3rd International Rare Earths Conference

The Automotive Industry: A Major Rare Earths Consumer

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Summary of Presentation

- The rare earths industry today
- How are rare earths used in the automotive and related industries?
- Rare earths demand in 2006
- Forecast future demand
- Issues

The Rare Earths Market Today

- Total demand: 118,000t REO pa (2007)
- Average price: US$10-12/kg REO
- Total value: US$1,300 million pa
- Constraints on Chinese supply are leading to shortages and price increases

Global RE Consumption 2006

Global Rare Earths Consumption in 2006 (t REO ±10%)						
Application	**China**	**Japan and SE Asia**	**USA**	**Europe**	**Others**	**Total**
Catalysts	6,500	3,500	6,000	5,000	500	21,500
Glass	7,250	3,500	1,000	1,000	250	13,000
Polishing	7,000	4,500	1,000	1,000	500	14,000
Metal Alloys	10,250	4,000	1,500	1,000	250	17,000
Magnets	15,000	4,500	250	500	250	20,500
Phosphors	4,500	2,750	500	500	250	8,500
Ceramics	2,000	2,000	1,000	500	negligible	5,500
Other	6,500	1,000	250	250	negligible	8,000
Total	58,000	25,750	11,500	9,750	2,000	108,000

Rare Earth Applications in a Hybrid

GLASS AND MIRRORS POLISHING POWDER
- Cerium

UV CUT GLASS
- Cerium

DIESEL FUEL ADDITIVE
- Cerium
- Lanthanum

LCD SCREEN
- Europium
- Yttrium
- Cerium

HYBRID ELECTRIC MOTOR AND GENERATOR
- Neodymium
- Praseodymium
- Dysprosium
- Terbium

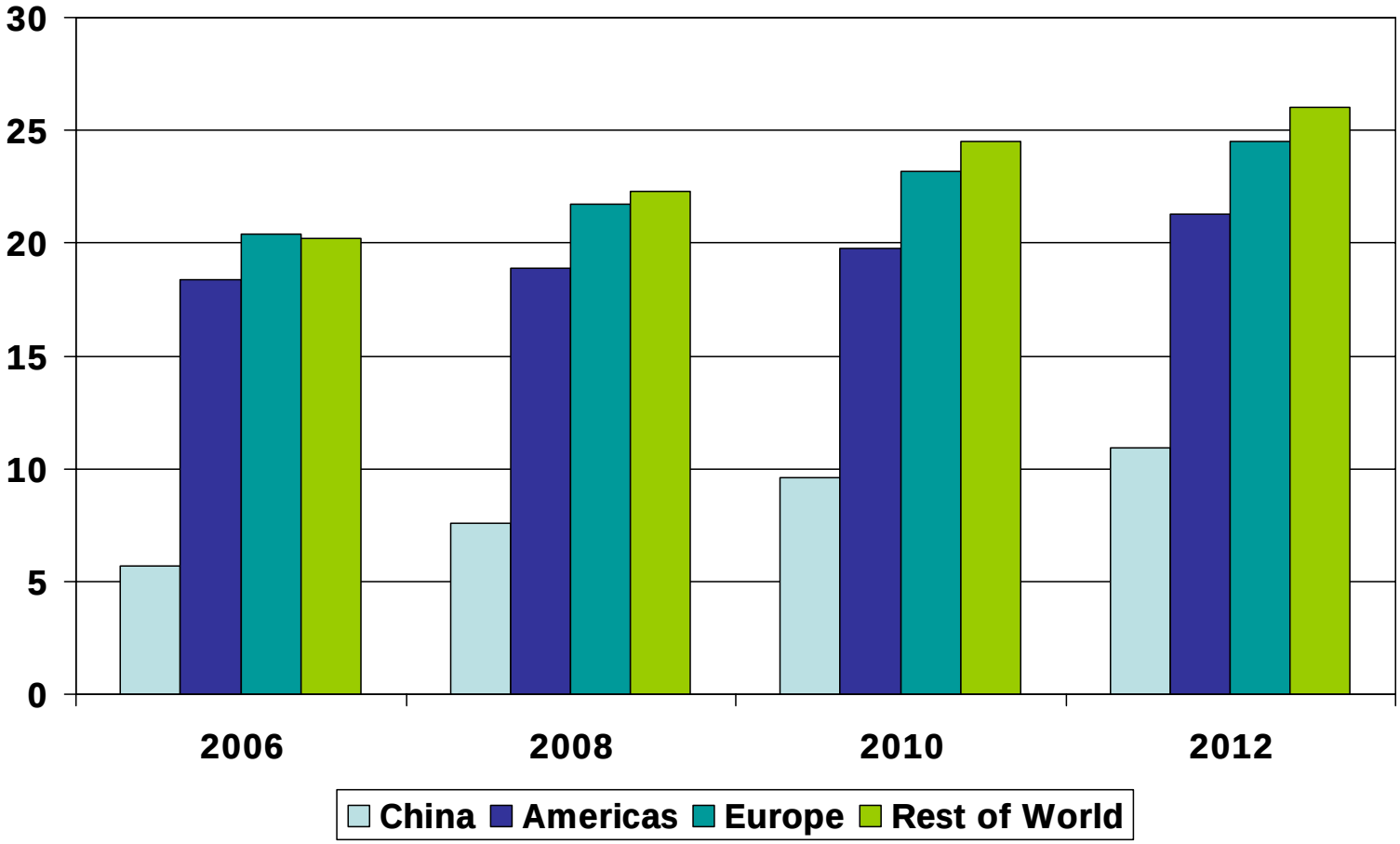
25+ ELECTRIC MOTORS THROUGHOUT VEHICLE
- Nd Magnets

