Developing a magnet and heavy rare earth supply chain

121 Mining Investment Conference
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NdFeB Permanent Magnet Supply Chain and Demand to 2030

**EV & OFFSHORE WIND DEMAND FOR NEW, ALTERNATIVE SUPPLY OF NdFeB PERMANENT MAGNETS WILL EXCEED SUPPLY**

- Rare earths are amongst the most resource-critical raw materials: they are of highest economic importance and at the same time feature a high supply risk – supply chain dominated by China.

- NdFeB magnets play a vital role in the industrial economy of the world, with about 130,000 tonnes produced in 2019 worldwide which corresponds to a market value of about US$7.5B.

- In 2019 ~ 5,000 tonnes of rare earth permanent magnets were used in EVs worldwide.

- By 2030, the number may rise to between 40,000 and 70,000 tonnes on a global scale.

- A global EV market worth about US$700B – US$1,100B (and growing) – dependent on securing access to sustainably produced rare earth magnets – a comparatively small but specialised market of about US$2.3B – US$3.4B billion.

- Wind turbine generator supply will add to demand, with expected addition of 235 GW (25% CAGR) to 2030.

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**Global EV sales, 2018-30**

- Global offshore wind power additions, 2018-30 (GW)

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**Evolution of NdFeB Supply Chain (2021)**

- China 60%
- China 87%
- China 91%
- China 94%
- EU 58%
- ROW 19%
- Japan 5%
- Japan 7%
- EU 1%
- ROW 1%
- Malaysia 11%
- Australia 9%
- Myanmar 11%
- USA 13%

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**Fig. 3:** From rare earths mining to wind turbine manufacturing: estimated market shares in 2019. Sources: Team analysis and Roskill 2018; Adamas Intelligence 2019; Piteves 2017; Carrara et al. 2020; IEA 2021; USGS 2021.
IonicRE targeting new, secure Rare Earths supply

DEVELOPING A SECURE, TRACEABLE, MAGNET AND HEAVY RARE EARTH SUPPLY CHAIN TO FACILITATE CARBON NEUTRALITY

The Mine – Makuutu
Makuutu is one of very few global ionic adsorption clay (IAC) deposits with scale to move the needle on heavy rare earth oxide (REO) supply
Updated MRE released with significant exploration upside
Simple mining and low capex processing to produce Mixed Rare Earth Carbonate (MREC)
No radionuclides

The Refinery – Secure Supply
Opportunity to maximise revenue from the Makuutu MREC product
Collaborate with end users on development of secure and traceable REO supply chain
REOs → Metal → Magnets
Magnet Recycling → REO
Life cycle ownership of REOs

The Basket – High Margin
One of the highest value REO baskets of all projects in evaluation today
43% magnet REOs (Nd, Pr, Dy, Tb, plus Sm, Gd, Ho)
44% Heavy REOs (Sm to Y)
93% of forecast value derived from magnet REOs plus Y
Major future source of Scandium production

Increasing Demand, Reducing Supply – NOW Urgent
World accelerating to net zero carbon, with 8-fold demand increase in both EVs and offshore wind turbine forecast by 2030
ESG drive globally to source sustainable critical raw materials
Limited future HREO supply from declining reserves of IACs in southern China
IonicRE Corporate Snapshot

STRATEGIC VALUE DRIVEN BY THE UNIQUE MAGNET AND HEAVY REO BASKET

<table>
<thead>
<tr>
<th>CAPITAL STRUCTURE (as @ 03/05/2022)</th>
</tr>
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<tbody>
<tr>
<td>Shares Outstanding</td>
</tr>
<tr>
<td>Total Options Outstanding</td>
</tr>
<tr>
<td>(exercisable at 1.8 to 6.4 cents)</td>
</tr>
<tr>
<td>Total Outstanding Performance Rights</td>
</tr>
<tr>
<td>Share Price</td>
</tr>
<tr>
<td>Market Capitalisation</td>
</tr>
<tr>
<td>12 month Share Price Range</td>
</tr>
<tr>
<td>12 month Average Daily Volume / Turnover</td>
</tr>
<tr>
<td>Cash Balance (30/04/2021)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IXR MAJOR SHAREHOLDERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Shareholders (Top 20)</td>
</tr>
<tr>
<td>Board, Executives, &amp; Key Advisors</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>BOARD AND MANAGEMENT</th>
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</thead>
<tbody>
<tr>
<td>Trevor Benson</td>
</tr>
<tr>
<td>Tim Harrison</td>
</tr>
<tr>
<td>Jill Kelley</td>
</tr>
<tr>
<td>Max McGarvie</td>
</tr>
<tr>
<td>Brett Dickson</td>
</tr>
</tbody>
</table>

![Graph showing share price and volume traded over time](chart.png)


Volume Traded (Millions)

IXR Share Price (A$)

Volume

Share Price
IonicRE Value Proposition

MAKUUTU’S STRATEGIC IMPORTANCE WILL INCREASE LONG TERM
• Large MRE upgraded, exploration upside remaining
• Long-life, low-CAPEX, high-payability MREC basket asset, modular development → responsive to future demand
• One of very few IACs outside of southern China / SE Asia
• Very strategic REO basket – 73% magnet plus heavy REO
• FS due October 2022, MLA planned for Q4 2022 → Planned operations in 2024

PATH TO VERTICAL INTEGRATED RARE EARTH COMPANY
• Addition of SerenTech providing internal rare earth element (REE) separation and refining capability to high purity REO
• Refinery Scoping Study underway, due Q3 2022
• Progressing initiatives to deliver secure and traceable new REE supply chains into western markets

MAGNET RECYCLING
• Potential for near term supply of magnet REOs sourced from environmentally favourable magnet recycling
• Chemical extraction technology, unique offering compared to peers
• Early market player in future REO supply chain from magnet recycling, which is expected to grow to 25% of REO supply chain by 2030

“When peering into the outlook for the next decade to come, it becomes quickly apparent that the rapid demand growth of the 2020s will soon be dwarfed by the astronomical demand growth of the 2030s – and therein lies the real defining challenge and opportunity facing the global rare earth industry today.

If the global industry continues to operate myopically – preparing, anticipating and investing only for a three to five-year outlook – the rate of demand growth for magnet rare earths will soon reach ‘escape velocity’, a point at which annual demand growth becomes so great (i.e. >6,000 tonnes per annum) that it is simply implausible for the already-lagging supply-side to catch up and keep up.”

