Eleonora Polo, CNR-ISOF

Quando finiranno i metalli? Scenari e prospettive.

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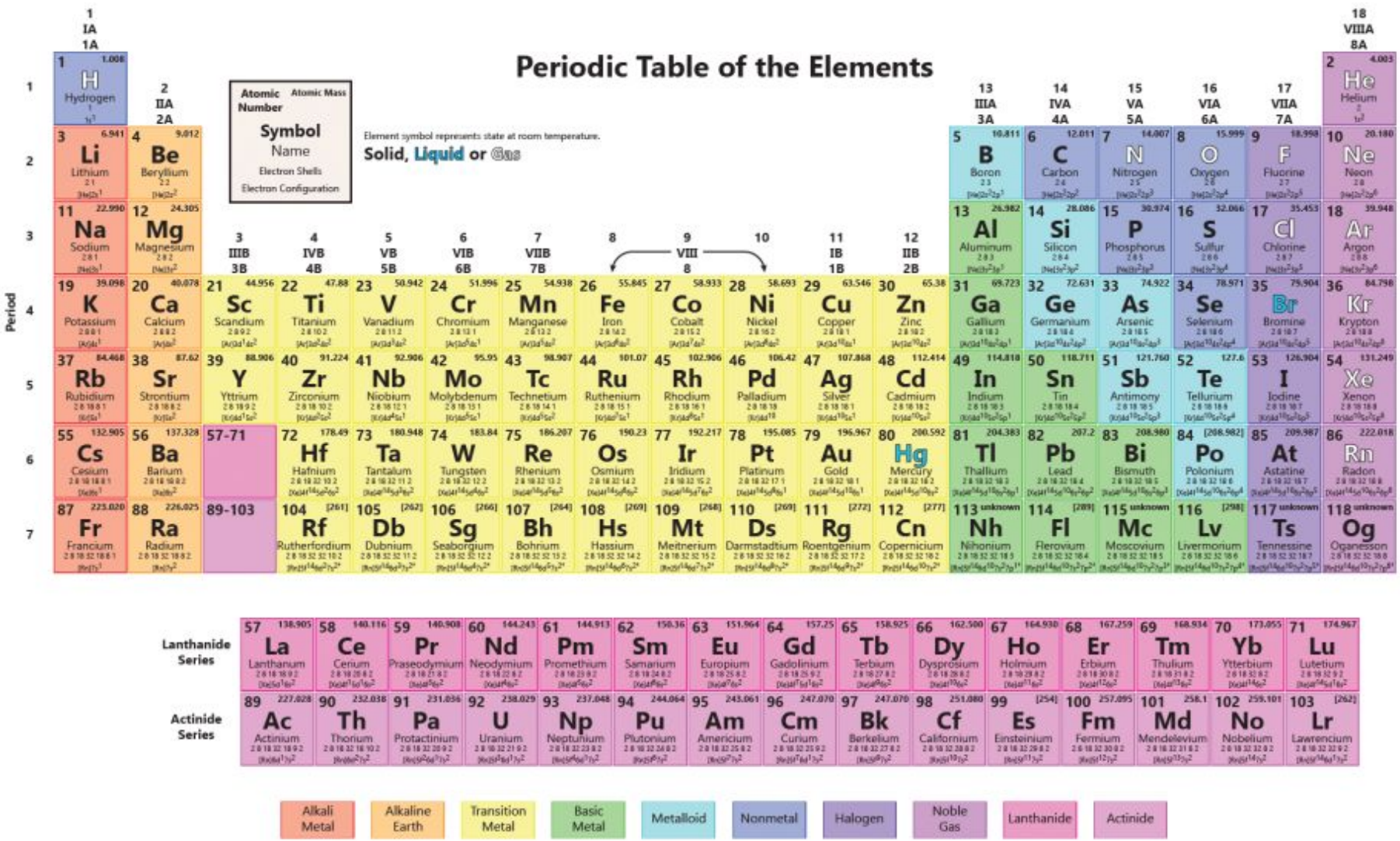

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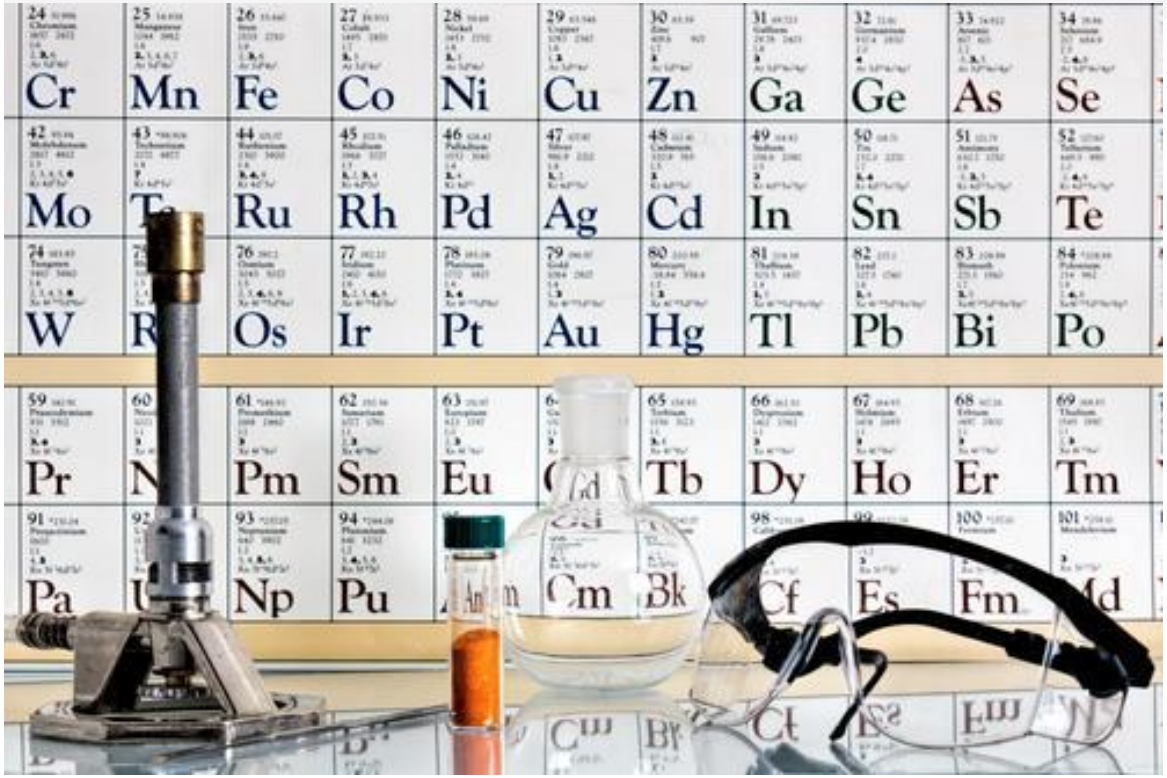
THE UNITED NATIONS PROCLAIMS THE INTERNATIONAL YEAR OF THE PERIODIC TABLE OF CHEMICAL ELEMENTS

28 December 2017



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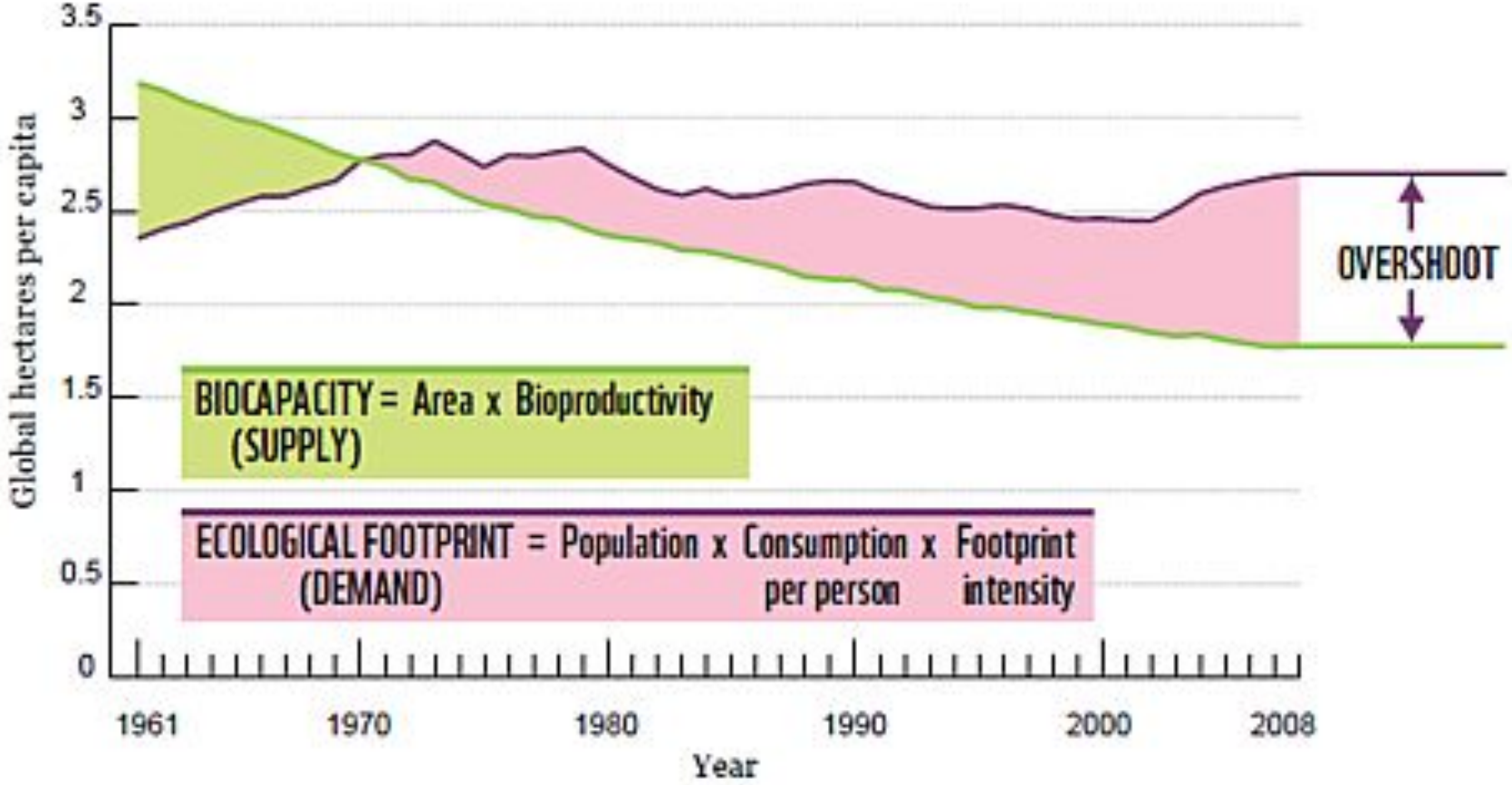
EARTH OVERSHOOT DAY:
AUG. 1, 2018

EARTH OVERSHOOT DAY



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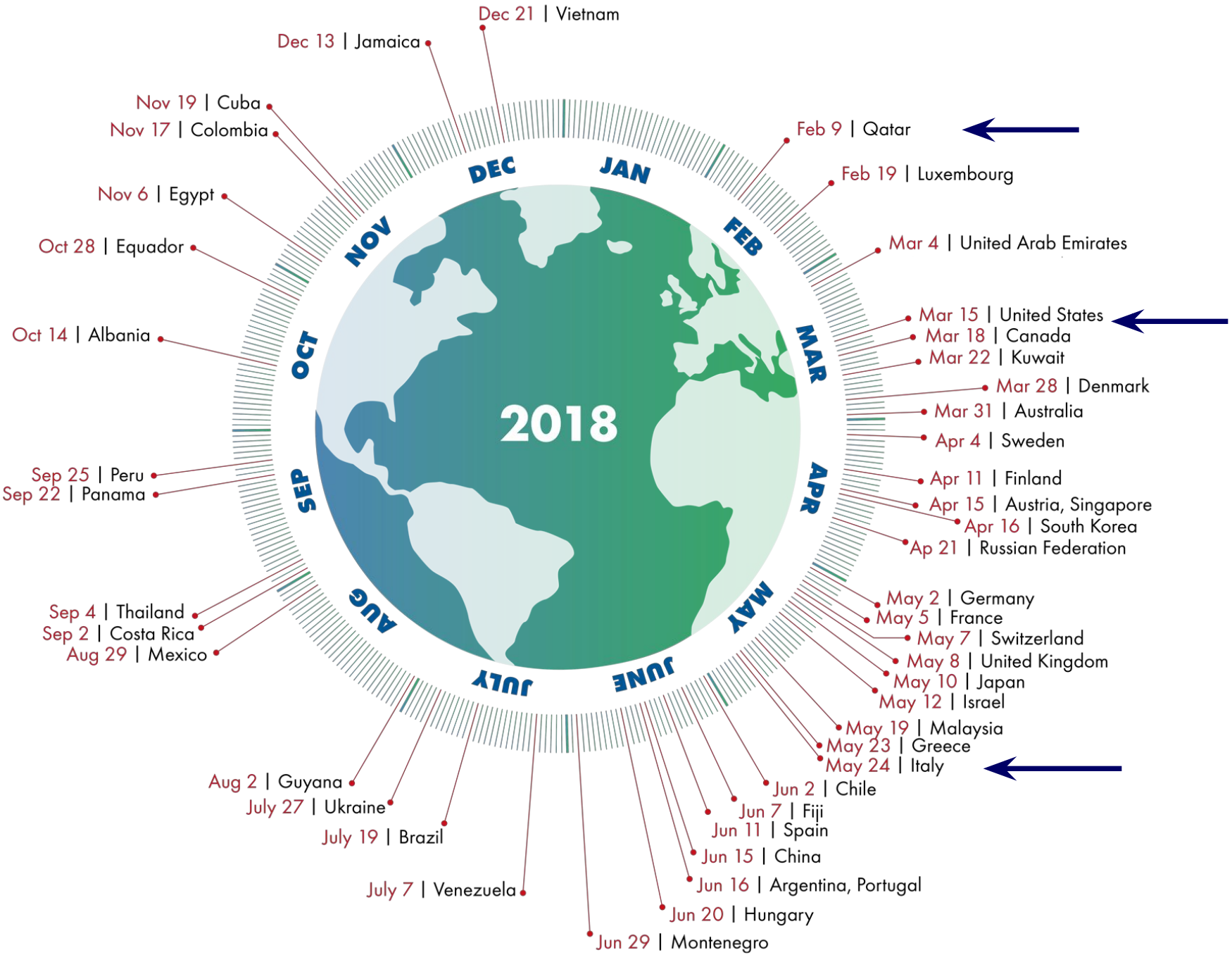

2018
DEC
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
Dec 21 | Vietnam
Dec 13 | Jamaica
Nov 19 | Cuba
Nov 17 | Colombia
Nov 6 | Egypt
Oct 28 | Equador
Oct 14 | Albania
Sep 25 | Peru
Sep 22 | Panama
Sep 4 | Thailand
Sep 2 | Costa Rica
Aug 29 | Mexico
Aug 2 | Guyana
July 27 | Ukraine
July 19 | Brazil
July 7 | Venezuela
Jun 29 | Montenegro
Jun 20 | Hungary
Jun 16 | Argentina, Portugal
Jun 15 | China
Jun 11 | Spain
Jun 7 | Fiji
Jun 2 | Chile
May 24 | Italy
May 23 | Greece
May 19 | Malaysia
May 12 | Israel
May 10 | Japan
May 8 | United Kingdom
May 7 | Switzerland
May 5 | France
May 2 | Germany
Ap 21 | Russian Federation
Apr 16 | South Korea
Apr 15 | Austria, Singapore
Apr 11 | Finland
Apr 4 | Sweden
Mar 31 | Australia
Mar 28 | Denmark
Mar 22 | Kuwait
Mar 18 | Canada
Mar 15 | United States
Mar 4 | United Arab Emirates
Feb 19 | Luxembourg
Feb 9 | Qatar

Se posticipassimo l'Overshoot Day di 4,5 giorni ogni anno, potremmo ritornare a utilizzare le risorse di un solo pianeta entro il 2050.

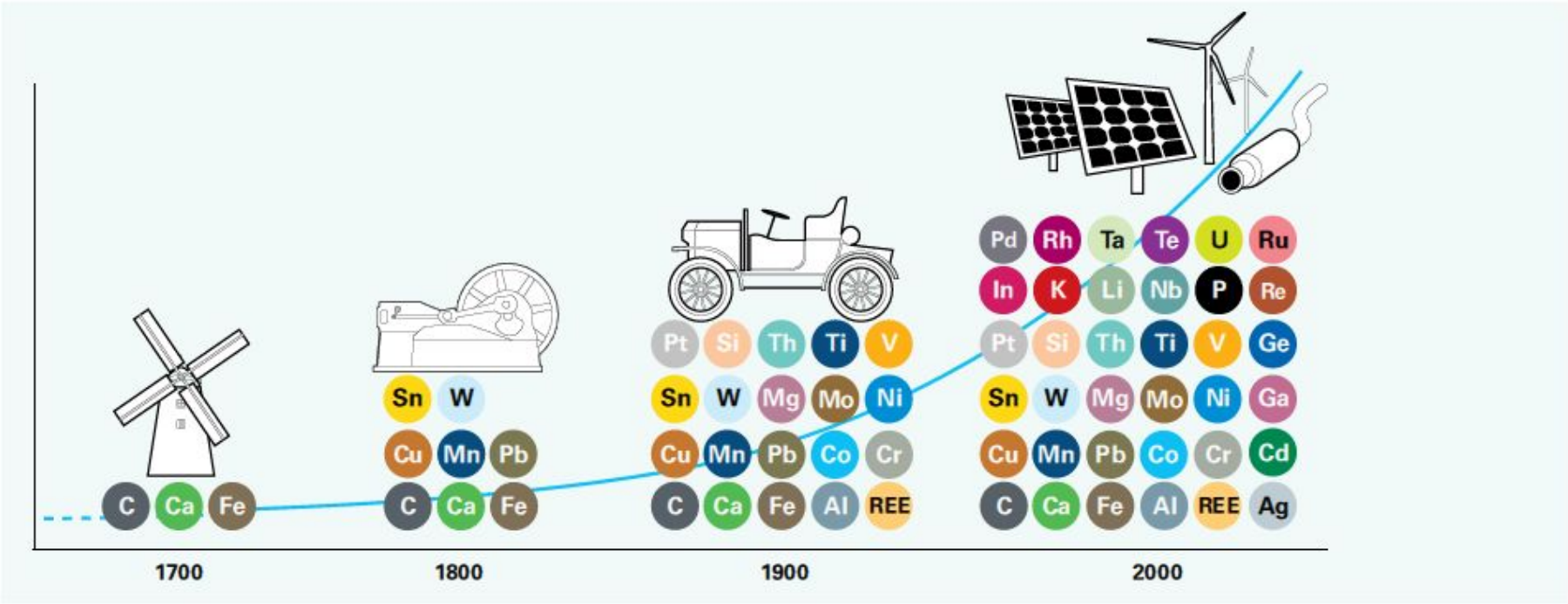
Come fare?

- Razionalizzare l'uso delle risorse, soprattutto quelle non rinnovabili (petrolio, metalli, gas, minerali non metalliferi, carbone) e ridurre gli sprechi
- Aggiustare quanto più possibile quello che si rompe
- Riciclare correttamente i rifiuti

Ogni abitante degli Stati Uniti nel corso della sua vita avrà bisogno di 14460 tonnellate di minerali, metalli e carburanti

Sale	124 q
Fosfati	69 q
Argille	53 q
Rame	4 q
Minerale di ferro	104 q
Zinco	2 q
Bauxite	17 q
carbone	1615 q
Piombo	4 q
Pietra, sabbia, ghiaia	6441 q
altri minerali e metalli	222 q
Petrolio	273992 l
Gas naturale	197368 m^3
Oro	58 g

Ogni progresso tecnologico ha sempre richiesto maggiori quantità/qualità di metalli



Elements widely used in energy pathways

N.B. Position on the time axis is indicative only

Chi sta sparecchiando la tavola periodica?

