Politecnico
di Torino

Critical Materials in the EU and international Agendas

Gian Andrea Blengini

Trieste, 29 marzo 2023

Overview on CRMs by:

Gian Andrea Blengini

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SHORT CV
(2022)

Gian Andrea Blengini received a Msc in Mining Engineering from the Politecnico di Torino, Italy (1994) and a PhD in Earth resources from TU Lisbon, Portugal (2006).

Presently an Associate Professor at the ***Politecnico di Torino*** (TU Turin, Italy) where he leads the Life Cycle Assessment (LCA) research group and lectures on Life Cycle Assessment (LCA) and Resources & Environmental Sustainability at undergraduate, master and postgraduate level.

He has been a senior researcher at the ***Joint Research Centre*** *of the* ***European Commission*** in the ***Land Resources Unit*** from October 2013 to October 2021, with a role of team coordinator in projects and activities: (1) in support of EC raw materials policies, with focus on critical raw materials and monitoring of Circular Economy, and (2) targeted to the EU Raw Materials Knowledge Base, including Life Cycle Inventory data availability, coherence and quality.

Main contributions / outcomes while at the EC:

- *-Revision of the Methodology for establishing the List of CRITICAL RAW MATERIALS for the EU*
- *-Monitoring Framework for the Circular Economy, COM(2018) 29 final and SWD(2018) 17 final*
- *-Launch of the Life Cycle Data Network, https://eplca.jrc.ec.europa.eu/LCDN*
- *-US-Japan-EU trilateral dialogue on Critical Raw Materials*
- *-The International Round Table on Materials Criticality, IRTC, https://irtc.info*
- *-Revision of the List of CRITICAL RAW MATERIALS for the EU (2020 list).*

mostly based on:

WPK leader	Gian Andrea Blengini
WPK leader backup	Fabrice Mathieux
Criticality experts	Cristina Torres de Matos
	Dominic Wittmer
	Cynthia Latunussa
	Umberto Eynard
	Kostas Georgitzikis
Substitution & Strategic sectors	Caudiu Pavel (JRC C7)
	Samuel Carrara (JRC C7)

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Critical Raw Materials and the EU Green Deal

The EU Green Deal recognizes **access to resources** as a strategic security question to fulfil EU's ambition towards 2050 climate neutrality

Speech | 3 September 2020 | Brussels

Speech by Vice-President Šefčovič at the Press Conference on critical raw materials resilience in the EU

- Raw materials will **play a hugely important part** in our future, especially **given the ongoing transition towards a green and digital economy** – a trend not only accelerated, but one, which lies at the heart of our recovery.

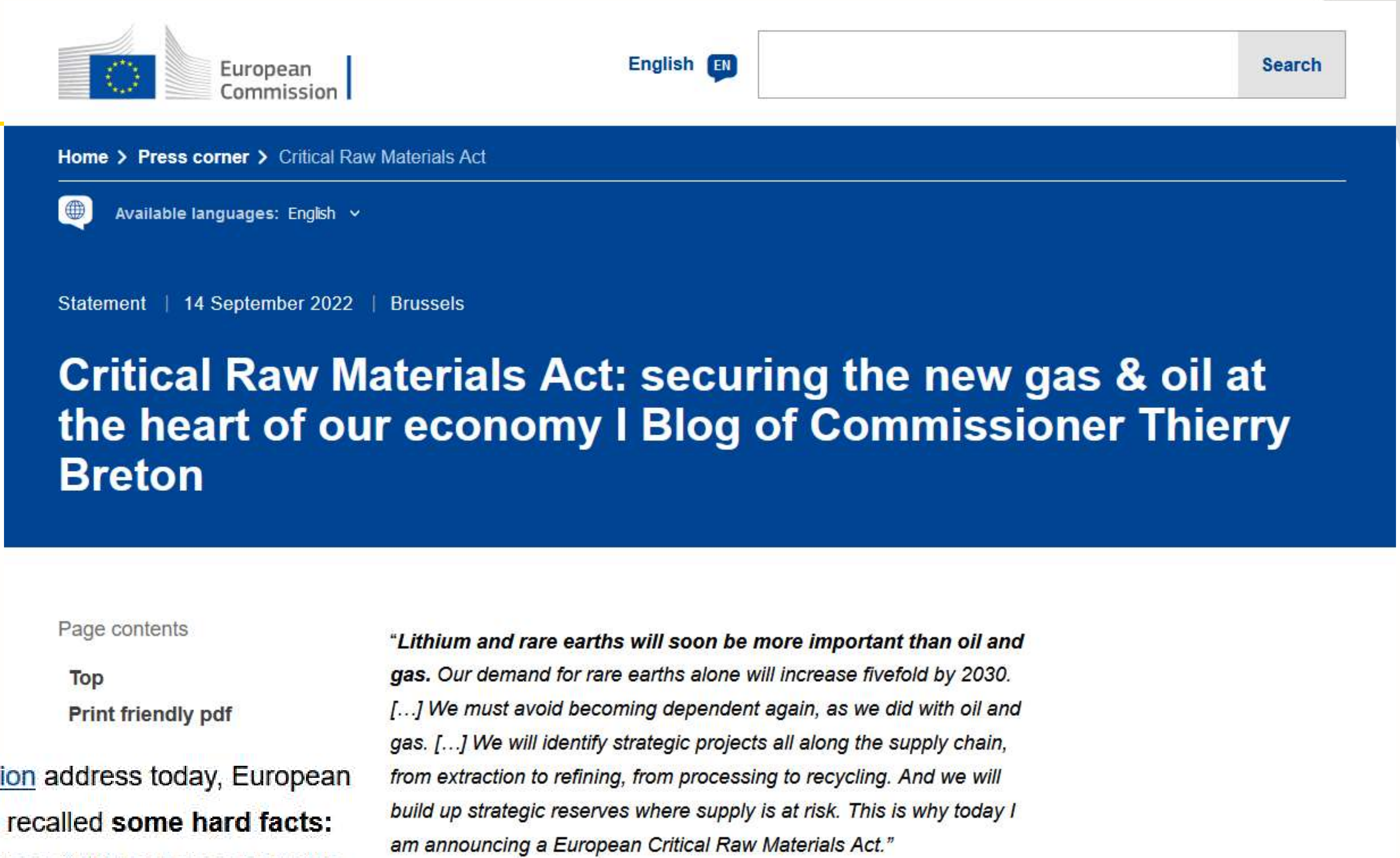
- We **need to ensure a secure and sustainable supply of raw materials** to meet the needs of the clean and digital tech including in the health sector and the space and d

- In order to succeed, **we must acknowledge some hard truths**.

- The simple truth also is th **unsustainable raw** **n much lower environmental a** s freedoms or unstable economies.

    - **we also need** to **scale up reuse, repair and recycling** of products;
    - We must support **innovation for alternatives and resource efficiency**;

- Today's **Action Plan outlines concrete steps we are taking in response** – altogether, they will help **make Europe more resilient**



Statement | 14 September 2022 | Brussels

Critical Raw Materials Act: securing the new gas & oil at the heart of our economy I Blog of Commissioner Thierry Breton

*"**Lithium and rare earths will soon be more important than oil and gas.** Our demand for rare earths alone will increase fivefold by 2030. […] We must avoid becoming dependent again, as we did with oil and gas. […] We will identify strategic projects all along the supply chain, from extraction to refining, from processing to recycling. And we will build up strategic reserves where supply is at risk. This is why today I am announcing a European Critical Raw Materials Act."*

In her 2022 State of the European Union address today, European Commission President von der Leyen recalled **some hard facts: without secure and sustainable access to the necessary raw materials, our ambition to become the first climate neutral continent is at risk.**

Critical Materials in the EU and international Agendas (2022)

Questions and answers | 16 March 2023 | Brussels

Questions and Answers on the European Critical Raw Materials Act

Why is action on European critical raw materials needed?

Critical Raw Materials (CRM) are indispensable for a wide set of technologies needed for EU strategic sectors such as the net-zero industry, digital, space and defence. While the demand for such critical raw materials has never been higher, it is expected to continue to grow driven by the green and digital transitions. For instance, EU demand for lithium used in electric-vehicles batteries and energy storage is expected to increase by twelve-fold by 2030.

Study on the Critical Raw Materials for the EU

2023

Final Report

Rare Earth Elements Applications

Curtin University

(Source: Barakos, 2021)

Speaker (magnets)
Pr, Nd, Tb, Dy

Colour screen
La, Pr, Eu, Gd,
Tb, Dy, Y

Vibrator (magnets)
Pr, Nd, Tb, Dy

Glass polishing
La, Ce, Pr

Circuit board electronics
La, Pr, Nd, Gd, Dy

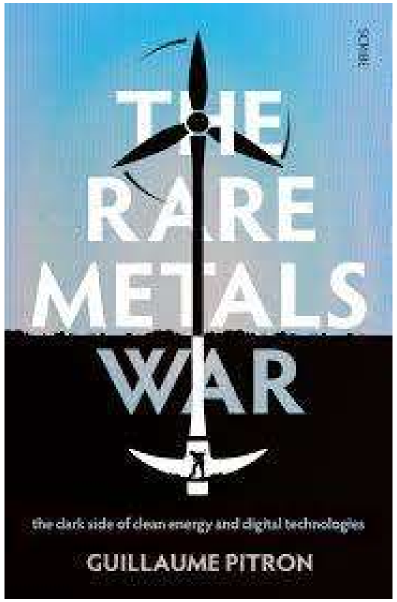
Electric vehicles:

A sustainable solution for low-carbon mobility?

☐ YES
☐ NO
☐ MAYBE

Possible impacts shifts:

- From use of diesel/gasoline to electricity generation
- From use phase to production phase (battery)
- From climate change / depletion non-renewables to Critical Raw Materials (WARS?)



SCRIBE

THE RARE METALS WAR

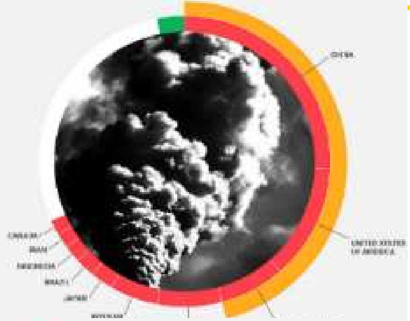
the dark side of clean energy and digital technologies

GUILLAUME PITRON

Study on the EU's list of Critical Raw Materials (2020)

Final Report

Critical Raw Materials in international agendas



● **3%**

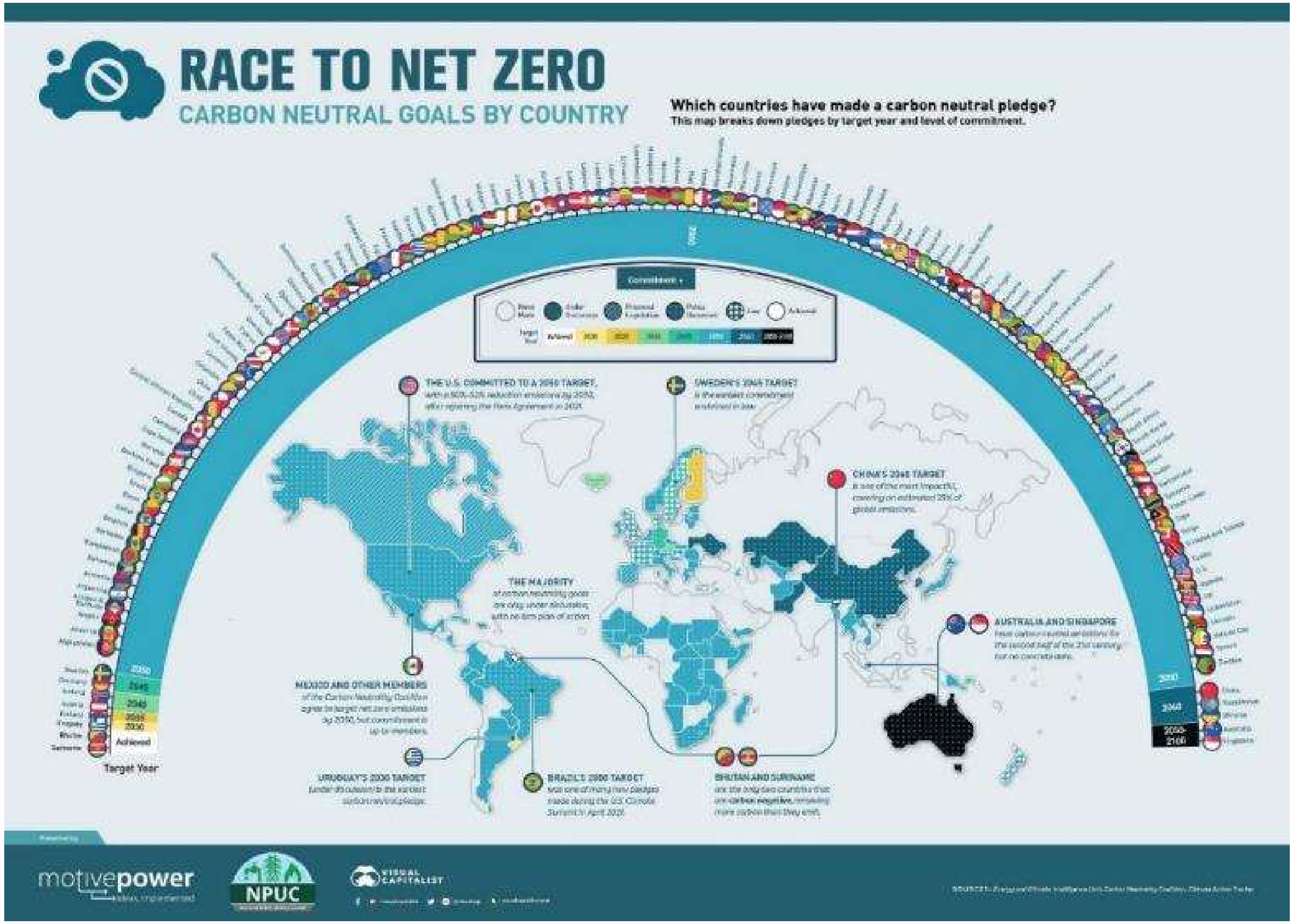
Contribution of the 100 least-emitting countries

● **68%**

The 10 largest greenhouse gas emitters contribute over two-thirds of global emissions

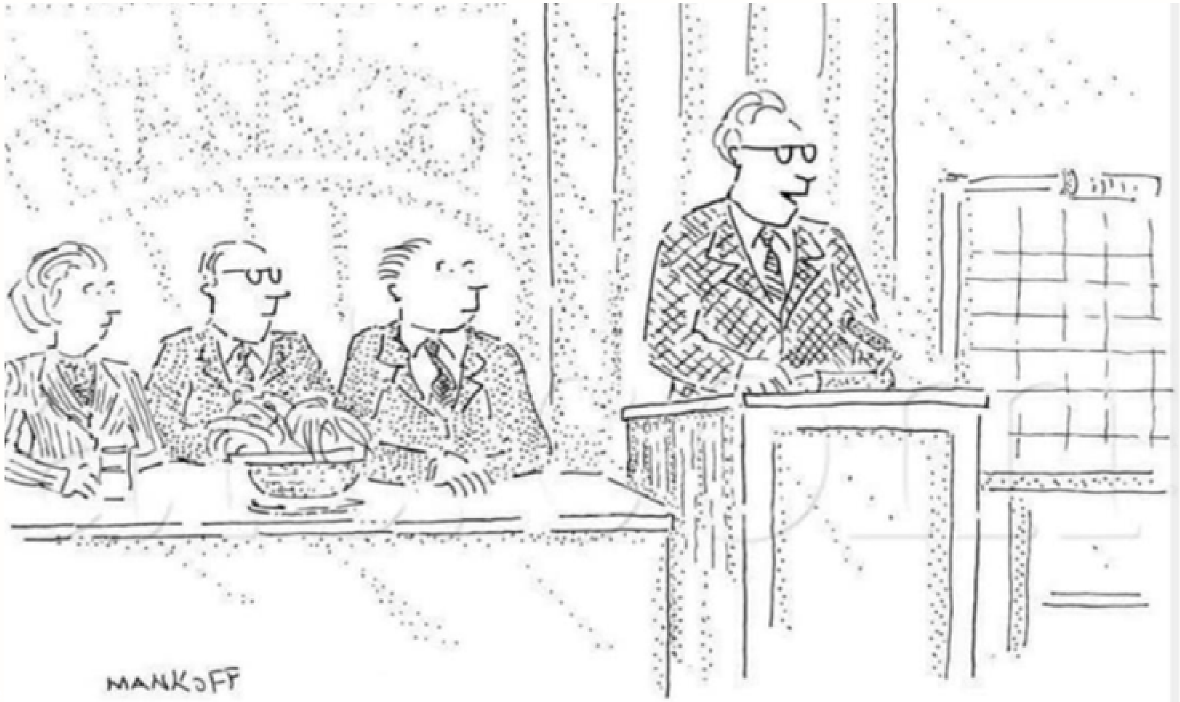
● **46%**

The top 3 greenhouse gas emitters contribute 16 times the emissions of the bottom 100 countries



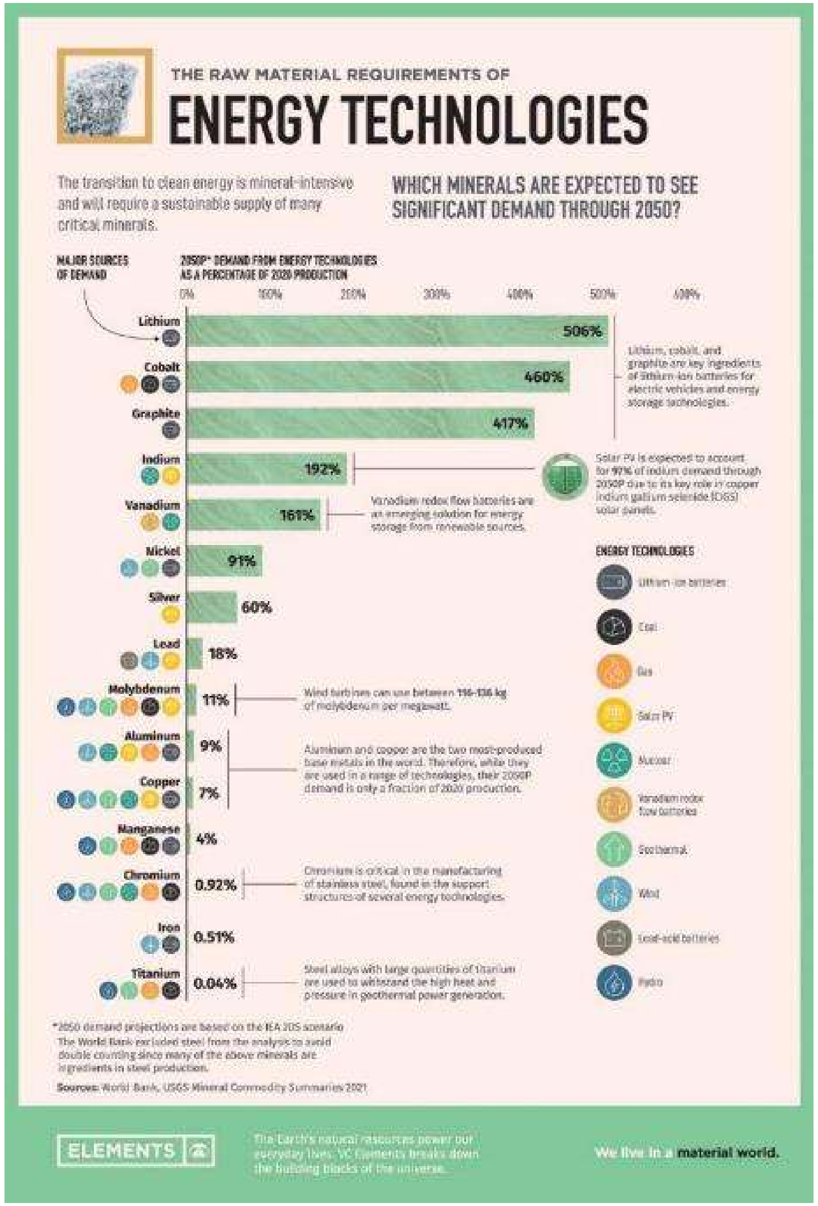
Critical Materials in the EU and international Agendas (2022)

Critical Raw Materials in international agendas



"And so, while the end-of-the-world scenario will be rife with unimaginable horrors, we believe that the pre-end period will be filled with unprecedented opportunities for profit."

