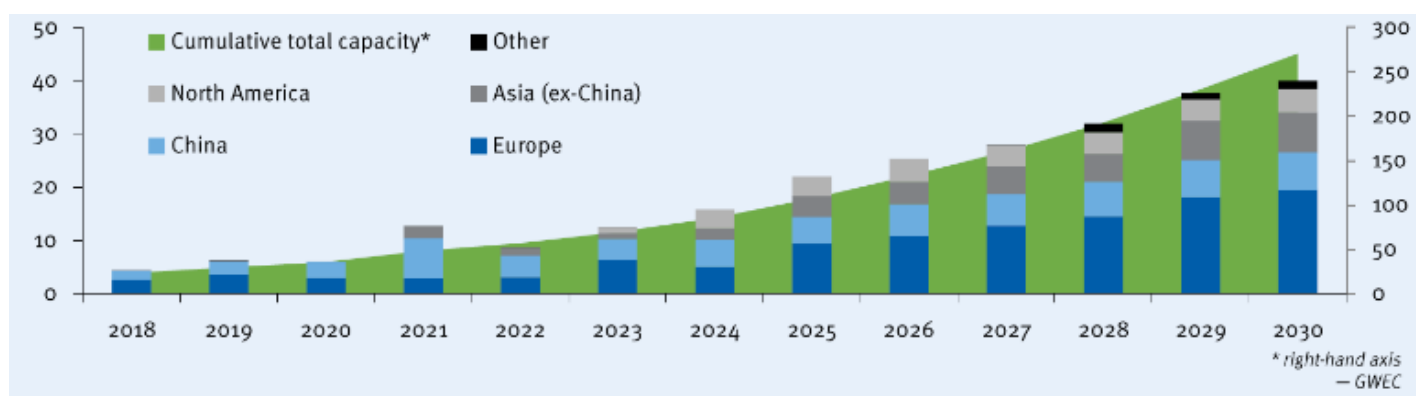
Permanent magnet use is the most important and highest-growth end use for REEs

Figure 7: Global EV sales



Source: IXR, Argus Analytics.

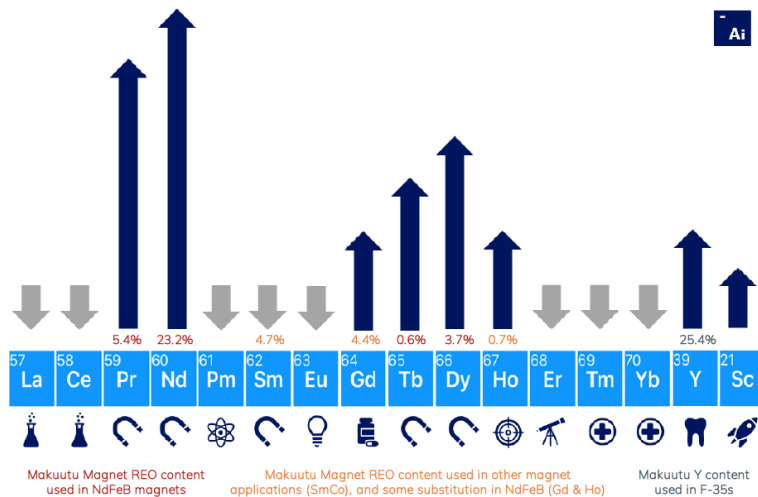
Figure 8: Global offshore wind power additions, 2018–2030 (GW)



Source: IXR.

Forecast demand drives long-term price appreciation for the Makuutu basket, with forecasts shown in Figure 9.

Figure 9: Pricing forecast for the Makuutu basket



Source: IXR.

Uses in rare earth permanent magnets (which underpin key modern technologies)

The use of magnet REEs and boron (B) is crucial for the design of ‘neodymium’ (NdFeB) PMs, commonly present in wind turbines and EVs.

HREEs (especially Dy/Tb) play a critical role in rare earth PMs. NdFeB PMs are crucial for developing efficient, lightweight, and compact traction motors. These magnets are composed of approximately 28–32% NdPr, with minor additions of DyTb (4–8%) to enhance performance under high-temperature conditions.