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.99840	10 Ne 20.1797
11 Na 22.98977	12 Mg 24.3050											13 Al 26.98153	14 Si 28.0855	15 P 39.97376	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.95591	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.93804	26 Fe 55.845	27 Co 58.93320	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.9085	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.9055	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.760	51 Sb 121.760	52 Te 127.60	53 I 126.9044	54 Xe 131.29
55 Cs 132.9054	56 Ba 137.327	57 La * 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.9665	80 Hg 200.59	81 Tl 204.3833	82 Pb 270.2	83 Bi 208.9804	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.025	89 Ac ‡ (227)	104 Rf (257)	105 Db (260)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (271)	111 Rg (272)	112 Cn (285)	113 Nh (284)	114 Fl (289)	115 Mc (288)	116 Lv (292)	117 Ts	118 Og

Lantanidi *	58 Ce 140.9077	59 Pr 144.24	60 Nd (145)	61 Pm 150.36	62 Sm 151.964	63 Eu 157.25	64 Gd 158.9253	65 Tb 158.9253	66 Dy 162.50	67 Ho 164.9303	68 Er 167.26	69 Tm 168.9342	70 Yb 173.04	71 Lu 174.967
Attinidi ‡	90 Th 232.0381	91 Pa 231.0289	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

5-50 years
50-100 years
100-500 years

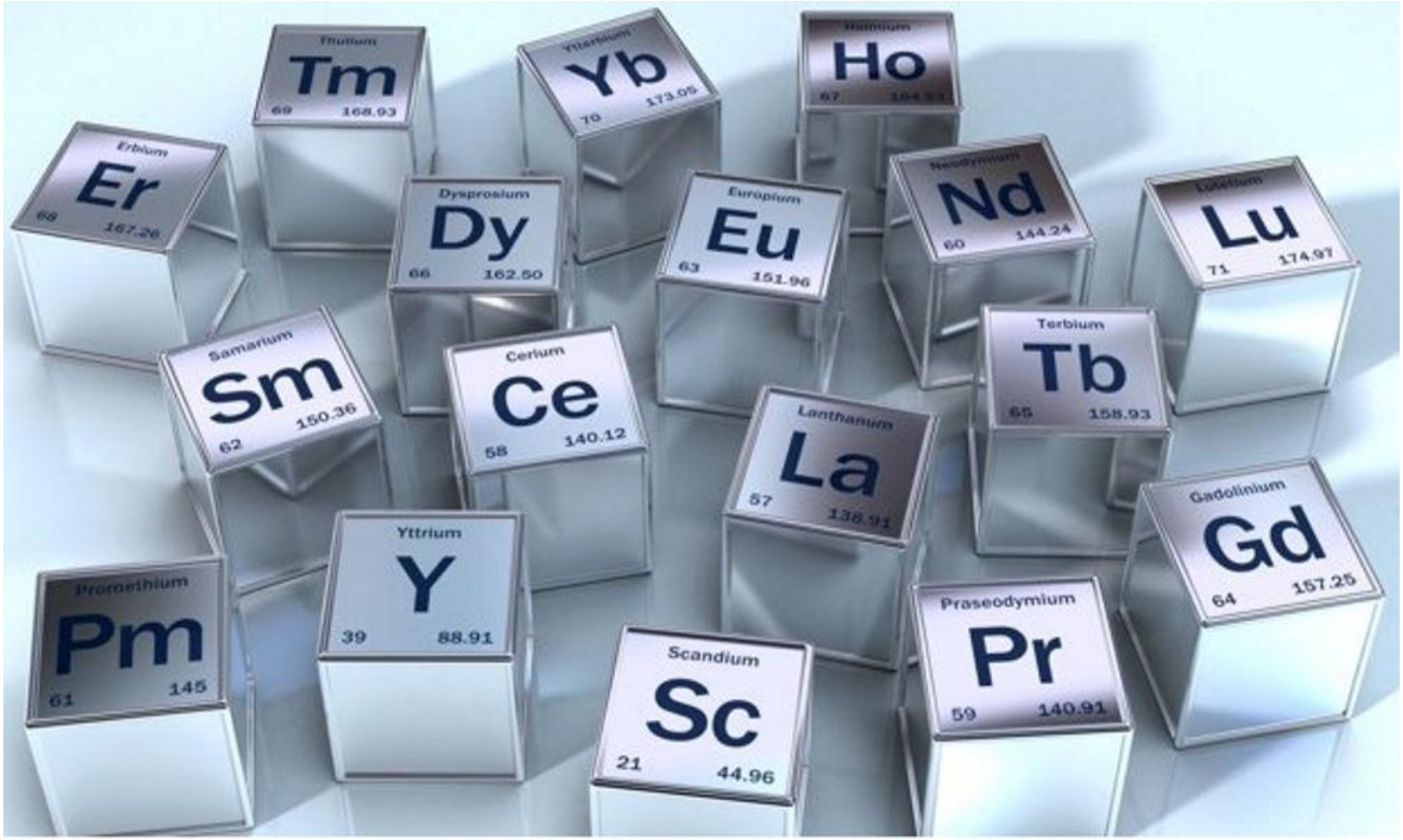
Anni che restano prima che si esauriscano le riserve (al ritmo attuale di estrazione)

Di cosa resteremo prima senza?

Le materie prime critiche per la Comunità Europea- terza ricognizione

2017 CRMs (26)			
Antimony	Gallium	Magnesium	Scandium
Baryte	Germanium	Natural graphite	Silicon metal
Beryllium	Hafnium	Natural Rubber	Tantalum
Bismuth	Helium	Niobium	Tungsten
Borate	HREEs	PGMs	Vanadium
Cobalt	Indium	Phosphate rock	
Fluorspar	LREEs	Phosphorus	

REE (Rare Earths Elements)



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Scenari e prospettive.

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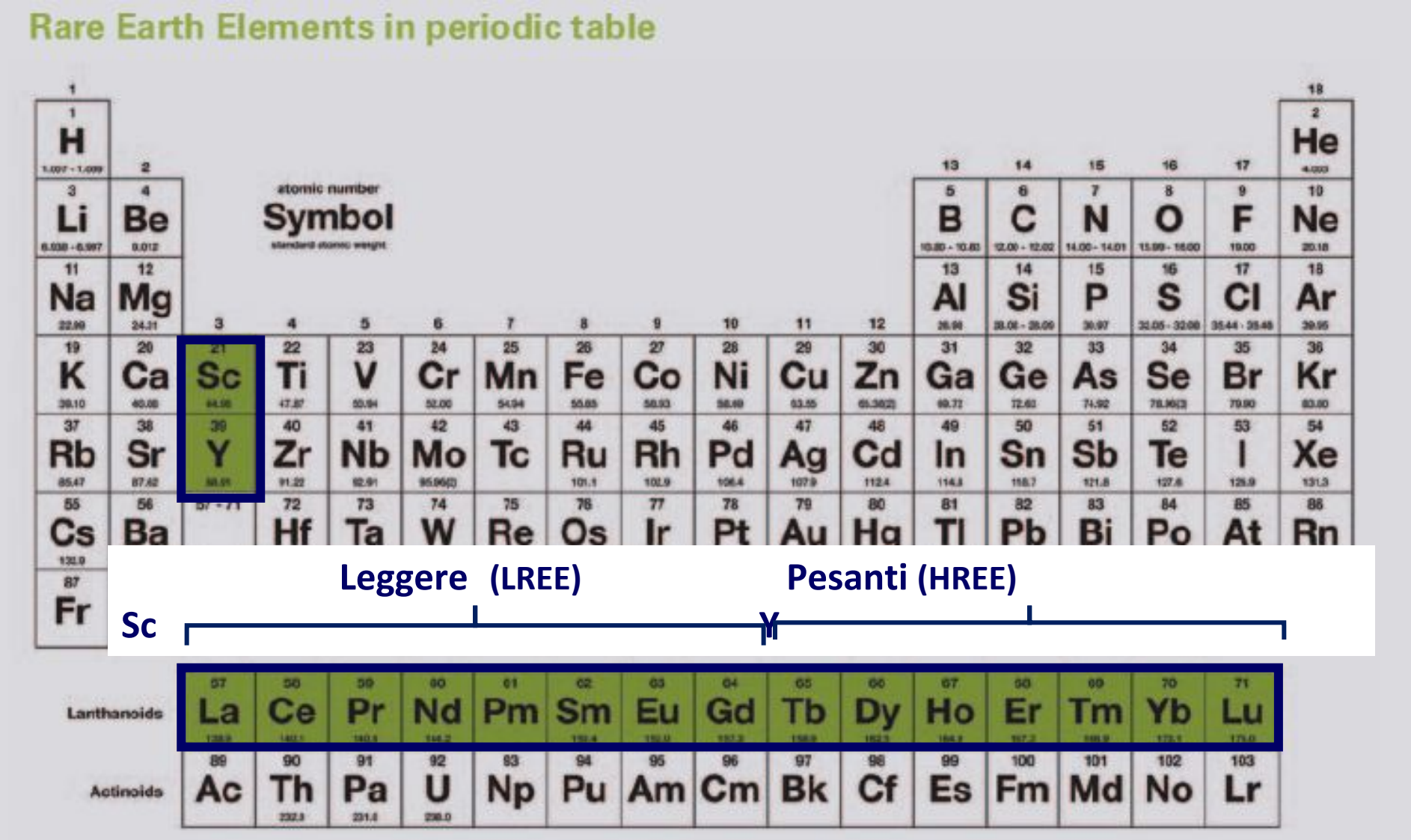
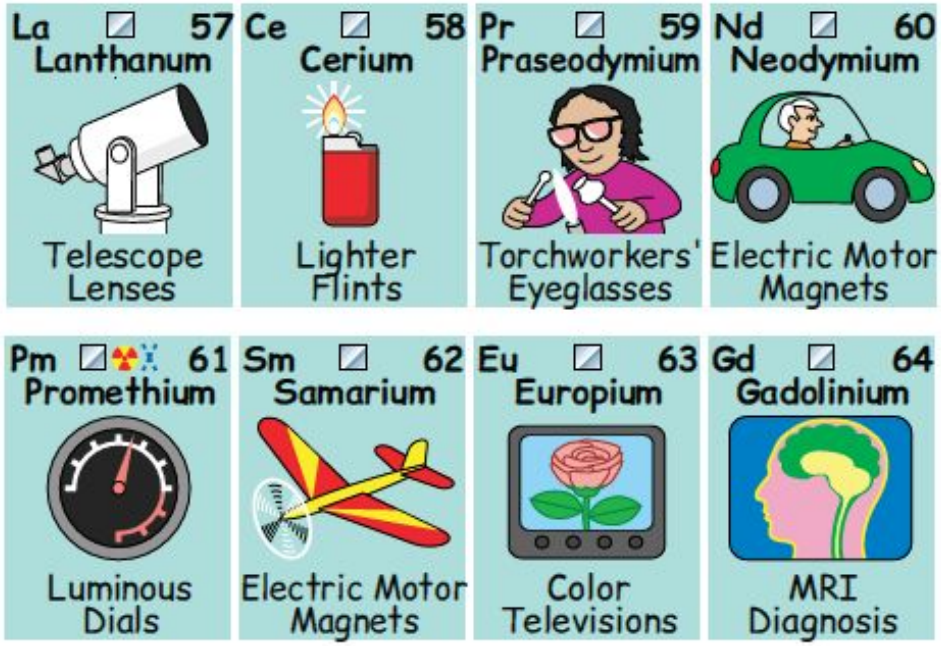
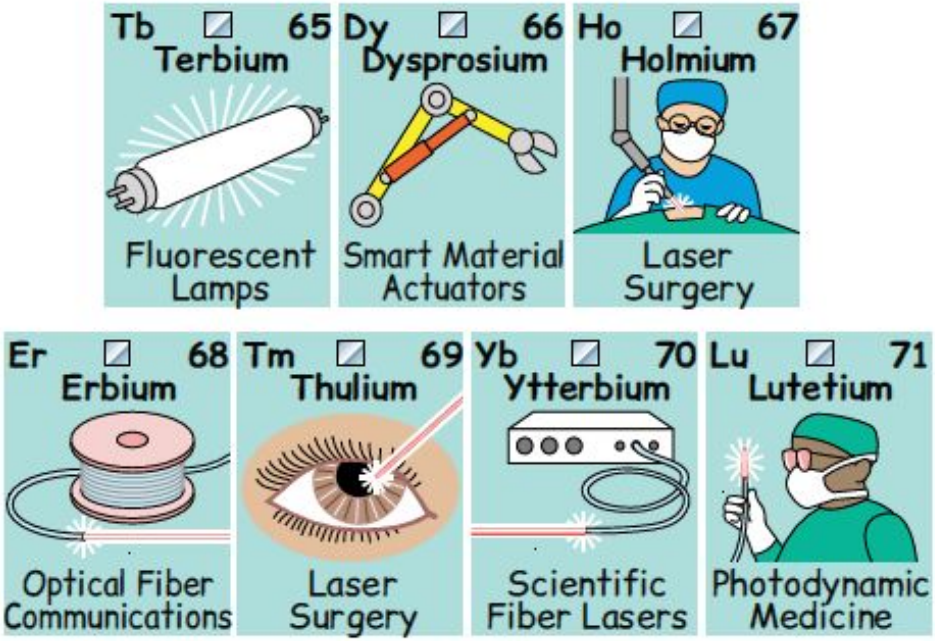
REE (Rare Earths Elements)



Terre Rare (REE)



Leggere (LREE)



Pesanti (HREE)

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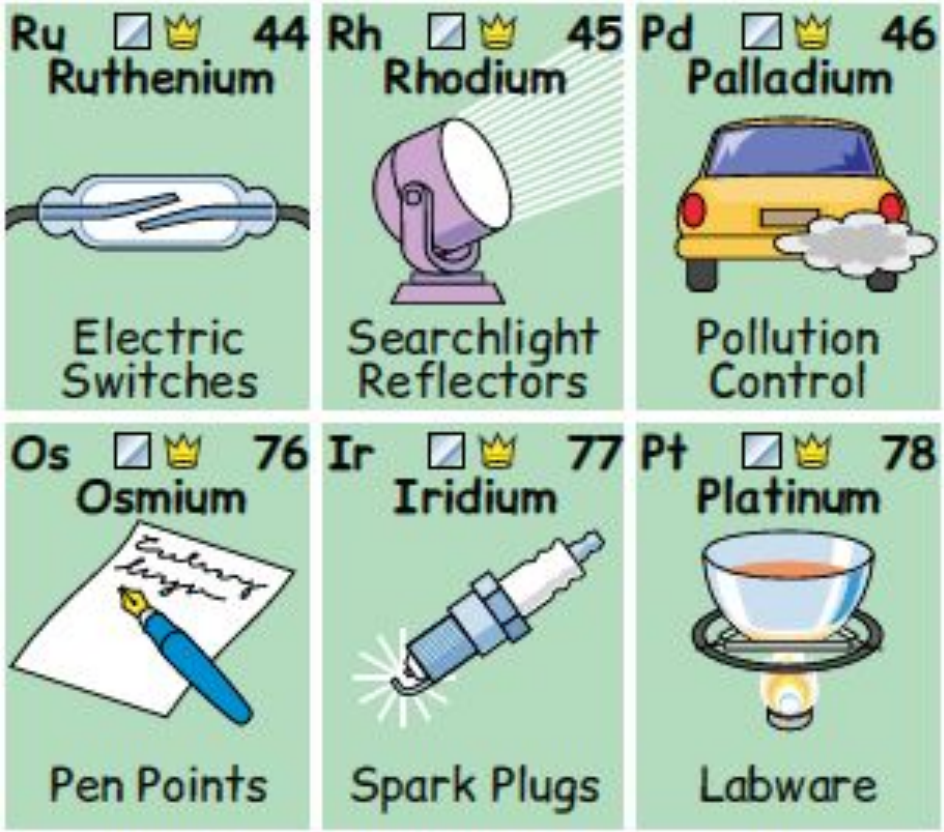
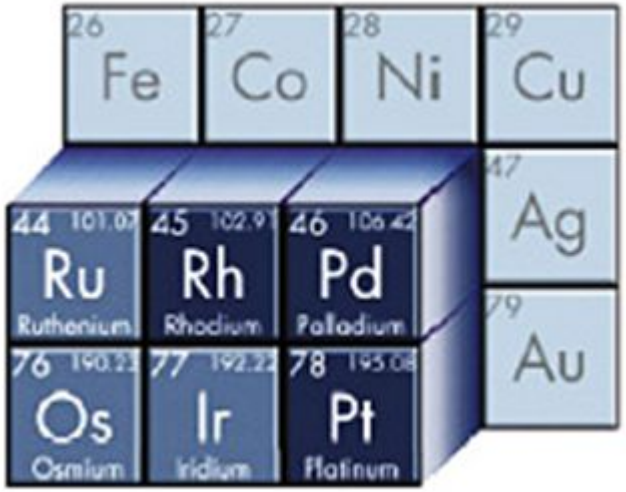
Metalli del gruppo del platino (PGMs, Platinum Group Metals)





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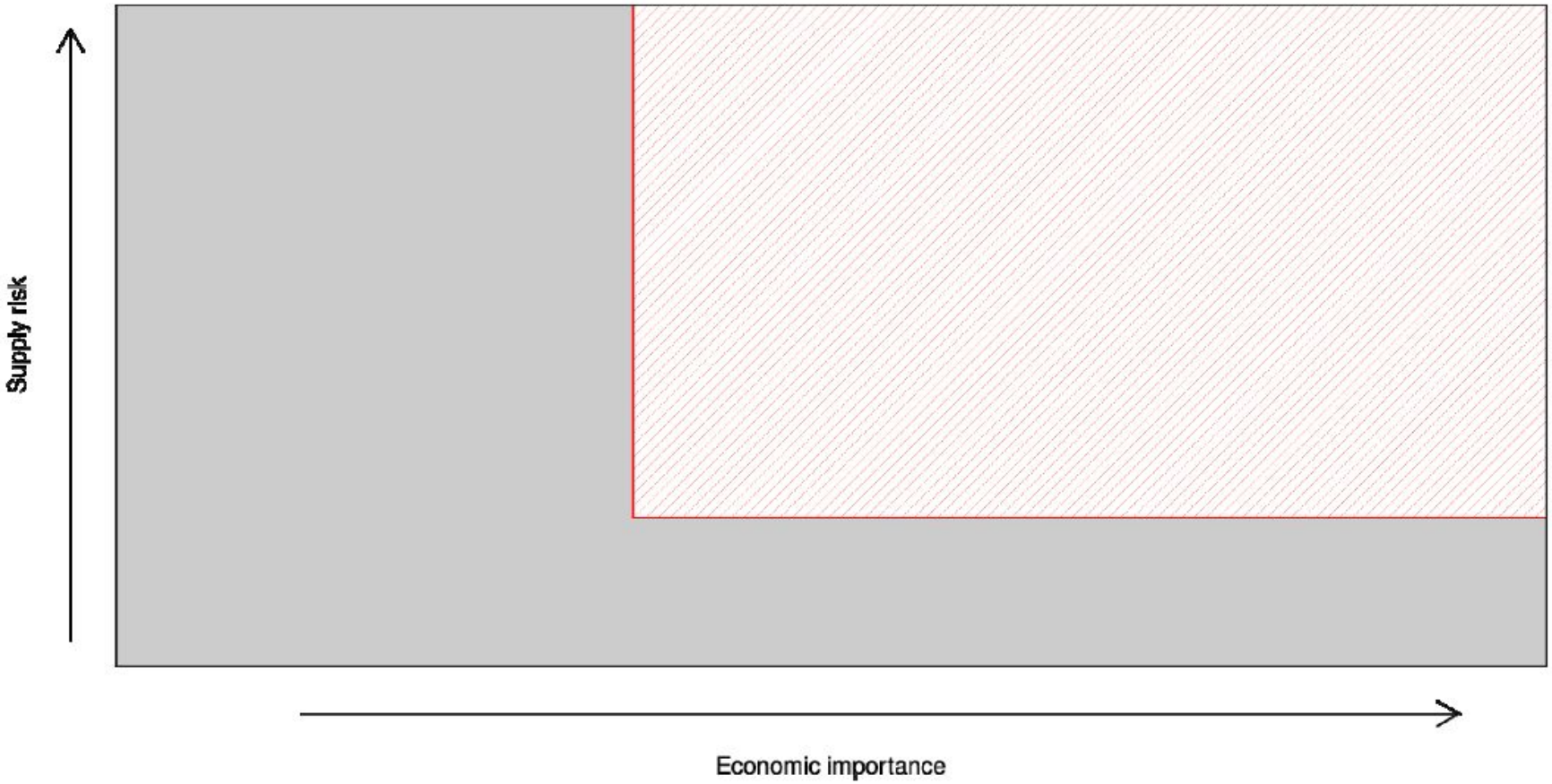
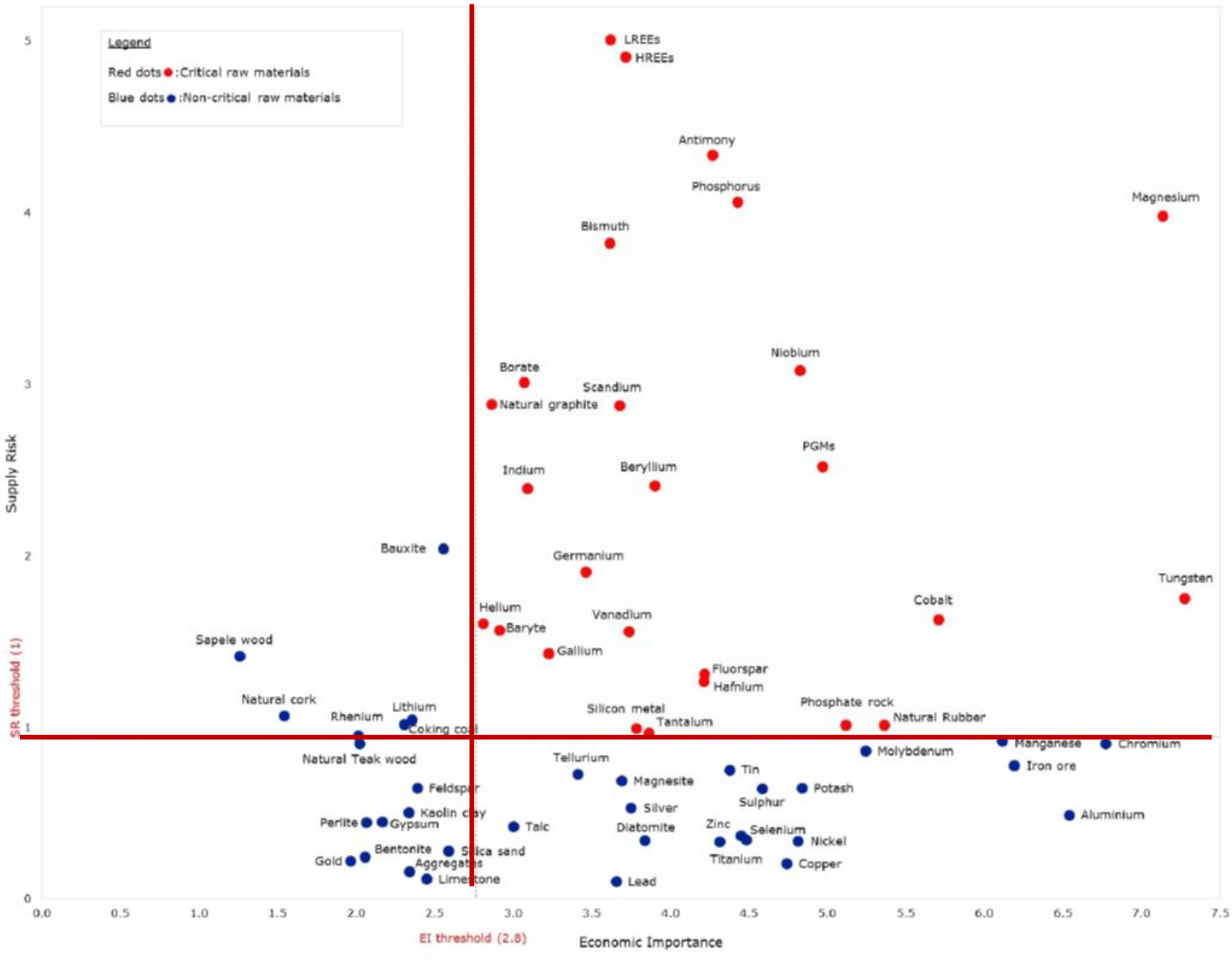
Criteri per valutare la criticità