Scale Mismatch: Not Enough Metals for Low Carbon Energy Transition


THE RAW MATERIAL REQUIREMENTS OF

ENERGY TECHNOLOGIES

The transition to clean energy is mineral-intensive and will require a sustainable supply of many critical minerals.

WHICH MINERALS ARE EXPECTED TO SEE SIGNIFICANT DEMAND THROUGH 2050?

Lithium, cobalt, and graphite are key ingredients of lithium-ion batteries for electric vehicles and energy storage technologies.

Solar PV is expected to account for 97% of indium demand through 2050P due to its key role in copper indium gallium selenide (CIGS) solar panels.

Vanadium redox flow batteries are an emerging solution for energy storage from renewable sources.

Wind turbines can use between 116-136 kg of molybdenum per megawatt.

Aluminum and copper are the two most-produced base metals in the world. Therefore, while they are used in a range of technologies, their 2050P demand is only a fraction of 2020 production.

Chromium is critical in the manufacturing of stainless steel, found in the support structures of several energy technologies.

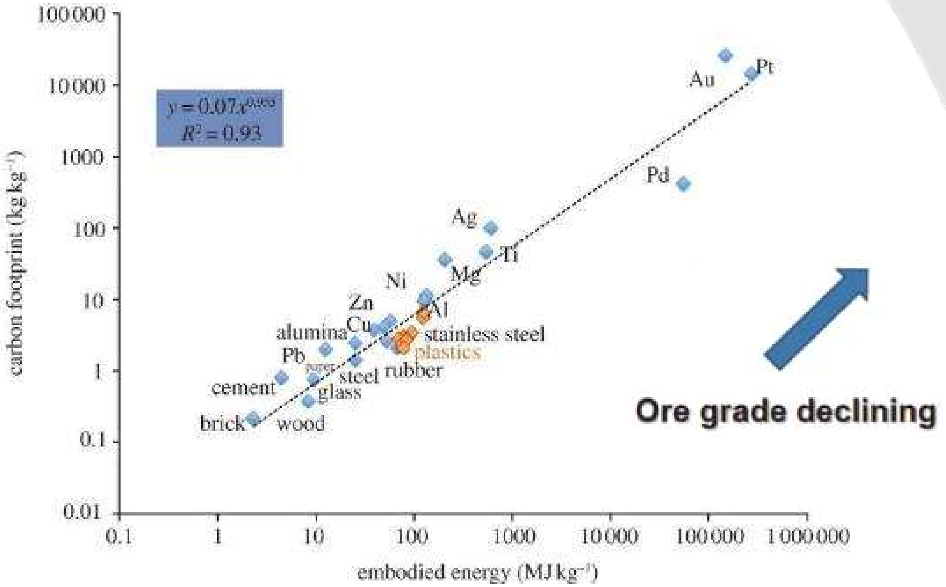
Steel alloys with large quantities of titanium are used to withstand the high heat and pressure in geothermal power generation.

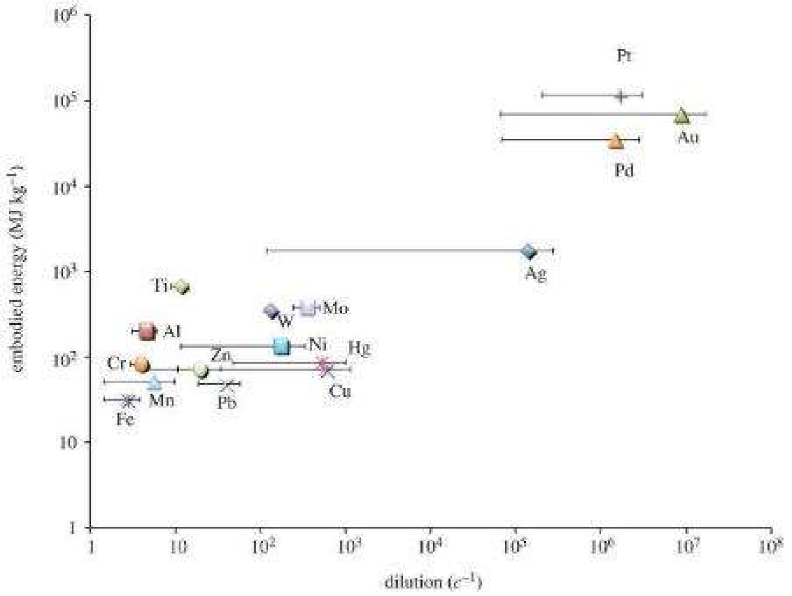
*2050 demand projections are based on the IEA 2DS scenario
The World Bank excluded steel from the analysis to avoid double counting since many of the above minerals are ingredients in steel production.

Sources: World Bank, USGS Mineral Commodity Summaries 2021

The Earth's natural resources power our everyday lives. VC Elements breaks down the building blocks of the universe.

We live in a material world.

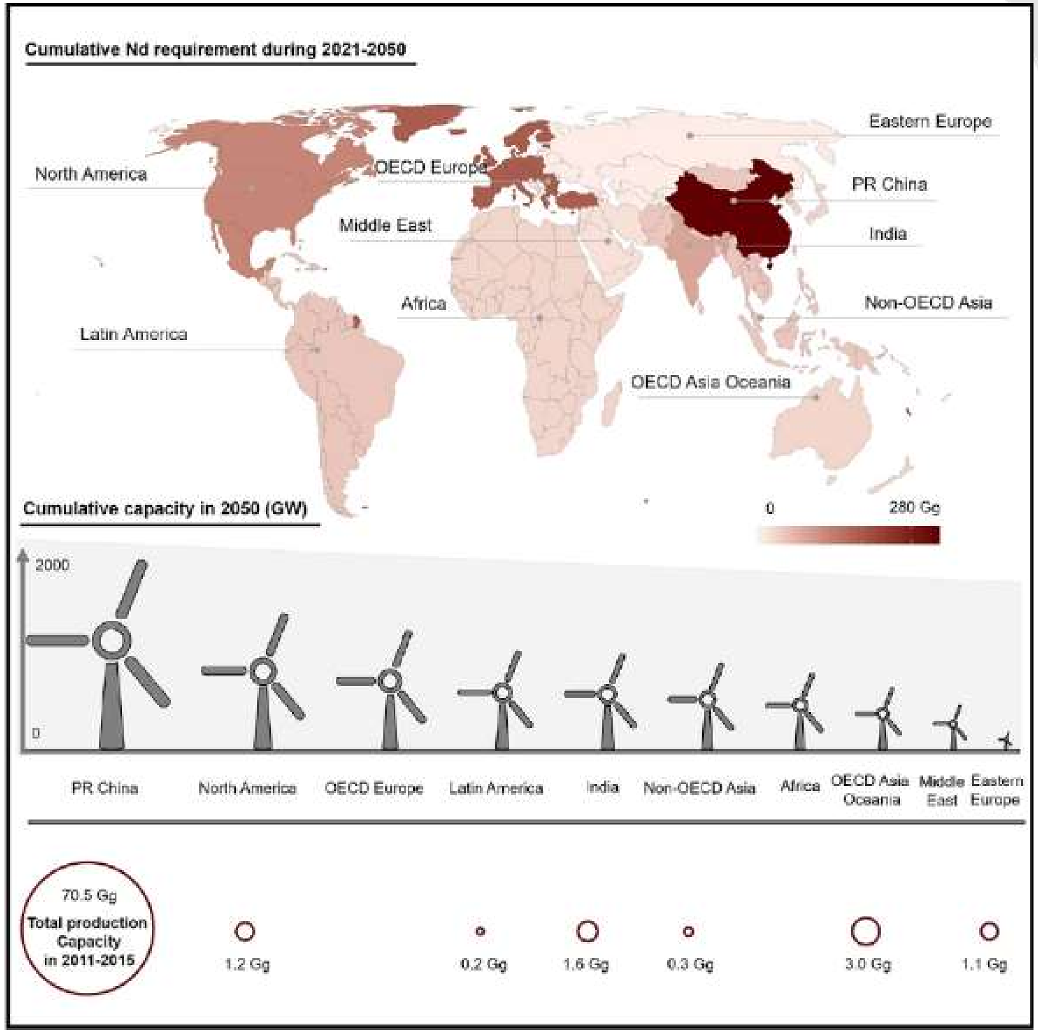




Scale Mismatch: Not Enough Low Carbon Energy for Metal supply expansion

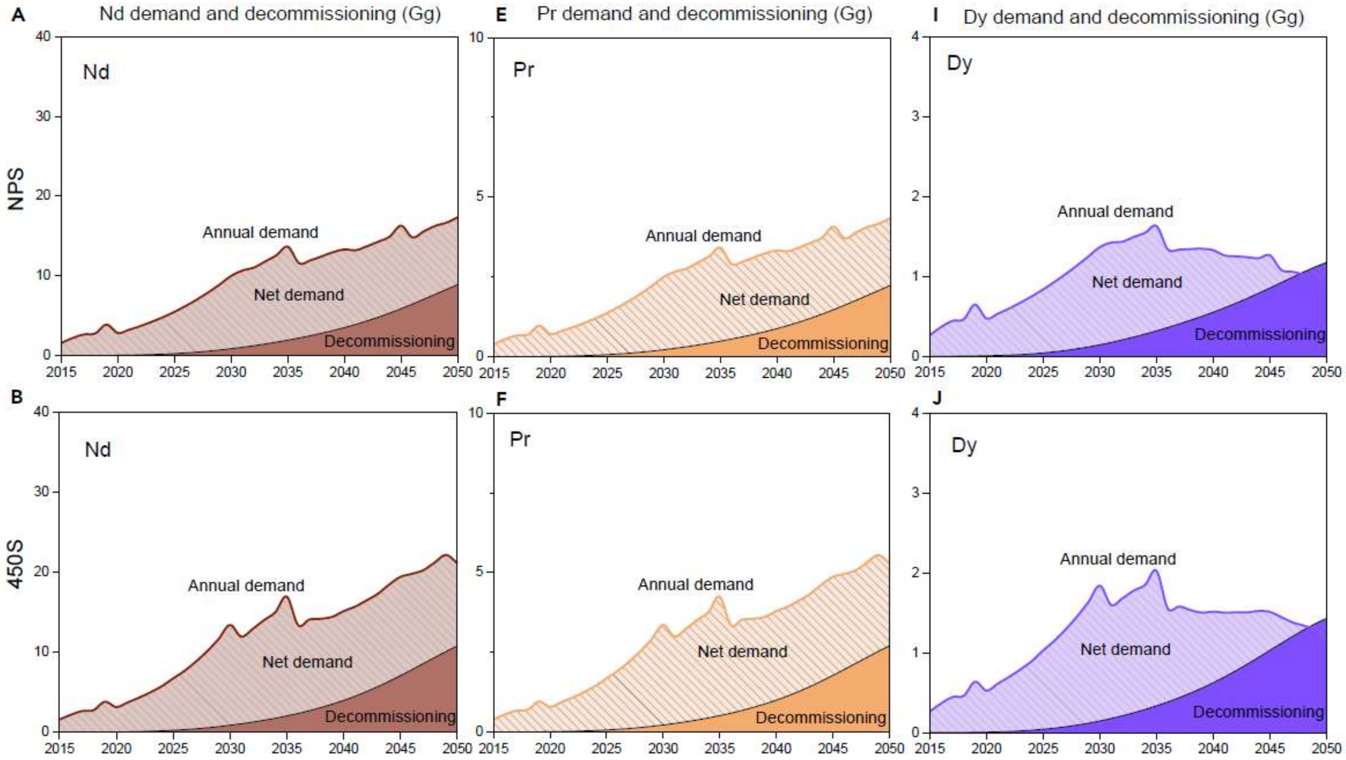
Source: Gutowski T G, et al. Philosophical Transactions of the Royal Society A, 2013

Spatial Mismatch: Regional Metals for Global Energy Transition



Li et al., 2020, One Earth *3*, 116–125
July 24, 2020 © 2020 The Author(s). Published by Elsevier Inc.
https://doi.org/10.1016/j.oneear.2020.06.009

Temporal Mismatch: Can we count on Recycling?



Li et al., 2020, One Earth *3*, 116–125
July 24, 2020 © 2020 The Author(s). Published by Elsevier Inc.
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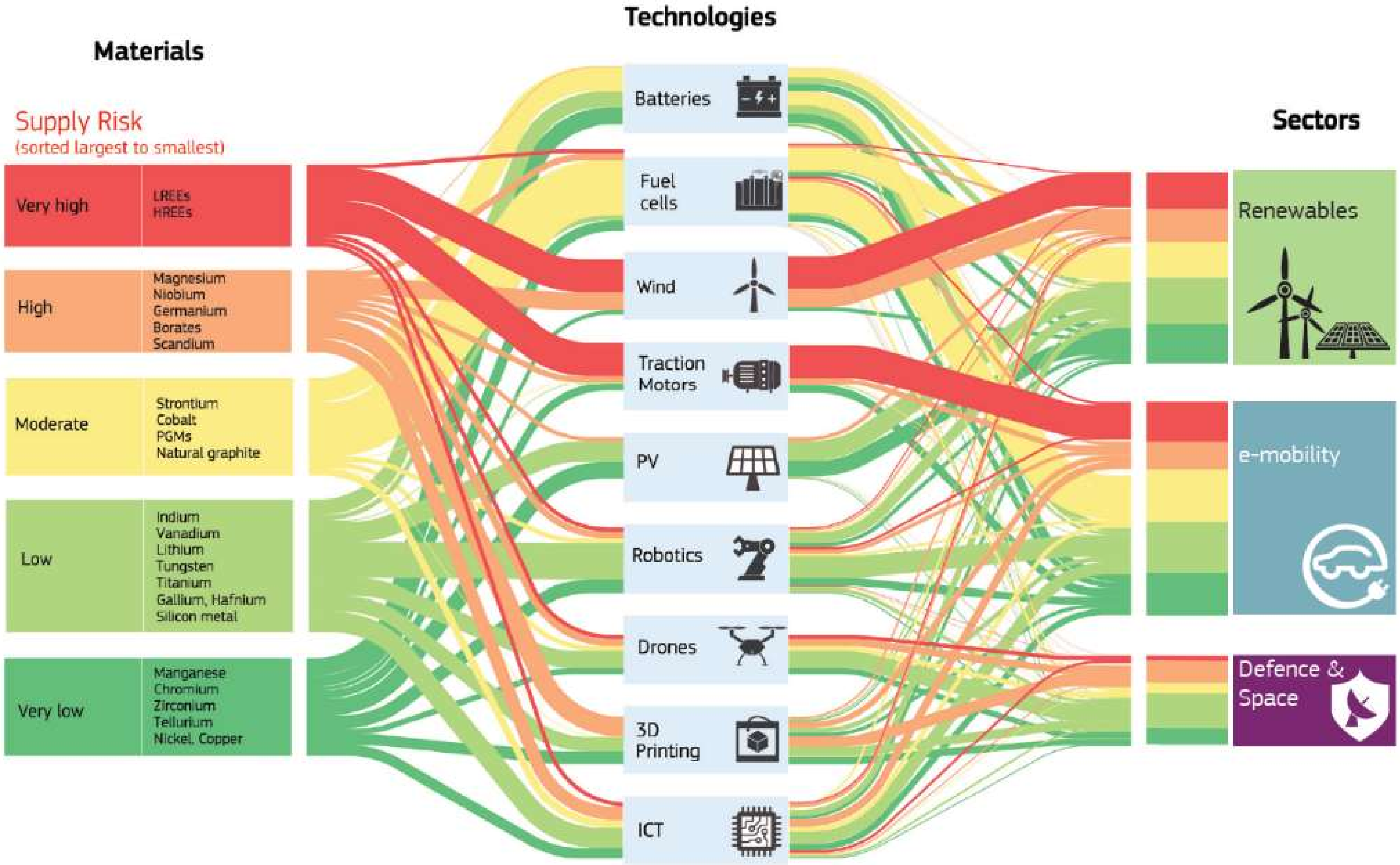


Materials

Supply Risk
(sorted largest to smallest)

Very high	LREEs HREEs
High	Magnesium Niobium Germanium Borates Scandium
Moderate	Strontium Cobalt PGMs Natural graphite
Low	Indium Vanadium Lithium Tungsten Titanium Gallium, Hafnium Silicon metal
Very low	Manganese Chromium Zirconium Tellurium Nickel, Copper

Technologies

- Batteries
- Fuel cells
- Wind
- Traction Motors
- PV
- Robotics
- Drones
- 3D Printing
- ICT

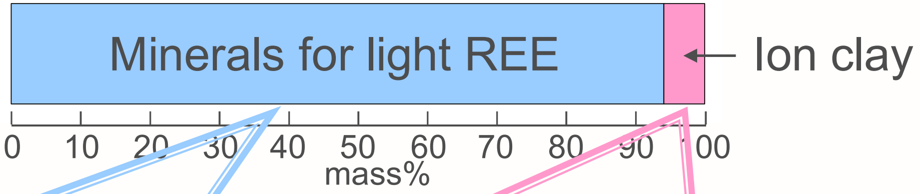
Sectors

- Renewables
- e-mobility
- Defence & Space

Critical Raw Materials for a clean planet?

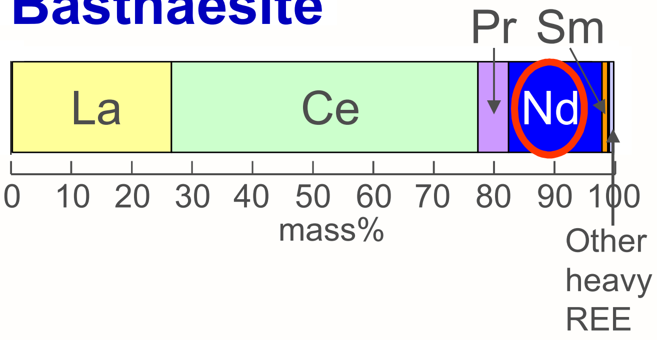
Critical Raw Materials for a clean planet?

