Eleonora Polo, CNR-ISOF

When will we run out of metals? Scenarios and perspectives

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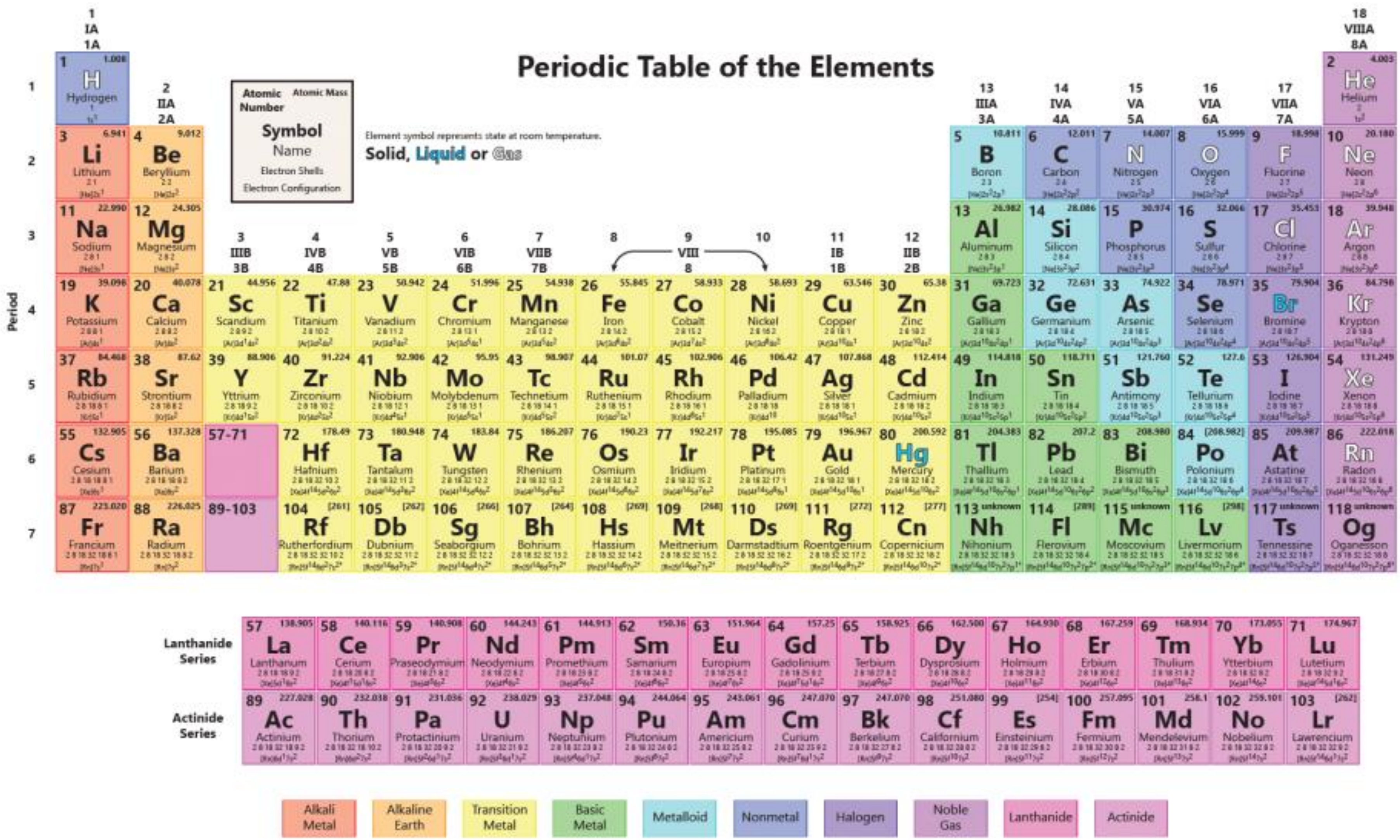

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THE UNITED NATIONS PROCLAIMS THE INTERNATIONAL YEAR OF THE PERIODIC TABLE OF CHEMICAL ELEMENTS

28 December 2017

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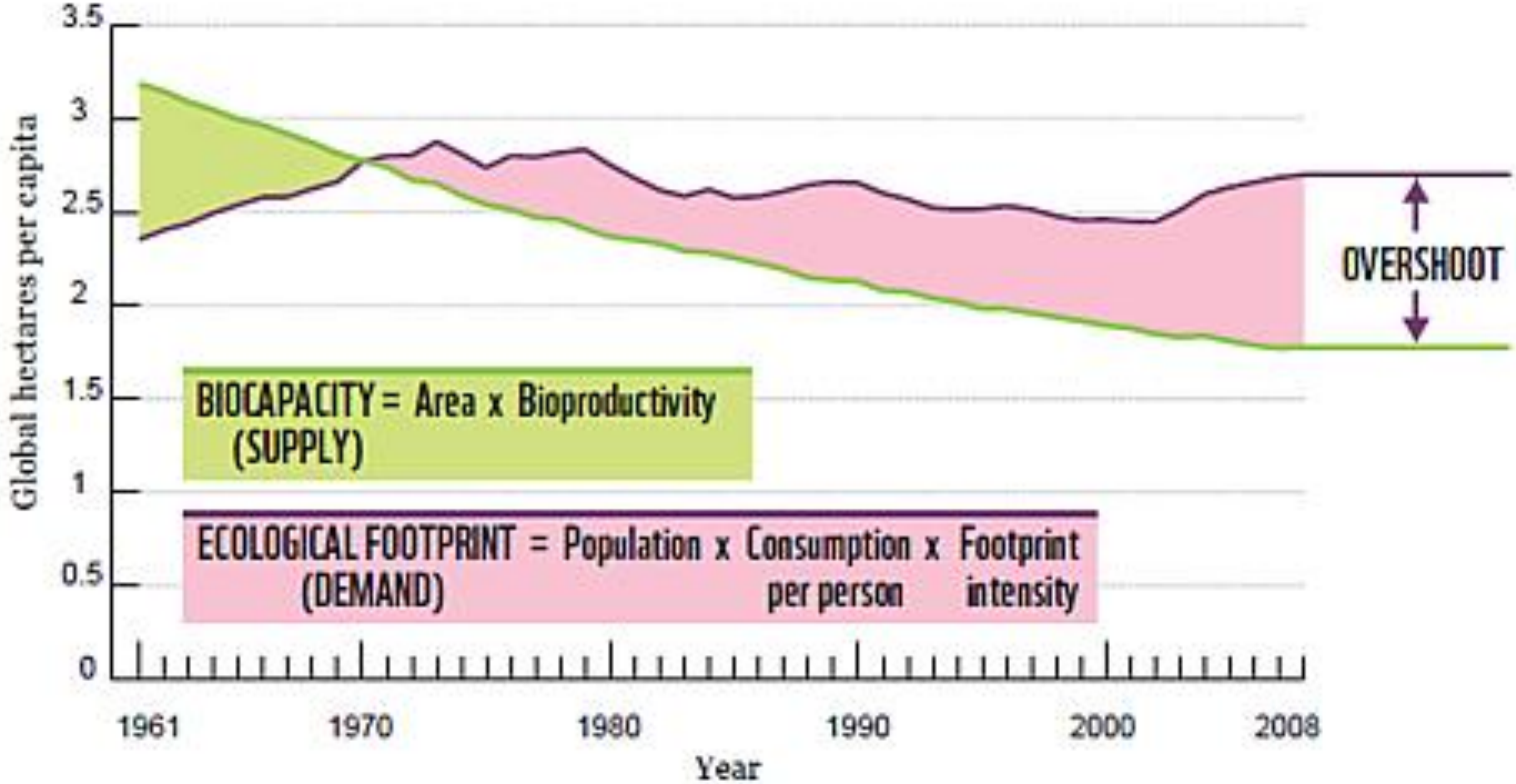
EARTH OVERSHOOT DAY:

AUG. 1, 2018

EARTH OVERSHOOT DAY



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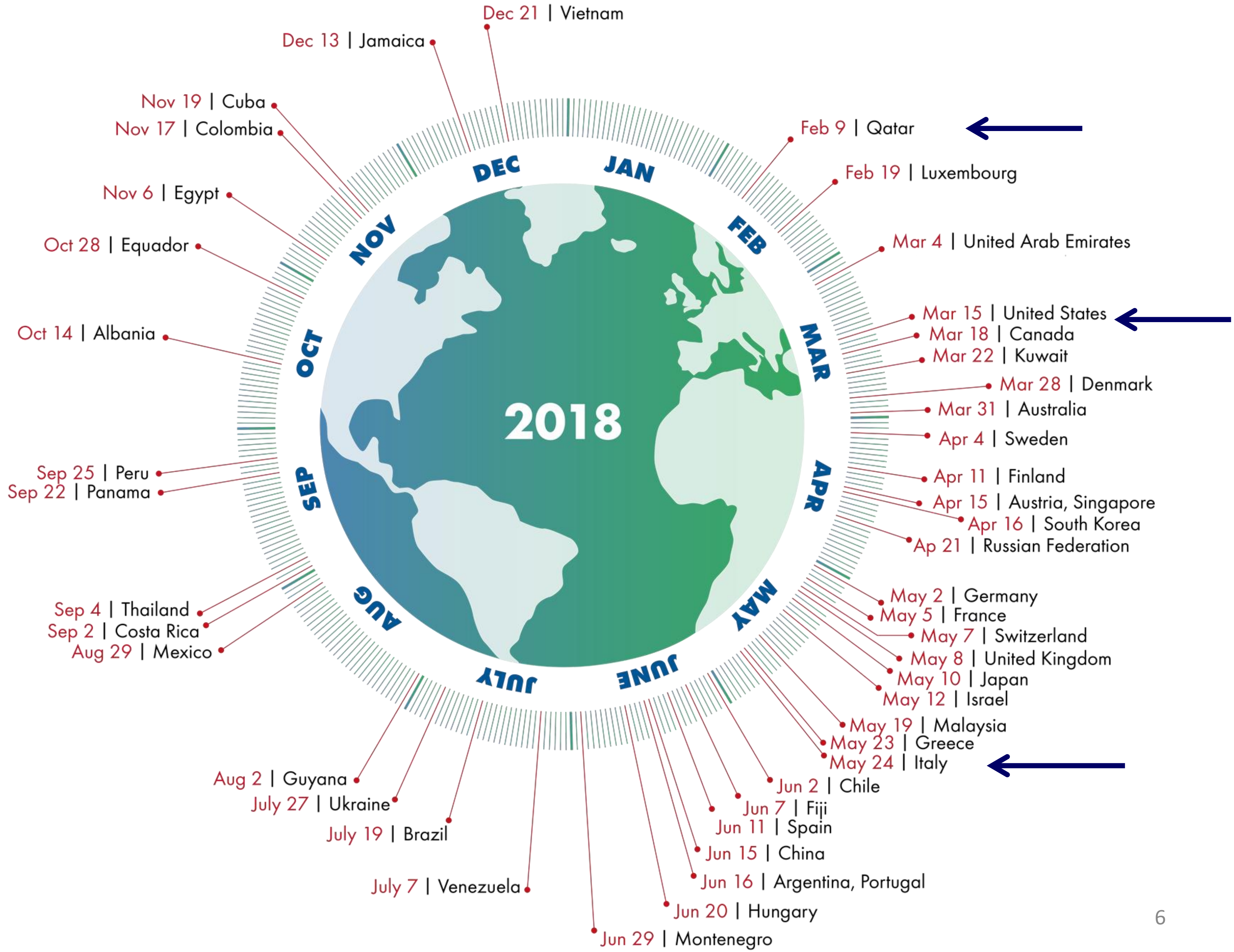
Dec 21 | Vietnam
Dec 13 | Jamaica
Nov 19 | Cuba
Nov 17 | Colombia
Nov 6 | Egypt
Oct 28 | Equador
Oct 14 | Albania
Feb 9 | Qatar
Feb 19 | Luxembourg
Mar 4 | United Arab Emirates
Mar 15 | United States
Mar 18 | Canada
Mar 22 | Kuwait
Mar 28 | Denmark
Mar 31 | Australia
Apr 4 | Sweden
Apr 11 | Finland
Apr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

If we could postpone the Overshoot Day of 4,5 days a year, we could reach balance 0 within the year 2050.

What can we do?

- Rationalize the uptake of non-renewable resources: minerals and metal ores, fossil fuels (coal, petroleum, natural gas), and minimize wastes
- Repair and reuse as much as possible
- Properly recycle urban waste

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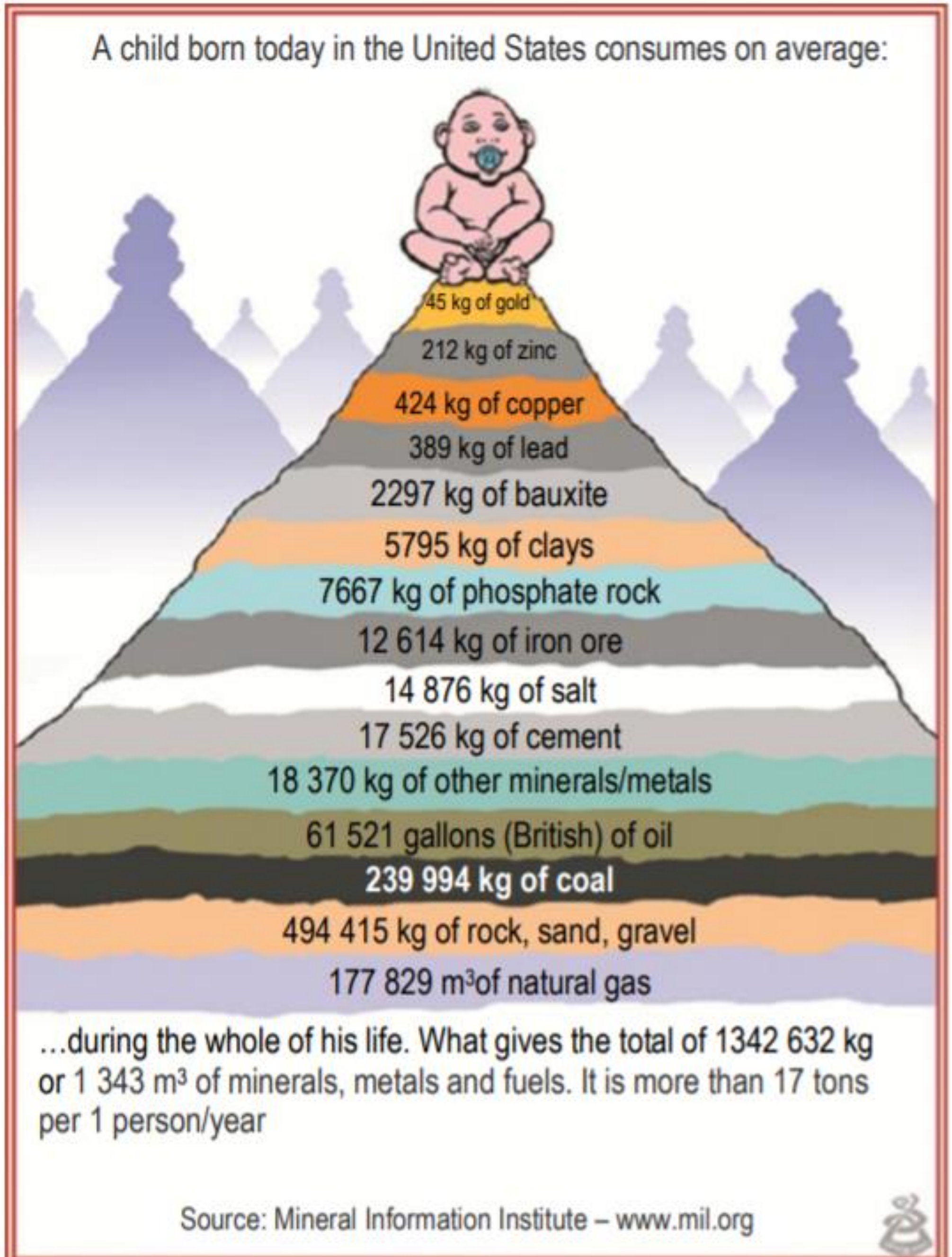
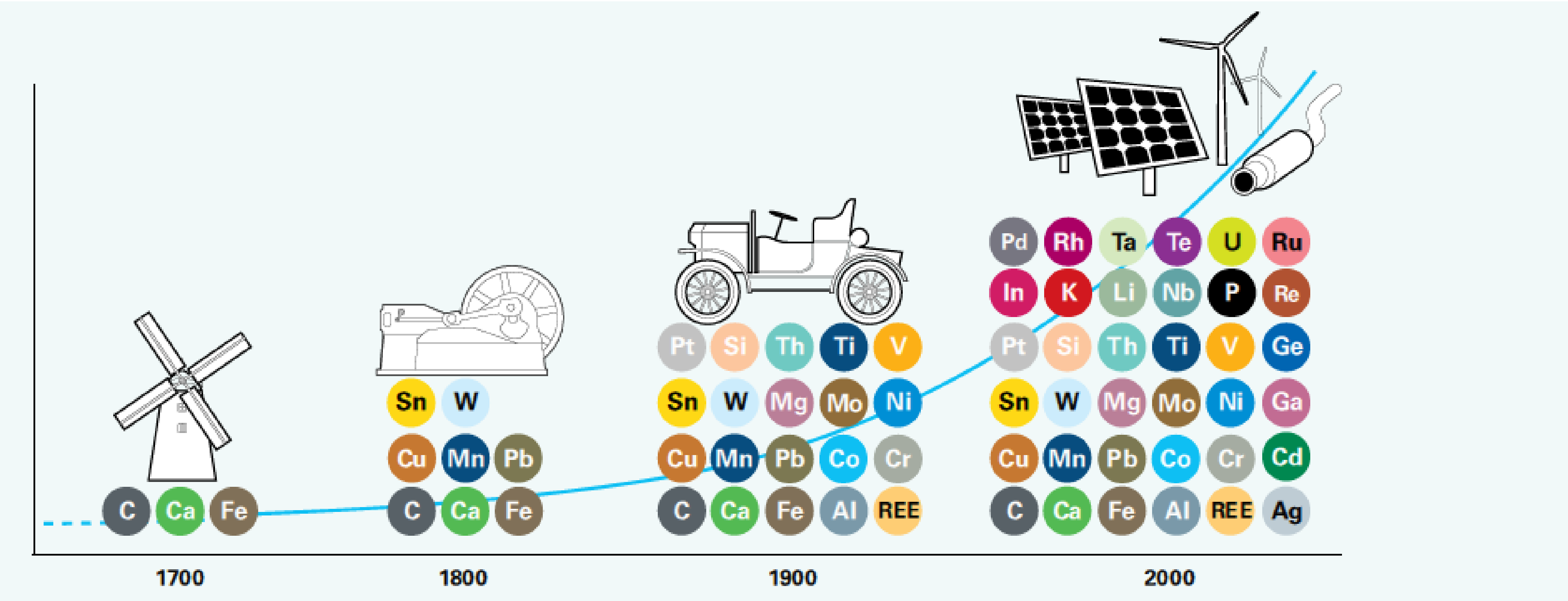

A child born today in the United States consumes on average:
45 kg of gold
212 kg of zinc
424 kg of copper
389 kg of lead
2297 kg of bauxite
5795 kg of clays
7667 kg of phosphate rock
12 614 kg of iron ore
14 876 kg of salt
17 526 kg of cement
18 370 kg of other minerals/metals
61 521 gallons (British) of oil
239 994 kg of coal
494 415 kg of rock, sand, gravel
177 829 m³of natural gas
...during the whole of his life. What gives the total of 1342 632 kg or 1 343 m³ of minerals, metals and fuels. It is more than 17 tons per 1 person/year
Source: Mineral Information Institute – www.mil.org



Elements widely used in energy pathways

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

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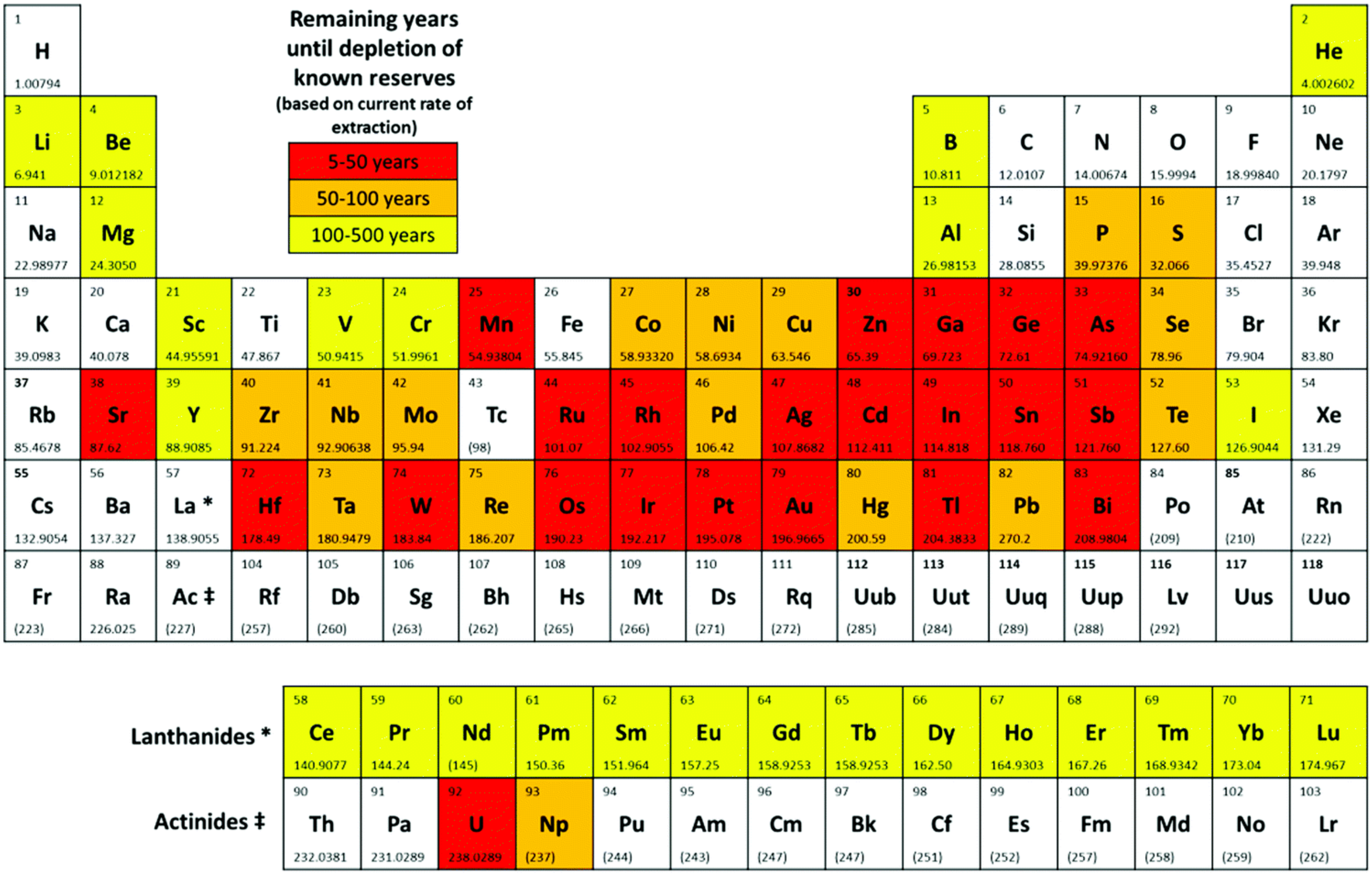
Who is «clearing» the periodic table?