Dysprosium (Dy) and terbium (Tb) are essential ingredients for high-performing modern PMs. Dy improves the temperature stability of NdFeB magnets, and Tb increases their energy for stronger magnets in high-temperature applications such as EVs and wind turbines.

Terbium, or Tb (65), is a silvery rare earth metal that is so soft it can be cut with a knife. It is used in compact fluorescent lighting, colour displays, and as an additive to permanent rare earth magnets so they can function better under higher temperatures. Other uses include fuel cells designed to operate at elevated temperatures, some electronic devices, and naval sonar systems. In its alloy form, Tb has the highest magnetostriction¹ of any such substance. Moreover, because of its magnetisation, its shape is easily changed in its alloy form, making it a vital component of Terfenol-D which is used in many defence and commercial technologies.

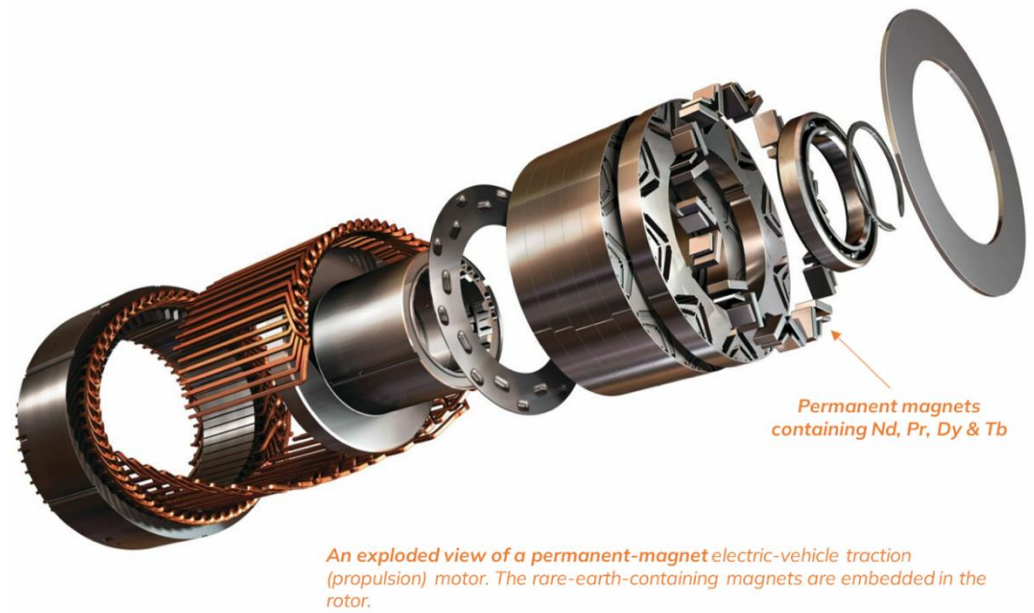
Dysprosium, or Dy (66), is a soft, silver metal with one of the highest magnetic strengths of all of the rare earths, matched only by holmium (Ho) (IXR has this too!). Dy is often added to rare earth PMs to help them operate more efficiently at higher temperatures. Other uses include lasers, commercial lighting, hard computer disks and other electronics, nuclear reactors, energy-efficient vehicles, and Terfenol-D.

The use of DyTb is essential for producing magnets that can withstand high temperatures. Adding DyTb to the magnet increases the coercivity of the motor, enabling it to operate at much higher temperatures (150–240°C), and more efficiently, than motors with only NdPr (maximum temperature: 80°C) which start to demagnetise at lower temperatures. Therefore, either Dy or Tb must constitute 10–15% of the rare earth elemental content in offshore wind turbines and EV magnets.

NdFeB magnets consist of about 28–32% NdPr and 4–8% DyTb, which improves high-temperature performance.

¹ Magnetostriction is a property of magnetic materials that causes them to change their shape or dimensions during the process of magnetisation. This effect causes energy loss due to frictional heating in susceptible ferromagnetic cores.

