

**Biennium Conference of the Global Partnership on
Waste Management GPWM
Osaka, Japan, 5-6 Nov '12
Panel 'Waste Management is Good Business'**

**The need for reclamation of critical
materials, such as rare earth metals**

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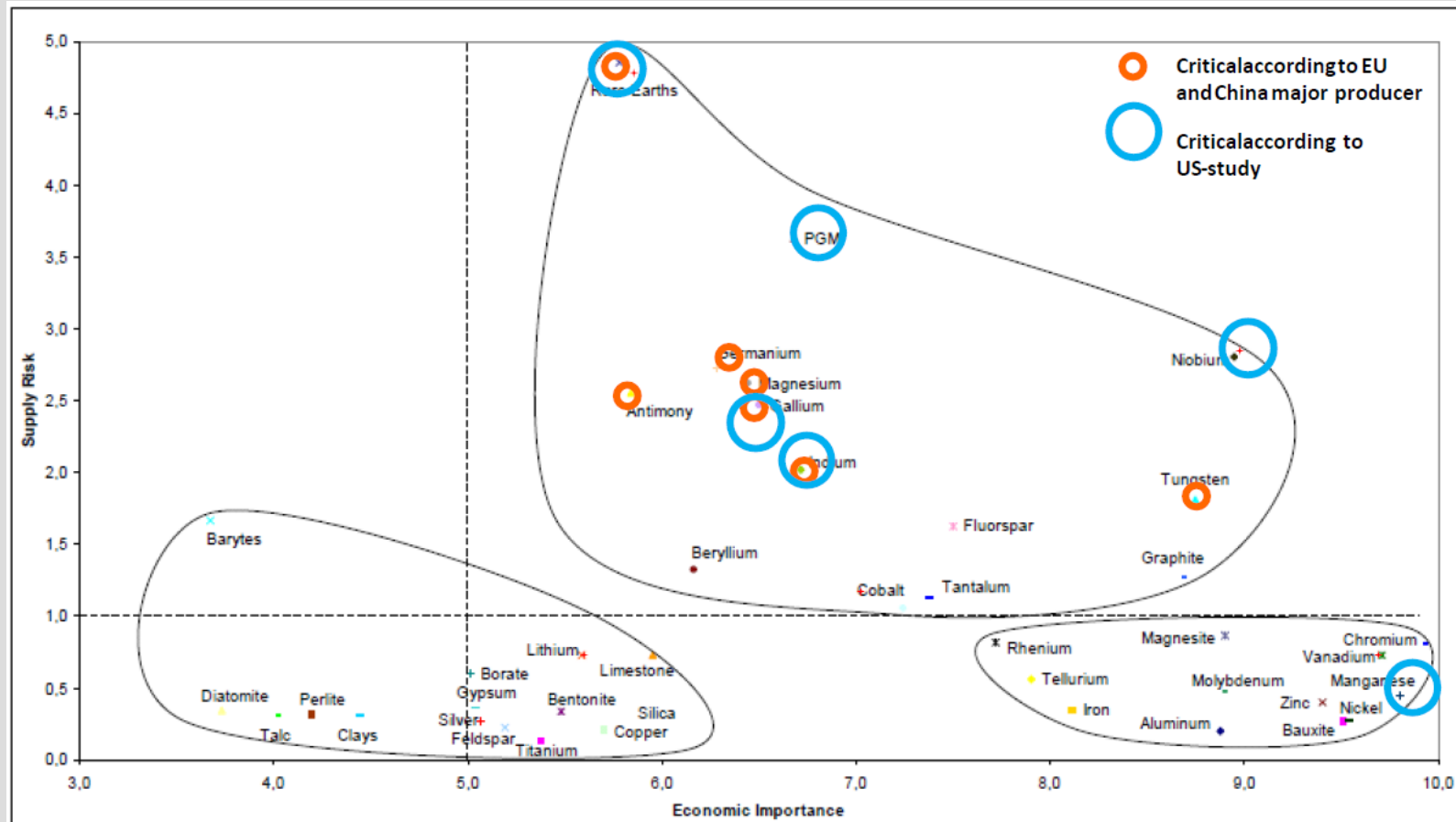
- 1. What are Critical Raw Materials [CRM]?**
‘Critical’ vs. ‘Essential’ Materials [for agriculture, construction, basic industries] – could become critical if access becomes restricted
- 2. Why are Rare Earth Elements [REE] critical?**
- 3. How much reclamation [and recycling] of CRM...and of REE is possible -- in addition to substitution?**
- 4. Public policies on CRM: EU/US/Japan**
- 5. Policies on reclamation [+recycling] of CRM... and REE in particular**

