Commodities

Rare Earths: Too Late To The Party?

Commodities | Australia

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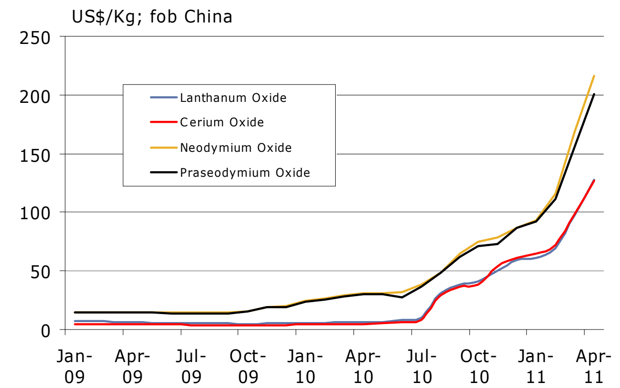
- The "Rare Earths" comprise a suite of 17 somewhat obscure chemical elements that are used in a wide range of high-tech applications, generally for their chemical, optical or magnetic properties.
- Annual global demand is c.130,000 tonnes, and supply is dominated by China, which currently accounts for more than 95% of global production. Rising demand for these elements in China, a desire to add value at home, and concerns about resource life and the environment have led China's government to cut export quotas, with severe reductions over the past 12 months. This has resulted in exponential price increases, and availability problems for Western consumers.
- The good news is that the rare earths are not particularly scarce geologically, although the number of economically viable concentrations is limited. New sources of supply are under development and we would expect market conditions to ease in the medium term.
- The bad news - for consumers - is that over the next two years we expect little relief in the way of improved availability or easier prices. Indeed, further cuts to China's export quotas look likely, which would suggest yet further upside price risk in the short term.
- But higher prices will incentivise the scramble for new capacity outside of China and we see two projects in particular - Mt Weld in Australia, and Mountain Pass in the USA - bringing the market back into balance beyond 2013, when prices should soften somewhat.
- In this article we provide a simple introduction to the rare earths, and a forecast for price trajectories over the period through to 2015. Please also refer to Ian Preston's article on today's *Daily Cable* initiating our coverage of Lynas Corporation.

RARE EARTHS: RECENT PRICE BEHAVIOUR

Fig. 1:

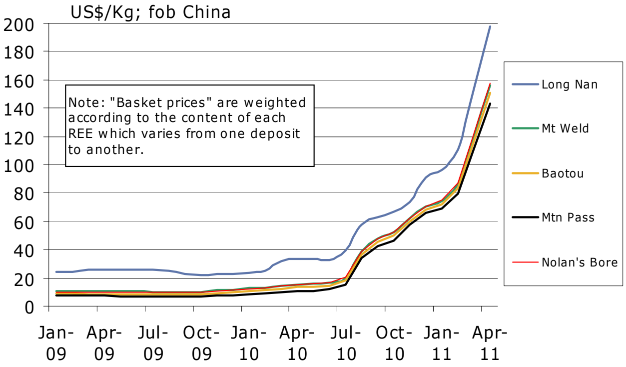
Recent Price Evolution for "Light" Rare Earth Oxides



Source: Metal Pages

Fig. 2:

Recent Price Evolution for REO "Baskets" for Selected Producers and Potential Producers



Source: Metal Pages; Company Data; GS&PA Research estimates

WHY ALL THE EXCITEMENT? A Rare Earths Primer

There are seventeen "rare earth" elements (REEs) or metals, which include the fifteen "lanthanides" plus two chemically similar metals - yttrium and scandium. These metals and some of their compounds have unique properties, which make them vital constituents in a wide variety of modern technology products including catalysts, batteries, high-powered magnets, lasers, and ceramics. Table 1 lists the commercially more important rare earths, and shows some of their major "first use" applications.

Table 1:

Rare Earth Applications: GS&PA Investment Research

	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Y	
	Light Rare Earths						Heavy Rare Earths				
	Lanthanum	Cerium	Praseodymium	Neodymium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Yttrium	Other*
Magnets			●●	●●	●		●	●	●		
Batteries	●●	●●	●	●●	●						
Metallurgy	●●	●●	●	●●							
Autocatalysts	●	●●	●	●							
Petroleum catalysts	●●	●									
Polishing Powders	●●	●●	●								
Glass Additives	●●	●●	●	●						●	●
Phosphors	●	●●				●	●	●		●●	
Ceramics	●●	●●	●	●●						●●	
Other	●●	●●	●	●●	●		●			●●	●●

Source: CRU International; USGS; Company Data *Other: Includes Erbium, Ytterbium, Thulium, Lutetium, Holmium

Annual demand for rare earth oxides (REO) is in the order of 130,000 tonnes (basis 2010) but, of course, each element can be considered to have its own individual supply / demand balance, and while yttrium and the lanthanides typically occur together geologically, they are by no means of equal abundance and the ratios in which they occur varies from one deposit to another. Inevitably this complicates supply and demand modelling.