What will we finish first?

UE Critical Raw Materials Third review

Critical Raw Materials			
Antimony	Fluorspar	LREEs	Phosphorus
Baryte	Gallium	Magnesium	Scandium
Beryllium	Germanium	Natural graphite	Silicon metal
Bismuth	Hafnium	Natural rubber	Tantalum
Borate	Helium	Niobium	Tungsten
Cobalt	HREEs	PGMs	Vanadium
Coking coal	Indium	Phosphate rock	

European Commission, Report on Critical Raw Materials and the Circular Economy, 16/01/2018

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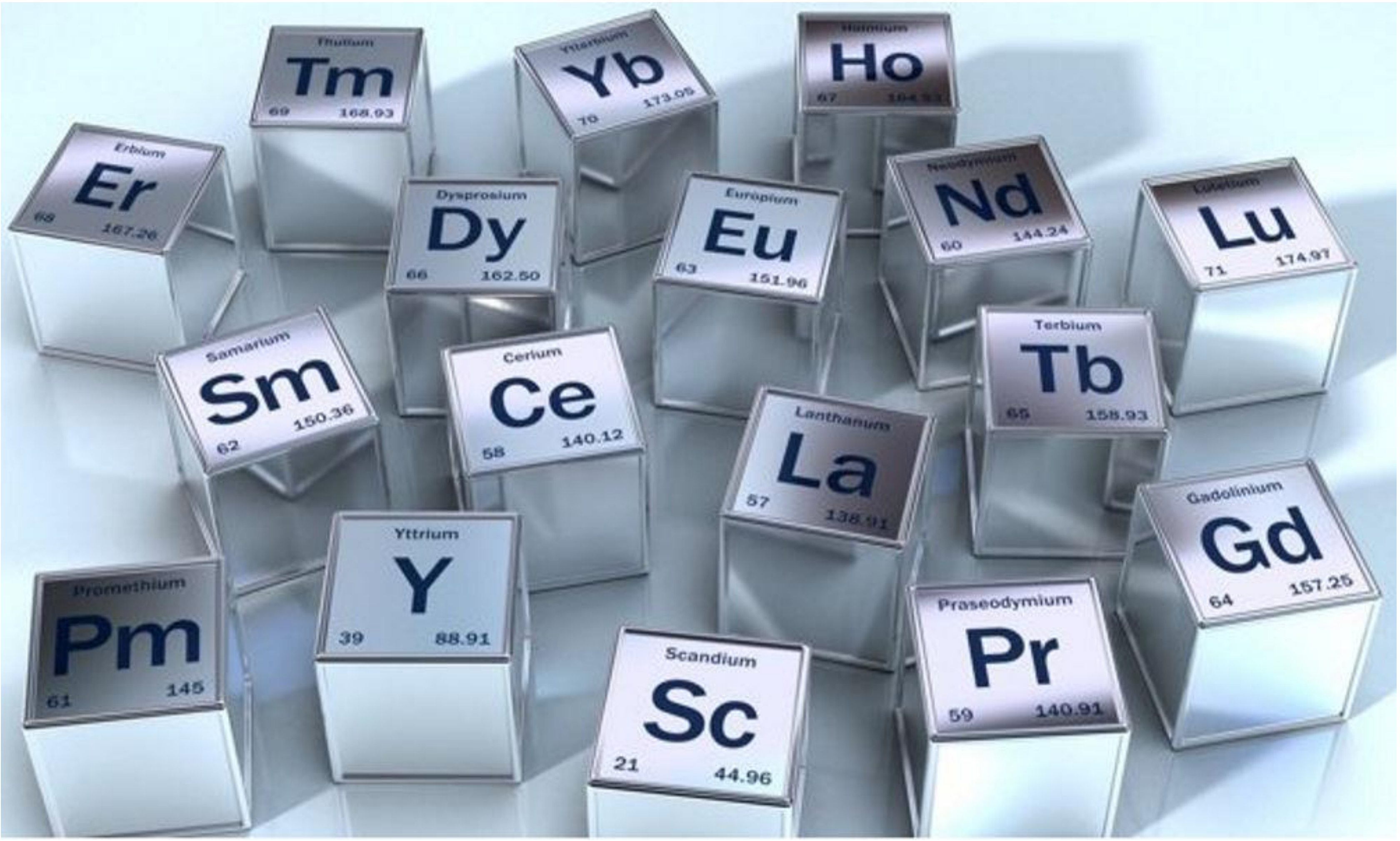
REE (Rare Earths Elements)



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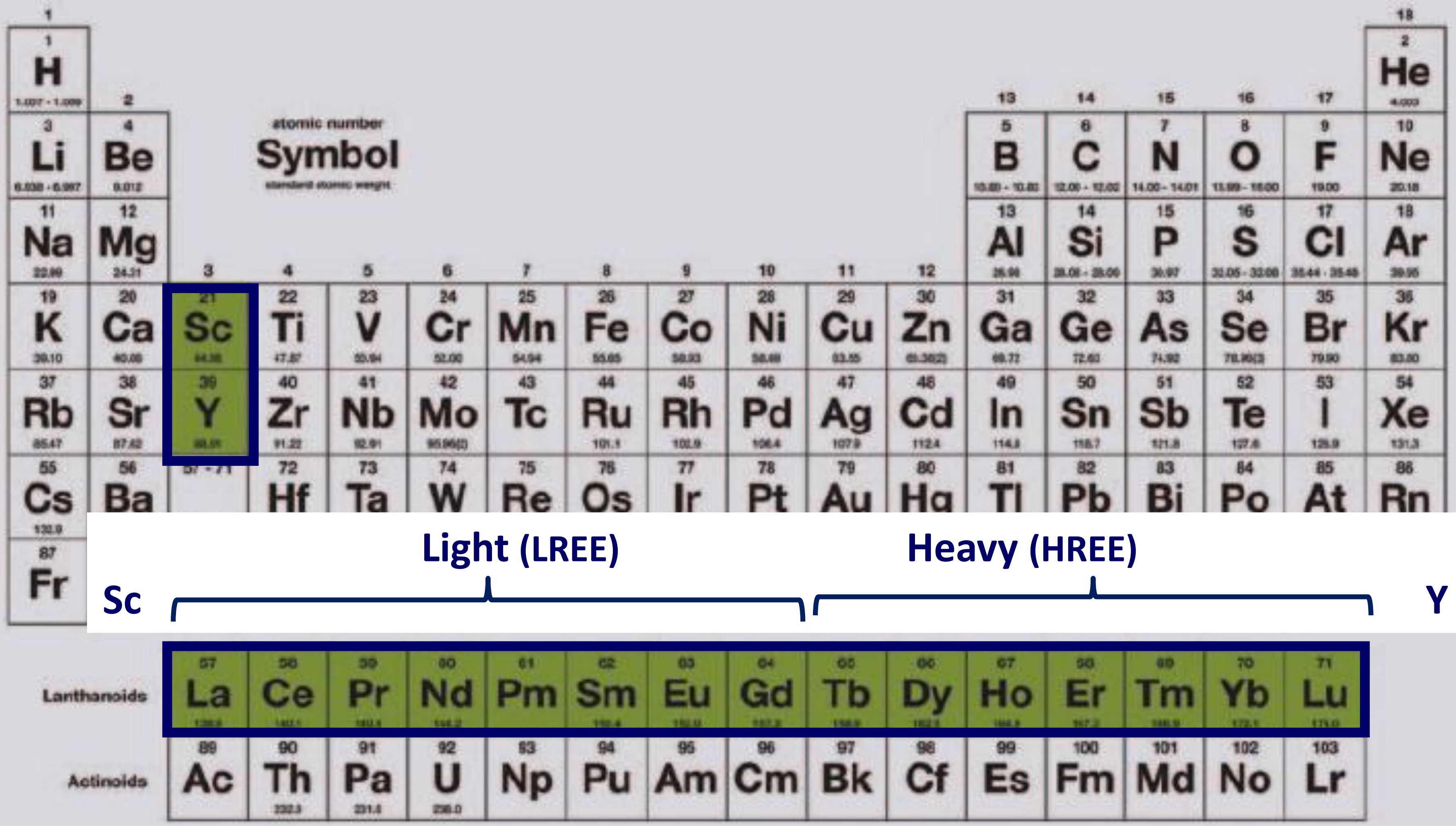
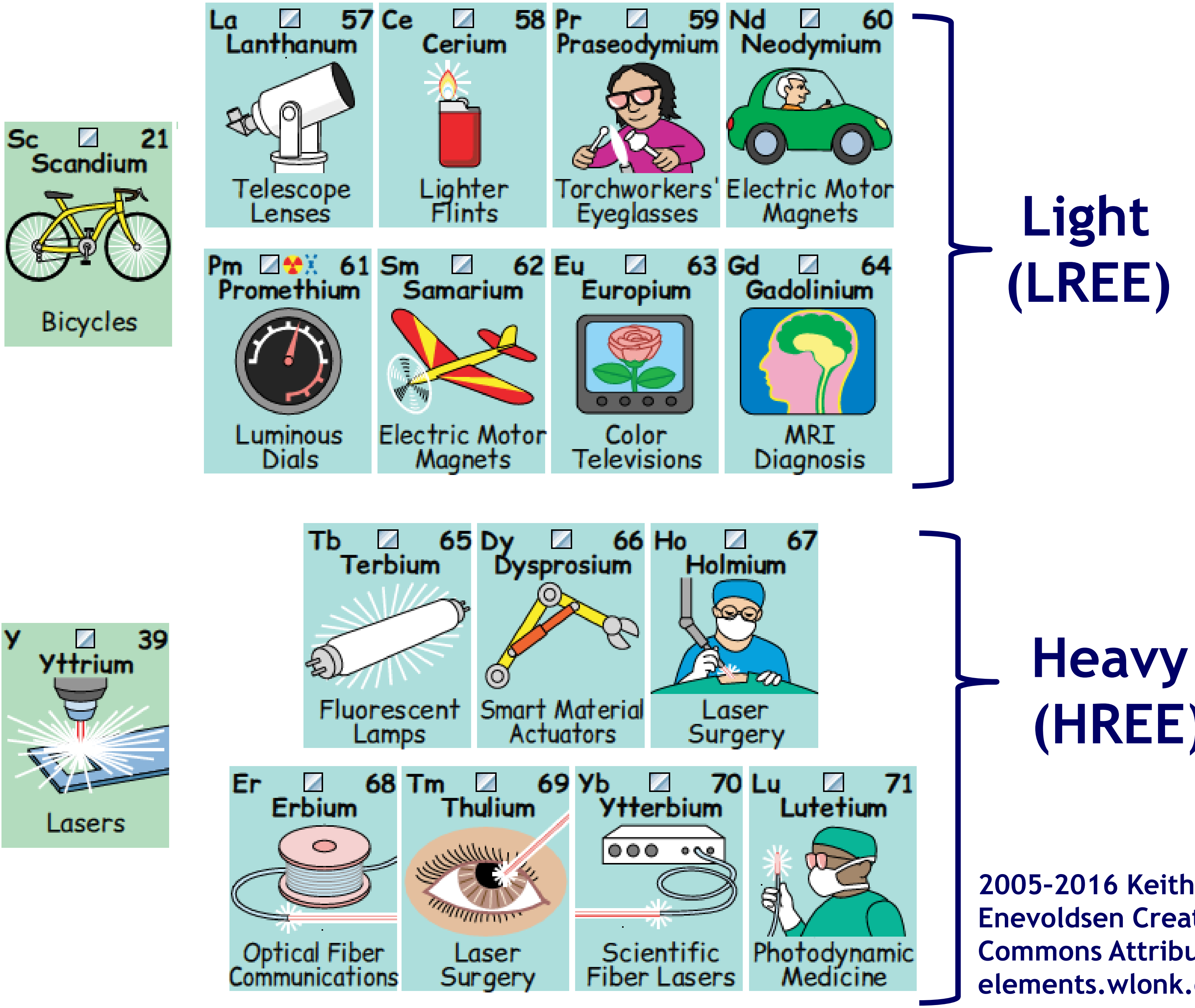
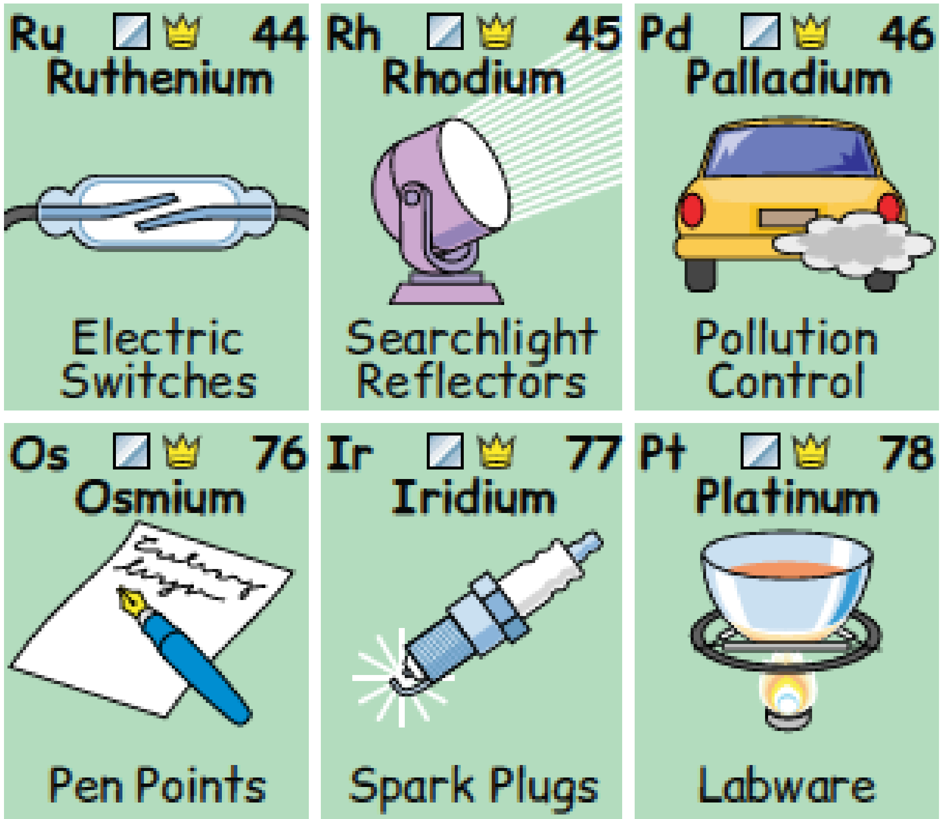
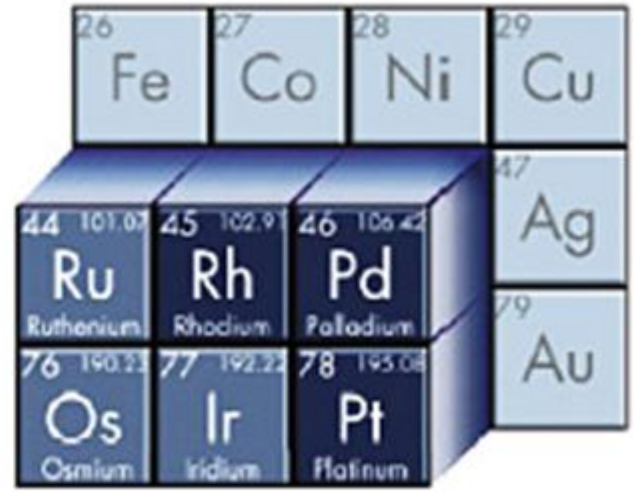
REE (Rare Earths Elements)



