

London Metal
G R O U P

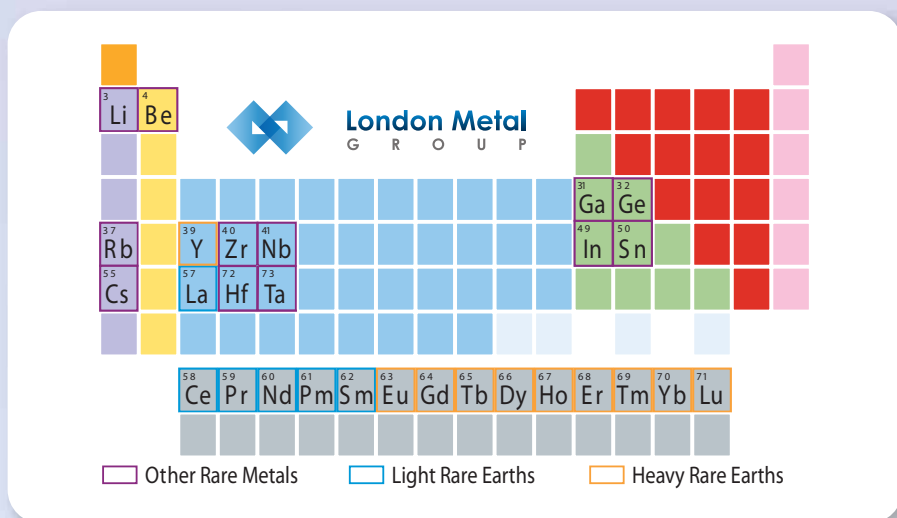
RARE EARTHS 101

RARE EARTH ELEMENTS: THE BASICS, ECONOMICS
SUPPLY CHAIN AND APPLICATIONS



RARE EARTH BASICS

Rare Earth Elements ('REE') are non-toxic elements essential to a cleaner environment and reduced reliance on fossil fuels. Also, REE are an enormous potential benefit to human health.



There are 16 REE in total, as defined by the U.S. Geological Survey, 15 lanthanide elements appearing at the bottom on the Periodic Table, with atomic numbers ranging from lanthanum (57) to lutetium (71), plus the metal yttrium (39); all of which display similar physical and chemical properties. REE deposits tend to occur in two sub-groups:

Light rare earth elements ('LREE'), which include lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), and samarium (Sm)

Heavy rare earth elements ('HREE'), which are less common and more valuable, include europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and lutetium (Lu)

Yttrium (Y) most commonly occur in association with HREE sub-group

REE are not particularly rare in the earth's crust, similar abundance to nickel or tin, but generally not concentrated in commercially viable ore deposits.

COMMON PROPERTIES OF RARE EARTHS

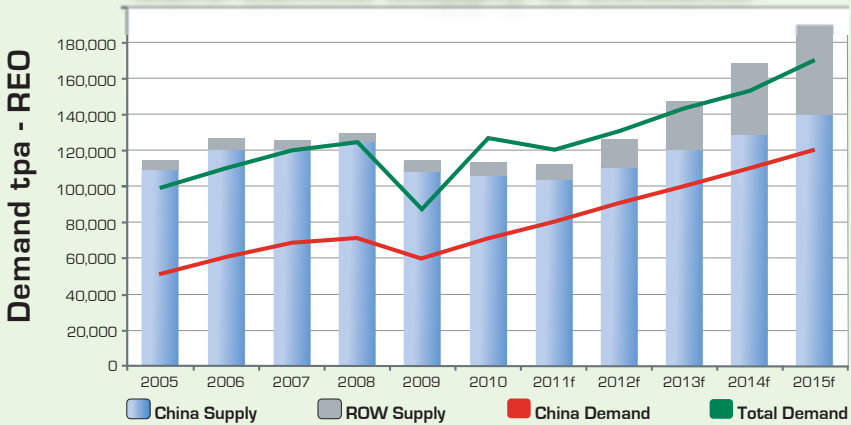
- Silvery-white metals that tarnish when exposed to air, thereby forming oxides
- Catalytic, chemical, electrical, metallurgical, nuclear, magnetic and optical properties
- Relatively soft metals; hardness increases with higher atomic numbers
- Many REE compounds fluoresce strongly under ultraviolet light
- Reacts with water to liberate hydrogen gas, slowly in cold/quickly upon heating
- Reacts with dilute acid to release hydrogen gas rapidly at room temperature
- Most REE compounds are strongly paramagnetic
- High melting and boiling points