Figure 10: Electric vehicles are driven by NdFeB magnets



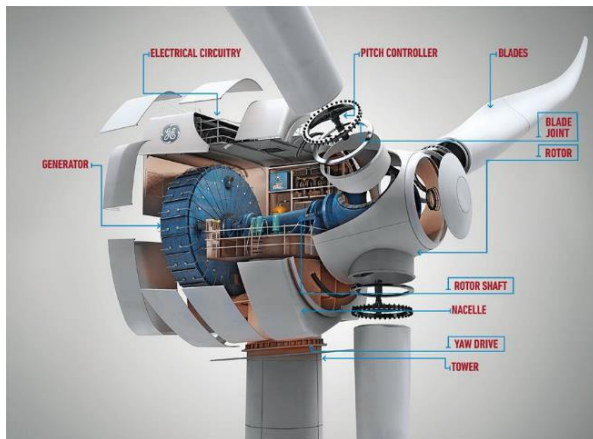
Source: IXR.

Without Dy and Tb, the performance and structure of offshore turbines would be significantly impaired.

A closer look at applications in wind turbines

Offshore wind turbines are equipped with PM generators containing NdPr and smaller quantities of DyTb. On average, the PM used in this application contains approximately 28.5% NdPr, 4.4% DyTb, 1% B and 66% Fe; DyTb is essential for the operation. Historically, a 6MW offshore direct drive wind turbine would consume PMs weighing up to 4 tonnes. Currently, wind turbines up to 16MW in capacity are in development, driven by economies of scale and maximum efficiency in offshore wind production (Figure 11). The development of larger turbines requires a greater role for such NdFeB magnets, driving significant forecast demand (Figure 12). Without Dy and Tb, the capacity (and structural integrity) of these turbines operating out at sea would be significantly compromised.

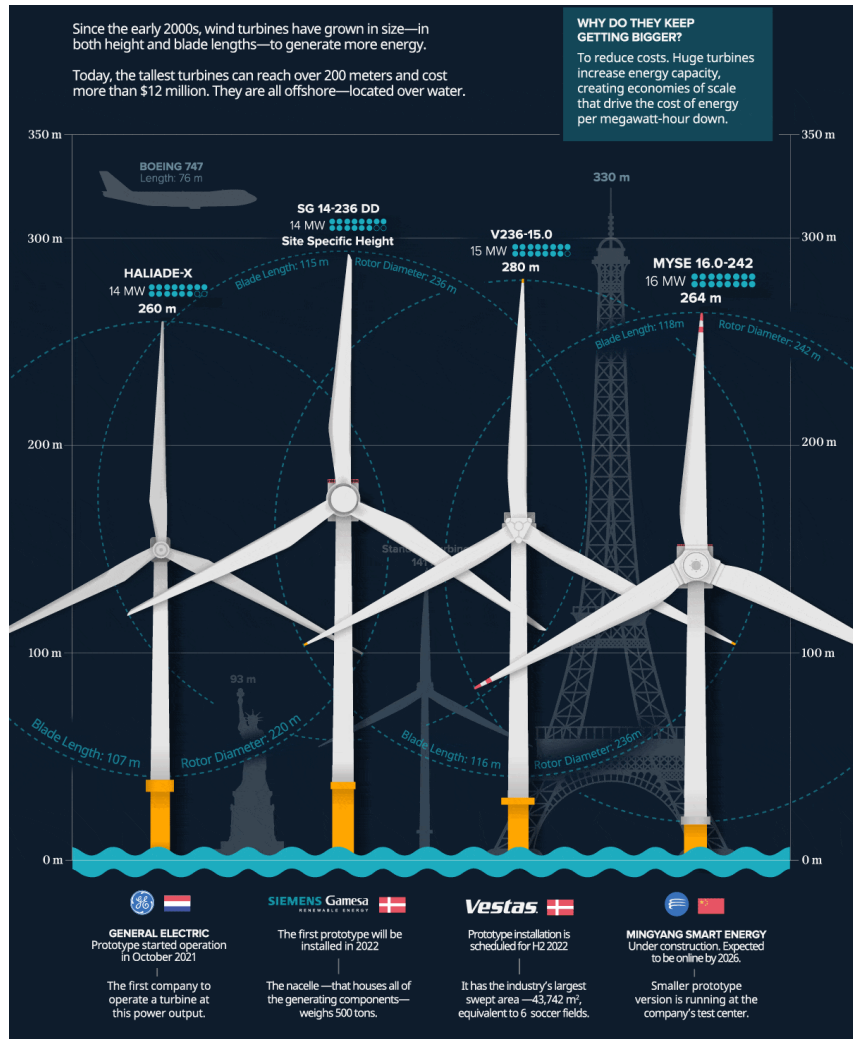
Figure 11: DyTb is critical for offshore wind turbine capacity



Source: IXR.

