Recycling and Substitution of Raw Materials

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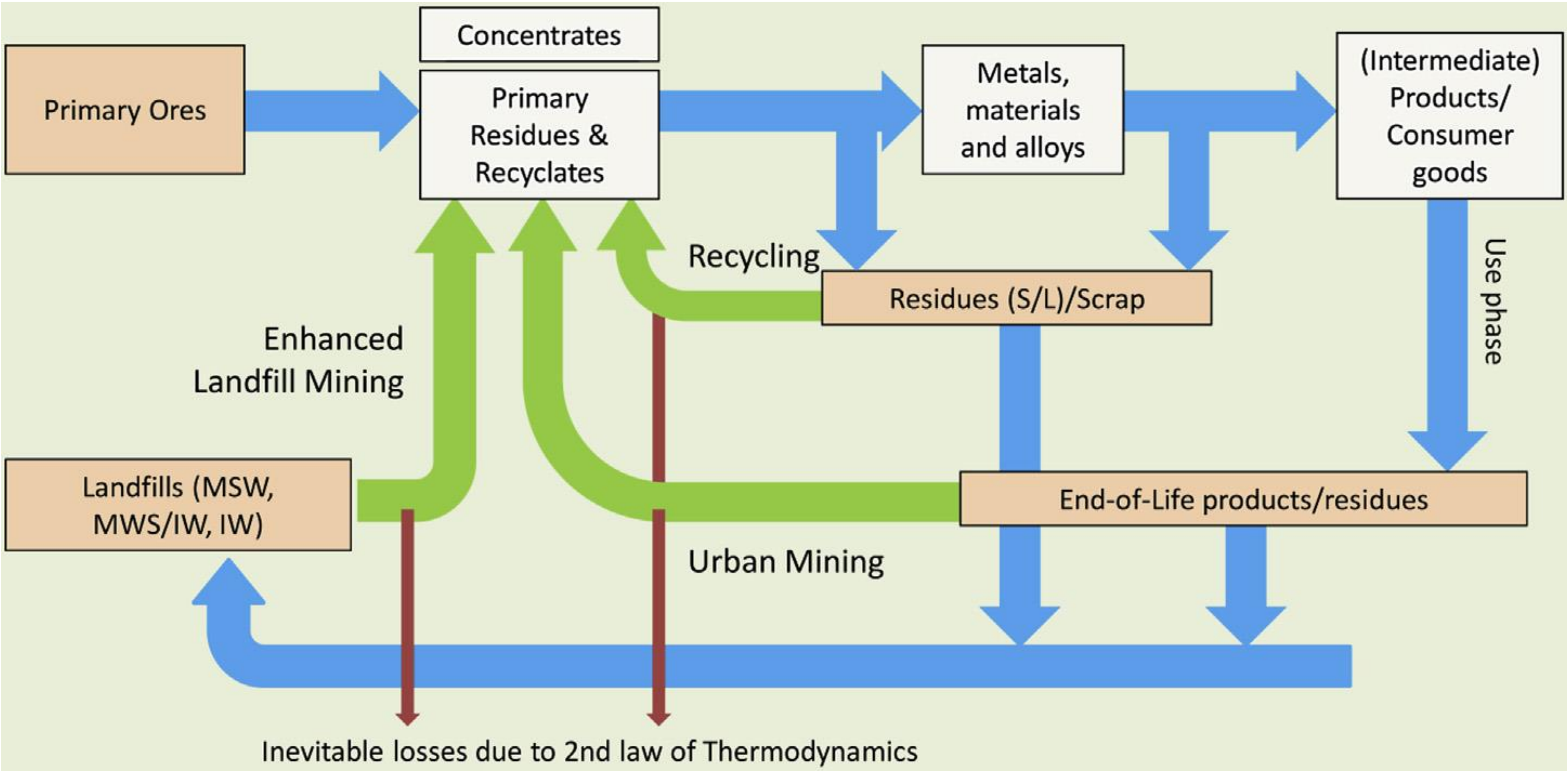
Problems to face in Europe

- The general shortage of metal primary resources.
- The specific scarcity of strategic/rare (critical) metals (such as PGM's, In, Ge, rare-earths), absolutely necessary to existing and emerging technologies (e.g. electronics, energy).
- Restrictions on landfilling and the need to recover valuable species from waste.

