Ionic Rare Earths Limited

IXR.AX

MST Access
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3 August 2023

4Q23: Production Begins of High Purity Rare Earth Magnet Oxides

NEED TO KNOW

- First high purity magnet rare earth oxides production
- Approval to build the Makuutu Demonstration Plant
- IXR Funds VMM's Acquisition of Top-tier Clay Deposit

REO Production from Recycled Magnets: Ionic Technologies' Belfast Plant has initiated production of high purity magnet rare earth oxides (REO) from spent magnets. It houses a sizable NdFeB magnet inventory, sourced globally and intended for plant trials. Visits at the Belfast site suggest imminent technology expansion and a focus on secure magnet REO production.

Demonstration plant approved and construction commenced: IXR has started building the Makuutu Demonstration Plant to strengthen local technical capabilities and streamline project validation. The plant's focus is on efficiency, production capacity, and impurity reduction. Construction is due for completion within four weeks.

IXR invests A$600k in VMM's acquisition of Brazilian clay deposit: Total cost of the acquisition is US$2m, and includes 41 licenses, covering 56km^2. The investment will aid the development of the Colossus Project. The deposit, adjacent to Meteoric's resource, displays promising rare earth grades recoverable through a single-step, cost-effective leaching process.

Investment Thesis

Essential elements for the modern economy: IXR are progressing towards 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 magnetic recycling: IXR's Ionic Technologies subsidiary (100%) has developed processes for separating and recovering REEs from mining ore concentrates and recycled permanent magnets. The proprietary technology efficiently recovers high-grade rare earth elements from diverse magnet grades, contributing to the production of high-performance magnets vital for sectors like 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 rare earths Project, using a discount rate of 12%. We applied a 75% risk weighting, and a lower head grade than what is being forecast in the project's later stages.

Risks

Key risks include delays in the mining licence application; increase in development capital costs; technological risks with processing REEs; and country risks with operating in Uganda.

Equities Research Australia

Mining and Energy

Jonathan Sharp, Analyst
jonathan.sharp@mstaccess.com.au

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$0.02**
Market cap	**A$87m**
Cash on hand	**A$11.1** *(Jun 31, 2023)*

Upcoming Catalysts/Newsflow

3Q2023	Approval of the Mining Licence Application
3Q2023	Decision on location of refinery
1Q2024	Secure project funding for Makuutu
CY2024	Commence construction of Makuutu

Share Price (A$)

Source: FactSet, MST Access.

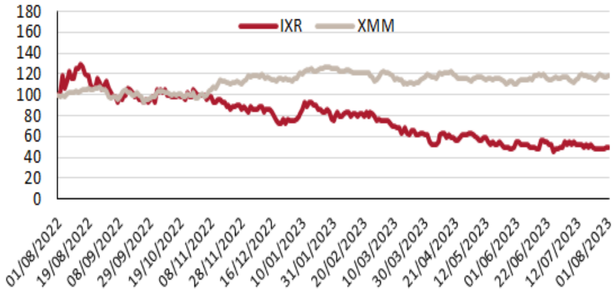
Financial Summary: Ionic Rare Earths Limited

IONIC RARE EARTHS LIMITED **IXR.AX**

Year end June 30

MARKET DATA		
Share Price	A$/sh	0.02
52 Week Low	A$/sh	0.02
52 Week High	A$/sh	0.06
Market Cap (A$m)	A$m	87
Net Debt / (Cash) (A$m)	A$m	(11)
Enterprise Value (A$m)	A$m	76
Shares on Issue	m	3,946
Options/Performance shares	m	157
Other Equity	m	1,154
Potential Diluted Shares on Issue	m	5,257

12-Month Relative Performance vs S&P/ASX Metals & Mining



INVESTMENT FUNDAMENTALS		Jun-21	Jun-22	Jun-23e	Jun-24e	Jun-25e
Reported NPAT	A$m	(2)	(5)	(6)	(6)	(6)
Underlying NPAT	A$m	(2)	(5)	(6)	(6)	(6)
EPS Reported (undiluted)	¢ps	(0.1¢)	(0.1¢)	(0.1¢)	(0.1¢)	(0.1¢)
EPS Underlying (undiluted)	¢ps	(0.1¢)	(0.1¢)	(0.1¢)	(0.1¢)	(0.1¢)
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	(56.0)	(24.2)	(11.6)	(18.8)	(20.2)
Free Cash Flow / Share	A$	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)
Price / Free Cash Flow	x	(13.7)	(6.1)	(4.9)	(18.8)	(0.9)
Book Value / Share	A$	0.01	0.01	0.01	0.02	0.02
Price / Book	x	4.22	1.80	2.01	1.36	1.46
NTA / Share	A$	0.01	0.01	0.01	0.02	0.02
Price / NTA	x	4.22	1.80	2.01	1.36	1.46
Year End Shares	m	3,392	3,943	3,943	5,097	5,097
Market Cap (spot)	A$m	75	87	87	112	112
Net Cash / (Debt)	A$m	11	27	11	50	(68)
Enterprise Value	A$m	64	60	76	62	180
EV / EBITDA	x	n/m	n/m	n/m	n/m	n/m
Net Debt / Enterprise Value		(0.1)	(0.4)	(0.1)	(0.7)	0.9

PRODUCTION AND PRICING		Jun-21	Jun-22	Jun-23e	Jun-24e	Jun-25e
CAPEX	$AUD					(113)
IXR REO Basket Price (excl. payability)	$US/kg	71	91	102	110	112
AUDUSD	:	0.75	0.73	0.70	0.70	0.70

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	0	0	0
Tax	-	-	-	-	-
Underlying NPAT	**(2)**	**(5)**	**(6)**	**(6)**	**(6)**
Exceptionals					
Reported Profit	**(2)**	**(5)**	**(6)**	**(6)**	**(6)**

Balance Sheet (A$m)	Jun-21	Jun-22	Jun-23e	Jun-24e	Jun-25e
Cash	11	27	11	118	9
Receivables	0	1	-	-	-
Inventory	-	-	-	-	-
PP&E	-	0	1	1	114
Exploration	3	12	17	17	17
Other	4	9	9	9	9
Assets	**18**	**49**	**38**	**144**	**149**
Creditors	0	1	-	-	-
Debt	-	-	-	68	78
Other	-	0	0	0	0
Liabilities	**0**	**1**	**0**	**68**	**78**
Shareholder's Equity	**18**	**48**	**43**	**82**	**77**

Cashflow (A$m)	Jun-21	Jun-22	Jun-23e	Jun-24e	Jun-25e
Net Cash From Operations	**(1)**	**(4)**	**(8)**	**(6)**	**(6)**
Capex	-	(0)	(2)	-	(113)
Exploration	(3)	(9)	(8)	-	-
Other	(1)	(2)	-	-	-
Net Cash From Investing	**(4)**	**(11)**	**(10)**	**-**	**(113)**
Equity	16	30	1	45	-
Borrowings	-	-	-	68	10
Dividend					
Net Cash From Financing	**16**	**30**	**1**	**113**	**10**
Effects of FX	-	(0)	(0)	-	-
Net Increase / (Decrease) in Cash	**10**	**16**	**(16)**	**107**	**(109)**

Source: Company Data, MST Access

4QFY23 Update Highlights

Cash position of A$11.1m, reduced Qtr. cash burn of A$3.4m

IXR reported Q4 FY23 results, highlighting a healthy cash position of A$11.1m and a reduced quarterly cash burn of A$3.4m, down from the previous ~A$5m. The company's main focus for the quarter was exploration (increase classification of Inferred Resources to Indicated Resources) at the Makuutu Rare Earths Project and launching magnet REO production at the Ionic Technologies' Belfast facility, spending ~A$2.3m on these activities. A key achievement was first production of high-purity magnet REO from spent magnets at Belfast, helping to open discussions with key supply chain actors and potential partners.