Rare Earth Element	Quantity kg per MW	Total Quantity for 6 MW (kg)	Total Quantity for 16 MW (kg)
Nd ₂ O ₃	~210	1,260	20,160
Pr ₆ O ₁₁	~42	254	4,032
Dy ₂ O ₃	~20	117	1,920
Tb ₄ O ₇	~8	49	768
Total	~280	1,680	26,880

Figure 12: Wind turbines keep getting bigger for increased economies of scale



Source: IXR.

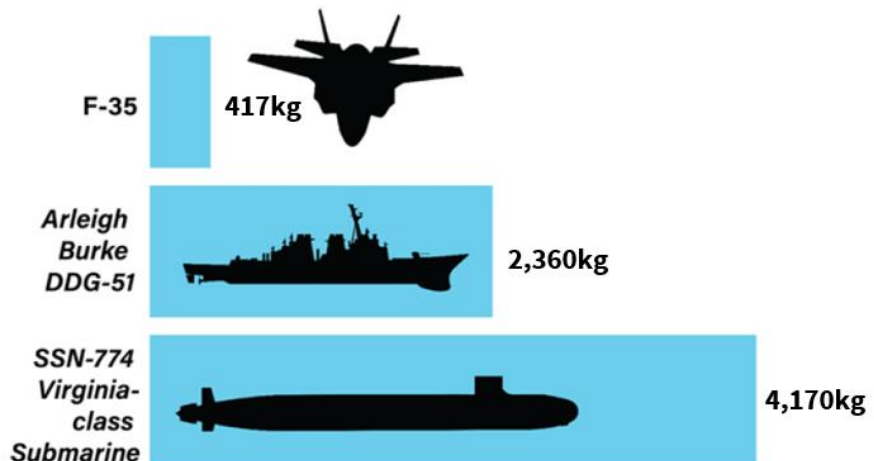
HREEs are strategically important for their unique properties and crucial role in various high-tech applications.

Uses in critical national security systems

Rare earths are used in a wide range of military equipment, communications systems, intelligence-gathering systems, nuclear weapons, and other strategic defence systems, which are essential for national security.

HREEs are considered to be of strategic military importance due to their unique properties and essential role in a wide range of high-tech applications (see Figure 13).

Figure 13: REEs crucial in defence applications



Source: IXR (Congressional Research Services).

Supply: HREE market faces growing supply constraints

LREEs: primarily obtained from monazite and bastnaesite concentrates

Typical deposit sources for light and heavy REEs – the geology

The commercial extraction of REEs is dominated by a few mineralogies, including hard rock minerals bastnaesite, monazite and xenotime, and IACs. These sources account for >95% of economic production.

LREEs are mainly recovered from concentrates of monazite and bastnaesite in China, the US, Australia, India, and Madagascar, but also loparite in Russia (Figure 14).

Figure 14: Major LREE minerals

Ore type	TREO%	Advantages	Disadvantages
Bastnaesite	1-8%	High REO content Established economic deposits	Uncommon in economic concentrations Chemical- and energy-intensive processing and refining
Monazite (primary and placer deposits)	0.5-10% (0.5-2.5%)	Weathered monazite particularly high REO contents and reduced Th & U Developed processing method	Typically occurs in carbonates which can increase reagent consumption during processing Mainly contains LREEs (La & Ce)
Loparite	2-3%	Developed processing method Titanium content	Often occurs along with U and Th minerals

Source: Roskill.

Most HREEs are sourced from IAC deposits in Myanmar and China, with minor volumes of xenotime mineralisation from Australia (Figure 15).

