

*“Meeting the Challenges of Rare Earths Supply  
in the Next Decade”*

by

Dudley J Kingsnorth

Industrial Minerals Company of Australia Pty Ltd

**The Hague Centre for Strategic Studies**

**1<sup>st</sup> December 2010**

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# Summary of Presentation

- The rare earths industry today
- China
- Present and future demand and supply
- Potential future new suppliers
- Sustainability through diversity

# Rare Earths: Type & Symbols

Element	Type	Symbol	Atomic Weight
Lanthanum	'Light' or 'Ceric'	La	138.92
Cerium		Ce	140.13
Praseodymium		Pr	140.92
Neodymium		Nd	144.27
Samarium	'Medium'	Sm	150.43
Europium		Eu	152.00
Gadolinium		Gd	156.90
Terbium	'Heavy' or 'Yttric'	Tb	159.20
Dysprosium		Dy	162.46
Holmium		Ho	163.50
Erbium		Er	167.20
Thulium		Tm	169.40
Ytterbium		Yb	173.04
Lutetium		Lu	174.99
Yttrium		Y	88.92

# The Rare Earths Market Today

- Estimated demand in 2010: 125,000t REO
- Prices: Early 2010 US\$11-13/kg; Now US\$20-30/kg REO
- Value of Output: US\$1½-2 Billion in 2010
- China is dominant (supplying 95% and consuming 60% of global supply/demand)
- Constraints on Chinese exports are creating opportunities for non-Chinese projects
- Several non-Chinese rare earths projects under development or being evaluated

# Key Drivers of Demand

Application	Rare Earths	Demand Drivers
Magnets	<b>Nd, Pr</b> , Sm, Tb Dy	Drives for computers, mobile phones, mp3 players, cameras. Hybrid vehicle electric motors. Electric motors for luxury vehicles. Mag-lev trains.
LaNiH Batteries	<b>La</b> , Ce, Pr, Nd	Hybrid vehicle batteries. Hydrogen absorption alloys for re-chargeable batteries
Phosphors	<b>Eu, Y, Tb</b> , La, Dy, Ce, Pr, Gd	LCDs. PDPs. LEDs. Energy efficient fluorescent lights/lamps.
Fluid Cracking Catalysts	<b>La</b> , Ce, Pr, Nd	Petroleum production – greater consumption by ‘heavy’ oils and tar sands
Polishing Powders	<b>Ce</b> , La, Nd	Mechano-chemical polishing powders for TVs, monitors, mirrors and (in nano-particulate form) silicon chips.
Auto Catalysts	<b>Ce</b> , La, Nd	Tighter NO <sub>x</sub> and SO <sub>2</sub> standards – platinum is re-cycled, but for rare earths it is not economic
Glass Additive	<b>Ce, La</b> , Nd, Er	Cerium cuts down transmission of uv light. La increases glass refractive index for digital camera lens.
Fibre Optics	<b>Er</b> , Y, Tb, Eu	Signal amplification

# Rare Earths – Some Concepts

- Rare earths are not commodities – customer specific
- Western rare earths enterprises are single project companies (debt has to be non-recourse project funded)
- Capital intensive (>US\$40,000/t annual capacity)
- Long start-up; limited expertise outside China
- Supply and demand for individual REOs is not in balance
- Used in small quantities:
  - REO price has negligible impact on final product price
  - Limited recycling

# Rare Earths Projects – Some Development Concepts

- Each orebody is different; so the process route is project specific
- All rare earths orebodies have U and Th associated with them; requiring safe disposal
- Pilot plant studies are required to:
  - Demonstrate technical viability
  - Generate samples for customer approval as basis for sales contracts
  - Provide data for bankable feasibility study
  - Generate data for environmental impact statement

# China: Rare Earths Export Transition

- 1970s: Rare earth mineral concentrates.
- 1980s: Mixed rare earth chemical concentrates.
- Early 1990s: Separated rare earth oxides and metals.
- Late 1990s: Magnets, phosphors, polishing powders.
- 2000s: Electric motors, computers, batteries, LCDs, mobile phones.