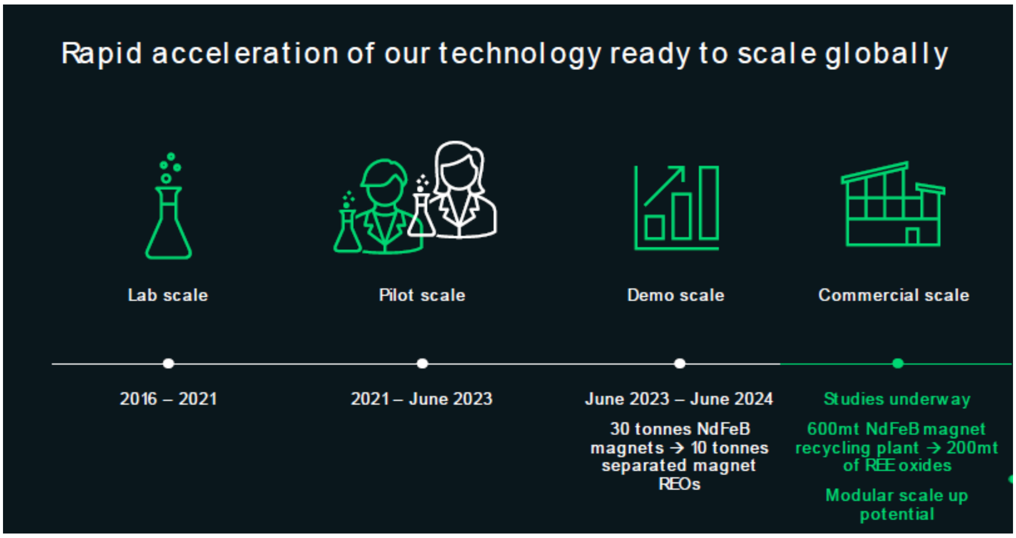
Rare earth oxides production at Ionic Technologies, Belfast, UK

In the June quarter, Ionic Technologies (IXR's 100% owned magnet recycling subsidiary in the UK) made substantial progress, initiating commissioning, and generating its first magnet rare earth oxides (REO) at the Belfast Demonstration Plant. The first batch of high-grade magnet REOs included:

- 4.2 kg of Nd_2O_3, grading at 99.7% and ~0.3% Dy_2O_3 (cumulative REO content of 99.99%); and
- 0.6 kg of Dy_2O_3, graded at 99.8% (total REO content of 99.9%).

With the preparation for NdPr oxide production underway, IXR is well-positioned to explore commercial opportunities with potential collaborators in the supply chain. Ionic Technologies, leveraging its proprietary technology, provides a flexible solution to extract high-grade rare earth elements from varying magnet grades. This technology has the potential to provide magnet REO for the production of modern high-performance magnets, which are integral to sectors like electric vehicles and wind turbines. Thus, we consider Ionic Technologies to be an important component in IXR's strategy, and potentially the first to generate revenue.

Figure 1: IXR's path to commercialisation



Rapid acceleration of our technology ready to scale globally

Lab scale
2016 – 2021

Pilot scale
2021 – June 2023

Demo scale
June 2023 – June 2024
30 tonnes NdFeB magnets → 10 tonnes separated magnet REOs

Commercial scale
Studies underway
600mt NdFeB magnet recycling plant → 200mt of REE oxides
Modular scale up potential

Source: IXR

Making Progress: Makuutu Rare Earths Project (60%)

IXR made progress in multiple areas of the Makuutu Rare Earths Project in Uganda this quarter.

Phase 5 drilling program

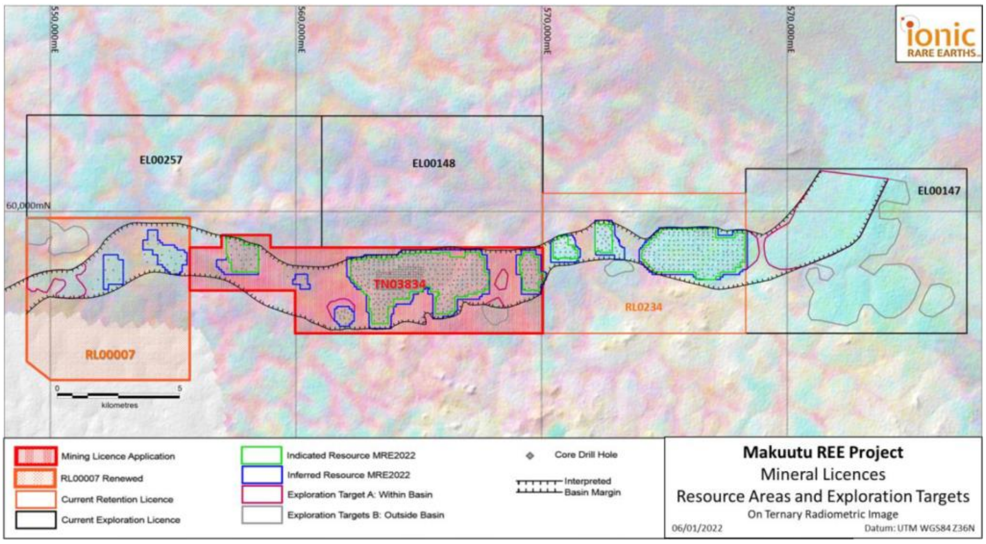
IXR commenced the Phase 5 drill program at its Makuutu project. The intent of the program is to upgrade the status of Inferred Resources on Retention Licence (RL) 00007 to an Indicated Resource category, aiming to accomplish ~4,380 metres of core drilling. At the end of the quarter, the program has resulted in the completion of 29 drill holes (totalling 558 metres), with cores now logged and sampled.

