Rare earths

Presentation for the workshop "Criticality and the EU Raw Materials Initiative"

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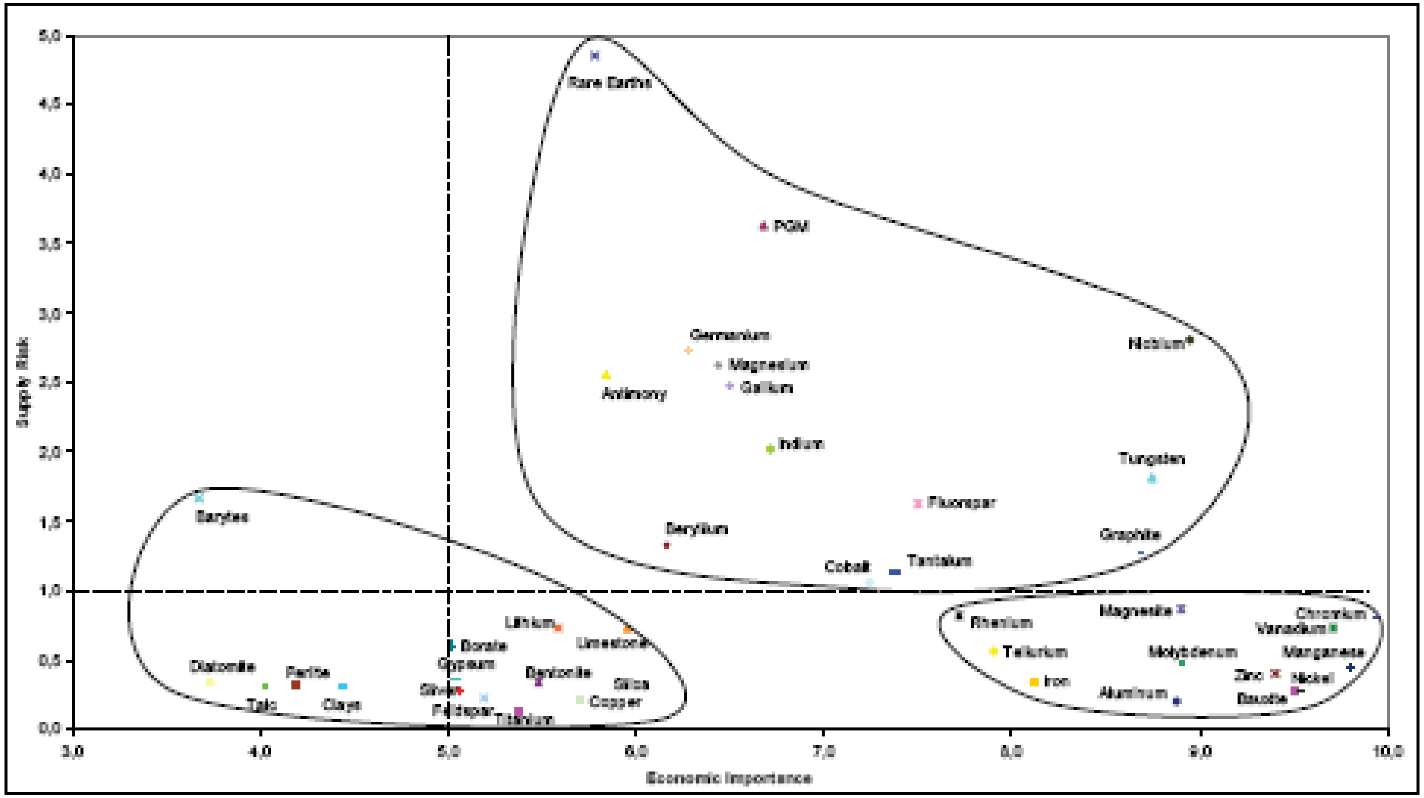
Agenda

- Introduction
- Reserves
- Supply
- Applications
- Demand
- Balance
- Substitution potential
- End of life recovery