These are small markets. Based on average prices for separated REOs in 2010, we estimate that the value of the global REEs market last year was in the order of US$3.9 billion, up from c. $1.25 billion in 2008. (For the sake of comparison, the global refined copper market had a value of c. $135 billion in 2010.)

China currently accounts for some 95% of global rare earths production. China's policy is to encourage value addition to its REE production, through refining (at the very least) but preferably through the manufacture of downstream technology. Coupled with government concern that China's REE resource base is finite, this policy has led China to impose export taxes, production quotas and a reducing export quota. The result has been a dramatic tightening of global markets for REEs, which has been reflected in recent price behaviour. Fig. 1 shows the recent price evolution for "light" rare earth oxides (REOs). Taking the most abundant of the rare earths as an example, the price of cerium oxide has risen 32-fold in the past 13 months, from US$ 4.15/kg in March 2010, to $134/kg at the end of April 2011. Fig. 2 shows the price evolution for rare earth "baskets" based on the rare earth "mix" recovered by some key producers and potential producers.

China's controversial imposition of diminishing export quotas has been the main price driver for the REEs, which in turn has provided ample incentive for the development of potential Western mine capacity. Fortunately for consumers, rare earths are not quite as scarce as the name suggests so that, geologically, there are opportunities for new producers in various parts of the world, although lead times vary considerably. Not surprisingly, share prices of listed companies with potential rare earth exposure have soared over the past 12 months.

So are we too late to the party?

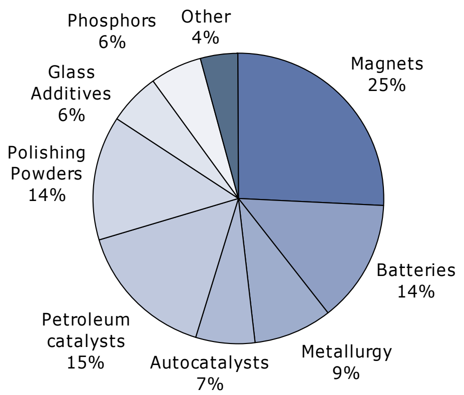
We are of the view that prices for rare earths have not yet peaked. Demand is growing briskly; China shows signs of getting serious in clamping down on illegal mining and cleaning up the environmental mess that has resulted from indiscriminate artisanal mining and processing in southern China, so we suspect that export quotas will shrink further. New projects outside of China will come to market and ramp up their production over the next five years. We envisage that the market for rare earths will remain in severe deficit in 2011 and 2012, and that prices will trend higher over the next 18 months. We envisage a closely balanced market in 2013, and modest surpluses thereafter - at least, for some of the more abundant light rare earths - with some price softening in the 2013 - 2015 period.

DEMAND FOR THE RARE EARTHS: Unfamiliar Metals, in Very Familiar Products

In Table 1 we show which of the major rare earth elements find use in a range of generic first-use applications. In Fig. 3 we show the relative size of the major first-use markets, and in Fig. 4 we show an approximate breakdown of total demand by individual REE. This latter distribution partly reflects demand requirements, but a more powerful influence is simply the relative abundance of these elements in nature and therefore the ratio in which they can be produced. In reality, the demand distribution will never match the supply distribution perfectly, so that it is quite possible for some elements to be in notional deficit, while others are in relative surplus.

Fig. 3:

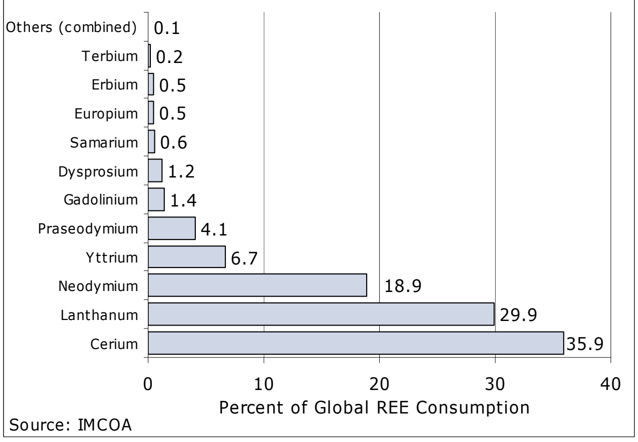
Major Applications for Rare Earths, 2010



Source: Lynas Corporation; GS&PA Research estimates

Fig. 4:

Rare Earths: Estimated Share of Demand by Element



Source: IMCOA

A quantitative mapping of the demand for individual rare earth elements to end-use applications would be complex and is well beyond the scope of this article. The following notes go some way to conveying the importance of these obscure metals in modern technology; to linking their first-use applications with more familiar industrial and consumer products; and to providing some indication of potential demand growth.