RARE EARTH ECONOMICS

GLOBAL SUPPLY & DEMAND HISTORY

- 1794 Rare Earths discovered by Johan Gaddin in Ytterby, Sweden
- 1903 First commercial production of rare earth flints at Treibach in Austria
- 1953 Demand approximately 1,000 tons (US\$25 million)
- 1965 First stand-alone rare earths mine opened at Mountain Pass, US
- 1985 Development of the NdFeB permanent magnet; China initiates low cost production
- 2003 Demand approximately 85,000 tons (US\$500 million)
- 2008 Demand approximately 124,000 tons (US\$1.25 billion)
- 2015 Demand approximately 200,000 tons (US\$8-9 billion)

Rare Earths Supply & demand



Source: IMCOA, September 2011

Today, China produces over 95% of the world's rare earth elements ("REE"). New sources are being developed in Canada, USA and Australia. In aggregate, demand and supply will be balanced; however, light rare earth elements ("LREE") are expected to be in surplus while heavy rare earth elements ("HREE") in deficit.

Year	RE Export Quota (tonnes)	% Change	Demand outside China (tonnes)	Surplus (Shortfall) (tonnes)
2005	65,609	0.0%	48,000	17,609
2006	61,821	-5.8%	53,000	8,821
2007	59,643	-3.5%	55,000	4,643
2008	56,939	-4.5%	54,000	2,939
2009	50,145	-11.9%	25,000	25,145
2010	30,258	-39.7%	52,500	(22,242)
2011	30,246	0.0%	40,000	(9,754)
2012	31,130	2.9%	41,000	(9,870)





Source: IMCOA, Metal-Pages, Chinese Ministry of Commerce

The China Factor-Reduced Exports

China's government has been implementing a range of policies putting the government in control of private and unauthorized mines that produce rare earth minerals (especially from the HREE-rich South China ionic clays), implementing stricter regulations towards improving environmental performance of its mining sector, and requiring foreign companies to move factories to China to complete production of items using rare earths. The outcome of these policies is reduced availability of rare earths outside China, higher prices, and the threat of further export restrictions. The market is encouraging companies to produce a secure source of rare earths outside China.

RARE EARTH APPLICATIONS

REE are used in everyday products to produce energy, reduce energy, increase energy efficiency, and in everyday lifestyle consumer and medical products.

Energy Production	Energy Reduction	Energy Efficiency	Lifestyle Products
			
Petroleum Refining	UV Filters in Glass	Electric / Hybrid Vehicles	Color Screens
La	Ce	Nd Sm	Y Eu Tb
High-Powered Electric Motors	Reducing Fuel Consumption	Rechargeable Batteries	Hardware Components
Nd Dy Tb	Nd	La	Nd
Electric / Hybrid Vehicles	Lighter Vehicles	Energy-Efficient Lighting	Medical Services
La	Dy	Eu Tb Ce Y La	Ce Nd Gd
Wind Turbines	Smaller, Lighter Electric Motors		
Nd Dy Tb	Nd Dy Tb		

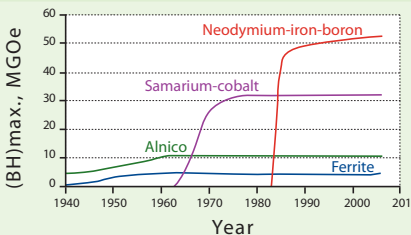
NdFeB PERMANENT MAGNETS ('NEO MAGNETS') are much more powerful than alternatives, providing better performance with a smaller size which has led to many miniaturisation applications. Rare earth magnets have been advanced by neodymium, dysprosium, samarium, praseodymium and terbium.

WIND TURBINE

power generation is directly proportional to the sweep area of the blades and the cube of wind-speed (similar principles underlie **TIDADPOWER**), hence wind turbine blade spans are getting larger and the overall assemblies taller.



- New designs use **Neo magnets** for direct drive turbines connected to permanent magnet generators.
- New designs eliminate gearboxes thereby reducing energy losses in the machine's internal operations, risk of failures and maintenance costs.
- Approximately 0.6 - 0.9 tonnes of **Neo magnets** per megawatt, of which approximately 30% is REE.



ELECTRIC MOTORS

are smaller, lighter weight, quieter and more energy efficient with REE magnets. Typically used in turn-drum type washer and dryer, motors, vacuum cleaners' motors, elevator wind-up motors, and compressor motors.



HYBRID VEHICLES

cut fossil fuel use by combining a gasoline engine, battery-powered electric motors and brakes that capture energy from stopping.



- Components requiring REE include: the metal hydride component of a nickel-metal hydride (NiMH) battery; the electric motor, generator and regenerative braking systems which are dependent on rare earth magnets.
- Typical hybrid vehicle contains approximately 30 kgs of REE, with the majority contained in a typical NiMH battery (approx. 15 kgs).
- REE play a critical role in automotive catalytic converters, which transform the primary pollutants in engine exhaust gases into non-toxic compounds.