Materials Criticality Background



Source: European Commission

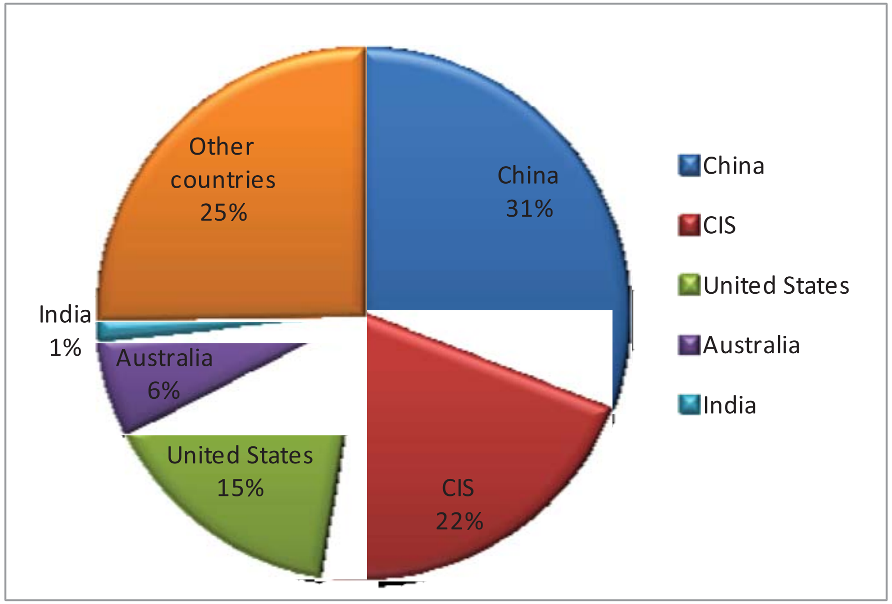
Rare earths supply critical

- High supply risk
- High impact of supply restriction

Reserves

- World reserves estimated at 88mt
- China with largest share
- Large non-Chinese reserves exist

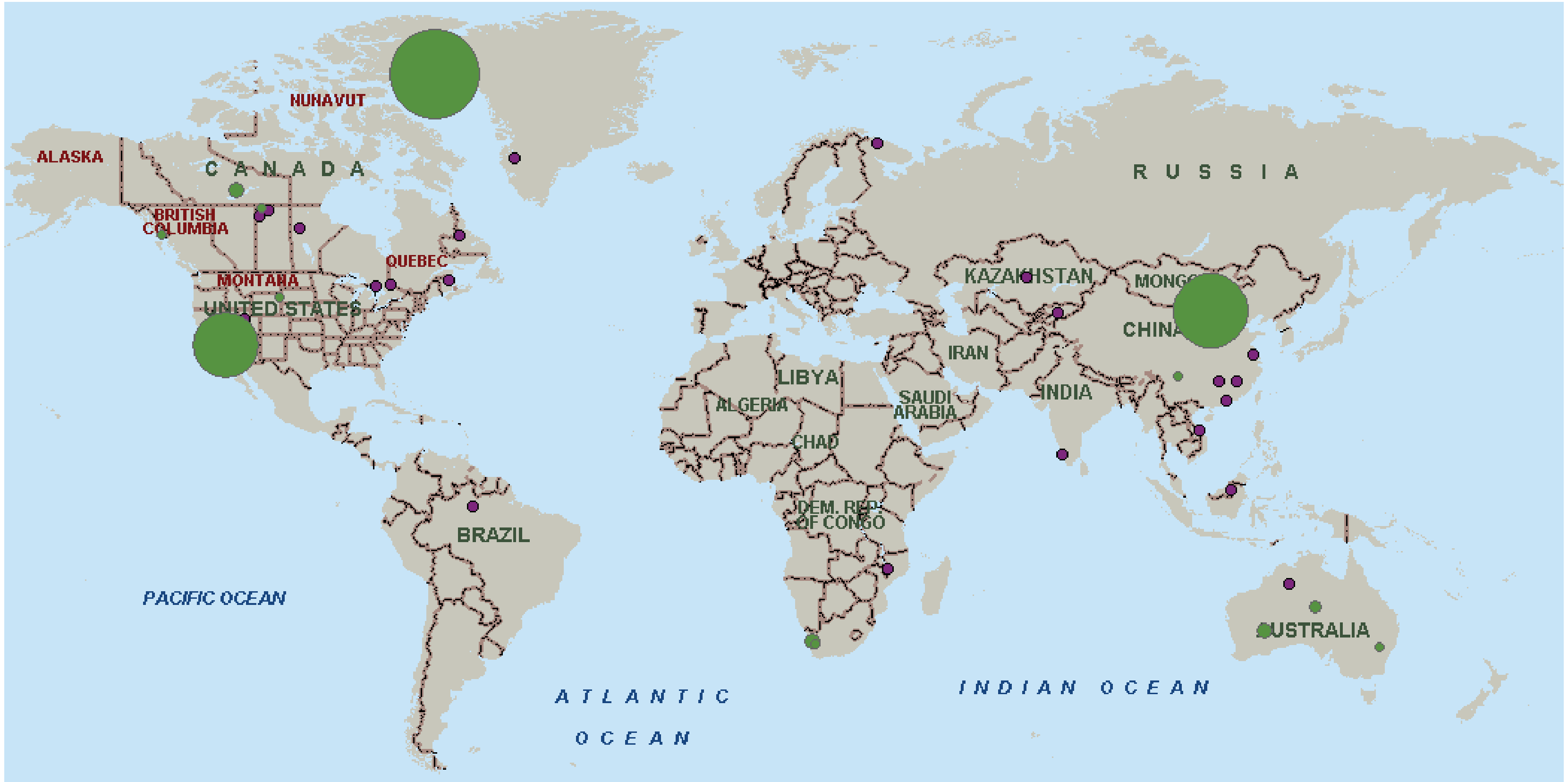
"Undiscovered resources are thought to be very large relative to expected demand."