Legend
Red dots ●:Critical raw materials
Blue dots ●:Non-critical raw materials
LREEs
HREEs
Antimony
Phosphorus
Magnesium
Bismuth
Niobium
Borate
Scandium
Natural graphite
PGMs
Indium
Beryllium
Bauxite
Germanium
Tungsten
Cobalt
Helium
Vanadium
Baryte
Sapele wood
Gallium
Fluorspar
Hafnium
Natural cork
Lithium
Rhenium
Silicon metal
Phosphate rock
Natural Rubber
Tantalum
Coking coal
Manganese
Chromium
Natural Teak wood
Molybdenum
Tellurium
Iron ore
Tin
Magnesite
Feldspar
Potash
Sulphur
Silver
Kaolin clay
Aluminium
Perlite
Gypsum
Talc
Diatomite
Zinc
Selenium
Nickel
Bentonite
Silica sand
Titanium
Gold
Aggregates
Copper
Limestone
Lead
Supply Risk
SR threshold (1)
EI threshold (2.8)
Economic Importance
0
1
2
3
4
5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5

Materie prime critiche per la UE (2017)

Grafite naturale

Fosforo, Rocce fosfatiche

Fluorite

Silicio metallico

Borati

Barite

5-50 years	
50-100 years	
100-500 years	

Anni che restano prima che si esauriscano le riserve (al ritmo attuale di estrazione)

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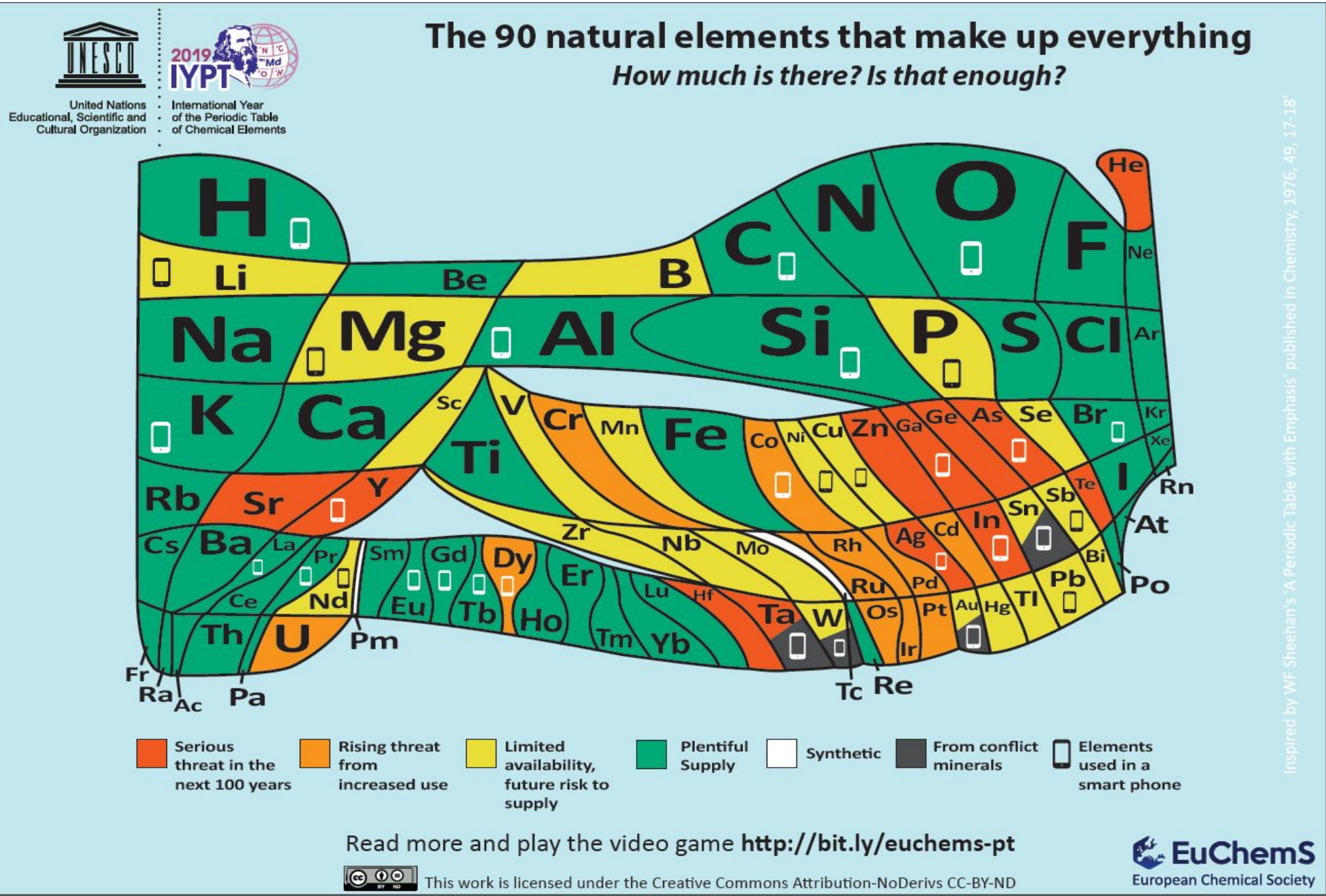
Che cosa rende un materiale critico?

1. Scarsa disponibilità sulla crosta terrestre



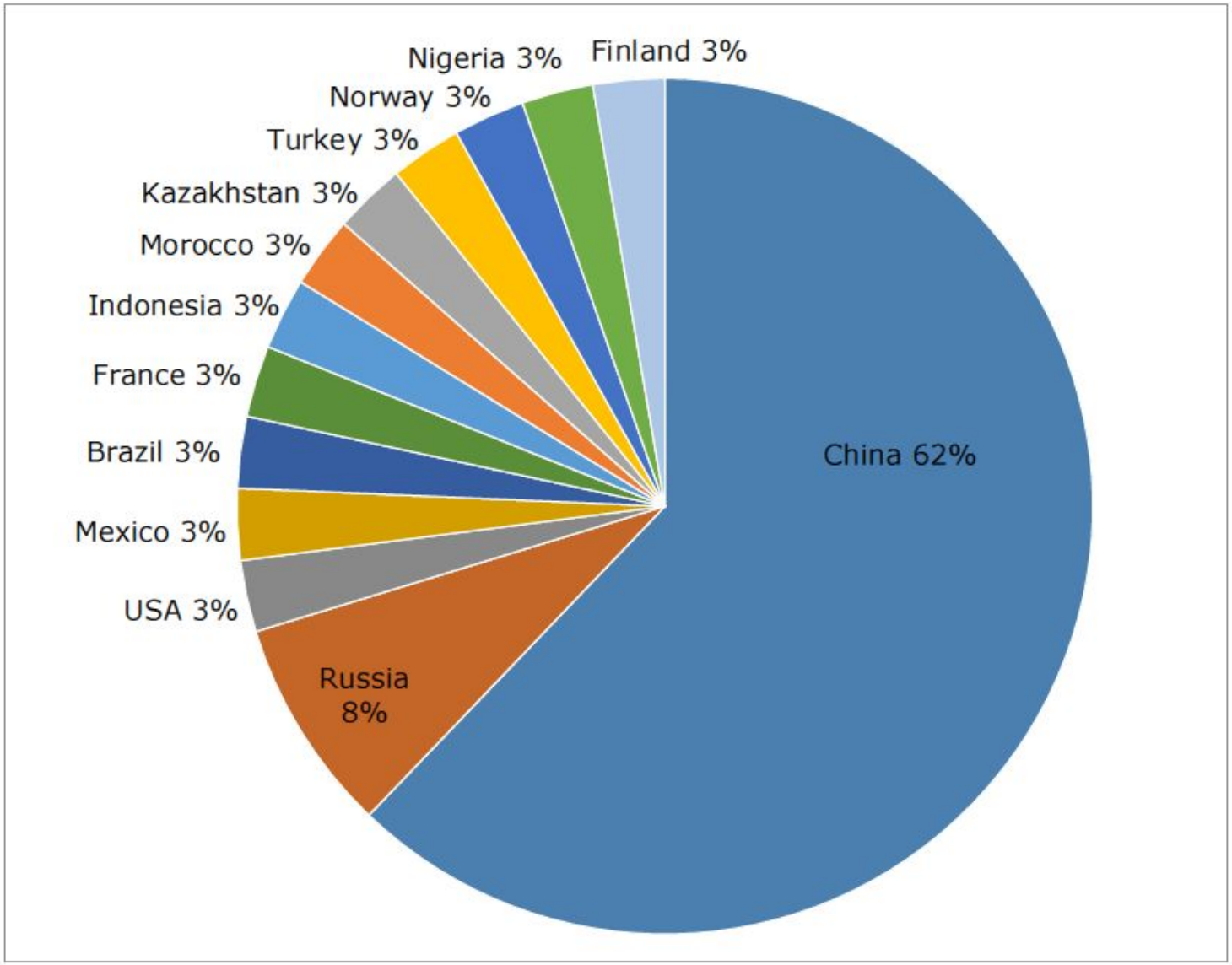
Abbondanza di alcuni elementi chimici sulla crosta terrestre (ppm)

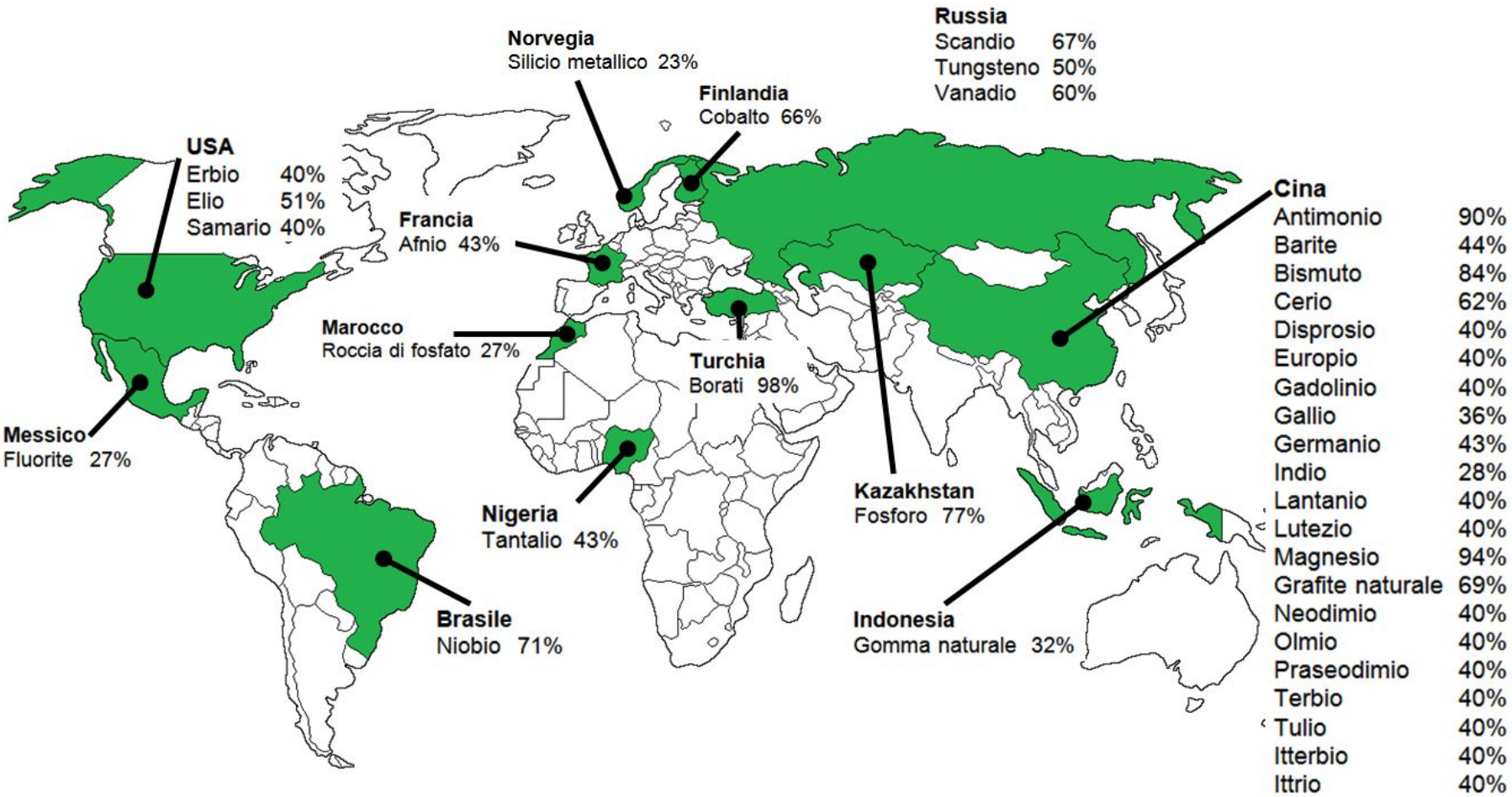
Alluminio	84.149	Niobio	8
Ferro	52.157	Torio	5,6
Magnesio	28.104	Arsenico	2,5
Sodio	22.774	Stagno	1,7
Titanio	4.136	Uranio	1,3
Manganese	774	Tungsteno	1
Fosforo	567	Iodio	0,71
Bario	456	Tantalo	0,7
Zolfo	404	Lutezio	0,3
Stronzio	320	Antimonio	0,2
Cromo	135	Cadmio	0,08
Zinco	72	Argento	0,055
Rame	27	Mercurio	0,03
Cobalto	26,6	Palladio	0,0015
Nickel	26,6	Platino	0,0015
Lantanio	20	Oro	0,0013
Litio	16	Rutenio	0,00057
Piombo	11	Iridio	0,000037

Fonte: rielaborazione dati British Geological Survey

2. I giacimenti sono localizzati in uno o pochi Paesi

Figure D: Main EU suppliers of CRMs (based on number of CRMs supplied out of 37), average from 2010-2014





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Scenari e prospettive.