# China: Export Quota History

## Chinese Export Quota History 2005-2010 (Tonnes Product)

Year	Rare Earth Quotas				ROW Demand
	Domestic Companies	Foreign Companies	Total	Change	
2005	48,040t	17,659t	65,609t	0%	46,000t
2006	45,752t	16,069t	61,821t	-6%	50,000t
2007	43,574t	16,069t	59,643t	-4%	50,000t
2008	Actual: 34,156t Adjusted: 40,987t*	Actual: 13,293t Adjusted: 15,834t*	Actual: 47,449t Adjusted: 56,939t*	-5½%*	50,000t
2009	33,300t	16,845t	50,145t	-12%	25,000t
<b>2010</b>	<b>22,512t</b>	<b>7,746t</b>	<b>30,258t</b>	<b>-40%</b>	<b>48,000t</b>

Note: \* Quotas adjusted to an equivalent 12 month quota as there was a change in the dates for which they were issued; so that now they are for a calendar year

# China: Industry Constraints

- Export quotas – recent reduction of 40%
- Production quotas – reserves limited
- Export taxes: 15-25%
- VAT rebate on exports withdrawn
- “Co-ordinated pricing”
- Industry consolidation
- Environmental legislation enforced
- **Lack of transparency**

# Global Rare Earths Consumption in 2010

## Estimated Global Rare Earths Demand in 2010 (t REO ±15%)

(Source: IMCOA, Roskill and Rare Earths Industry Stakeholders)

Application	China	Japan & NE Asia	USA	Others	Total	Market Share
Catalysts	9,000	3,000	9,000	3,500	24,500	20%
Glass	7,000	1,500	1,000	1,500	11,000	9%
Polishing	10,500	6,000	1,000	1,500	19,000	15%
Metal Alloys	15,500	4,500	1,000	1,000	22,000	18%
Magnets	21,000	3,500	500	1,000	26,000	21%
Phosphors	5,500	2,000	500	500	8,500	7%
Ceramics	2,500	2,500	1,500	500	7,000	5%
Other	4,000	2,000	500	500	7,000	5%
<b>Total</b>	<b>75,000</b>	<b>25,000</b>	<b>15,000</b>	<b>10,000</b>	<b>125,000</b>	<b>100%</b>
<b>Market Share</b>	<b>60%</b>	<b>20%</b>	<b>12%</b>	<b>8%</b>	<b>100%</b>	<b>-</b>

# Rare Earths Supply in 2009

(Source: Roskill Information Services Pty Ltd)

- **China:** 120,000t REO (down from 124,800t in 2008).  
Includes 30-40,000t REO 'heavies', but excludes 15-20,000t REO from *unofficial* sources.
- **Russia:** 2,000t REO (down from 2,470t in 2008).
- **India:** 75t REO (up from 50t in 2008)
- **USA:** 1,700t REO (from stockpiled concentrates)
- **Others:** Small amounts
- **ROW Total:** <5% of global supply

# The Last 18-24 Months

- China suspends shipments of rare earths to Japan for political reasons (September 2010)
- Chinese export quotas reduced significantly
- Global financial crisis (Growth set back 2 years)
- China declares 'heavy' rare earths resources are finite (approximately 15 years)
- Chinese rare earths industry consolidation
- Mt Weld & Mountain Pass to move rapidly to 20,000tpa REO each

# Some Thoughts/Comments on Recent Announcements in China

- China has long held that prices are too low  
(Consider 1985 Prices:  $\text{Eu}_2\text{O}_3$ : US\$2,500,  $\text{Y}_2\text{O}_3$ : US\$175,  $\text{La}_2\text{O}_3$  US\$18 per kg REO)
- Since the announcements prices have risen by 20-600%, but sales volumes have been limited
- Could it be a temporary exercise to extinguish excess stocks (outside China) to support higher prices?
- 'To assist' establishing better environmental standards
- Resultant high prices will encourage illegal mining
- This may be the last opportunity, until Mountain Pass & Mt Weld start-up, for China to persuade rare earths consuming manufacturers to move to China