Source: USGS

Reserves

Known reserves and production

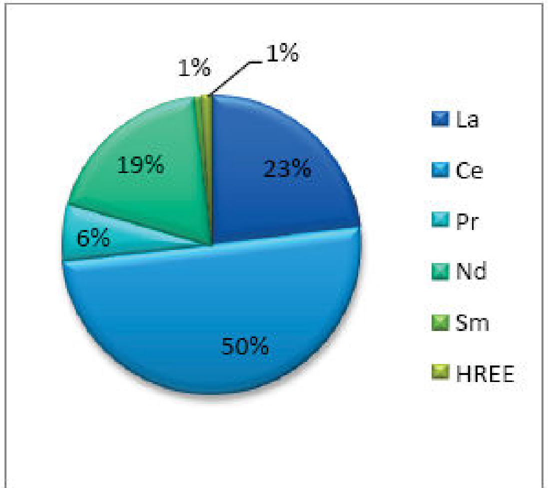


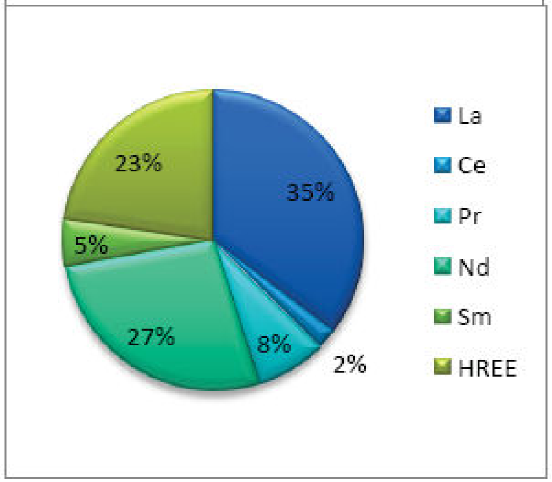
Supply

- 97% of REO from China and tightening controls for production and exports
- China to remain dominant in short term due to the development time of new mine capacity
  - Each ore-body is unique
  - REs can be mined uniquely or as co-products
  - Marketing customer specific
  - High capital costs (30,000US$ per tonne of annual separated capacity)
- By 2014 between 2 and 4 new mines outside of China are likely to open
- Possibilities for rare earth extraction as by-products (tin, titanium)