- **Magnets** (c. 25% of REE demand): **Neodymium**, and **praseodymium** (as well as smaller amounts of **samarium, terbium**, and **dysprosium**) are used to produce high-intensity permanent magnets. Neodymium-iron-boron, and cobalt-samarium are perhaps two of the better-known RE magnet alloys. Rare earth magnets are used in electronic applications such as computer hard-drives, mobile phones, and power tools, and on a larger scale in medical imaging equipment, electric motors for hybrid vehicles, wind turbines, and Mag-lev trains. Potential growth rate: 10-12% p.a.
- **Petroleum Catalysts** (c. 15% of REE demand): **Lanthanum**, (and smaller quantities of **cerium**, **neodymium**, and **praseodymium**) are used in fluid-cracking catalysts for petroleum refining. Potential growth rate: c. 3 - 5% p.a.
- **Polishing Powders** (c. 14% of REE demand): **Cerium** oxide (and smaller quantities of **lanthanum** and **neodymium** oxides) are used for polishing glass in applications where a high quality finish is required. Traditionally, this has included TV (and other cathode ray tube) screens and precision mirrors and lenses for optical instruments such as telescopes, microscopes, etc. In nano-particulate form, these polishing powders are used in the manufacture of silicon chips. Potential growth rate: 5-10% p.a.
- **Battery Alloys** (c. 14% of REE demand): Rechargeable batteries are an important market for lanthanum (and smaller quantities of **cerium**, **neodymium**, and **praseodymium**). Hybrid vehicles provide an important end-use both in terms of volume and growth potential. Potential growth rate: 12-15% p.a.
- **Metallurgy** (c. 9% of REE demand): Rare earths, commonly in the form of **mischmetal** (i.e. non-separated REMs) are used in a variety of metallurgical applications in the steel sector, in aluminium alloys, in specialty magnesium alloys, and in lighter flints. Potential growth rate: c. 2% p.a.
- **Autocatalysts** (c. 7% of REE demand): **Cerium** (and lesser amounts of **lanthanum** and **neodymium**) are used in autocatalysts. Potential growth rate: 7 - 10% p.a.

- **Phosphors** (c. 6% of REE demand): **Europium**, **yttrium**, and **terbium**, (and smaller amounts of **lanthanum**, **gadolinium**, **cerium**, **dysprosium**, and **praseodymium**) are used in phosphors for LEDs, LCDs, and energy efficient fluorescent lighting. Potential growth rate: 5-8% p.a.

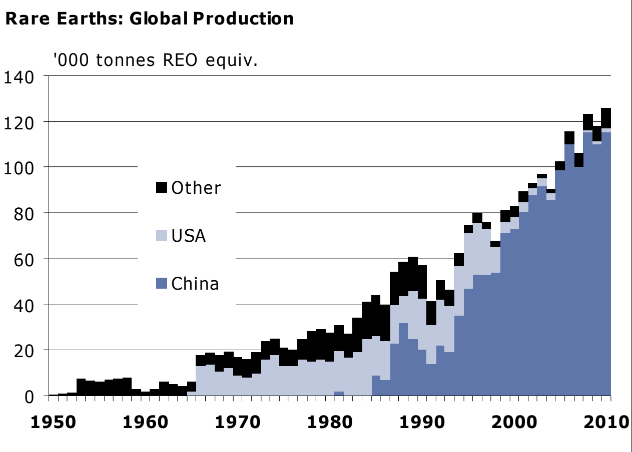
- **Glass Additives** (c. 6% of REE demand): **Cerium** and **lanthanum** oxides (and smaller amounts of **erbium** and **neodymium**) are used in specialty glasses. Cerium is used to reduce the transmission of ultraviolet light, while lanthanum increases the refractive index of optical glass for camera lenses, etc. **Praseodymium** is used as a yellow colorant in the glass and ceramics industry; a warmer yellow colouration can be achieved with the addition of **cerium**. Potential growth rate: Mature, but potentially some further post-GFC recovery.

- **Other applications** (c.4% of REE demand): **Erbium, yttrium, terbium**, and **europium** find use in signal amplification for fibre-optic transmission; yttrium and lanthanum find use in superconductors; **yttrium** oxide is an additive in cubic zirconia (a diamond simulant); **yttrium, scandium, gadolinium** and **neodymium** are used in certain laser applications. Potential growth rate: 5-10% p.a.

SUPPLY OF RARE EARTHS: China Dominant… for now…

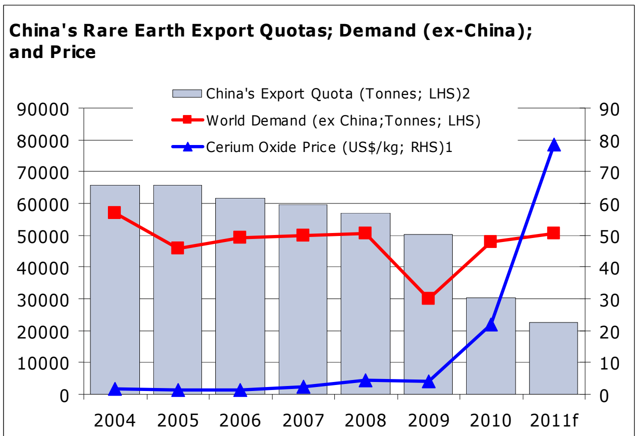
The supply of rare earths - at both the mine production and refined production levels - is currently dominated by China, which accounted for in excess of 90% of global production in 2010.