CATALYTIC CONVERTER
- Cerium/Zirconium
- Lanthanum

HYBRID NiMH BATTERY
- Lanthanum
- Cerium

Global Light Vehicle Production

(millions per annum)



Auto Applications of Individual Rare Earths:

La, Ce, Pr, Nd and Sm

Lanthanum	• alloys are used in lanthanum-nickel-hydride batteries • oxide is a component of fcc catalysts for petroleum refining • metal used an additive to produce nodular cast iron • alloys/mischmetal used in hydrogen absorption alloys and creep resistant magnesium alloys
Cerium	• oxide is used in autocatalysts • oxide is used in 'uv cut' glass for automobiles • oxide is used as a glass polishing agent
Praseodymium	• metal improves corrosion resistance of neodymium-iron-boron magnets
Neodymium	• metal used in neodymium-iron-boron magnets, in lap-top computers, personal audio-visual equipment (i-pods) and voice coils •oxide is used in autocatalysts to enhance the performance
Samarium	• metal used in permanent magnet ($SmCo_5$) • oxide is a catalyst for the dehydration and dehydrogeneration of ethanol

Auto Applications of Individual Rare Earths:

Eu, Tb & Dy and Y

Europium

- oxide used as a phosphor activator
- europium-activated yttrium vanadate is used in red phosphors

Terbium

- oxide is an activator for green phosphors
- used in rare earth magnets to enhance magnetic properties
- used with ZrO_2 as a crystal stabilizer of fuel cells which operate at elevated temperatures

Dysprosium

- used in rare earth magnets to improve high temperature properties

Yttrium

- yttrium-europium phosphors give the red colour in colour television tubes
- metal increases the strengths of alloys of metals such as aluminium and magnesium

FCC Catalysts

- 2006: Demand for fcc catalysts 750-800kt, with approx 2% REO
- Concentrates purchased for the fcc catalysts contain 80-100% La_2O_3
- Demand is forecast to grow at 4-7%pa under the influence of the rapidly growing BRIC economies
- 2012: Forecast demand: 24,000t REO

Potential Impact of Hybrid Vehicles on the RE Market

- Toyota committed to produce 1M hybrid vehicles in 2010, considering 2M
- Assume total of 3M hybrid in 2012
- Typically an LaNiH battery for a hybrid vehicle contains 10-12kg rare earths
- If LaNiH batteries for hybrids achieve a

  60-70% market share; then additional demand would be 20-25,000t REO p.a.