Ore composition

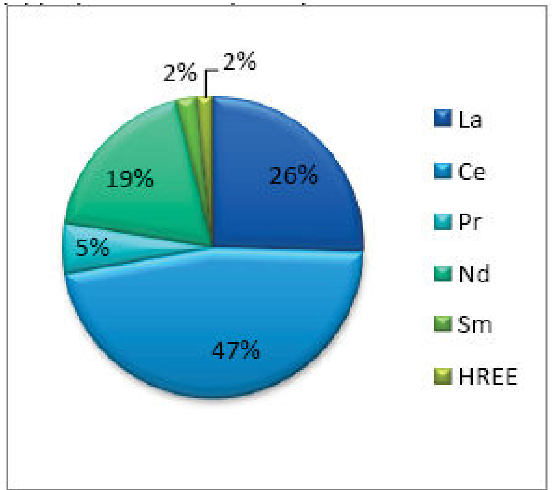
Inner Mongolia and Jiangxi, China

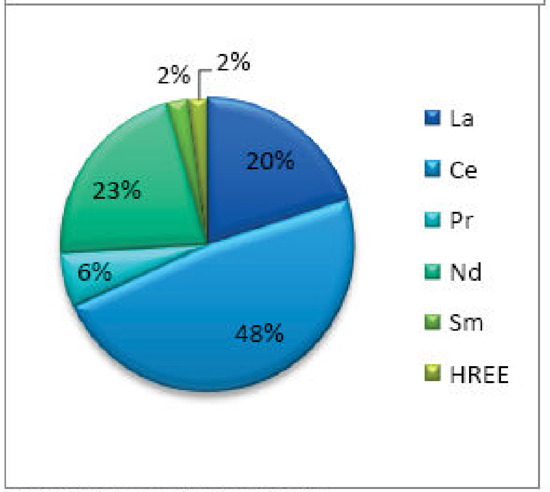




Source: '2007 Rare Earth Yearbook & Rare Earth Factsheet', USGS

Mount Weld and Nolans, Australia

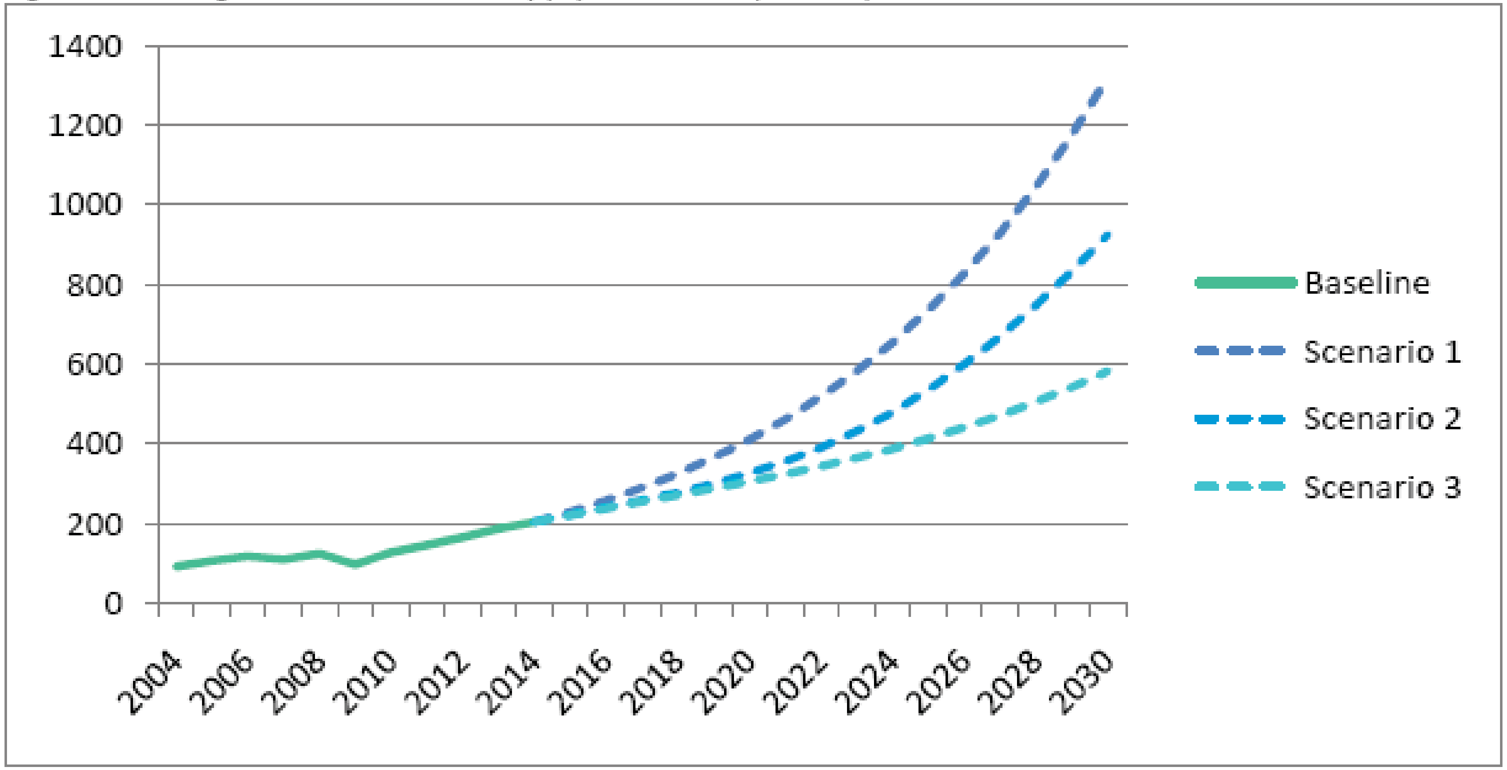




Source: Lynas and Arafura Websites