Ratio of production amount of Minerals for REE in China (oxide base)



(USGS Mineral Commodity Summaries)

Bastnaesite

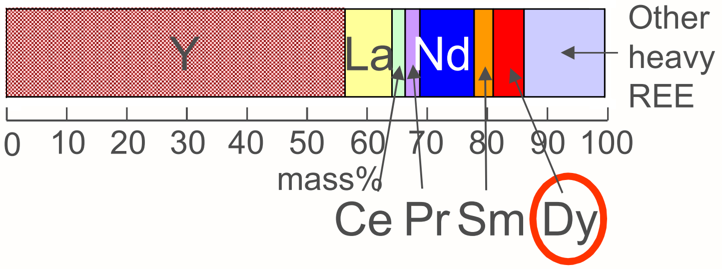


○ Rich in light REE
(La, Ce, Pr, Nd)

× Contain U and Th

○ Abundant all over the world

Ion adsorption ore (ion clay)



◎ Rich in heavy REE
(Tb, Dy, Ho, Er, Tm, Yb)

○ No U and Th

× Scarce and limited

× Distributed only in China

Critical Raw Materials for a clean pla

Bottleneck of rare earth:

Ganzhou city at Southern Jiangxi province, "famous" for Ion Clay

http://www.asahi.com/business/intro/TKY2
01206030331.html

http://www.recordchina.co.jp/group.php?groupid=51816

今では、
“レアアース　環境　汚染”
をキーワードに
Googleで画像検索すると、
多くの映像が出てくる。

中国南部のイオン吸着型鉱山

写真提供：Courtesy: Prof. A. Shibayama
秋田大学大学院工学資源学研究科　柴山　敦　教授

写真提供：Courtesy: Prof. A. Shibayama

秋田大学大学院工学資源学研究科 柴山 敦 教授

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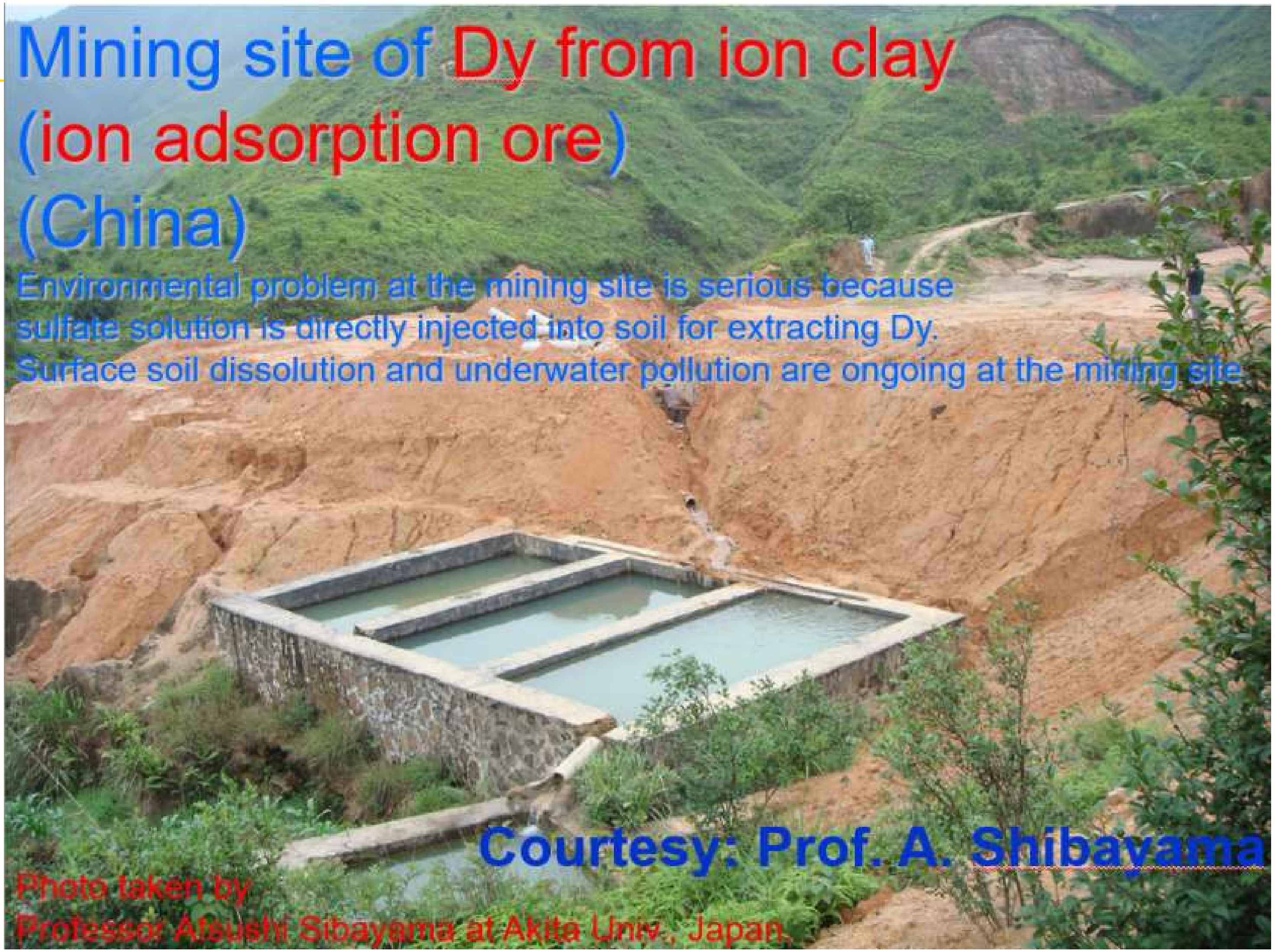
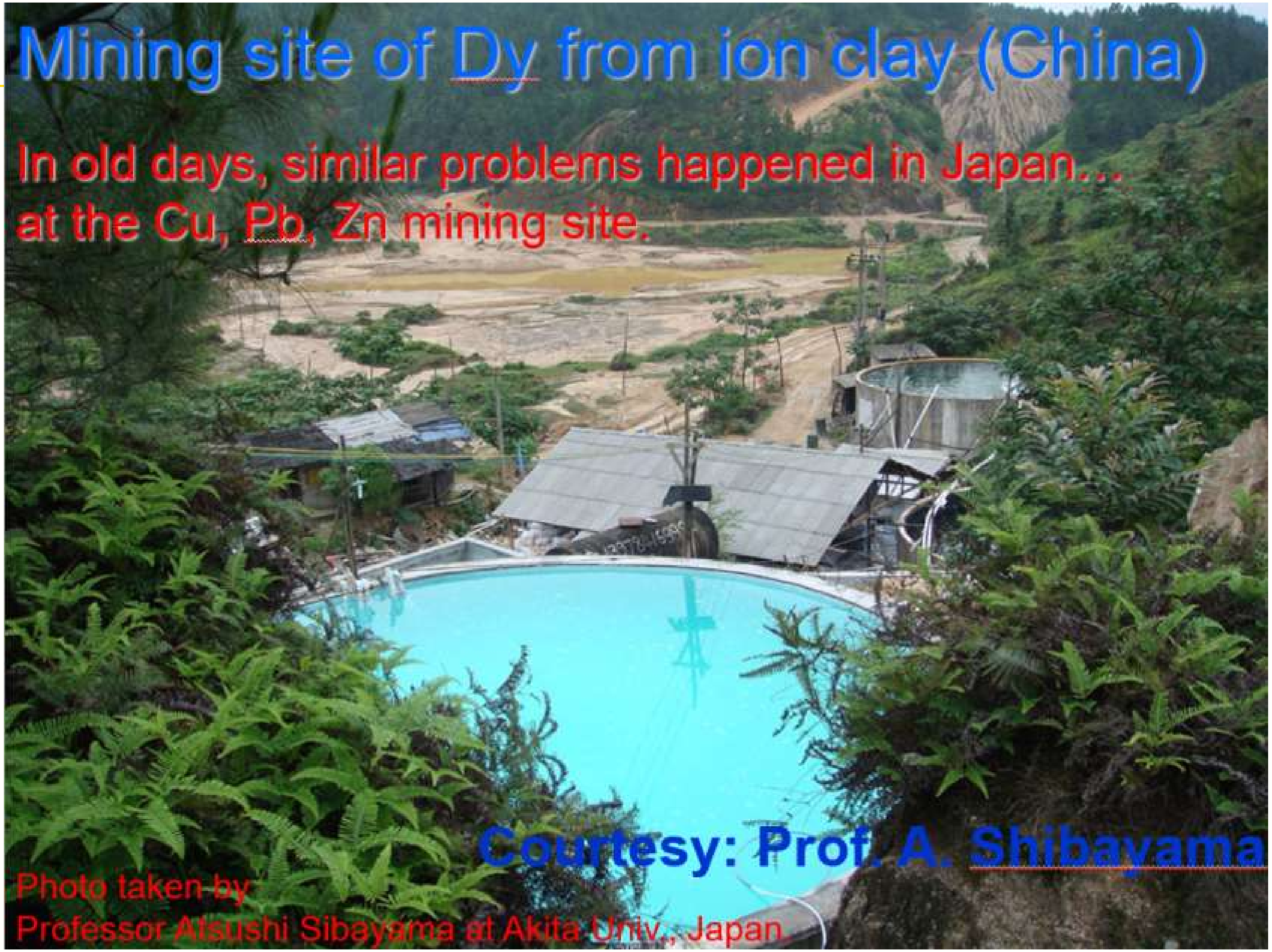


Mining site of Dy from ion clay (ion adsorption ore) (China)

Environmental problem at the mining site is serious because sulfate solution is directly injected into soil for extracting Dy.
Surface soil dissolution and underwater pollution are ongoing at the mining site.

Courtesy: Prof. A. Shibayama

Photo taken by
Professor Atsushi Sibayama at Akita Univ., Japan.



Mining site of Dy from ion clay (China)

In old days, similar problems happened in Japan…
at the Cu, Pb, Zn mining site.

Courtesy: Prof. A. Shibayama

Photo taken by
Professor Atsushi Sibayama at Akita Univ., Japan

Refining plant of Dy obtained from ion clay (China)

Recovered Dy containing solutions are concentrated and refined at the plant.

Environmental problem at the refining plant is also serious because large amount of waste solution is generated.

Courtesy: Prof. A. Shibayama

Photo taken by
Professor Atsushi Sibayama at Akita Univ., Japan.

Forbidden zone

部外者の
立ち入りは
禁止されている

Photo by Toru H. Okabe 2013.8, Ganzhou

Pyrometallurgical refining

→ Molten salt electrolysis

乾式製錬

→溶融塩電解

Photo by Toru H. Okabe 2013.8, Ganzhou

EC definition of CRM

- *A **Critical Raw Material** is one with high risk of supply disruptions and, at the same time, with high economic importance.*
- ***High risk of supply disruption** means that supply might not be **adequate** to meet EU industry demand.*
- ***High economic importance** means that the raw material is fundamental in industry sectors to create added value and jobs, which are lost in case the raw material is not available **and adequate substitutes cannot be used instead.***

Moreover, the expression "adequate supply" implicitly suggests that industry concerns are linked to aspects of e.g. **quantity**, **quality**, **price** and **timing** on which different stakeholders might have different interpretations and expectations.

CRM methodology

Economic importance

- Importance of a raw material per economic sector & importance of the sector in the EU economy (value added)
- Substitution (technical and cost performance)

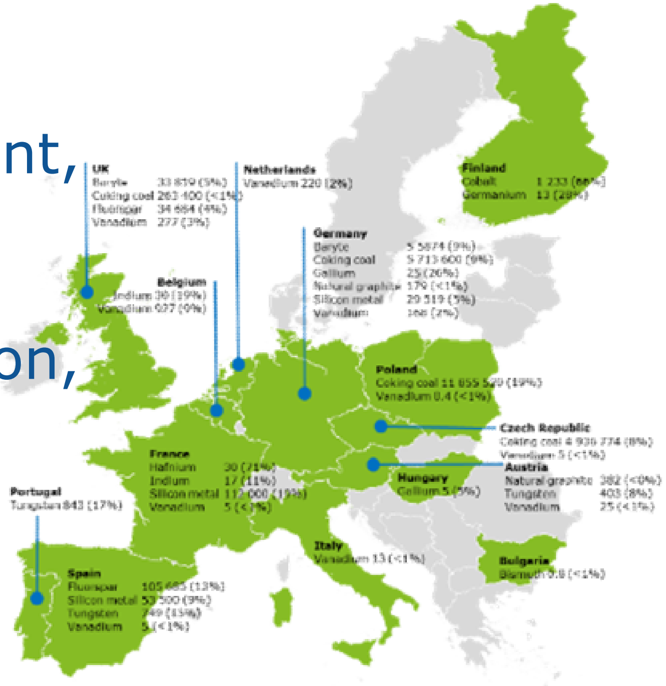
Supply risk

- Global supply and EU sourcing (ores/refined materials)
- Market concentration (HHI)
- Governance performance (WGI)
- Import reliance
- Trade agreements and restrictions
- End-of-Life Recycling Input Rate
- Substitution (production, criticality, co/by-production)

CRM assessment

The List of CRMs has been a valuable push for:

- ✓ Implementing the EU policies and incentivising the EU production of CRMs
- ✓ Prioritising needs and actions (R&D, investment, circular economy)
- ✓ Negotiating trade agreements, drafting legislation, challenging trade distortion measures
- ✓ National policy making
- ✓ Building the EU Knowledge base



textiles

construction

electronics

plastics

European
Commission

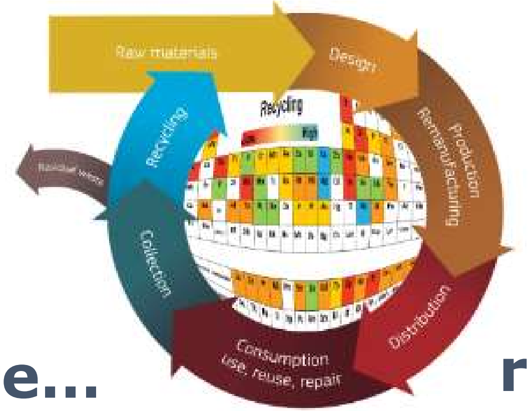
Circular Economy Action Plan

The European Green Deal

March 2020
#EUGreenDeal

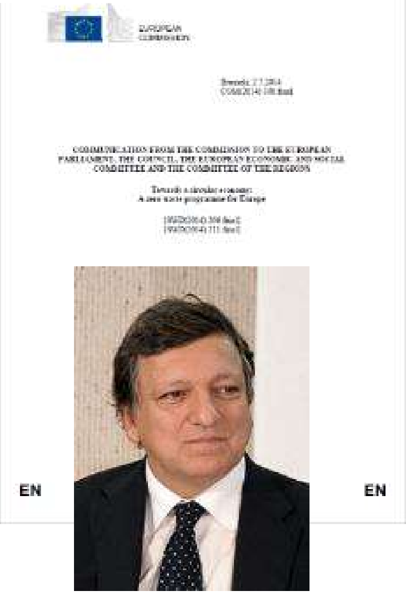
The new **Circular Economy Action Plan** presents new initiatives along the entire life cycle of products in order to modernise and transform our economy while protecting the environment. It is driven by the ambition to make sustainable products that last and to enable our citizens to take full part in the circular economy and benefit from the positive change that it brings about.

cut here… →



re-industrialize →

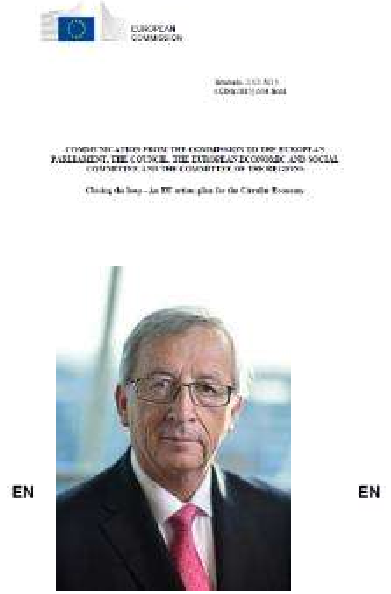
Green Deal


EUROPEAN COMMISSION

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Towards a circular economy:
A zero waste programme for Europe

EN EN


EUROPEAN COMMISSION

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Closing the loop - An EU action plan for the Circular Economy

EN EN


EUROPEAN COMMISSION

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

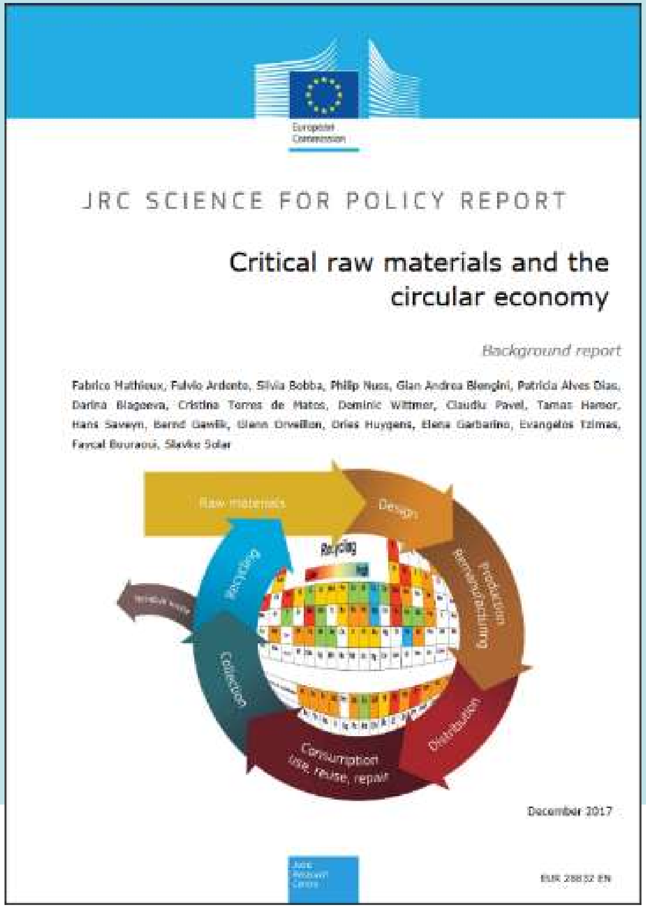
A new Circular Economy Action Plan
For a cleaner and more competitive Europe

EN EN

2014 → 2015 → 2020

Report on CRMs in Circular Economy

Raw Materials Initiative Circular Economy



European Commission

JRC SCIENCE FOR POLICY REPORT

Critical raw materials and the circular economy

Background report

Fabrice Mathieux, Fulvio Ardente, Silvia Bobba, Philip Nuss, Gian Andrea Blengini, Patricia Alves Dias, Darina Blagoeva, Cristina Torres de Matos, Dominic Wittmer, Claudiu Pavel, Tamas Hamor, Hans Saveyn, Bernd Gawlik, Glenn Orveillon, Dries Huygens, Elena Garbarino, Evangelos Tzimas, Faycal Bouraoui, Slavko Solar

December 2017

Joint Research Centre

EUR 28832 EN

Objectives:

- To help EU Member States implement the new provisions on critical raw materials in the EU Waste Framework Directive
- Provide information, data sources and identify best practices and possible further actions