Fig. 5:



Source: USGS; Company Data; IMCOA; GS&PA Research Estimates

Fig. 6:



Note: 1. 2011 price is the average for 1Q; 2. 2011 quota is the announced 1H quota, plus an assumed 2H quota of 7,986 tonnes (i.e. same as for 2H2010).
Source: IMCOA; Metal Pages; GS&PA Research Estimates

Production History

Yet China only became a significant rare earths producer as recently as the mid-1980s (Fig. 5). Until that time, production was dominated by two Western companies:

- Rhone Poulenc of France processed and refined REEs from monazite concentrates sourced from various parts of the world.

- Molycorp, in the USA, mined and processed bastnaesite ores from the Mountain Pass mine in California.

Monazite (a rare earth phosphate) is a by-product, or potential by-product, of many mineral sands operations and, in some parts of the world, of alluvial tin mining. Indeed, a substantial proportion of Rhone Poulenc's feedstock in the 1980s was drawn from Australian mineral sand operations. The problem is that most monazite contains thorium, and by the early 1990s a growing aversion of Western societies to the disposal of thorium-bearing wastes put increasing pressure on Rhone Poulenc's activities.

In California, Molycorp's bastnaesite ore was much cleaner; (bastnaesite, by the way, is a rare earth carbonate). Production from Mountain Pass commenced in 1951, but the rapid development of China's rare earths industry in the 1990s drove prices down to a level at which neither Mountain Pass, nor Rhone Poulenc's monazite-processing with its attendant environmental issues was competitive. By the turn of the century, China accounted for some 90% of global production, a share which it has maintained or even exceeded subsequently. US production fell from 22,200 tonnes (REO equiv.) in 1995, to 10,000 tonnes in 1998, and mining ceased altogether at Mountain Pass in 2002, although small-scale recovery of REEs from stockpiled raw materials has continued subsequently.

Current Production - China

In China, REEs are produced from three major sources:

- In **Inner Mongolia**, at the Bayun Obo mine near Baotou, REEs are produced as a co-product of iron ore in the form of a bastnaesite concentrate. This one mine operated by the Baotou Steel and Rare Earth Group currently accounts for roughly 50% of global rare earths production, and is the dominant source of the light REEs. We recently visited the Baotou Steel and Rare Earth Group (March 2011) and we were told that, subject to no change in government quotas, production should remain at the current level of c. 50,000tpy for the foreseeable future. The company was dismissive of the idea that declining ore grades or waste disposal issues would cause a fall in output.

- In **Sichuan Province**, REEs are recovered from a number of small-to-medium-sized mines with a combined theoretical capacity of c. 50,000tpy REO (Source: *Sichuan Rare Earth Association*). However, since 2007, provincial authorities have adopted a stringent policy to eliminate illegal mining and as of late 2010 only a single mine producing c. 12,000tpy was operating at Mianning. A consolidation of smaller mines in Sichuan has been mandated by the authorities and is approaching completion, and we understand that a number of mine reactivations will occur in 2H2011. These are bastnaesite operations, producing mainly the lighter REEs.

- In southern China, centred on **Jiangxi Province**, the so-called ion-adsorption ores, or ionic clays, appear to be a unique ore type resulting from the intense weathering of xenotime-bearing igneous rocks. They are distinguished by their relative richness in heavy rare earths such as yttrium, terbium, gadolinium and dysprosium. Their near-surface occurrence and ease of mining has led to widespread exploitation, much of it by artisanal workers who operate in contravention of provincial or federal regulations. This has led not only to some severe environmental issues, but also to a sub-optimal use of the resource. Authorities in China are currently clamping down on illegal mining, legislating on processing methods, and enforcing stricter production quotas in an attempt to avoid further damage and conserve a dwindling resource. In recent years these ores have contributed some 25%-30% of global rare earths production, but they are overwhelmingly the world's dominant source of heavy REEs.

Fig. 7:

Rare Earth Content of Selected Ore Types (% of REO)

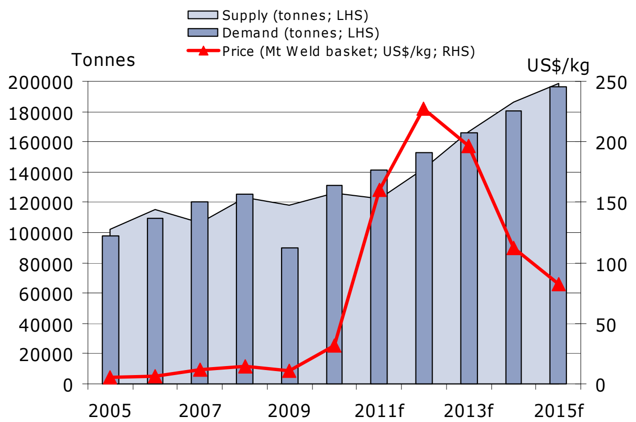
	Mt Weld[1]	Mtn. Pass[2]	Bayun Obo[3]	Long Nan[4]	Nolan's Bore[5]
La_2O_3	25.5	32.0	23.0	1.8	19.7
CeO_2	45.7	49.0	50.0	0.4	47.5
Nd_2O_3	18.6	13.5	18.5	3.0	21.2
Pr_6O_{11}	5.4	4.4	6.2	0.7	5.8
Sm_2O_3	2.4	0.5	0.8	2.8	2.4
Dy_2O_3	0.2	0.0	0.1	6.7	0.3
Eu_2O_3	0.6	0.1	0.2	0.1	0.4
Gd_2O_3	1.0	0.2	0.7	6.9	1.0
Tb_4O_7	0.1	0.0	0.1	1.3	0.1
Y_2O_3	0.4	0.1	0.0	65.0	1.3
Total	**99.9**	**99.8**	**99.6**	**88.7**	**99.8**