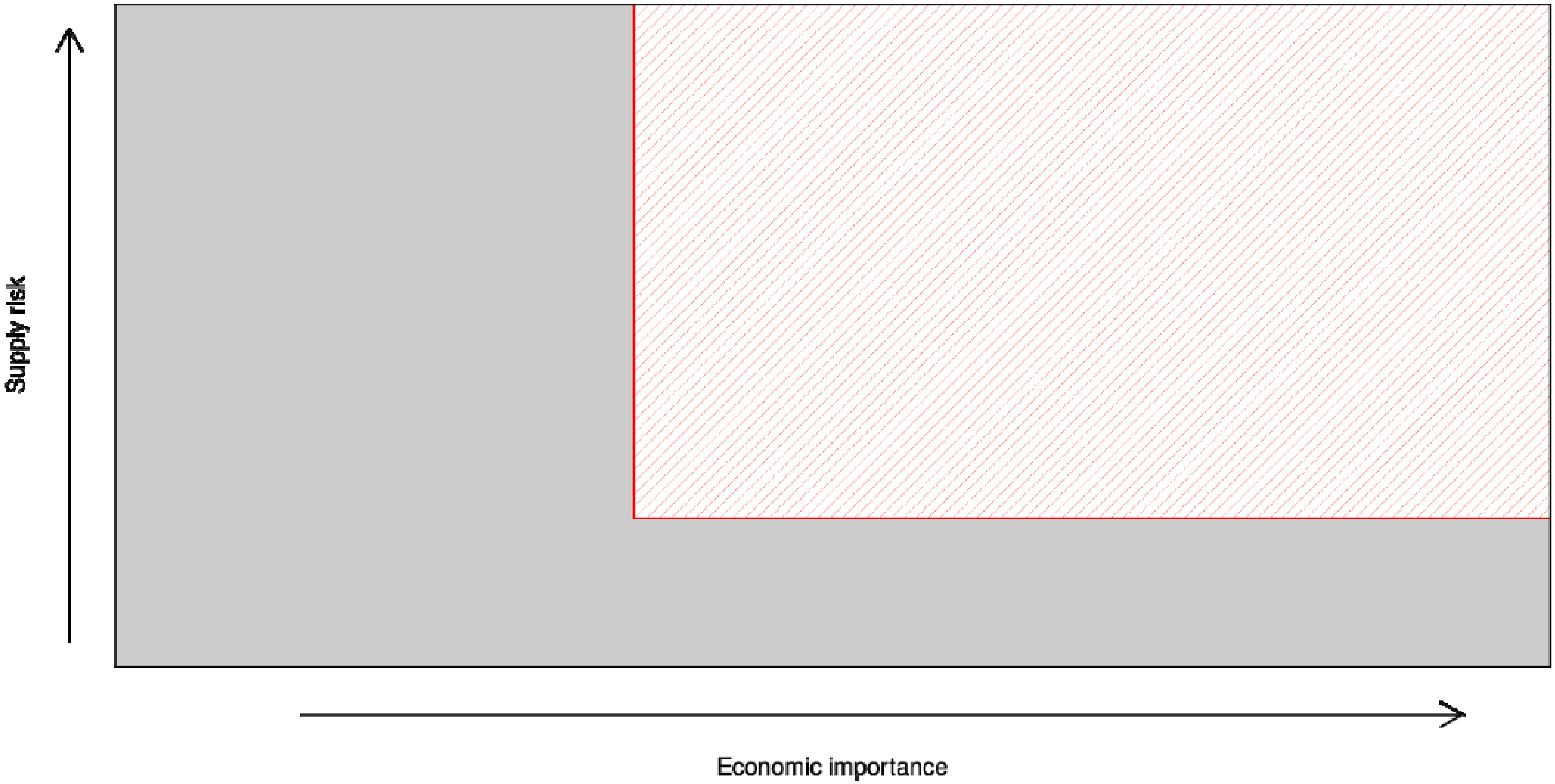

Sc 21 Scandium Bicycles
Y 39 Yttrium Lasers
La 57 Lanthanum Telescope Lenses
Ce 58 Cerium Lighter Flints
Pr 59 Praseodymium Torchworkers' Eyeglasses
Nd 60 Neodymium Electric Motor Magnets
Pm 61 Promethium Luminous Dials
Sm 62 Samarium Electric Motor Magnets
Eu 63 Europium Color Televisions
Gd 64 Gadolinium MRI Diagnosis
Light (LREE)
Tb 65 Terbium Fluorescent Lamps
Dy 66 Dysprosium Smart Material Actuators
Ho 67 Holmium Laser Surgery
Er 68 Erbium Optical Fiber Communications
Tm 69 Thulium Laser Surgery
Yb 70 Ytterbium Scientific Fiber Lasers
Lu 71 Lutetium Photodynamic Medicine
Heavy (HREE)

PGMs, Platinum Group Metals





The EC criticality methodology



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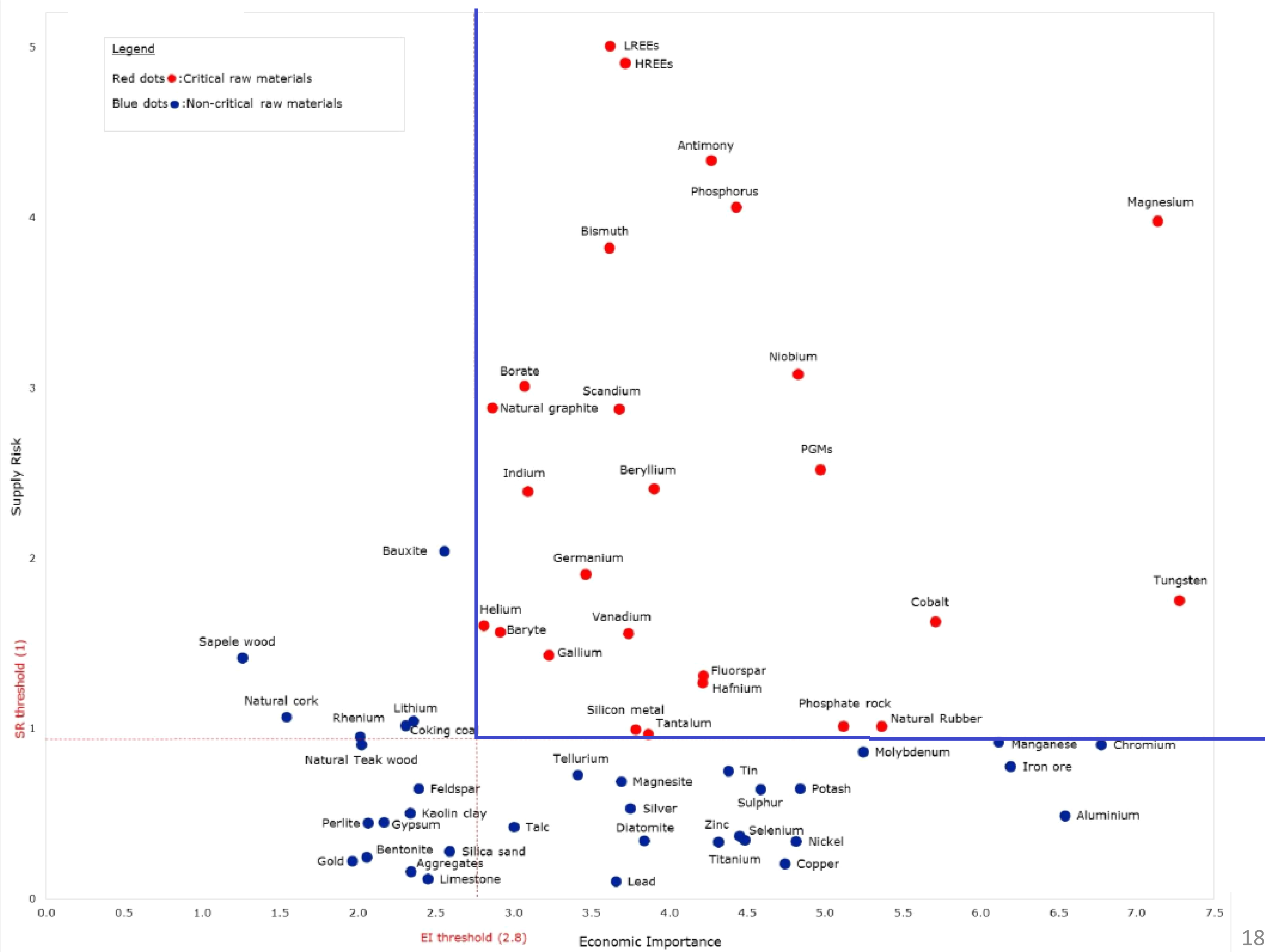
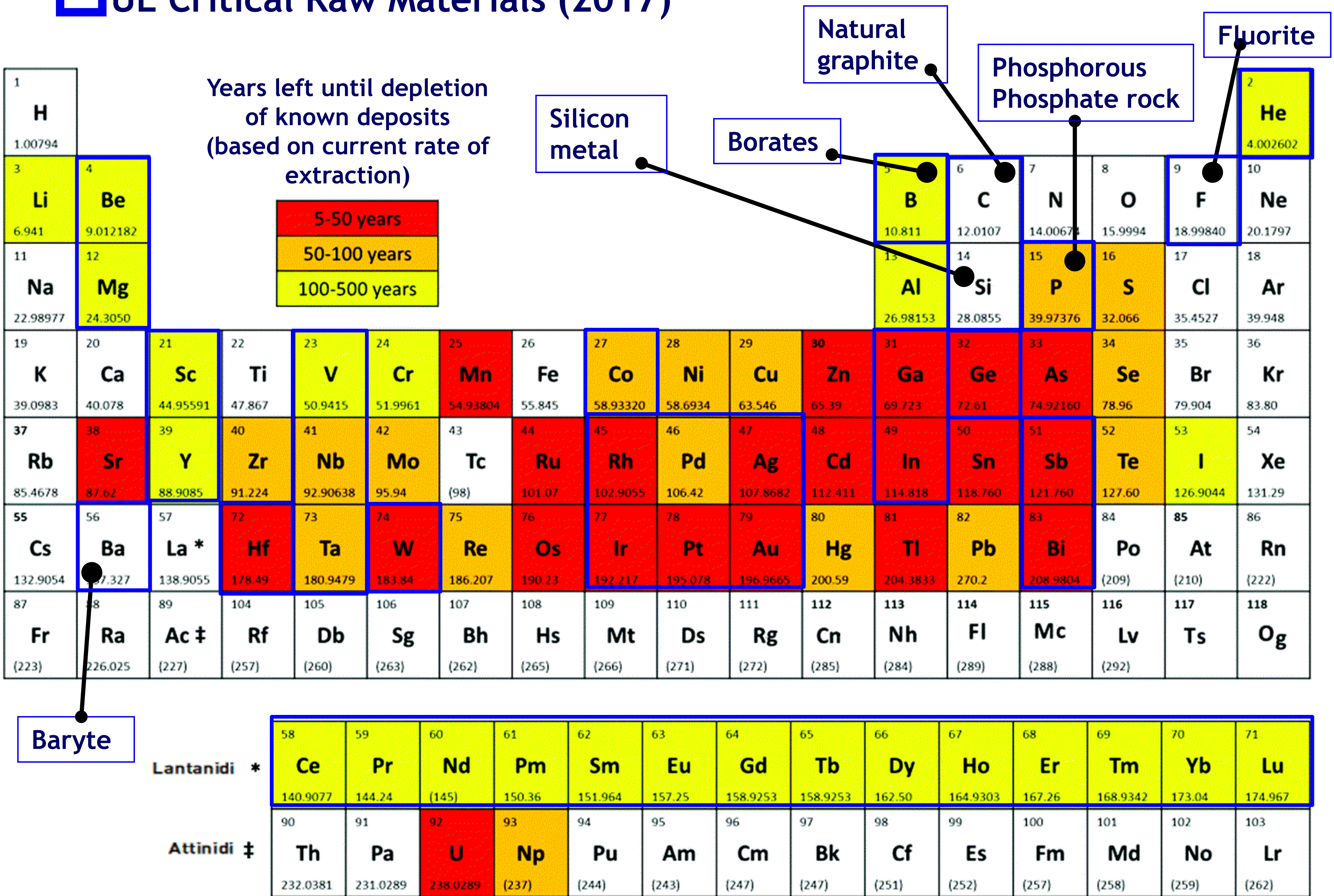
Economic importance and supply risk results of 2017 criticality assessment



UE Critical Raw Materials (2017)



Why a material becomes critical?

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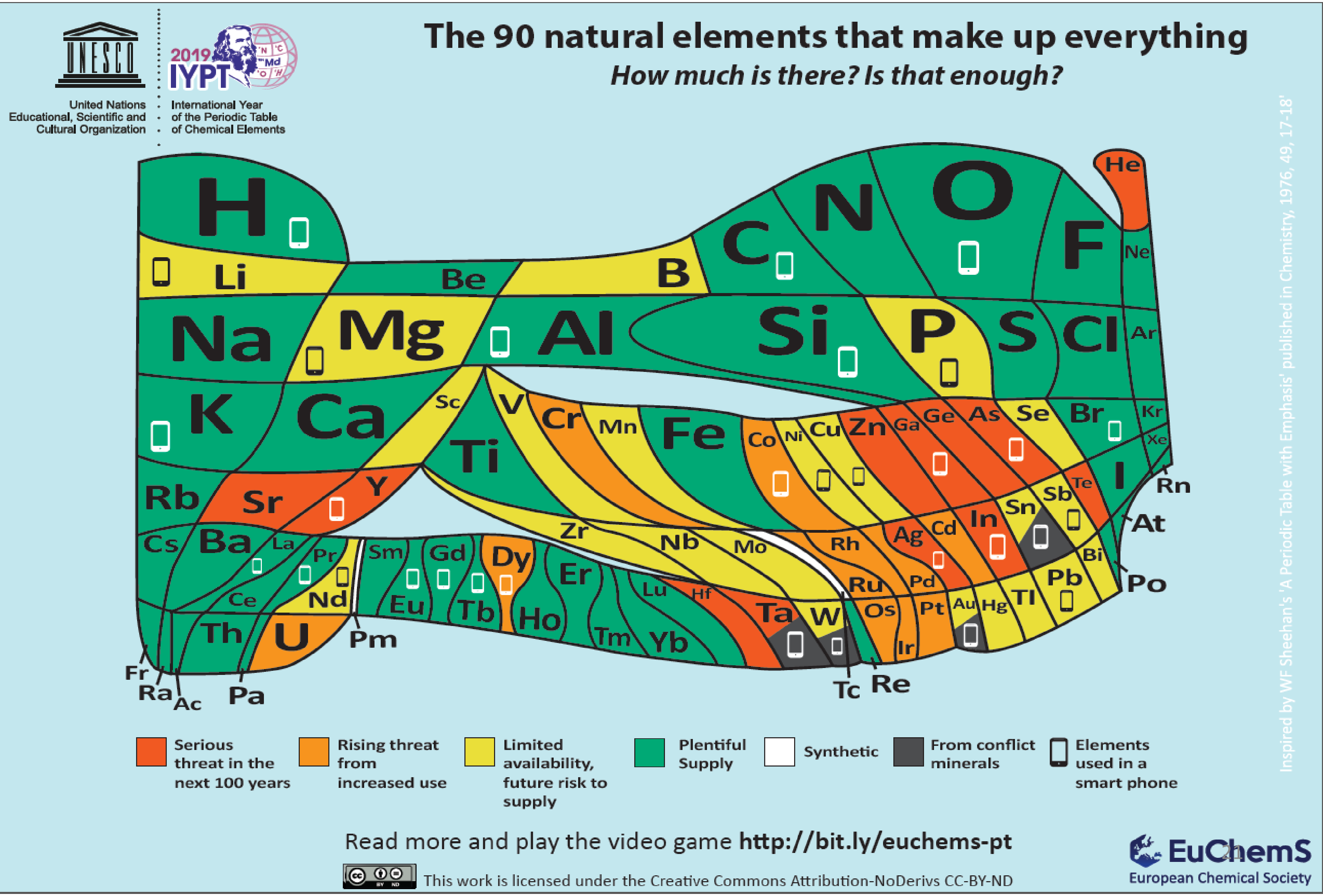
1. Low abundance on Earth's crust



Abundance of some chemical elements on the Earth's crust (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

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2. Deposits are localized in one or very few countries

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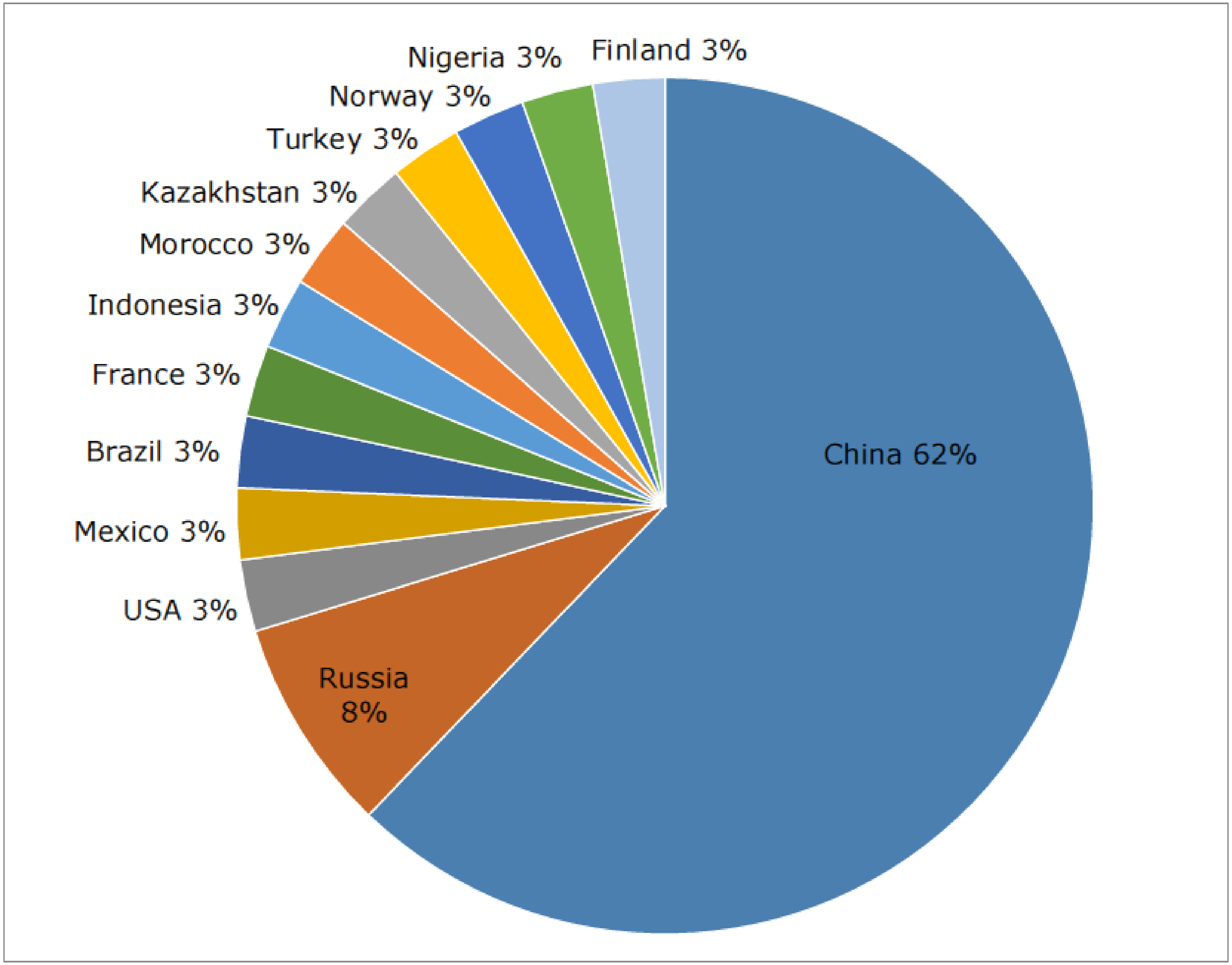
Figure D: Main EU suppliers of CRMs (based on number of CRMs supplied out of 37), average from 2010-2014



Contribution of primary global suppliers of critical raw materials, average from 2010-2014

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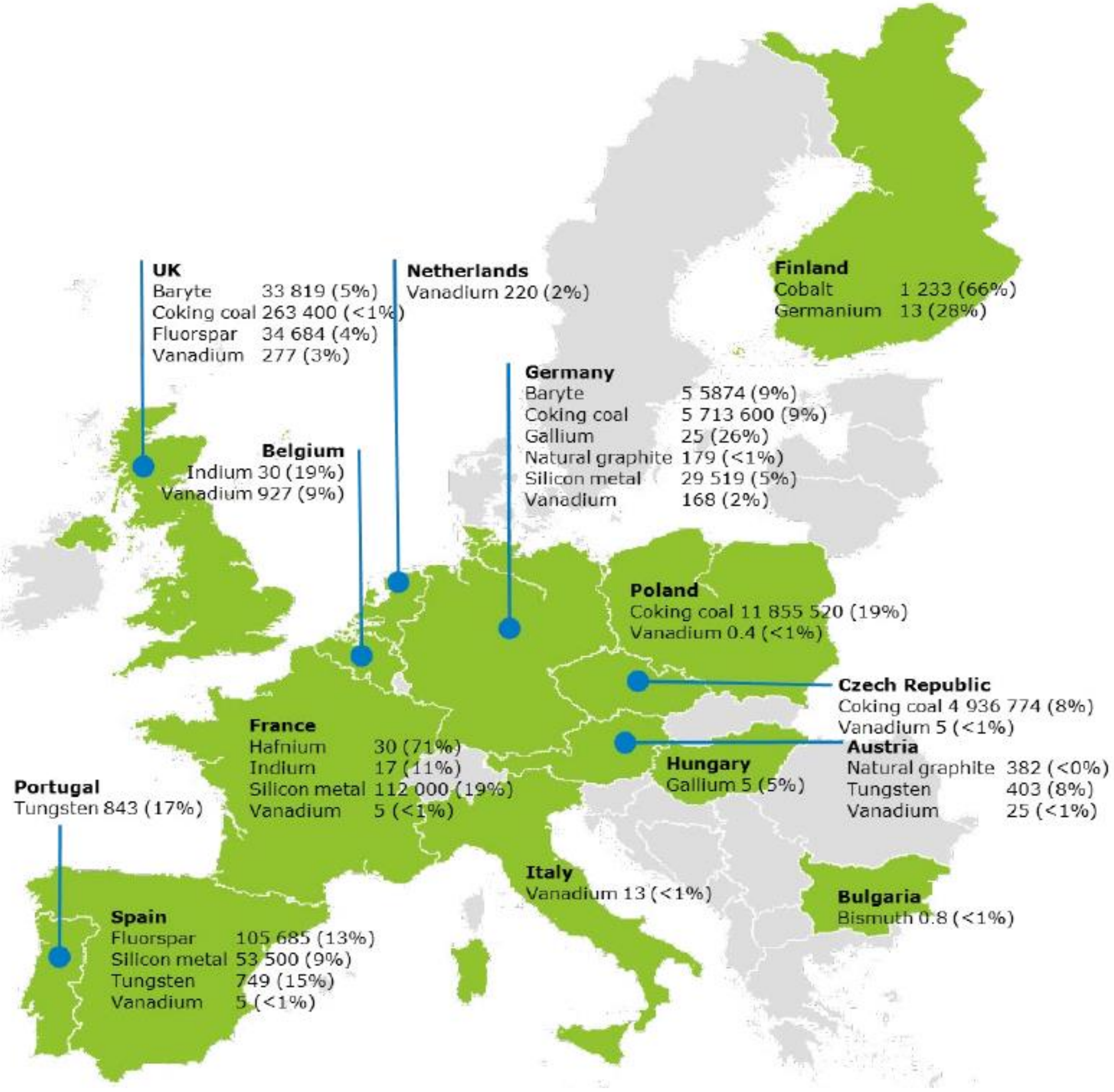
EU production of primary CRMs in tonnes (and share of supply to EU), average from 2010-2014