Adamas Intelligence, Sept 28, 2020
Makuutu Rare Earths Project

Low Capital, Modular, Ionic Adsorption Clay Project
MRE update delivered 70% increase in total resource, 500%+ increase in Indicated Resource to support Feasibility Study underway, due Oct 2022

Strategic importance of Makuutu (51% IonicRE ownership moves to 60% on completion of FS ~ Oct 2022)

IonicRE has pre-emptive right on remaining 40% of the Project

Makuutu is unique and receiving global interest due to high quality balanced (magnet + HREO) basket

Classified as medium Yttrium, high Europium IAC deposit

Discussions continue with other groups looking to secure long-term magnet and heavy REO supply, and potential feed to standalone IonicRE Rare Earth Refinery

Existing Infrastructure at Makuutu

- Highway and road access to site plus rail
- Nearby 132 kV power infrastructure with readily available low-cost hydropower
- Cell phone communications available across site
- Water available

Significant Exploration upside at Makuutu still to be realised

Already one of worlds largest Ionic Adsorption Clay (IAC) deposits

Highly prospective licence EL00147 recently tested via RAB drilling with assays confirming clay hosted REE mineralisation present

Exploration Target being revised, due late Q2

Makuutu provides a uniquely balanced basket with 73% magnet and heavy rare earths
ESG initiatives advancing at Makuutu

ESG FRAMEWORK TO BUILD LASTING LEGACY, DEFINING PATH TO NET ZERO CARBON RARE EARTH FOOTPRINT

Environmental and Social Impact Assessment (ESIA) submitted in December 2021, feedback in process

Focus on carbon footprint reduction using low cost renewable (hydro) power

Minviro engaged to commence Life Cycle Analysis (LCA) in April

Rehabilitation plans to ensure net positive climate legacy

Water treatment for reagent recovery and rehabilitation strategy

Rehabilitation to consider development of longer term industrial programs for employment

Aligned with Uganda’s 3rd National Development Plan (NDPIII)
  • Agricultural Programs to increase productivity
  • Aquaculture and fish farming
  • Agroforestry

Community Support Programs identified

Working together to build a future where everyone has a pathway to health and opportunity

Establishment of an Advisory Committee to coordinate community development investment priorities

Key focus being community health and education

Community socio-economic baseline surveys across initial project area underway

Establishing Ugandan team to drive Project activity in country

Community and Stakeholder engagement ramping up

Local support for sub-district health clinics during Covid-19

Resettlement Action Plan (RAP) underway across RL 1693

• Agricultural Programs to increase productivity
• Aquaculture and fish farming
• Agroforestry

Working together to build a future where everyone has a pathway to health and opportunity

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IONIC RARE EARTHS

Mineral Resource Estimate Update

**UPDATED MRE DELIVERS 70% INCREASE TO OVER 500 MILLITON TONNES & 500%+ INCREASE IN INDICATED RESOURCE BASE**

Updated JORC MRE¹ of 532 million tonnes @ 640 ppm Total Rare Earths Oxide (TREO), at a cut-off grade of 200 ppm TREO-CeO₂

76% of Makuutu MRE now converted to Indicated Resource, at 404 million tonnes at 670 ppm TREO

Increased resource confidence at Makuutu to support Feasibility Study with potential to look at faster ramp up, increased throughput and production

Makuutu Central Zone (MCZ), now connected, provides a continuous resource area over 5.5km long and 3km wide for a combined 234 million tonnes or 44% of the total resource and 52% of the total Indicated Resource

Shallow, near surface IAC mineralisation, with clay layer averaging 5 to 12m thick under cover approximately 3m deep. Average hole depth ~18m, maximum clay thickness ~29m

Longer term, numerous exploration targets identified for drilling in 2022/2023

- 67 RAB drill holes (Phase 3) announced in July 2021 confirmed extension of mineralisation east to EL00147, between previous identified radiometric anomalies, and to northwest (EL00257)
- Total tenement package ~ 300 km² across 37km of mineralisation trend with plans to initiate field exploration programs in Q2 2022 and mobilising additional scout drilling later in 2022

<table>
<thead>
<tr>
<th>Category</th>
<th>Estimation Domain</th>
<th>Tonnes (Mt)</th>
<th>TREO (ppm)</th>
<th>TREO no CeO₂ (ppm)</th>
<th>LREO (ppm)</th>
<th>HREO (ppm)</th>
<th>CREO (ppm)</th>
<th>Sc₂O₃ (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicated</td>
<td>Clay</td>
<td>404</td>
<td>670</td>
<td>450</td>
<td>500</td>
<td>170</td>
<td>230</td>
<td>30</td>
</tr>
<tr>
<td>Inferred</td>
<td>Clay</td>
<td>127</td>
<td>540</td>
<td>360</td>
<td>400</td>
<td>140</td>
<td>180</td>
<td>30</td>
</tr>
<tr>
<td>Total Resource</td>
<td>Clay</td>
<td>532</td>
<td>640</td>
<td>430</td>
<td>480</td>
<td>160</td>
<td>220</td>
<td>30</td>
</tr>
</tbody>
</table>

¹ Makuutu Mineral Resource Estimate reported to ASX on 3 May 2022. ² Phase 3 RAB results announced 15 July and 20 July 2021.
 Tier-One Infrastructure already there – supports low CAPEX Development

EXCELLENT LOCAL INFRASTRUCTURE SUPPORTS LOW CAPEX DEVELOPMENT

LOGISTICS
Approximately **10 km from Highway 109**, connecting Makuutu to both capital city Kampala and Port of Mombasa, Kenya

Approximately **20 km from rail line** connecting to Port of Mombasa

POWER
Large hydroelectric generation capacity (+810MW) within 65 km of Makuutu Project area will deliver **very low-cost power** (US$0.05/kWh), plus further capacity being developed

Existing electrical grid infrastructure immediately adjacent to site to provide stable power

WATER
Plentiful fresh water within and near project area (water harvesting)

WORKFORCE
No camp required – low-cost professional local workforce available
IonicRE Basket is a highly strategic basket with High Value

### DOWNSTREAM PROCESSING TO REO AND VALUE ADDED PRODUCTS UNLOCKS SIGNIFICANT UPSIDE

**IonicRE progressing & evaluating downstream REE separation and refining circuit**

- Test work underway to feed into process modelling and optimisation – iterative process
- Exploring opportunities to value add beyond REOs
  - **MREC product** typically has payability ~ 60-70% (~US$50-59/kg\(^1\)) depending upon destination
  - **Refined REO** payability increased to 100% (~US$84/kg\(^1\))
  - **Value added metals and alloys** creates significant step change in revenue potential from (~US$118/kg\(^1\))