Furthermore, IXR has completed exploration rotary air blast (RAB) drilling at extensive exploration targets identified across Exploration Licences (EL) EL00147, EL00257, and RL00007 (see

Figure 2: Makuutu Project resource map

). All 76 RAB holes (totalling 1,663 metres) have been drilled, logged, sampled, and are now in Perth for analysis.

Figure 2: Makuutu Project resource map



Source: IXR

Demonstration plant approved and construction commenced

IXR received approval from Ugandan authorities to resume the construction of the Makuutu Demonstration Plant technical facility. This 780m² site is expected to strengthen 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. After the quarter's end, site preparations have advanced, and the facility is projected to be erected within four weeks.

Figure 3: Demonstration plant earthworks progressing

Source: IXR

Mining Licence Approval Progressing, but Hindered by Delayed Mining Regulations

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), see Figure 2. Despite these delays, the Ugandan government, in its commitment to balancing economic growth and sustainable mining, has assured a swift publication of the revised regulations post review. While the Directorate of Geological Survey and Mines (DGSM) has pledged a swift review of the Stage 1 Definitive Feasibility Study (DFS) to minimise potential delays in the evaluation of the MLA.

With no further anticipated inter-departmental queries, it is expected that the updated regulations will be officially published within the next two weeks.

Strengthening Capabilities: Enabling the Delivery of IXR's Strategy

To drive its strategic goals, IXR has decided to implement changes to the Board.

Mr. Nitin Tyagi and Mr. Sufian Ahmad join as non-executive directors. Tyagi, currently VP of supply chain at Our Next Energy (ONE), brings knowledge of international demand trends and will focus on optimising supply chain engagement. Ahmad brings legal and business expertise, with over a decade in corporate advisory services.

Dr. Tommie van der Walt has been appointed Chief Operating Officer (COO). With substantial experience in African mining project development, Dr. van der Walt will manage the Makuutu Rare Earths Project's day-to-day operations and strategies for its growth. He was previously involved in substantial projects at EMR Capital and Newmont.

Meanwhile, Mr. Trevor Benson has resigned from the Board, effective from 30 June 2023.

IXR: Cornerstone Investor in VMM's High-Grade Brazilian Clay Deposit Acquisition

In a post-quarterly announcement, IXR will become the cornerstone investor in Virdis' (ASX: VMM) acquisition of a prime Ionic Adsorption Clay deposit in Brazil, injecting A$600k at the corporate level (VMM). This investment, constituting part of the total US$2m acquisition cost, will cover 41 Licenses (inclusive of 2 Mining Licenses) across 56km^2. The investment is pivotal for two main reasons:

1. Preliminary exploration, although just 3m deep, has unveiled encouraging grades the deposit, including:

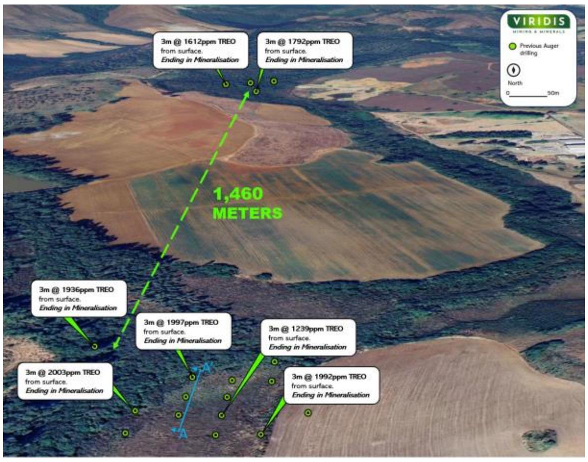
    - 3m @ 2,003 ppm TREO from surface (22% MREO)
    - 3m @ 1,997 ppm TREO from surface (22% MREO)
    - 3m @1,785 ppm TREO from surface (34% MREO)
    - 3m @ 1,936 ppm TREO from surface (19% MREO)
    - 3m @ 1,780 ppm TREO from surface (31% MREO)
    - 3m @ 1,950 ppm TREO from surface (19% MREO)

    The mineralisation remains open in all directions and at depth, with drilling to date not exceeding 3 metres, revealing negligible Uranium and Thorium levels. In Ionic Adsorption Clay (IAC) deposits, higher concentrations of Rare Earth Elements (REEs) are typically found in an intermediate weathered layer, meaning grades are often lowest in the first 5 meters.

2. The deposit is an extension of the proven Meteoric Resource deposit, a notable "Ionic Adsorption Clay Deposit," and one of the highest quality ionic clay discoveries outside of China. Being a genuine "Ionic Adsorption Clay Deposit", the deposit enables efficient extraction of Rare Earths, especially valuable Heavy REE, through a cost-effective single-step leaching process with Ammonia Sulphate at room temperatures, significantly reducing operational expenses.

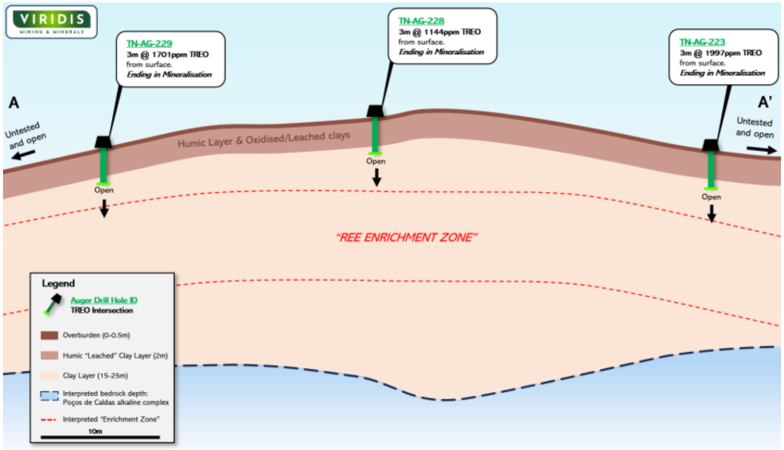
By making this investment, IXR opens avenues to capitalize on their expertise in Ionic Clay Deposits, forging valuable partnerships with firms that own such world-class deposits.

Figure 4: Exploration License 830.927/2016



Source: VMM Market Announcement

Figure 5: Interpretation of Cross Section



Source: VMM Market Announcement

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Valuation: A$0.10/Share, fully diluted

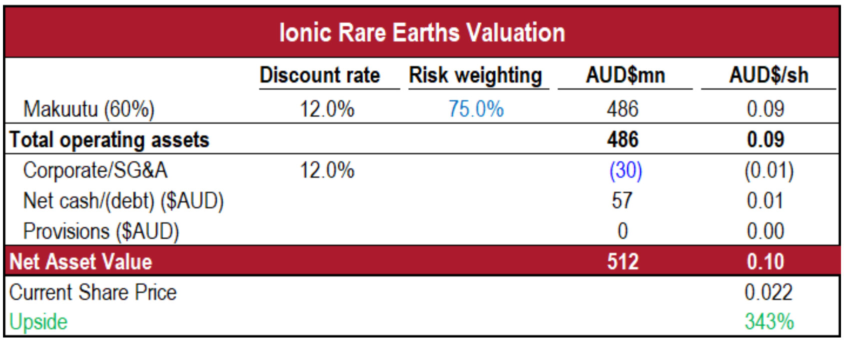
We value IXR at A$0.10/share, fully diluted, with 12% discount rate and 75% probability risk weighting

Our valuation of IXR stands at A$0.10/share, fully diluted, derived from our discounted cash flow (DCF) analysis of IXR's flagship Makuutu Project. The valuation maintains a cautious approach, considering factors such as:

- Conservative pricing due to the critical status of Makuutu product basket
- Probability risk weighting of 75%
- Conservative head grade in the later years of the Project.