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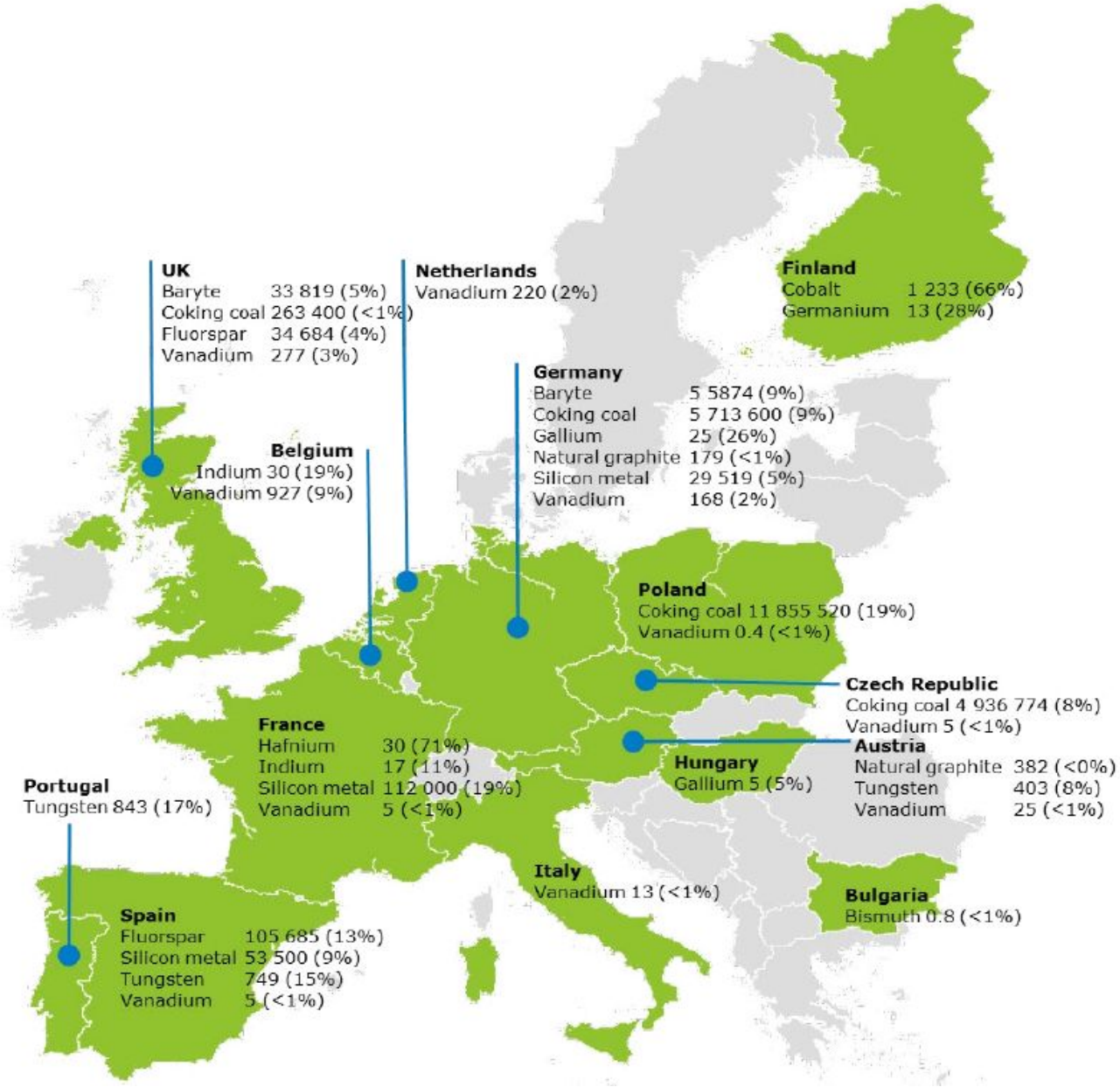
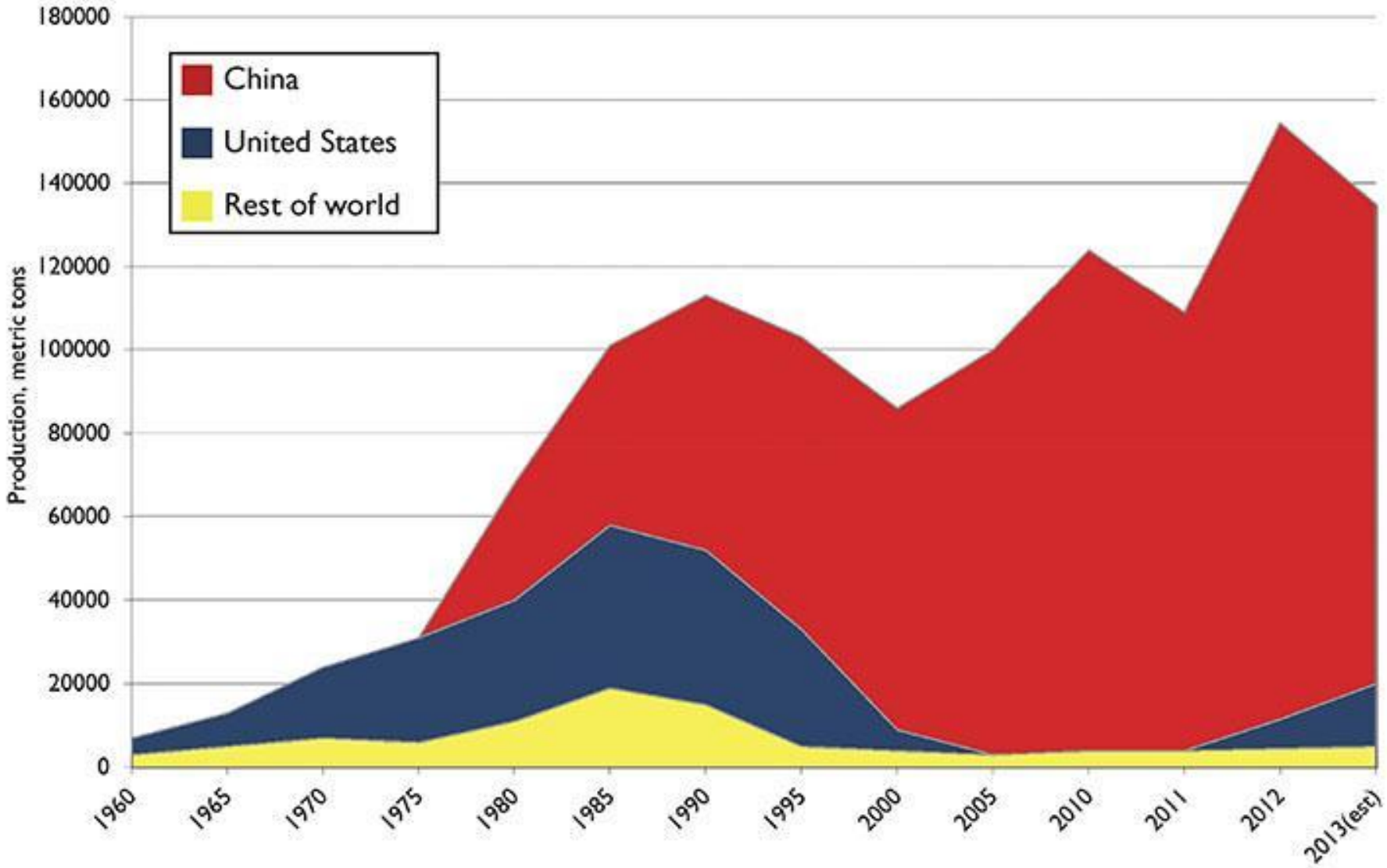
EU production of primary CRMs in tonnes (and share of supply to EU), average from 2010-2014



La crisi delle terre rare

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation



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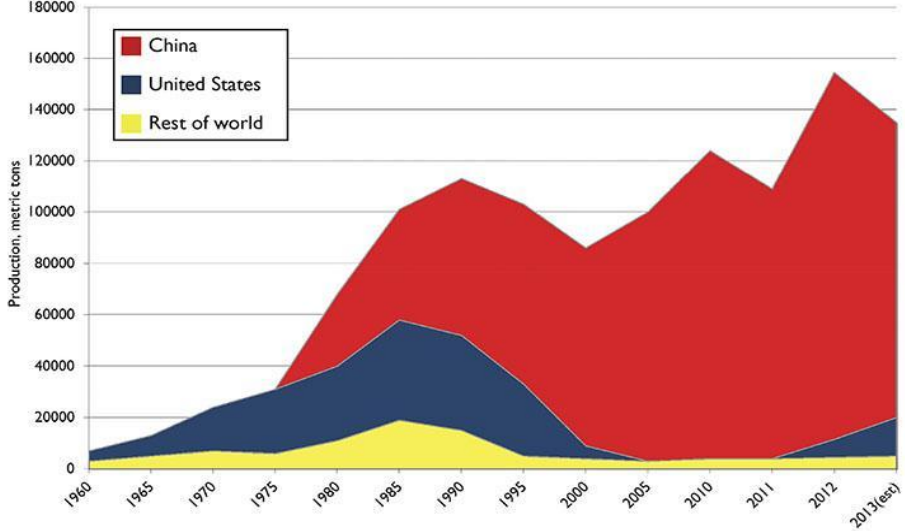
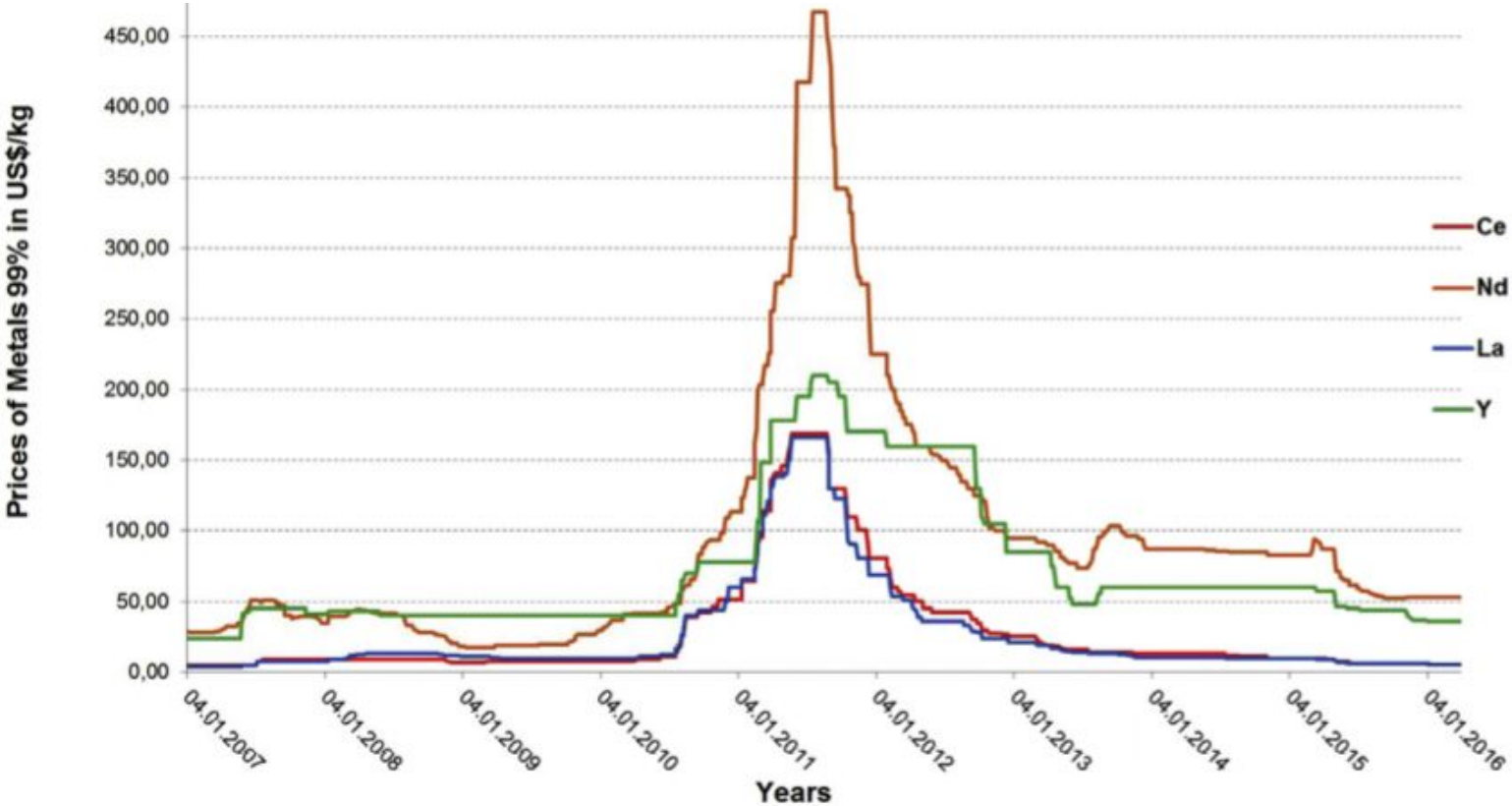




Metal prices development during the last 10 years for selected REE (Metal-pages, 2016).

As Rare Earth Fell, So Did Molycorp
Mining company fate tied to neodymium prices
China Neodymium Metal Market Price Shanghai (R1)
Molycorp Inc (L1)
20
15
10
5
0.043
0.7M
0.65M
0.6M
0.55M
0.5M
0.45M
0.4M
0.372M
0.3M
2012
2013
2014
2015
2016
2017
Bloomberg

3. Il metodo di estrazione inquina ed è pericoloso per i lavoratori

acidi da una miniera di rame

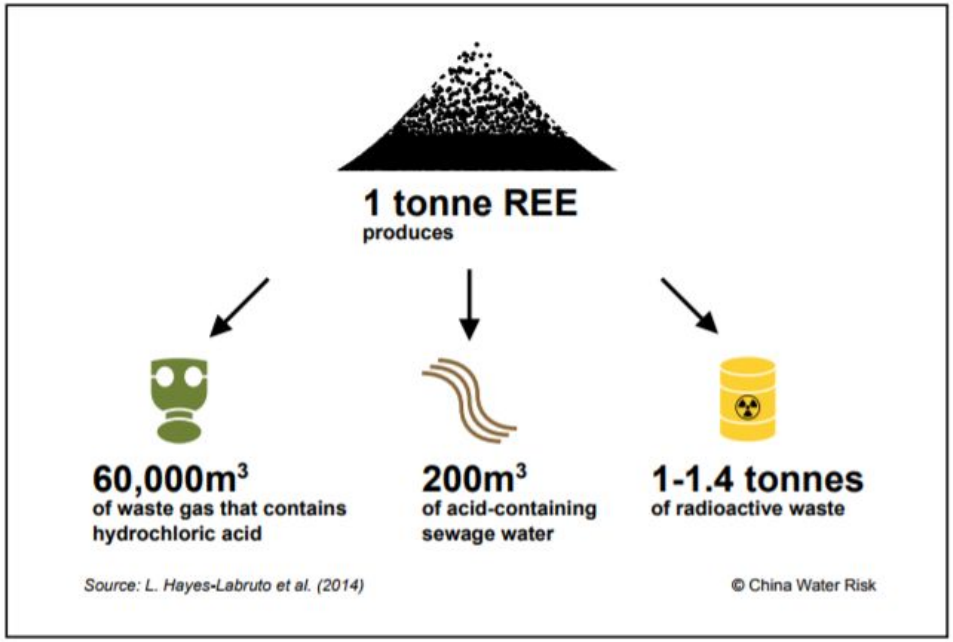
Argentina, la fuoriuscita di cianuro da una miniera inquina cinque fiumi

pesci morti a causa del cianuro

città mineraria di Norilsk (Russia)

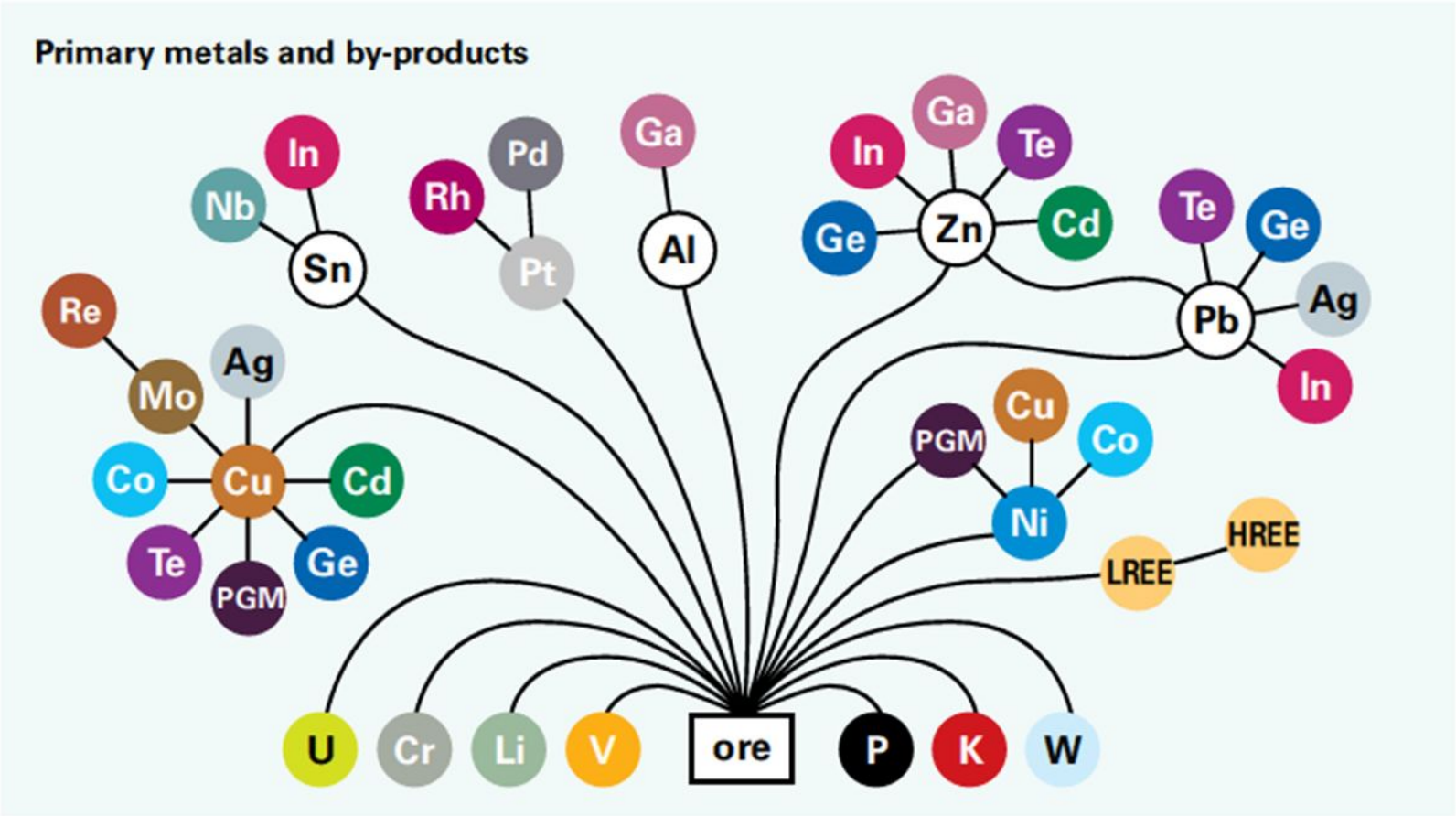
Produce il 35% Pd, 25% Pt, 20% Ni, 10% Co mondiale

Miniera di Mountain Pass negli Stati Uniti



Un film de Guillaume Pitron, Serge Turquier (2012)
https://www.youtube.com/watch?v=C9SDUmEZZxk

Gli "autostoppisti"



Schematic representation of the routes from ... elements described in this book, all each indicating

4. Non possono essere sostituiti in una o più applicazioni tecnologiche

H																	He
Li 41	Be 63											B 41	C	N	O	F	Ne
Na	Mg 94											Al 44	Si	P	S	Cl	Ar
K	Ca	Sc 65	Ti 63	V 63	Cr 76	Mn 96	Fe 57	Co 54	Ni 62	Cu 70	Zn 38	Ga 38	Ge 44	As 38	Se 47	Br	Kr
Rb	Sr 78	Y 95	Zr 66	Nb 42	Mo 70	Tc	Ru 63	Rh 96	Pd 39	Ag 44	Cd 38	In 60	Sn 36	Sb 57	Te 38	I	Xe
Cs	Ba 63	*	Hf 38	Ta 41	W 53	Re 90	Os 38	Ir 69	Pt 66	Au 40	Hg 45	Tl 100	Pb 100	Bi 46	Po	At	Rn
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

* Lanthanides	La 75	Ce 60	Pr 41	Nd 41	Pm	Sm 38	Eu 100	Gd 63	Tb 63	Dy 100	Ho 63	Er 63	Tm 88	Yb 88	Lu 63
** Actinides	Ac	Th 35	Pa	U 63	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Substitute Performance

Excellent — Poor

0 10 20 30 40 50 60 70 80 90 100

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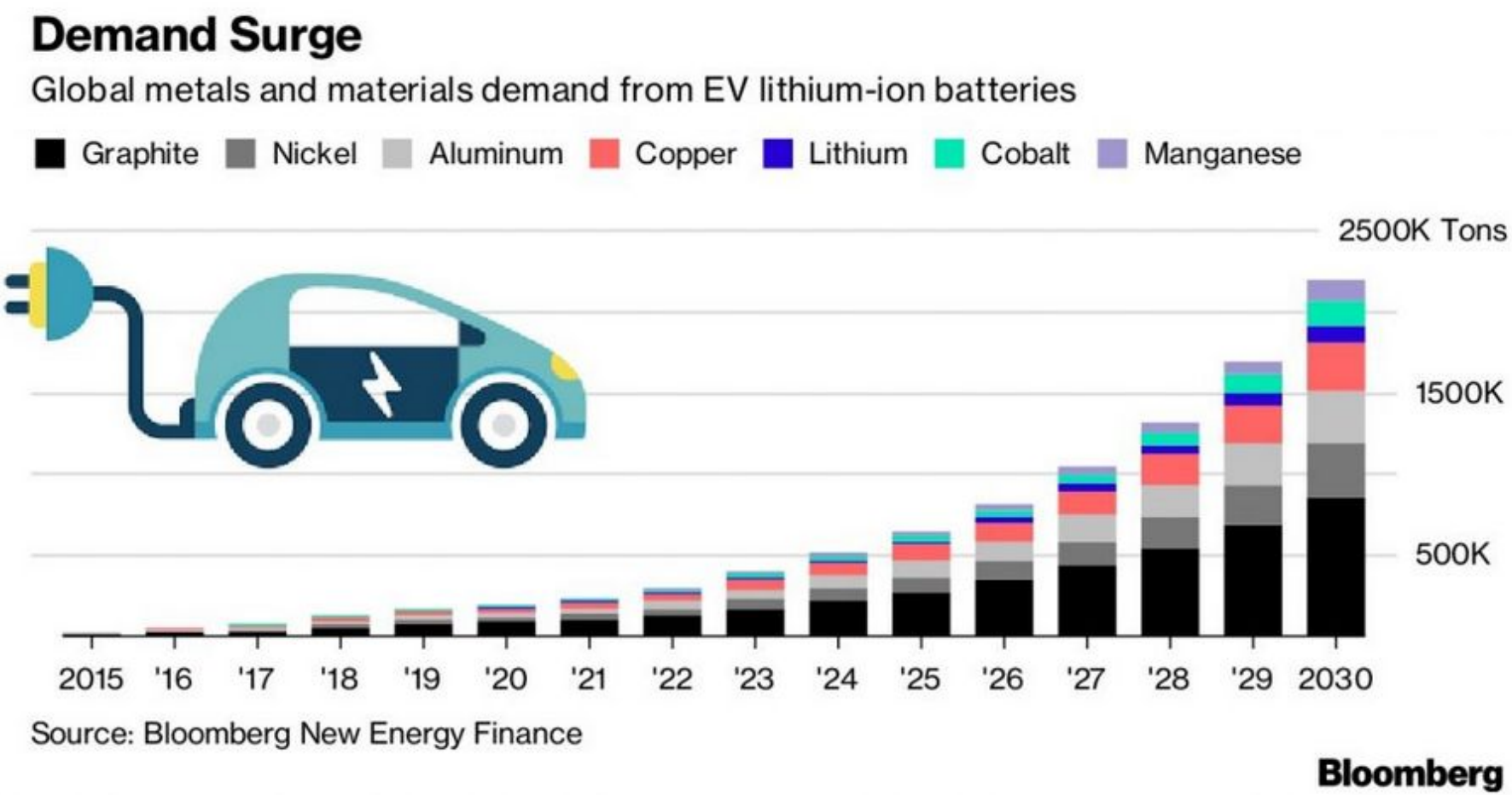

E.Polo Quando finiranno i metalli? Scenari e prospettive.