Notes: 1. Monazite; 2. Bastnaesite; 3. Bastnaesite; 4. Ionic Clay; 5. Monazite/apatite

Source: CRU International; IMCOA; Company Data

Fig. 8:

Rare Earths: Global Supply, Demand and Price Forecast



Source: IMCOA; Company Data; GS&PA Research Estimates

China's Production and Export Quotas

China's government has been steadily reducing export quotas for rare earths since 2005 (Fig. 6). We believe that there are five main reasons for this:

1. A recognition that China's rare earth resource is finite and that profligate production is not in the country's long-term interests.
2. Meanwhile, China's domestic demand for REEs is growing briskly.
3. Increasing concern about the severe environmental damage, particularly in southern China, where artisanal mining and processing of ionic clay-type ores has been poorly controlled.
4. An increasing determination to clamp down on illegal mining and to consolidate the mining and processing industries.
5. A preference to export high-value rare-earth products rather than raw materials.

China's diminishing annual export quotas are shown in Fig. 6. The situation is a little more complex than the chart suggests, in that quotas are generally (but not always) announced on a half-year basis, and there have been separate quotas applied for domestic companies and for foreign joint ventures. Note also that our quota estimate for 2011 is simply the 1H quota (14,446 tonnes) plus an assumption that the 2H2011 quota is unchanged from pcp (at 7,986 tonnes); however, recent trends suggest that the 2H quota will show a further decline.

Fig. 6 also shows our estimate of global demand for rare earths *excluding* China, and an indication of price (we use cerium oxide prices as a proxy in this context). The quota reduction was of limited significance until 2010 because, with a little help from the global financial crisis, export quotas were more than sufficient to meet non-Chinese demand. However, the much larger quota reduction in 2010, coupled with a demand recovery left the world ex China with a severe shortfall, and the deficit continues to widen in 2011. As we have already noted, the price response has been dramatic (Figs. 1 and 2).

China's export quota for 1H2011 is 14,446 tonnes, compared with 22,282 tonnes for 1H2010, and just 7,986 tonnes in 2H2010. The 2H2011 quota will be announced mid-year. Of course these quotas do not include tonnages of REEs exported illegally; trade data indicates exports of 39,813 tonnes in 2010, which is 9,555 tonnes higher than the full year quota of 30,258 tonnes. Almost certainly, a significant additional tonnage of illegal exports went unrecorded.

The massive price increases triggered by China's recent imposition of mining and export quotas have brought China's dominance in rare earths production into alarming focus, and caused a scramble to develop rare earth mine and processing capacity in other parts of the world. (We note that China banned the toll-treatment of rare earths from 2006.) We find it intriguing and just a little ironic that, twenty years ago, China's rapid ascendance as the dominant producer of rare earths initiated significant price declines which contributed to the closure of Western capacity, but today the reverse is happening; in the 1980s, cerium oxide prices were quoted (by Rhone Poulenc) in the US$15-20/kg range; between 2004 and 2009 the cerium oxide price (fob China) was typically in the US$1-5/kg range, but in 2010 the average price was a little under $22/kg - not too dissimilar to the 1980s price. Perhaps an appropriate price perspective is that rare earth consumers enjoyed a period of artificially low prices in the late 1990s and early 2000s because China flooded the market; today prices have normalised as China stems the flood.

Future Production

Mining for rare earths, and the production of a mineral concentrate, is relatively straightforward in that conventional mining and beneficiation techniques are used. But moving beyond the concentrate stage requires increasingly complex chemical processing. Very simplistically, a typical processing route for a bastnaesite or monazite concentrate would comprise (1) drying the concentrate; (2) adding concentrated sulphuric acid and treating in a sulphating kiln to "crack" or convert the REEs to soluble sulphates; (3) treatment of the sulphate solution to remove unwanted elements such as iron and base metals; and (4) further treatment by a multi-stage solvent extraction refining process to obtain individual rare earths of the required purity.