Figure 6 presents a summary of our valuation, using a discount rate of 12%. The valuation assumes a A$45m capital raise (60/40 debt to equity for IXR's share of capex) at A$0.04/share (65% premium to the current share price), increasing share count by 1.15bn (+30%).

Figure 6: Base-case valuation summary for IXR



Ionic Rare Earths Valuation				
	Discount rate	**Risk weighting**	**AUD$mn**	**AUD$/sh**
Makuutu (60%)	12.0%	75.0%	486	0.09
Total operating assets			**486**	**0.09**
Corporate/SG&A	12.0%		(30)	(0.01)
Net cash/(debt) ($AUD)			57	0.01
Provisions ($AUD)			0	0.00
Net Asset Value			**512**	**0.10**
Current Share Price				0.022
Upside				343%

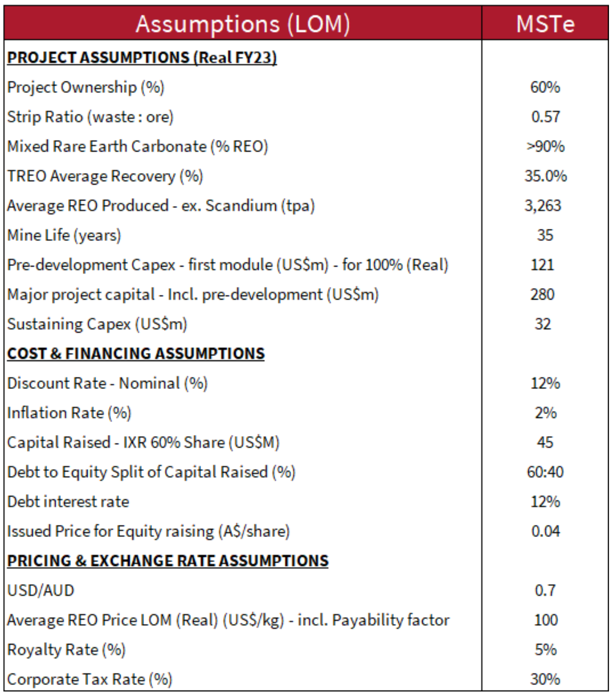
Source: MST Access.

MST's assumptions

The critical assumptions for MST's valuation are shown in Figure 7. 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$0.4/share. The remaining three modules (2.5mtpa of additional processing capacity) will be self-funded through Makuutu's free cash flow.

Figure 7: 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$m) - for 100% (Real)	121
Major project capital - Incl. pre-development (US$m)	280
Sustaining Capex (US$m)	32
COST & FINANCING ASSUMPTIONS	
Discount Rate - Nominal (%)	12%
Inflation Rate (%)	2%
Capital Raised - IXR 60% Share (US$M)	45
Debt to Equity Split of Capital Raised (%)	60:40
Debt interest rate	12%
Issued Price for Equity raising (A$/share)	0.04
PRICING & EXCHANGE RATE ASSUMPTIONS	
USD/AUD	0.7
Average REO Price LOM (Real) (US$/kg) - incl. Payability factor	100
Royalty Rate (%)	5%
Corporate Tax Rate (%)	30%

Source: MST Access.

Appendices – Refresher on Company Strategy and Rare Earth Market

Appendix 1: An Integrated, Life-Cycle Rare Earth Company with a Three-Pillar Strategy

An Integrated, Life-Cycle Rare Earth Company with a Three-Pillar Strategy

IXR has a three-pillar strategy that will allow it to supply a circular economy of sustainable and traceable magnet and heavy REE products for electric vehicles, 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 rare earth oxides (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 downstream magnetic recycling business**

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

Makuutu's Mineral Resource: 532 mt at 640 ppm TREO for 340,000t of contained TREOs

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, a with the potential to significantly expand.

IACs are known geology with well understood mineralisation of REE, and a key source of global rare earths (REE) supply (particularly HREEs). Makuutu's Mineral Resource Estimate is 532 mt at 640 ppm total rare earths oxides (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 rare earth oxides (REOs) and compounds . A scoping study is nearing completion, and the company is now finalising its preferred locations with an expected decision in Q2 CY2023. The refinery will produce all 15 rare earths plus scandium and will be a key step in ensuring IXR will be a key partner and 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 received ~A$2.9m UK grant for a demo-scale magnet recycling plant

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.

Appendix 2: Understanding the Rare Earths 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.

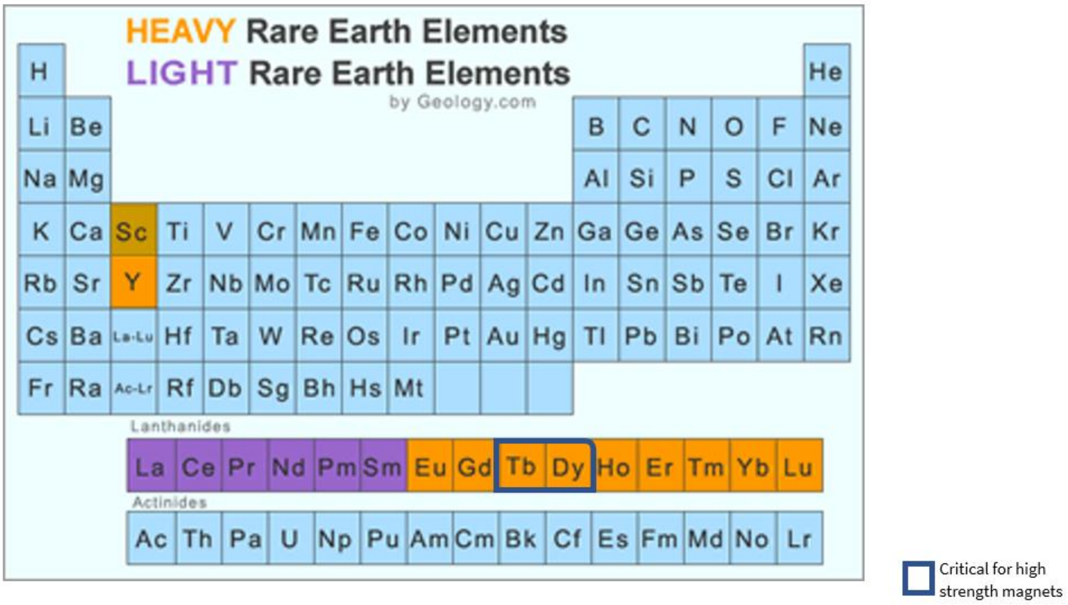
Definition of rare earths: what are they?