1. CRM definition

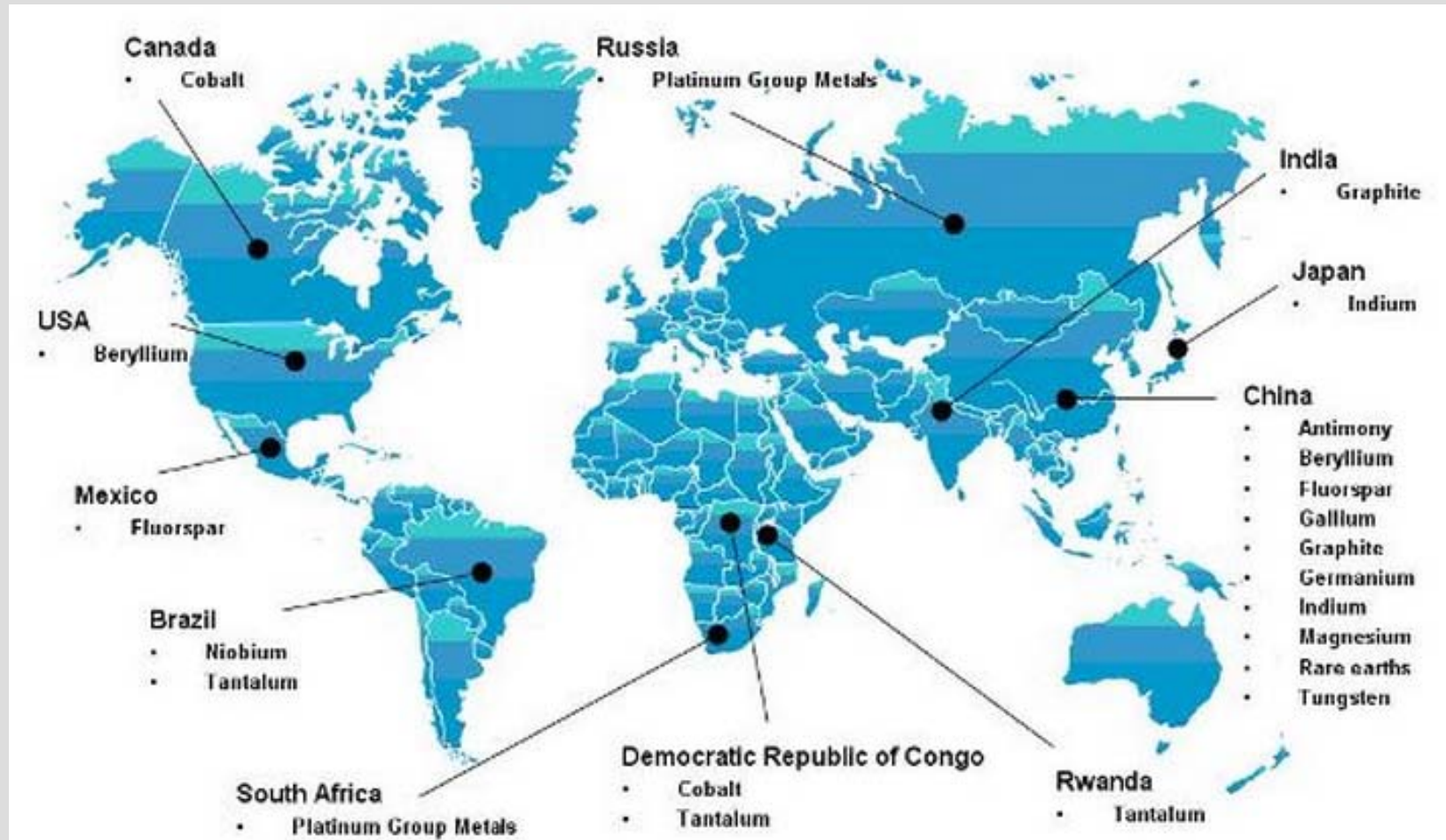
EU Report of the Ad-hoc Working Group on defining critical raw materials, July 2010