ELEMENTS OF A SMARTPHONE

ELEMENTS COLOUR KEY: ALKALI METAL | ALKALINE EARTH METAL | TRANSITION METAL | GROUP 13 | GROUP 14 | GROUP 15 | GROUP 16 | HALOGEN | LANTHANIDE

SCREEN

49 In Indium | 8 O Oxygen | 50 Sn Tin

Indium tin oxide is a mixture of indium oxide and tin oxide, used in a transparent film in the screen that conducts electricity. This allows the screen to function as a touch screen.

13 Al Aluminium | 14 Si Silicon | 8 O Oxygen | 19 K Potassium

The glass used on the majority of smartphones is an aluminosilicate glass, composed of a mix of alumina (Al_2O_3) and silica (SiO_2). This glass also contains potassium ions, which help to strengthen it.

39 Y Yttrium | 57 La Lanthanum | 65 Tb Terbium | 59 Pr Praseodymium | 63 Eu Europium | 66 Dy Dysprosium | 64 Gd Gadolinium

A variety of Rare Earth Element compounds are used in small quantities to produce the colours in the smartphone's screen. Some compounds are also used to reduce UV light penetration into the phone.

ELECTRONICS

Copper is used for wiring in the phone, whilst copper, gold and silver are the major metals from which microelectrical components are fashioned. Tantalum is the major component of micro-capacitors.

29 Cu Copper | 47 Ag Silver | 79 Au Gold | Ta Tantalum

Nickel is used in the microphone as well as for other electrical connections. Alloys including the elements praseodymium, gadolinium and neodymium are used in the magnets in the speaker and microphone. Neodymium, terbium and dysprosium are used in the vibration unit.

28 Ni Nickel | 66 Dy Dysprosium | 59 Pr Praseodymium | 65 Tb Terbium | 60 Nd Neodymium | 64 Gd Gadolinium

Pure silicon is used to manufacture the chip in the phone. It is oxidised to produce non-conducting regions, then other elements are added in order to allow the chip to conduct electricity.

14 Si Silicon | 8 O Oxygen | 51 Sb Antimony | 33 As Arsenic | 15 P Phosphoru | Ga Gallium

Tin & lead are used to solder electronics in the phone. Newer lead-free solders use a mix of tin, copper and silver.

50 Sn Tin | 82 Pb Lead

BATTERY

3 Li Lithium | 27 Co Cobalt | 8 O Oxygen | 6 C Carbon | 13 Al Aluminium

The majority of phones use lithium ion batteries, which are composed of lithium cobalt oxide as a positive electrode and graphite (carbon) as the negative electrode. Some batteries use other metals, such as manganese, in place of cobalt. The battery's casing is made of aluminium.

CASING

Magnesium compounds are alloyed to make some phone cases, whilst many are made of plastics. Plastics will also include flame retardant compounds, some of which contain bromine, whilst nickel can be included to reduce electromagnetic interference.

6 C Carbon | 12 Mg Magnesium | 35 Br Bromine | 28 Ni Nickel

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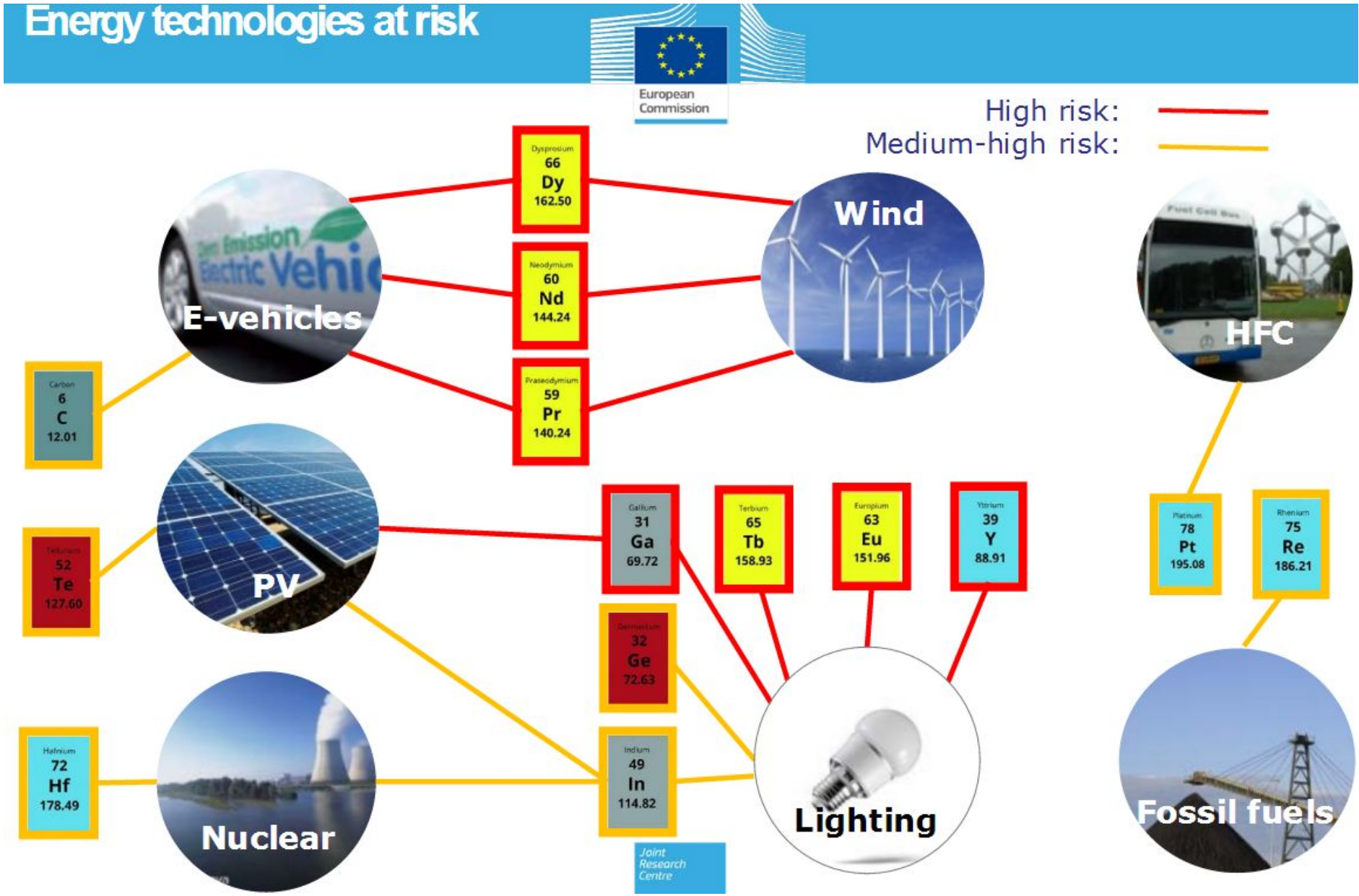


RawMaterials RM@Schools

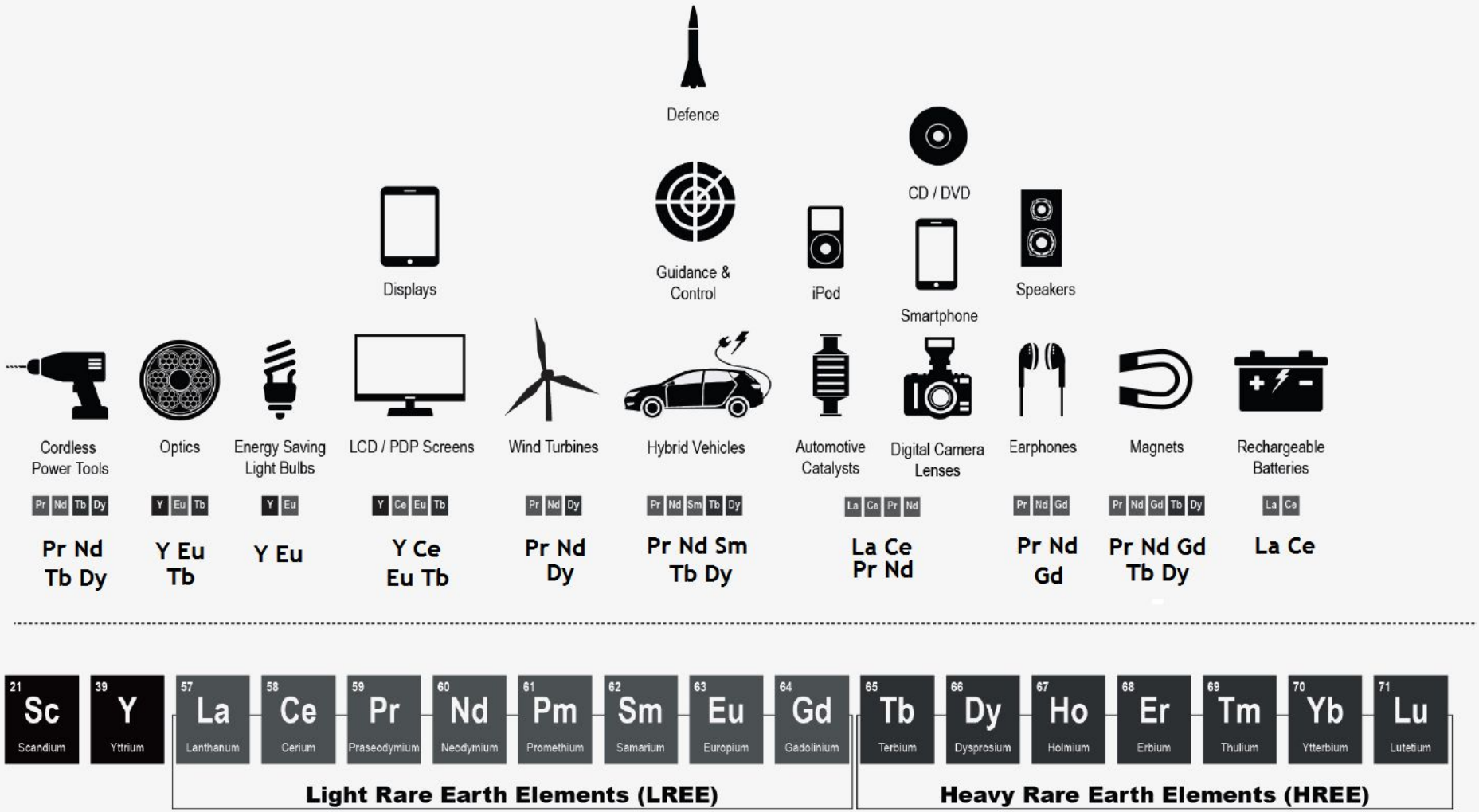
E.Polo Quando finiranno i metalli? Scenari e prospettive.

E-MINING @ SCHOOL

Una turbina da 3 MW contiene

- 335 tonnellate di acciaio
- 4,7 tonnellate di rame
- 1200 tonnellate di cemento
- 3 tonnellate di alluminio
- 2 tonnellate di terre rare
- zinco
- molibdeno

Fonte : (NW Mining Association)



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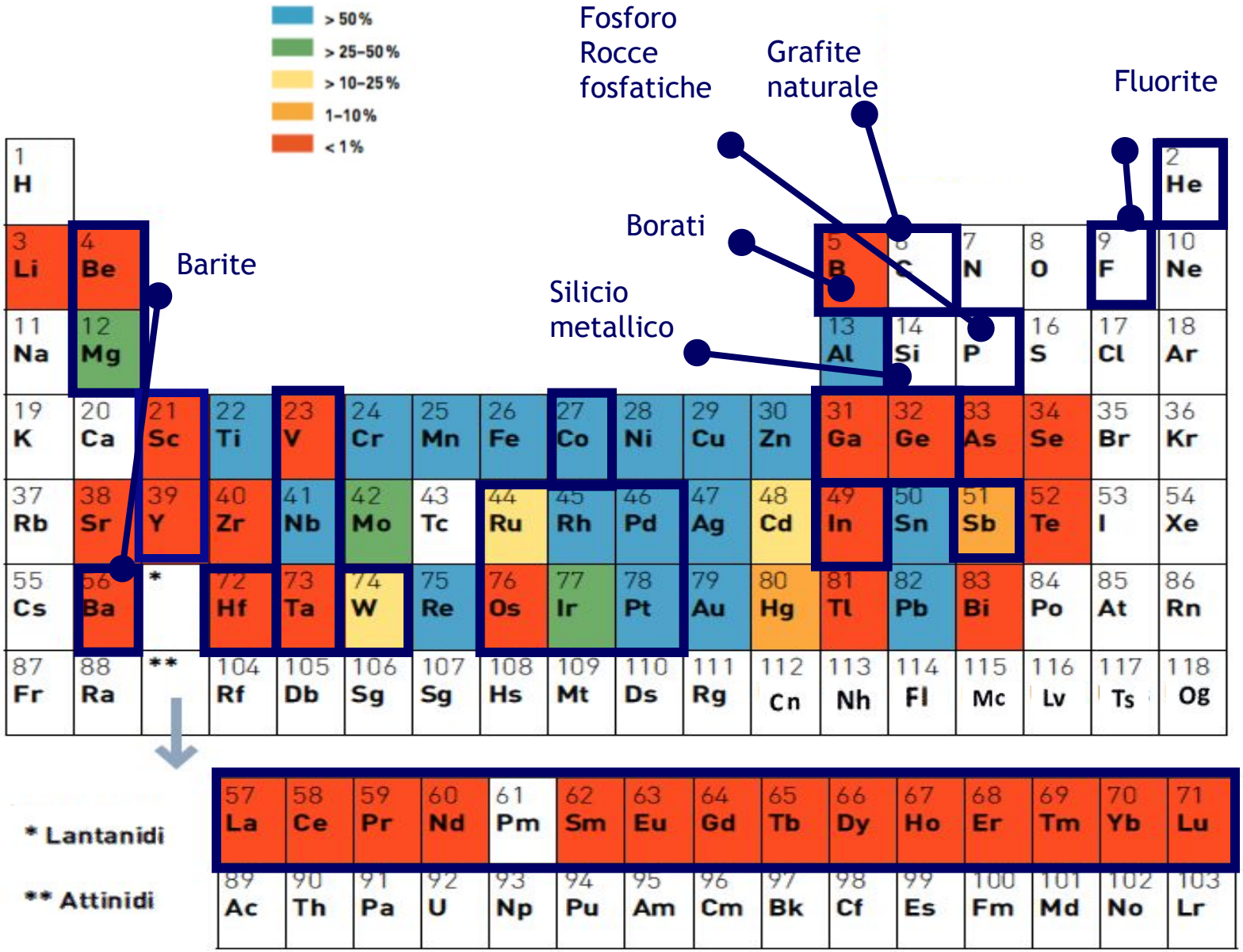
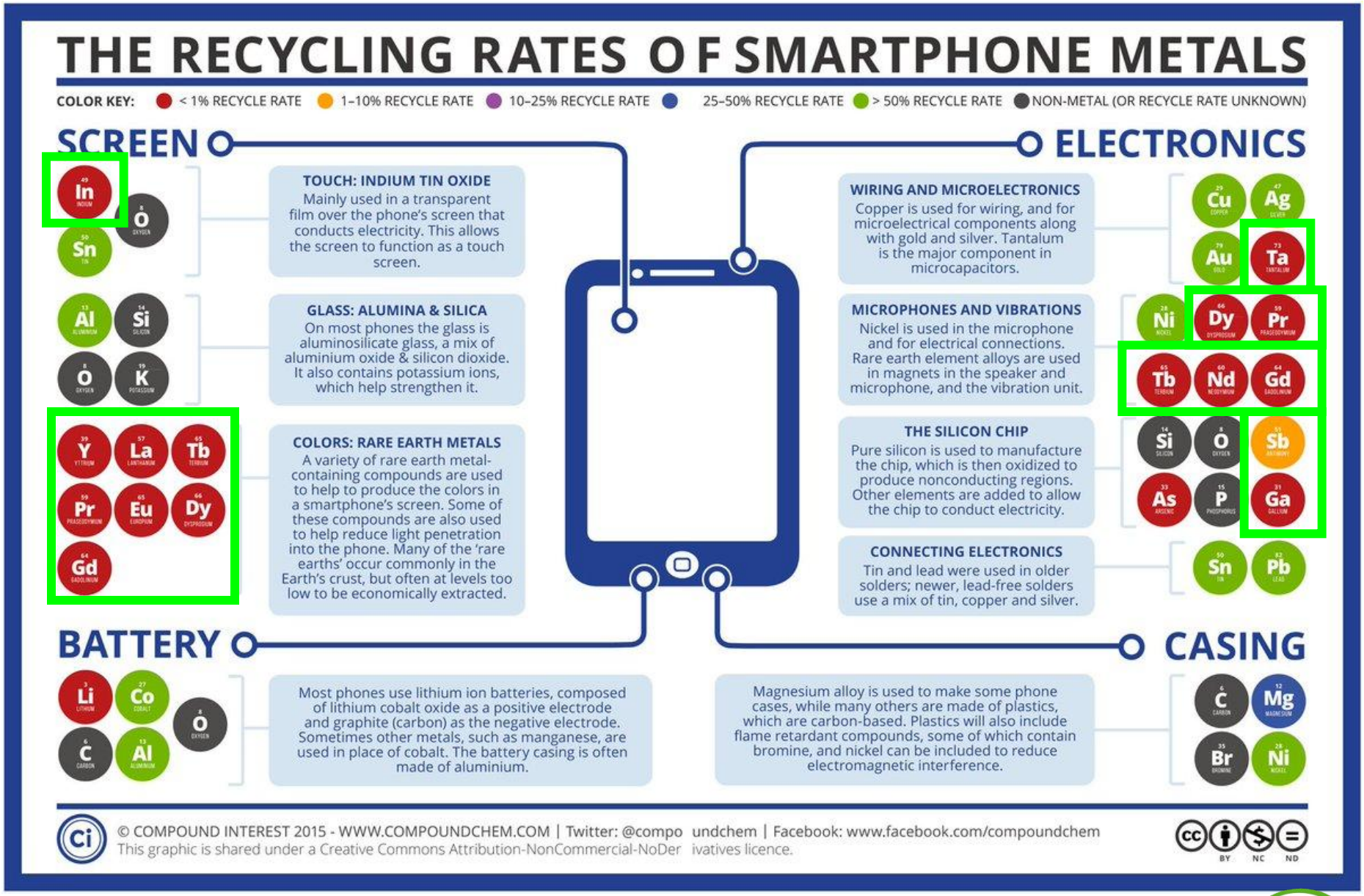
E.Polo Quando finiranno i metalli? Scenari e prospettive.