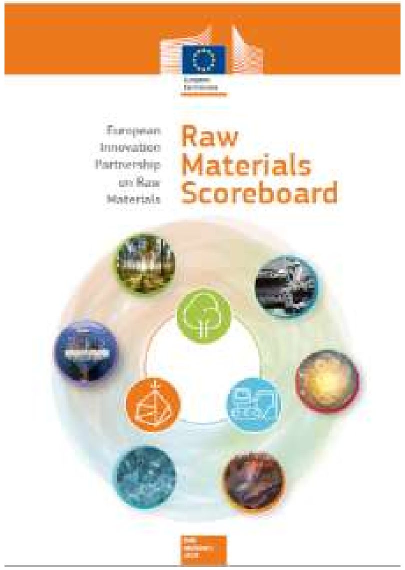
Issued in January 2018 (SWD(2018)36), taking into account the 2017 list of 27 critical raw materials

Key Sectors:

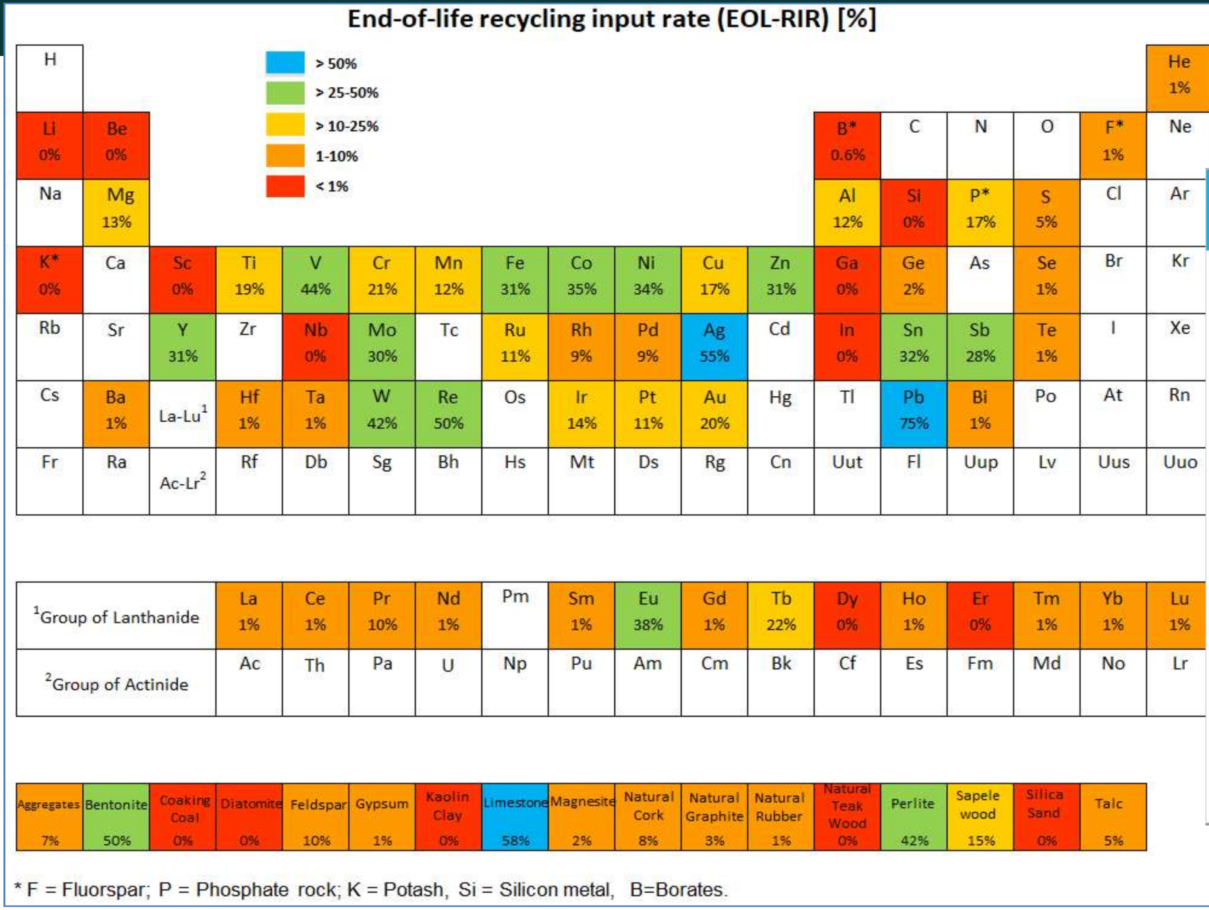
- Electric and Electronic Equipment
- Automotive
- Batteries
- Renewable Energy
- Defense equipment
- Chemicals & Fertilizers

Raw Materials Scoreboard

The role of recycling to meet demand for raw materials.


European Innovation Partnership on Raw Materials

Raw Materials Scoreboard

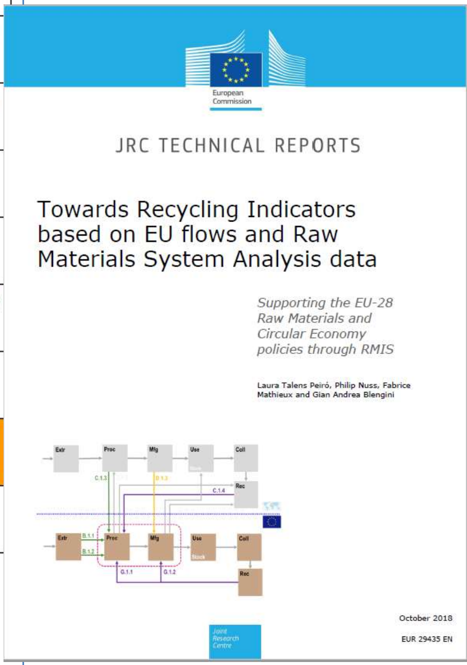

End-of-life recycling input rate (EOL-RIR) [%]

🟦 > 50%
🟩 > 25-50%
🟨 > 10-25%
🟧 1-10%
🟥 < 1%

H																	He 1%
Li 0%	Be 0%											B* 0.6%	C	N	O	F* 1%	Ne
Na	Mg 13%											Al 12%	Si 0%	P* 17%	S 5%	Cl	Ar
K* 0%	Ca	Sc 0%	Ti 19%	V 44%	Cr 21%	Mn 12%	Fe 31%	Co 35%	Ni 34%	Cu 17%	Zn 31%	Ga 0%	Ge 2%	As	Se 1%	Br	Kr
Rb	Sr	Y 31%	Zr	Nb 0%	Mo 30%	Tc	Ru 11%	Rh 9%	Pd 9%	Ag 55%	Cd	In 0%	Sn 32%	Sb 28%	Te 1%	I	Xe
Cs	Ba 1%	La-Lu[1]	Hf 1%	Ta 1%	W 42%	Re 50%	Os	Ir 14%	Pt 11%	Au 20%	Hg	Tl	Pb 75%	Bi 1%	Po	At	Rn
Fr	Ra	Ac-Lr[2]	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo
[1]Group of Lanthanide			La 1%	Ce 1%	Pr 10%	Nd 1%	Pm	Sm 1%	Eu 38%	Gd 1%	Tb 22%	Dy 0%	Ho 1%	Er 0%	Tm 1%	Yb 1%	Lu 1%
[2]Group of Actinide			Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Aggregates 7%	Bentonite 50%	Coaking Coal 0%	Diatomite 0%	Feldspar 10%	Gypsum 1%	Kaolin Clay 0%	Limestone 58%	Magnesite 2%	Natural Cork 8%	Natural Graphite 3%	Natural Rubber 1%	Natural Teak Wood 0%	Perlite 42%	Sapele wood 15%	Silica Sand 0%	Talc 5%

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


European Commission

JRC TECHNICAL REPORTS

Towards Recycling Indicators based on EU flows and Raw Materials System Analysis data

Supporting the EU-28 Raw Materials and Circular Economy policies through RMIS

Laura Talens Peiró, Philip Nuss, Fabrice Mathieux and Gian Andrea Blengini

Joint Research Centre

October 2018

EUR 29435 EN

European Commission methodology to define the *List of CRMs for the EU*

→2010 first release

→2013 update

→2015 revision (*DG JRC*)

JRC TECHNICAL REPORTS

Assessment of the Methodology for Establishing the EU List of Critical Raw Materials

Background Report

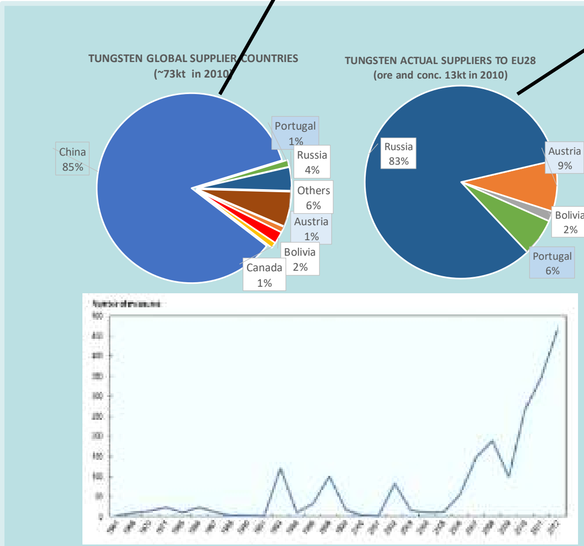
2017

METHODOLOGY FOR ESTABLISHING THE EU LIST OF
CRITICAL RAW MATERIALS

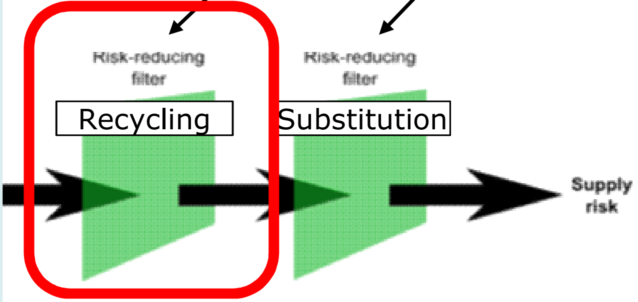
• Guidelines •

SUPPLY RISK → role of circularity /recycling

$$SR = \left[\left(HHI_{WGI-t}\right)_{GS} \cdot \frac{IR}{2} + \left(HHI_{WGI-t}\right)_{EUsourcing}\left(1 - \frac{IR}{2}\right)\right] \boxed{\left(1 - EoL_{RIR}\right)} \, SI_{SR}$$



- -**Supply concentr. (HHI)**
- -**Poor Governance (WGI)**
- -**Global vs EU**
- -**Import dependency**
- -**Trade**
- -**Supply chain**
- -**Substitution**
- -**Recycling**



- -**Black → already in 2014**
- -**Red → JRC introduced**
- -**Blue → JRC improved**

Resources Policy

EU methodology for critical raw materials assessment: Policy needs and proposed solutions for incremental improvements

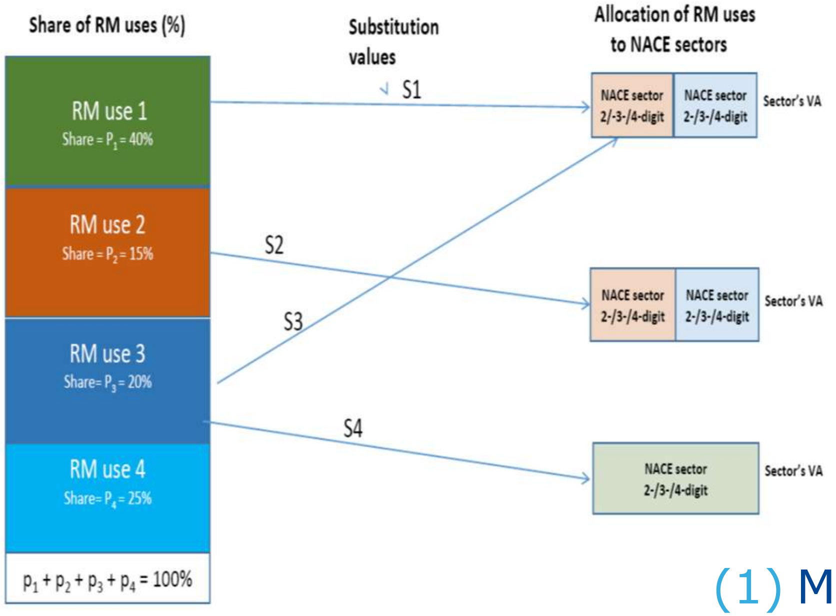
Gian Andrea Blengini, Philip Nuss, Jo Dewulf, Viorel Nita, Laura Talens Peirò, Beatriz Vidal-Legaz, Cynthia Latunussa, Lucia Mancini, Darina Blagoeva, David Pennington, Mattia Pellegrini, Alexis Van Maercke, Slavko Solar, Milan Grohol, Constantin Ciupagea

ARTICLE INFO

ABSTRACT

European Commission

ECONOMIC IMPORTANCE



$$EI = \sum_{s} (A_s * Q_s) * SI$$

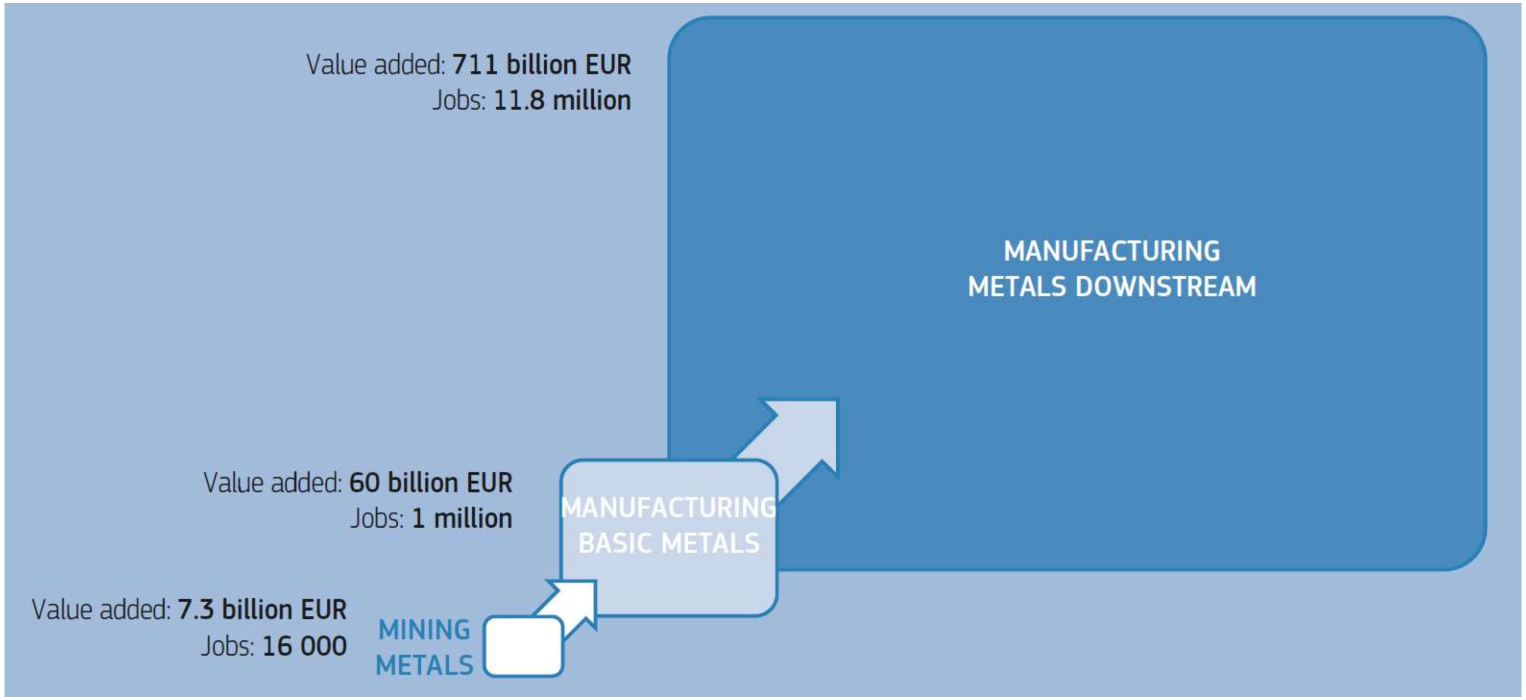
(1) MEGASECTORS → NACE-2

(2) allocation of RM uses (NACE-6)

(3) RM-specific substitution index

Raw Materials Scoreboard

More than 11 million jobs in manufacturing industries depend on the secure supply of metals



Value added: **711 billion EUR**
Jobs: **11.8 million**

MANUFACTURING
METALS DOWNSTREAM

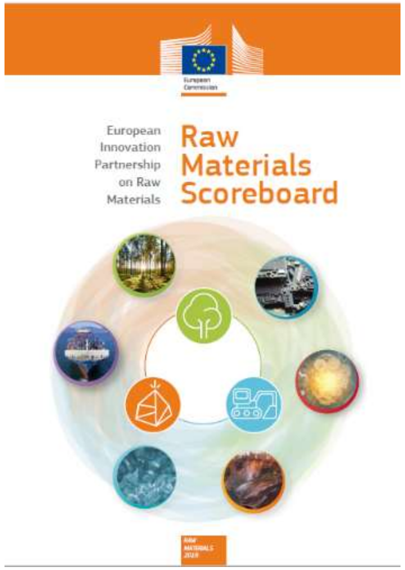
Value added: **60 billion EUR**
Jobs: **1 million**

MANUFACTURING
BASIC METALS

Value added: **7.3 billion EUR**
Jobs: **16 000**

MINING
METALS

Figure 19: Value added and number of jobs associated with metals (mining, basic manufacture and downstream sectors) in the EU (2012)