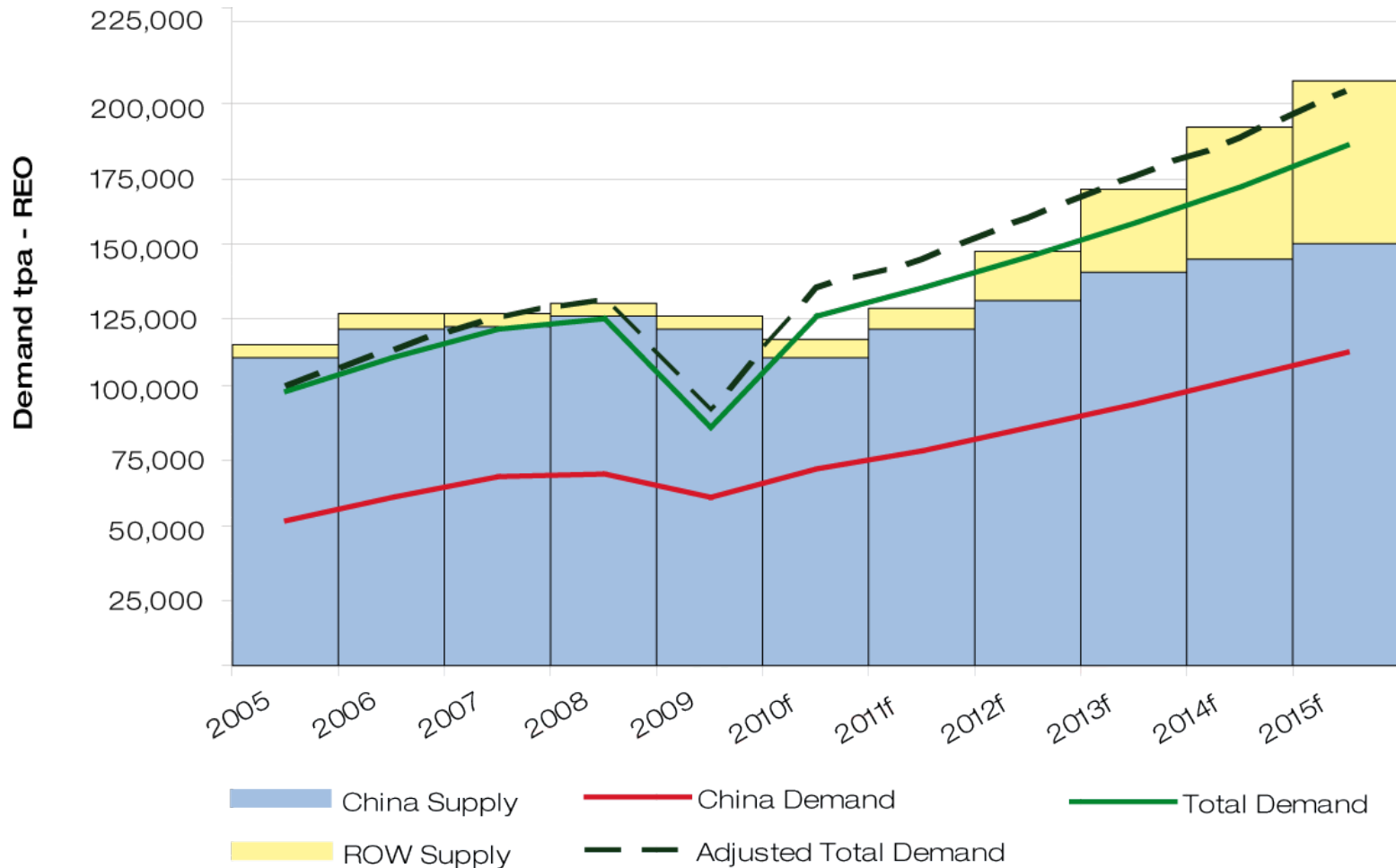
# Global Rare Earths Consumption in 2015

## Estimated Global Rare Earths Demand in 2015 (t REO ±15%)

(Source: IMCOA, Roskill and Rare Earths Industry Stakeholders)