**Makuutu current spot REO basket price** ~35% higher than initial 5 years of Scoping Study forecast prices adopted

**Scandium upside represents potential increase of 20-25% additional revenue potential from Makuutu LOM**

<table>
<thead>
<tr>
<th>Rare Earth Oxide</th>
<th>Makuutu Basket Composition</th>
<th>REO Pricing (China) Argus Metals 30-APR-2022 US$/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>La(_2)O(_3)</td>
<td>% 13.5%</td>
<td>$ 1.52</td>
</tr>
<tr>
<td>CeO(_2)</td>
<td>% 13.5%</td>
<td>$ 1.58</td>
</tr>
<tr>
<td>Pr(_2)O(_3)</td>
<td>% 5.5%</td>
<td>$ 137.50</td>
</tr>
<tr>
<td>Nd(_2)O(_3)</td>
<td>% 23.2%</td>
<td>$ 139.00</td>
</tr>
<tr>
<td>Sm(_2)O(_3)</td>
<td>% 4.7%</td>
<td>$ 3.60</td>
</tr>
<tr>
<td>Eu(_2)O(_3)</td>
<td>% 0.9%</td>
<td>$ 31.50</td>
</tr>
<tr>
<td>Gd(_2)O(_3)</td>
<td>% 4.4%</td>
<td>$ 74.00</td>
</tr>
<tr>
<td>Tb(_2)O(_3)</td>
<td>% 0.6%</td>
<td>$ 2,210.00</td>
</tr>
<tr>
<td>Dy(_2)O(_3)</td>
<td>% 3.7%</td>
<td>$ 408.00</td>
</tr>
<tr>
<td>Ho(_2)O(_3)</td>
<td>% 0.7%</td>
<td>$ 193.00</td>
</tr>
<tr>
<td>Er(_2)O(_3)</td>
<td>% 2.0%</td>
<td>$ 69.00</td>
</tr>
<tr>
<td>Tm(_2)O(_3)</td>
<td>% 0.3%</td>
<td>$ 850.00</td>
</tr>
<tr>
<td>Yb(_2)O(_3)</td>
<td>% 1.3%</td>
<td>$ 16.30</td>
</tr>
<tr>
<td>Lu(_2)O(_3)</td>
<td>% 0.2%</td>
<td>$ 805.00</td>
</tr>
<tr>
<td>Y(_2)O(_3)</td>
<td>% 25.4%</td>
<td>$ 14.30</td>
</tr>
<tr>
<td><strong>Sum Total</strong></td>
<td>100%</td>
<td><strong>$ 84.14</strong></td>
</tr>
</tbody>
</table>

**Magnet REO** % 43%

**Light REO** % 56%

**Heavy REO** % 44%

**Critical REO** % 54%

**Basket Value** US$/kg $ 84.14

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1 Based upon current Chinese spot REO pricing. 2 Light REO = La, Ce, Pr, Nd. 3 Heavy REO = Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Y. 4 Critical REO = Nd, Eu, Tb, Dy, Y.

Note. Rounding Applied to nearest 0.1%.
IonicRE Basket – Revised Forecast Pricing tailwinds

**FORECAST REO PRICING REVISED UPWARDS OVER PAST 12 MONTHS**

- **Makuutu current spot REO basket price ~35% higher than initial 5 years of Scoping Study forecast prices adopted**
- **Recent Q1 2022 consensus pricing from Adamas Intelligence (to 2035), Argus Metals (to 2031) and Wood Mackenzie (to 2050) forecasting significant increases in Makuutu basket price over that used in the 2021 Scoping Study**
- **Forecast consensus pricing indicating ~40% increase to 2030**
- **Potential to accelerate Makuutu ramp up to benefit from increases basket price forecast**

Consensus pricing sourced from Argus (Rare Earths Analytics 1H 2022 Data 31-Mar-22), Adamas Intelligence (Rare Earth Magnet Market Outlook Update - April 2021), and Wood Mackenzie (Global Rare Earths Strategic Planning Outlook - Q1 2022 31-Mar-22).
Ionic Adsorption Clay (IAC) deposit mineralisation is highly desirable given it produces a balanced basket dominant in magnet & heavy REO.

Globally one of the largest IAC deposits discovered outside of southern China and SE Asia & one of less than a handful of economic size and scale, and only near term IAC near development ready project with offtake available for US and EU markets.

High margin basket potential, approx. 73% of basket is magnet + heavy REO (magnet REOs make up 43% of basket) → High Value Product, seeing appreciation in forecast basket pricing to 2030 and beyond.

Feasibility Study to explore more aggressive ramp up to meet global demand for Makuutu’s basket and incorporate 500%+ increase to MRE Indicated Resource classification.

Scoping Study¹ completed in April 2021 defined a very robust base case with highly attractive 11-year Base Case economic parameters;

- Post-tax long term free cash flow US$766 million over 11 years
- EBITDA of US$1.28 billion
- Post-tax Net Present Value (8) of US$321 million
- Internal Rate of Return of 38%
- Pre-production CAPEX requirement of US$89 million (1 MODULE) or US$129 million (2 MODULES)
- Expansion CAPEX of $212 million funded by Project free cash flow
- 10% increase in basket REO price leads to 30% increase in post tax NPV(8)

Global Appeal – Strategic importance of Makuutu product basket seen as critical for governments to deliver carbon neutral policy objectives & major appeal to key defence applications.

Scandium upside is significant with MRE containing ~9,450 tonne Sc₂O₃, potential annual production from 25 to ~100 tonnes per annum.

¹ Makuutu Rare Earths Project Scoping Study reported to ASX on 29 April 2021.
Project Development Activities

MAKUUTU FEASIBILITY STUDY PROGRESSING TOWARDS COMPLETION Q4 2022

- Metallurgical testwork ramped up
  - Accelerated variability bottle rolls, heap leach columns, mineralogy programs progressing towards geometallurgical model for Makuutu, with broad scale variability columns planned for Q2
  - Heap leach columns demonstrating successful scale up
    - 1m → 2m → 3m → 5m now underway
- Process Model developed for flowsheet trade-off analysis and optimisation of desorption chemistry, along with 3D Process Plant Model
- Engineering at 64% completion – completing first draft capital and operating cost estimates
- MRE update now being used for initial mine planning and scenario evaluation
- ESIA feedback and ongoing community consultation sessions and hearings with outcome expected Q2 2022
- Resettlement Action Plan progressing with planned completion mid year
- Exploring options for more aggressive ramp up to align with demands from potential partners on magnet REO supply chain
- Mining Licence Application planning underway for Q4 2022
- Planning for Demonstration Plant post MLA
- Continuing to build capacity in Uganda adding project resources to team
- Extensional / field exploration programs being evaluated
Investment in Uganda – The Pearl of Africa

**MAJOR INTERNATIONAL INVESTMENT INTO UGANDA IS UNDERWAY**

- Ugandan law allows for 100% foreign-owned businesses, and foreign businesses are allowed to partner with Ugandans without restrictions.
- The US$10B Lake Albert Oil Project (Total (56.67%), CNOOC (28.33%) and UNOC (15%)) development encompasses Tilenga (operated by Total) and Kingfisher (operated by CNOOC) upstream oil projects in Uganda, delivering a combined production of 230,000 barrels per day, and the construction of the East African Crude Oil Pipeline (EACOP) transporting from the oilfields in Uganda 1440km to the port of Tanga in Tanzania.
- Uganda is rich in natural resources. Foreign Direct Investment (FDI) mainly goes to the coffee and mining sectors. Kenya, Germany and Belgium are the country’s main investors.
- Good support from government agencies including the Directorate of Geological Survey and Mines (DGSM)
- Transparent Mining Cadastral system implemented in Uganda for tenement management
- Ugandan Mining Act 2003 outlines royalties for base metals at 5% and Corporate Tax Rate = 30%
- Asset depreciation given Project is > 50km from Kampala is 50% initial depreciation allowance, and 100% of the assets in a 3-year period.