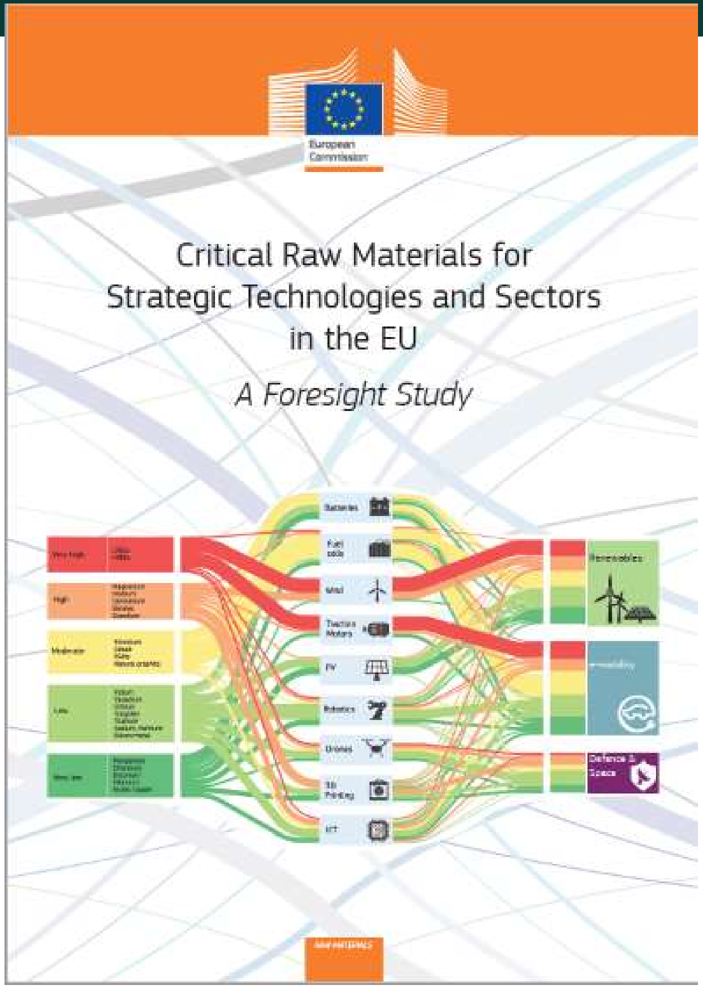


European
Innovation
Partnership
on Raw
Materials

Raw
Materials
Scoreboard

European Commission

JRC foresight study on CRMs in strategic sectors



European Commission

Critical Raw Materials for
Strategic Technologies and Sectors
in the EU

A Foresight Study

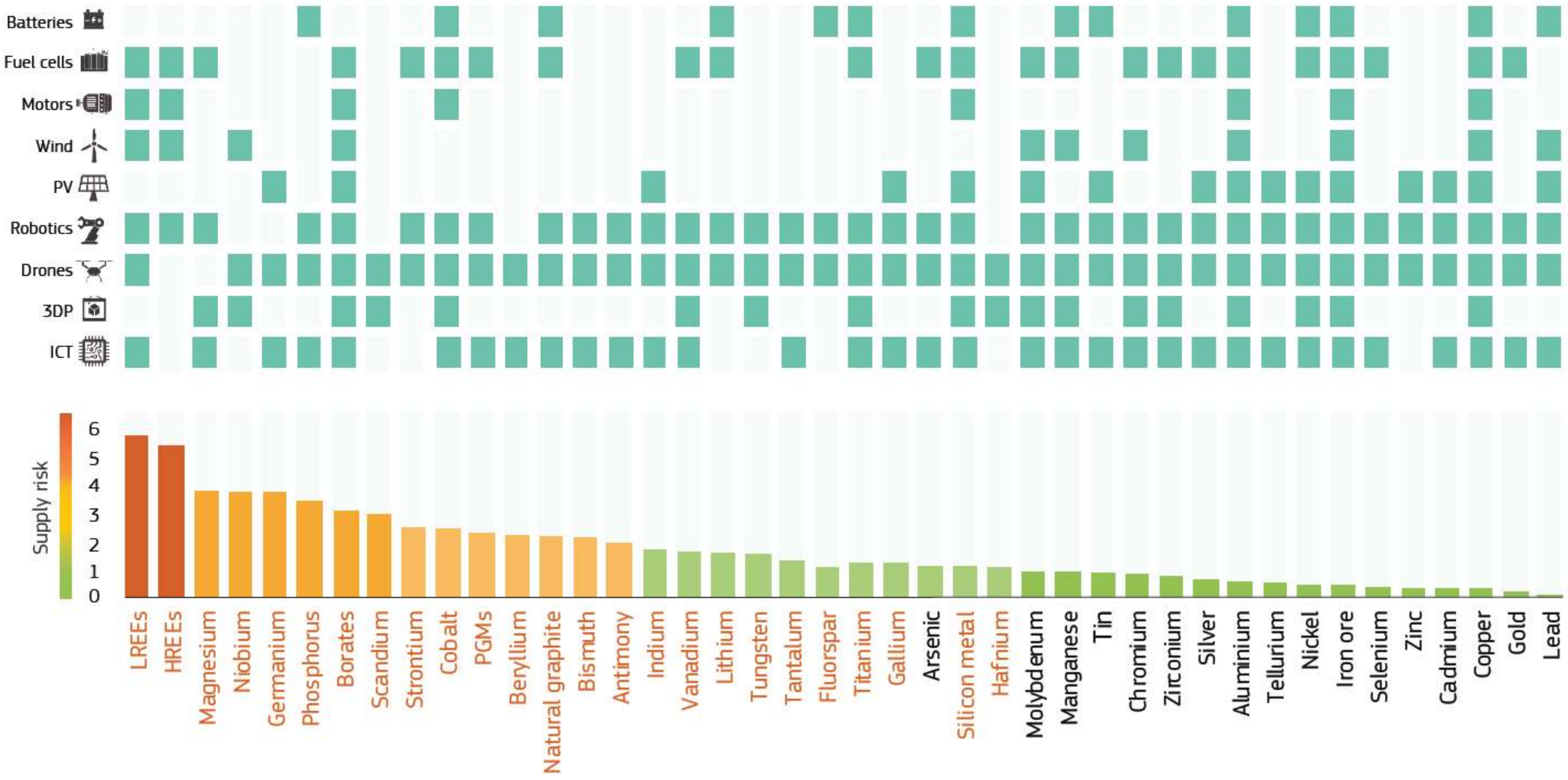
Speech | 3 September 2020 | Brussels

Speech by Vice-President Šefčovič at the Press Conference on critical raw materials resilience in the EU

- In the world of **tomorrow,** this overreliance may become even more acute. Our **strategic foresight tells us that the demand for raw materials is only going to rise**: for example, Europe will need almost **60 times more lithium and 15 times more cobalt by 2050** for electric cars and energy storage alone. Demand for **rare earths** used in permanent magnets, critical for products like wind generators, could **increase ten-fold in the same period**.

JRC Report: → up to 60 times and up to 15 times…

SUPPLY RISK OF RAW MATERIALS FOR KEY TECHNOLOGIES



	Batteries	Fuel cells	Motors	Wind	PV	Robotics	Drones	3DP	ICT
LREEs		🟩	🟩	🟩		🟩	🟩		🟩
HREEs		🟩	🟩	🟩		🟩			
Magnesium		🟩				🟩		🟩	🟩
Niobium				🟩			🟩	🟩	
Germanium					🟩		🟩		🟩
Phosphorus	🟩					🟩	🟩		🟩
Borates		🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Scandium							🟩	🟩	
Strontium		🟩				🟩	🟩		
Cobalt	🟩	🟩	🟩			🟩	🟩	🟩	🟩
PGMs		🟩				🟩	🟩		🟩
Beryllium							🟩		🟩
Natural graphite	🟩	🟩				🟩	🟩		🟩
Bismuth						🟩	🟩		🟩
Antimony						🟩	🟩		🟩
Indium					🟩	🟩	🟩		🟩
Vanadium		🟩				🟩	🟩	🟩	🟩
Lithium	🟩	🟩				🟩	🟩		
Tungsten						🟩	🟩	🟩	
Tantalum						🟩	🟩		🟩
Fluorspar	🟩					🟩	🟩		
Titanium	🟩	🟩				🟩	🟩	🟩	🟩
Gallium					🟩	🟩	🟩		🟩
Arsenic		🟩				🟩	🟩		🟩
Silicon metal	🟩	🟩	🟩		🟩	🟩	🟩	🟩	🟩
Hafnium							🟩	🟩	
Molybdenum		🟩		🟩	🟩	🟩	🟩	🟩	🟩
Manganese	🟩	🟩		🟩		🟩	🟩	🟩	🟩
Tin	🟩				🟩	🟩	🟩		🟩
Chromium		🟩		🟩		🟩	🟩	🟩	🟩
Zirconium		🟩				🟩	🟩	🟩	🟩
Silver		🟩			🟩	🟩	🟩		🟩
Aluminium	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Tellurium					🟩	🟩	🟩		🟩
Nickel	🟩	🟩			🟩	🟩	🟩	🟩	🟩
Iron ore	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Selenium		🟩				🟩	🟩		🟩
Zinc					🟩	🟩	🟩		
Cadmium					🟩	🟩	🟩		🟩
Copper	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Gold		🟩				🟩	🟩		🟩
Lead	🟩			🟩	🟩	🟩	🟩		🟩

List of materials/groupings covered in the 2020 assessment

Critical Raw Materials 2020

Individual materials		
🟧 Aggregates	Germanium	🟩 Phosphate rock
Aluminium	🟩 Hafnium	Rhenium
Antimony	🟧 Helium	Scandium
🟦 Arsenic	🟦 Hydrogen	🟩 Selenium
Baryte	Indium	🟧 Sulphur
Bauxite	Iron Ore	🟩 Potash
Bentonite	🟧 Lead	Silica Sand
Beryllium	Limestone	🟩 Silicon Metal
🟧 Bismuth	🟩 Gold	Silver
Boron (Borates)	Gypsum	🟦 Strontium
🟦 Cadmium	Lithium	Talc
Chromium	Magnesite	Tantalum
Kaolin clay	Magnesium	Tellurium
Cobalt	Manganese	🟩 Tin
🟩 Coking coal	Molybdenum	Titanium
Copper	Natural Graphite	Tungsten
Diatomite	Nickel	Vanadium
Feldspar	Niobium	Zinc
Fluorspar	Perlite	🟦 Zirconium
Gallium	🟧 Phosphorus	
Platinum group metals (PGMs)		
Iridium	Platinum	Ruthenium
Palladium	Rhodium	
Rare earth elements (REEs)		
LREEs	HREEs	
Cerium	Dysprosium	Lutetium
Lanthanum	Erbium	Terbium
Neodymium	Europium	Thulium
Praseodymium	Gadolinium	Ytterbium
Samarium	Holmium	Yttrium
Biotic materials		
🟩 Natural Rubber	🟧 Natural cork	
🟧 Sapele wood	🟧 Natural Teak wood	

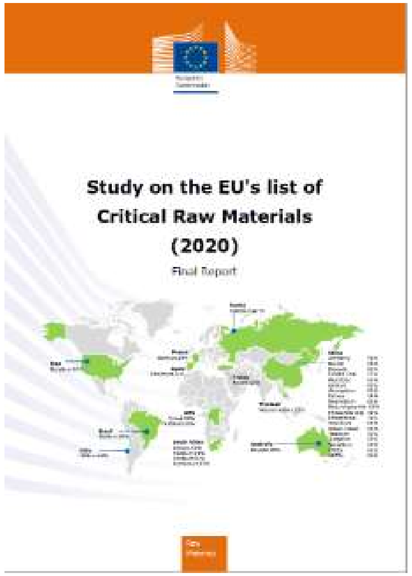
Legend:	
🟩 Green boxes	Materials covered in 2014 but not in the 2011 assessments
🟧 Orange boxes	Materials covered in 2017 but not in the 2014 assessments
🟦 Light blue boxes	New materials covered in the 2020 assessment

Critical Raw Materials 2020

COM(2020) 474 final

EUROPEAN
COMMISSION

EN EN



Study on the EU's list of
Critical Raw Materials
(2020)

Final Report

2020 Critical Raw Materials (30)			
Antimony	Fluorspar	Magnesium	Silicon Metal
Baryte	Gallium	Natural Graphite	Tantalum
Bauxite	Germanium	Natural Rubber	Titanium
Beryllium	Hafnium	Niobium	Vanadium
Bismuth	HREEs	PGMs	Tungsten
Borates	Indium	Phosphate rock	Strontium
Cobalt	Lithium	Phosphorus	
Coking Coal	LREEs	Scandium	

Critical Raw Materials 2023

Study on the Critical Raw Materials for the EU
2023
Final Report

Screened raw materials in 2023 assessment (new materials in blue)	
Industrial and construction minerals	aggregates, baryte, bentonite, borates, diatomite, feldspar, fluorspar, gypsum, kaolin clay, limestone, magnesite, natural graphite, perlite, phosphate rock, phosphorus, potash, silica sand, sulphur, talc
Iron and ferro-alloy metals	chromium, cobalt, manganese, molybdenum, nickel, niobium, tantalum, titanium, titanium metal, tungsten, vanadium
Precious metals	gold, silver, and Platinum Group Metals (iridium, palladium, platinum, rhodium, ruthenium)
Rare earths	heavy rare earths - HREE (dysprosium, erbium, europium, gadolinium, holmium, lutetium, terbium, thulium, ytterbium, yttrium); light rare earths - LREE (cerium, lanthanum, neodymium, praseodymium and samarium); and scandium
Other non-ferrous metals	aluminium/bauxite, antimony, arsenic, beryllium, bismuth, cadmium, copper, gallium, germanium, gold, hafnium, indium, lead, lithium, magnesium, rhenium, selenium, silicon metal, silver, strontium, tellurium, tin, zinc, zirconium
Bio and other materials	natural cork, natural rubber, natural teak wood, sapele wood, coking coal, hydrogen, helium, roundwood, neon, krypton, xenon

Critical Raw Materials 2023

European Commission

Study on the Critical Raw Materials for the EU

2023

Final Report

Raw Materials

2023 CRMs vs. 2020 CRMs			
aluminium/bauxite	gallium	phosphate rock	vanadium
antimony	germanium	phosphorus	arsenic
baryte	hafnium	PGM	feldspar
beryllium	HREE	scandium	helium
bismuth	lithium	silicon metal	manganese
borate	LREE	strontium	copper
cobalt	magnesium	tantalum	nickel
coking coal	natural graphite	titanium metal	~~indium~~
fluorspar	niobium	tungsten	~~natural rubber~~

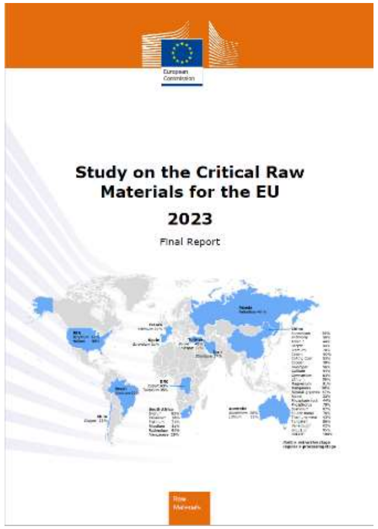
Legend:

Black: CRMs in 2023 and 2020

Red: CRMs in 2023, non-CRMs in 2020

~~Strike:~~ Non-CRMs in 2023 that were critical in 2020

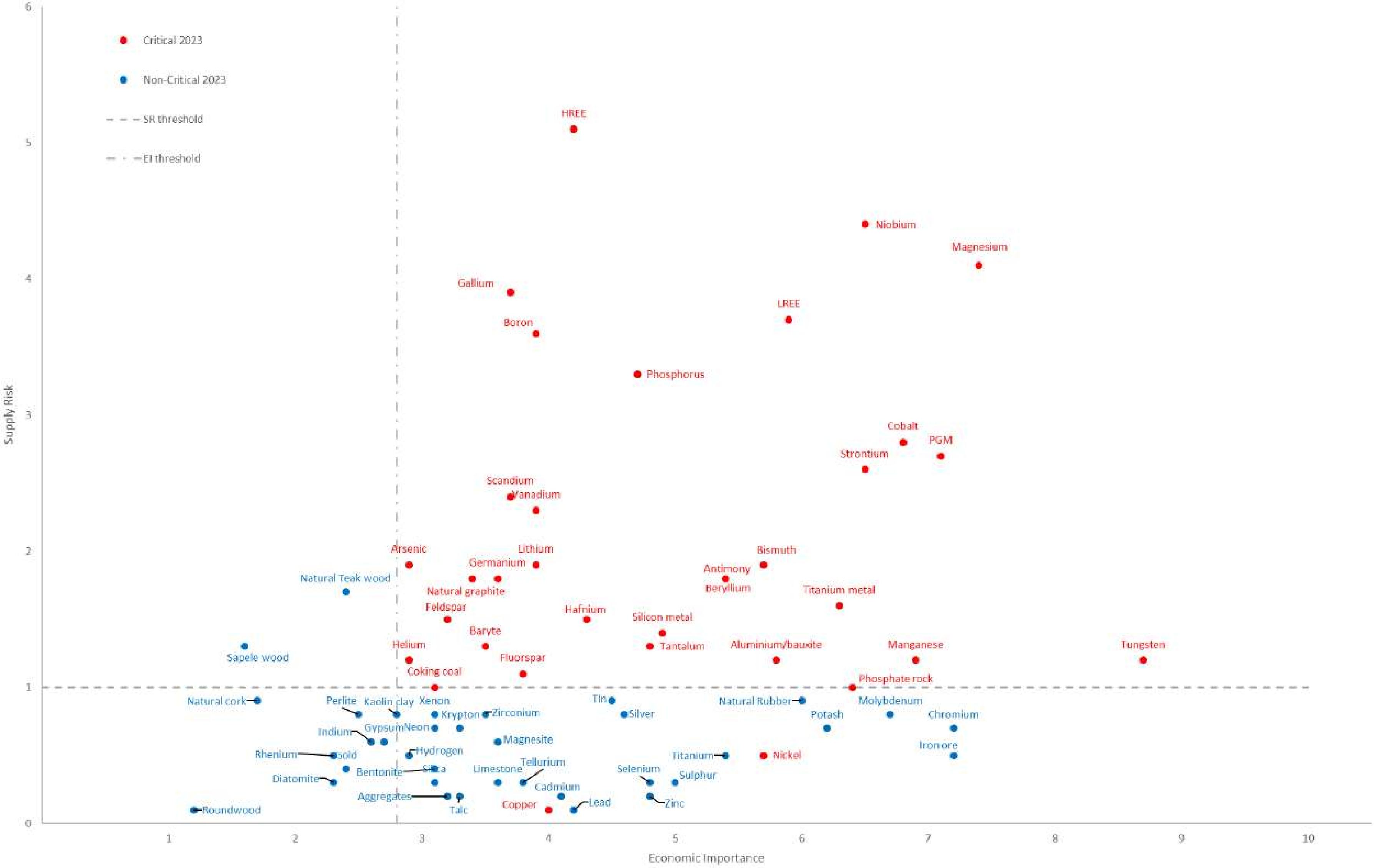
Critical Raw Materials 2023



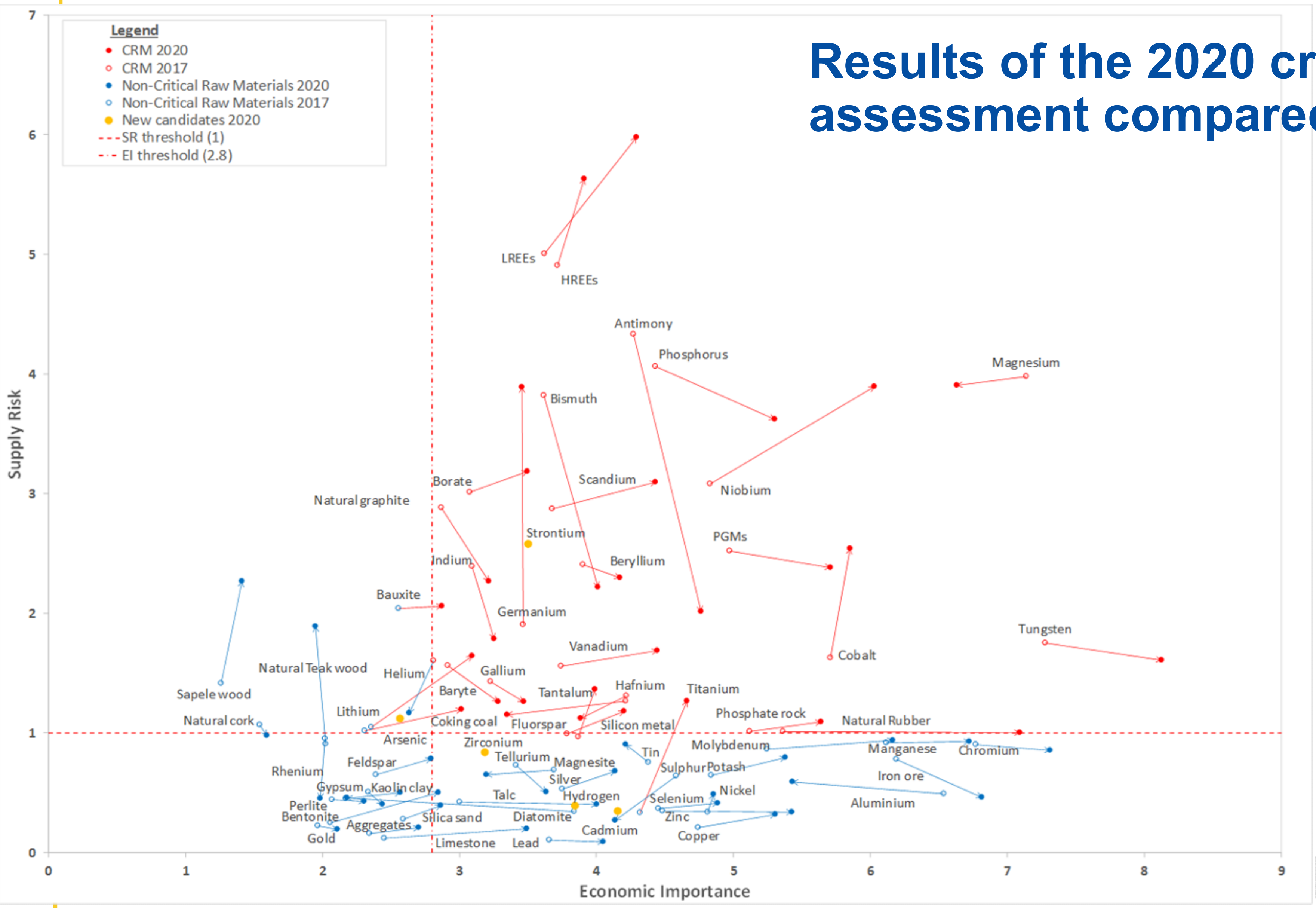
Study on the Critical Raw Materials for the EU