E-MINING @ SCHOOL

Europio combinato con gallio, stronzio, zolfo, alluminio e bario è impiegato negli inchiostri anti-contraffazione delle banconote dell'euro

5. La filiera del riciclo non funziona o è poco praticabile





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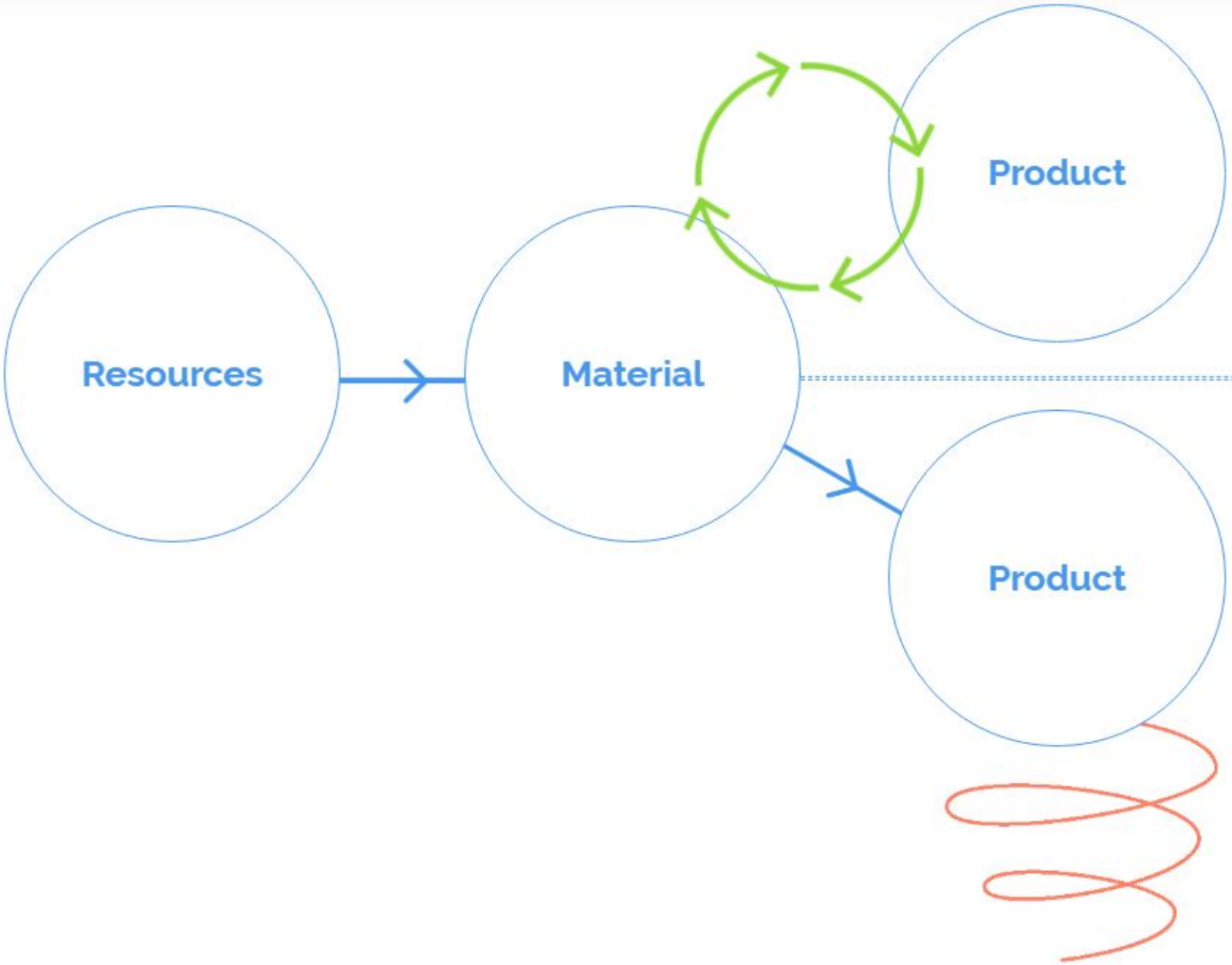
E.Polo Quando finiranno i metalli? Scenari e prospettive.

E-MINING @ SCHOOL



METAL ∞ recycles forever™

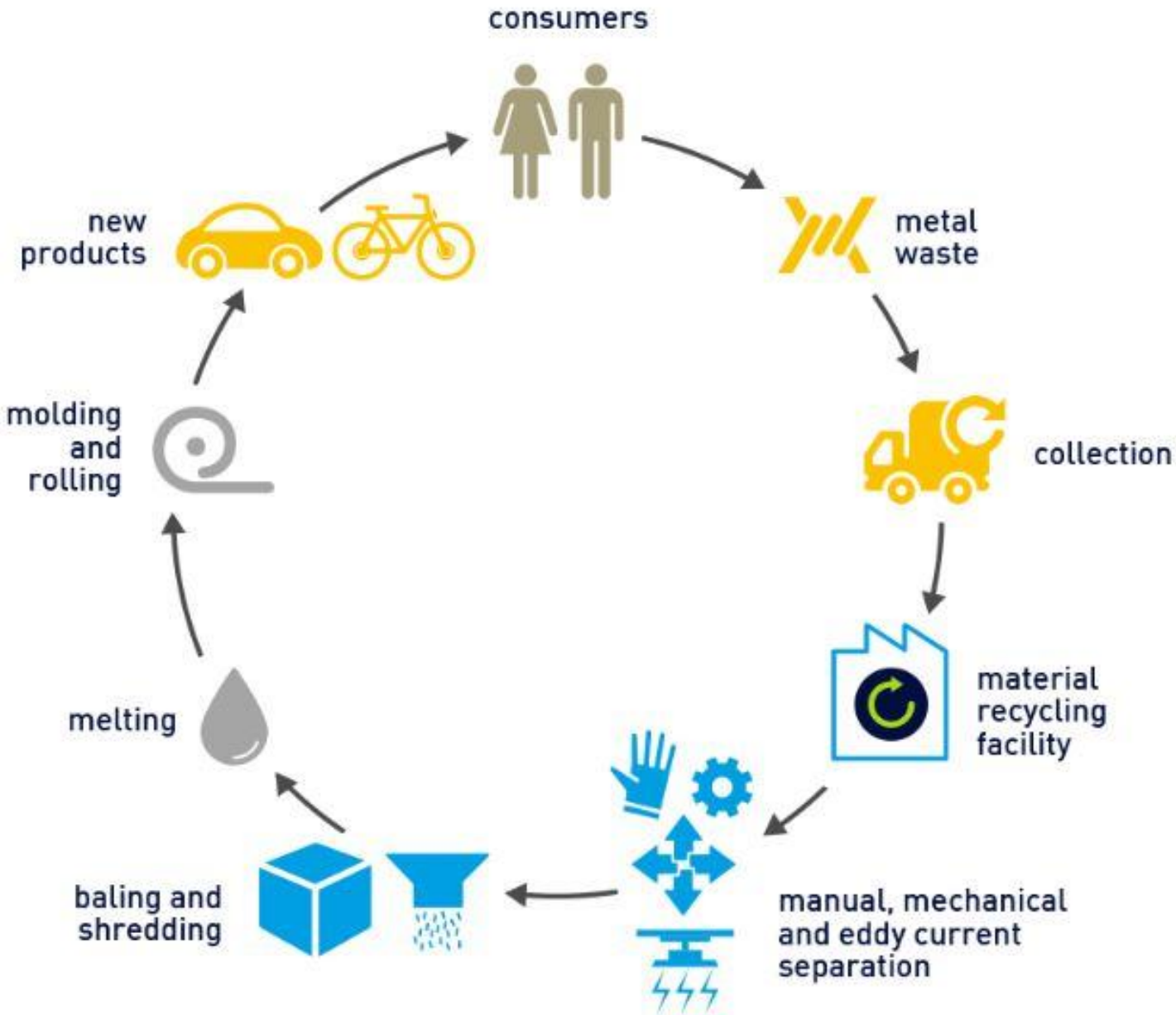
Permanent material loop

Non-permanent material spiral to end of life

RawMaterials RM@Schools

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

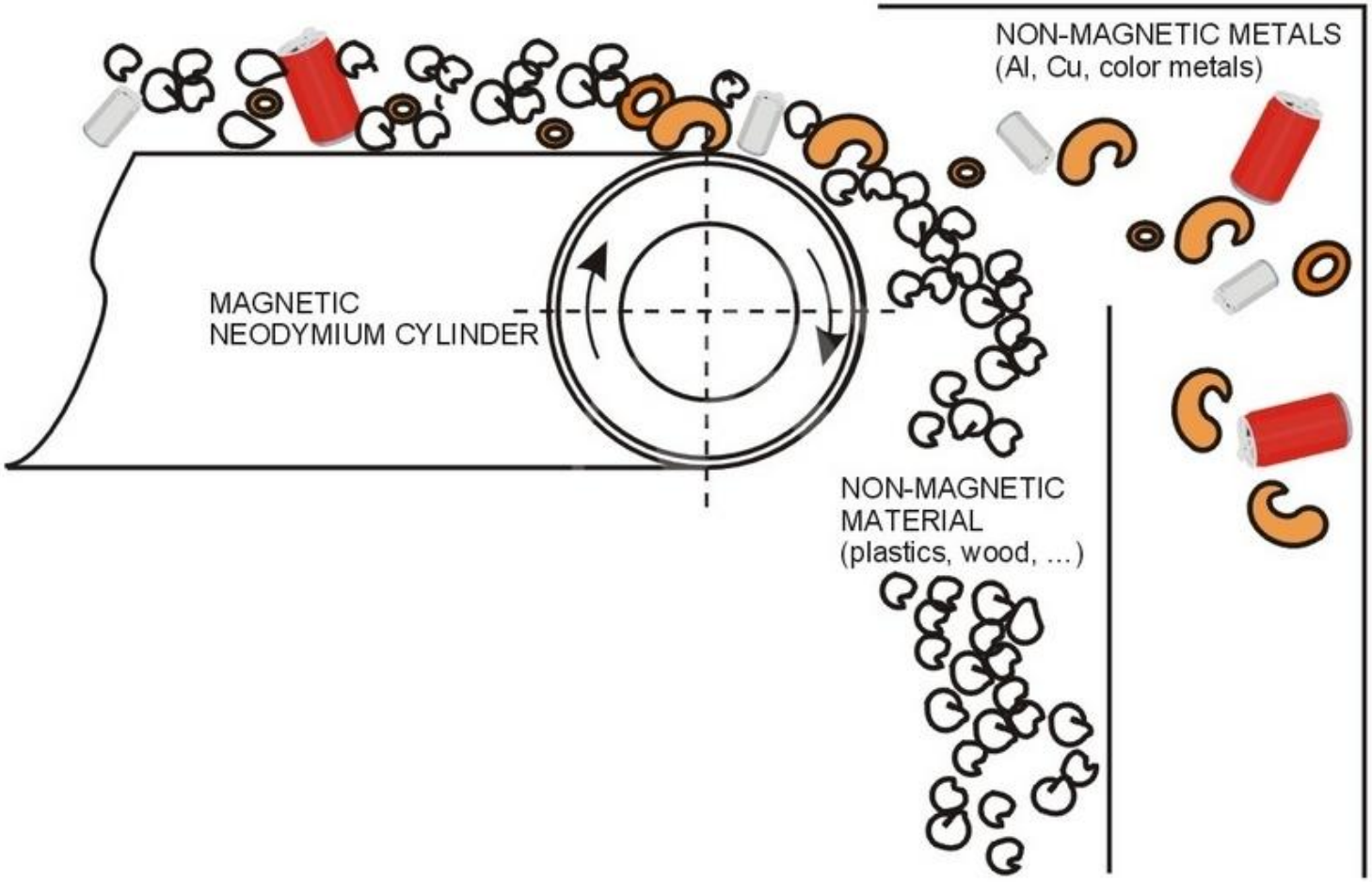
E-MINING @ SCHOOL

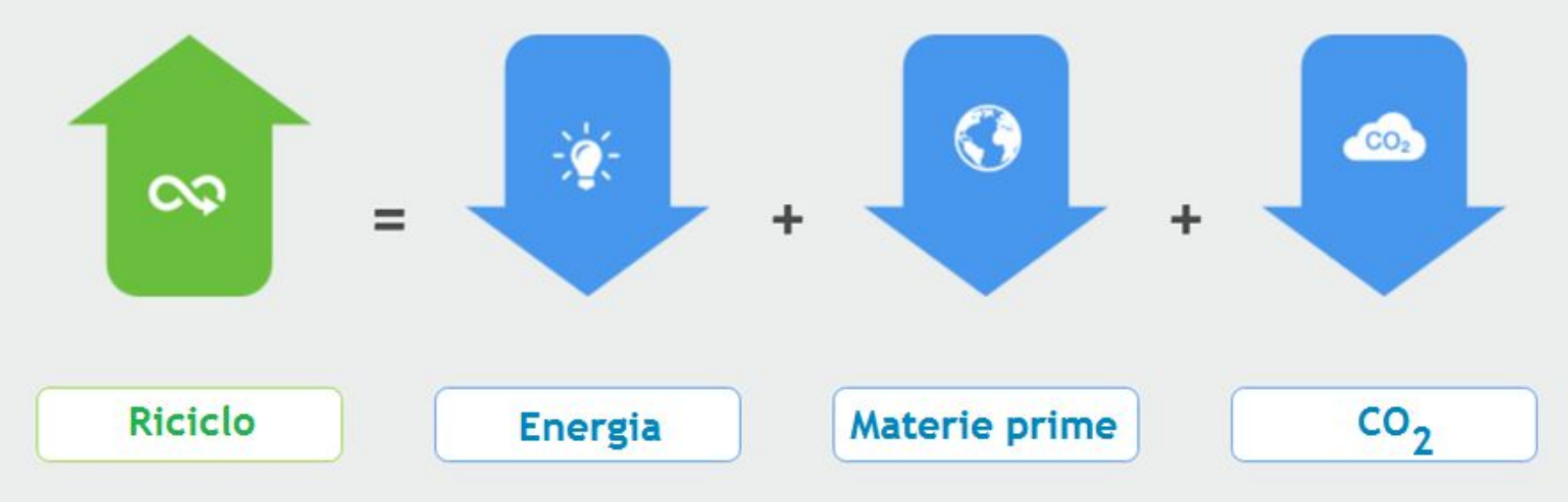

consumers
metal waste
collection
material recycling facility
manual, mechanical and eddy current separation
baling and shredding
melting
molding and rolling
new products

Separazione di rifiuti metallici

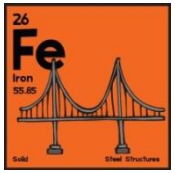
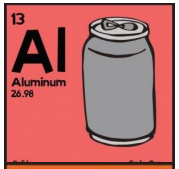
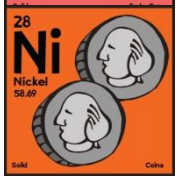
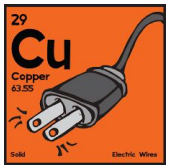
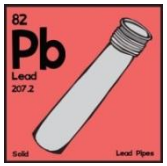
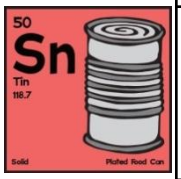
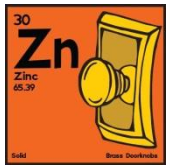
Ferrosi (magnetici): ferro, acciaio, ghisa

Non ferrosi





I metalli possono essere recuperati anche dalle ceneri dei termovalorizzatori, ma la qualità è inferiore a quella del materiale da riciclo

	Metallo	Riciclo (%)	Energia risparmio (%)	CO_2 risparmio annuale (%)
	Acciaio	42	60	58
	Alluminio	40	95	92
	Nichel	60	90	90
	Rame	35	80	65
	Piombo	74	98	99
	Stagno	75	98	99
	Zinco	20	60	76

Quando si verificano perdite nella filiera di recupero?

- I RAEE non sono raccolti, va tutto in discarica

- Sono raccolti, ma:
  - Sono rubati nei punti di raccolta municipali o nelle fasi successive della catena di riciclo
  - Sono esportati per un riuso legale in Paesi in cui non si fa riciclo
  - Sono esportati per un finto riuso in Paesi che recuperano solo alcuni elementi in modo scorretto

E-waste in India

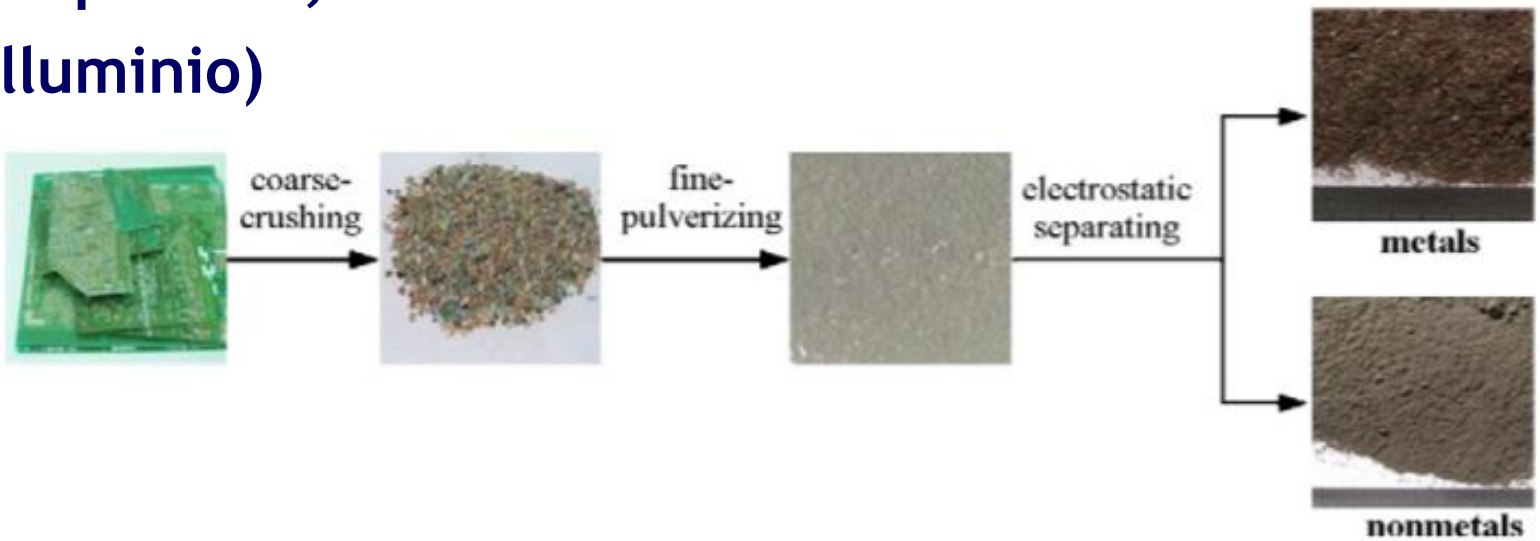
E-waste in India

"Low–tech" gold recycling in Bangalore/India (photo by courtesy of EMPA, Switzerland)

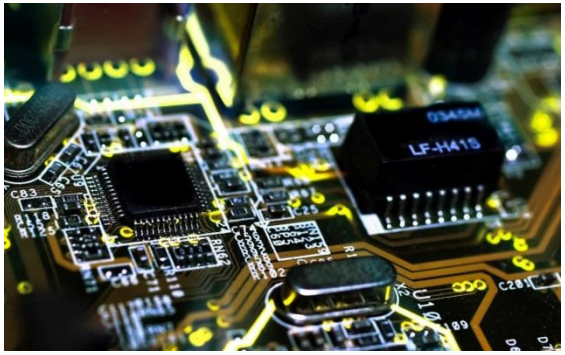
© Getty Images

❖ Se c'è una filiera di recupero ci possono essere perdite dovute a:

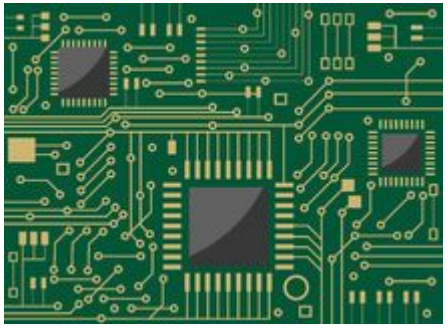
- Separazione sbagliata (es., cellulari conferiti insieme ad altri materiali come plastica o indifferenziato)
- Perdite nel trattamento meccanico (es., metalli preziosi nelle polveri, nella plastica, o nella frazione di ferro e alluminio)