Figure 15: Major HREE minerals

Ore type	TREO%	Advantages	Disadvantages
Ion adsorption clays	<0.5%	Well established main source Easy to process Low cost	Lower TREO content Potentially environmentally damaging mining techniques
Eudialyte (RE silicates)	~0.5-1.5%	Contains Higher Value HREEs	Hard rock deposits requiring more processing stages, high reagent consumption No widely established metallurgical process
Xenotime	1-2%	High yttrium content Established process	Deposits of “pure” xenotime are quite unusual and are often small Some deposits have significant levels of Th and U
Uranium tailings	~5%	Material already mined reducing overall mining costs	Composition variable; Y levels may be low Capacity limited by amount of tailings generated

Source: Roskill.

Geographical distribution of light and heavy REEs – China has most HREEs by far

Southern China has almost all of the world’s IAC deposits, the primary source of HREEs. Geological settings where REEs are found can be grouped into two main categories: **placer deposits**², which include IAC deposits, and **lode deposits**³, which can be considered as hard rock mines.

IAC deposits are considered highly desirable due to their balanced composition of REEs, with both light and heavy REOs, giving them higher product value and broader appeal. The key benefits of IAC deposits over hard rock (LREE) deposits are shown in Figure 16.

² Placer deposits are a type of mineral deposit that forms as a result of weathering and erosion of primary mineral deposits. They are characterised by the secondary concentration of minerals.

³ Lode deposits are formed by the primary concentration of minerals in the host rock and are characterised by the presence of mineral-rich veins. They are often found in hard rock, such as granite or quartz, and typically mined using underground or open-pit mining methods.

Figure 16: Comparison of IAC REE deposits (typically containing HREEs) vs hard rock–hosted REE deposits (typically containing LREEs)

Stage	Ionic Adsorption Clay	Hard Rock
Mineralisation	Soft material, high HREO content	Hard rock, bastnaesite and monazite (LREO dominant), Xenotime (HREO dominant)
Mining	Low cost, surface mining, progressive rehabilitation	High cost, blasting, high strip ratios
Processing	Simple process, potential for in-situ leaching	Comminution, beneficiation with expensive reagents
Mine product	Mixed high-grade rare earth oxide/carbonate	Mixed REE mineral concentrate, high LaCe content
Payability	60–70% as mixed rare earth oxide/carbonate	30–35% as mineral concentrate
Environmental	Non-radioactive tailings, solution treatment and reagent recovery	Radioactive tailings, complex and costly disposal, legacy tailing management
Refinery	Simple acid solubilisation, lower capex	High temperature mineral "cracking", complex capital-intensive plant, complex recycling of reagents and water

Source: IXR.

The availability of magnetic HREEs, the most valuable subset, is heavily concentrated in China.

Magnetic HREE deposits: strategically important to the West

The availability of magnetic HREEs, the most valuable sub-set of HREEs, is heavily skewed towards China, which dominates the global production of these elements. This is due to the unique geological conditions in China, which favour the formation of IAC deposits – the primary source of HREEs.

The West (i.e., regions of Australasia, Europe, and the Americas), on the other hand, has a plethora of hard rock rare earth mines, rich in LREEs, but very few IAC deposits. This creates a supply imbalance, with Western countries heavily dependent on imports of HREEs from China.

Makuutu boasts a significant presence of magnet REOs, with 43% of its basket made up of these vital elements. Additionally, the deposit holds valuable dysprosium (Dy) and terbium (Tb) oxides, which are scarce outside of China and Myanmar. This strategic positioning places Makuutu in a prime position to supply these in-demand oxides to the Western market.

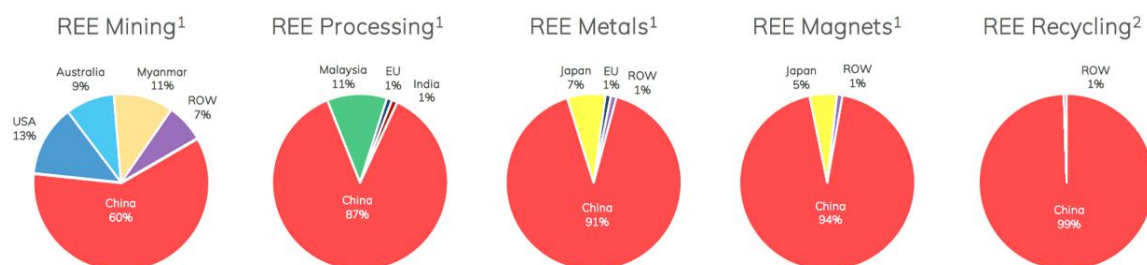
Refining and production – China the dominant player

Most refined rare earths go through China

Rare earth minerals are processed into refined products, either as mixed or semi-separated compounds or individual rare earth compounds. Further refinement, or metallisation into rare earth metals and alloys, is necessary for magnetic applications. Most refining occurs in China (~91%), comprised of both domestically mined product and imported ores and mineral concentrates for separation and refining.