The rare earth crisis

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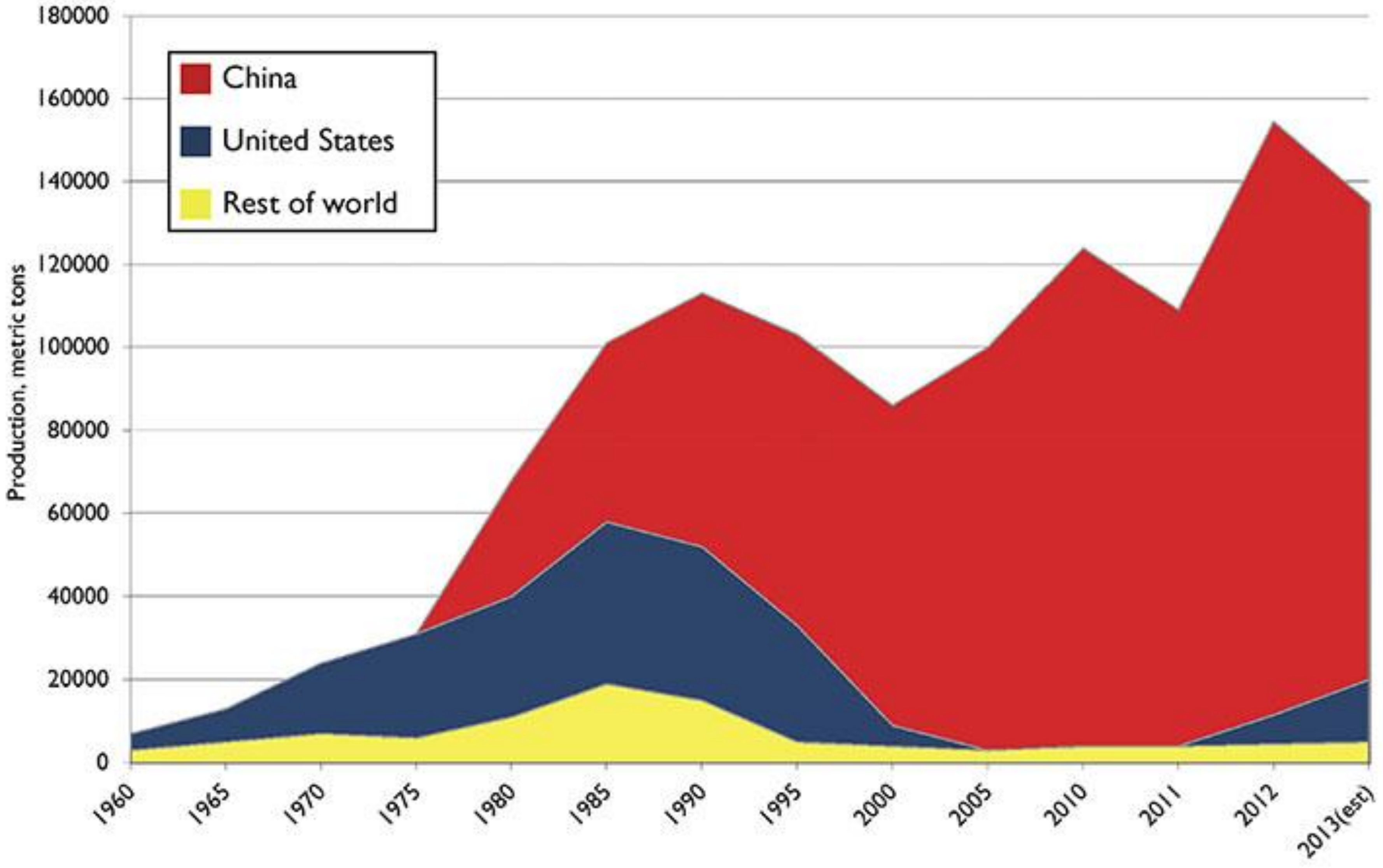

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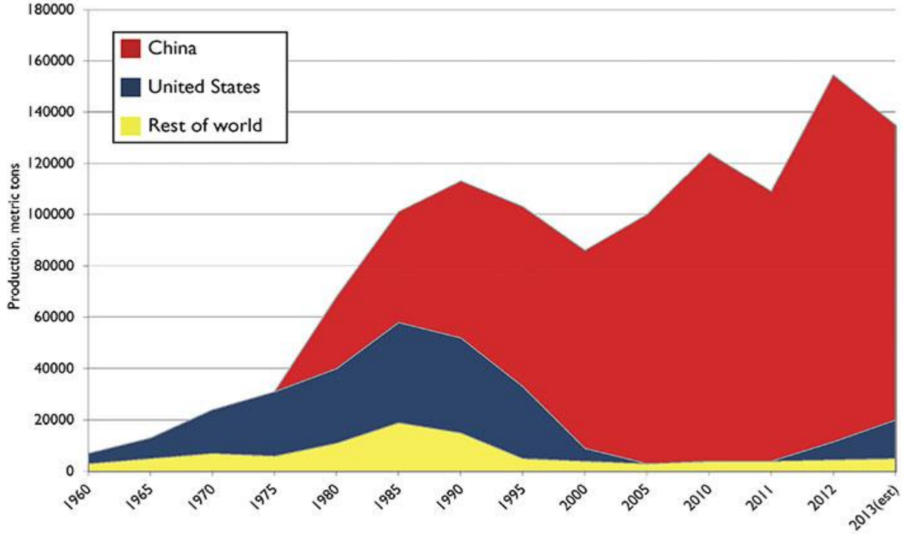
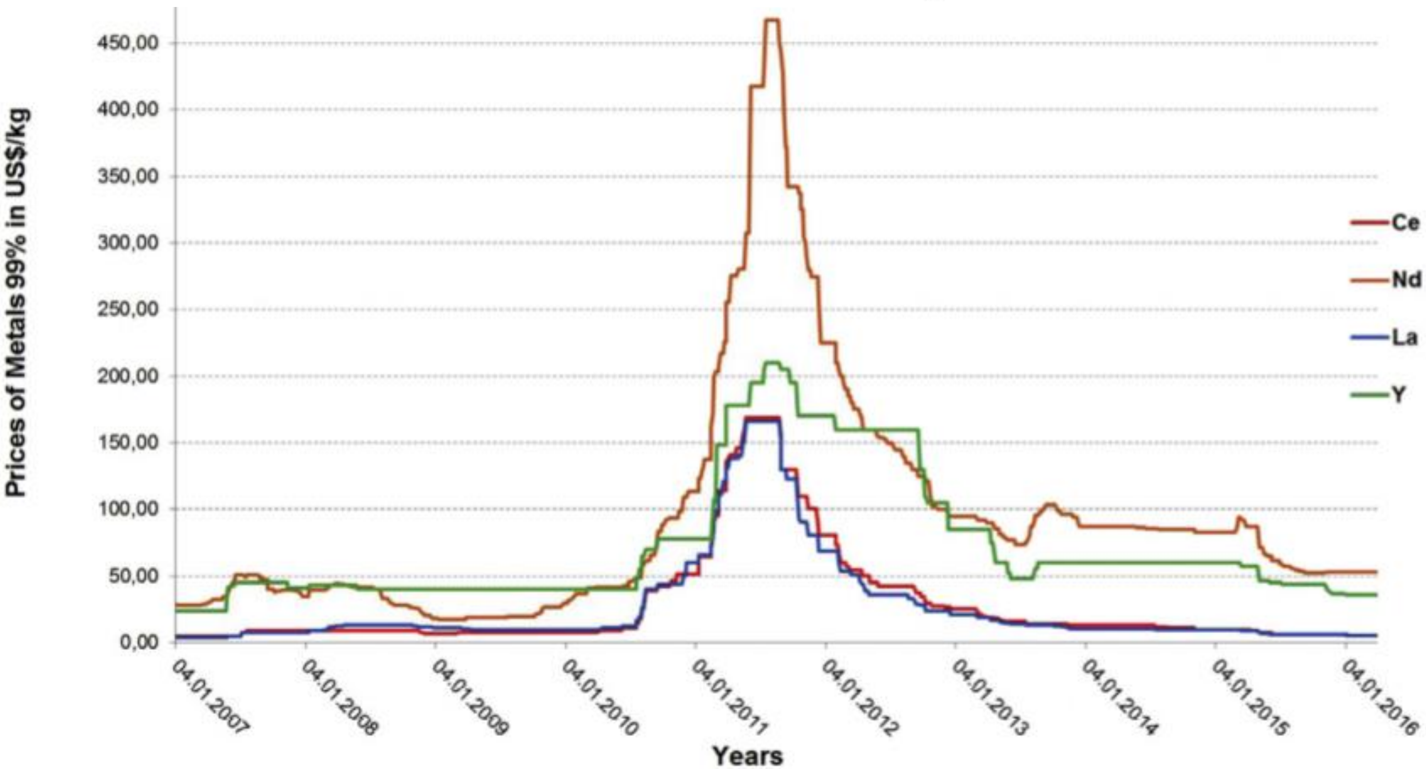




Metal prices development during the last 10 years for selected REE (Metal-pages, 2016).

As Rare Earth Fell, So Did Molycorp

Mining company fate tied to neodymium prices

3. The extraction method is dangerous and/or produces pollution

acids from a copper mine

Argentina, cyanide spill caused the pollution of five rivers

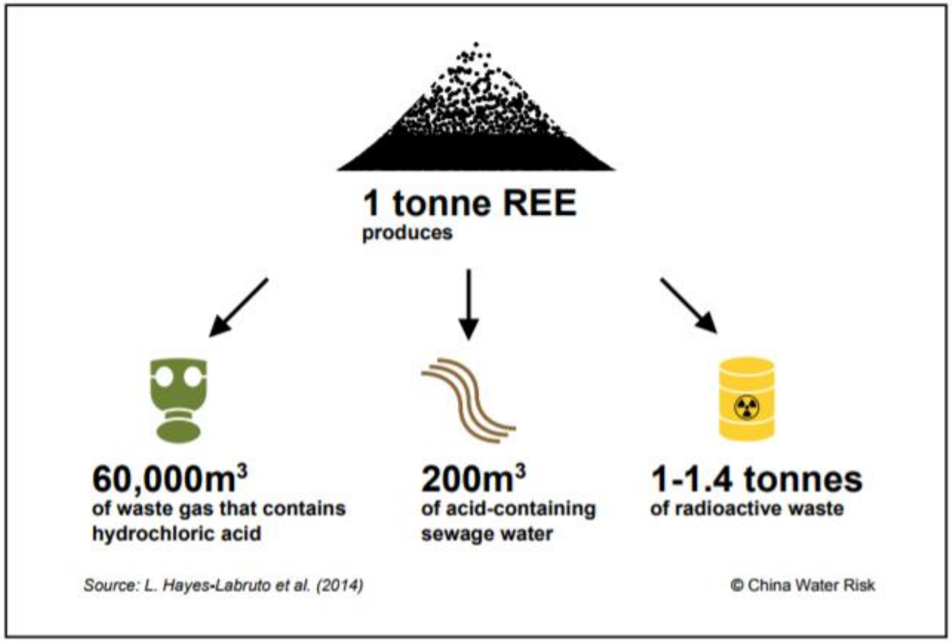
fishes killed by a cyanide spill

Mining town of Norilsk (Russia)

Production of 35% Pd, 25% Pt, 20% Ni, 10% Co of the world

Mountain Pass mine (USA)

Rare Earth Production Comes With Toxic Waste



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

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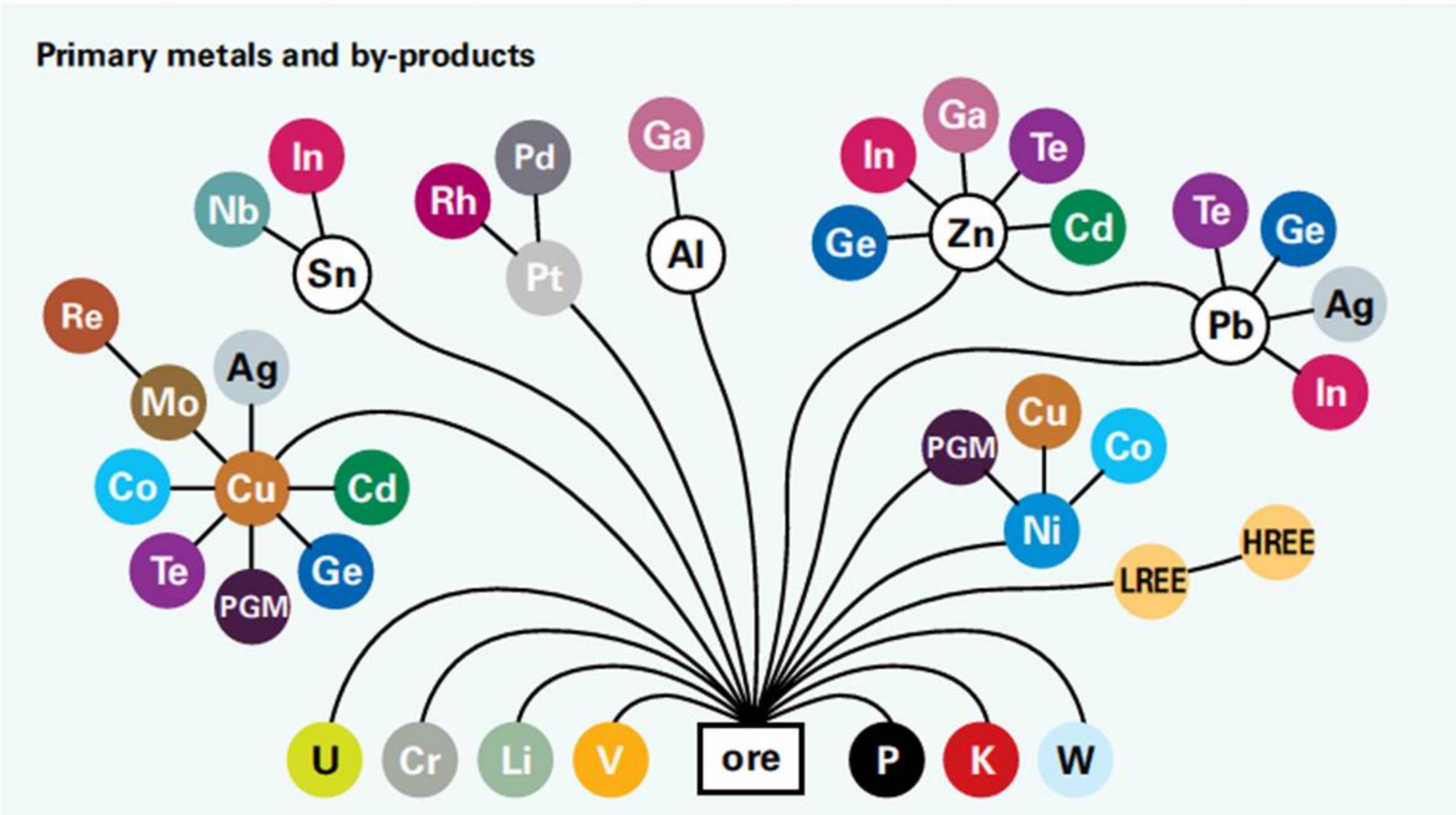
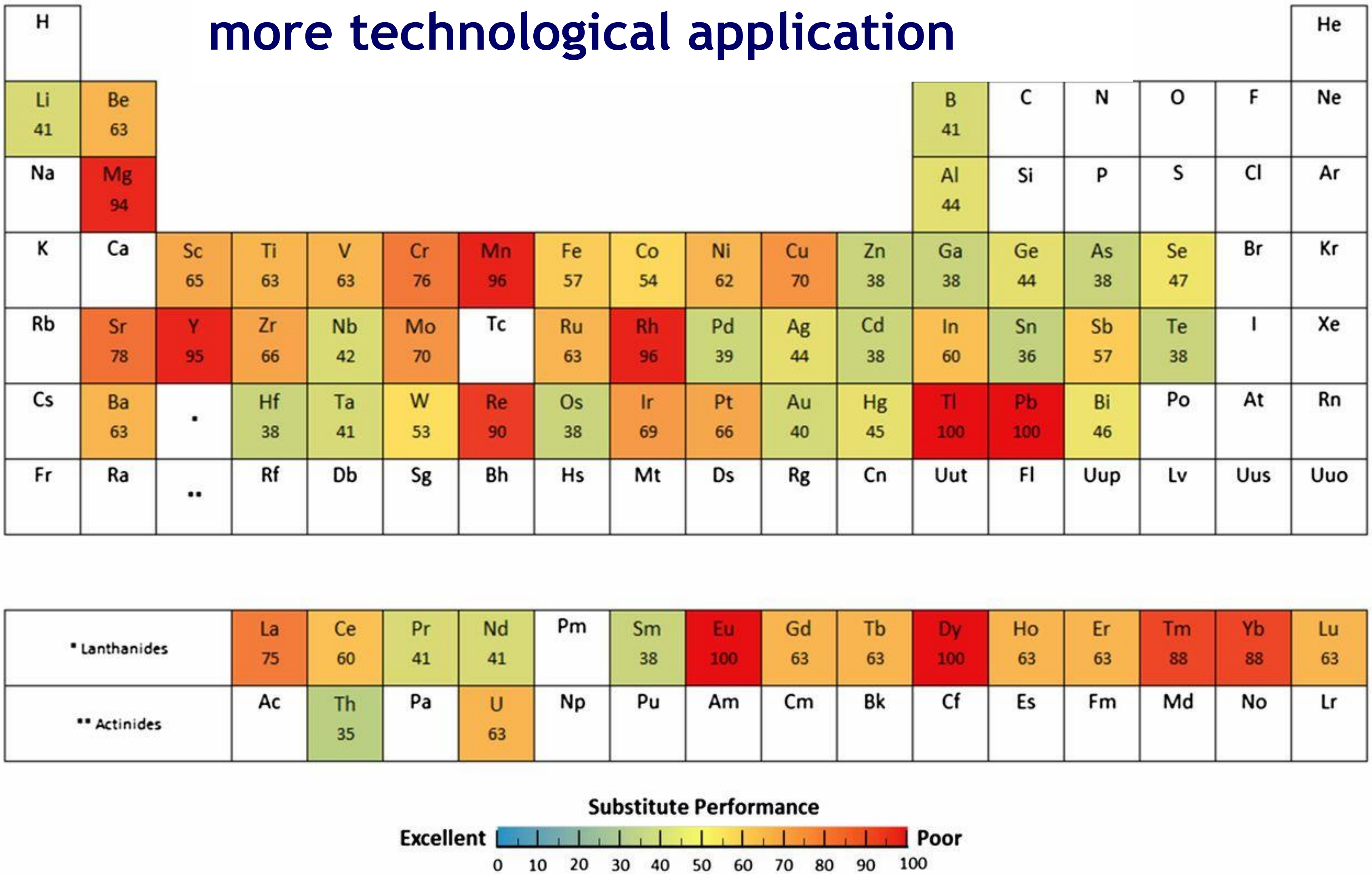
The hitch-hikers



Schematic representation of the routes from ore to elements described in this handbook, indicating primary versus those produced as co- or by-products (adapted from Hagelüken & Meskers, 2010).