- “**Critical**”: when the risks of **supply shortage** and their impacts on the **economy** [applications etc] are higher compared with most of the other raw materials.
- Two types of risks considered
- "**supply risk**" → **political-economic** stability of the producing countries, the level of concentration of production, the potential for substitution and the recycling rate
- "**environmental country risk**" → risks taken by countries with weak environmental performance in order to protect the environment and, in doing so, endanger the supply of raw materials to the EU

1. Criticality for EU, US



1. Production concentration of CRM by source country



1. Major CRM primary producing countries

- **China: leading producer of 9: antimony (91%), fluorspar (59), gallium (32), germanium (71), graphite (71), indium (50), magnesium (77), REEs (97), tungsten (81); in top 3 largest producers of 2 other CRM: beryllium (14%) and cobalt (10)**
- **Brazil: niobium (92%), tantalum (16), graphite (7), REEs (1)**
- **US: beryllium (86%), magnesium (7), germanium (3)**

2. Rare Earth Elements

Cerium (Ce)	Dysprosium (Dy)	Erbium (Er)	Europium (Eu)	Gadolinium (Gd)	Holmium (Ho)
Lanthanum (La)	Lutetium (Lu)	Neodymium (Nd)	Praseodymium (Pr)	Promethium (Pm)	Samarium (Sm)
Scandium (Sc)	Terbium (Tb)	Thulium (Tm)	Ytterbium (Yb)	Yttrium (Y)	

2. Why the interest in REE?

- **Foreign sources: 95-97% of world's current supply**
- **Limited number of currently developed non-Chinese sources**
- **Processing difficulties, incl. environmental**

Uses

- **All types of modern electronics and green technologies [CO₂-reducing], incl. medical, renewables and defense**
- **Very light & strong permanent magnets, alloys, batteries, catalysts, lighting/displays, lasers, wind turbines, solar panels,...**
- **Russia: agricultural uses!**

2. CRM uses - Why the interest in CRM?

	Antimony	Beryllium	Cobalt	Fluorspar	Gallium	Germanium	Graphite	Indium	Magnesium	Niobium	PGMs	REES	Tantalum	Tungsten
Automotive/Aerospace		■	■				■		■	■			■	
Batteries			■				■					■		
Catalysts			■			■					■	■		
Cemented carbide tools			■											■
Chemicals				■										
Construction									■					
Electrical equipment					■		■	■	■			■		
Electronics/IT	■	■			■	■		■			■	■	■	
Flame retardants	■													
Optics					■	■								
Packaging									■					
Steel & steel alloys				■			■		■			■		

3. CRM reclamation, recycling, substitution

- **Urban mining**
- **CRM recovery [reclamation] technologies**
- **Recycling of CRM**
- **Life Cycle Assessment [LCA]**