<table>
<thead>
<tr>
<th>Foreign Direct Investment¹</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDI Inward Flow (million US$)</td>
<td>803</td>
<td>1,055</td>
<td>1,266</td>
</tr>
<tr>
<td>FDI Stock (million US$)</td>
<td>11,996</td>
<td>13,051</td>
<td>14,317</td>
</tr>
<tr>
<td>Number of Greenfield Investments</td>
<td>8</td>
<td>17</td>
<td>29</td>
</tr>
<tr>
<td>Value of Greenfield Investments (million US$)</td>
<td>290</td>
<td>366</td>
<td>960</td>
</tr>
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¹ Source: UNCTAD - Latest available data.
# Makuutu Timeline to Production

## Accelerating Makuutu Towards Planned Production in 2024

<table>
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<tr>
<th>ACTIVITY</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
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<tbody>
<tr>
<td></td>
<td>Q2</td>
<td>Q3</td>
<td>Q4</td>
</tr>
<tr>
<td>Metallurgy Testwork</td>
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<tr>
<td>MRE Update</td>
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<td>ESIA (submitted Dec 2021)</td>
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<tr>
<td>Feasibility Study</td>
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<tr>
<td>Landowner Agreements</td>
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<td>Funding Agreements</td>
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<td>Mining Licence Application</td>
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<td>Final Investment Decision</td>
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<td>Site Early Works</td>
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<tr>
<td>Construction</td>
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<td>Mining Commences</td>
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<td>Commissioning</td>
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<tr>
<td>Plant Production</td>
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</table>
IONIC REE Supply Chain and IonicRE Capability to date

IONICRE ADDING CAPACITY TO BECOME MORE INTEGRATED IN NEW FUTURE RARE EARTH SUPPLY CHAINS

1. Makuutu Rare Earths Project
   - Low Capital, modular development enables IonicRE to bring on highly sought-after basket of REEs
   - Expandable with free cash flows and growing market demand
   - MLA planned for late 2022
   - Commencing operations in 2024

2. IonicRE Refinery
   - Under Evaluation now assessing potential economics → Scoping Study due Q3 2022
   - Targeting separation of MREC from Makuutu to produce refined REOs for downstream conversion to metals and alloys
   - Potential to receive MREC feed or HREO products from other producers

3. Magnet Recycling
   - Low capital development to recycle spent magnets and swarf to produce separated and refined 99.9%+ REOs
   - Near term magnet REO production capacity (Nd, Pr, Dy and Tb – potential for Sm, Gd, Ho)
   - Modular recycling plants located in numerous jurisdictions
China Dominates Global REE Separation & Refining Capacity

ALL HEAVY RARE EARTH ROADS LEAD TO CHINA .... UNTIL NOW

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 no committed timelines as yet

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

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

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\(^1\) Argus Analytics.
Standalone Refinery to unlock value of balanced basket REOs

DEVELOPMENT SUPPLY CHAIN TO PRODUCE REOs OF INCREASING DEMAND AND DECREASING SUPPLY

- Rare earth separation and refinery facility developed to take advantage of **long life, secure and traceable supply** source from Makuutu
  - Plan to ramp up to ~ 4,000 tonnes per annum of REO
  - **Long life potential** producing a basket with suite of individual REEs that will appreciate in value near / long term
  - Increase of Makuutu MRE → extension of life → increased appeal to go downstream
- Potential to **source additional REO feed stocks** (as heavy MREC products) by other REE mines for additional revenue generation
- **Inclusion of magnet recycling increased Nd, Pr, Dy and Tb** production capacity longer term
- **Facilitate the value of the refined REOs into downstream industry**
  - Opportunity for **OEMs to participate** in secure and traceable supply chain
  - Various industrial opportunities to **create JVs in new industrial applications**
  - Maximise revenue upside from development of the Sc market

### Rare Earth Element | REO Production Capacity (t/annum) | Major Applications and Uses
---|---|---
Lanthanum (La) | 580 | Battery alloys, metal alloys, auto catalysts, petroleum refining, polishing powders, glass additives, phosphors, ceramics, and optics
Cerium (Ce) | 550 | Battery alloys, metal alloys, auto catalysts, petroleum refining, polishing powders, glass additives, phosphors, and ceramics
Praseodymium (Pr) | 220 | Permanent magnets, battery alloys, metal alloys, auto catalysts, polishing powders, glass additives and colouring ceramics
Neodymium (Nd) | 1,000 | Permanent magnets, battery alloys, metal alloys, auto catalysts, glass additives and ceramics
Samarium (Sm) | 180 | Magnets, ceramics, and radiation treatment (cancer)
Europium (Eu) | 35 | Phosphors, optical fibres, flat panel displays
Gadolinium (Gd) | 170 | Ceramics, nuclear energy, and medical (magnetic resonance imaging X-rays)
Terbium ( Tb) | 25 | Permanent magnets for high temperature applications, fluorescent lamp phosphors, defence applications
Dysprosium (Dy) | 140 | Permanent magnets, defence
Holmium (Ho) | 30 | Permanent magnets, nuclear energy and microwave equipment
Erbium (Er) | 75 | Nuclear energy, fibre optic communications, and glass colouring
Thulium (Tm) | 11 | X-rays (medical) and lasers
Ytterbium (Yb) | 65 | Cancer treatment and stainless steel
Lutetium (Lu) | 10 | Age determination, medical and petroleum refining
Yttrium (Y) | 1,000 | Battery alloys, metal alloys, phosphors, catalytic converters, ceramics and defence
Scandium (Sc) | 120 | High strength, low weight aluminium scandium alloys, solid state energy storage, 3D printing, high intensity lighting

1 Nominal capacity aligned with Makuutu Scoping Study production capacity.
NdFeB Magnet Recycling

DEVELOPING CAPACITY ON RARE EARTH SEPARATION, REFINING AND RECYCLING

• IonicRE completed acquisition of Seren Technologies Ltd (ASX: April 2022), a leading magnet recycling technology company

• Previous pilot plant campaigns have processed rare earth waste magnets received from supply chain stake holders and achieved extraction of recycled REE content to produce oxides at purity of 99.9%. Optimisation pilot plant campaign planned to commence Q2 in Belfast, UK

• Commercialisation strategy being revised, examining options to develop scalable recycling facility processing up to 600 tpa waste magnets and swarf to produce ~ 200 tonne magnet REO (Nd, Pr, Dy and Tb)

• Provide springboard to accelerated rare earth production capacity, with potential to commence operation in 2023 whilst Makuutu is being developed and ramped up and in parallel to the development of the Refinery
Looking Forward to remainder of 2022

KEY ACTIVITIES OVER THE REMINDER OF 2022 TO UNLOCK SUBSTANTIAL VALUE AT IONIC RARE EARTHS

• Updated Exploration Target for Makuutu Project tenements (Q2 2022)
• Feedback on ESIA in Uganda (Q2 2022)
• Phase 2 Metallurgical variability and testwork (Q2 2022)
• Finalise Makuutu Project Approvals (Q3 2022)
• Makuutu Feasibility Study (Oct 2022)
• Makuutu Mining Licence Application target submission (Oct 2022)
• Refinery Scoping Study (Q3 2022)
  → Downstream Opportunity and how IonicRE can play a larger role in development of alternative, secure and traceable rare earth supply chains and alliances
• Ongoing Exploration Activity – RAB scout exploration drilling at EL00147 and EL0257 (H2 2022)
• Magnet recycling demonstration plant (H2 2022)
### Ionic Clay Rare Earth Elements Vs Hard Rock Rare Earth Elements