4. Cannot be substituted in one or more technological application



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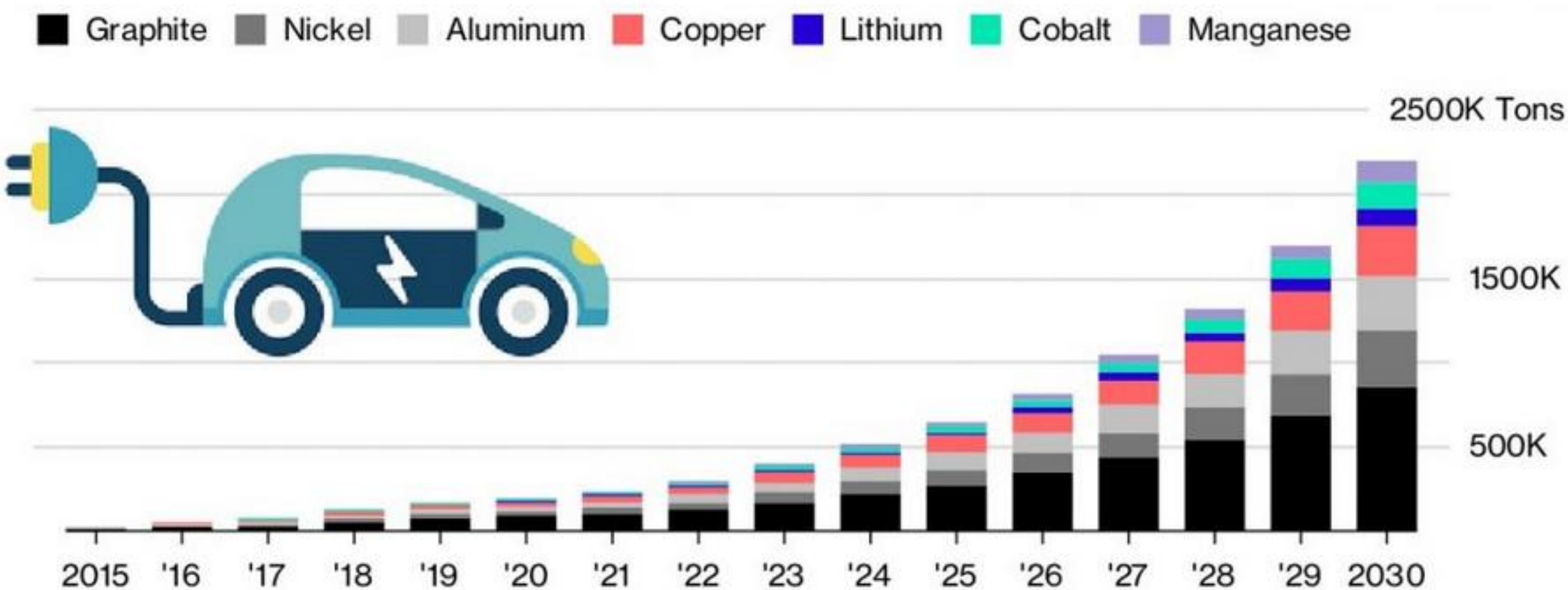
Demand Surge

Global metals and materials demand from EV lithium-ion batteries



Source: Bloomberg New Energy Finance

Bloomberg

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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

29 Cu Copper · 47 Ag Silver · 79 Au Gold · 73 Ta Tantalum

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.

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

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.

14 Si Silicon · 8 O Oxygen · 51 Sb Antimony · 33 As Arsenic · 15 P Phosphorus · 31 Ga Gallium

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.

50 Sn Tin · 82 Pb Lead

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

BATTERY

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

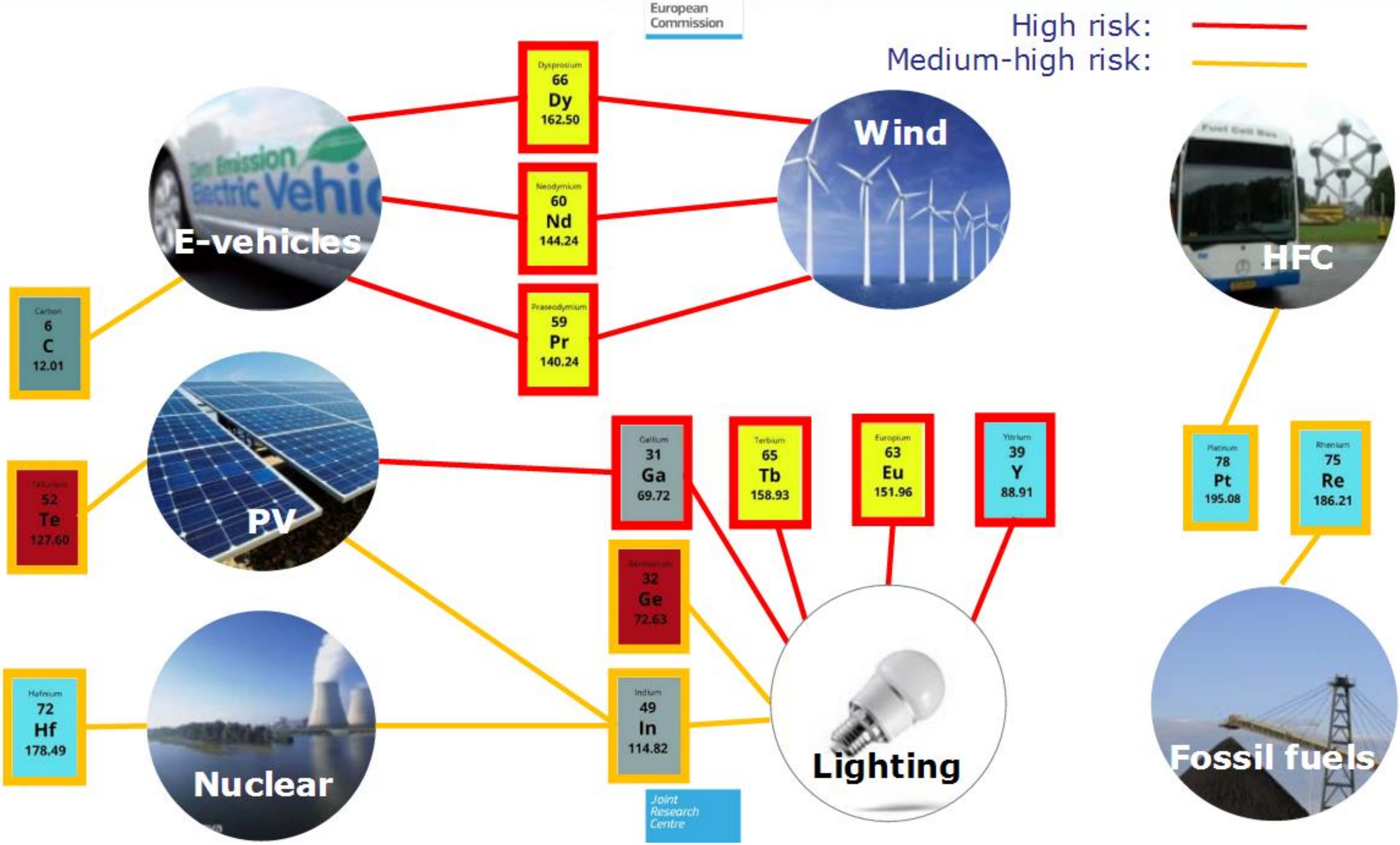
The majority of phones use lithium ion batteries, which are composed of lithium cobalt oxide as a positive electrode and graphite (carbon) as the negative electrode. Some batteries use other metals, such as manganese, in place of cobalt. The battery's casing is made of aluminium.

CASING

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

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.

Energy technologies at risk



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One 3-MW turbine contains

- 335 tons of steel
- 4.7 tons of copper
- 1,200 tons of concrete (cement and aggregates)
- 3 tons of aluminum.
- 2 tons of rare earth elements
- zinc
- molybdenum

Source: (NW Mining Association)

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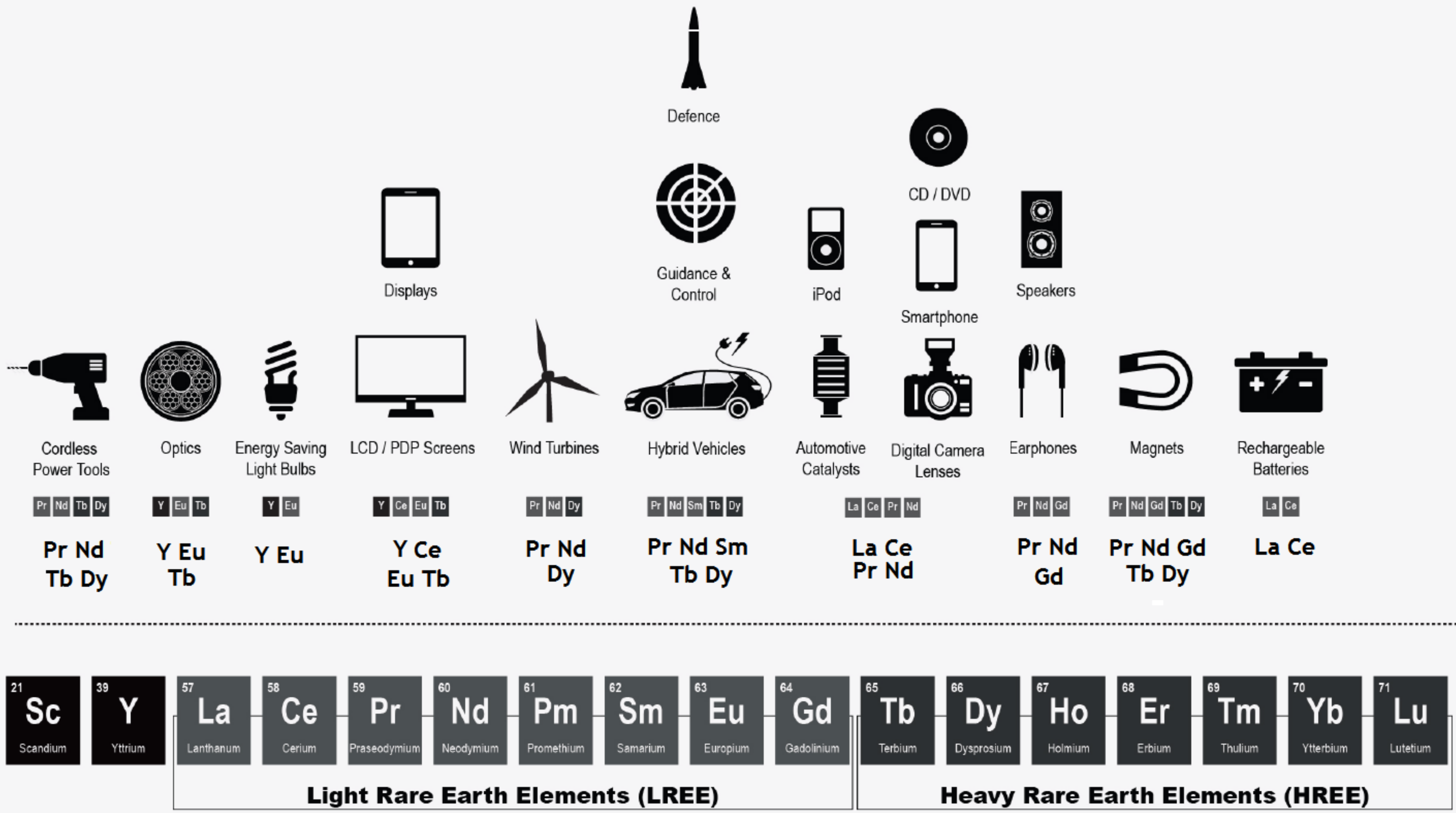

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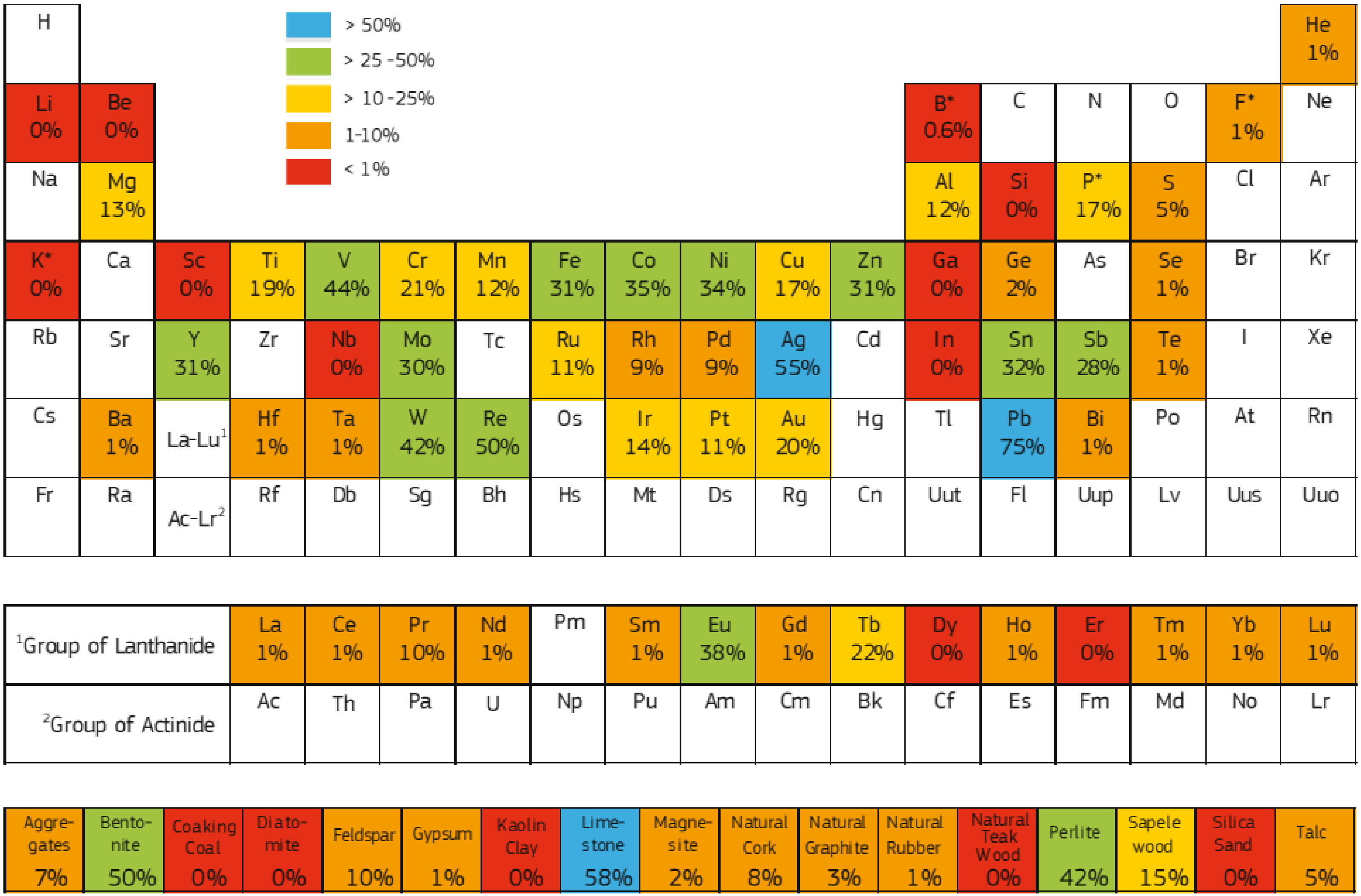
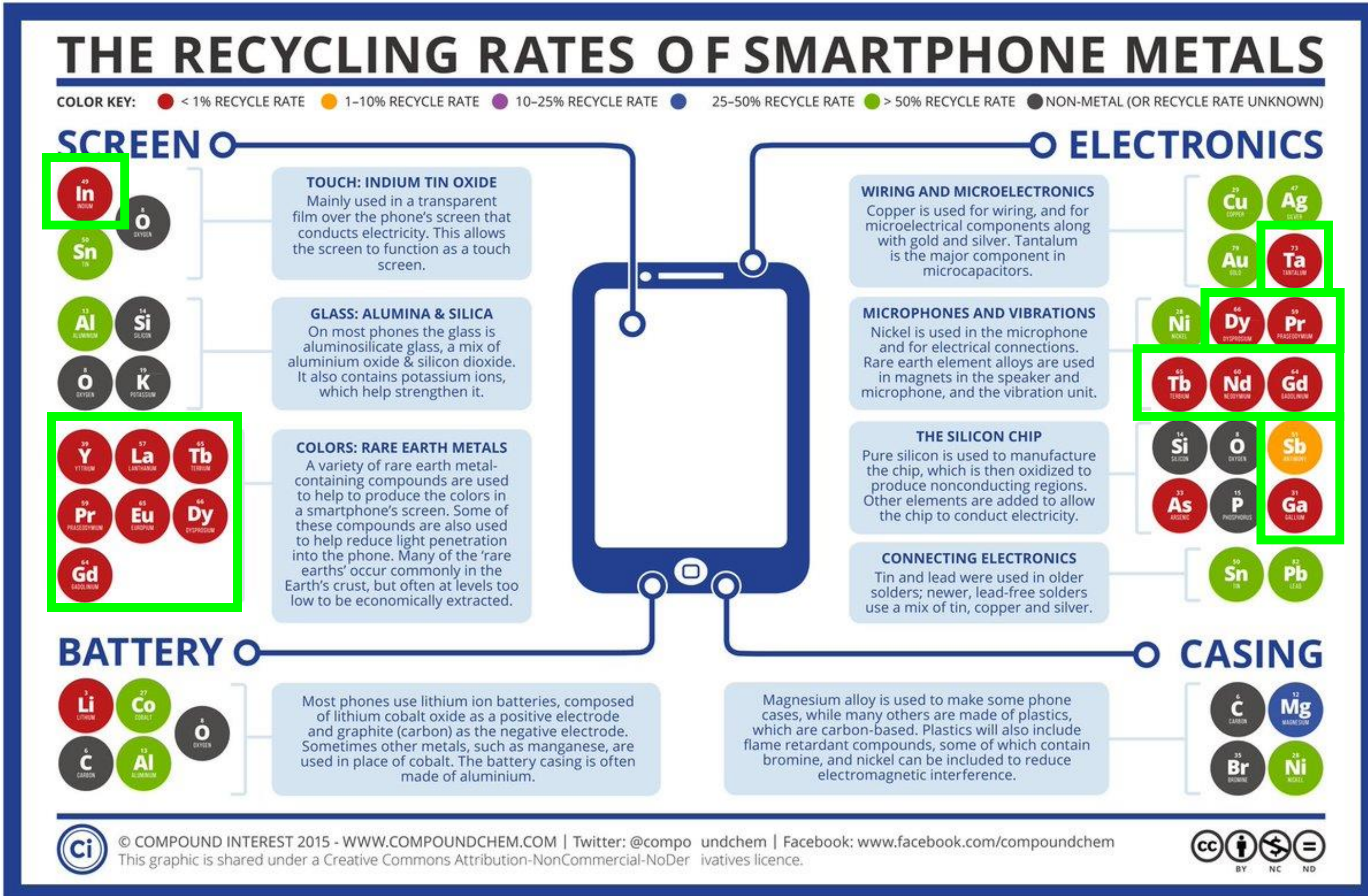
5. Recyclig is absent, insufficient or difficult

End-of-life recycling input rates (EOL-RIR) in the EU-28 (CRMs and non-CRMs)

End-of-life recycling input rate (EOL-RIR) [%]



* F = Fluorspar; P = Phosphate rock; K = Potash, Si = Silicon metal, B = Borates.