2023

Final Report

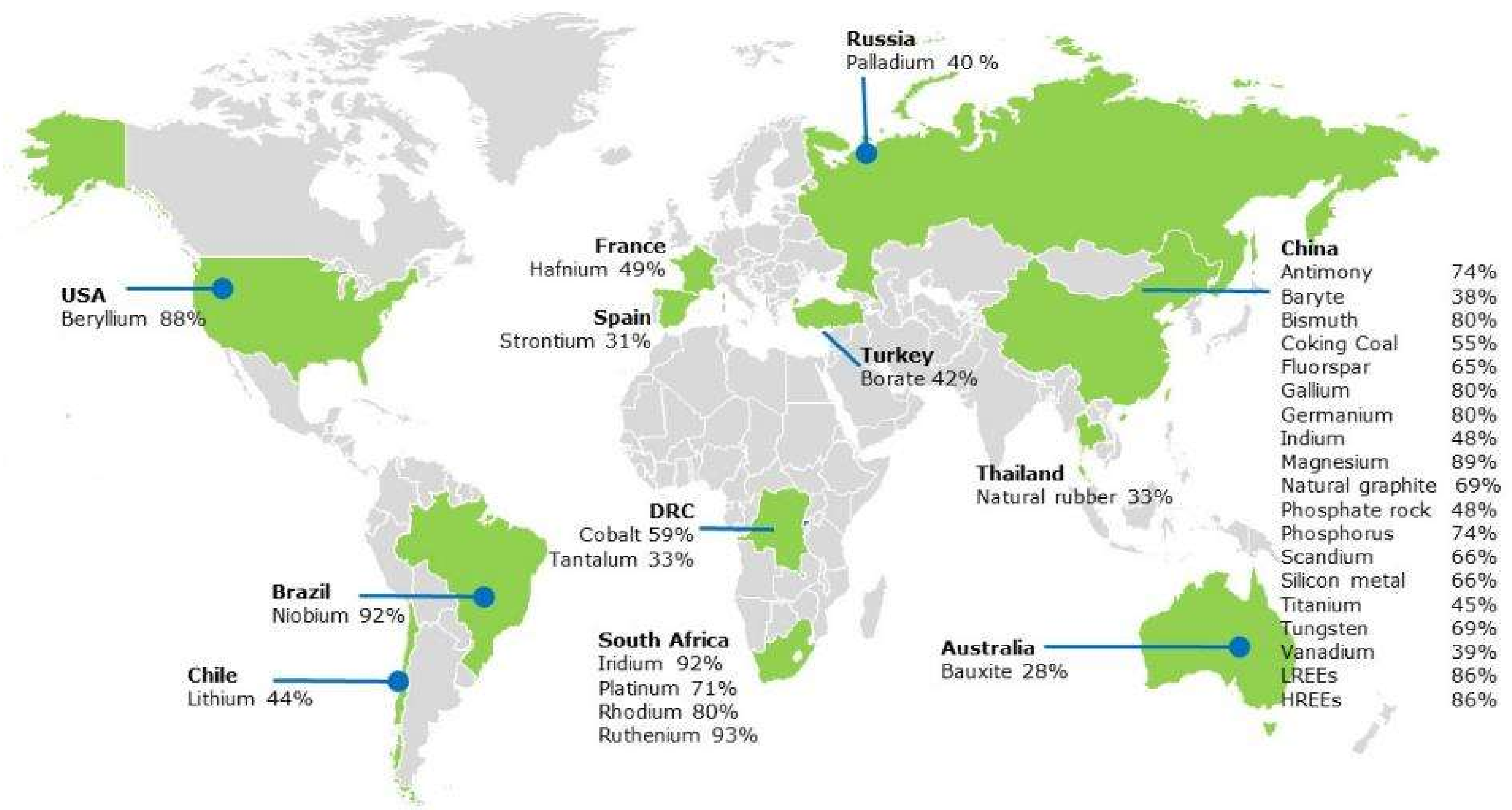


Results of the 2020 criticality assessment compared to 2017



European Commission

Critical Raw Materials (2020 list of CRMs for the EU)



Russia
Palladium 40 %

USA
Beryllium 88%

France
Hafnium 49%

Spain
Strontium 31%

Turkey
Borate 42%

Thailand
Natural rubber 33%

DRC
Cobalt 59%
Tantalum 33%

Brazil
Niobium 92%

Chile
Lithium 44%

South Africa
Iridium 92%
Platinum 71%
Rhodium 80%
Ruthenium 93%

Australia
Bauxite 28%

China

Antimony	74%
Baryte	38%
Bismuth	80%
Coking Coal	55%
Fluorspar	65%
Gallium	80%
Germanium	80%
Indium	48%
Magnesium	89%
Natural graphite	69%
Phosphate rock	48%
Phosphorus	74%
Scandium	66%
Silicon metal	66%
Titanium	45%
Tungsten	69%
Vanadium	39%
LREEs	86%
HREEs	86%

Countries accounting for largest share of global supply of CRMs

JRC TECHNICAL REPORTS

Assessment of the Methodology for Establishing the EU List of Critical Raw Materials

METHODOLOGY FOR ESTABLISHING THE EU LIST OF CRITICAL RAW MATERIALS

- Guidelines -

COM(2020) 474 final

EN EN

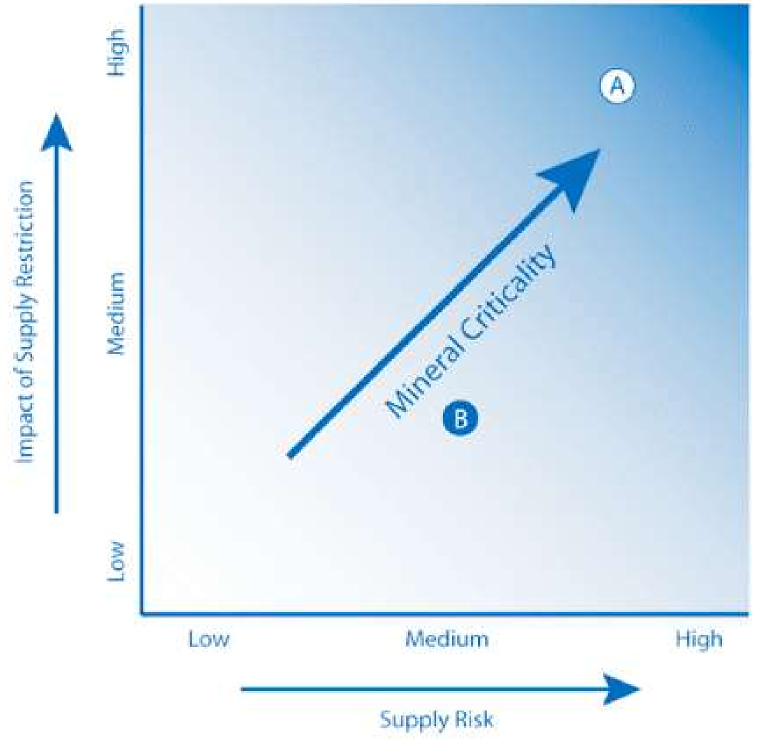
Criticality assessment is:

- a call for attention → **not panic**

- a screening exercise

- prelude to detailed assessment

US NRC, 2008


High
Medium
Low
Impact of Supply Restriction
A
Mineral Criticality
B
Low
Medium
High
Supply Risk

IRTC, 2020

Resources, Conservation & Recycling 155 (2020) 104617

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

journal homepage: www.elsevier.com/locate/resconrec

A review of methods and data to determine raw material criticality

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[y] Empa, Swiss Federal Laboratories for Materials Science and Technology, Technology & Society Laboratory, Lerchenfeldstrasse 5, CH-9014 St. Gallen, Switzerland

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Abbreviations: BGS, British Geological Survey; BRGM, Bureau de Recherches Géologiques et Minières; CRM, Critical Raw Materials; EC, European Commission; Empa, Swiss Federal Laboratories for Materials Science and Technology; EIT, European Institute of Innovation & Technology; EU, European Union; GE, General Electric; HDI, Human Development Index; HHI, Herfindahl-Hirschman-Index; ICIRCE, Instituto Universitario Investigación CIRCE Universidad Zaragoza; INSEAD, Institut Européen d'Administration des Affaires; IRTC, International Round Table on Materials Criticality; ISO, International Organization for Standardization; KIRAM/KITECH, Korea Institute for Rare Metals/Korea Institute of Industrial Technology; LCA, Life Cycle Assessment; NEDO, New Energy and Industrial Technology Development; NIES, National Institute for Environmental Studies; NRC, National Research Council; NSTC, National Science and Technology Council; OECD, Organisation for Economic Co-operation and Development; OH, Oakdene Hollins; PGM(s), Platinum Group Metal(s); PPI, Policy Perception Index; REE(s), Rare Earth Element(s); SDU, University of Southern Denmark; SI, Supplementary Information; UBA, Umweltbundesamt; UNDP, United Nations Development Programme; UNEP IRP, United Nations Environment Programme International Resource Panel; US DOE, United States Department of Energy; USGS, United States Geological Survey; VDI, Verein Deutscher Ingenieure; WGI, Worldwide Governance Indicators

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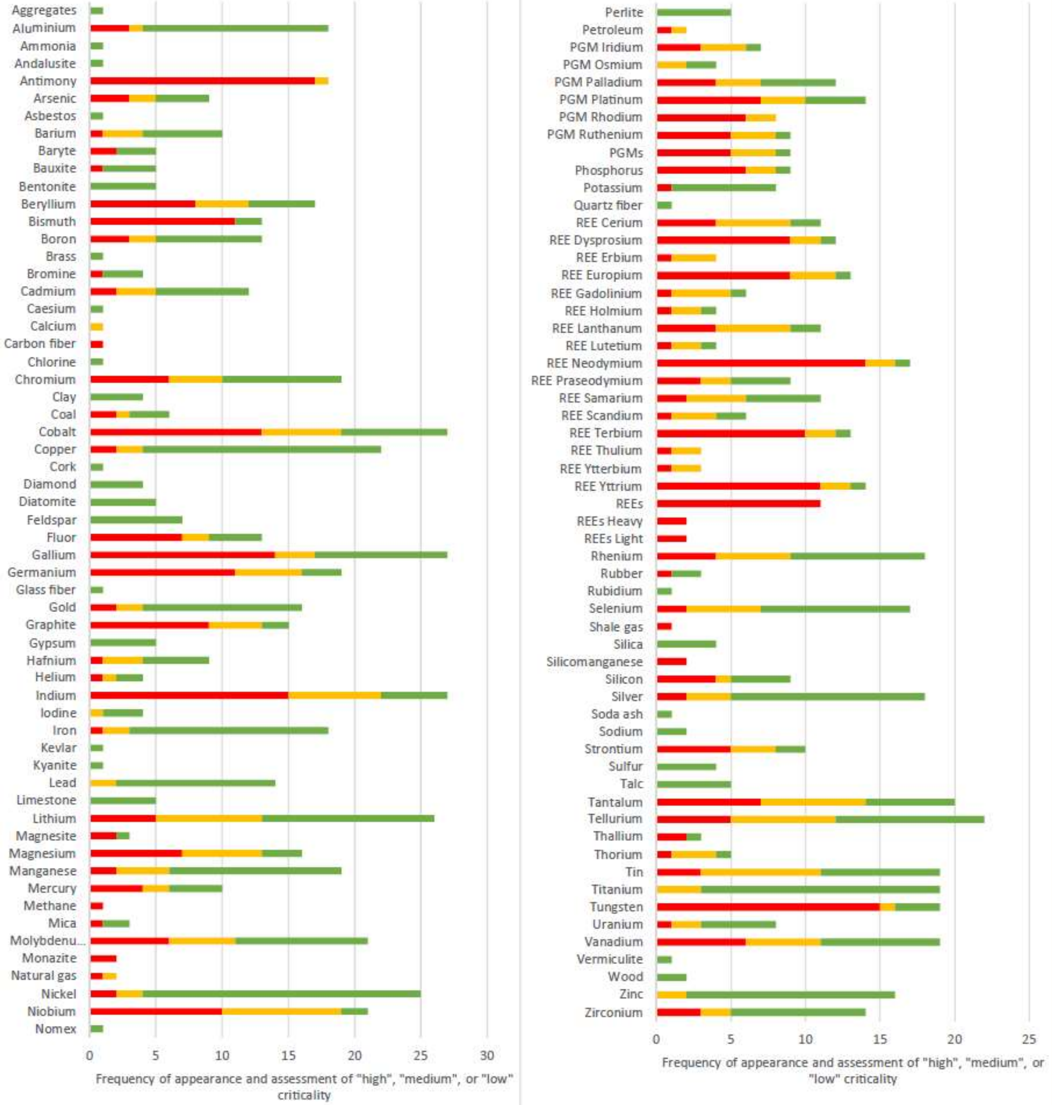