3. Urban mining

- **Recovery of elements and compounds from waste materials & products**
- **Consumer electronics increasingly subject to urban mining practices— w/ > 6.5 mi mt personal computers, monitors & peripherals, televisions, & mobile devices generated/yr in US, Europe, China, India**
- **Introductory video on urban mining, focusing on efforts in Japan, available on the Internet**

3. CRM reclamation....

Two steps

- **Dismantling of WEEE, removing specific components eg high grade circuit boards, liquid crystal displays [LCDs], hard disk drives [HDDs], batteries & phosphor powder coated glass + segregating these into streams for further processing by specialist operators**
- **Recovery of CRM fm waste streams from the treatment centres, much of which is carried out by the large metal refiners and smelters using a combination of specialist pyrometallurgical, hydrometallurgical and mechanical processes**

3...CRM reclamation....

PGM

- **Recovery level of PGMs in automotive catalysts remains << 50%, for electronic applications only ~ 10%. Challenge in PGMs in consumer applications: collection and channeling through the recycling chain to the metal recovery processes; dissipation: economic & technical challenges on recycling.**

Graphite and fluorspar

- **Options limited**
- **Exception?: hydroflux recovery fm sludge left fm stainless steel finishing [pickling], for its fluorspar content - could then be reused in production processes. Leading stainless steel producer developed, patented, successfully piloted such process: 'profitability of full-scale plant investment for the technology dependent on energy cost + fluorspar price ...Discussions ongoing w/ suppliers for viable + cost effective supply route'**

3...CRM reclamation...

Antimony trioxide

- **Sb₂O₃ recovery fm plastic flame retardants: most significant opportunity. Sb₂O₃ fate follows plastic where it is contained...but greater separation of brominated flame retardant plastics could enable its recovery. Flame retardants: major application of global Sb consumption; usage in general plastics is dissipative but within particular types of plastic the concentration is ~ 5-8%.**
- **Recovery technology successfully tested by Umicore within their integrated metal smelter, via calorific value of waste electrical and electronic equipment [WEEE] plastics; for less diversified recycling companies recovery appears more marginal and dependent on Sb₂O₃ price**

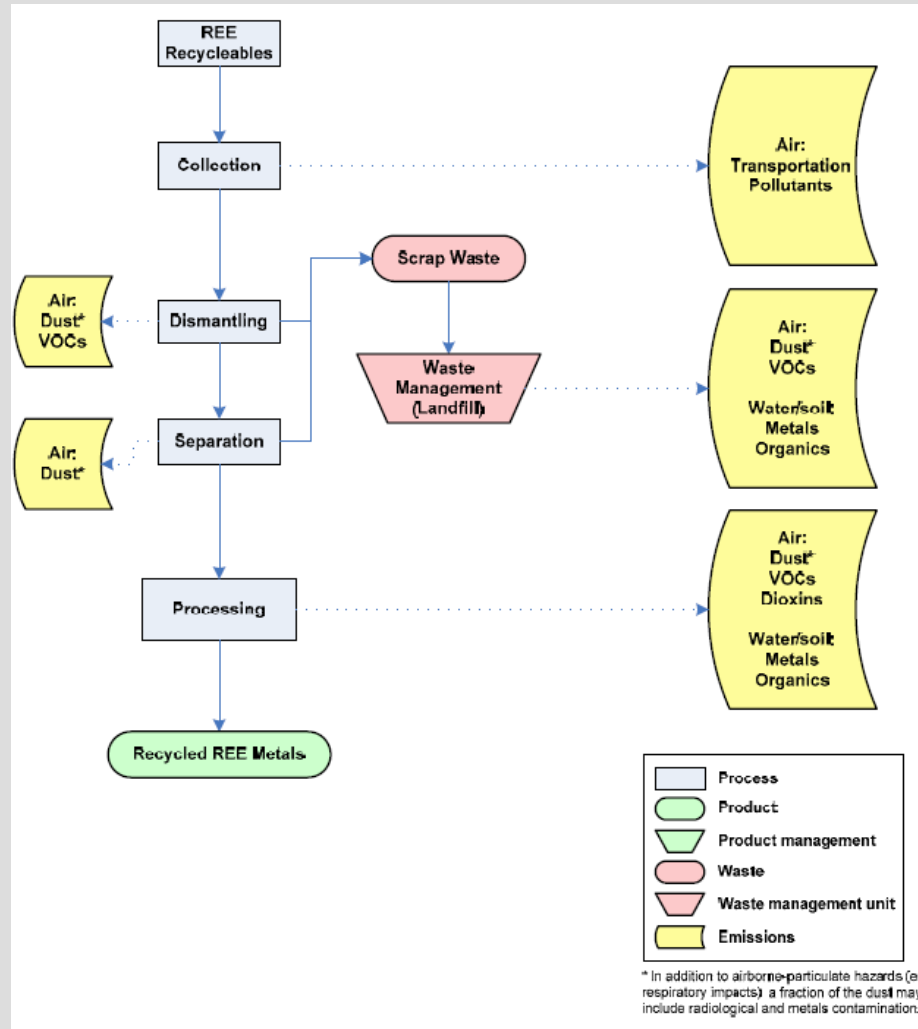
3...REE reclamation...