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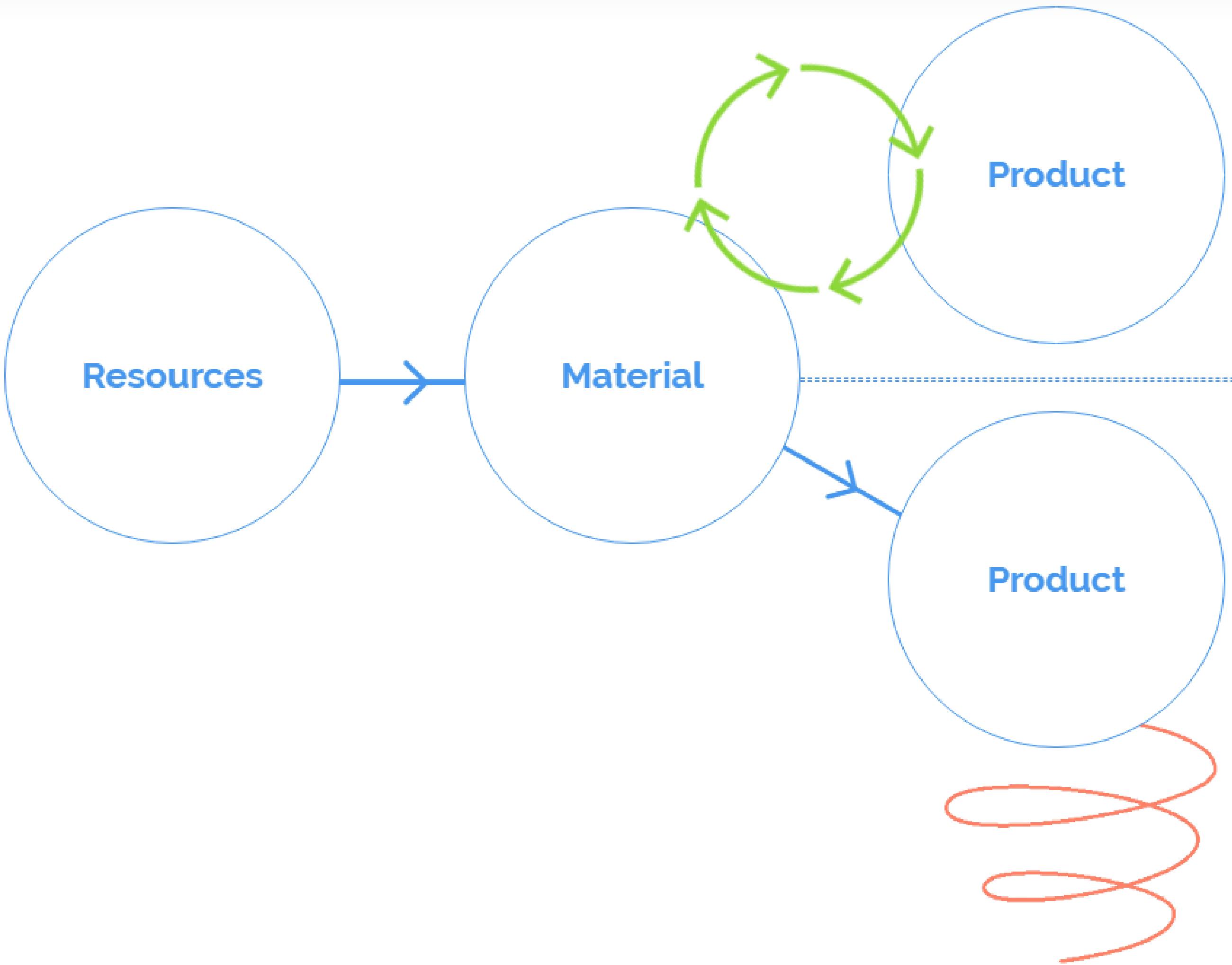

METAL recycles forever™

Permanent material loop

Non-permanent material spiral to end of life

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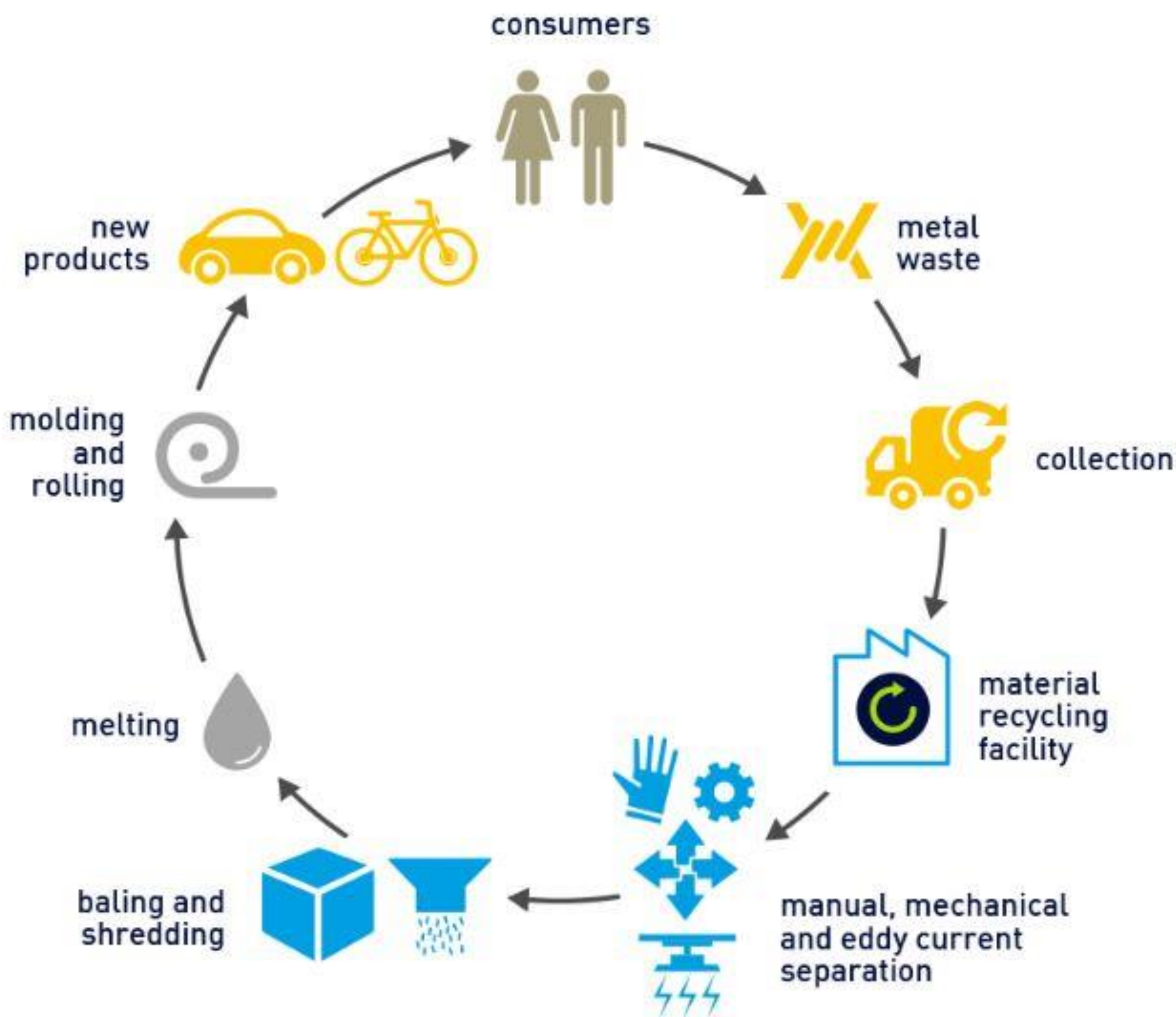
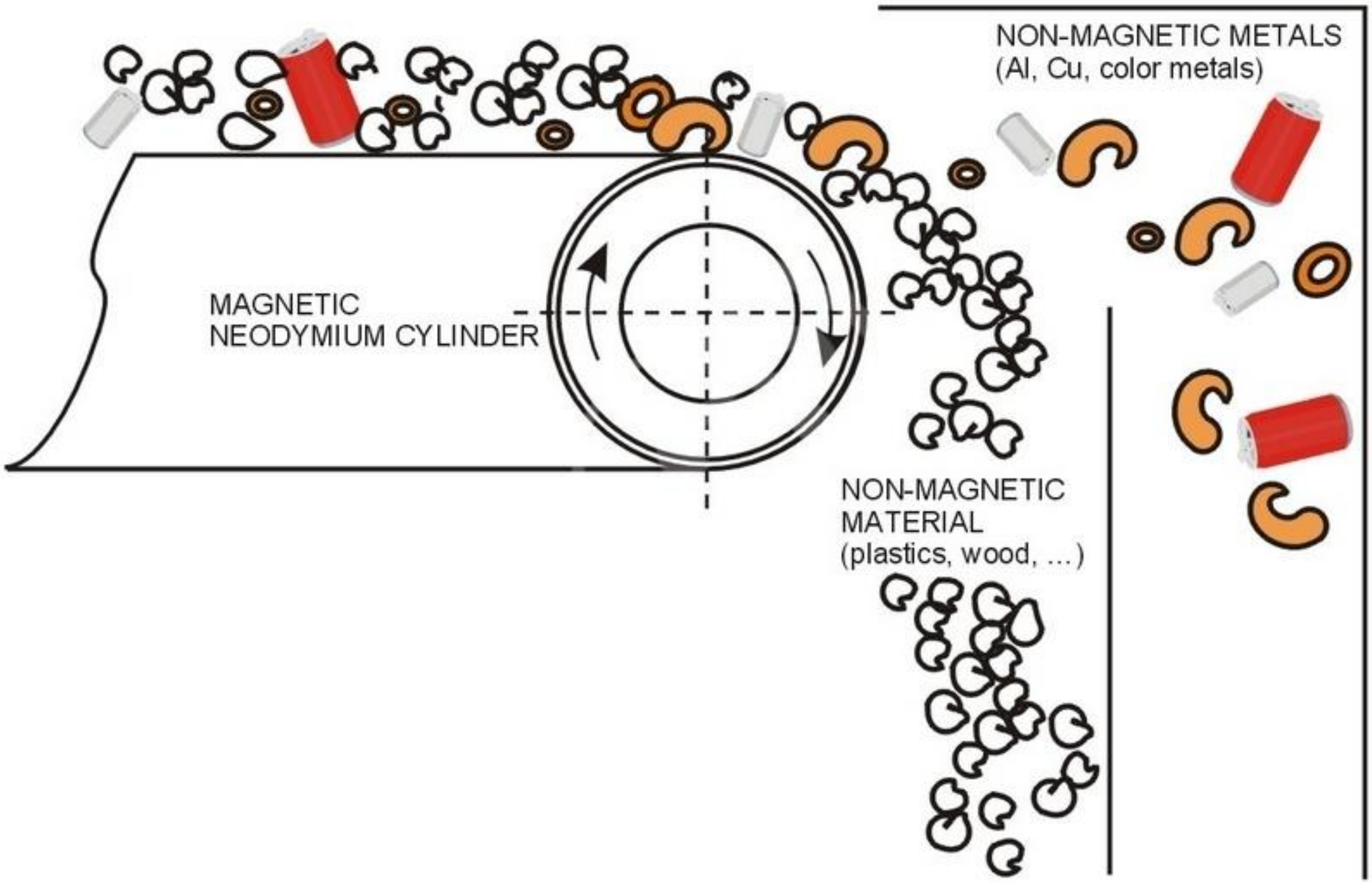

consumers
metal waste
collection
material recycling facility
manual, mechanical and eddy current separation
baling and shredding
melting
molding and rolling
new products

Metal waste separation



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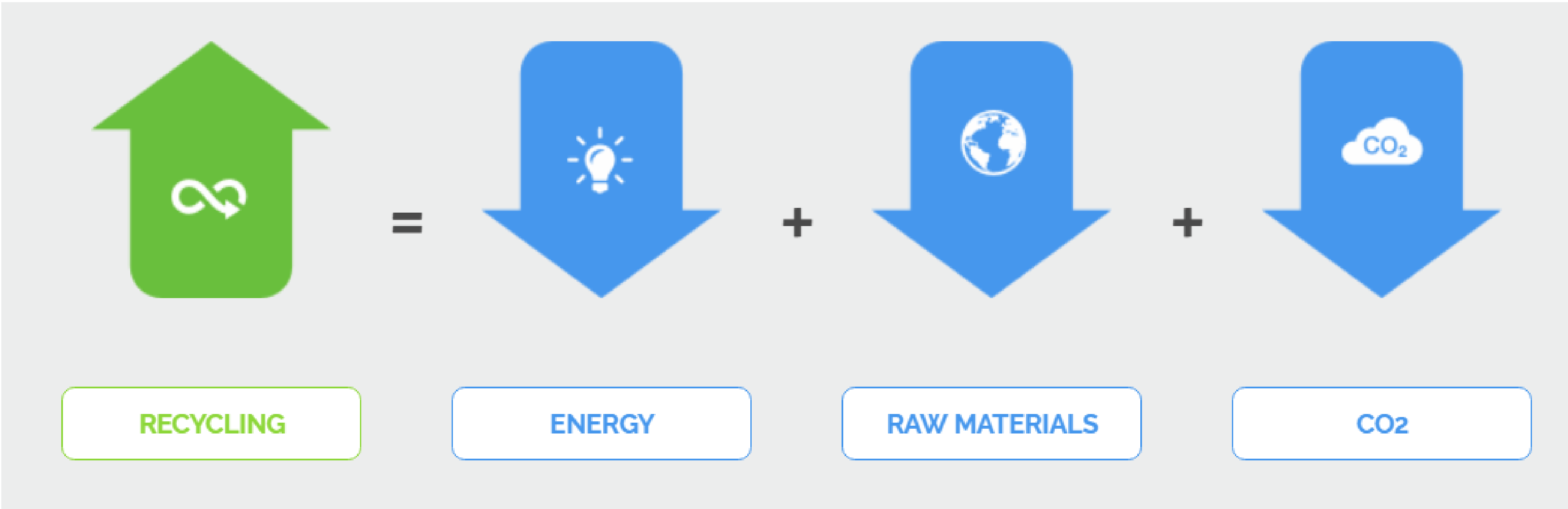

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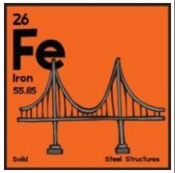

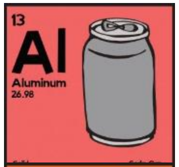

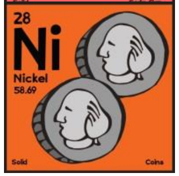

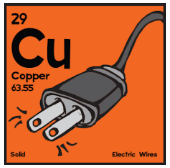

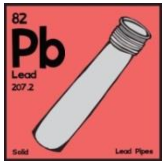

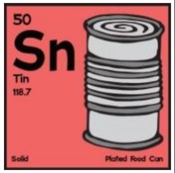

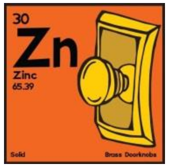

Metal	Recycle (%)	Energy saved (%)	CO_2 saved (%)
Steel	42	60	58
Aluminum	40	95	92
Nickel	60	90	90
Copper	35	80	65
Lead	74	98	99
Tin	75	98	99
Zinc	20	60	76

Losses in the recovery chain

❖ WEEE are not collected, everything ends in a landfill

❖ WEEE are collected, but:

- Are stolen in municipal collecting points or during the following recycling stages

- Are legally exported in developing countries were recycling is not active

- Are collected for sham recycling


E-waste in India


E-waste in India

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

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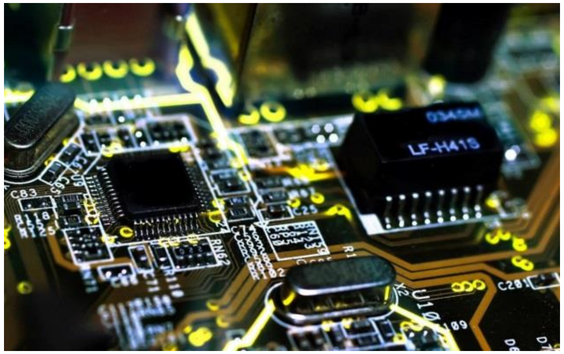
❖ When WEEE collection is active, there are losses in recycling due to:

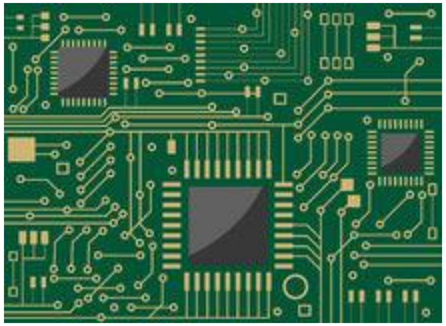
- Wrong separate collection

- Losses in the mechanical treatment

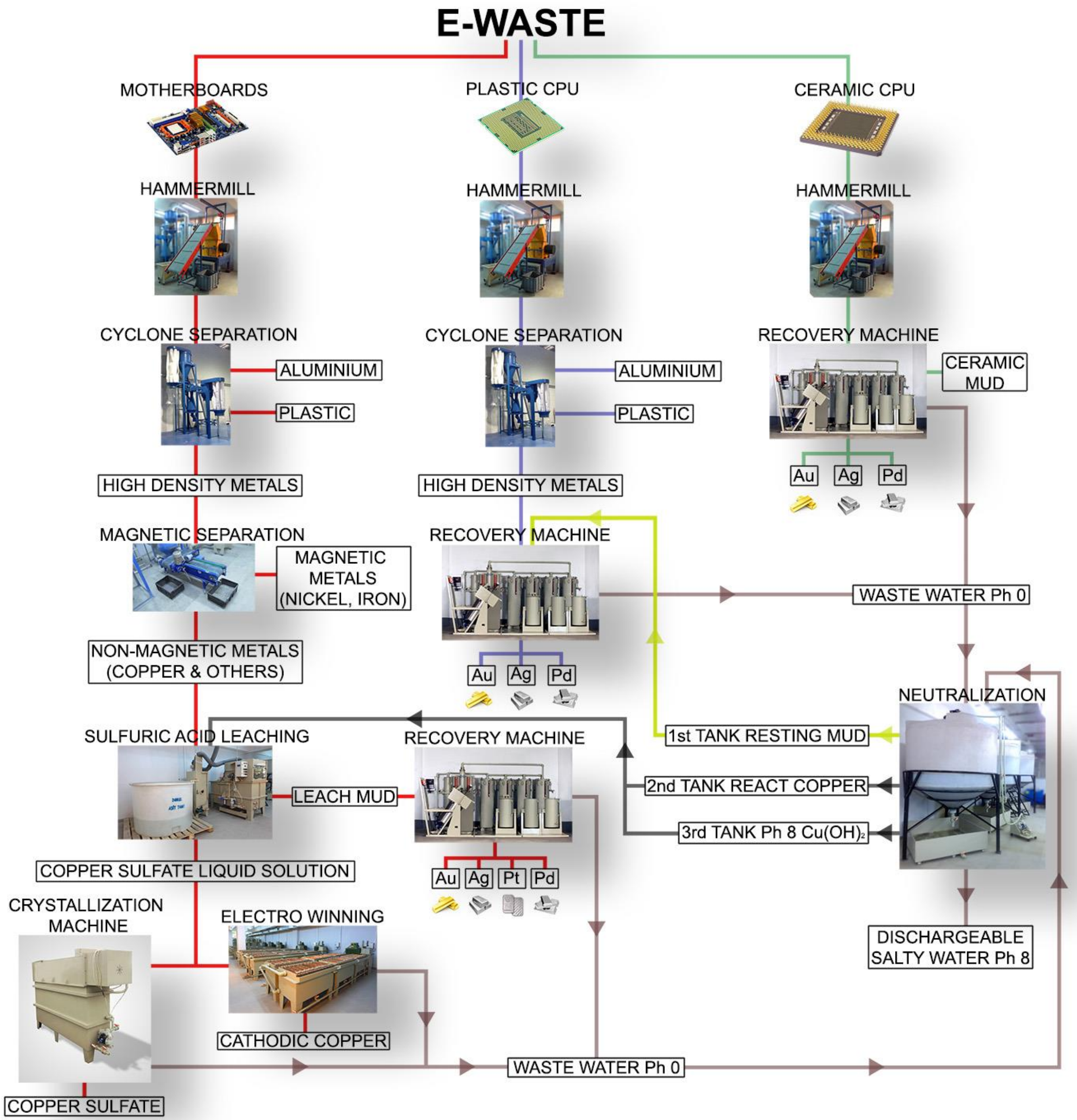
•Technical limits for the recovery of metals from several alloys