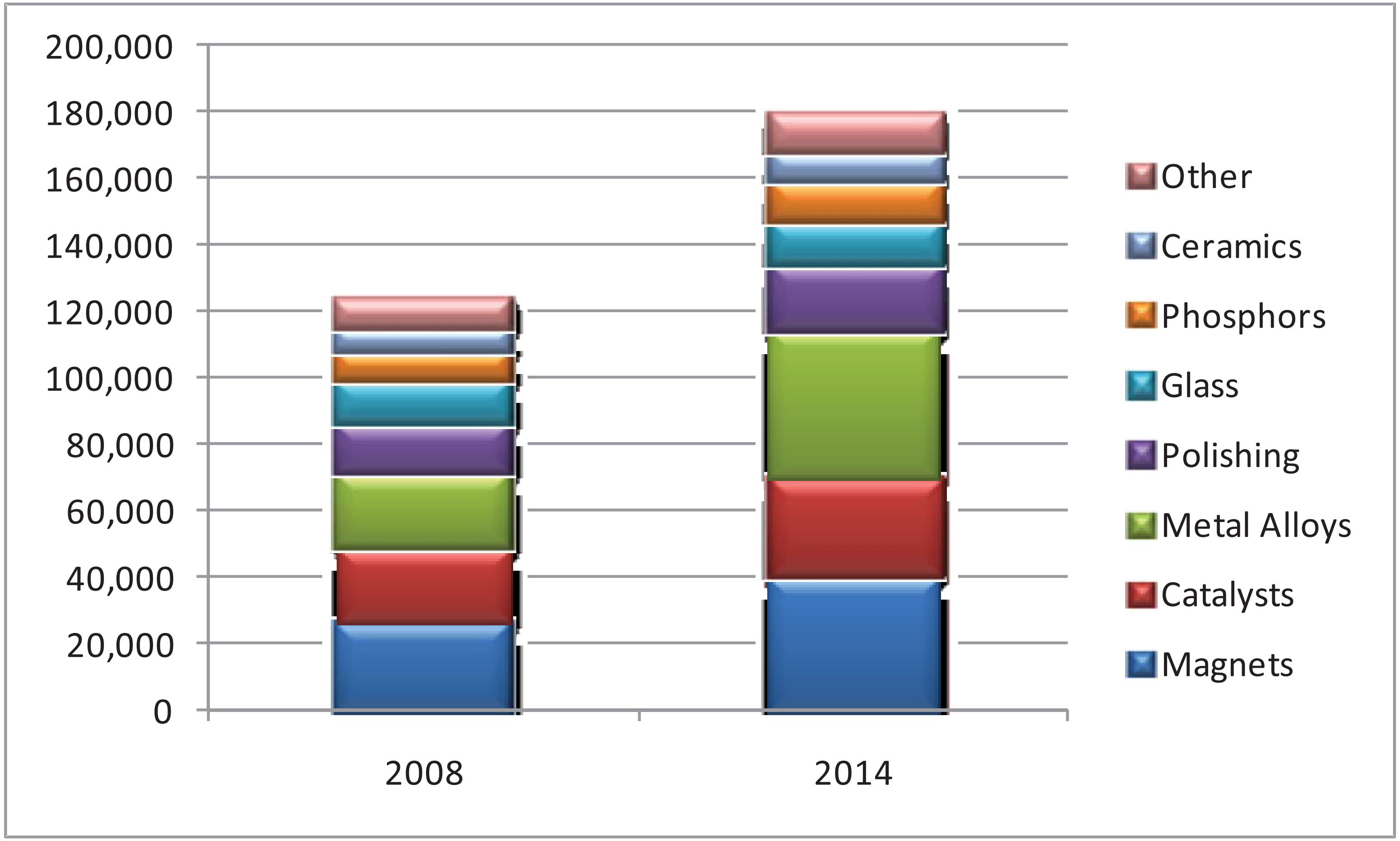
Supply Scenarios to 2030

Supply Scenarios for Rare Earths (as REOs, kt)



Source: IMCOA forecasts up till 2014, own calculations thereafter

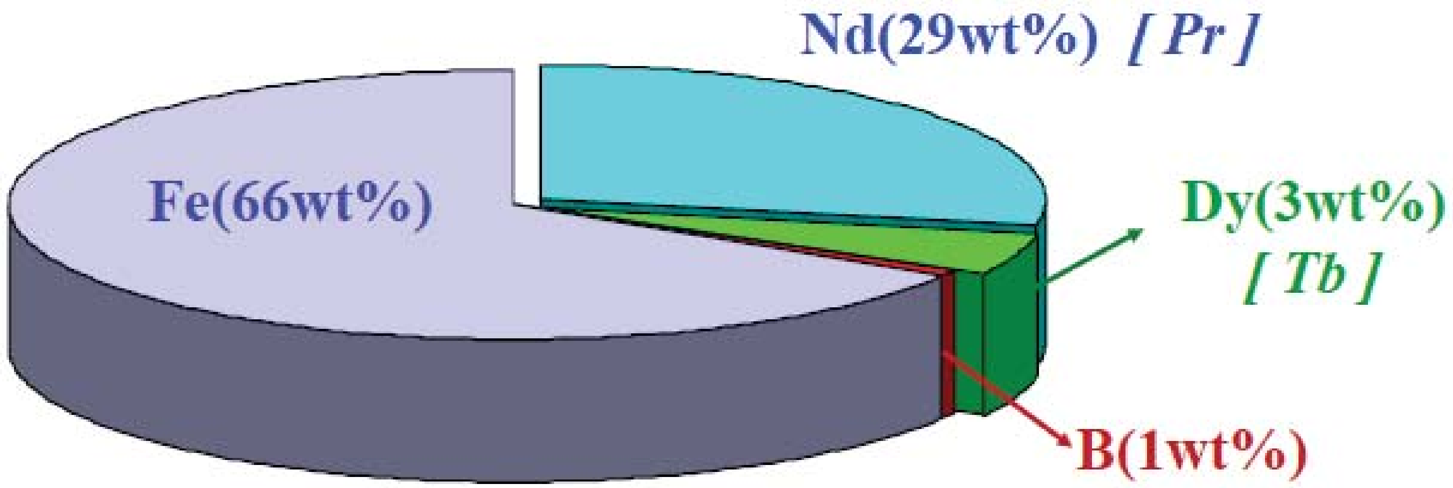
Demand – Consumption



Source: IMCOA

Applications – Magnets (NdFeB)

