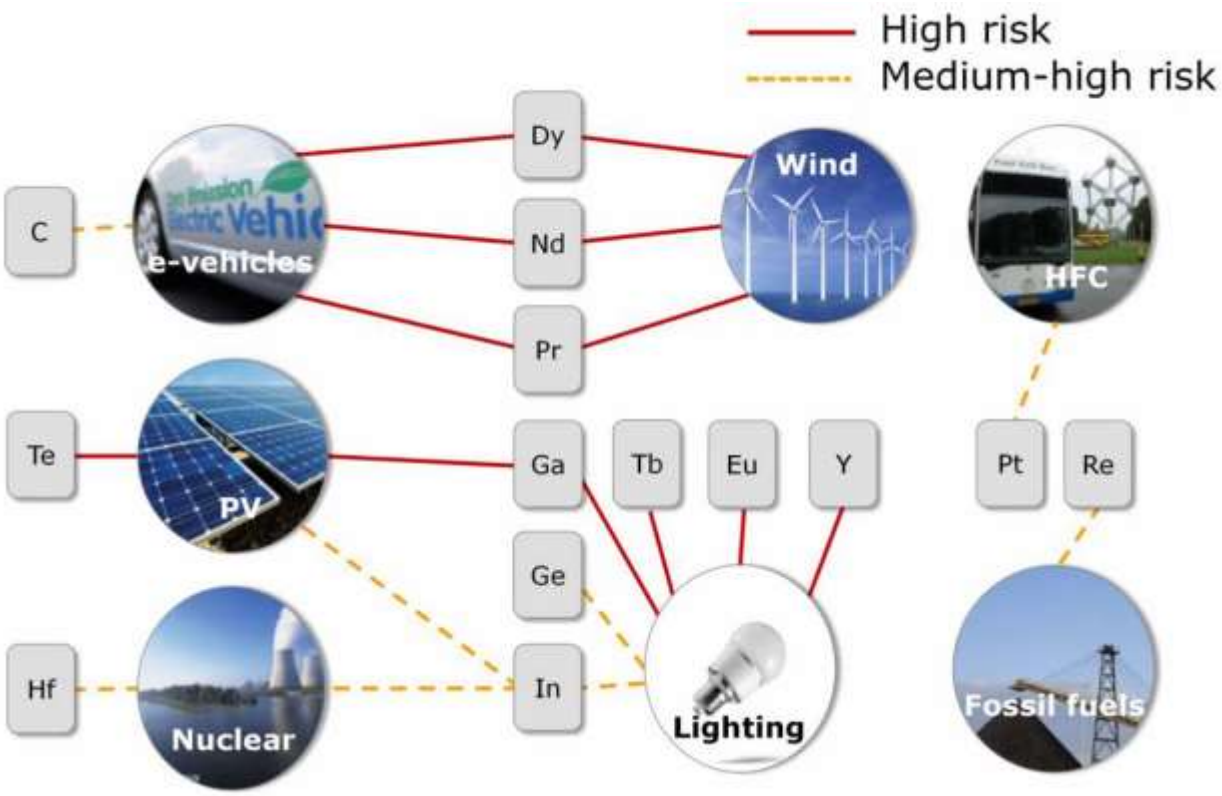
"MATERIAS PRIMAS MINERALES PARA EL ALMACENAMIENTO DE ENERGÍA, LAS ENERGÍAS RENOVABLES Y LA MOVILIDAD"



Juan F. Llamas

Webinar 24/06/2020

Critical raw materials for the EU

Report of the Ad-hoc Working Group on defining critical raw materials

The *ad-hoc* Working Group is a sub-group of the Raw Materials Supply Group and is chaired by the European Commission

Version of 30 July 2010

Note: The full report will be available on the Enterprise and Industry Directorate General website http://ec.europa.eu/enterprise/policies/raw-materials/documents/index_en.htm