MRI MACHINES used for medical imaging and diagnostics, now incorporate rare earth permanent magnets to generate high strength magnetic fields.



- Permanent magnets are replacing expensive traditional systems of super cooling wire coils in liquid helium system to reduce the electrical resistance in the wire coils.
- New units also provide wider, less claustrophobic space for the patient.

LIGHT EMITTING DIODES (LEDS) are 80% more efficient than incandescent lighting, and 40% more efficient than compact fluorescent bulbs (CFLs).



- LEDs have an expected life of 50,000 hours and some are sold with 5 year warranties.
- LED market value was approx. \$4.6 billion in 2007, and expected to be more than \$11 billion in 2012.
- Global policy shift of banning incandescent light bulbs, to be replaced by CFLs and LEDs, is gaining momentum. CFLs increasingly seen as an interim step, as they present mercury disposal management issues.

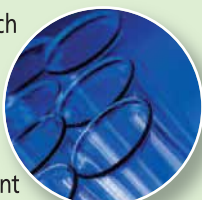
CONSUMER ELECTRONICS

such as Apple's iPod music players as well as other high performance speakers, headphones or buds, are driven by tiny **Neo magnets**, resulting in smaller, lighter speakers with faster bass response and lower overall distortion.



GLASS PRODUCTS

such as those used in monitors, requires **cerium oxide**, with unique physical and chemical properties, as a building block for very efficient polishing compounds through chemical dissolution and mechanical abrasion, such as solar cell protective glass.



MEDICAL: Rare earths are used in a wide range of applications including drug treatments, diagnostic techniques and equipment.



- Catalyst in biomedical and chemical research.
- Organize complexes used in intravenously administered contrasting agents to enhance imaging.
- Laser cases and radioisotopes used in cancer treatments.

MONITORS

for computers and plasma televisions are coated with phosphors, which generate the primary colours red, blue, and green. Red requires **europium**, new blue **europium** phosphor retains brightness ten times longer than previous blue phosphors, and green is generated by phosphor doped with **terbium**.



- A combination of these primary colour phosphors are used to create the white "backlight" used in LCD screens and the energy efficient "tri-phosphor" light bulbs.

FLUID CRACKING CATALYSTS

use **lanthanum** and **cerium** in the refining of crude oil, and is the major contributor to the process that enables the transformation of heavy molecules into lighter compounds that make up gasoline and other fuels (e.g. gas, jet fuel and diesel).



REE SUPPLY CHAIN

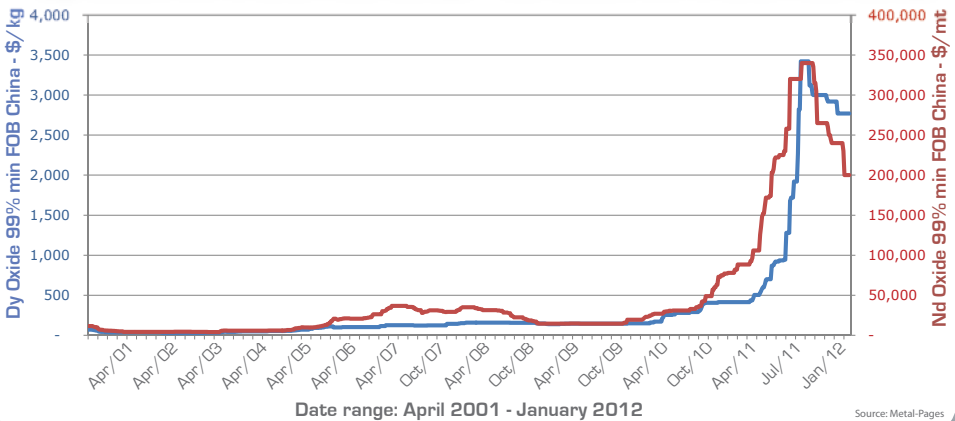
RARE EARTH ELEMENT PROCESS: FROM ROCK TO TOMORROW'S PRODUCTS

Mining	Milling	Hydrometallurgy	Separation	Refining	Products
From the ground to crushed ore	Grinding and beneficiation of REE minerals	Cracking the REE minerals to produce mixed REE oxides concentrate	Separating and purifying the individual REE oxides	To meet specific downstream technology applications	Permanent magnets, LED's, consumer electronics



REE PRICING: DYSPROSIUM AND NEODYMIUM

Dy Oxide 99% min FOB China - Nd Oxide 99% min FOB China



CORPORATE SOCIAL RESPONSIBILITY

Rare Earths are essential components in many clean and green technologies. Social and environmental responsibility and good corporate governance are integral to the exploration, development and production stages of any resource project.

London Metal Group will publish its first Global Reporting Initiative (GRI) CSR Annual Report by Q1-2012.