•Miniaturization and use of strong glues in circuits



•Many plants recover only metals with have an established and profitable market



Materials recovered

plastic

ceramic

gold

silver

platinum

palladium

copper

aluminum

nickel

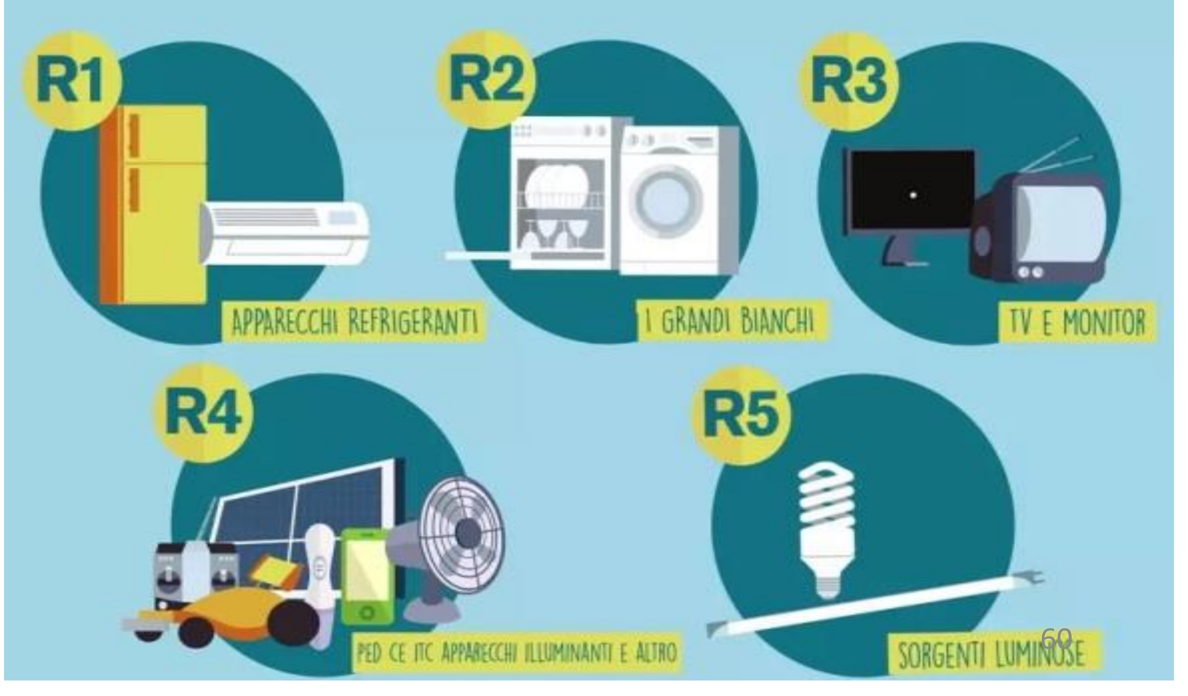
iron

Metals in waste

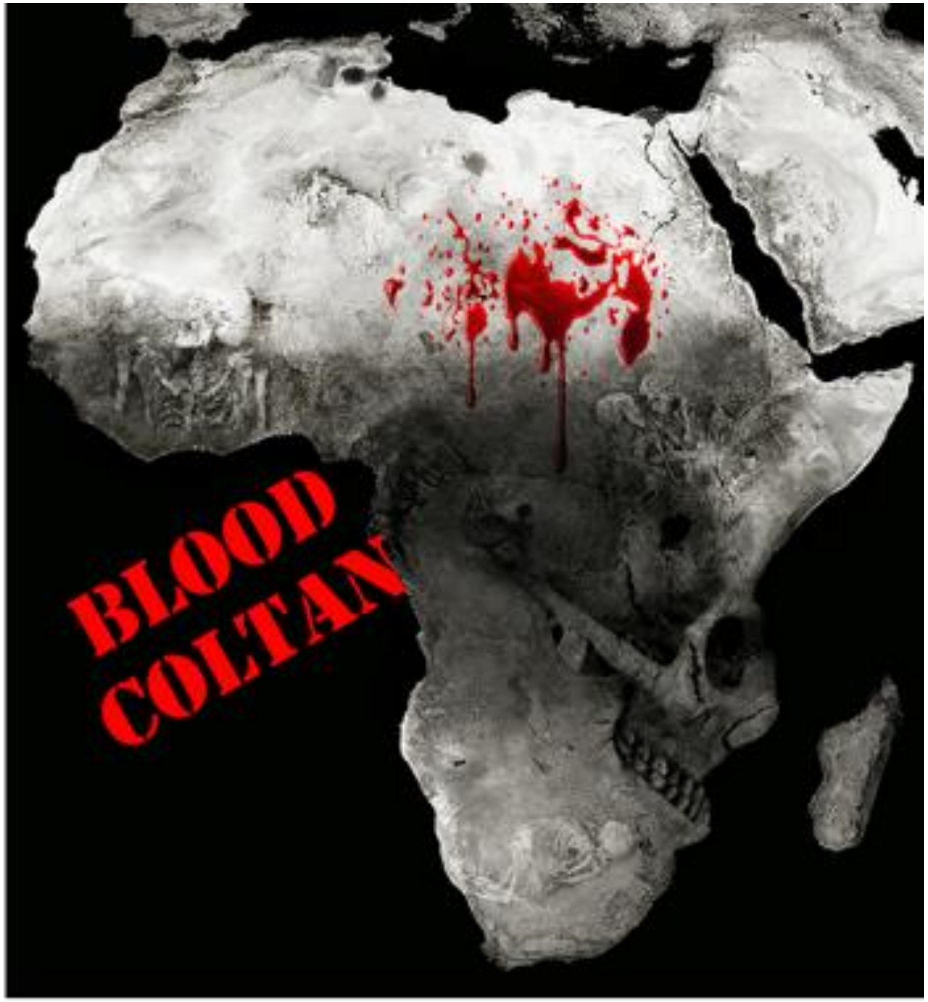
Industrial waste, car demolition, building, big equipments (mainly aluminum, iron, steel)

Urban waste (cans, metal containers, WEEE): a bit of everything, but are recovered mainly aluminum, iron, steel, copper, nickel, zinc, lead, and precious metals.

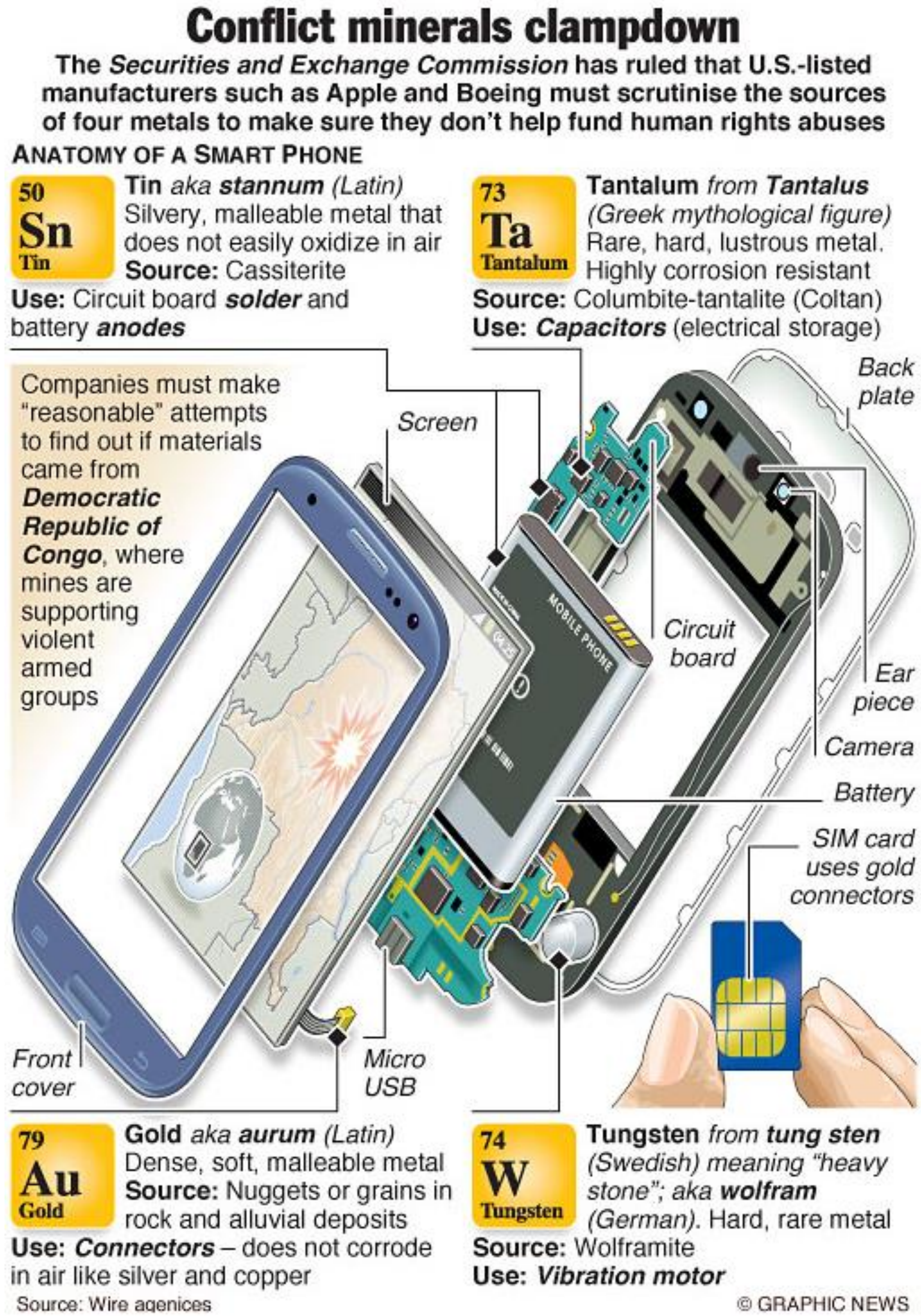
WEEE categories in Italy

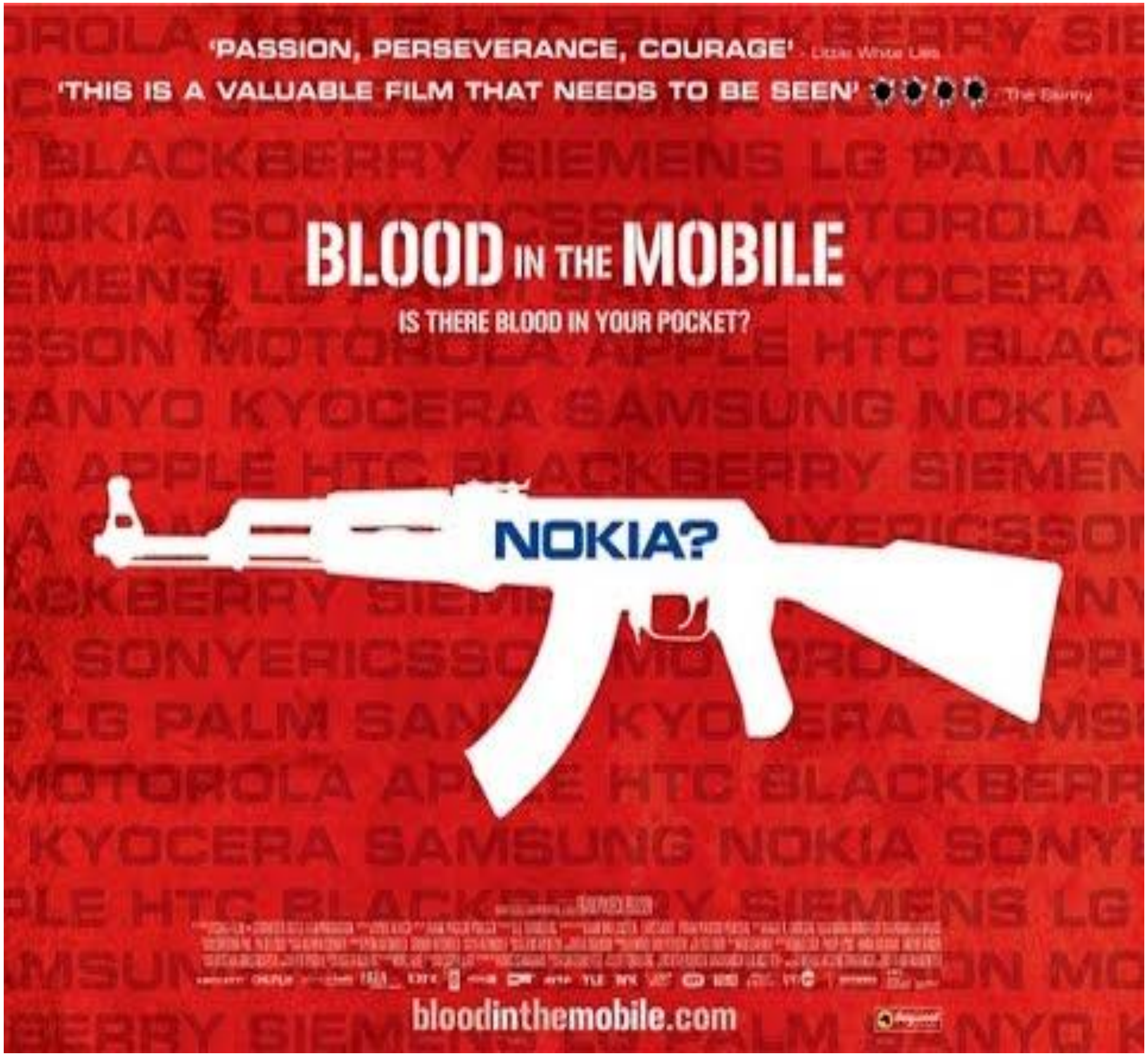


THE DARK SIDE OF THE SMARTPHONES



11 MILLION DEATHS


Conflict minerals clampdown
The Securities and Exchange Commission has ruled that U.S.-listed manufacturers such as Apple and Boeing must scrutinise the sources of four metals to make sure they don't help fund human rights abuses
ANATOMY OF A SMART PHONE
50 Sn Tin
Tin aka stannum (Latin) Silvery, malleable metal that does not easily oxidize in air
Source: Cassiterite
Use: Circuit board solder and battery anodes
73 Ta Tantalum
Tantalum from Tantalus (Greek mythological figure) Rare, hard, lustrous metal. Highly corrosion resistant
Source: Columbite-tantalite (Coltan)
Use: Capacitors (electrical storage)
Companies must make "reasonable" attempts to find out if materials came from Democratic Republic of Congo, where mines are supporting violent armed groups
Screen
Back plate
Circuit board
Ear piece
Camera
Battery
SIM card uses gold connectors
Front cover
Micro USB
79 Au Gold
Gold aka aurum (Latin) Dense, soft, malleable metal
Source: Nuggets or grains in rock and alluvial deposits
Use: Connectors – does not corrode in air like silver and copper
74 W Tungsten
Tungsten from tung sten (Swedish) meaning "heavy stone"; aka wolfram (German). Hard, rare metal
Source: Wolframite
Use: Vibration motor
Source: Wire agenices
© GRAPHIC NEWS



Blood in the Mobile (2010) a documentary by Frank Piasecki Poulsen, https://www.youtube.com/watch?v=Tv-hE4Yx0LU

“Kids in Congo are being sent down into mines to die so that kids in Europe and America can kill imaginary aliens in their living rooms or text each other” (Oona King)

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E-MINING @ SCHOOL

Solutions?

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a) Research of substitutes more easily available or of innovative technological solutions

The person behind the important revolutionary discovery in this battery industry is Mya Le Thai, a Vietnamese-born graduate student who is preparing to earn her Ph.D. at UCI.

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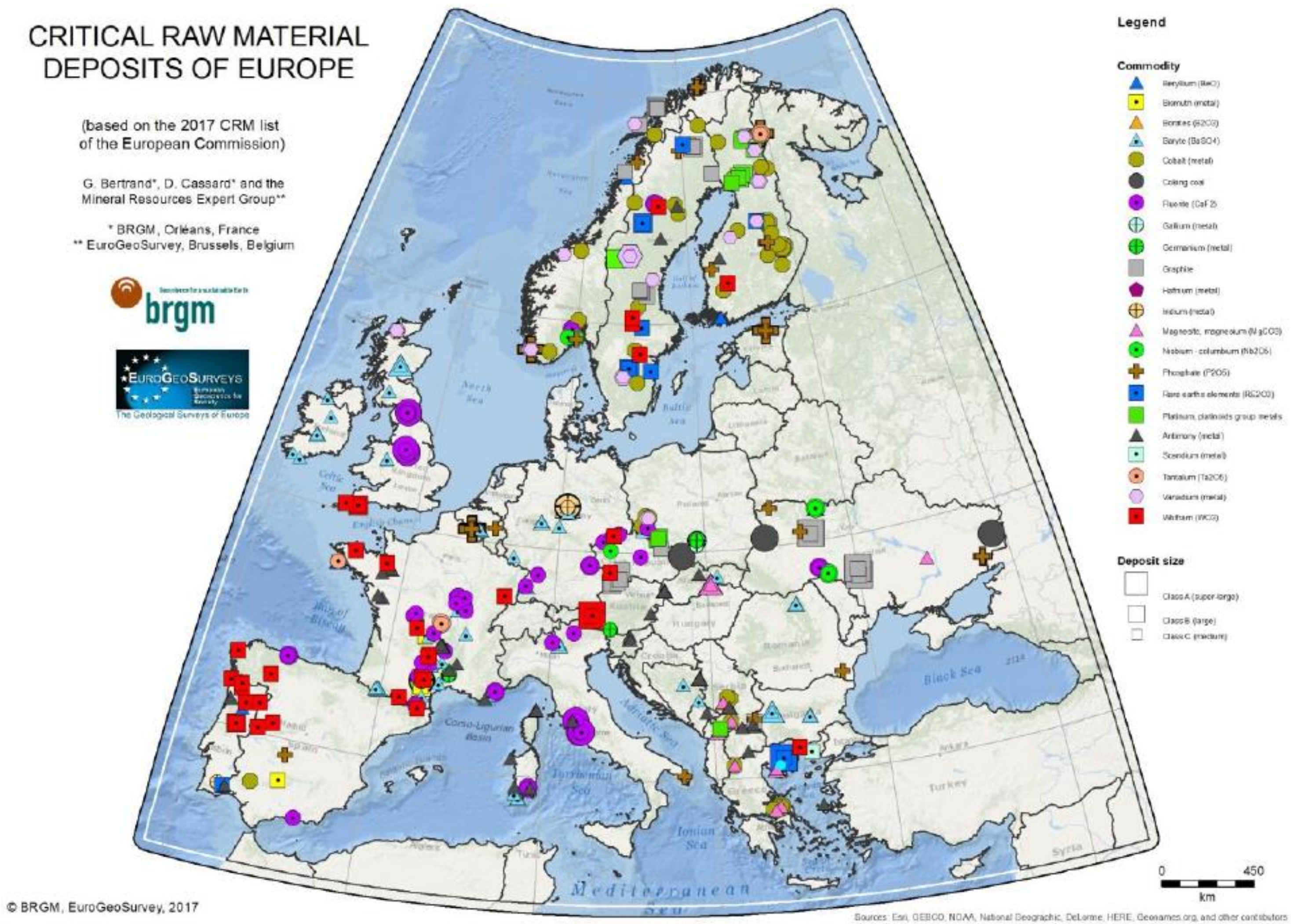
E-MINING SCHOOL

b1) Search of new mines, recover mineral wastes of old ones, sift the oceans, …

Map of CRM ore deposits in Europe



b2) … the Moon

WHY MINE THE MOON?