European Commission
Enterprise and Industry

We Mean Business

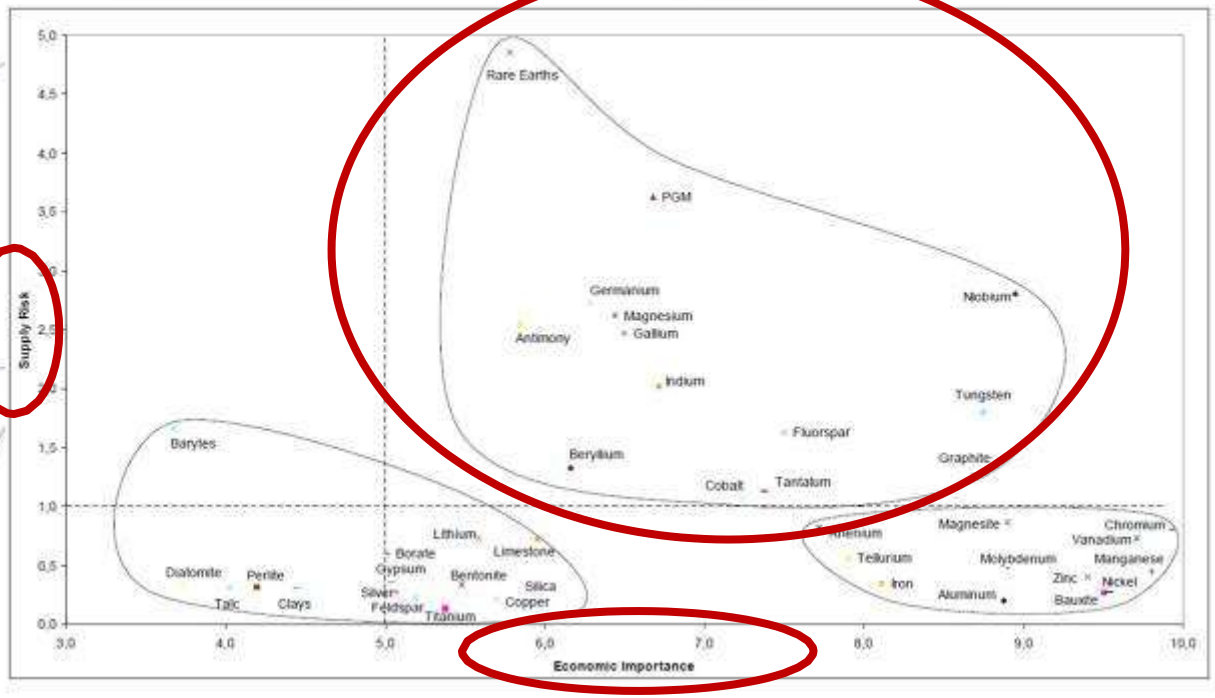
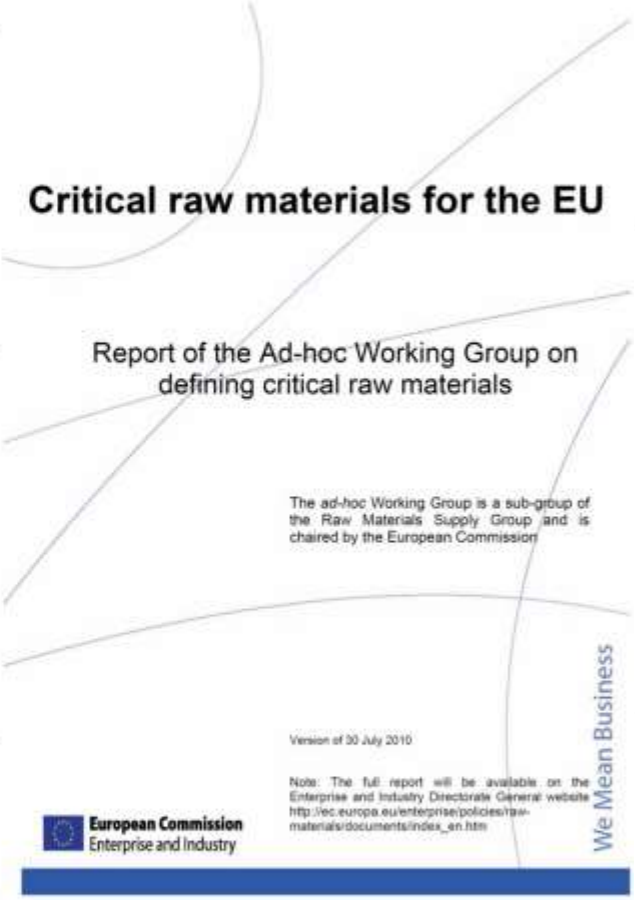