Secondary sources of materials

- Historical dumps and tailings ("*landfill mining*")
- Mining, metallurgical and other industrial residues; metal-rich sludge/fines from distinct processes: red mud, Al-anodising, surface coating/finishing (Ni/Cr plating), foundry sand, …
- End-of-life (metal-containing) products (e.g. vehicles, electronics, batteries): "*urban mining*"
- Inorganic non-metallic wastes:
  - MSWI and biomass combustion ashes (thermoelectric power stations and co-generation on paper-pulp industries);
  - CDW, etc …

Recycling



Fonte: Journal of Cleaner Production 51 (2013) 1-22

European priorities

- Recycling of raw materials from products, buildings and infrastructure
  - new innovative separation, sorting, recycling and/or reuse processes are needed to treat complex products and buildings:

    (1) **End-of-life products**: (a) pre-processing technologies for complex products …; (b) metallurgical recovery with focus on technology/critical metals.

    (2) **Packaging**: innovative technological solutions for recovery of materials from complex streams.

    (3) **Construction and demolition (C&D) waste**: (i) the feasibility of increasing the recovery rate of components (metals, aggregates, concrete, bricks, plasterboard, glass and wood), and (ii) the economic and environmental advantages associated with C&D waste treatment, attempting to reach the 2020 recycling target of 70% for C&D waste, as set in the Waste Framework Directive.

Challenges

- Insufficient information about composition/metals distribution (mainly rare metals) in mining and other industrial wastes.

- Complex combination of different materials and metals:
  - › Development of new and more efficient pre-processing technologies (e.g. advanced sorting) for complex EOL-products;
  - › Development of new metallurgical processes, highly efficient (materials/energy) and highly selective;
  - › Development of eco-design of products/processes to improve dismantling and recycling.

- **Absence of relevant actors** (e.g. pyrometallurgical or hydrometallurgical industries), **needed to close the loop** (producers + waste managers + users) + academia/R&D.

- Need to **create multidisciplinary teams** (Materials Sci., Environment, Management, Design, …) to fully cover all relevant aspects of the entire value chain (e.g. LCA, economics).