<table>
<thead>
<tr>
<th>Mining &amp; Processing Stages</th>
<th>Ionic Adsorption Clay – Hosted REE</th>
<th>Hard Rock – Hosted REE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mineralisation</strong></td>
<td>Soft material, negligible (if any) blasting Elevated HREO/CREO product content</td>
<td>Hard rock: Bastnaesite and Monazite (LREO dominant); Xenotime (HREO dominant)</td>
</tr>
<tr>
<td><strong>Mining</strong></td>
<td>Low relative operating costs: Surface mining (0-20m) Minimal stripping of waste material Progressive rehabilitation of mined areas</td>
<td>High relative operating costs: Blasting required Could have high strip ratios</td>
</tr>
<tr>
<td><strong>Processing/Mining Site</strong></td>
<td>No crushing or milling Simple process plant Potential for static or in-situ leaching with low reagent at ambient temperatures</td>
<td>Comminution, followed by beneficiation that often requires expensive (flotation) reagents to produce mineral concentrate</td>
</tr>
<tr>
<td><strong>Mine Product</strong></td>
<td>Mixed high-grade Rare Earths precipitate, either oxide or carbonate (≥90% TREO grade) for feedstock directly into Rare Earth separation plant, low LaCe content</td>
<td>Mixed REE mineral concentrate (typically 20-40% TREO grade), high LaCe content, requires substantial processing before suitable for feed to rare earth separation plant</td>
</tr>
<tr>
<td><strong>Product Payability</strong></td>
<td>60-70% payability as mixed Rare Earth oxide/ carbonate</td>
<td>30-35% payability as a mineral concentrate</td>
</tr>
<tr>
<td><strong>Processing - Environmental</strong></td>
<td>Non-radioactive tailings Solution treatment and reagent recovery requirements (somewhat off-set by advantageous supporting infrastructure)</td>
<td>Tailings often radioactive (complex and costly disposal) Legacy tailing management</td>
</tr>
<tr>
<td><strong>Processing - Refinery</strong></td>
<td>Simple acid solubilisation followed by conventional REE separation Complex recycling of reagents and water Lower Capex (~$100-$200m)</td>
<td>High temperature mineral &quot;cracking&quot; using strong reagents to solubilise the refractory REE minerals Complex capital-intensive plant (~$500m-$1B) required Radionuclide issues follow REE mineral concentrates</td>
</tr>
</tbody>
</table>

**Significant Advantages for IAC Mining/Processing vs Hardrock**

- Ionic Adsorption Clay (IAC) deposit mineralisation is highly desirable given it produces a balanced REO basket dominant in magnet & heavy REO with higher value and broader appeal
- Near surface IAC mineralisation translates to lower strip ratios with lower cost mining methods
- IAC ores require much lower CAPEX intensity to produce refined REOs
- IACs produce value added Mixed Rare Earth Carbonate product from IAC deposits, higher grade and basket value
- IAC product achieves approx. double the payability
- IACs experience none of the radionuclide issues the plague hard rock LREO Projects
- IAC separation and refining much lower CAPEX requirement
The REE Basket Problem – the Solution requires ‘Balance’

IONIC THROUGH MAKUUTU CAN DELIVER UNIQUE BALANCE TO WESTERN HREO PRODUCTION FROM ‘RARE’ IAC MINERALISATION

Ionic Adsorption Clay (IAC) deposit mineralisation is highly desirable given it produces a balanced REO basket dominant in magnet & heavy REO with higher value and broader appeal.

Hard rock rare earth mines typically >90-95% LREE, i.e. very low in HREE content.

Very few true IAC deposits (<5) identified of scale outside of southern China, Myanmar and south east Asia.

Increased LREE production to facilitate oversupply, and potentially suppress LREE prices, specifically NdPr.

IAC HREE mines complement hard rock LREE mines in China, providing ‘balance’ to REE supply quotas.

IAC HREE mines typically much lower production capacity than hard rock LREE mines, however much higher value product.

The rare earth solution for the future requires a balance; LREE readily sourced but HREE is truly rare.
Makuutu Basket is Balanced, magnet +HREO Dominant, & High Value

<table>
<thead>
<tr>
<th>Company</th>
<th>Ionic Rare Earths</th>
<th>Aclara1</th>
<th>Serra Verde2</th>
<th>Lynas Rare Earths3</th>
<th>MP Materials4</th>
<th>Arafura Resources5</th>
<th>Australian Strategic Materials6</th>
<th>Hastings Technology Metals7</th>
<th>Peak Resources8</th>
<th>Pensana Rare Earths9</th>
<th>Northern Minerals10</th>
<th>Namibia Rare Earths11</th>
<th>USA Rare Earths12</th>
<th>REO Pricing</th>
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<tbody>
<tr>
<td><strong>Mineralisation</strong></td>
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**Note. Rounding Applied to nearest 0.1%.**
Makuutu and Critical Raw Materials 2020

MAKUUTU BASKET CONTAINS HIGH RANKED CRMs IDENTIFIED IN 2020 EU STUDY REQUIRED TO ACHIEVE CARBON NEUTRALITY

Secure and sustainable supply of both primary and secondary raw materials, specifically of critical raw materials (CRM)

Targeting key technologies and strategic sectors as renewable energy, e-mobility, digital, space and defence is one of the pre-requisites to achieve climate neutrality

European Commission report identified Global competition for resources will become fierce in the coming decade

Dependence of critical raw materials may soon replace today’s dependence on oil

Makuutu has all the REO requirements in appreciable quantities

Scandium potential at Makuutu to facilitate light weighting transportation

Long term stable supply is not a given – will require investment further up the supply chain

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**Economic Importance vs Supply Risk results for 2020 criticality assessment**

IonicRE Vision – Facilitating Manufacturing

DEVELOPING MAGNET & HEAVY REO SUPPLY CHAIN TO CREATE NEW INDUSTRY AND JV’S

- Through the availability of long-life, low-cost MREC from Makuutu, IonicRE aiming to develop relationships with key industry participants to generate EU and US based manufacturing activity
- Initial focus on permanent magnets used in Electric Vehicles, Offshore Wind Turbines and Defence
  - Expanded out shortly after to cover other magnet REO applications with Sm, Gd and Ho
- Longer term focus in heavy rare earth growth opportunities
  - Niche heavy rare earth applications and high-end technologies – communications, medical, laser optics
- Providing a secure and traceable supply of magnet and heavy rare earths – Seeds of Technology – to facilitate new R&D to propagate new applications and innovations with partners
- Development of new age alloys for new technologies - Aluminium-Scandium alloys in light weighting transportation
- Facilitating Life Cycle ownership of Rare earth processing
  - Magnet recycling and redeployment of magnet REOs back to new high quality, high intensity applications
NdFeB Magnet Recycling – low cost, modular plan

**FIRST MOVER CAPABILITY FOR DOWNSTREAM MAGNET RECYCLING TO SEPARATED 99.99%+ MAGNET RARE EARTH OXIDES**

- Seren Technologies patented process uses chemical extraction to extract the magnet REE from the spent magnets to enable recycling back to the refined 99.9%+ REO quality

- Unique technology that has significant advantages over existing technologies which are unable to separate the individual REOs