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 8. 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 8: 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. 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.

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 in REEs, the clay deposits of south China are economic because the REEs can be easily extracted via low capital developments from the clays with weak acids, and low labour costs. The IAC deposits are often enriched in high-value HREEs and given chemical precipitate form have a higher payability than mineral concentrates providing superior return.

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

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

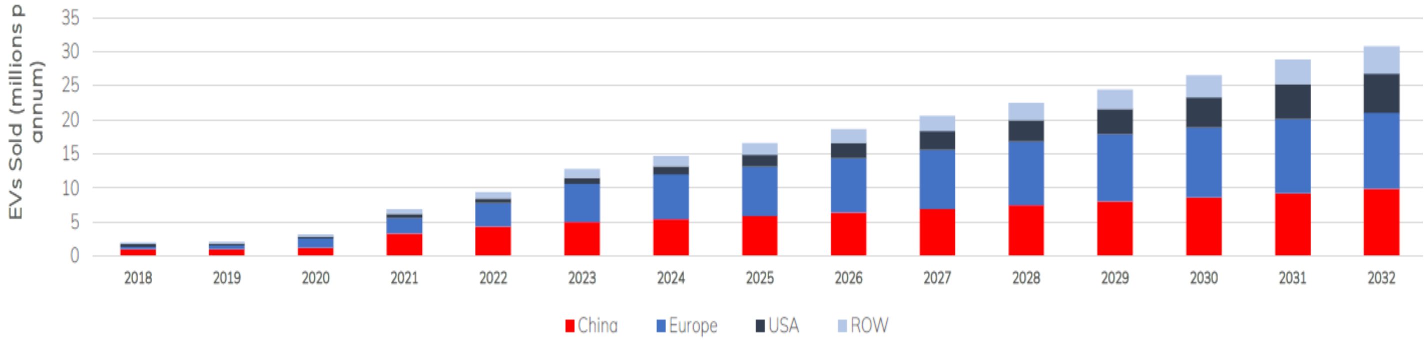
REEs have a wide range of industrial applications, including in rare earth permanent magnets (e.g. NdFeB magnets), catalysts, glass and ceramics, metal alloys, and electronics.

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, permanent magnet use is the most important and highest-growth end use for REEs. In 2019, approximately 5,000 tonnes of rare earth permanent magnets 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 permanent magnets 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 9.

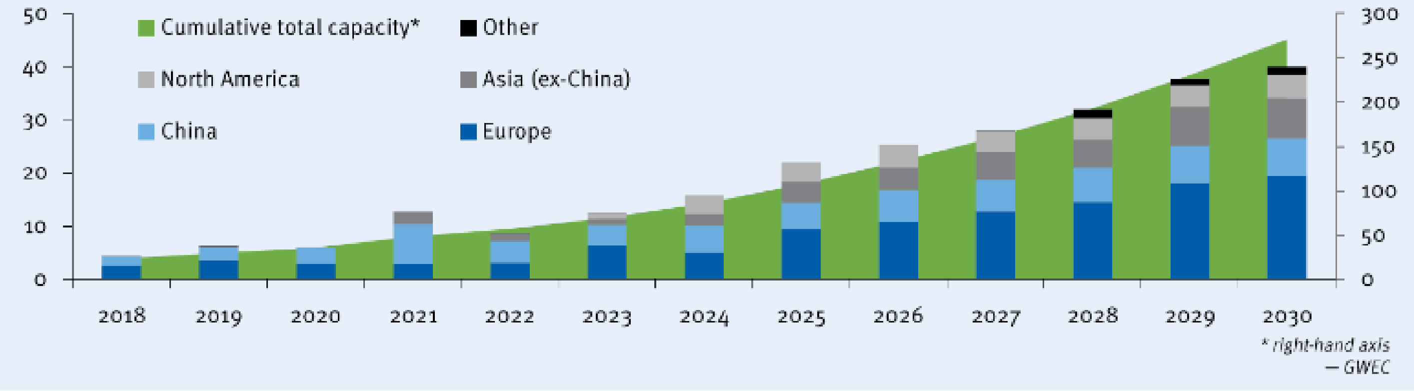
Demand for rare earth permanent magnets is further driven by the use of such magnets in wind turbine generators, with an expected addition of 235GW (25% CAGR) by 2030 (Figure 10).

Figure 9: Global EV sales



Source: IXR, Argus Analytics, April 2022.

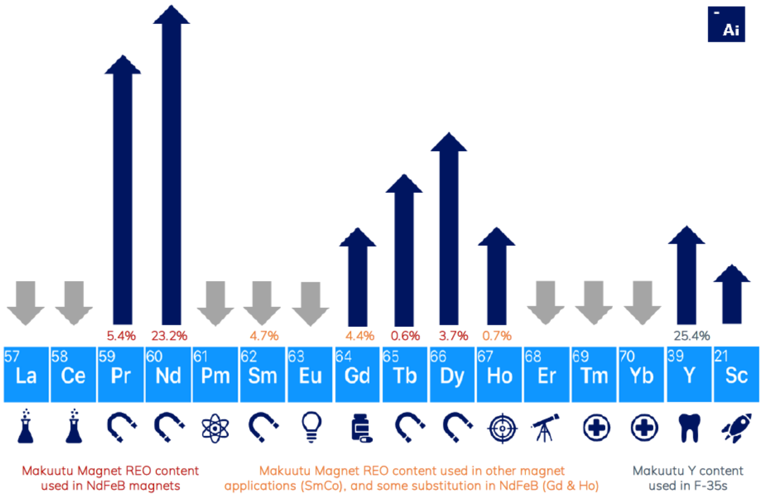
Figure 10: Global offshore wind power additions, 2018–2030 (GW)



Source: IXR.

Forecast demand drives long-term price appreciation for the Makuutu basket, with forecasts shown in Figure 11.

Figure 11: 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) permanent magnets, commonly present in wind turbines and electric vehicles (EVs).

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

HREEs (especially Dy/Tb) play a critical role in rare earth permanent magnets. NdFeB permanent magnets (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 permanent magnets. 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 magnetostriction[1] 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 permanent rare earth magnets 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 (150–240ºC), and more efficiently, than motors with only NdPr (maximum temperature: 80ºC) 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.