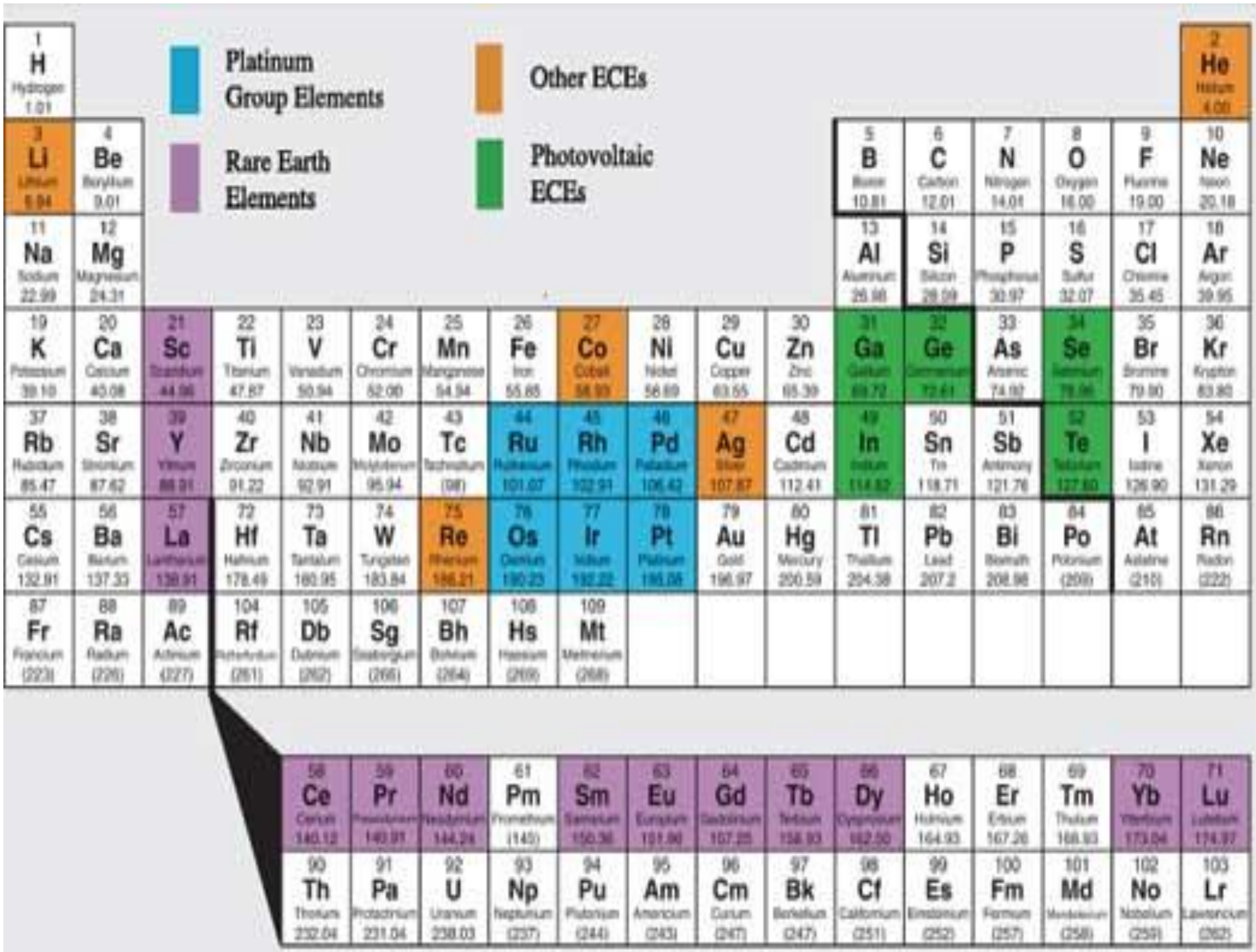
Goal

- WASTE to RESOURCE/ENERGY

Recycling

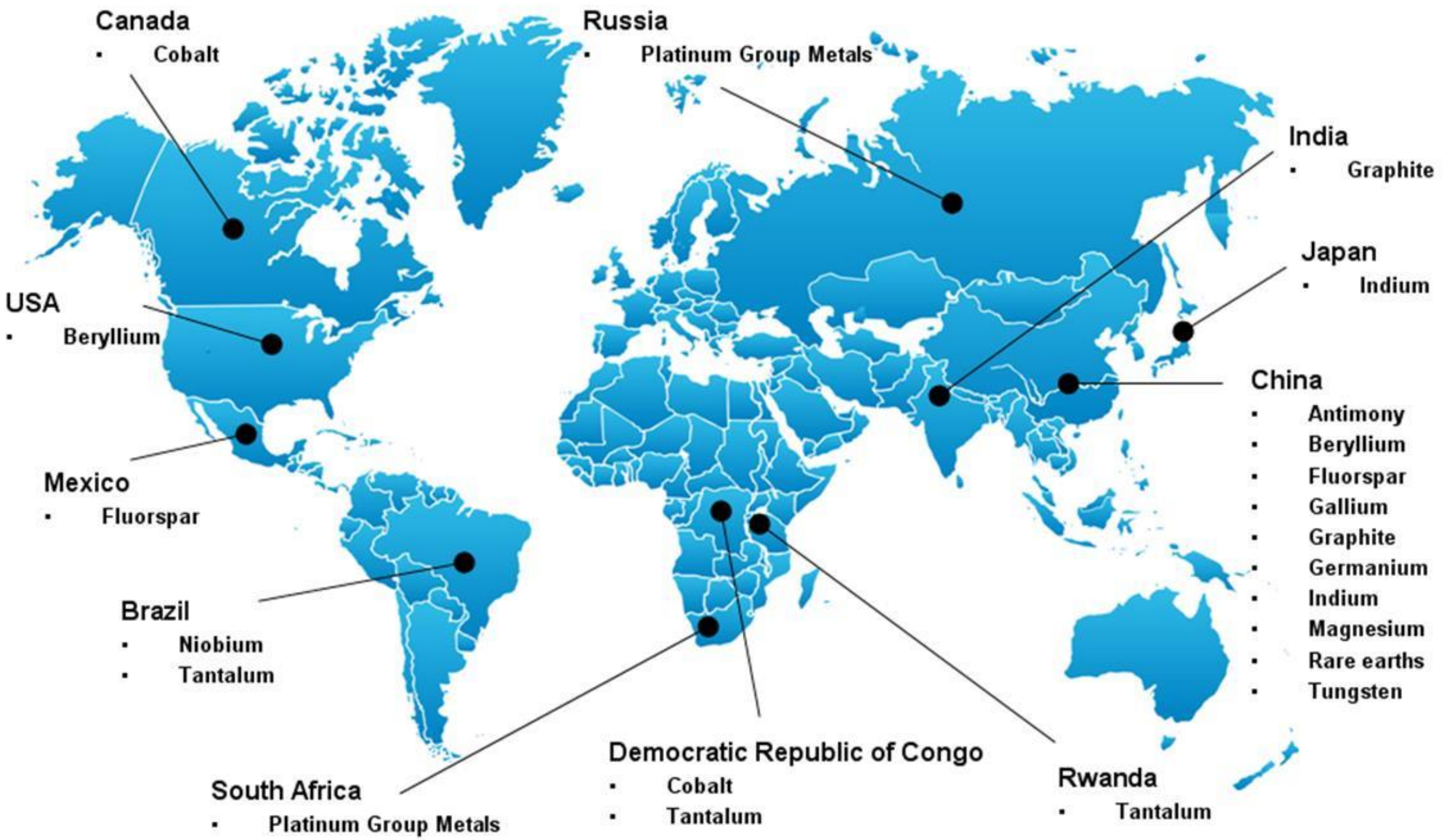
CALL – WASTE: A RESOURCE TO RECYCLE, REUSE AND RECOVER RAW MATERIALS	2014	2015	EU contribution/ project	Type project
industrial symbiosis	X		8-10 M€	IA two-stage
reduction, recycling and reuse of **food waste**	X			RIA two-stage
recycling of raw materials from **products and buildings**	X		6-8 M€	RIA one-stage
near-zero waste at European and global level a) A European near-zero waste stakeholder network (2014) b) Global waste dimension (2014) c) secondary raw materials inventory (2014) d) Raw materials partnerships (2015)	 X X X	 X		CSA one-stage
preparing and promoting **innovation procurement** for resource efficiency	X			CSA one-stage
eco-innovative waste management and prevention as part of sustainable urban development a) eco-innovative solutions b) eco-innovative strategies		 X X	8-10 M€	two-stage IA RIA
sustainable use of **agricultural waste, co-products and by-products**		X		RIA two-stage