REE

- Recovery processes have been developed, but current commercial viability? For most applications substitutes for REE are available but w/ loss of performance. REE recovery to be through complex processing to chemically break down REE-containing minerals. Mining operations [& associated support facilities e.g. waste material management areas, tailings ponds] @ scale expected for recovery of REE minerals require large areas to accommodate an individual mine → mixed ownership of land, including federal and private combination
- Diagram in next slide

3. Steps for REE

Collection, dismantling, separation (pre-processing), processing



3. REE recycling operations, technologies, current status, benefits...

Company	Target Feedstock/ Element	Technology to Be Used	Anticipated Time to Commercialization	Benefits (Cost and Environmental)
Hitachi	Rare earth magnets from air conditioner compressors and hard disk drives	Automated separation process and dry extraction process	Anticipates recycling will meet 10% of its need by 2013 when facility goes online	Dry extraction method that allows processing without acids; resulting waste water problem. Automated separation process is faster than manual. Cost savings anticipated.
Toyota	Hybrid car batteries	Unknown	Ongoing	Main driver is supply concerns
Japan's Shin-Etsu Chemical	Air conditioners	Plans to recycle recovered REEs into magnets	2011	No information readily available.
Showa Denko KK	Dysprosium and didymium (a mixture of praseodymium and neodymium)	No information readily available.	Estimated output of 800 tons from recycling facility	No information readily available.

3...REE recycling operations, technologies, current status, benefits

Company	Target Feedstock/ Element	Technology to Be Used	Anticipated Time to Commercialization	Benefits (Cost and Environmental)
Mitsubishi (with Panasonic and Sharp)	Neodymium and dysprosium, washing machines and air conditioners	No information readily available.	Currently in research stage. Anticipated production stage by 2014	No information readily available.
Kosaka, Dowa Holdings	Existing electronics recycling plant—future processing of neodymium.	Smelter—300 tons of material per day are processed, resulting in 150 grams of rare metals	Research being conducted to develop technologies for REE recovery	Factory is making money. Process for neodymium extraction is estimated to be costly.
Raptor Technology Group	Mine tailings (from hardrock ore deposits from Washoe mine).	"Advanced chromatography and innovative separation technologies"	2,000 tons of ore per year, currently. New facility being built with capacity of over 10,000 tons of ore per year.	Cost savings; reclaimed mine wastes; chemical recycling and water savings.
Creative Recycling Systems/ GreenRock Rare Earth Recovery Corporation	Electronics	"Closed loop" process. Details not available	By end of 2011, estimated to have four processing facilities with a capacity to process 500 million pounds of electronics per year.	No information readily available.