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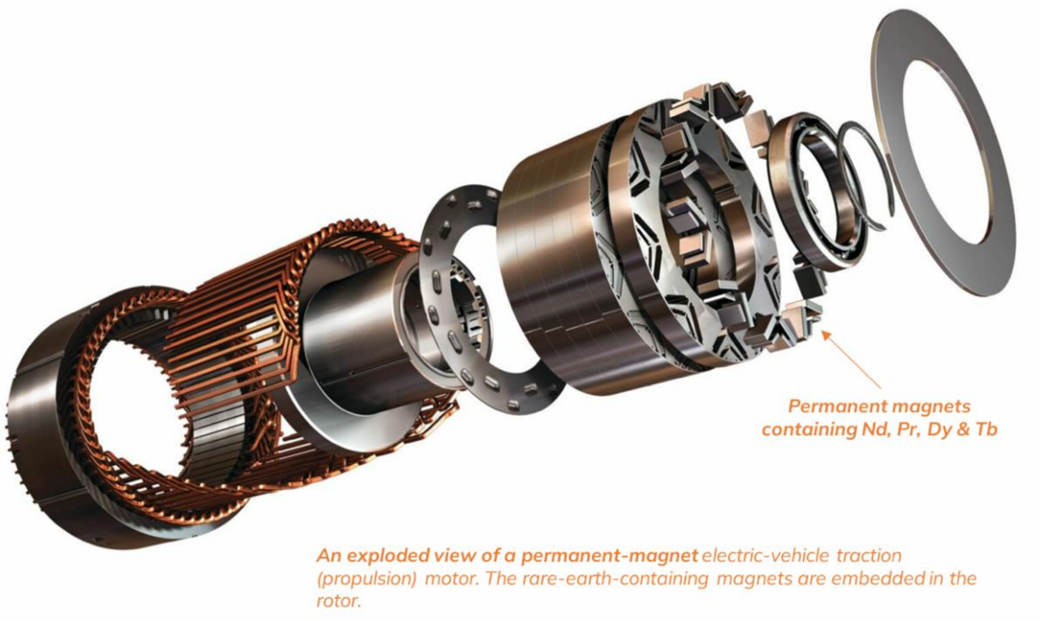
[1] Magnetostriction is a property of magnetic materials that causes them to change their shape or dimensions during the process of magnetisation. This effect causes energy loss due to frictional heating in susceptible ferromagnetic cores.

Figure 12: Electric vehicles are driven by NdFeB magnets



An exploded view of a permanent-magnet electric-vehicle traction (propulsion) motor. The rare-earth-containing magnets are embedded in the rotor.

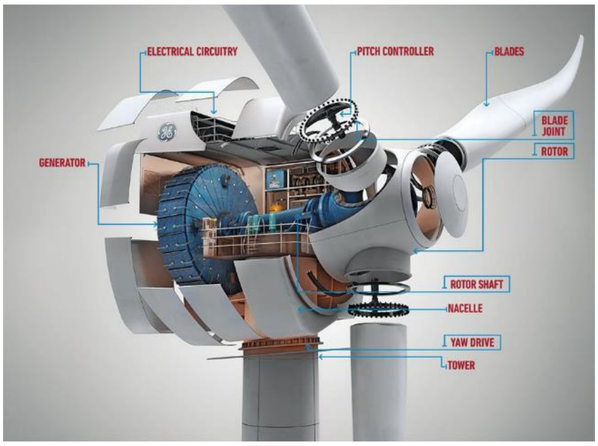
Source: IXR

A closer look at applications in wind turbines

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

Offshore wind turbines are equipped with permanent magnet generators containing NdPr and smaller quantities of DyTb. On average, the permanent magnet 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 permanent magnets 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 13). The development of larger turbines requires a greater role for such NdFeB magnets, driving significant forecast demand (Figure 14). Without Dy and Tb, the capacity (and structural integrity) of these turbines operating out at sea would be significantly compromised.

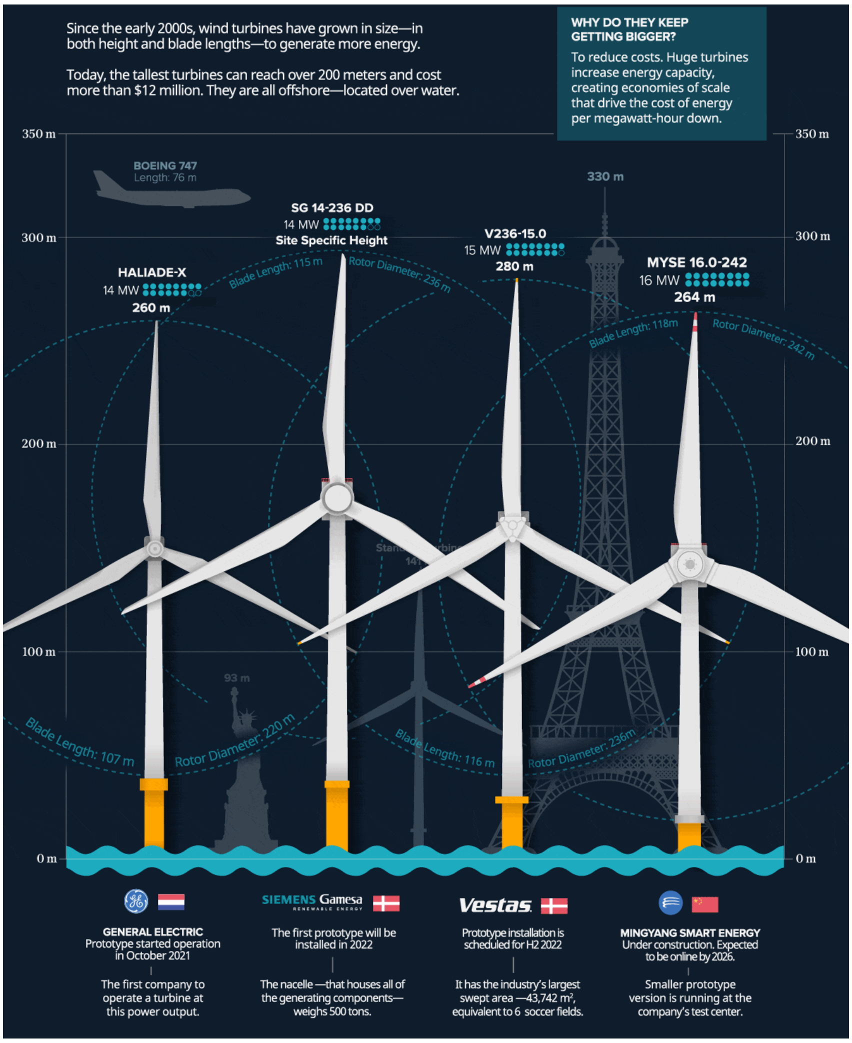
Figure 13: DyTb is critical for offshore wind turbine capacity



Rare Earth Element	Quantity kg per MW	Total Quantity for 6 MW (kg)	Total Quantity for 16 MW (kg)
Nd_2O_3	~210	1,260	20,160
Pr_6O_{11}	~42	254	4,032
Dy_2O_3	~20	117	1,920
Tb_4O_7	~8	49	768
Total	**~280**	**1,680**	**26,880**

Source: IXR.