Figure 9: Ranking of eligible raw materials according to their environmental country risk

Table 3 **The portfolio of emerging technologies analysed**

Automotive engineering, aerospace industry, traffic engineering	1. Light-gauge steel with tailored blanks 2. Electric traction motors for vehicles 3. Fuel cells electric vehicles 4. Super capacitors for motor vehicles 5. Scandium alloys for constructing lightweight airframes
Information and communication technology, optical technologies, micro technologies	6. Lead-free solders 7. RFID – Radio Frequency Identification 8. Indium-Tin-Oxide (ITO) in display technology 9. Infrared detectors in night vision equipment 10. White LED 11. Fiber optic cable 12. Microelectronic capacitors 13. High performance microchips
Energy, electrical and drive engineering	14. Ultraefficient industrial electric motors 15. Thermoelectric generators 16. Dye-sensitized solar cells 17. Thin layer photovoltaics 18. Solarthermal power stations 19. Stationary fuel cells – SOFC 20. CCS – Carbon Capture and Storage 21. High performance lithium-ion batteries 22. Redox flow batteries for electricity storage 23. Vacuum insulation
Chemical, process, production and environmental technology, mechanical engineering	24. Synthetic fuels 25. Seawater desalination 26. Solid state lasers for industrial applications 27. Nano-silver
Medical engineering	28. Orthopaedic implants 29. Medical tomography
Materials technology	30. Superalloys 31. High-temperature superconductors 32. High performance permanent magnets


Critical raw materials for the EU

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European Commission
Enterprise and Industry