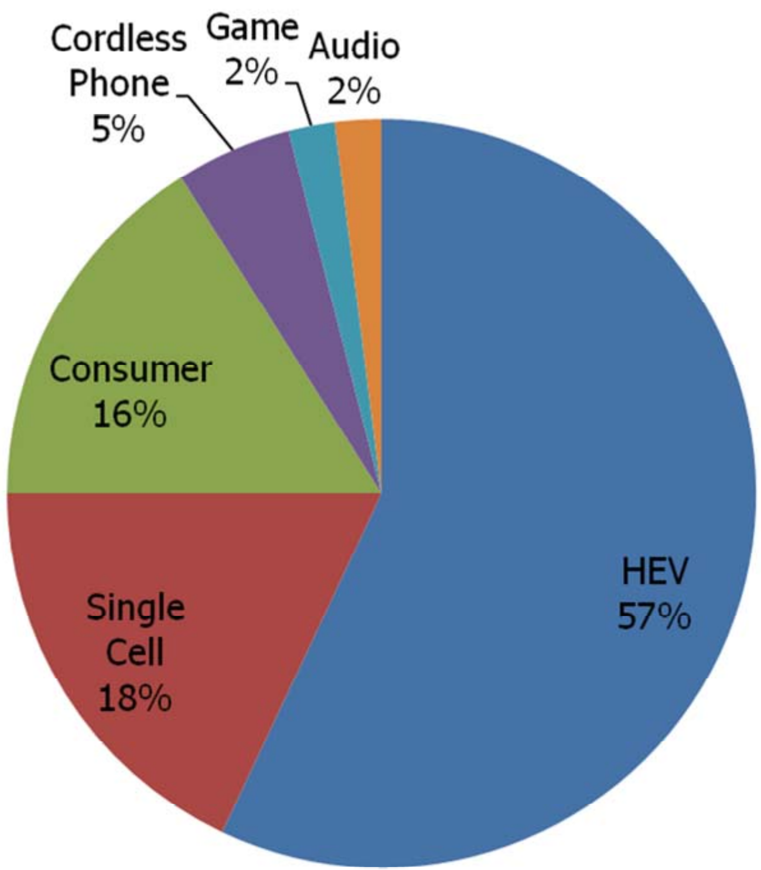
- Key elements are Nd and Dy
- Possible to alter composition or substitute
- Widely used outside of hybrid and electric vehicles: HDD, motors



Source: Shin-Etsu

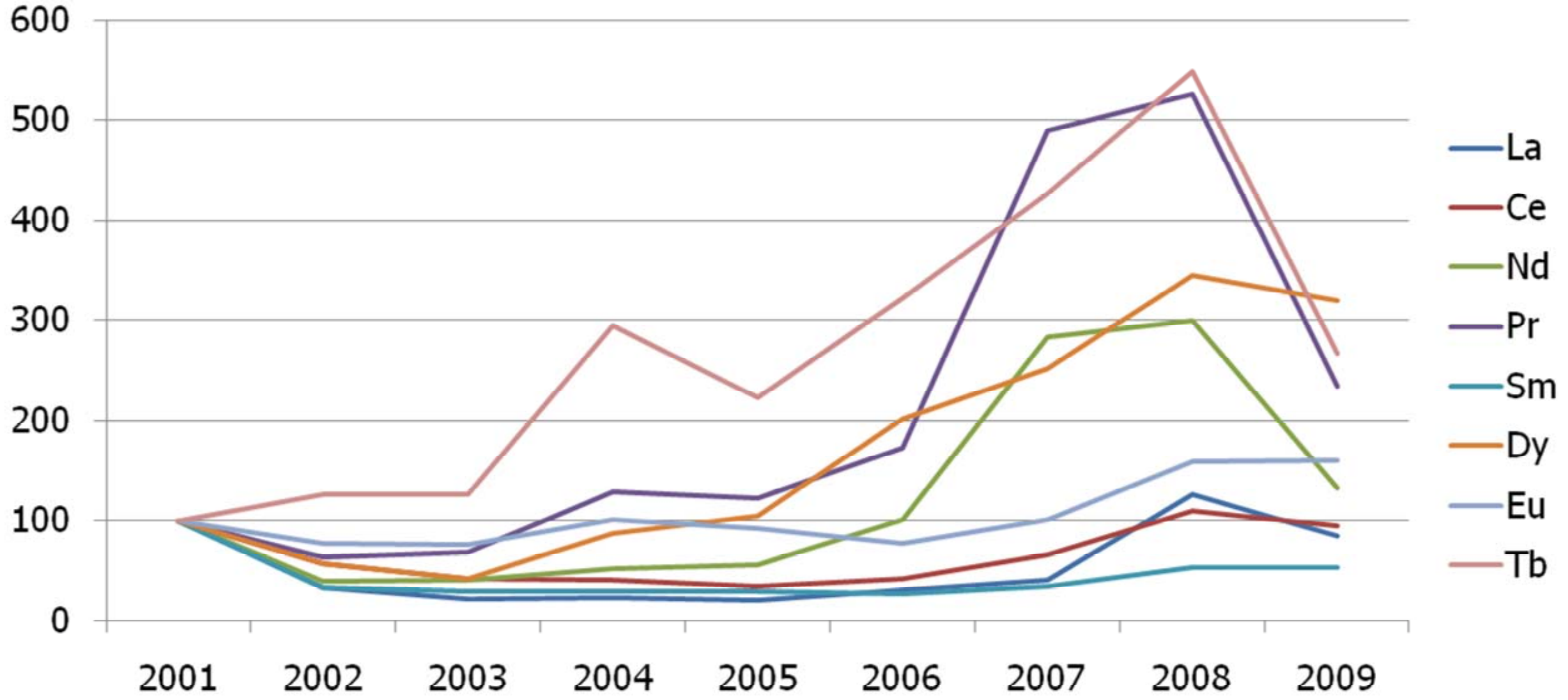
Applications – Batteries (NiMH)