Figure 14: Wind turbines keep getting bigger for increased economies of scale



Since the early 2000s, wind turbines have grown in size—in both height and blade lengths—to generate more energy.

Today, the tallest turbines can reach over 200 meters and cost more than $12 million. They are all offshore—located over water.

WHY DO THEY KEEP GETTING BIGGER?

To reduce costs. Huge turbines increase energy capacity, creating economies of scale that drive the cost of energy per megawatt-hour down.

GENERAL ELECTRIC
Prototype started operation in October 2021

The first company to operate a turbine at this power output.

SIEMENS Gamesa RENEWABLE ENERGY

The first prototype will be installed in 2022

The nacelle —that houses all of the generating components—weighs 500 tons.

Vestas

Prototype installation is scheduled for H2 2022

It has the industry's largest swept area —43,742 m², equivalent to 6 soccer fields.

MINGYANG SMART ENERGY
Under construction. Expected to be online by 2026.

Smaller prototype version is running at the company's test center.

Source: IXR

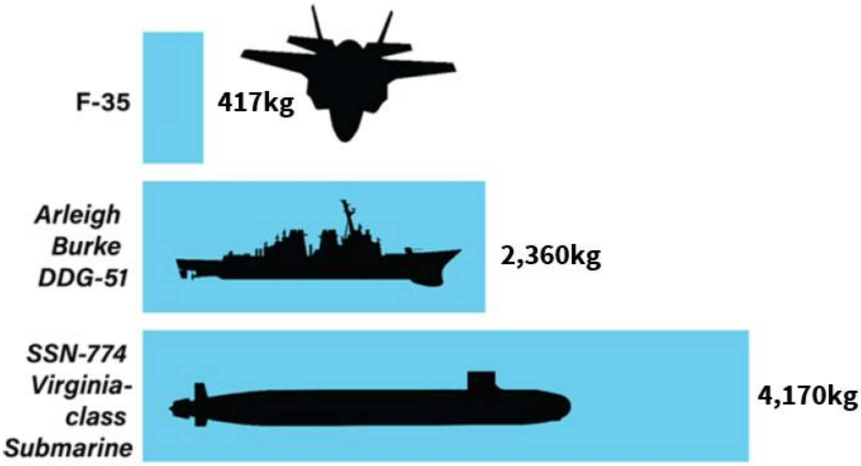
HREEs are strategically important for their unique properties and crucial role in various high-tech applications.

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 15).

Figure 15: REEs crucial in defence applications



Source: IXR (Congressional Research Services).

LREEs: primarily obtained from monazite and bastnaesite concentrates

Supply: HREE market faces growing supply constraints

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 16).

Figure 16: 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 17).

Figure 17: Major HREE minerals

Ore type	TREO%	Advantages	Disadvantages
Ion adsorption clays	<0.5%	Well established main source, easy to process, Low cost	TREO content, potentially environmentally damaging mining techniques
Eudialyte (RE Silicates)	~0.5-1.5%	Favourably contains 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 ionic adsorption clay (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 ionic adsorption clay deposits (IAC) over hard rock (LREE) deposits are shown in Figure 18.

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[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 18: 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 Mining Site	Simple process, potential for in-situ leaching	Comminution, beneficiation with expensive reagents
Mine Product	Mixed high-grade Rare Earths 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

Magnetic HREEs' availability, 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.

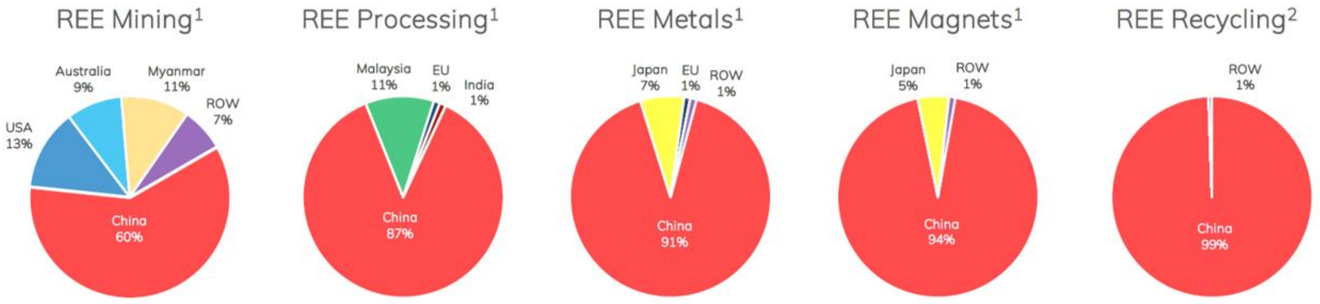
Refining and production – China the dominant player

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 metalisation 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 19, China currently dominates processing (87%), metal making (91%), magnet making (94%), and REE recycling (99%).

Figure 19: China is dominant at all stages of the rare earth supply chain



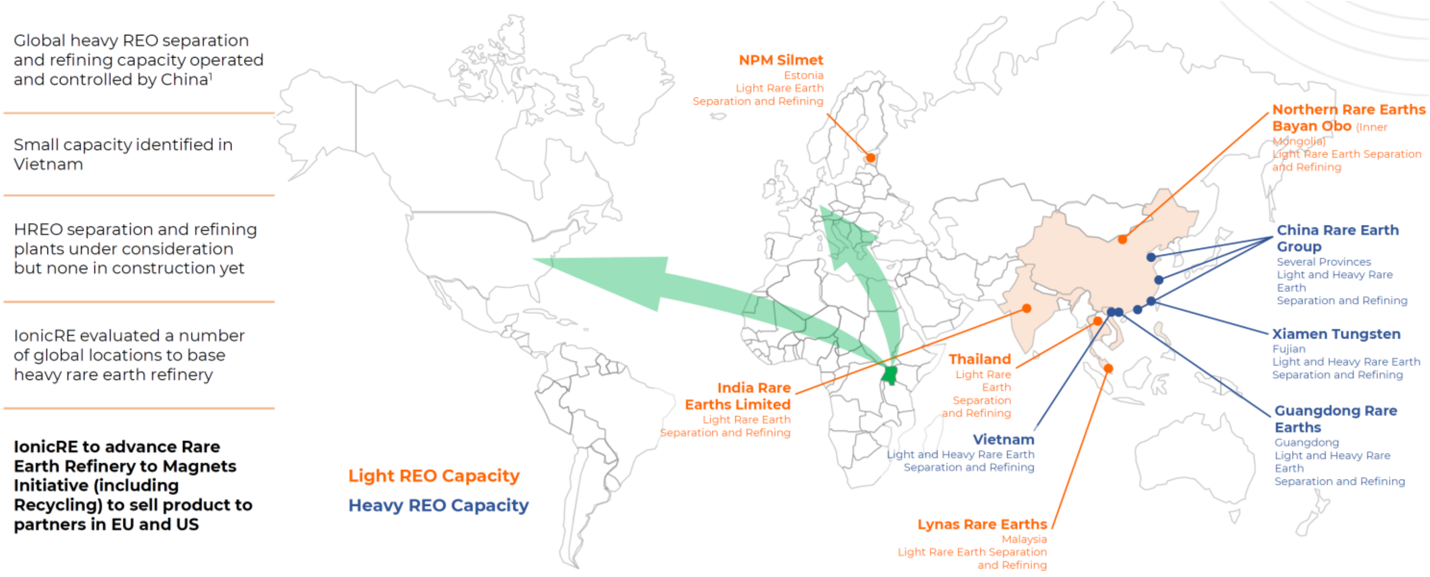
Source: [1]Rare Earth Magnets and Motors: A European Call for Action A report by the Rare Earth Magnets and Motors Cluster of the EuropeanRaw Materials Alliances, Oct 2021. Argus Analytics Oct 2021. [2]Wood Mackenzie Global rare earths short-term outlook August 2022.