As shown in Figure 17, China currently dominates processing (87%), metal making (91%), magnet making (94%), and REE recycling (99%).

Figure 17: China is dominant at all stages of the rare earth supply chain



Source: ¹Rare Earth Magnets and Motors: A European Call for Action – A report by the Rare Earth Magnets and Motors Cluster of the European Raw Materials Alliances, Oct 2021. Argus Analytics Oct 2021. ²Wood Mackenzie Global rare earths short-term outlook August 2022.

Global refining capability is dominated by China – see Figure 18.

Figure 18: The global landscape of refining capability

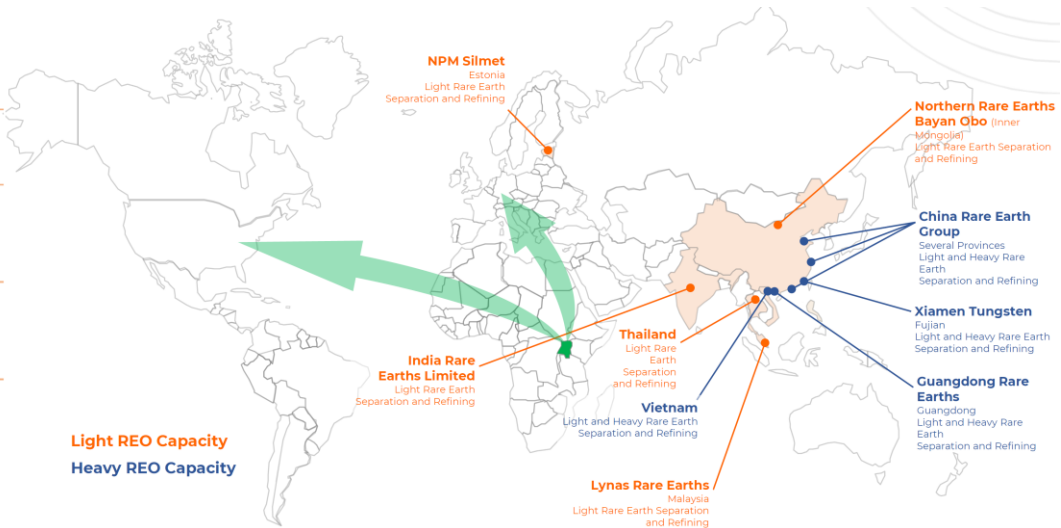
Global heavy REO separation and refining capacity operated and controlled by China¹

Small capacity identified in Vietnam

HREO separation and refining plants under consideration but none in construction yet

IonicRE evaluated a number of global locations to base heavy rare earth refinery

IonicRE to advance Rare Earth Refinery to Magnets Initiative (including Recycling) to sell product to partners in EU and US



Source: IXR.

As the global demand for REEs increases and the West seeks to establish alternative supply chains outside of China, it is crucial to develop the necessary assets and cultivate the essential expertise and capability to extract and process REEs effectively. This includes the knowledge and resources to separate and refine the various REE compounds and convert them into value-added components.