- Key element is La
- Misch metal often used so possible to conserve other elements
- Hybrids as main application
- Li-ion batteries expected to displace NiMH over time



Source: Roskill

Demand – Prices



Element	La	Ce	Nd	Pr	Sm	Dy	Eu	Tb
Price ($/kg)	5.9	3.8	14.5	14.5	4.8	112.0	495.0	360.0

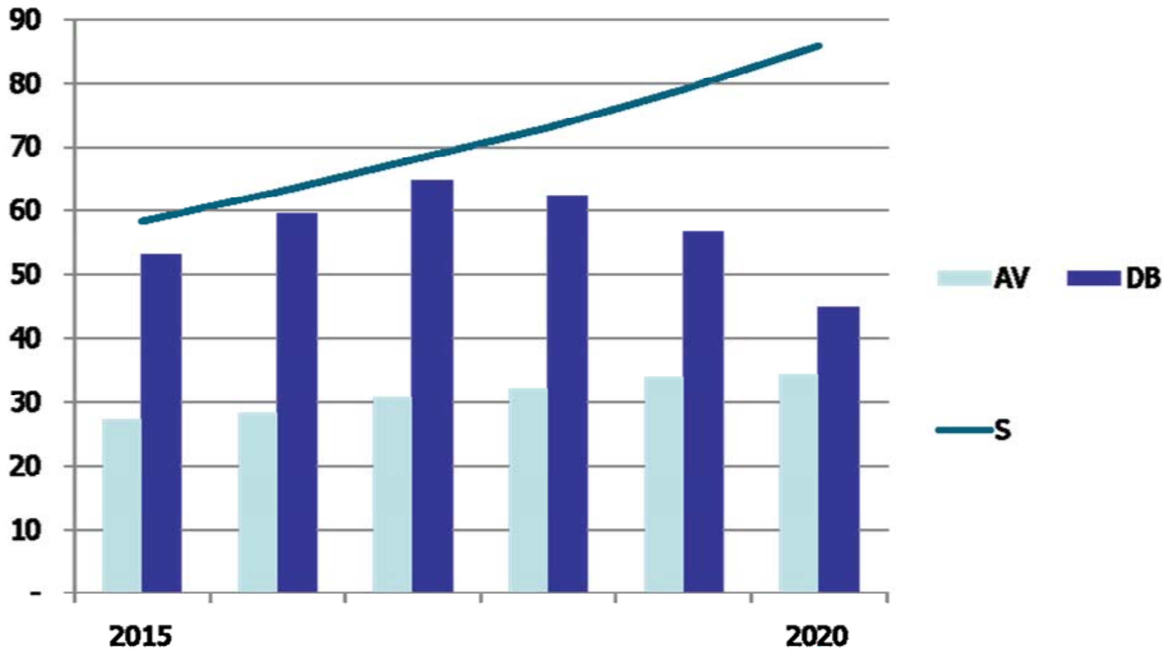
Source: Lynas

Demand – HEVs & EVs

- HEVs set to double share of market 2009-2012
- Each contain • 1kg Nd & 10-15kg La
- Rare requirements are small (1,225 tonnes Nd_2O_3 over 3 years)
- Mid-range take-up of EVs & PHEVs to consume modest volumes of Nd_2O_3

Lanthanum in NiMH batteries

Lanthanum oxide requirements of hybrids plotted with forecasted supply (S) (kt)