LaNiH Batteries

- 2006: Estimated demand for rare earths, based on 10-12 kg rare earth metal per vehicle, 8,000t REO
- Typical analysis is Ni: 50%, Co:11%, Mn: 4%, Al:2%, La: 20%, Ce: 9%, Nd: 3% and Pr: 1%. (Source: GWT)
- 2012: Forecast demand is 30,000t Reo based on a growth rate of 25-30%pa.

Potential Impact of Ongoing High Demand for NdFeB Magnets

- Demand for rare earth magnet alloys grew from 2,500tpa REO in 1990, to 12,000tpa in 2000 to 20,000tpa in 2006.
- 2003/06 growth in demand was 15-20%pa
- Demand for rare earth magnets for drives of equipment in vehicles and for electronic equipment remains high.
- At current rates of growth, total demand for Nd_2O_3 could be 50,000tpa REO in 2012, but price and supply constraints mean it is more likely to be 40-50,000tpa REO.

RE Magnets for Electric Motors

- RE magnets are found in an increasing number of electric motors in automobiles from the drives in hybrids, to the multitude of motors driving internal seating features, to the speakers.
- 2006: Demand for these magnets 2-3,000t REO.
- There is an increasing use of electric motors in both luxury and standard vehicles, with some industry representatives estimating that it could exceed 100 per vehicle within 5 years.
- 2012: Forecast demand: 4-6,000t REO

Autocatalysts and Additives

- 2006: Demand for CeO_2 in autocatalysts estimated at 5,000t REO
- 2006: Demand for CeO_2 in diesel fuel additives estimated at 1,000t REO
- Increasing demand for automobiles in the BRIC economies coupled with an increasing awareness of noxious emissions will generate growth in demand of 6-8%pa
- 2012: Forecast demand: 9,000t REO

UV Cut Glass

- 2006: Demand, which is currently limited to Japan, 1,500t CeO_2
- An increasing awareness of the harmful effects of UV light may increase demand, but unlikely.
- 2012: Forecast demand: 2,000t CeO_2

Automotive RE Consumption

2006 & 2012

Rare Earth Consumption: Total and Automotive Industry (tREO ±10%)				
	2006		2012	
Application	Total	Autos	Total	Autos
Catalysts	21,500	21,000	32,000	31,000
Glass	13,000	1,500	14,000	2,000
Polishing	14,000	200	21,000	300
Metal Alloys	17,000	6,000	43,000	28,000
Magnets	20,500	2,000	42,000	4,000
Phosphors	8,500	negligible	14,000	negligible
Ceramics	5,500	negligible	9,000	negligible
Other	8,000	negligible	13,000	negligible
Total	108,000	30,700	188,000	65,300
Percent	100%	28%	100%	33-36%