Table 2:

Rare Earths: Key Projects for Development, 2011-2015

Project	Country	Company	Project Type	Status	Probable Start-Up	2011	GS&PA Production Assumptions (tonnes REO equiv.; pre-disruption) 2012	2013	2014	2015
Mt Weld	Australia	Lynas Corp.	Greenfield	Firm	2011	846	8984	14500	19300	22000
Mountain Pass	USA	Molycorp	Reactivation	Firm	2012	3000*	12000	25000	35000	38000
Dubbo Zirconia	Australia	Alkane Resources	Greenfield	Prob.	2013	0	0	800	1800	2500
Nolans Bore	Australia	Arafura Resources	Greenfield	Prob.	2014	0	0	0	5000	12000
Nechalacho	Canada	Avalon Rare Metals	Greenfield	Poss.	2015	0	0	0	0	500
Bear Lodge	USA	Rare Element Resources	Greenfield	Poss.	2015+	0	0	0	0	0
Steenkampskraal	S.Africa	Great Western Minerals	Greenfield	Poss.	2015+	0	0	0	0	0
Hoidas Lake	Canada	Great Western Minerals	Greenfield	Poss.	2015+	0	0	0	0	0
Kvanefjeld	Greenland	Greenland Minerals & Energy	Greenfield	Poss.	2015+	0	0	0	0	0
Kangankunde	Malawi	Lynas Corp.	Greenfield	Poss.	2015+	0	0	0	0	0

Note: *New mine production from Mountain Pass will commence in 2012, but small-scale production from stockpiled raw materials has already been reactivated.

Source: Company Data; GS&PA Research estimates

We noted above that the more common REEs - lanthanum and cerium - are actually more abundant in the earth's crust than metals like copper, although it is also fair to say that economic concentrations of REEs are much scarcer. Table 2 lists significant projects that have the potential to produce REEs during a five-year forecast time frame.

Two key project developments will supplement REE supply over the next three years, namely the reactivation of Molycorp's Mountain Pass operation in California, and the start-up of Lynas Corporation's Mt Weld mine in Western Australia. Both of these operations are relatively rich in light rare earths, and relatively poor in heavy rare earths.

At this point it is appropriate to reiterate that the relative abundance of individual REEs varies considerably from one deposit to another according to mineralogy and mineral chemistry. Fig. 8 shows the weight percent composition of REEs in a selection of rare earth deposits from different parts of the world. These weightings are used to calculate "basket prices" for individual producers as further discussed below and as shown in Table 3.

MARKET BALANCE AND PRICE OUTLOOK:

We have deliberately chosen not to attempt a modelling of supply, demand, and price for individual REEs, but rather to focus on a composite balance in terms of total REO equivalent. On the one hand, this approach cannot identify potential shortages (or surpluses) of individual REEs but, on the other hand, it is notable that the light REEs (lanthanum, cerium, neodymium, praseodymium) are very much more abundant than the heavies (samarium, europium, dysprosium, etc.) and therefore have a much larger weighted influence on "basket pricing" for most rare earths producers. Therefore while an overall surplus in terms of REO equivalent might mask a continuing shortage of, for example, dysprosium, we believe it a reasonable assumption that the move to *generic* surplus would be reflected in a declining "basket price".

Table 3:

Rare Earths: Global Market Summary (tonnes REO equiv.)