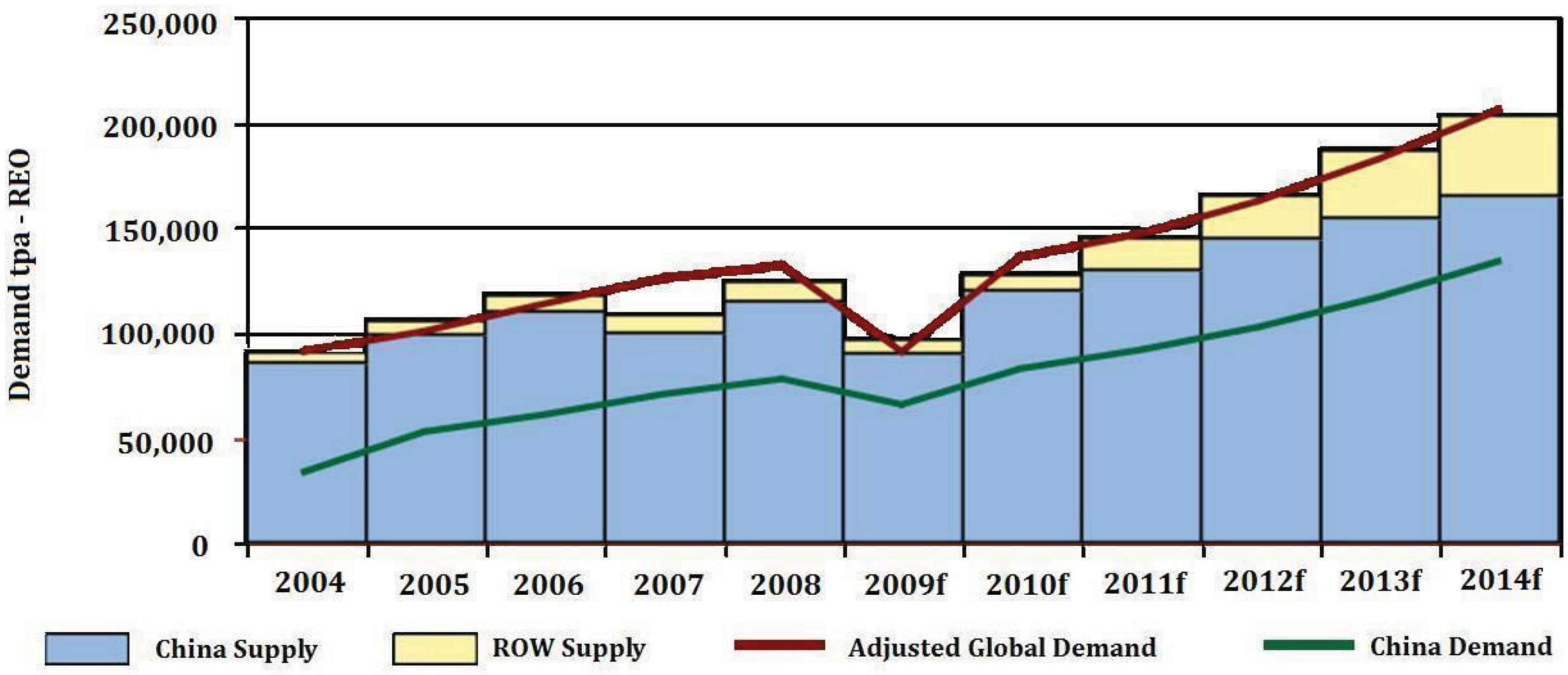
Sources: Avicenne (AV), Deutsche Bank (DB), Oakdene Hollins (S)

Demand – Cars vs Wind Turbines

	2010-2020			2020-2030		
Scenario	New cars p.a.	Nd_2O_3 demand p.a. (tn)	% of 2014 demand	New cars p.a.	Nd_2O_3 demand p.a. (tn)	% of 2014 demand
Business-as-usual	26,600	31	0.1	273,000	318	0.9
Mid-Range	79,500	93	0.3	330,000	385	1.1
High-Range	154,500	180	0.5	965,000	1,126	3.2
Extreme-Range	309,500	361	1.0	1,750,000	2,041	5.8
	Capacity, GW			Capacity, GW		
Gearless Turbines	13	3,135	9.0	28	6,709	19.2

Demand-Supply Balance

- Demand and supply set to increase
- Rising ROW share of world production



Source: IMCOA

Demand-Supply Balance

Global Demand in 2014, ±15% (ktpa)

REO	Supply	Demand	Balance	Surplus / Shortage (%)
La	55	51	4	7
Ce	82	66	16	24
Pr	10	8	2	27
Nd	33	35	-2	-5
Sm	4	1	3	188
Eu	1	1	0.01	1
Gd	3	2	1	30
Tb	0.4	1	-0.2	-41
Dy	2	2	-0.3	-14
Er	1	1	0.1	6
Y	12	12	-0.4	-3
Others	1	0	1	550
Total	**204**	**180**	**24**	**13**

Source: IMCOA

Alternative Technologies - Magnets

- 3 REE minimisation strategies identified
  1. Improvement of existing NdFeB magnets
  2. Replacement magnetic materials
  3. Alternative motor technologies

Alternative Technologies - Batteries

- Key area of technological development for EVs
- NiMH batteries soon displaced by Li
- Many alternatives in the pipeline –
  metal-air, supercapacitors, hydrogen
- None pose significant demands on REEs (other resources at risk)

End of life recovery

- No collection infrastructure for the NiMH batteries
- Pre-existing research into the recycling of rare earth metals, mainly in Japan
- Potential processes but yield & cost issues, liquid metals
- Patents from the early 1990s
- Some current UK research

Conclusions

- Substantial rare earth reserves
- China dominates production (>95%)
- China will remain the main world supplier in short-medium term
- 8-11% p.a. growth for demand 2011-2014
- Hybrids and wind turbine competition for the essential materials

Conclusions

- Possible shortages for Dysprosium and Terbium
- No alternatives to REs in high strength magnets
- REs in NiMH batteries will be rapidly reduced -Li-Ion type batteries
- No recovery of REs in used batteries

Conclusions

- Viable extraction processes for recovery but yields & cost issues
- Growth in demand will mean recycling benefits will be modest
- Environmental and carbon benefits in use outweigh environmental impacts of mining and extraction, even at low ore grades

Recommendations

- Application-focus development of RE magnets most relevant for EU countries
- Development of recycling/life extension infrastructure and policies
- International collaboration necessary for magnet development (USA/Japan/EU)
- Be cautious on support for gearless magnet generator technology

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