Water

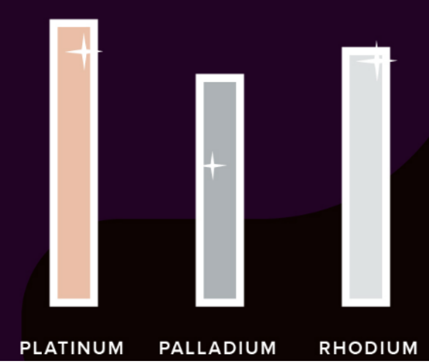
There may be water on the moon brought there by asteroids during collisions. And we are in need of fresh water. NASA scientists found that in 37 aquifers of fresh water on the earth, **21 are past the sustainability point.** [4]

Rare earth metals (REMs)

The fifteen lanthanides, as well as scandium and yttrium – used in modern electronics and mostly produced in China

Precious metals

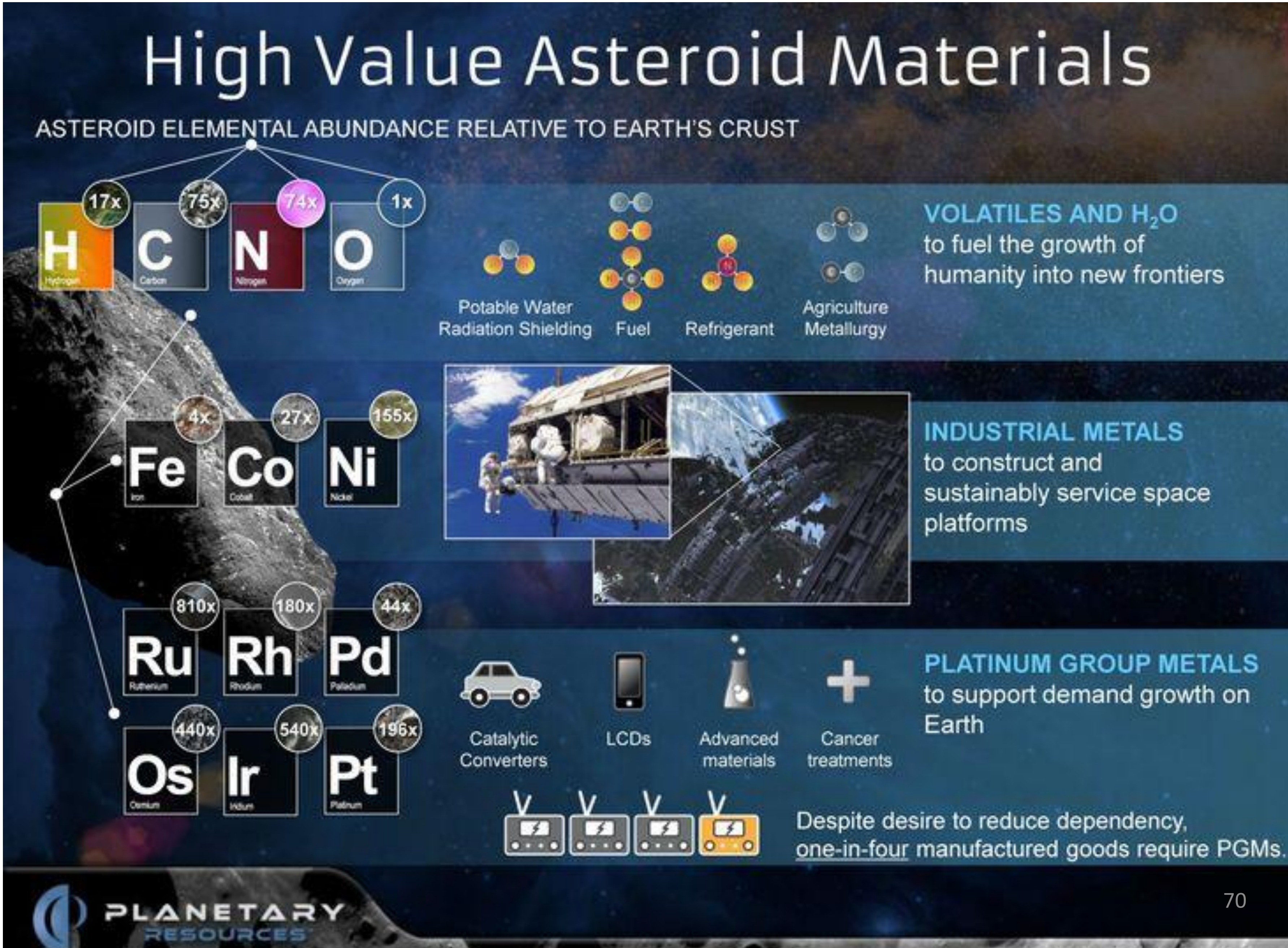
Many precious metals are used in everything from jewelry to smartphones to cancer treatments. Iron, nickel and cobalt may also be found on the moon.



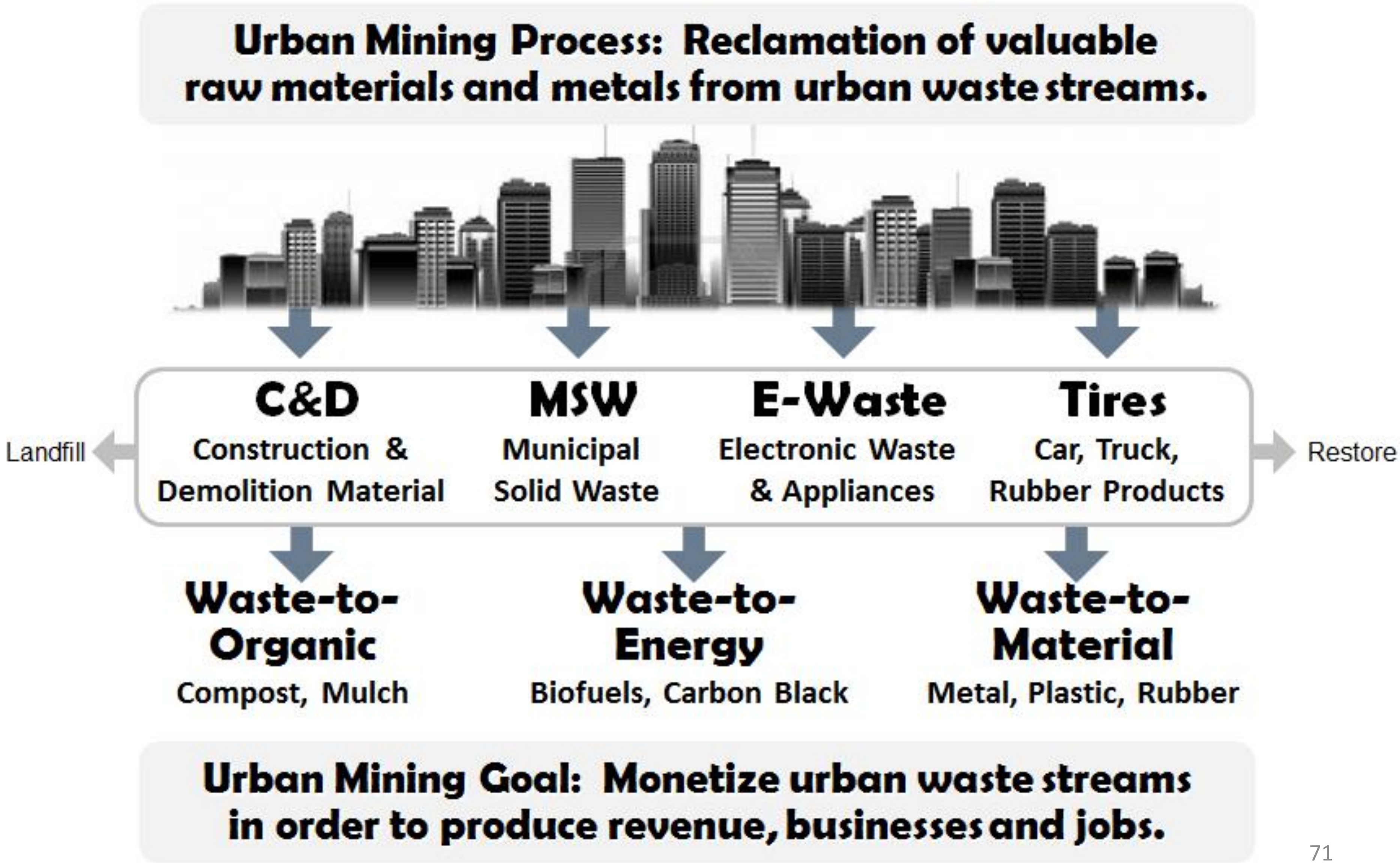
Helium-3

This element is rare on Earth, much more common on the moon and ideal for work in nuclear fusion. In recent years due to demand, the price of helium-3 can be as much as $2,000 per liter.

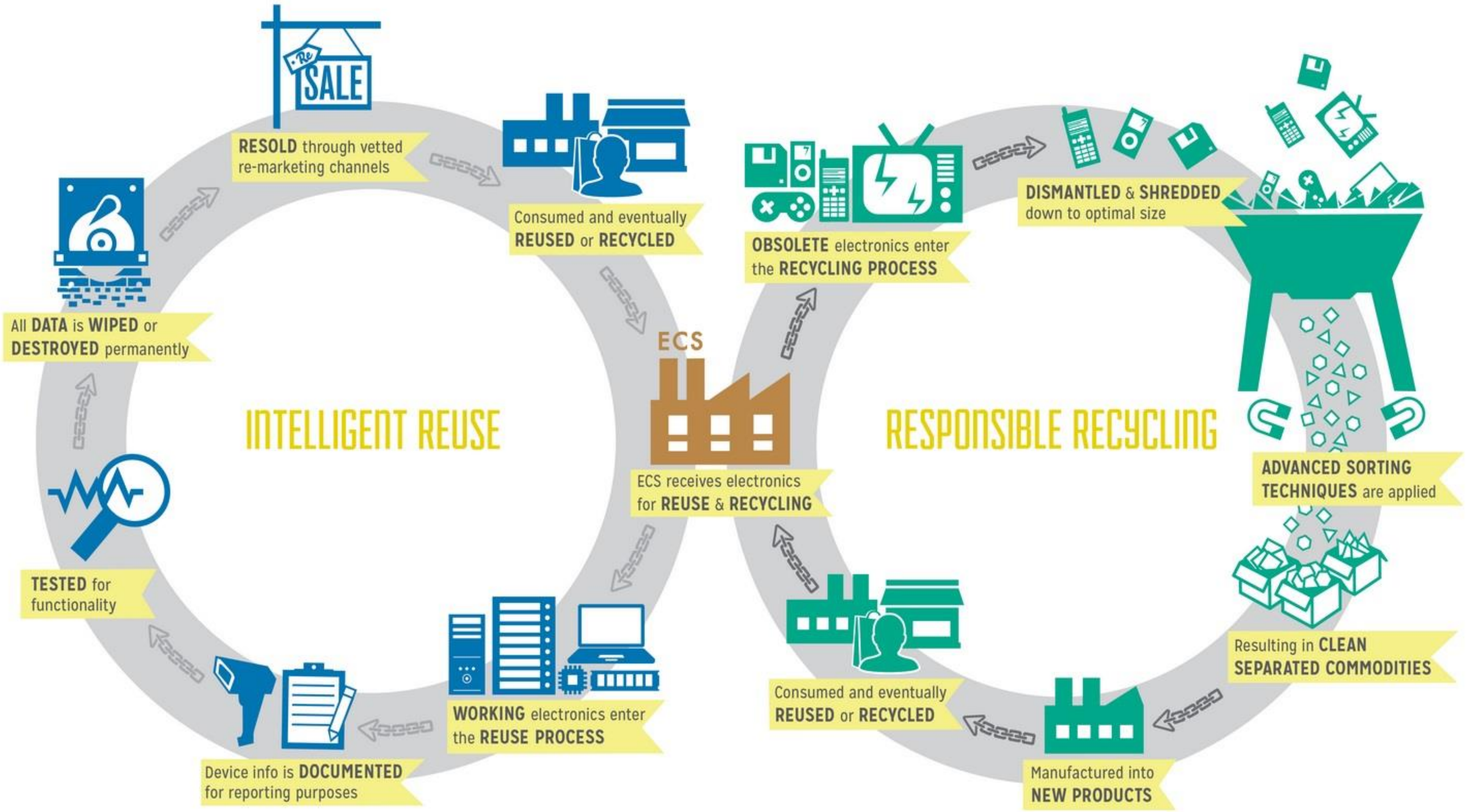
b3) … the asteroids



b4) …urban minig



c) Improve E-waste recovery and reuse



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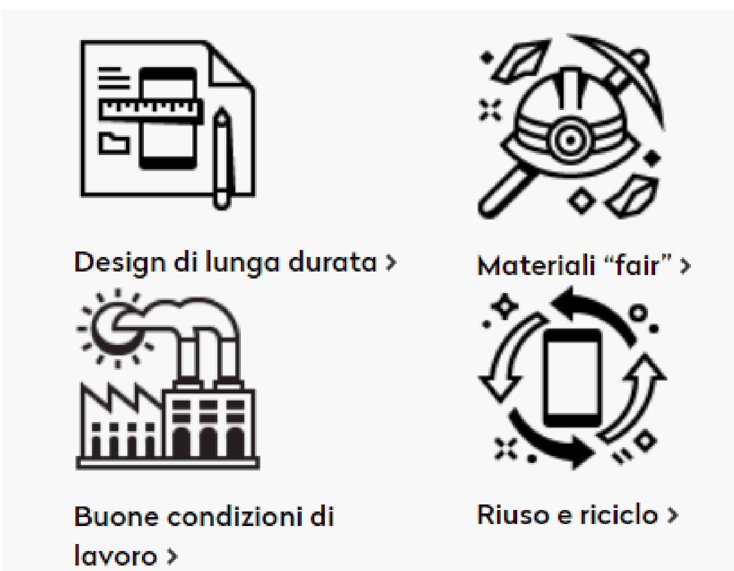
d) Get informed before buying.

Prefer factories with more efficient design and ethical chain of supply



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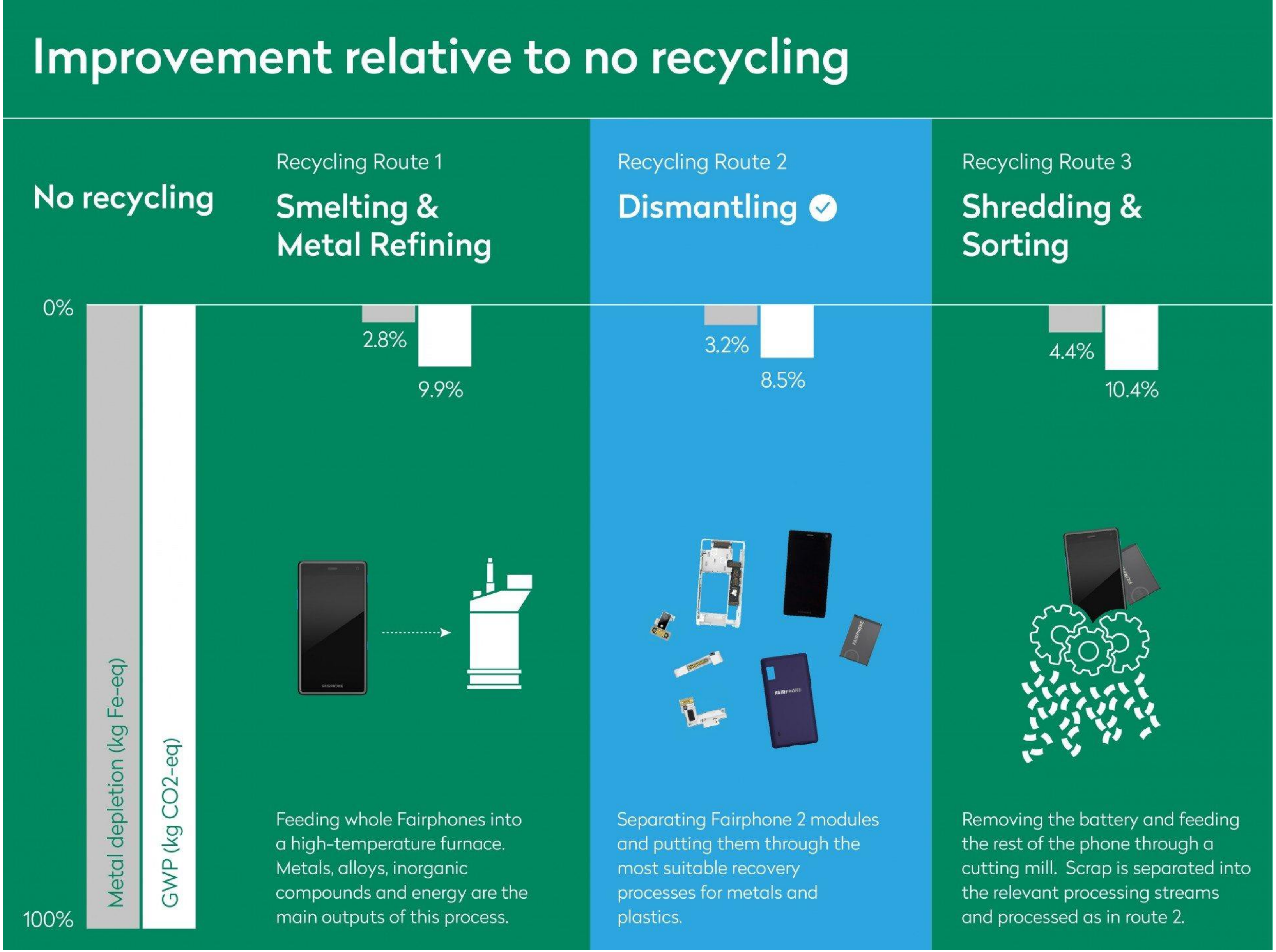


The least metal depletion, but also the second-highest rate of global warming potential (GWP, measured by CO_2 equivalent).

A bit higher metal depletion than route 1, but with the lowest GWP

The least desirable results, both in terms of metal depletion and GWP

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

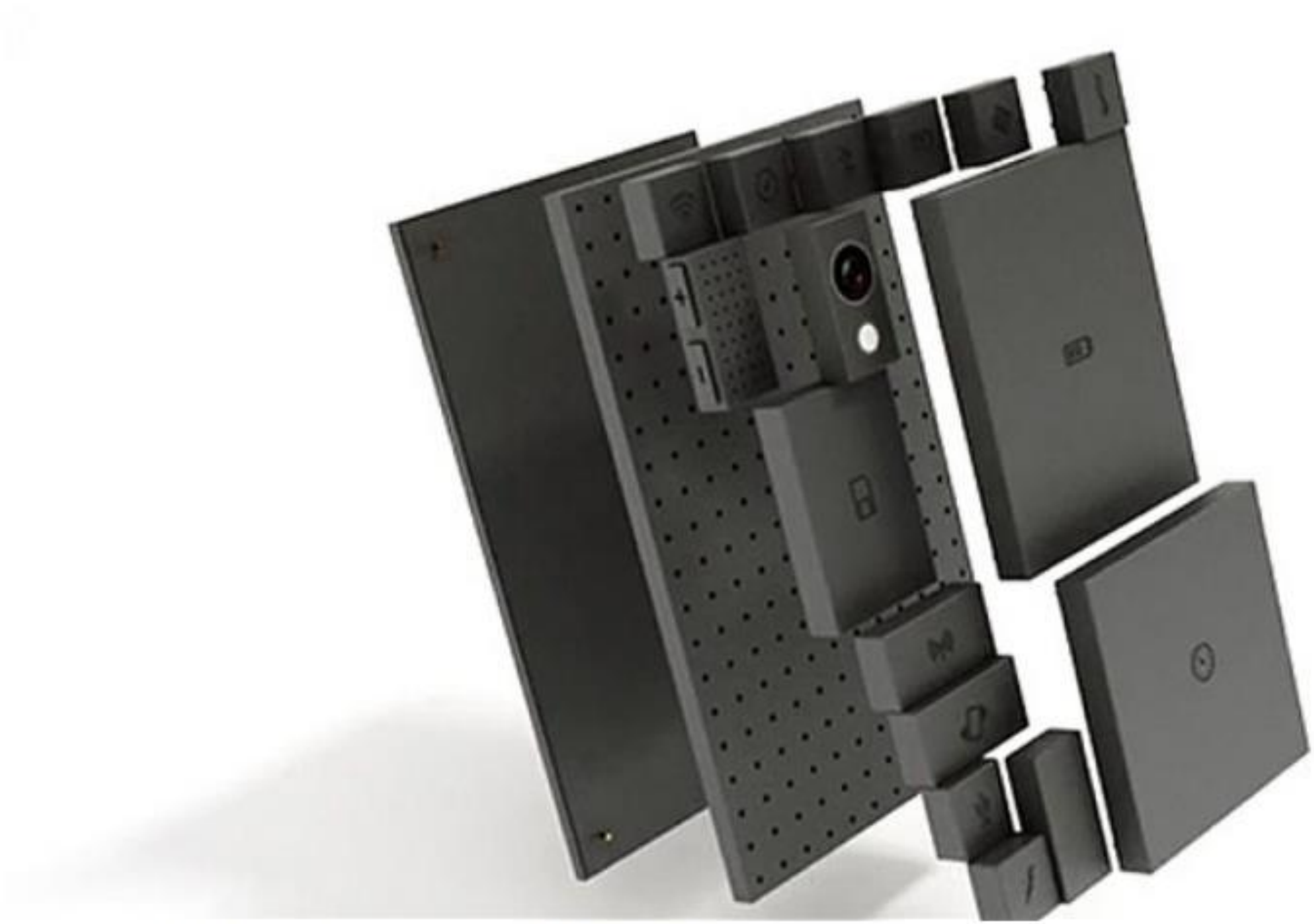
The Spine is the structure: the high-res display. Core spine elements will be available in a variety of sizes and materials.

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

Long queues outside London Apple store as new iPhone X goes on sale

With prices starting at £999, it is the most expensive iPhone ever.

People queue outside the Apple Store on Regent Street, London, as the iPhone X goes on sale (Martyn Landi/PA)