China’s HREE production is declining

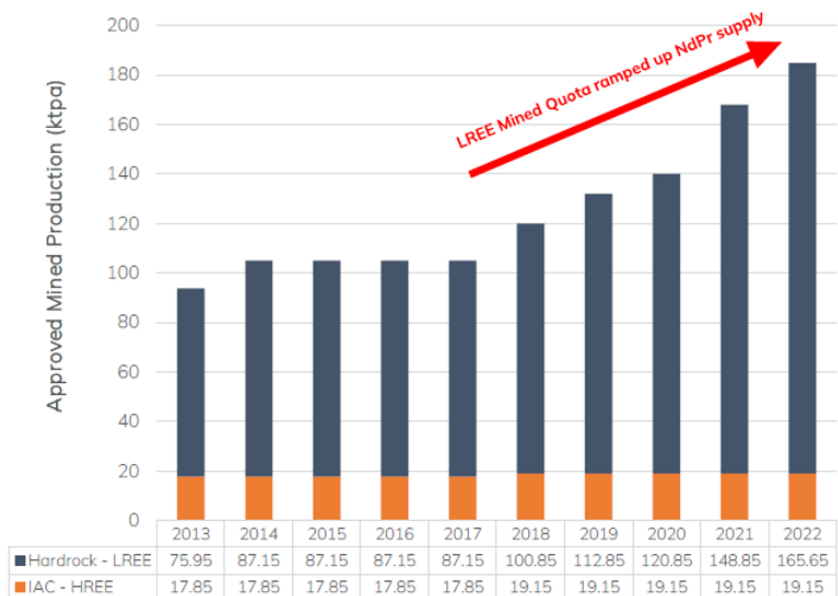
Over the last five years, China has ramped up its capacity of LREE mineral concentrates (see Figure 19), but it has not been able to increase production of HREEs from the IACs to the same extent. This is due to the depletion of economic IAC deposits and a tightening of industrial and environmental controls.

A 2012 White Paper by the Ministry of Industry and Information Technology (MIIT) which oversees China’s REE industry states that ‘the reserve-extraction ratio of ion-absorption-rare-earth mines in China’s southern provinces has declined from 50 two decades ago to the present 15.’

China has been a significant investor in Myanmar’s REE mining industry to replace this declining domestic production and is currently ramping up production in Myanmar to such an extent that the HREEs coming out of Myanmar now surpass what is being mined in China. As a result, Chinese HREE-focused refineries are operating well below capacity, diminishing strategic stockpiles and driving higher prices for key HREEs such as Dy and Tb.

China boosted LREE capacity but not HREE production from IACs in recent years due to resource depletion and tighter regulations

Figure 19: Chinese REO mining production quota

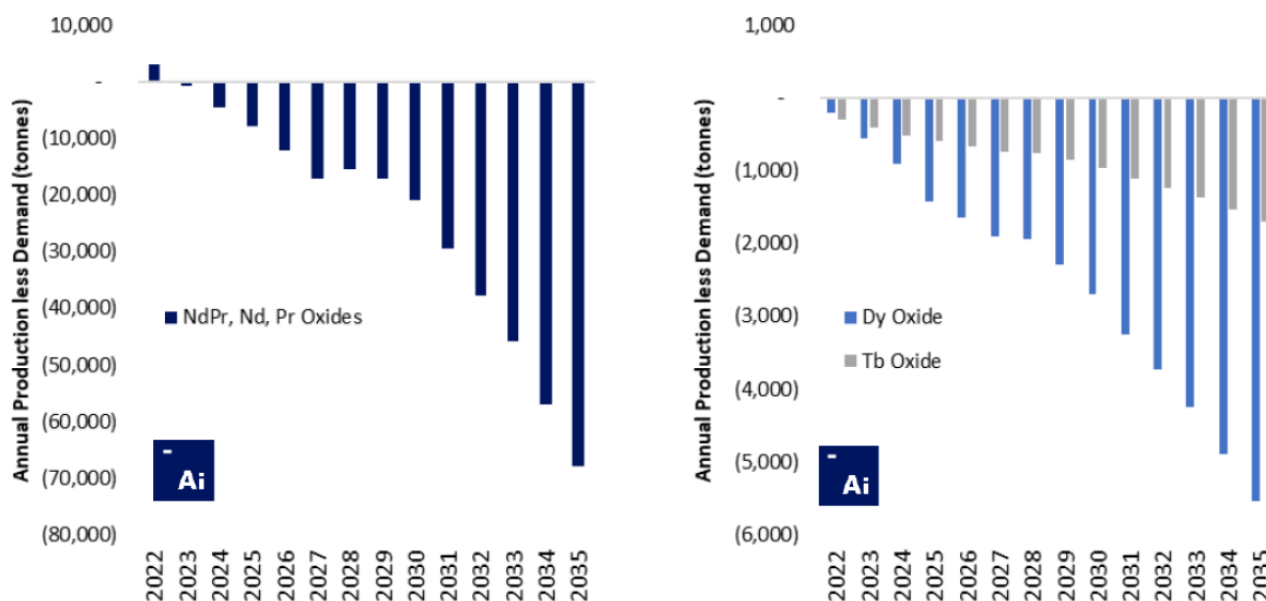


Source: IXR, Ministry of Industry and Information Technology, China, 2022.