Application	China	Japan & NE Asia	USA	Others	Total	Market Share
Catalysts	12,500	3,000	10,000	3,000	28,500	15½%
Glass	7,000	2,000	1,000	1,000	11,000	6%
Polishing	12,500	10,000	4,000	4,000	30,500	16½%
Metal Alloys	25,000	7,000	2,000	1,000	35,000	19%
Magnets	37,000	6,000	3,000	2,000	48,000	26%
Phosphors	8,000	3,000	1,000	1,000	13,000	6%
Ceramics	3,000	3,000	2,000	1,500	9,500	5½%
Other	6,000	2,500	500	500	9,500	5½%
<b>Total</b>	<b>111,000</b>	<b>36,500</b>	<b>23,500</b>	<b>14,000</b>	<b>185,000</b>	<b>100%</b>
<b>Market Share</b>	<b>60%</b>	<b>20%</b>	<b>13%</b>	<b>7%</b>	<b>100%</b>	<b>-</b>

# Rare Earths Supply & Demand



(Source: Roskill, IMCOA, CREIC, Discussions with Rare Earths Industry Stakeholders)

# The Issue of 'Balance' in 2015

## Forecast Supply and Demand for Selected Rare Earths in 2015 (Tonnes REO, $\pm 15\%$ )

Rare Earth Oxide	Demand @ 185,000tpa REO	Supply @ 208,500tpa REO
Cerium	65-70,000t REO	80-85,000t REO
Neodymium	35-40,000t REO	30-35,000t REO
Europium	725-775t REO	575-625t REO
Terbium	450-500t REO	400-450t REO
Dysprosium	2,500-3,000t REO	1,500-2,000t REO

# Resource Compositions Vary

Per Cent REO Content of Major Rare Earths Source Minerals

Rare Earths Oxide	Bastnasite		Ion Adsorption Clays		Monazite		Loparite
	Bayan Obo Inner Mongolia	Mountain Pass USA	Xunwu Jiangxi China	Longnan Jiangxi China	Mt Weld Australia	Guangdong China	Lovozersky Russia
<b>La<sub>2</sub>O<sub>3</sub></b>	23.0%	33.2%	43.4%	1.8%	25.5%	23.0%	28.0%
<b>CeO<sub>2</sub></b>	50.0%	49.1%	2.4%	0.4%	46.7%	42.7%	57.5%
<b>Pr<sub>6</sub>O<sub>11</sub></b>	6.2%	4.3%	9.0%	0.7%	5.3%	4.1%	3.8%
<b>Nd<sub>2</sub>O<sub>3</sub></b>	18.5%	12.0%	31.7%	3.0%	18.5%	17.0%	8.8%
<b>Eu<sub>2</sub>O<sub>3</sub></b>	0.2%	0.1%	0.5%	0.1%	0.4%	0.1%	0.1%
<b>Tb<sub>4</sub>O<sub>7</sub></b>	0.1%	trace	trace	1.3%	0.1%	0.7%	0.1%
<b>Dy<sub>2</sub>O<sub>3</sub></b>	0.1%	trace	trace	6.7%	0.1%	0.8%	0.1%
<b>Y<sub>2</sub>O<sub>3</sub></b>	trace	0.1%	8.0%	65.0%	0.3%	2.4%	trace

# Potential North American Suppliers

Factor	MOUNTAIN PASS (USA) Molycorp Minerals, LLC	HOIDAS LAKE (Canada) Great Western Minerals Group	NECHALACHO (Canada) Avalon Ventures Ltd	BEAR LODGE (USA) Rare Element Resources Ltd
Status	Re-commissioned separation plant. Feasibility study of re-commencing mining and processing underway.	Advanced exploration. Some preliminary test work completed. Could be supplemented by Steenkampskraal Project in South Africa	Pre-feasibility study underway. Some preliminary test work completed.	Resource engineering study underway. Process development commenced
Resource	20Mt @9.2% REO 1.8Mt REO contained (a proven reserve)	1.4Mt @ 2.6% REO 0.04Mt REO (inferred)	65Mt @2.5%REO 1.6Mt REO (inferred)	9 Mt @ 4.1% REO 0.4 Mt REO (inferred)
Potential Production	Target: 18,000t pa REO; start-up in 2012. Phase #2 : +100%	Hoidas : 3-5,000 tpa REO Start-up post 2014. Steenkampskraal maybe in 2013/14	3-5,000 tpa REO Start-up post 2014	Unknown
Critical Issues	<ul style="list-style-type: none"> <li>■ New owners</li> <li>■ Completing DFS</li> <li>■ Re starting an 'old' plant.</li> </ul>	<ul style="list-style-type: none"> <li>■ Define ore reserve</li> <li>■ Develop process</li> <li>■ Complete DFS</li> <li>■ Approvals</li> <li>■ Customer support</li> </ul>	<ul style="list-style-type: none"> <li>■ Define ore reserve</li> <li>■ Develop process</li> <li>■ Complete DFS</li> <li>■ Approvals</li> <li>■ Customer support</li> </ul>	<ul style="list-style-type: none"> <li>■ Define ore reserve</li> <li>■ Develop process</li> <li>■ Complete DFS</li> <li>■ Approvals</li> <li>■ Customer support</li> </ul>