- Recycled REO can then be used to make higher quality magnets with greater proportions of heavy rare earths Dy and Tb for high-cost applications such as offshore wind turbines

- Low capital and modular production of Nd, Pr, Dy and Tb oxides
REE Demand – Magnet Recycling to help fill the void

LAG IN INVESTMENT OF PRIMARY RARE EARTH EXTRACTION & POTENTIAL FOR NEAR TERM MAGNET RECYCLING

• Lack of historical investment will result in near term demand far exceeding supply
• Installation of primary extraction (i.e. mining) of rare earths from new or existing mining projects (by-product) is significant, with estimations up to 8-15 years
• Significant time advantage with low-cost modular Ionic Adsorption Clay (IAC) capacity also producing a more balanced basket of magnet REEs required magnet production
• New primary REO production will lag demand creating an opportunity for secondary sources (i.e. magnet recycling) to help fill the void
• > 100,000 tonnes of rare earth permanent magnets are consumed each year in renewable energy, machine tools, robotics, loudspeakers, water pumps, mobility, and ICT
• 16,000 tonnes of rare earth permanent magnets are exported from China to Europe each year, representing approximately 98% of the EU market
• < 1% recovery of rare earth permanent magnet scrap in Europe, which represents a large potential resource at a low carbon footprint
• Similar opportunity exists in Nth America and Asia to deploy low cost, REE recovery from waste and spent permanent magnets
• As magnet production increases, so does longer term opportunity for magnet recycling, which could make up 20-25% of REO supply chain by 2030
Facilitating the automotive rEVolution

43% Magnet REOs required for Permanent Magnet drives for EVs
Electric Vehicles – Driven by NdPr (and DyTb)

Nd, Pr, Dy & Tb EXPECTED TO BE IN DEFICIT BY 2027

- Worldwide EV demand driving insatiable appetite for NdPr, but DyTb largely overlooked
- NdFeB permanent magnets (PM) are essential for producing light, compact and high efficiency traction motors. Approx. 28-32% of the NdFeB magnet is magnet NdPr, with DyTb used as a minor additive (~4-8%) to improve magnet performance at high temperatures
- Global governments mandate change with ICE to be banned in several countries from 2025, with significant changes expected in Europe where demand driven by government incentives will see it overtake China by 2030 as largest market for EVs
- Global EV sales in 2020 ~ 3.1 million, with global EVs sales expected to hit ~13-14 million in 2025, and ~25 million by 2030
- US announced target of 50% EV penetration by 2030 – ICE ban from 2035 in California

### Proposed Internal Combustion Engine (ICE) Bans

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>2025</td>
<td>Norway</td>
</tr>
<tr>
<td>2030</td>
<td>Denmark, Iceland, Ireland, Netherlands, Slovenia, Sweden, UK</td>
</tr>
<tr>
<td>2040</td>
<td>France, Spain</td>
</tr>
<tr>
<td>2050</td>
<td>Japan</td>
</tr>
</tbody>
</table>

1 Pavel, et al., Role of substitution in mitigating the supply pressure of rare earths in electric road transport applications, 2017; Roskill, Rare Earths: Outlook to 2030, January 2021; 2 Argus Analytics, October 2021;
Facilitating Offshore Wind Capability

IonicRE basket producing all the Nd, Pr, Dy and Tb required for offshore wind turbines
Land Constrained – Go Offshore

CURRENT WORLD OFFSHORE WIND TURBINE CAPACITY IS 36 GW

Argus\(^1\) estimates an additional 235 GW of installed offshore wind turbine capacity to be added by 2030 \(
\rightarrow\) 25% CAGR for the remainder of the decade.

In its 2019 World Energy Outlook, the International Energy Agency (IEA) Sustainable Development Scenario has up to 570GW of offshore wind in 2040. If achieved, the world would be on track to reach about 1TW in 2050\(^2\).

The International Renewable Energy Agency (IRENA) also has a 1TW ambition by 2050.

US DOE announced in March 2021 a plan to develop 30GW of offshore wind turbine by 2030. Further, achieving this target also will unlock a pathway to 110 GW by 2050.

Ambitious target announced in December 2020, Ocean Renewable Energy Action Coalition (OREAC) calling on governments to up their offshore renewable energy ambition to achieve the coalition’s vision of 1,400 GW of offshore wind by 2050.

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1 Argus analytics, October 2021; 2 Ocean Renewable Energy Action Coalition, The Power of our Ocean, December 2020;
No DyTb – No Offshore Wind Turbine Capacity

THE BASICS – HOW MUCH REO IS REQUIRED PER MW OF OFFSHORE TURBINE CAPACITY?

Rare-earth elements and boron (B) are essential for turbine designs that employ permanent magnets (NdFeB). The HREOs Dy2O3, Tb4O7 and in some cases Ho2O3, can be substituted to improve the operability of the NdFeB magnets. Adding these HREOs helps the high temperature direct drive turbines maintain their magnetic characteristics. Substitution is not an option.

Most direct-drive turbines, but also to different extents certain technical designs with gearboxes, are equipped with permanent magnet generators, which contain NdPr and smaller quantities of DyTb. On average, a permanent magnet contains 28.5% NdPr, 4.4% DyTb, 1% B and 66% Fe and weighs up to 4 tonnes for a 6MW offshore direct drive wind turbine.

### HALIDE* 150-MV OFFSHORE WIND TURBINE

- Each 6 MW of offshore direct drive wind turbine capacity requires ~ 1,700 kg magnet REOs;
  - ~210 kg/MW Nd2O3 x 6 MW = 1,260 kg Nd2O3
  - ~42 kg/MW Pr6O11 x 6 MW = 254 kg Pr6O11
  - ~20 kg/MW Dy2O3 x 6 MW = 117 kg Dy2O3
  - ~8 kg/MW Tb4O7 x 6 MW = 49 kg Tb4O7
- HaliadeX 13 MW offshore direct drive wind turbines now under development

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1 Roskill, Rare Earths: Outlook to 2030, January 2021; 2 European Commission, Raw materials demand for wind and solar PV technologies in the transition towards a de-carbonised energy system, 2020; 3 Li et al., One Earth 3, Critical Rare-Earth Elements Mismatch Global Wind Power Ambitions, 2020; Haliade 150-6MW turbine by GE Renewable Energy @GErenewables;
Makuutu & Offshore Wind Turbine Capacity

MAGNET REO – SUPPLY FAILING DEMAND → ‘ESCAPE VELOCITY’ BY 2027

- Forecast offshore capacity increase by 235 GW by 2030¹² (25% CAGR)
- 2020 global offshore wind turbine capacity of 35.7 GW
- 2020 added capacity of 6.07 GW with 2021 installations increasing to 12.7 GW (+110% of 2020 added capacity)

- **By 2025 the crunch will come**, with forecast supply of magnet REOs is forecast to be below demand
- By 2027 heavy magnet REOs Dy₂O₃ and Tb₂O₇ significantly in deficit
- By 2030 demand of magnet REOs forecast to exceed supply by 40%
- Beyond 2030 however the rate of growth on offshore wind turbine appears to exceed the capability to supply magnet REEs

- Projections of future wind turbine installation growth beyond 2030 to 2050 have highlighted the inadequacy of existing REO supply chains, with an estimated 11-to-26-fold expansion of current magnet REO supply required to meet global wind turbine targets².