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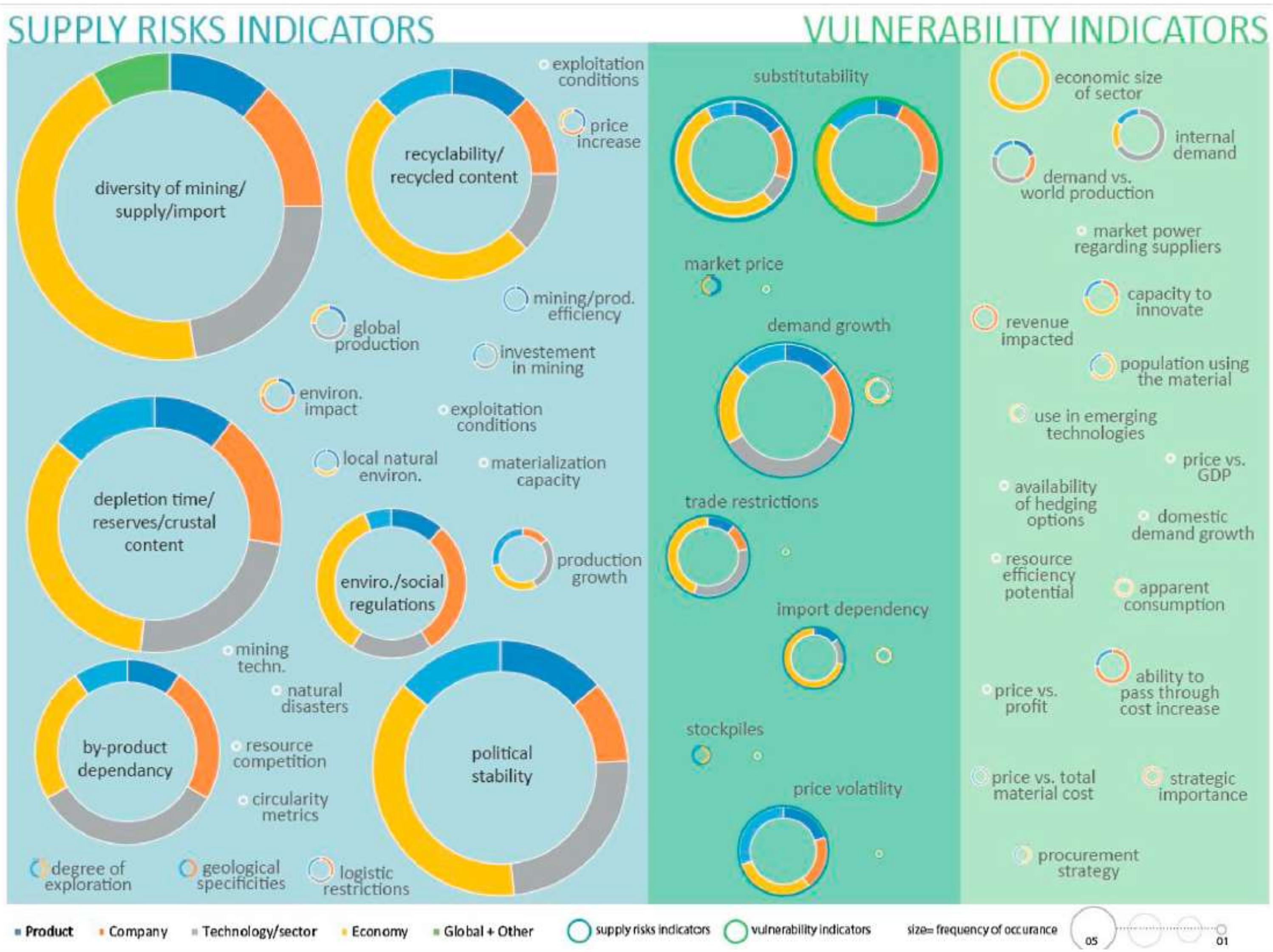
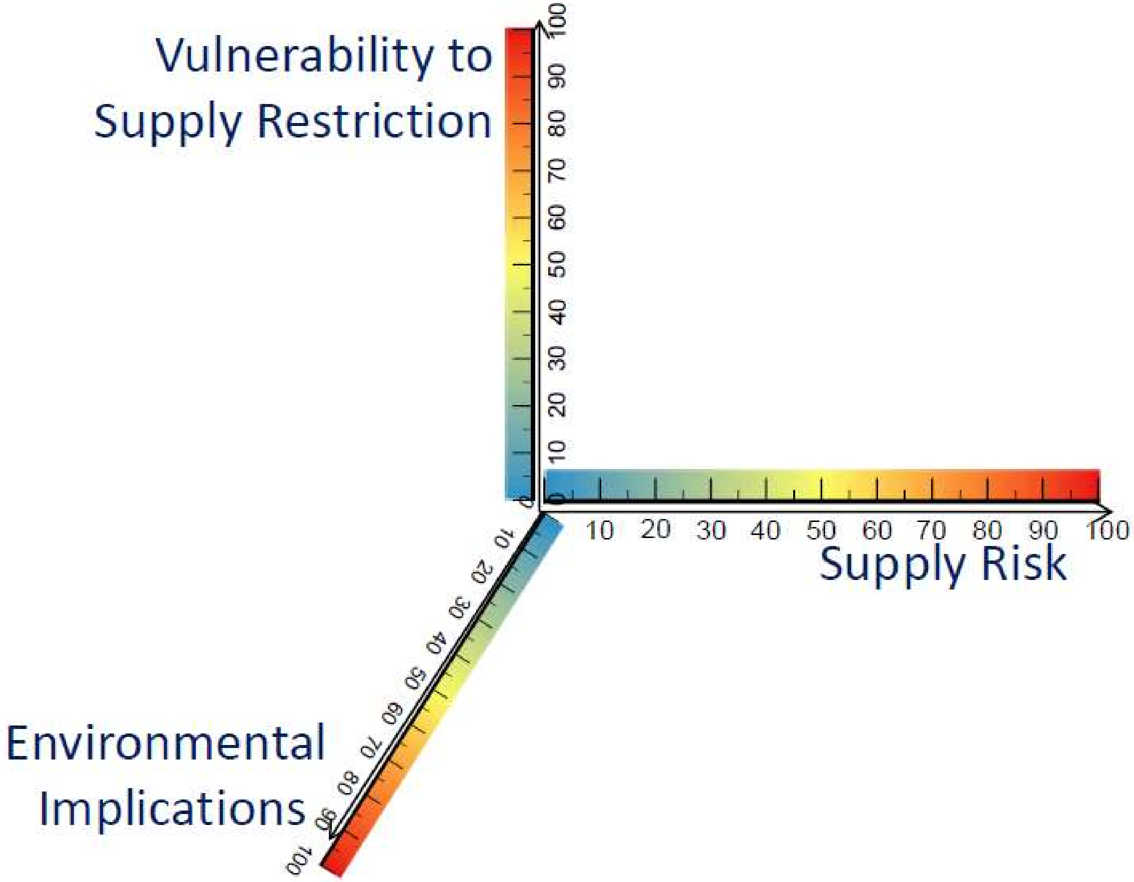
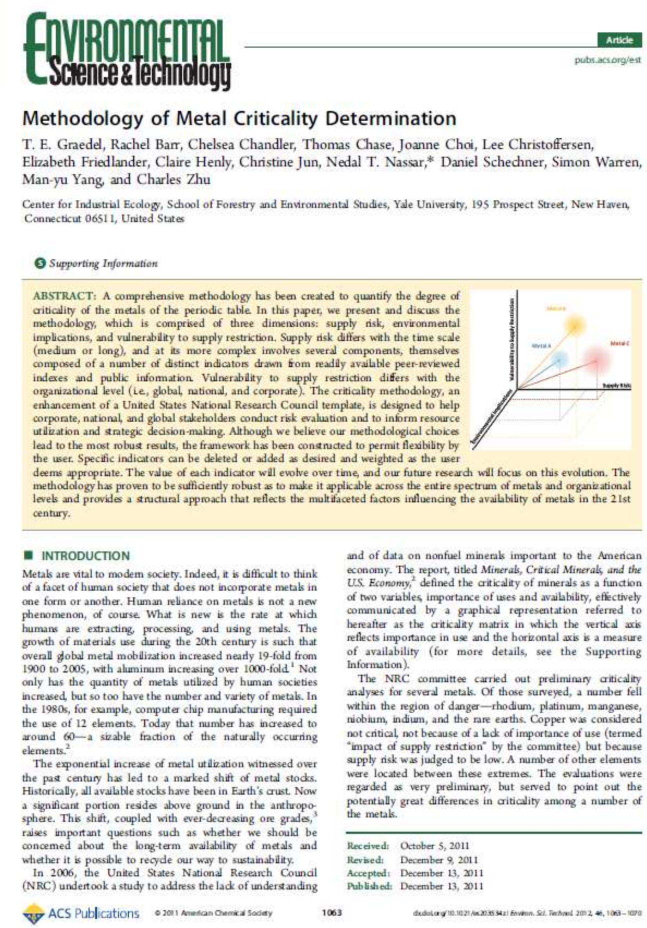


Critical Materials in the EU and international Agendas (2022)

YALE UNIV, 2012





Environmental Science & Technology
Article
pubs.acs.org/est

Methodology of Metal Criticality Determination

T. E. Graedel, Rachel Barr, Chelsea Chandler, Thomas Chase, Joanne Choi, Lee Christoffersen, Elizabeth Friedlander, Claire Henly, Christine Jun, Nedal T. Nassar,* Daniel Schechner, Simon Warren, Man-yu Yang, and Charles Zhu

Center for Industrial Ecology, School of Forestry and Environmental Studies, Yale University, 195 Prospect Street, New Haven, Connecticut 06511, United States

Supporting Information

ABSTRACT: A comprehensive methodology has been created to quantify the degree of criticality of the metals of the periodic table. In this paper, we present and discuss the methodology, which is comprised of three dimensions: supply risk, environmental implications, and vulnerability to supply restriction. Supply risk differs with the time scale (medium or long), and at its more complex involves several components, themselves composed of a number of distinct indicators drawn from readily available peer-reviewed indexes and public information. Vulnerability to supply restriction differs with the organizational level (i.e., global, national, and corporate). The criticality methodology, an enhancement of a United States National Research Council template, is designed to help corporate, national, and global stakeholders conduct risk evaluation and to inform resource utilization and strategic decision-making. Although we believe our methodological choices lead to the most robust results, the framework has been constructed to permit flexibility by the user. Specific indicators can be deleted or added as desired and weighted as the user deems appropriate. The value of each indicator will evolve over time, and our future research will focus on this evolution. The methodology has proven to be sufficiently robust as to make it applicable across the entire spectrum of metals and organizational levels and provides a structural approach that reflects the multifaceted factors influencing the availability of metals in the 21st century.

INTRODUCTION

Metals are vital to modern society. Indeed, it is difficult to think of a facet of human society that does not incorporate metals in one form or another. Human reliance on metals is not a new phenomenon, of course. What is new is the rate at which humans are extracting, processing, and using metals. The growth of materials use during the 20th century is such that overall global metal mobilization increased nearly 19-fold from 1900 to 2005, with aluminum increasing over 1000-fold.[1] Not only has the quantity of metals utilized by human societies increased, but so too have the number and variety of metals. In the 1980s, for example, computer chip manufacturing required the use of 12 elements. Today that number has increased to around 60—a sizable fraction of the naturally occurring elements.[2]

The exponential increase of metal utilization witnessed over the past century has led to a marked shift of metal stocks. Historically, all available stocks have been in Earth's crust. Now a significant portion resides above ground in the anthroposphere. This shift, coupled with ever-decreasing ore grades,[3] raises important questions such as whether we should be concerned about the long-term availability of metals and whether it is possible to recycle our way to sustainability.

In 2006, the United States National Research Council (NRC) undertook a study to address the lack of understanding and of data on nonfuel minerals important to the American economy. The report, titled *Minerals, Critical Minerals, and the U.S. Economy*,[2] defined the criticality of minerals as a function of two variables, importance of uses and availability, effectively communicated by a graphical representation referred to hereafter as the criticality matrix in which the vertical axis reflects importance in use and the horizontal axis is a measure of availability (for more details, see the Supporting Information).

The NRC committee carried out preliminary criticality analyses for several metals. Of those surveyed, a number fell within the region of danger—rhodium, platinum, manganese, niobium, indium, and the rare earths. Copper was considered not critical, not because of a lack of importance of use (termed "impact of supply restriction" by the committee) but because supply risk was judged to be low. A number of other elements were located between these extremes. The evaluations were regarded as very preliminary, but served to point out the potentially great differences in criticality among a number of the metals.

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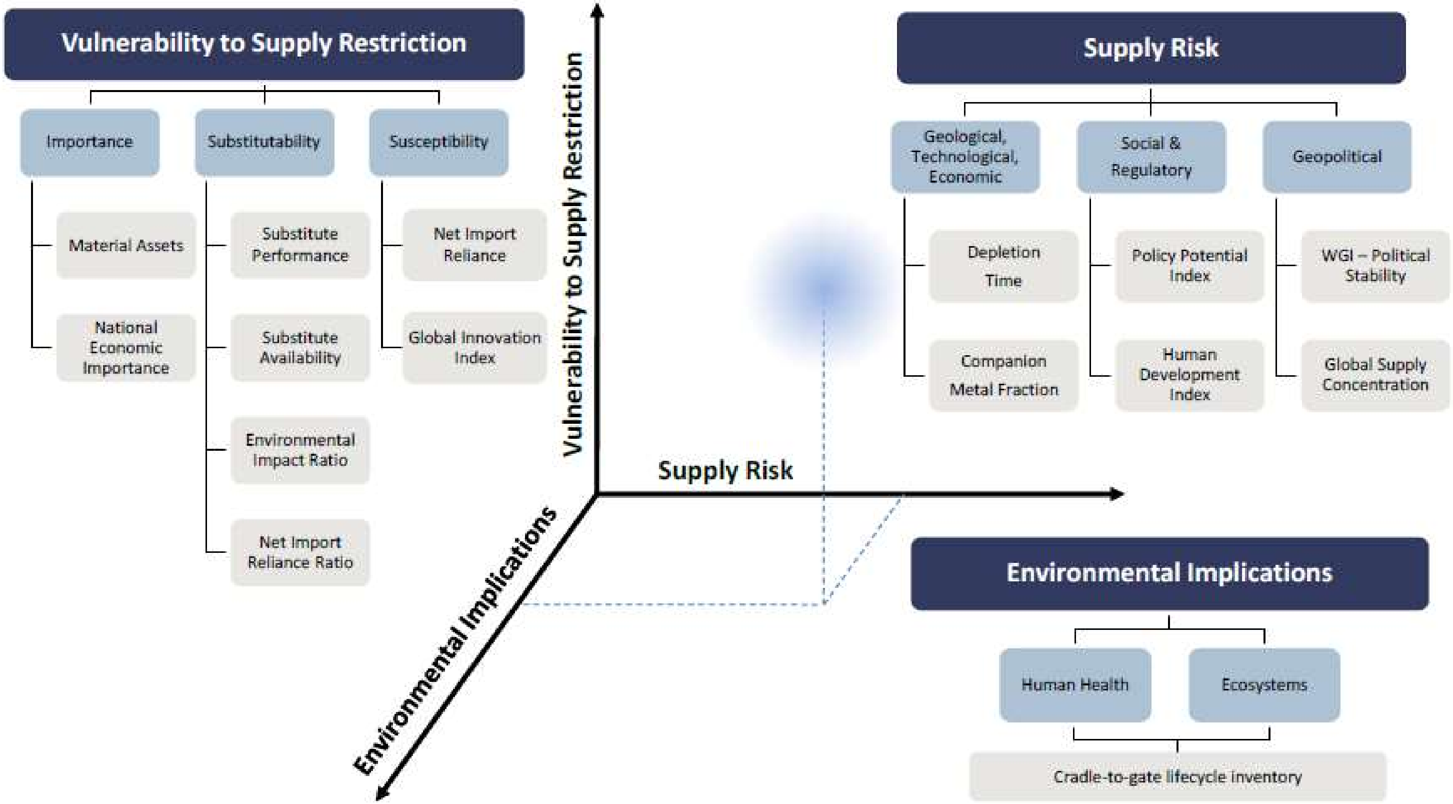
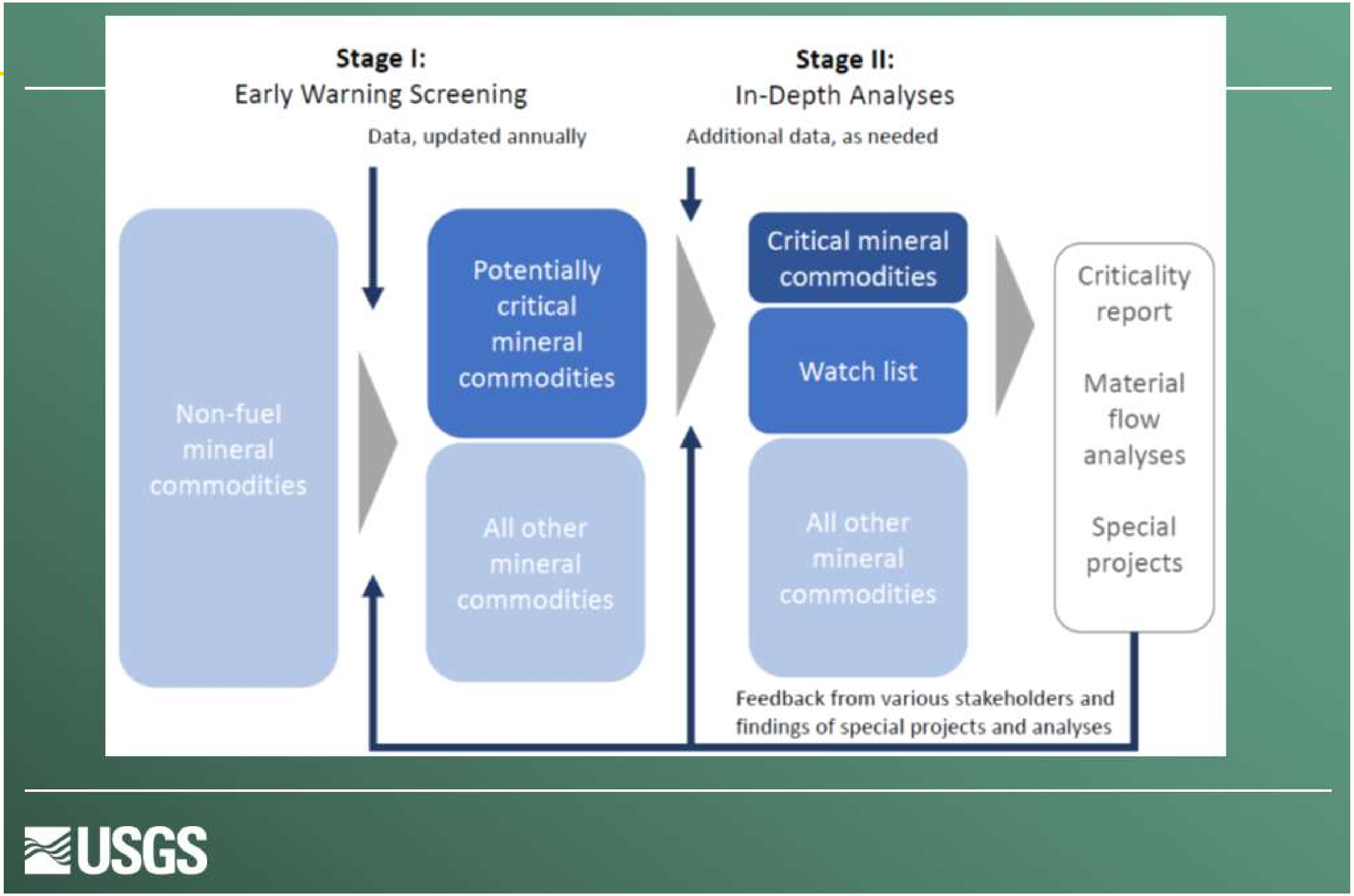
YALE UNIV



Graedel et al. (2012)