Global refining capability is dominated by China – see

Figure 20: The global landscape of refining capability

, which depicts refinery capacity for HREEs (blue) and LREEs (orange). All HREE refining capacity is within China except for a small amount in Vietnam.

Figure 20: The global landscape of refining capability



Global heavy REO separation and refining capacity operated and controlled by China[1]

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

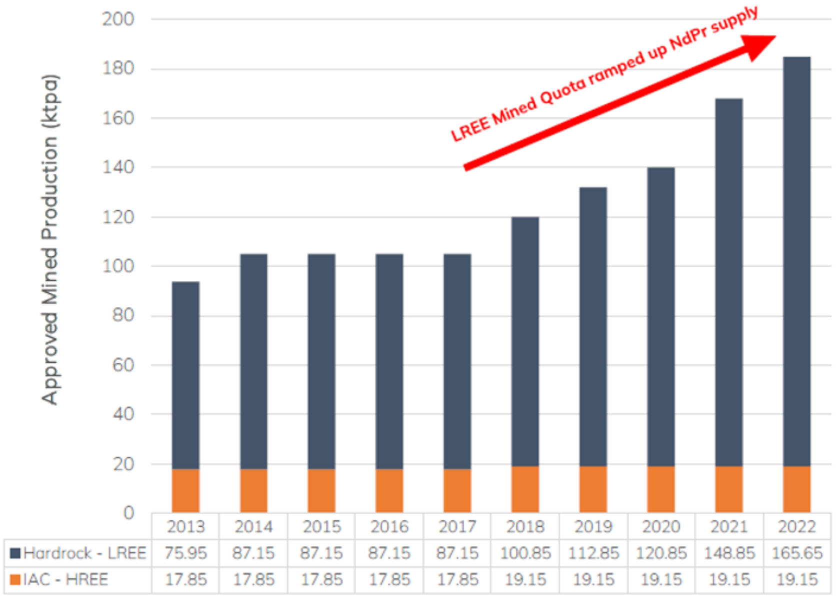
China's HREE production is declining

Over the last five years, China has ramped up its capacity of LREE mineral concentrates (Figure 21), but it has not been able to increase production of HREEs from the IACs to the same extent. This is attributed 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.

Figure 21: Chinese REO mining production quota



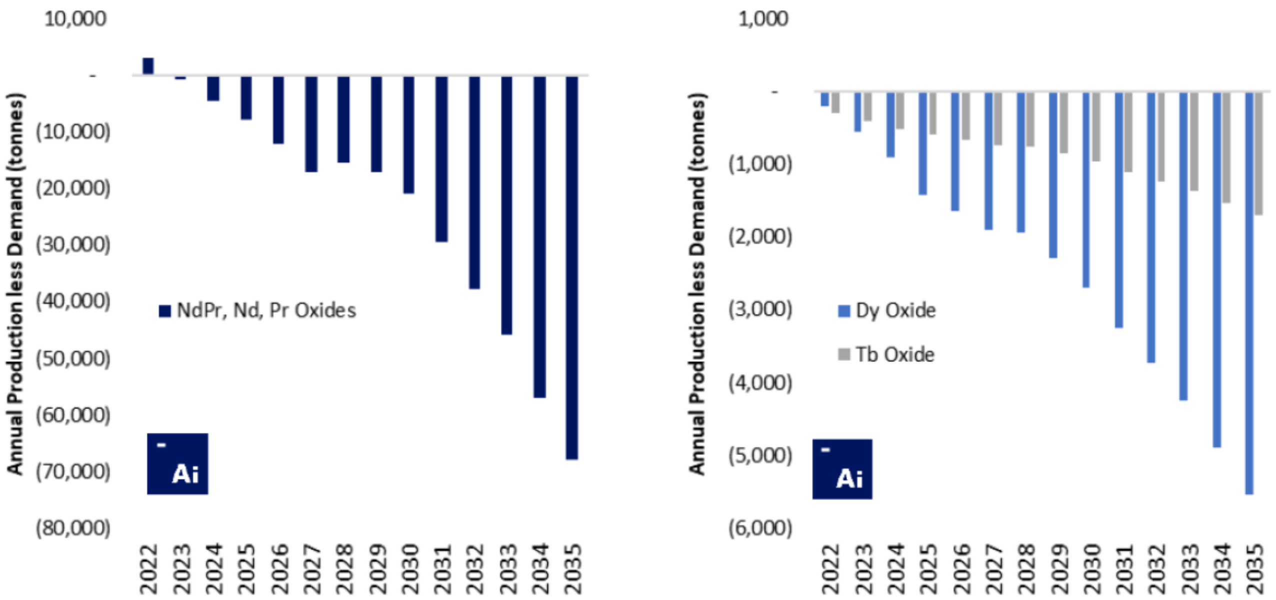
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
■ Hardrock - LREE	75.95	87.15	87.15	87.15	87.15	100.85	112.85	120.85	148.85	165.65
■ IAC - HREE	17.85	17.85	17.85	17.85	17.85	19.15	19.15	19.15	19.15	19.15

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 22).

Figure 22: 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?

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

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.

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

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.

Recent (1Q2022) consensus pricing forecast from leading industry analysts, including Adamas Intelligence (through 2035), Argus Metals (through 2031), and Wood Mackenzie (through 2050), predicts 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 & 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 global scandium resource reported.

Scandium (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 prices for Scandium Oxide (Sc_2O_3) sold product is US$700/kg (<25tpa) with long term pricing basis being US$800/kg (>30tpa). A payability of 70% has been applied to the Sc_2O_3.

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