	2005	2006	2007	2008	2009	2010	2011f	2012f	2013f	2014f	2015f	CAGR ('10-'15)	CAGR ('05-'10)
Consumption by Region													
China	52000	60000	70000	75000	60000	83000	91000	100000	109500	119500	130000	9.4	9.8
% annual growth rate	*57.6*	*15.4*	*16.7*	*7.1*	*-20.0*	*38.3*	*9.6*	*9.9*	*9.5*	*9.1*	*8.8*		
Other Asia (incl. Japan)	23000	24650	25000	24750	15000	23925	25262	26627	28329	30433	33010	6.6	0.8
% annual growth rate	*-19.3*	*7.2*	*1.4*	*-1.0*	*-39.4*	*59.5*	*5.6*	*5.4*	*6.4*	*7.4*	*8.5*		
USA	14720	15776	16000	15750	9600	15312	16168	17042	18131	19477	21126	6.6	0.8
% annual growth rate	*-19.3*	*7.2*	*1.4*	*-1.6*	*-39.0*	*59.5*	*5.6*	*5.4*	*6.4*	*7.4*	*8.5*		
Rest-of-World	8280	8874	9000	10000	5400	8613	9094	9586	10199	10956	11884	6.6	0.8
% annual growth rate	*-19.3*	*7.2*	*1.4*	*11.1*	*-46.0*	*59.5*	*5.6*	*5.4*	*6.4*	*7.4*	*8.5*		
Global	**98000**	**109300**	**120000**	**125500**	**90000**	**130850**	**141524**	**153255**	**166159**	**180366**	**196020**	8.4	6.0
% annual growth rate	*8.9*	*11.5*	*9.8*	*4.6*	*-28.3*	*45.4*	*8.2*	*8.3*	*8.4*	*8.6*	*8.7*		
Consumption by Application													
Catalysis	19000	21500	24500	26500	18000	28000	29540	31165	32879	34687	36595	5.5	8.1
% annual growth rate	*5.6*	*13.2*	*14.0*	*8.2*	*-32.1*	*55.6*	*5.5*	*5.5*	*5.5*	*5.5*	*5.5*		
Glass Additives	13500	13000	12500	12000	5500	7500	7650	7803	7959	8118	8281	2.0	-11.1
% annual growth rate	*-3.6*	*-3.7*	*-3.8*	*-4.0*	*-54.2*	*36.4*	*2.0*	*2.0*	*2.0*	*2.0*	*2.0*		
Polishing Powders	12500	14000	15000	15000	12000	18200	19747	21425	23247	25223	27367	8.5	7.8
% annual growth rate	*8.7*	*12.0*	*7.1*	*0.0*	*-20.0*	*51.7*	*8.5*	*8.5*	*8.5*	*8.5*	*8.5*		
Battery Metal Alloys	16000	17000	17000	18500	14000	18700	21318	24303	27705	31584	36005	14.0	3.2
% annual growth rate	*6.7*	*6.3*	*0.0*	*8.8*	*-24.3*	*33.6*	*14.0*	*14.0*	*14.0*	*14.0*	*14.0*		
Other Metal Alloys	8500	10000	11000	11500	8000	11700	11934	12173	12416	12664	12918	2.0	6.6
% annual growth rate	*6.3*	*17.6*	*10.0*	*4.5*	*-30.4*	*46.3*	*2.0*	*2.0*	*2.0*	*2.0*	*2.0*		
Magnets	16000	20500	25000	27000	22000	33500	37185	41275	45816	50855	56449	11.0	15.9
% annual growth rate	*28.0*	*28.1*	*22.0*	*8.0*	*-18.5*	*52.3*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*		
Phosphors	7000	7800	8500	9000	6000	7750	8293	8873	9494	10159	10870	7.0	2.1
% annual growth rate	*16.7*	*11.4*	*9.0*	*5.9*	*-33.3*	*29.2*	*7.0*	*7.0*	*7.0*	*7.0*	*7.0*		
Ceramics & Other	5500	5500	6500	6000	4500	5500	5858	6238	6644	7076	7535	6.5	0.0
% annual growth rate	*10.0*	*0.0*	*18.2*	*-7.7*	*-25.0*	*22.2*	*6.5*	*6.5*	*6.5*	*6.5*	*6.5*		
Production:													
Australia	0	0	0	0	0	0	846	8984	15300	21100	24500		
China	99000	110000	100000	115000	110000	115000	112000	115360	118821	122385	126057		
USA	0	0	0	1000	1400	2000	3000	12000	25000	35000	39000		
Other (incl. recycling)	3500	5500	6500	7000	6500	9000	9450	10000	12500	13500	15000		
Disruption allowance (%)	--	--	--	--	--	--	*2.0*	*3.0*	*3.0*	*3.0*	*3.0*		
Disruption allowance (t)	0	0	0	0	0	0	-2506	-4390	-5149	-5760	-6137		
Global Production	**102500**	**115500**	**106500**	**123000**	**117900**	**126000**	**122790**	**141954**	**166472**	**186226**	**198420**	9.5	4.2
% annual growth rate	*12.6*	*12.7*	*-7.8*	*15.5*	*-4.1*	*6.9*	*-2.5*	*15.6*	*17.3*	*11.9*	*6.5*		
Notional Surplus / (Deficit)	**4500**	**6200**	**-13500**	**-2500**	**27900**	**-4850**	**-18734**	**-11301**	**313**	**5860**	**2401**		
"Basket Prices" (US$/kg REO)													
Mt Weld	**5.00**	**6.66**	**11.42**	**14.39**	**10.54**	**31.81**	***160***	***227***	***196***	***113***	***82***		
Mountain Pass	2.92	4.25	7.78	10.18	7.21	27.06	n.f.	n.f.	n.f.	n.f.	n.f.		
Baotou	3.94	5.81	10.37	12.58	8.65	29.73	n.f.	n.f.	n.f.	n.f.	n.f.		
Long Nan	12.28	16.02	21.41	30.85	25.26	47.55	n.f.	n.f.	n.f.	n.f.	n.f.		

Source: IMCOA; Company Data; GS&PA Research estimates

Our market summary is presented in Table 3, and it is appropriate to comment that the accuracy of historical numbers is considerably weaker, in our opinion, than for the base metals or bulk commodities, where we believe the processes for gathering primary data are somewhat more established. Thus we regard the consumption breakdowns - both by application and by geography - as informed estimates. Similarly, the confidence limits around the production data are wide, partly because of the significant amount of illegal mining and processing in China that doesn't get caught in the official statistics. That said, we believe that this exercise provides a useful snapshot of the global market for rare earth elements.