Substitution

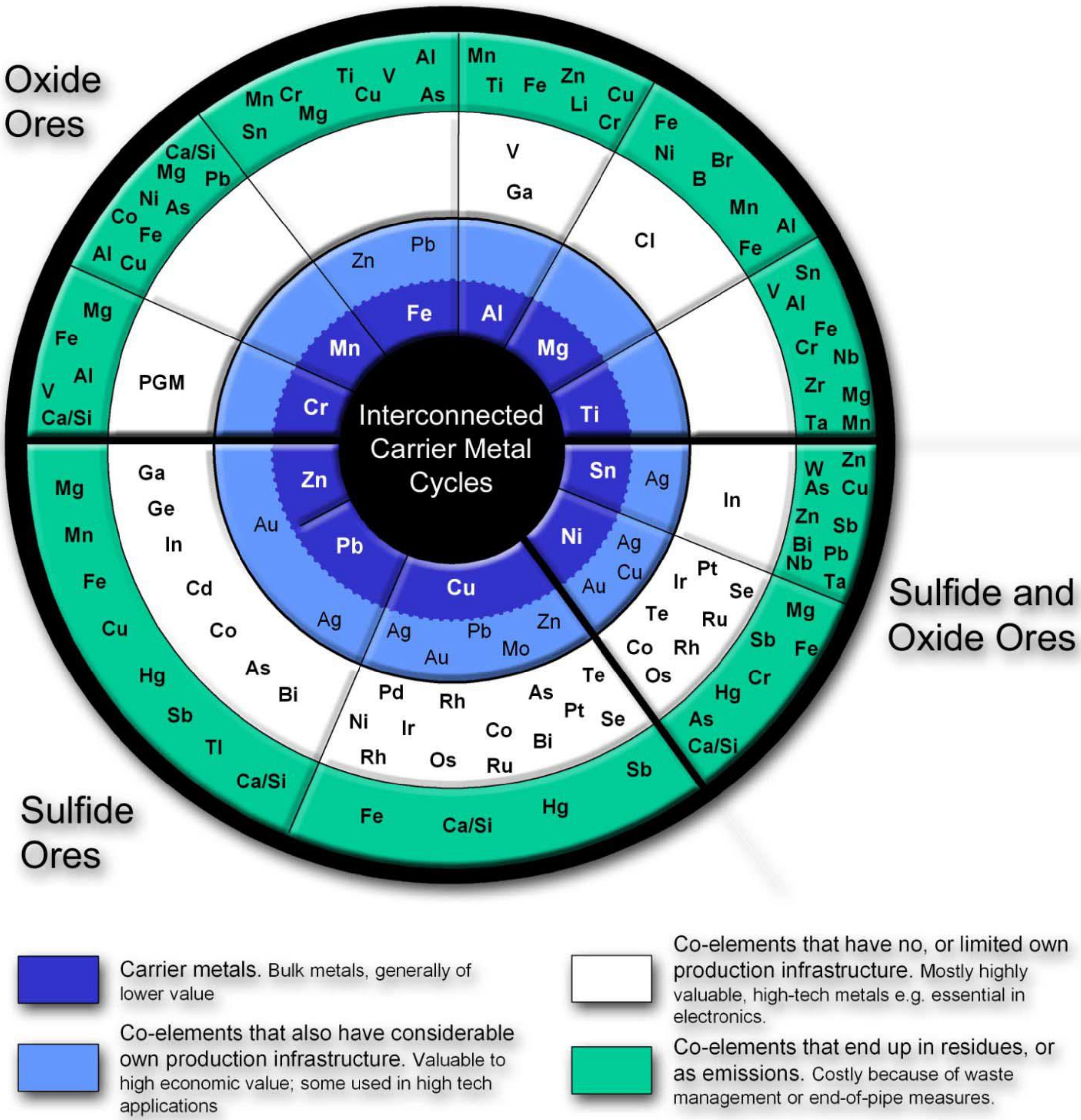


Substitution

Production concentration of critical raw mineral materials



Substitution



Substitution

The main driving emerging technologies for the critical raw materials are the following:

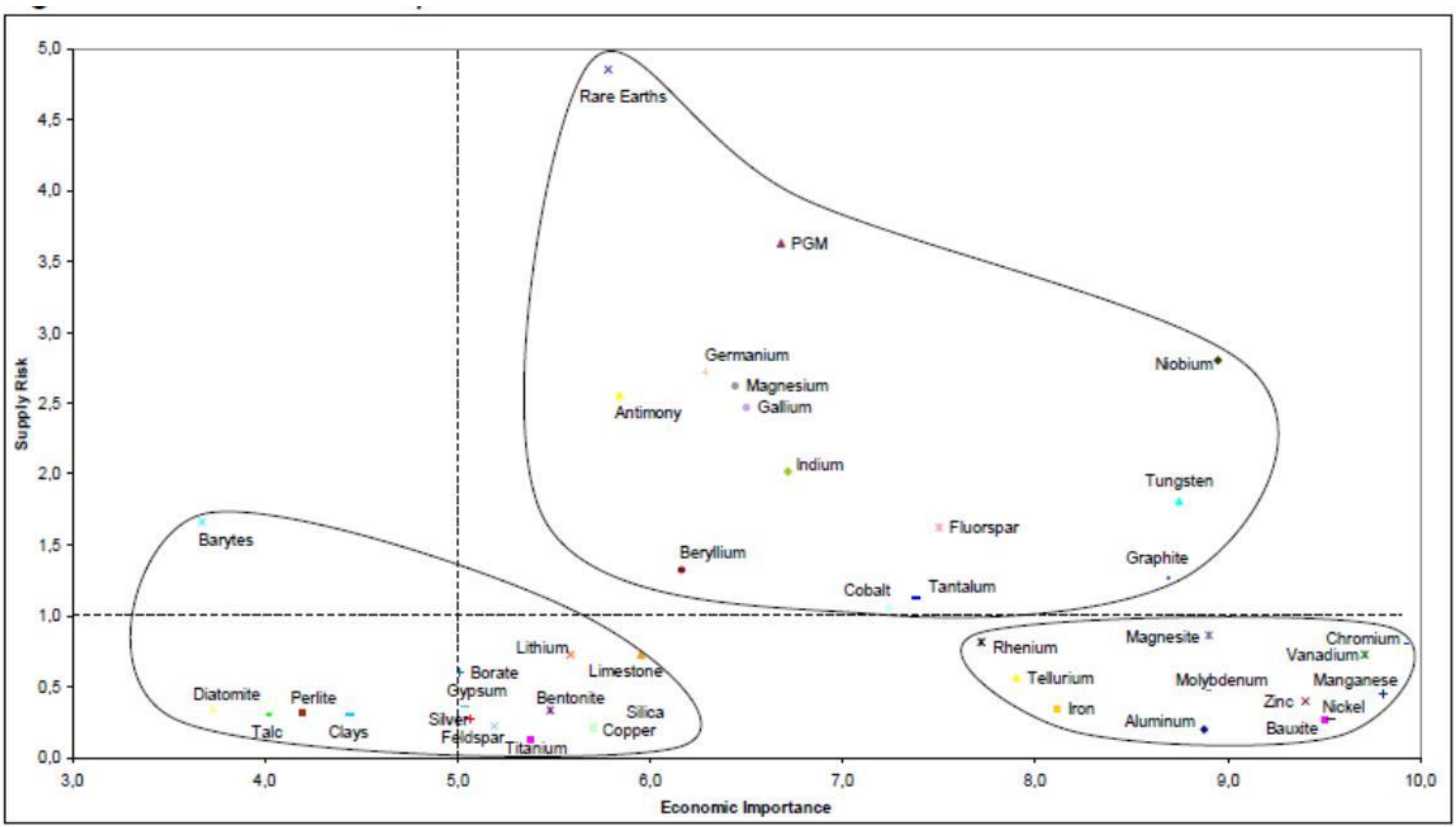
Raw material	Emerging technologies (selected)
Antimony	ATO, micro capacitors
Cobalt	Lithium-ion batteries, synthetic fuels
Gallium	Thin layer photovoltaics, IC, WLED
Germanium	Fibre optic cable, IR optical technologies
Indium	Displays, thin layer photovoltaics
Platinum (PGM)	Fuel cells, catalysts
Palladium (PGM)	Catalysts, seawater desalination
Niobium	Micro capacitors, ferroalloys
Neodymium (rare earth)	Permanent magnets, laser technology
Tantalum	Micro capacitors, medical technology