# Potential Australian Suppliers

Factor	MT WELD (Australia/Malaysia) Lynas Corporation	DUBBO ZIRCONIA (Australia) Alkane Resources	NOLANS (Australia) Arafura Resources	BROWNS RANGE & JOHN GALT (Australia) Northern Uranium
Status	Start-up in late 2011. Project approvals in place. Construction well advanced.	3 <sup>rd</sup> generation pilot plant in 'production' for customer samples. Approvals process well advanced	Pre-feasibility study complete. Pilot plant studies ongoing. Approvals process started.	Possible xenotime resource. Drilling to commence in 2011
Resource	12Mt @ 9.7% REO 1.2Mt REO contained (a proven reserve)	73Mt @ 0.9% REO 0.65Mt REO contained (a proven reserve)	30Mt @ 2.8% REO 0.85Mt REO contained	Unknown Rare earths mineralisation appears to be xenotime
Potential Production	10,500t REO pa in 2011. Many sales contracts in place. Increase to 21,000t REO in 2012/13?	1,200-1,400tpa REO in 2013/14. REOs (rich in Y) ; by-products to zirconium chemical and niobium production.	20,000 tpa REO in 2015/16. Phosphate, calcium chloride & uranium co-products.	Target is ~3,000tpa REO in 2015/16
Critical Issues	<ul style="list-style-type: none"> <li>■Funding in place - no debt.</li> <li>■Technical support from Rhodia</li> <li>■Separation of mining and processing</li> </ul>	<ul style="list-style-type: none"> <li>■Complete DFS</li> <li>■Approvals (started)</li> <li>■Customer support</li> </ul>	<ul style="list-style-type: none"> <li>■Confirm process</li> <li>■Complete DFS</li> <li>■Approvals (started)</li> <li>■Customer support</li> </ul>	<ul style="list-style-type: none"> <li>■Confirm mineralogy</li> <li>■Exploration success</li> <li>■Develop process</li> <li>■Complete DFS</li> </ul>

# Projects with Japanese Support

- **Sumitomo/Kazatomprom:**  
Sareco JV to treat Y-rich tailings in Kazakhstan. 3ktpa in 2013?
- **Toyota/Sojitz/Govt of Vietnam;**  
Based on Dong Pao orebody. 3ktpa in 2013?
- **Toyota/Indian Rare Earths JV:**  
New monazite processing plant in Orissa. Target 10ktpa 2015?
- **Mitsubishi/Neo Material Technologies:**  
Based on treatment of tailings from Pitinga Sn/Ta/Nb mine in Brazil.

# Lithium – Threat or Necessity?

- Lanthanum supply will probably not be able to meet total HEV demand beyond 2015/16.
- The ‘conversion’ to Li-ion batteries from LaNiH is likely to be slower than many commentators currently believe – but it will happen.
- In other words the successful development of a mass-production lithium battery technology is essential if the 2020 goals for HEVs and EVs is to be met.

# The Ten Steps to Rare Earths Commercial Production

STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7	STEP 8	STEP 9	STEP 10
Establish Resource	Minerology	Scoping	PILOT PLANT(S)			EIS Approval	Letters of Intent (LOI)	DFS & Funding	EPC & Startup
			Beneficiation	Extraction	Separation				

**Mt Weld**

(Lynas)

**Mountain Pass**

(Molycorp)

**Dubbo**

(Alkane)

**Nolans**

(Arafura)

**Steenkampskraal**

(RareCo)

**Nechalacho**

(Avalon)

**Bear Lodge**

(Rare Element)

**Dong Pao**

(Vietnam)