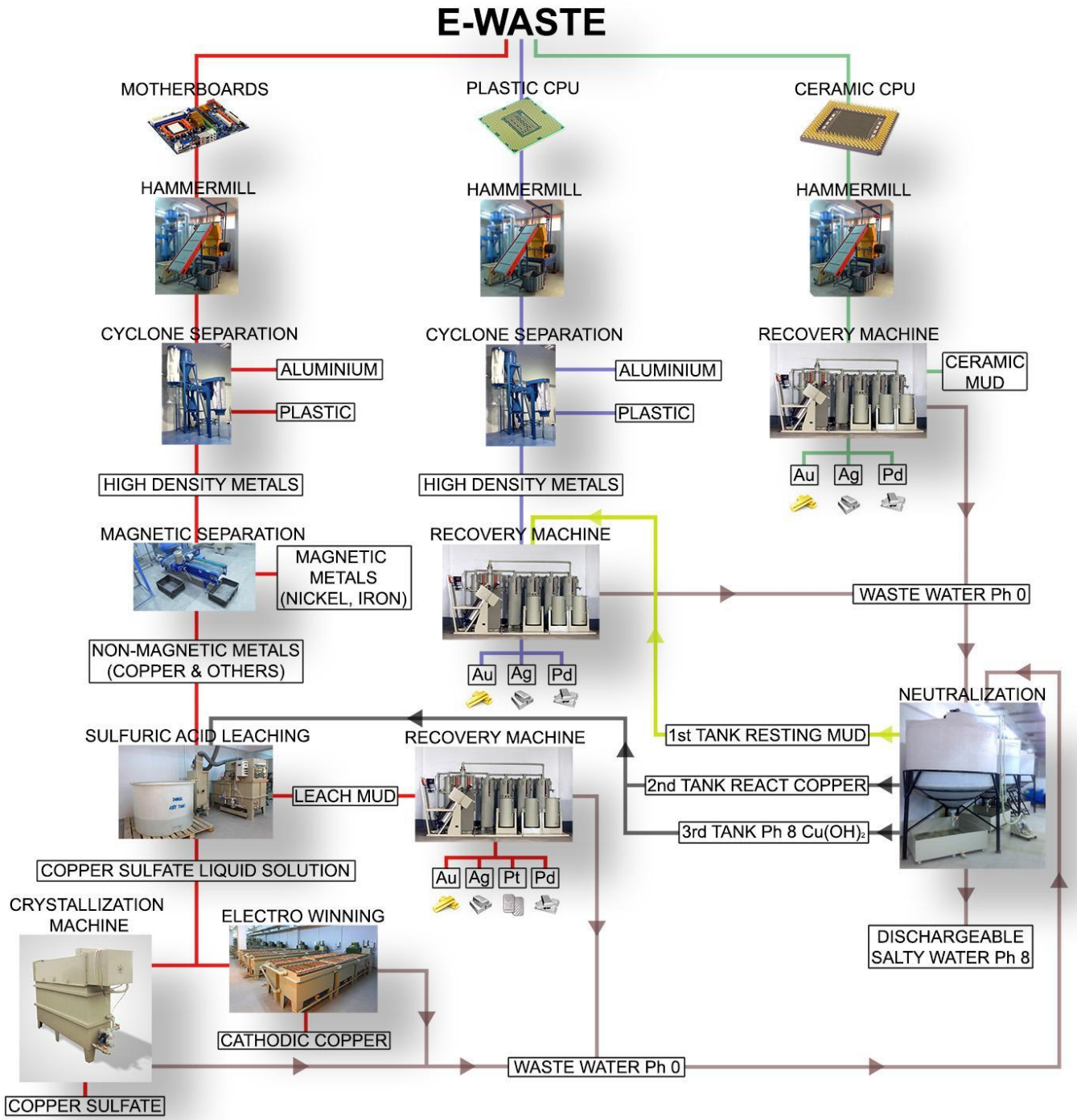
- Limiti tecnici al recupero di alcuni metalli in particolari leghe



- Miniaturizzazione e uso di colle nei circuiti



- Molti impianti recuperano solo i metalli che hanno un mercato garantito



Si recuperano

Plastica

Ceramica

oro

argento

platino

palladio

rame

alluminio

nichel

ferro

Metalli nei rifiuti

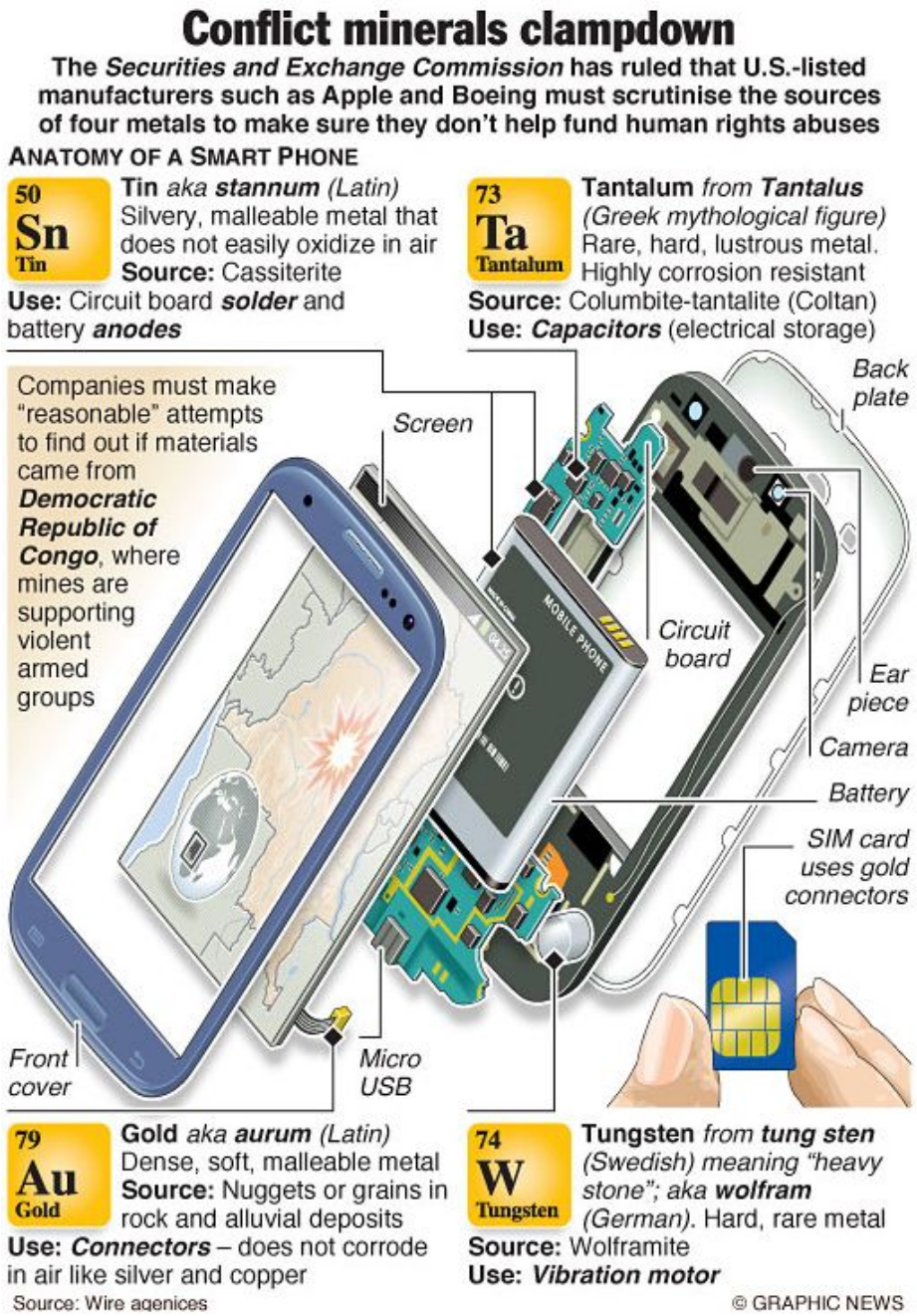
Rifiuti industriali, demolizione auto, edilizia, grosse apparecchiature (dominano alluminio, ferro e acciaio)

Rifiuti urbani (lattine, contenitori, RAEE): c'è un po' di tutto, ma si recuperano soprattutto alluminio, ferro, acciaio, piombo, nichel, rame, zinco e metalli preziosi.

Categorie RAEE

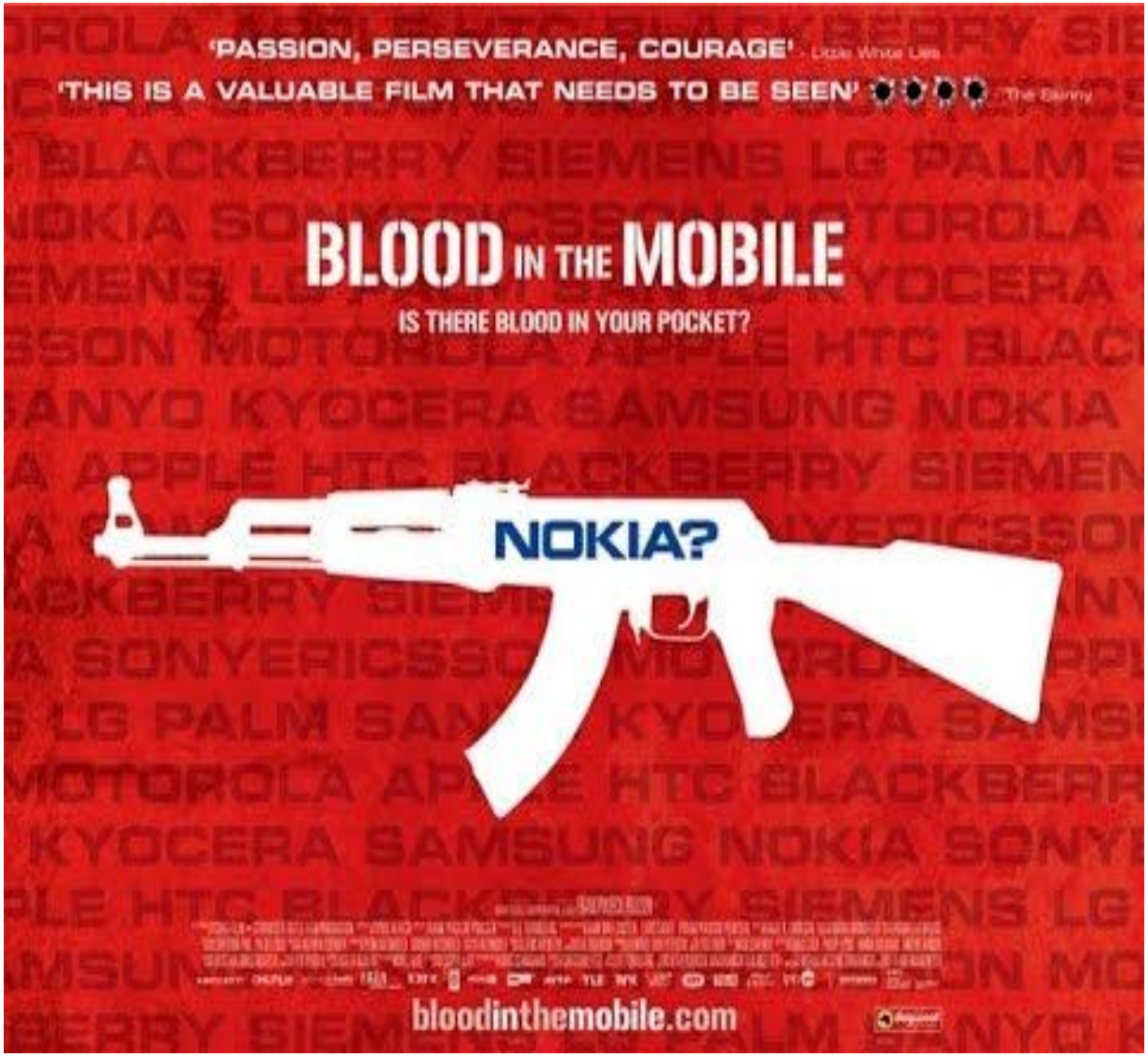
Il lato oscuro dei metalli

11 milioni di morti



I "minerali da conflitto" provengono dalla Repubblica Democratica del Congo (RDC) e dalle regioni confinanti e le attività correlate (estrazione, lavorazione, ecc.) finanziano conflitti armati.

Sono cassiterite, wolframite, oro,columbite-tantalite e loro derivati (tungsteno, stagno, tantalio, niobio).



Blood in the Mobile (2010) è un documentario del regista danese Frank Piasecki Poulsen, https://www.youtube.com/watch?v=Tv-hE4Yx0LU

"I bambini in Congo sono mandati a morire nelle miniere affinché altri bambini in Europa e America possano uccidere alieni immaginari nella loro sala da pranzo o mandarsi messaggini nella stessa stanza" (Oona King, Bush and Seeds 2008, p. 1)

CHE FARE?

RawMaterials RM@Schools

E.Polo Quando finiranno i metalli?
Scenari e prospettive.

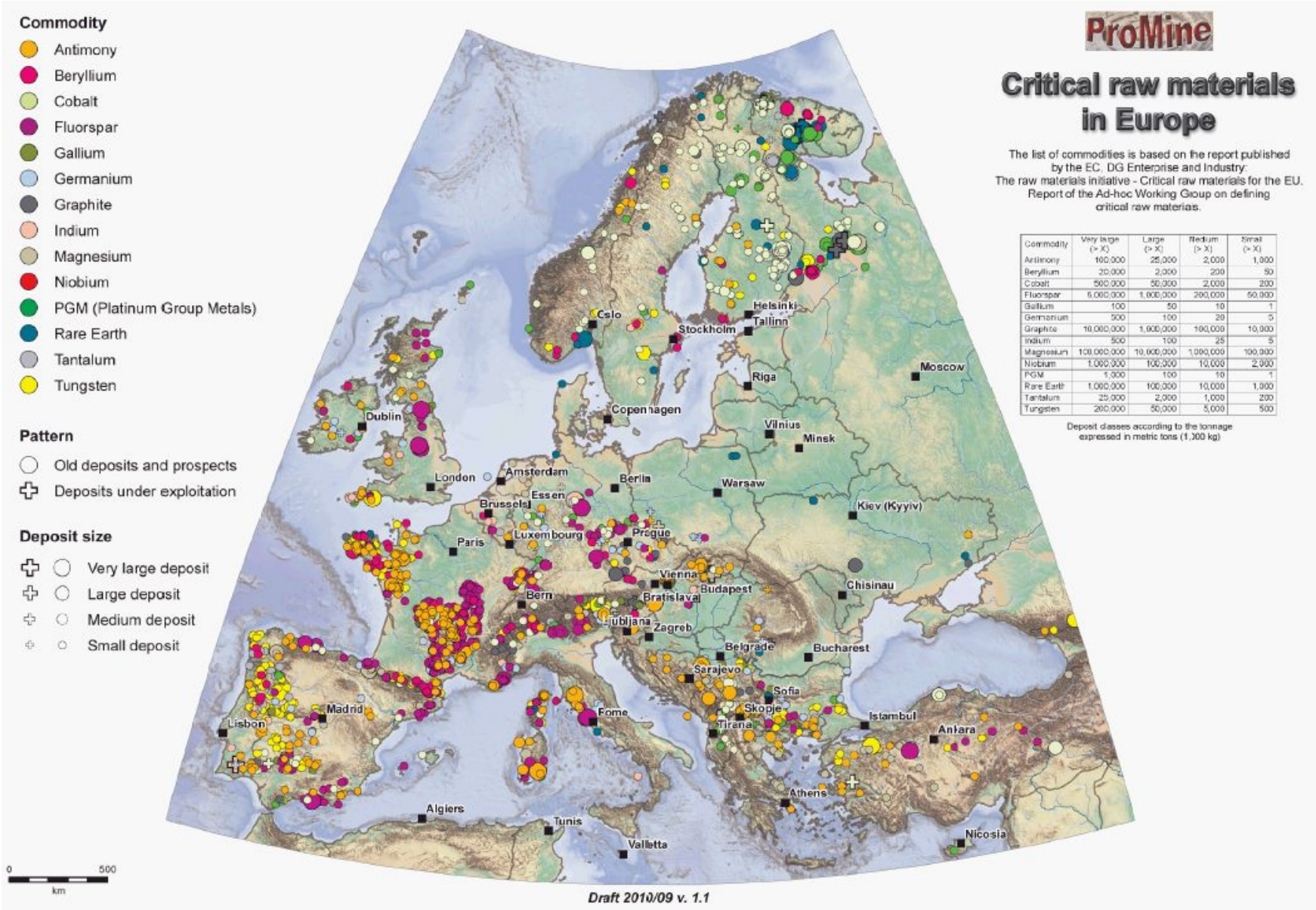
E-MINING @ SCHOOL

a) Ricerca di materiali sostitutivi più facili da reperire/ produrre o inventare soluzioni innovative

Labodif
22 minuti fa

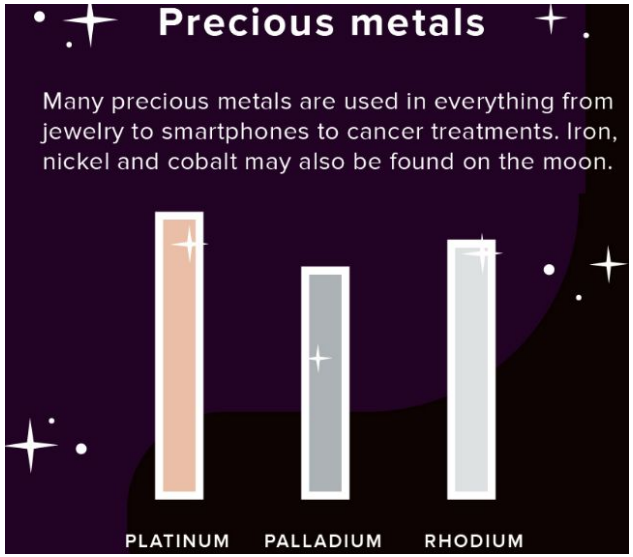
Ecco la nostra #giovanedonna di oggi.
(Si chiama #MyaLeThai, è una studentessa di chimica all'università della California e ha inventato una pila che potrebbe durare 400 volte di più di quelle in uso oggi. Mentre faceva il dottorato si è concentrata su come migliorare le prestazioni di condensatori per conservare una carica elettrica, e poi l'idea geniale: mettergli un cappotto in plexiglas, come un gel. Il risultato è stato sbalorditivo: la sua batteria è durata per 200,000 cicli di ricarica invece che i 6,000 cicli di oggi. Molti dei dispositivi elettronici che usiamo dipendono da batterie ma durano poco il che porta a milioni di batterie nelle discariche. Thai e la sua squadra ammettono che c'è ancora molto lavoro da fare prima che la loro batteria possa essere disponibile in commercio. Ma é una svolta straordinaria. Grazie Thai).
Osservatorio #Labodifgiovanidonne n.41

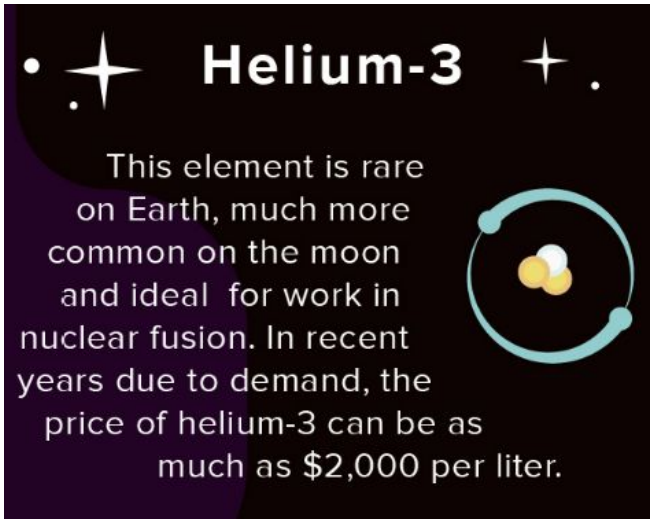
b1) Cercare nuove miniere, riaprire quelle chiuse, setacciare gli oceani …