- **Makuutu magnet REO production ramped up from 2024 to supply an estimated 17 GW of offshore wind turbine capacity by 2030, 11-year LOM estimated to enable 35 GW of capacity, LOM potential 90+ GW of capacity with scale to grow substantially**

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¹ Argus Analytics October 2021. ² Li et al., One Earth 3, Critical Rare-Earth Elements Mismatch Global Wind Power Ambitions, 2020. ² Excludes US DOE plan to add 30 GW by 2030
Facilitating Defence Capability

IonicRE basket – Heavy Rare Earth Strategic Appeal for Defence Applications
Magnet & Heavy REO crucial in Defence Applications

DEFENCE HREO SUPPLY CHAIN – PROVIDING SECURE SOURCE OPTION

Rare Ingredients
Here is the breakdown of rare-earth materials used to make each.

- **F-35**: 920 lbs.
- **Arleigh Burke DDG-51**: 5,200 lbs.
- **SSN-774 Virginia-class Submarine**: 9,200 lbs.

Y$_2$O$_3$ used in F-35 presently sourced from IACs in southern China and Myanmar

Makuutu Basket ~73% used in Defence Applications

- Y$_2$O$_3$: 25.4%
- CeO$_2$: 13.5%
- Pr$_6$O$_{11}$: 5.5%
- La$_2$O$_3$: 13.5%
- Lu$_2$O$_3$: 0.2%
- Yb$_2$O$_3$: 1.3%
- Tm$_2$O$_3$: 0.3%
- Er$_2$O$_3$: 2.0%
- Ho$_2$O$_3$: 0.7%
- Dy$_2$O$_3$: 3.7%
- Tb$_4$O$_7$: 0.6%
- Gd$_2$O$_3$: 4.4%
- Eu$_2$O$_3$: 0.9%
- Sm$_2$O$_3$: 4.7%
- Nd$_2$O$_3$: 23.2%

Source: Congressional Research Service
## Magnet & Heavy REO crucial in Defence Applications

**DEFENCE HREO SUPPLY CHAIN – MAKUUTU POTENTIALLY SUPPLIES IT ALL**

- Numerous Magnet & HREO materials are used in defence applications in the engines, disk drive motors, radar of the aircraft, fin actuators in missile guidance and control systems, control devices in tanks, missile systems, command and control centres; lasers, interrogators, underwater mines, countermeasures; satellite communications, radar, and sonar on submarines and surface ships; optical equipment and speakers, components in anti-missile defense systems, satellites and night vision devices among others.

- REE metals used in F-35 fighter (417kg); Virginia-class submarine (4,170kg); and Arleigh-Burke guided missile destroyer (2,360kg).

- Terfenol-D is a rare earth alloy made of Tb, Fe and Dy that is used in high-power sonar on ships and submarines.

- Stealth helicopters also use Terfenol-D speakers in their noise cancellation technology blades and NdFeB magnets.

<table>
<thead>
<tr>
<th>PRODUCT / APPLICATION</th>
<th>RARE EARTH ELEMENT (REE)</th>
<th>USAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-35 Lightning II joint strike fighter</td>
<td>Y</td>
<td>Jet engine</td>
</tr>
<tr>
<td>ATHENA laser weapon system</td>
<td>Er, Yb, Nd</td>
<td>Optical fibres in fibre laser module</td>
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<tr>
<td>Tomahawk missile</td>
<td>Combination of Nd, Pr, Dy, Tb, Sm</td>
<td>Fin actuators in missile guidance and control systems, GPS, sensors</td>
</tr>
<tr>
<td>Joint Direct Attack Munition (JDAM) guided bombs</td>
<td>Combination of Nd, Pr, Dy, Tb, Sm</td>
<td>Fin actuators in missile guidance and control systems, GPS, sensors</td>
</tr>
<tr>
<td>AN/ALQ-184 Electronic Attack Pod</td>
<td>Y</td>
<td>Electronic jamming devices, storage batteries</td>
</tr>
<tr>
<td>Zumwalt-class destroyer</td>
<td>Nd, Pr, Dy, Tb, Sm</td>
<td>Electric motors</td>
</tr>
<tr>
<td>HUMVEE military truck</td>
<td>Y, Eu, Tb</td>
<td>Humvee-mounted Laser Avenger</td>
</tr>
<tr>
<td>F-16, F-15, F-22</td>
<td>Er, Sm</td>
<td>Jet engine, Electric systems- permanent magnets</td>
</tr>
<tr>
<td>M1A2 Abrams tank</td>
<td>Sm, Eu, Nd, Tb, Y</td>
<td>Navigation system, Laser-equipped computer main gun sight</td>
</tr>
<tr>
<td>Stinger MANPAD</td>
<td>Combination of Nd, Pr, Dy, Tb, Sm</td>
<td>Fin actuators in missile guidance and control systems, GPS, sensors</td>
</tr>
<tr>
<td>Precision-guided munitions</td>
<td>Combination of Nd, Pr, Dy, Tb, Sm</td>
<td>Fins attached to fuselage, special magnets</td>
</tr>
<tr>
<td>PATRIOT missile air defence system</td>
<td>Gd, Sm, Y</td>
<td>Radio frequency circulators</td>
</tr>
<tr>
<td>MQ-9, MQ-1 Predator drones</td>
<td>Y, Tb</td>
<td>Laser Weapon System</td>
</tr>
</tbody>
</table>

N.B. Numerous Magnet & HREO materials are used in defence applications in the engines, disk drive motors, radar of the aircraft, fin actuators in missile guidance and control systems, control devices in tanks, missile systems, command and control centres; lasers, interrogators, underwater mines, countermeasures; satellite communications, radar, and sonar on submarines and surface ships; optical equipment and speakers, components in anti-missile defense systems, satellites and night vision devices among others.

![Lockheed Martin F-35 Lightning II Joint Strike Fighter](https://www.defenseworld.net/feature/33/US_Companies_Threatened_With_Sanctions_May_be_Denied_Chinese_Rare_Earth_Materials#.YI_Z_mJAzYuU)
Magnet & Heavy REO – IonicRE Production Delivers Every Need

**Figure 1. Rare Earth Elements in Guidance and Control Systems**

- La
- Sm
- Tb
- Pr
- Eu
- Lu
- Nd
- Dy
- Y

**Figure 2. Rare Earth Elements in Defense Electronic Warfare**

**Figure 3. Rare Earth Elements in Targeting and Weapon Systems**

**Figure 4. Rare Earth Elements in Electric Motors**

**Figure 5. Rare Earth Elements and Communication**

Sources: Compiled from presentations by the Rare Earth Industry and Technology Association, the United States Magnet Manufacturing Association, and David Pinesak, “Global Rare Earth Element Review,” Defense National Stockpile Center, spring 2010.
Heavy Rare Earth Dominant

IonicRE basket – 44% Heavy Rare Earths deployed in high end applications
Key HREO Applications without Substitute – New Supply Required