The result: a supply shortage of HREEs

The global rare earth market is expected to face a shortage of HREEs, such as DyTb, due to limited global production and uncertain supply from Myanmar, a major producer of these elements. According to Adamas Intelligence, by 2035, the market could be short more than 5X the amount of DyTb oxide supply currently produced by China, unless production increases significantly (Figure 20).

Figure 20: Forecast deficit in magnet REOs from 2023 accelerating over the next decade: DyTb deficit escalating now



Source: IXR, Adamas Intelligence.

Pricing – IXR basket pricing looks set to rise

How are REEs sold?

Most ex-China production is sold as ore concentrate or moderately beneficiated products, e.g., mixed rare earth carbonate (MREC). Lynas produces a range of refined REOs in Malaysia (mostly LREEs), sold to customers in other end markets including Japan. Lynas also produces small quantities of mixed SEG (samarium, europium and gadolinium) and HREEs (holmium to yttrium), sold as mixed products to Chinese refiners.

Some REEs are also sold in other forms (such as metals, alloys, or salts), depending on the specific application and the processing requirements of the end user. For example, dysprosium, terbium and ytterbium are used in the form of metals, while cerium and lanthanum are used in the form of salts.

How are REEs priced?

Since REEs are largely a niche commodity with bespoke products and end uses, most commercial terms for pricing and sale are negotiated between producers and downstream consumers. In China, the price is more tightly controlled by the few large SOE producers, with the annual mining quotas used a tool to increase or constrain supply in the market (where possible).

Many pricing references exist for the variety of REOs and metals. REE prices are typically referenced in US dollars per metric tonne. They can also be quoted in other currencies or as a price per unit of weight. Prices can be obtained through various sources, such as industry publications, commodity exchanges, and consulting firms.

Examples of industry publications that provide rare earth prices include Asian Metal, Metal-Pages, Shanghai Metals Market and Industrial Minerals.

Consulting firms such as Adamas Intelligence, Argus Metals, Project Blue, CRU, and Wood Mackenzie also provide REE prices as part of their research and consulting services. However, REE prices can fluctuate widely due to a variety of factors, such as supply and demand, production costs, and government policies.

Upward trend for IXR basket pricing: industry experts predict strong growth

The 'basket price' refers to the blended average received across all of the various REEs sold or contained in the intermediate products (rare earth concentrate, mixed rare earth carbonate). Since each element will have a different price and a different composition by weight within the final product, the basket price represents the weighted average price of each of the 15 constituent REEs.

REEs, being niche commodities with specific uses, have their prices and sales terms negotiated between producers and consumers.

Forecasts from top analysts predict significant price increases for the Makuutu basket in the coming years.

Consensus pricing forecasts from leading industry analysts, including Adamas Intelligence (through 2035), Argus Metals (through 2031), and Wood Mackenzie (through 2050), predict significant increases in the price of the Makuutu basket. These forecasts (consensus) indicated an approximate 40% increase by 2030 to that used in the 2021 scoping study.

Scandium: what is it and pricing models for sales

The Makuutu Project has the potential to create a low-cost scandium co-product with minimal additional processing, making it an attractive opportunity. Makuutu presently boasts the second-largest reported global scandium resource.

Scandium oxide (Sc_2O_3) is usually found in the same ores as other rare earth elements such as yttrium and lanthanum, and nickel laterite deposits. Its major applications are varied, including high strength-low weight aluminium-scandium alloys, solid state energy storage, 3D printing, and high-intensity lighting.

For modelling purposes, we have assumed the price for scandium oxide (Sc_2O_3) sold product is US\$700/kg (<25tpa), with a long-term pricing basis of US\$800/kg (>30tpa). A payability of 70% has been applied to the Sc_2O_3 .

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