# Rare Earths Prices 2005 - 10

## Comparison of Selected Rare Earths Prices US\$/kg REO 2005-10

(Notes: 1.Source is *metal pages*© 2. Prices have been rounded 3. US\$1.00 = C¥6.85)

Rare Earths Product	Rare Earths Price FOB China				Rare Earths Price FOB China 3Q2010
	2005	2007	2009	1H2010	
Lanthanum Oxide	US\$1.60	US\$3.10	US\$5.90	US\$6.50	US\$27
Cerium Oxide	US\$1.40	US\$2.50	US\$4.20	US\$4.90	US\$25
Praseodymium Oxide	US\$8.30	US\$28.00	US\$14.75	US\$28.50	US\$48
Neodymium Oxide	US\$7.40	US\$29.00	US\$14.85	US\$29.00	US\$50
Europium Oxide	US\$280	US\$300	US\$465	US\$505	US\$575
Dysprosium Oxide	US\$50	US\$85	US\$105	US\$170	US\$275
Terbium Oxide	US\$325	US\$555	US\$350	US\$475	US\$585
Yttrium Oxide	n/a	US\$6.85	US\$13.50	US\$11.00	US\$26
Rare Earth Carbonate (in China)	n/a	US\$4.80	US\$3.00	US\$5.10	US\$6.15

# The Outlook for 2015

- China will not directly deny the ROW of rare earths, but it will take whatever measures are necessary to maximise 'value add' manufacturing in China.
- Chinese constraints could constrain global growth.
- Supply will be tight.
- 'Balance' will still be an issue; so prices for Nd and Dy will remain strong..
- First of new projects will be on-stream and looking to expand.
- *Next generation* projects could be in early stages of start up.

# Forecast Rates of Growth 2010-2020

Forecast Rare Earths Sector Rates of Growth 2010-2020			
Application	Growth 2010-2015	Growth 2015-2020	Comments
Catalysts	3-5%pa	3-5%pa	Growth rate unchanged through the decade.
Glass	Negligible	Negligible	Negligible growth rate as use in television and computer screens falling off rapidly.
Polishing	7-10%pa	8-12%pa	Until recently growth was forecast at 4-8%pa, but with increasing use in nano-particulate polishing powders for the electronic industry growth has been strong.
Metal Alloys	8-12%pa	4-8%	From 2010 to 2015 growth will be driven by the use of NiMH batteries in hybrid vehicles. IMCOA is of the view that meaningful substitution of hybrids by electric vehicles driven by Li-ion batteries will not occur before 2015/16.
Magnets	10-15%pa	10-15%pa	<b>The real driver of demand in the next decade; price and availability a constraint.</b> Could be greater than the indicated forecast if more of the rare earths used in permanent magnets were to become available.
Phosphors	6-10%pa	3-6%pa	New lighting devices under development use less rare earths, even though television and computer screens are getting bigger and being replaced more often.
Ceramics	6-8%pa	4-8%pa	Steady growth rates at historic rates.
Other	6-8%pa	4-8%pa	Barring the development of a new application with a high demand; steady growth rates at historic rates. Use of gadolinium for refrigeration is included.

# Supply & Demand Trends 2015-2020

- Demand in 2020: 250-300,000t REO.
- Demand trends:
  - Greater availability of non-Chinese products
  - Prices will still be strong
  - Electric vehicles
  - Impact of substitution
  - Location of value add manufacturing
- Supply Trends
  - Consolidation of industry in China
  - Re-cycling
  - Emphasis on heavy rare earths
  - Bayan Obo (falling iron ore prices)

# Sustainability through Diversity

European Union adopts a purchasing code that requires all included imported 'strategic minerals' for EU use in the total supply chain are sourced so that:

- No more than 30/40% of imported 'strategic minerals' originate in any one country outside the EU (unless a bilateral trade agreement exists).
- No stockpiles or 'picking winners'.
- It is not specific to rare earths and/or China.
- Independent verification of supply chain.
- If it is simple other entities will adopt the code.
- Allow time; say, effective 1<sup>st</sup> January 2015.
- EU, Japan, USA and Australia to co-operate in the development of rare earths technologies.
- Grants to develop technology (CRC in Australia?).

*Thank you*

Dudley J Kingsnorth

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