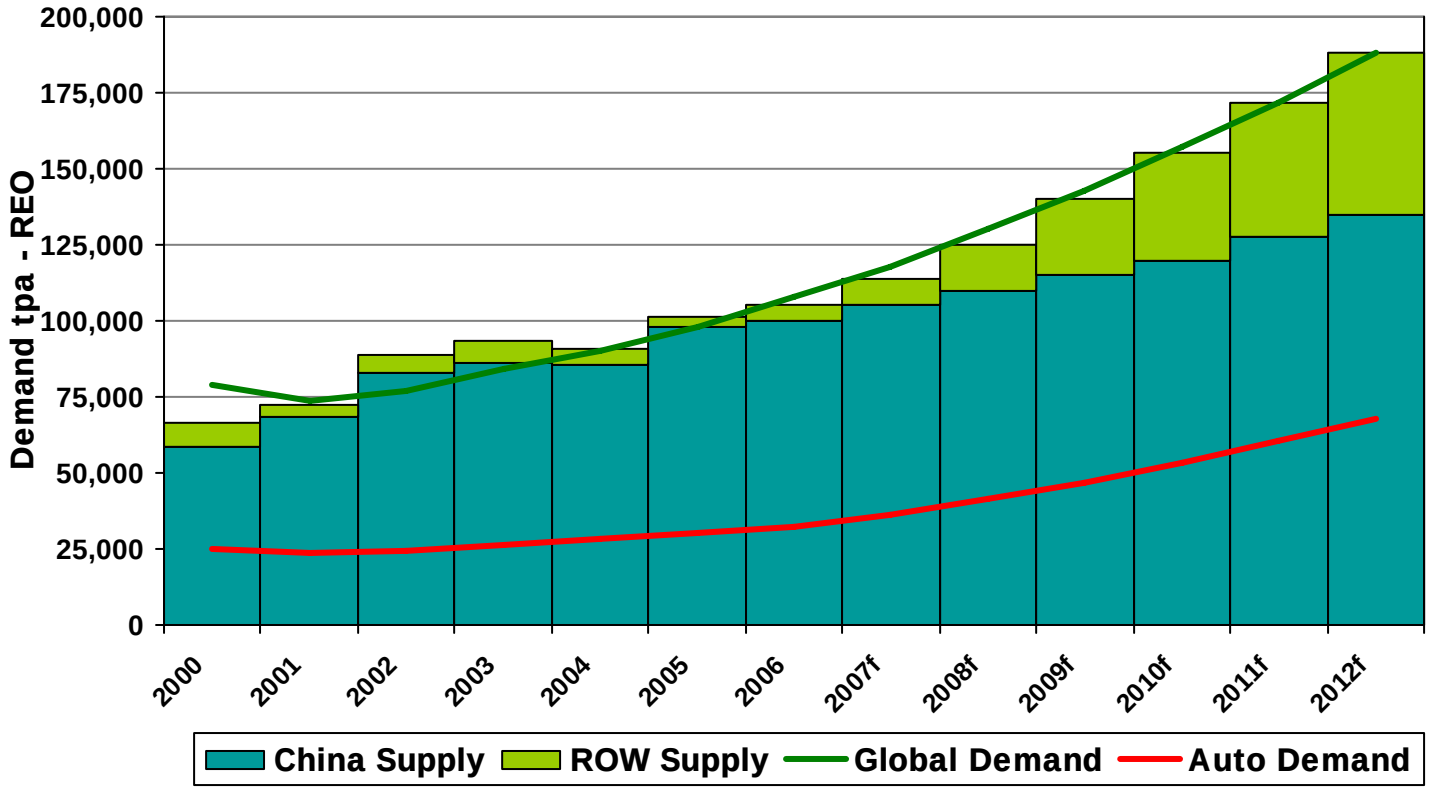
Occurrence & Demand for Individual REs in 2012 (±10%)

	Global RE Occurrence	Total Demand 2012 (f)	Auto Demand 2012 (f)
Lanthanum	**24-26%**	**28-30%**	**60-70%**
Cerium	38-40%	36-38%	30-40%
Praseodymium	4-6%	3-5%	10-20%
Neodymium	15-17%	17-20%	10-20%
Terbium	~¼%	¼-½%	5-10%
Dysprosium	~1%	½-¾%	10-20%

The Lanthanum Equation in 2012

- Total REO demand in 2012: 188,000t REO
- La_2O_3 demand @ 29% La_2O_3 : 55,000t
- La_2O_3 produced @ 25% La_2O_3 : 47,000t
- Extra production to meet La_2O_3 :35,000t
- Extra 'cost' to process @ US$ 9/kg: US$300M
- Assume the extra ore processing would 'solve' the potential La, Nd and Tb shortages
- Avg. extra cost per kg La, Nd & Tb sold would be US$3½/kg REO (Say Tb: 25, Nd: 8 and La 1 US$/kg REO)

Rare Earths Supply & Demand



The Issues

- Can China maintain control of: rare earth mining and production, environmental management practices and rare earth exports?
- Will higher prices impact demand?
- How quickly can the new projects come on-stream – to meet a potential shortfall > 40,000t REO in 2012?
- How quickly will Li batteries replace LaNiH batteries?
- Can the automotive industry reduce its dependence on lanthanum?

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Sources of Reference

- Data from Roskill's 13th Edition "The Economics of Rare Earths and Yttrium" (published in November 2007)
- Prices from *metal pages*©
- CREIC Newsletters