Substitution

Table 4: Global demand of the emerging technologies analysed for raw materials in 2006 and 2030 related to today's total world production of the specific raw material (Updated by BGR April 2010)

Raw material	**Production 2006** [1] **(t)**	**ETRD 2006 (t)**	**ETRD 2030 (t)**	**Indicator 2006**	**Indicator 2030**
Gallium	152 [6]	28	603	0,18 [1]	**3,97** [1]
Indium	581	234	1.911	0,40 [1]	**3,29** [1]
Germanium	100	28	220	0,28 [1]	**2,20** [1]
Neodymium[7]	16.800	4.000	27.900	0,23 [1]	**1,66** [1]
Platinum[8]	255	very small	345	0	1,35 [1]
Tantalum	1.384	551	1.410	0,40 [1]	**1,02** [1]
Silver	19.051	5.342	15.823	0,28 [1]	0,83 [1]
Cobalt	62.279	12.820	26.860	0,21 [1]	0,43 [1]
Palladium[8]	267	23	77	0,09 [1]	0,29 [1]
Titanium	7.211.000 [3]	15.397	58.148	0,08	0,29
Copper	15.093.000	1.410.000	3.696.070	0,09	0,24
Ruthenium[8]	29 [4]	0	1	0	0,03
Niobium	44.531	288	1.410	0,01	0,03
Antimony	172.223	28	71	<0,01	<0,01
Chromium	19.825.713 [2]	11.250	41.900	<0,01	<0,01

Substitution



Substitution

List of critical raw materials at EU level (in alphabetical order):

Antimony	Indium
Beryllium	Magnesium
Cobalt	Niobium
Fluorspar	PGMs (Platinum Group Metals)[1]
Gallium	Rare earths[2]
Germanium	Tantalum
Graphite	Tungsten

Objective

- Substitutes for 3 applications (minimum) where critical/scarce elements (CRMs) are used/crucial.

Several strategies are possible:

(1) **Reduction** – less amount while keeping the functionality;

(2) **Alternative material;**

(3) **Alternative system** – substitution of one/several components in the same product;

(4) **Alternative product** – substitution of actual technology by novel product or service.