3. Environmental implications of REE recycling

- **Primary emissions** – Hazardous substances contained in e-waste e.g., Pb, Hg, As, polychlorinated biphenyls [PCBs], O₃-depleting substances
- **Secondary emissions** – Hazardous reaction products that result from improper treatment e.g., dioxins or furans formed by incineration/inappropriate smelting of plastics with halogenated flame retardants
- **Tertiary emissions** – Hazardous substances or reagents used during recycling [e.g., cyanide or other leaching agents] & released due to inappropriate handling/treatment: biggest challenge in developing countries engaged in small-scale & uncontrolled recycling operations
- **Need for 'Life Cycle Assessment'**

3. CRM substitution...

Difficult, or not economical, to achieve w/o deterioration in product quality or performance

Direct Substitution

- **NEDO, Japan: motor for hybrid vehicles using ferrite [instead of REE] magnets**
- **Hitachi Metals: magnet minimising REE via employing Cu alloys**
- **Toyota: induction motor w/o REE magnets**
- **GE: wind turbine generators w/ reduced dependence on REE**
- **UK: design of next generation electric vehicle motors [Switched Reluctance Traction Motor] eliminating use of expensive magnets.**
- **Panasonic seeks RE in recycled televisions in Japan - Aug. 27, '12**
- **Milking fly ash for REE, alumina to be economically viable - Orbite Sept '12**
- **Ford: Sept 24, '12: nickel-metal [Nd, Ce, La, Pr]-hydride batteries will be replaced w/ Li-ion alternatives**

3...CRM substitution

Indirect Substitution

- Gradual move fm using hard disk drives w/ 0.2% REE, to solid state memory devices, w/0.001% REE
- Sept 20, '12 Researchers aim to extract platinum group metals [PGM] discarded during mine processing which might then be used in catalysis. The research will investigate 'phyto-mining', which involves growing plants on mine waste materials to sponge up PGM into their cellular structure.

4. Policies...

Policy criteria, general

Market imperfections eg:

- **preservation of resources**
- **national defense**
- **minimizing environmental impact**
- **social aspects eg employment & EHS**

Policy criteria, CRM Reclamation/Recycling

- **reduce reliance on CRM imports through greater recycling and measures to reduce waste**
- **reduce risk that CRM supplies fail to keep pace with demand**
- **important for CRM w/ limited substitutes**
- **reduce environmental impacts fm disposal of end-of-life products & equipment**

4. Policies re. CRM: EU/US/Japan - history

- **Paley Commission, 1952: US President's Materials Policy Commission**
- **National Security Study Memorandums [NSSM],1974: The Critical Imported Materials**
- **European Community 1975: The supply of the Community**
- **U.S. Congressional Budget Office, 1983: Strategic Critical Nonfuel Minerals: Problems and Policy Alternatives**
- **National Research Council, 2007: Minerals, Critical Minerals, and the U.S. Economy**
- **Resource Efficiency KTN, 2008: Material Security -Ensuring resource availability for the UK economy**
- **European Commission, 2010: Critical Raw Materials for the EU**
- **European Commission, 2011: Tackling the Challenges in the Commodity Markets and in Raw Materials**
- **RPA study Jan '12 adds Aggregates, Cu, Nb, Li and Wood**
- **US, Japan etc. CRM lists slightly different fm EU**

4...Policies UN, US

UN

- **'UNEP-DTIE-IETC Global Partnership on Waste Management'**
- **\$2.5 mi fm EPA, to track discarded mobile phones & electronic wastes generated in the US to develop solutions aimed at recovering REEs – project includes other international partners**

US

- **Re-establish domestic REE industry**
- **Prohibit export of certain electronics waste**
- **Modernize US policies on production, processing, manufacturing., recycling, environmental protection – focus on minerals for military security & strong economy**
- **Direct DOI to conduct research to ensure CRM supply throughout the supply chain**
- **DOE ARPA-E - \$30 mi to REE Alternatives in Critical Technologies [REACT]**
- **NSF-funded Center for Resource Recovery will develop technologies for greater scrap utilization**