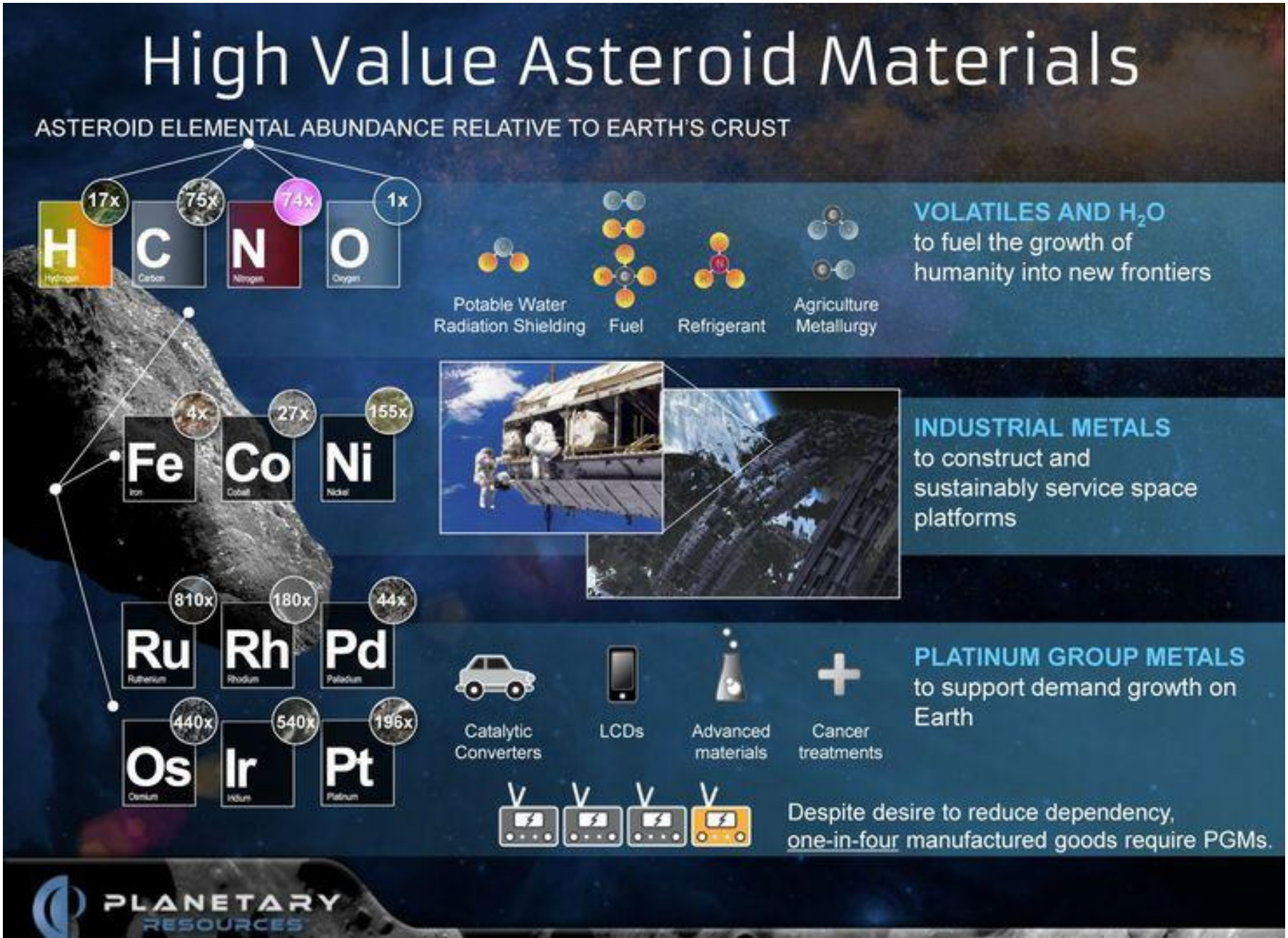
Commodity	Very large (> X)	Large (> X)	Medium (> X)	Small (> X)
Antimony	100,000	25,000	2,000	1,000
Beryllium	20,000	2,000	200	50
Cobalt	500,000	50,000	2,000	200
Fluorspar	5,000,000	1,000,000	200,000	50,000
Gallium	100	50	10	1
Germanium	500	100	20	5
Graphite	10,000,000	1,000,000	100,000	10,000
Indium	500	100	25	5
Magnesium	100,000,000	10,000,000	1,000,000	100,000
Niobium	1,000,000	100,000	10,000	2,000
PGM	1,000	100	10	1
Rare Earth	1,000,000	100,000	10,000	1,000
Tantalum	25,000	2,000	1,000	200
Tungsten	200,000	50,000	5,000	500

b2) … o estrarli sulla Luna

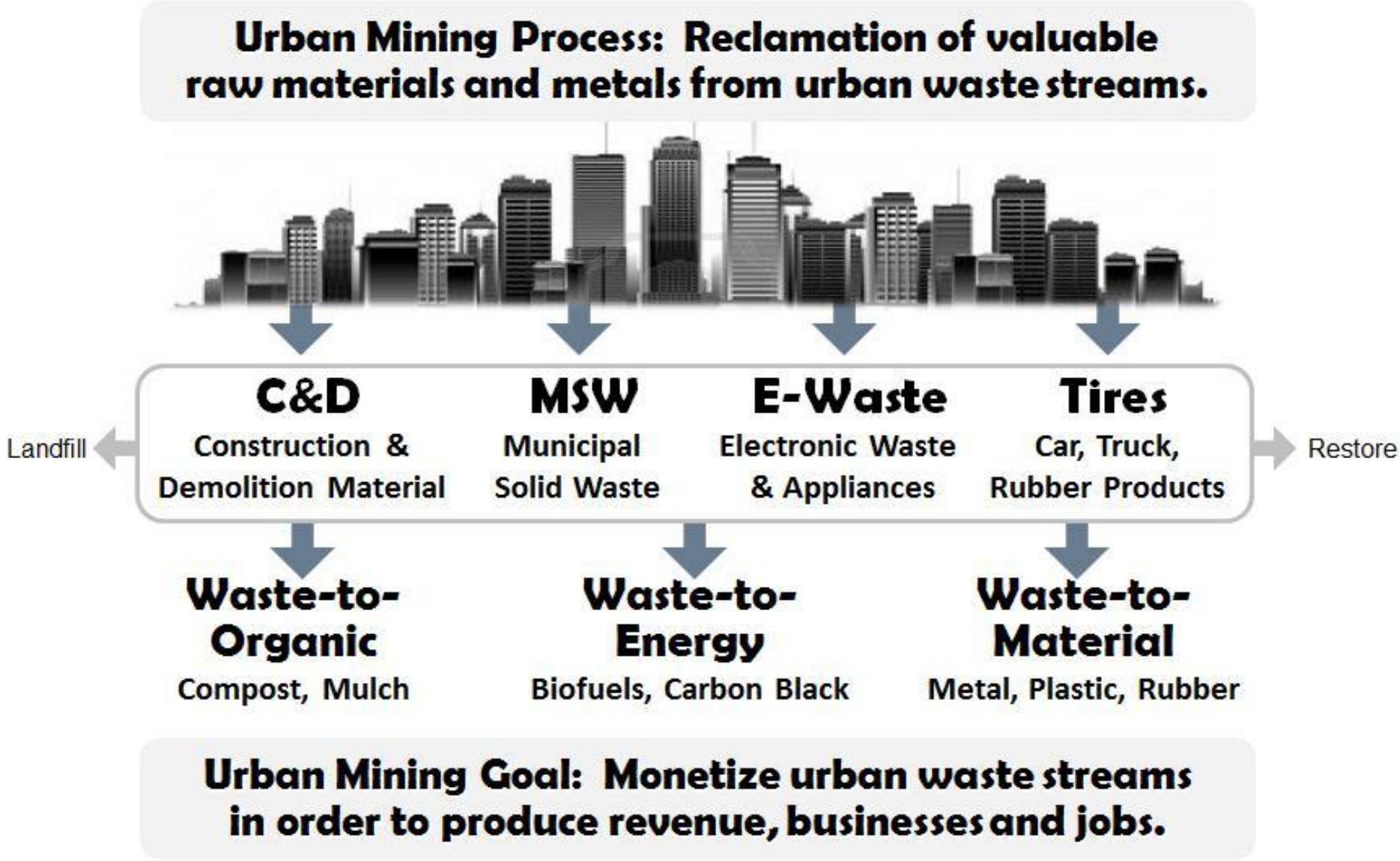




b3) … o sugli asteroidi

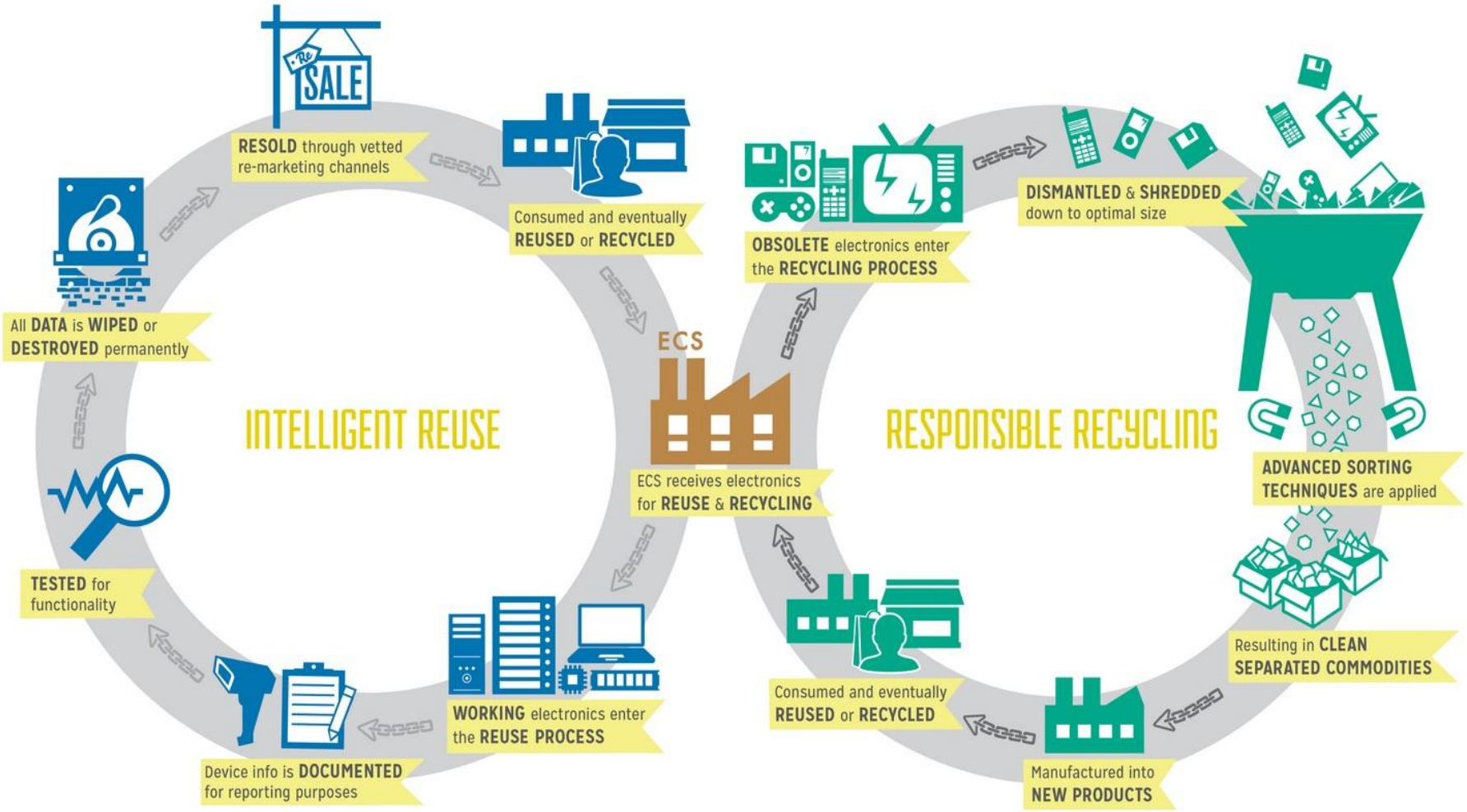


b4) urban minig ovvero raspare nelle discariche



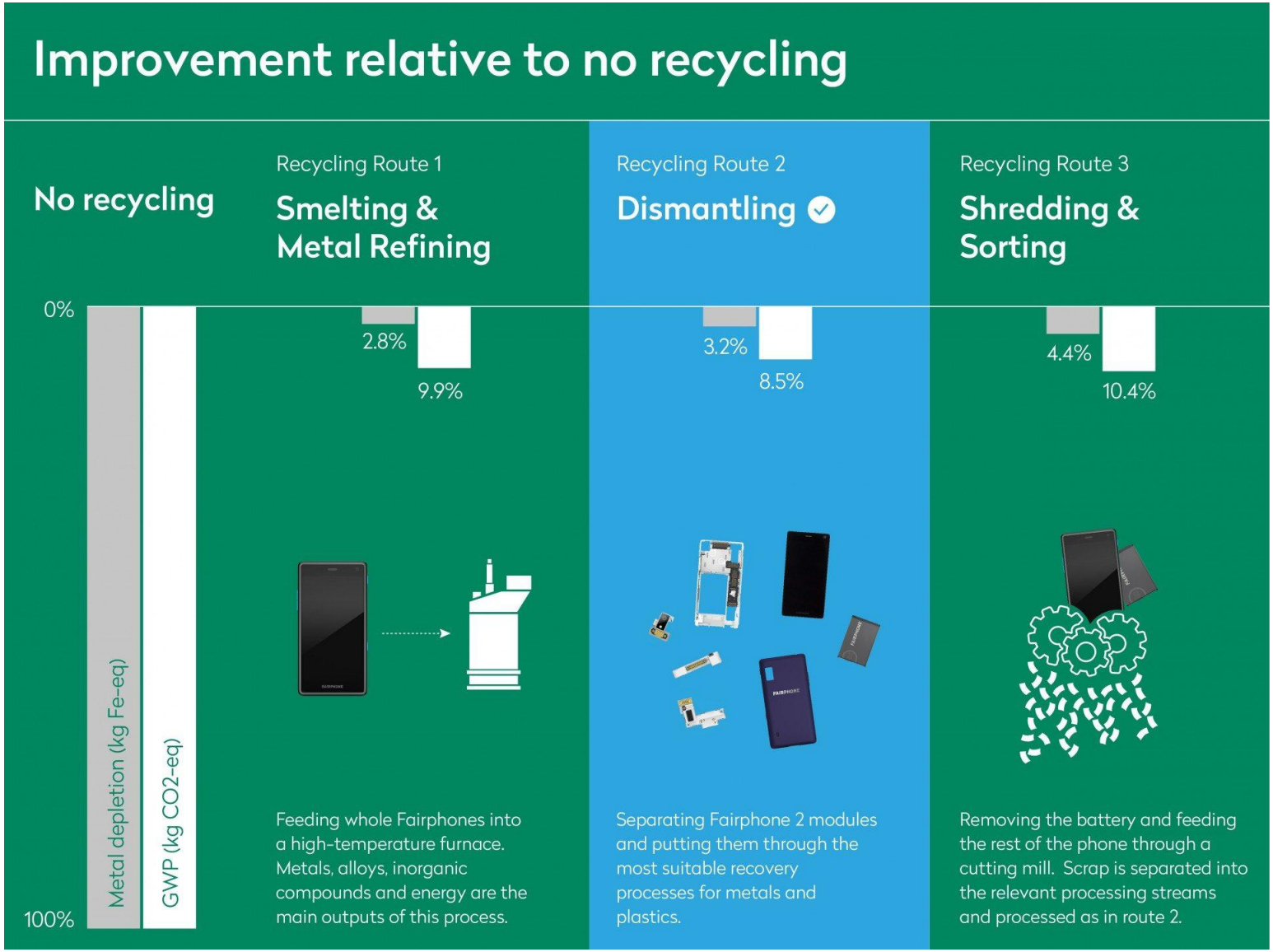
c) Perfezionare la filiera del recupero dei materiali elettronici

Riuso intelligente Riciclo responsabile



d) Preferire aziende che adottano un design studiato per facilitare la sostituzione dei componenti e il recupero dei materiali

FAIRPHONE



% di recupero più bassa: metalli (14%), altri materiali (11%), energia (11%). Scarsa qualità dei materiali recuperati

% elevata di recupero: metalli (19%), altri materiali (9%), energia (3%). Varietà più ampia dei materiali recuperati

La % di recupero più alta: metalli (22%), altri materiali (8%), energia (1%). Minore varietà dei materiali recuperati

PuzzlePhone is the long-lasting smartphone with three easy-to-change modules. Repair and customize your device easily - make it last and make it your own. PuzzlePhone is reliable, upgradeable, and repairable!

Need more power? Did you break your screen? Need a special module with extra sensors? All are easily replaced - by the user!

1 Brain

The Brain contains critical electronics: the CPU, GPU, RAM, memory, and cameras.

2 Spine

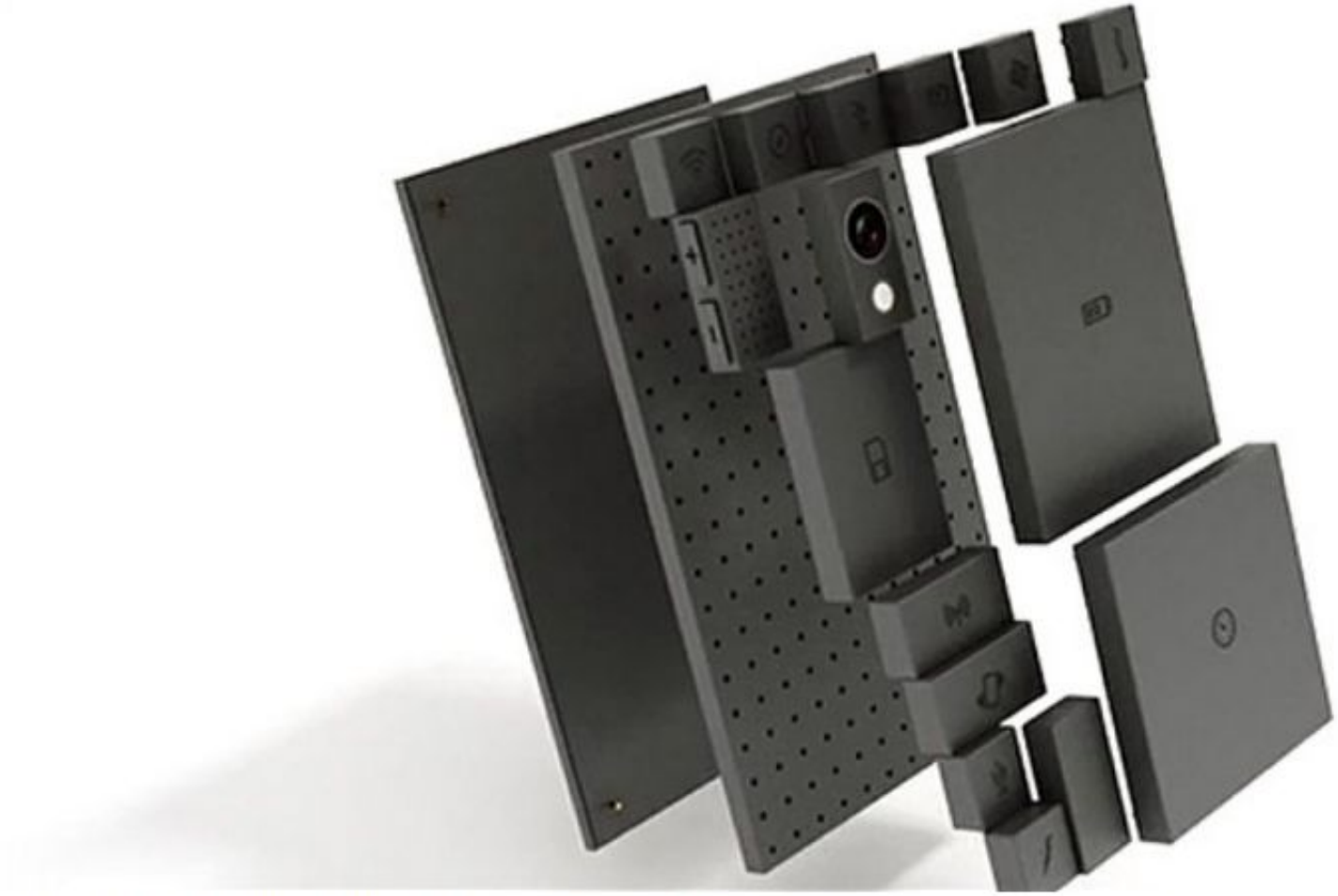
The Spine is the structure: the high-res display. Core spine elements will be available in a variety of sizes and materials.

3 Heart

The Heart contains the battery: it will be the enabler of secondary electronics and features chosen by the user.

Phonebloks: a phone that can be built like Lego

Phonebloks is a smartphone made up of separate parts that can be swapped and replaced like Lego so it lasts for ever and can be customised



A screenshot of Phoneblok's design featured in the video Photo: DAVE MOVIES

e) Non rincorrere l'ultimo modello di tablet, telefonini, … a tutti costi.

Non è detto che la novità comporti un miglioramento <u>sostanziale</u> delle prestazioni.

IL NUOVO OGGETTO DEL DESIDERIO

Iphone X, il «Day one» a Roma Notte in coda: «Dobbiamo averlo»

di Ester Palma

Nell'Apple store all'Eur le storie di chi lo smartphone «de luxe» del decennale lo voleva subito: amicizie, risse, numeretti e emozione. C'è chi è venuto da fuori e ha passato la notte nel parcheggio, chi tenta di infilarsi e scatena risse