The choices and possible combinations must account with distinct alternatives: (i) increasing CRM production; (ii) recycling of such element(s); (iii) substitution/reduction of its use.

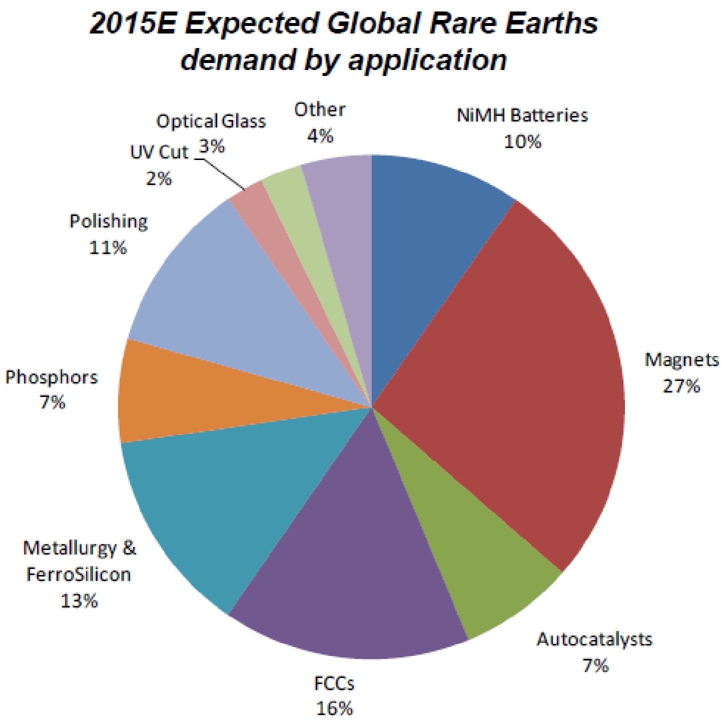
Whenever possible we should use renewable resources (e.g. bio-based).

Critical/target applications

- Materials for **green energy technologies** (heavy REE in magnets; CRM in batteries/catalysts/photovoltaic materials);
- Materials for **electronic devices** (indium in transparent conductive layers; CRM in light sources);
- Materials under **extreme conditions** (CRM in heat resistant super alloys/hard materials: Re, W in superalloys);
- Applications using materials in **large quantities** (CRM in super alloys and steels alloyed with scarce elements, TiO_2, natural rubber in tires).

Substitution

Challenges



- Substitution of rare earth elements in permanent magnets and their applications:
  - › permanent magnets based on ferrite and Mn/Al alloys and neodymium-iron-boron;
- Substitution of rare earth elements in energy efficient lighting systems:
  - › use of transition metal ions such as Mn^{2+}, or reducing the phosphor rare earth element content;
- Substitution of indium in transparent conductive layers:
  - › search for alternatives to ITO (e.g. ZnO);
- Substitution of W-Co in hard/cutting tools (Si_3N_4; SiC …)

Substitution

CALL – GROWING A LOW CARBON, RESOURCE EFFICIENT ECONOMY WITH A SUSTAINABLE SUPPLY OF RAW MATERIALS				
ENSURING THE SUSTAINABLE SUPPLY OF NON-ENERGY AND NON-AGRICULTURAL RAW MATERIALS	**2014**	**2015**	**EU contribution/ project**	**Type project**
New solutions for **sustainable production** of raw materials a) new exploration technologies and geomodels (2015) b) mining of small deposits and alternative mining (2014) c) deep mining on continent and in sea-bed (2015) d) flexible processing technologies (2014) e) new metallurgical systems (2015)	 X X 	 X X X	2-8 M€	RIA one-stage
Innovative and sustainable solutions leading to **substitution of raw materials** a) materials for electronic devices (2014) b) materials under extreme conditions (2015)	 X 	 X	2-8 M€	RIA one-stage
Coordinating and supporting raw materials research and innovation a) Mineral deposits of public importance (2014) b) Raw materials intelligence capacity (2015) c) Innovation friendly minerals policy framework (2015) d) Raw materials research and innovation coordination (2015) e) Dialogues and co-operation on raw materials with technologically advanced countries (2014) f) Dialogues and co-operation with raw materials producing countries (2015)	 X X 	 X X X X		CSA