4...Policies EU

In 2012

- **EuroMed workshop on Raw Materials 15-16 Oct '12**
- **European Parliament Luncheon debate on Critical Materials, REACH - Brussels, 17 Oct '12**
- **Raw Materials Supply Group meeting, 12 Nov '12. Draft agenda: European Innovation Partnership; Review of CRM list; Member States national raw materials policy e.g. Germany agreements w/ Kazahstan, Mongolia**

4...Policies China

- **Cut export quotas**
- **No new mining licenses to 2015**
- **Consolidating the number of their companies**
- **Co-ordinated pricing**
- **VAT rebate on exports withdrawn**
- **Tougher EHS**
- **Increasing taxation for Chinese producers**
- **Assistance in R&D**
- **Stockpiling strategic reserves**
- **REE trading platform + National REE pricing system 'within Sept '12 to level out price volatility in the market'**

Non-Chinese companies and govts secure RE by operating in China, benefiting fm cheaper RE prices, eg Rhodia processing near Baotou, Molycorp buying Neo Materials etc

4...Policies Japan

World's largest REE importer, to lose more

With ROK: jv + supply agreements w/ 3rd countries, strategic stockpiles outside China, economizing/substituting/recycling

Goal	Business Policy	R&D Policy	Materials of Interest
Secure a stable supply of raw materials for Japanese industries	<ul style="list-style-type: none"> • Funding for international mineral exploration • Loan guarantees for high risk mineral projects • Stockpiling • Information gathering 	<ul style="list-style-type: none"> • Substitution research funded through METI and MEXT • Exploration, excavation, refining and safety research funded through JOGMEG 	Ni, Mn, Co, W, Mo, V**

4...Policies Japan CRM

- **Strategy for rare metals, Ministry METI 07/09: ensure stable supplies of critical metals, maintain + strengthen competitiveness of manufacturing industry: 'Govt takes focussed/strategic approach to determine which metals are critical to the economy and to ensure sufficient supplies for the future'.**
- **Four pillars for securing critical metals:**
 1. **Securing overseas resources, mainly via JOGMEG**
 2. **Recycling, both scrap & post-consumer products, better utilising existing recycling system + establishing a new one if necessary, R&D of recycling technology**
 3. **Devt of alternative materials via government-industry-academia Partnerships; investment in R&D activities → nanotechnology-based applications of alternative materials**
 4. **Stockpiling**

5. Policies on reclamation/recycling EU

EU

In addition to the above,

Ad-hoc Working Group [under Raw Materials Supply Group]

'recommends that policy actions make recycling of raw materials or

raw material-containing products more efficient by:

- **mobilising End of Life products with CRM for proper collection instead of stockpiling them in households (hibernating) or discarding them into landfill or incineration**
- **improving overall organisation, logistics and efficiency of recycling chains, focusing on interfaces and a systems approach**
- **preventing illegal exports of End of Life products containing critical raw materials and increasing transparency in flow**
- **promoting research on system optimisation and recycling of technically-challenging products and substances**

5. ...Policies on reclamation/recycling US

EPA: Primary drivers for renewed focus include increased demand for REEs, concern about REE supplies, increasing cost of REEs, and new policies implemented by some countries mandating REE recycling for selected items

Emerging Policies/Programs to support REE recycling, aiming at energy independence:

- **‘Promotion of alternative sources of power generation is crucial’**
- **House of Representatives RE and Critical Materials Revitalisation Act to ‘reestablish US as leading REE producer, self-sufficient, never depend on China for national security’**
- **US Pentagon distancing from ‘strategic danger’ rhetoric**
- **Congressional Bills Introduced 2010-2011**

From the Saatchi Gallery, London Oct '12



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Other

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Thank you very much!
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