Our demand forecasts are based on growth assumptions for the main first-use applications as shown in Table 3. For some of these applications the projected growth rates may appear to err on the side of caution, but we believe this to be appropriate given that the rare earth market is likely to remain severely supply-constrained at least through to 2013. Our production forecasts draw on our estimate of likely start-up times and commissioning profiles for new projects (refer Table 2), and an assumption that there will still be some modest growth (c. 3% p.a.) in Chinese production; reactivation of operations in Sichuan province will, in our view, more than offset the reduction in illegal mining in southern China. We apply an annual disruption allowance of 3% (2% in 2011) to our production forecast.

Table 3 shows four historical price series based on the compositional "baskets" for major producers / potential producers. These "basket price" histories are weighted average prices calculated from the prices of individual REOs (US$/kg, fob China) published by *Metal Pages* and the weight-percent of production attributable to each element for each producer. Theoretical "basket" compositions for a selection of sources are shown in Fig. 8. We show a price forecast only for the Mt Weld "basket", based on our modelling of annual supply / demand imbalances, and on our view that US$60/kg (Mt Weld basket; REO equiv.) is a reasonable equilibrium price assumption taking into account (a) the difficulty of identifying new potential projects and (b) the technical issues and capital requirements associated with their development.

On the basis of our supply/demand modelling, we expect the global rare earth market deficit to peak this year with a shortfall in the order of 18,730 tonnes. We project a narrower 2012 deficit in the order of 11,300 tonnes due mainly to production ramp-ups at Mt Weld and Mountain Pass, but of course this implies a continuing widening of the cumulative deficit and in no way suggests that prices would soften; indeed we suggest that the peak of the price cycle in annual average terms will occur in 2012. We project a return to modest annual surplus only from 2013 and, in our opinion, this will depend critically on the timing of commissioning and the ramp-up of Phase II operations at Mountain Pass. We note that Molycorp has recently approved the Phase II investment and we believe it reasonable to assume that the expanded production begins to kick in from 2013.

Fig. 8 summarises our supply/demand balance and base case price forecast.

Where are the Risks?

There is little question, in our view, that the rare earths market is severely supply constrained, although the extent to which the constraints are capacity-related, as opposed to a function of China's government policy, is somewhat more debateable. Either way, China's imposition of diminishing export quotas and the recent run-up in prices has drawn international attention to China's overwhelmingly dominant supply-side role, and the scramble is on to develop new capacity in other parts of the world. While we can identify sources of both upside and downside risk to our base case forecast, it appears to us that the risks have a strong positive skew at least in the early years of the forecast period.

- **China's production, export quotas, and inventory policy:** While authorities in China appear serious in their efforts to ban illegal mining and processing of rare earths, it is by no means clear how successful they will be. According to our industry contacts in China, the national mine production quota was set at 89,000 tonnes in 2010. It was exceeded because of an indeterminable volume of unapproved production - probably in the 10,000 to 30,000 tonnes range. We surmise that the efforts to limit illegal production will intensify, although there will be a significant offset later this year and into 2012 from the reactivation of mines in Sichuan Province. On balance we assume that China's REE production will fall by around 2.5% this year, before resuming modest growth from 2012. A more stringent clamp on illegal mining, and further aggressive cuts in export quotas would exacerbate the rising price trend. Our base case assumes a modest (2.6%) fall in China's REE production this year and a resumption of modest production growth (c. 3% p.a.) from 2012. A successful elimination of illegal mining could result in a more significant and durable fall in output, again leading to higher prices.
- **Project delays:** There are few advanced REE projects of a size that could make a significant difference to the globla market before 2014 and, in our view, returning the market to a more balanced condition depends critically on the timing of commissioning and the ramp-up in production from the two largest and most advanced - Mt Weld in Australia, and Mountain Pass in the USA. Mountain Pass will commission a little later but, with its long production track record, and its production of a bastnaesite concentrate, the risk of delay appears to be low. Neither are we expecting delays for Mt Weld, but we note that the low levels of radiation in the monazite concentrate and in the waste from the Malaysian process plant have raised some concerns and there may be a risk - small, in our view - that operating permits could be subject to some delay. Once again this is not our base case view, but it is clear that any delay in the ramp-up of either of these two key projects would be highly constructive for prices.
- **Inventories:** The inventory situation for REEs is extremely opaque. We consider it very likely that Western consumers of REEs would have built some limited stockpiles as China's intention to reduce export quotas became clearer. However, the quantities involved are probably small and, while they may provide consumers with some operational flexibility in the short term, we doubt the existence of inventories on a scale that would influence our thinking on global supply and demand. China could be the exception, but we also think it very unlikely that China would suddenly release inventory, especially in an environment where the shortfall between production and consumption is still growing. On the contrary, recent comments from Chinese authorities suggest that strategic stockpiling of REEs is just beginning and we must therefore consider that China's near-term inventory policy is more likely to exacerbate prices than provide relief.
- **Demand destruction:** Our model already assumes a degree of demand destruction in that we believe we are erring on the cautious side with our consumption forecasts in order to help avoid implausibly wide forecast deficits. There may be some specific applications where price and/or non-availability cause additional demand destruction. At this stage we suspect that such events would be more element-specific, and less likely to have an impact on our overall REO balance.

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Sell	6%	2%
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