**HREO USED IN HIGH END FOR NICHE APPLICATIONS – NO SUBSTITUTION FOR REOS IN SPECIFIC APPLICATIONS**

- IAC mines in southern China and Myanmar produce approximately 95% of the world’s production of HREO.
- Export Control Ban implemented by China on 1 December 2020 now focused on prioritising Chinese consumption and strategic stockpiling.
- High-value niche medical applications such as:
  - Magnetic Resonance Imaging (MRI) machines using Gd;
  - Positron Emission Tomography (PET) imaging using Lu;
  - X-rays, Solid-state lasers, optical isolators and microwave equipment using Er, Ho, Tm, Yb, Y;
- Critical applications REE are essential for electronic devices as permanent magnets (PM) in speakers, computer components, global positioning systems (GPS), sonar, defence systems and lasers – will start to see this flow through to consumer item availability and cost.
- Er is a key input into enabling 5G technology – Erbium doped fibre amplifiers (EDFA) are used to compensate the loss of an optical fibre in long-distance optical communication and can amplify multiple optical signals simultaneously. No Erbium, No 5G.
- Nuclear power plant use Sm-Co permanent magnets, and Dy & Er in neutron-absorbing control rods.
Key HREO Applications – Fibre Laser outlook to 2030

GLOBAL FIBRE LASER MARKET VALUE ESTIMATED TO REACH US$8.42 BILLION BY 2030 (CAGR 14.5%)

• Global fiber laser market value estimated to be US$2.23 Billion in 2020
• Optical fibers used in the fiber laser are doped with rare earth metals such as Yb, Er, Nd, Tb and Eu.
• Fibre lasers are optically pumped devices mostly used with laser diodes (uses REE) amplify the produced light. Fiber lasers has a large surface-to-volume ratio (heat dissipation is relatively easy). Laser is comparatively smaller and lighter in weight than traditional lasers
• Widely used in number of industrial manufacturing processes: marking, metal cutting and welding of automotive and aircraft components. Technological advancements, rapid improvement in infrastructure coupled with research and development in this field have contributed to the growth of the market.
• Automotive industry (growing demand of EVs) vital for the growth of fibre laser market.
• Growing demand for compact, cost-effective lasers along with widespread adoption of fibre lasers into numerous new industries are also anticipated to propel the market growth.
Scandium Upside

IonicRE basket – Scandium to unlock new industries and 'Blue Sky'
Makuutu is one of the largest global Scandium resources... and growing

2ND LARGEST GLOBAL SCANDIUM RESOURCE REPORTED

Key to the success of the scandium industry is a diverse and reliable supply chain

While historically the scandium market has been dominated by Chinese supply, there are companies producing scandium or actively developing scandium supply

The Makuutu Rare Earths Project's scandium endowment and time to market make it a key future global player in the scandium market

Scandium market expected to grow very quickly once stable supply is demonstrated
Due to its high strength and high corrosion resistance, aluminium alloys are a growing material of choice for shipbuilding.

‘Marine grade’ aluminium is 100 times less prone to corrosion than its steel counterpart.

‘Marine-grade’ aluminium alloys are both strong and weldable, which mean large sections of ships can be constructed with no joints or bolts, which reduce corrosion and the risk of water ingress.

While historically niche sub-sector of aerospace, the commercial space industry represents a fast-growing sector where aluminium has a long, deep-rooted history.

Rockets use a range of aluminium alloys in propellant tanks, providing a strong, lightweight material which can operate over large temperature ranges.

Advanced aluminium alloys, combined with 3D printing, provide the space industry a unique opportunity to mass produce reusable rockets and satellites.

Aluminium is well-established in aerospace, with most airplanes constructed of aluminium alloys. While carbon fibre materials are lighter, they are more expensive, have a higher maintenance cost and require costly metals (such as titanium) to be used in concert. More advanced aluminium alloys can provide comparable low-cost alternative to composites.

The next aerospace aluminium alloys will be strong and weldable, removing the need for rivets, providing enormous weight saving.

Aluminium is displacing high-strength steel (HSS), a lower cost and heavier competitor, in several components.

Advantages of using aluminium in aerospace include:
- Lower density
- Better fatigue resistance
- Lower maintenance cost
- Improved performance

Aluminium is also used in high-speed trains, where its light weight and high strength to minimise friction loss are particularly beneficial.

Aluminium has had a long history with rail, widely used in both freight and passenger cars.

Aluminium provides ~30-35% weight reduction over steel and does not corrode, leading to a much longer service life.

High-speed trains realise the greatest benefit from aluminium, which require low weight and high-strength to minimise friction loss.

Like aerospace, aluminium has an extensive history in the rail sector, with significant use in both freight and passenger vehicles.

Aluminium provides a weight reduction of around 25% compared to steel, which is beneficial for reducing wear and tear on tracks and improving overall efficiency.

Aluminium in vehicles has been steadily increasing, driven by stricter efficiency and emissions requirements.

The electric vehicle (EV) revolution is dramatically accelerating aluminium’s market share through new parts (e.g. battery boxes) and the need to increase vehicle range.

EVs have 35-50% more aluminium than internal combustion engine vehicles.

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Scandium Market Potential

**SIGNIFICANT POTENTIAL FOR SCANDIUM MARKET TO GROW RAPIDLY IN GLOBAL TRANSPORT SECTORS**

While the current scandium (Sc) market is 15-20 tonnes per annum scandium oxide (Sc$_2$O$_3$), the global transportation industry has the potential to turn scandium into a billion-dollar market.

**Scandium supply chain:**

- **Makuutu**
  - Makuutu Sc$_2$O$_3$
    - 20-90 tpa
    - 2.5-12% market share
  - Master Alloy Producers
    - 2% Scandium master alloy
      - 26,000 tpa
  - Aluminium Alloy Producers
    - 0.05-0.1% Scandium-containing alloys
      - 700,000 tpa
  - Other Scandium Producers
    - Sc$_2$O$_3$
      - 710-780 tpa
  - Other Alloysing Elements
    - Aluminium
      - 7Mtpa aluminium consumption in global transport:
        - Automotive: 5-6Mtpa
        - Aerospace: 1Mtpa
        - Space, Marine, Rail: <1Mtpa
  - Other Scandium Producers
    - Aluminium
      - 700ktpa aluminium consumption with scandium with a 10% market penetration over the next 5-10 years

**Contestable Scandium Market**

The adoption of scandium will be heavily dependent on its price-point. As the market grows, the scandium price will decrease as economies of scale for production can occur. This will allow aluminium-scandium to be used in an increasing number of applications.

While the initial price of scandium could be US$1,000/kg Sc$_2$O$_3$ at low tonnages, this will likely drop to ~US$700/kg with increased volumes.

**Scandium Market Value**

- Avg Sc content: 0.075%
- Required Scandium: 525tpa (800tpa Sc$_2$O$_3$)
- Sc price range: US$700-1,000/kg Sc$_2$O$_3$

**Makuutu Scandium**

- 20-90+ tpa Sc$_2$O$_3$
  - (2.5-12% total market share)
  - US$20-63M+ p.a. Revenue

**Future Markets / Applications:**

- Military Vehicles & Armour
- Wind Turbines
- Electrical Cable
- Magnesium-scandium alloys

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