USGS



Stage I:
Early Warning Screening

Data, updated annually

Stage II:
In-Depth Analyses

Additional data, as needed

Non-fuel mineral commodities

Potentially critical mineral commodities

All other mineral commodities

Critical mineral commodities

Watch list

All other mineral commodities

Criticality report

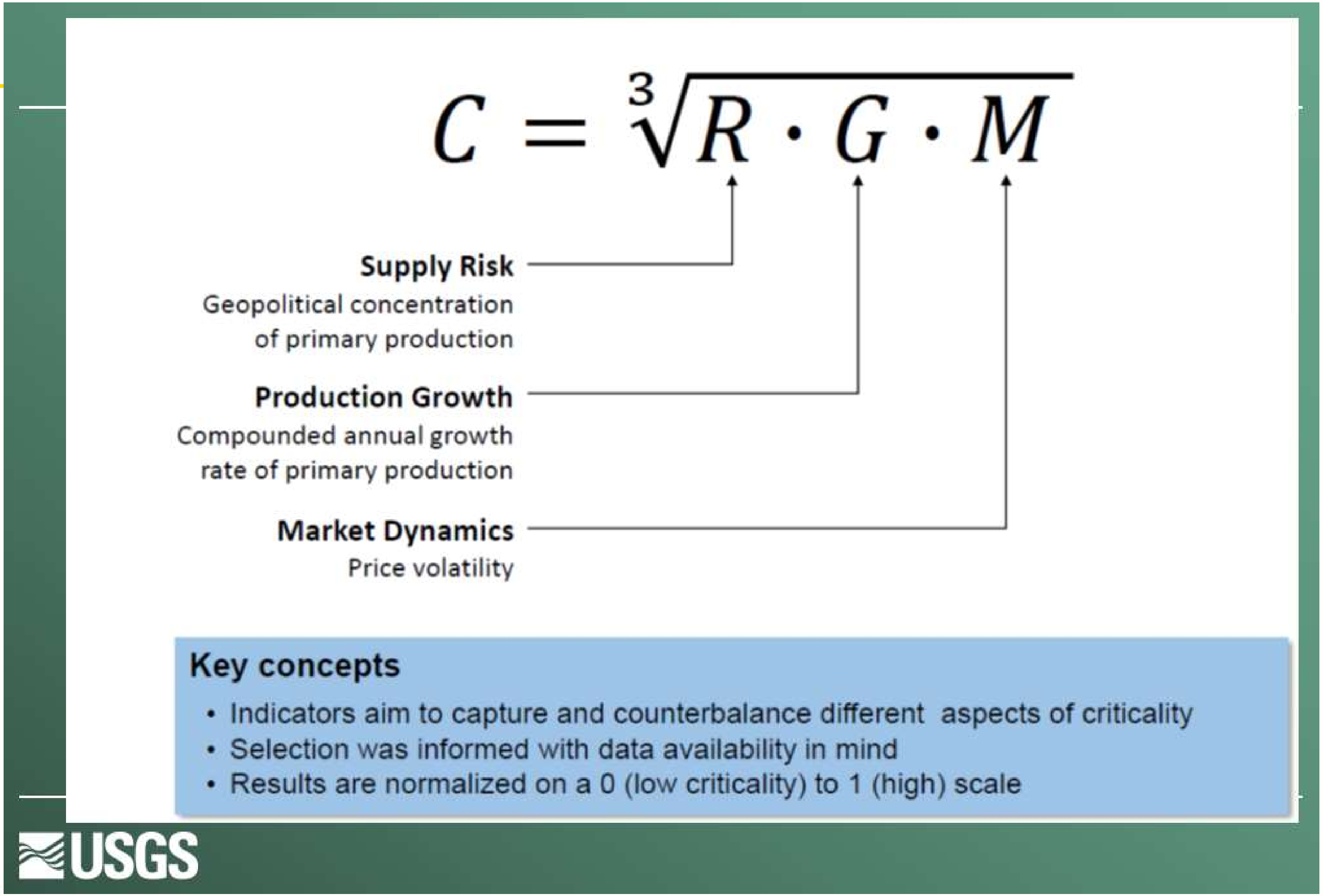
Material flow analyses

Special projects

Feedback from various stakeholders and findings of special projects and analyses

USGS

USGS



$$C = \sqrt[3]{R \cdot G \cdot M}$$

Supply Risk
Geopolitical concentration of primary production

Production Growth
Compounded annual growth rate of primary production

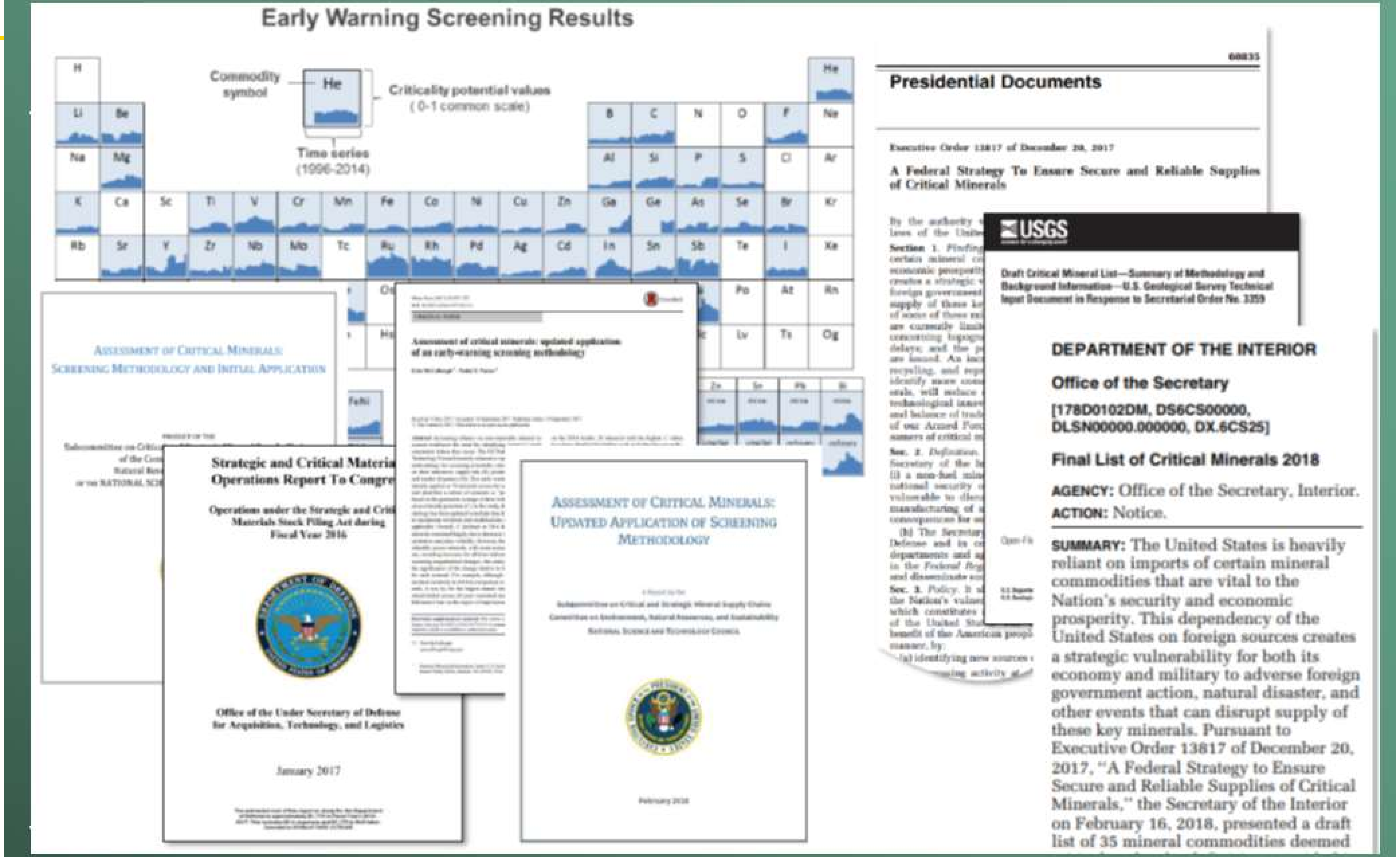
Market Dynamics
Price volatility

Key concepts

- Indicators aim to capture and counterbalance different aspects of criticality
- Selection was informed with data availability in mind
- Results are normalized on a 0 (low criticality) to 1 (high) scale

USGS

US list of CRMs – 2018



Early Warning Screening Results

Presidential Documents

Executive Order 13817 of December 20, 2017

A Federal Strategy To Ensure Secure and Reliable Supplies of Critical Minerals

USGS

Draft Critical Mineral List—Summary of Methodology and Background Information—U.S. Geological Survey Technical Input Document in Response to Secretarial Order No. 3359

DEPARTMENT OF THE INTERIOR

Office of the Secretary

[178D0102DM, DS6CS00000, DLSN00000.000000, DX.6CS25]

Final List of Critical Minerals 2018

AGENCY: Office of the Secretary, Interior.

ACTION: Notice.

SUMMARY: The United States is heavily reliant on imports of certain mineral commodities that are vital to the Nation's security and economic prosperity. This dependency of the United States on foreign sources creates a strategic vulnerability for both its economy and military to adverse foreign government action, natural disaster, and other events that can disrupt supply of these key minerals. Pursuant to Executive Order 13817 of December 20, 2017, "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals," the Secretary of the Interior on February 16, 2018, presented a draft list of 35 mineral commodities deemed

ASSESSMENT OF CRITICAL MINERALS: SCREENING METHODOLOGY AND INITIAL APPLICATION

Strategic and Critical Materia
Operations Report To Congre

Operations under the Strategic and Cri
Materials Stock Piling Act during
Fiscal Year 2016

Office of the Under Secretary of Defense
for Acquisition, Technology, and Logistics

January 2017

Assessment of critical minerals: updated application of an early-warning screening methodology

ASSESSMENT OF CRITICAL MINERALS: UPDATED APPLICATION OF SCREENING METHODOLOGY

A Report by the
Subcommittee on Critical and Strategic Mineral Supply Chains
Committee on Environment, Natural Resources, and Sustainability
National Science and Technology Council

February 2016

USGS

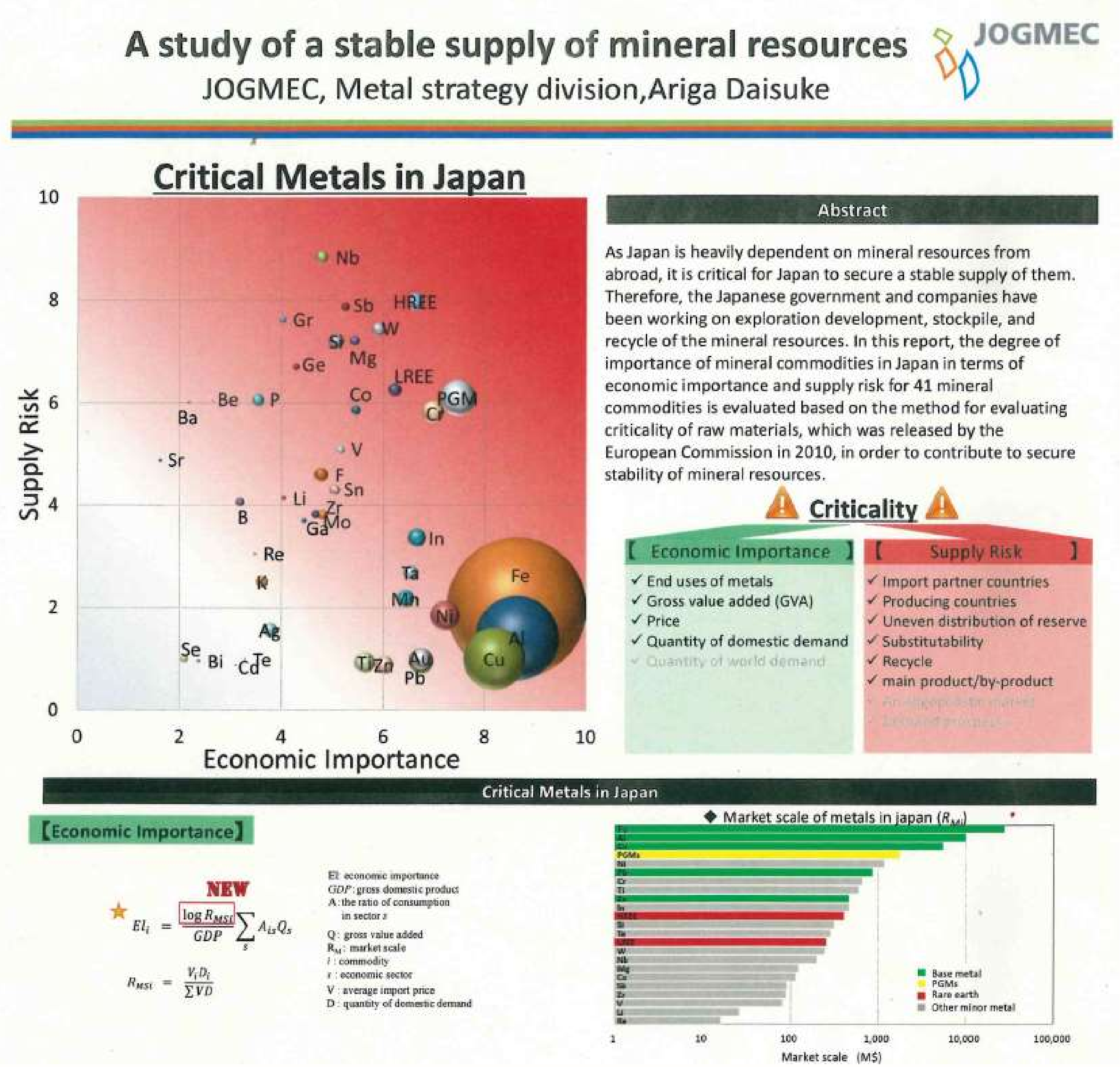
Result: 35 CRMs

Critical Materials in the EU and international Agendas (2022)

POLITECNICO DI TORINO

Gian Andrea Blengini

JAPAN



A study of a stable supply of mineral resources

JOGMEC, Metal strategy division,Ariga Daisuke

JOGMEC

Critical Metals in Japan

Abstract

As Japan is heavily dependent on mineral resources from abroad, it is critical for Japan to secure a stable supply of them. Therefore, the Japanese government and companies have been working on exploration development, stockpile, and recycle of the mineral resources. In this report, the degree of importance of mineral commodities in Japan in terms of economic importance and supply risk for 41 mineral commodities is evaluated based on the method for evaluating criticality of raw materials, which was released by the European Commission in 2010, in order to contribute to secure stability of mineral resources.

Criticality

【 Economic Importance 】	【 Supply Risk 】
✓ End uses of metals	✓ Import partner countries
✓ Gross value added (GVA)	✓ Producing countries
✓ Price	✓ Uneven distribution of reserve
✓ Quantity of domestic demand	✓ Substitutability
✓ Quantity of world demand	✓ Recycle
	✓ main product/by-product

Critical Metals in Japan

【Economic Importance】

NEW

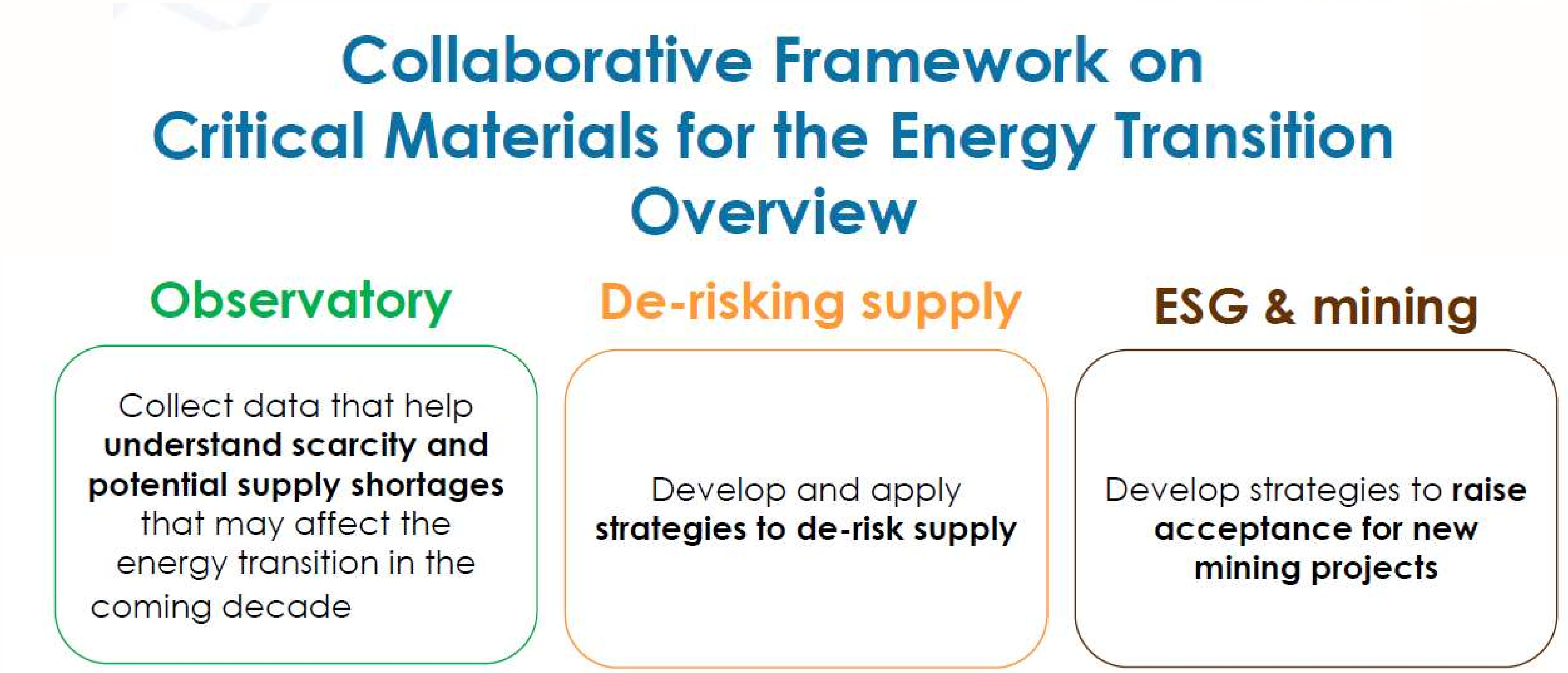
$$★\ EI_i = \frac{\boxed{\log R_{MSi}}}{GDP} \sum_s A_{is} Q_s$$

$$R_{MSi} = \frac{V_i D_i}{\sum VD}$$

EI: economic importance
GDP: gross domestic product
A: the ratio of consumption in sector s
Q: gross value added
R_M: market scale
i: commodity
s: economic sector
V: average import price
D: quantity of domestic demand

◆ Market scale of metals in japan (R_{Mi})

IRENA



Collaborative Framework on Critical Materials for the Energy Transition Overview

Observatory

Collect data that help **understand scarcity and potential supply shortages** that may affect the energy transition in the coming decade

De-risking supply

Develop and apply **strategies to de-risk supply**

ESG & mining

Develop strategies to **raise acceptance for new mining projects**

IEA

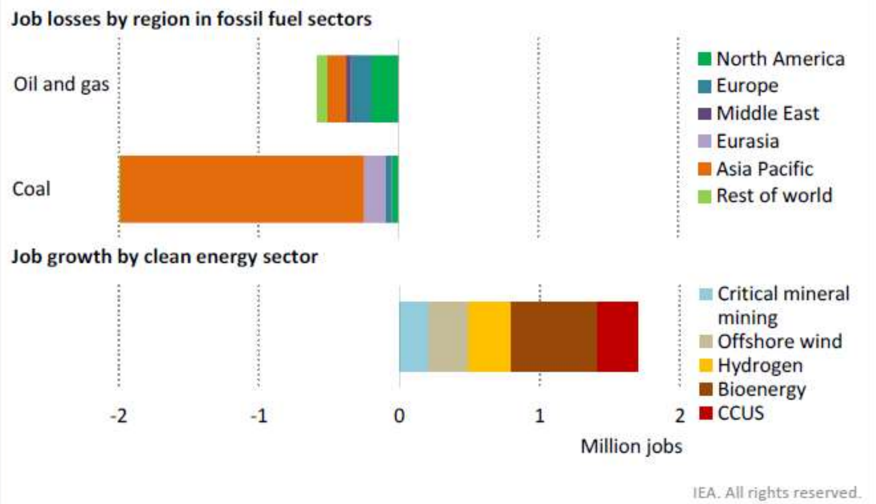
The Role of Critical Minerals in Clean Energy Transitions


Net Zero by 2050

A Roadmap for the Global Energy Sector

World Energy Outlook 2021

Figure 1.18 ▷ Changes in fossil fuel employment and energy areas with overlapping skills in the Announced Pledges Scenario to 2030



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Skilled fossil fuel workers have opportunities to transition to clean energy jobs, though the options are not a direct match for most coal sector jobs lost in Asia

DERA

The German Mineral Resources Agency (DERA) is the national information and consultancy platform for mineral raw materials.

DERA German Mineral Resources Agency

Federal Institute for Geosciences and Natural Resources

DERA was established in 2010 by decree of the Federal Ministry of Economic Affairs and Climate Action (BMWK) and is part of the Federal Institute for Geosciences and Natural Resources, BGR. Hence, DERA builds on many years of expertise and a wide scientific and technical infrastructure.

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Accueil / Conférence / **Lancement de l'OFREMI - Observatoire français des ressources minérales pour les filières industrielles**

CONFÉRENCE

Lancement de l'OFREMI - Observatoire français des ressources minérales pour les filières industrielles

Le 29 novembre 2022 - Paris


Comment garantir la disponibilité et l'accès aux ressources stratégiques de nos grands secteurs industriels pour les prochaines décennies ?

Suite aux recommandations du rapport Varin, le BRGM, le CEA, l'IFPEN, l'Ademe, l'IFRI et le CNAM créent, avec le soutien du CSF Mines et Métallurgie, l'Observatoire Français des Ressources Minérales pour les Filières Industrielles (OFREMI), une cellule d'intelligence économique réactive, prospective et pérenne, en appui aux pouvoirs publics et à l'industrie.

▪THANKYOU

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