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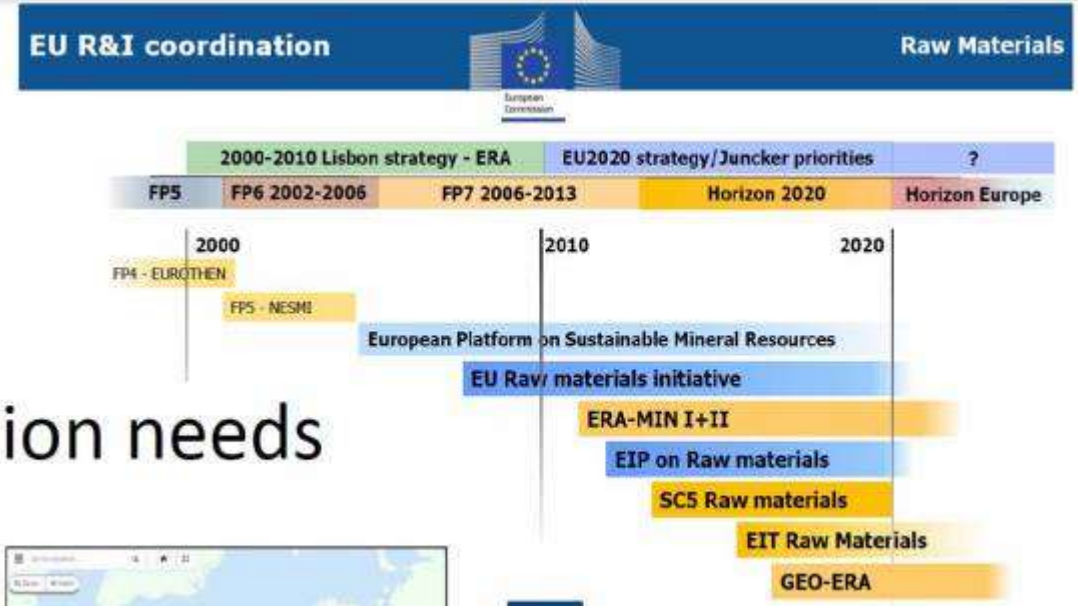
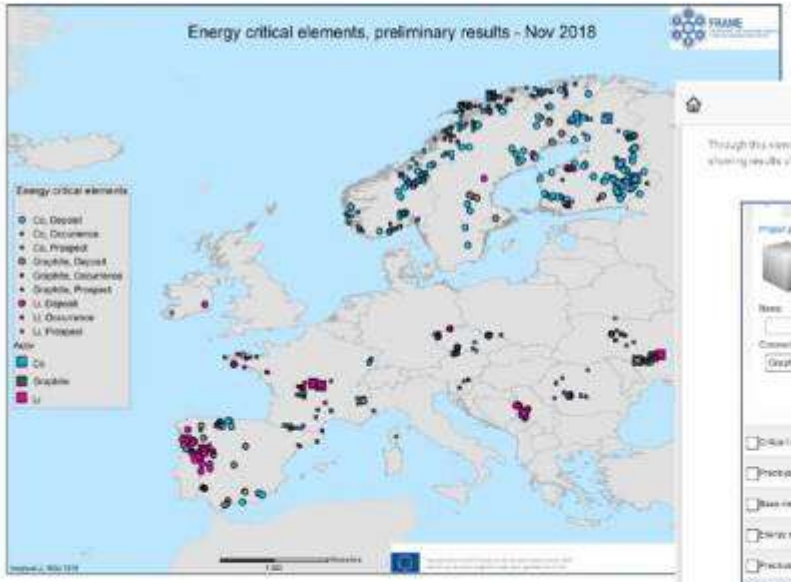
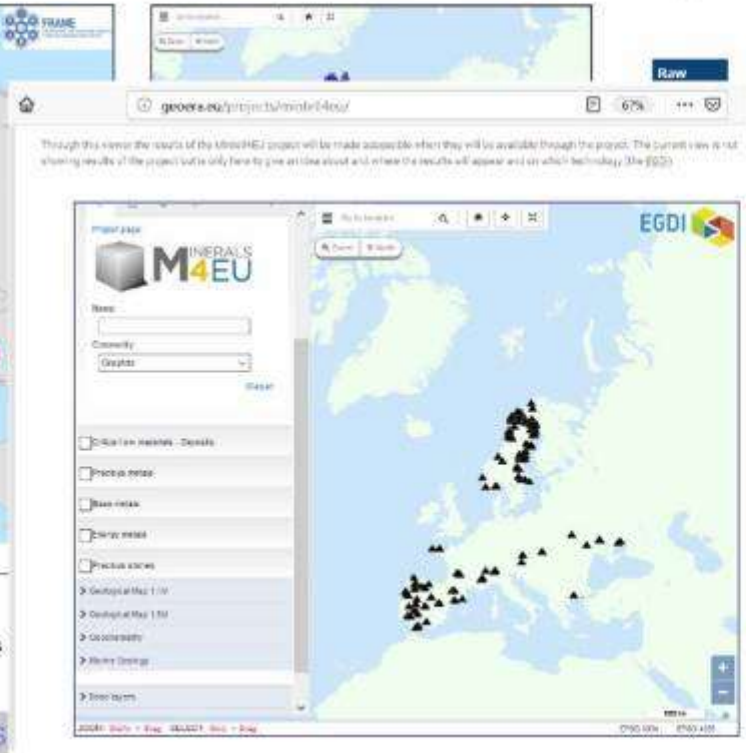
GeoERA RAW MATERIALS

GeoERA - European Geological Surveys joint action to improve Data Management



Serving energy transition needs





http://geoera.eu/projects/mintell4eu/

EGDI

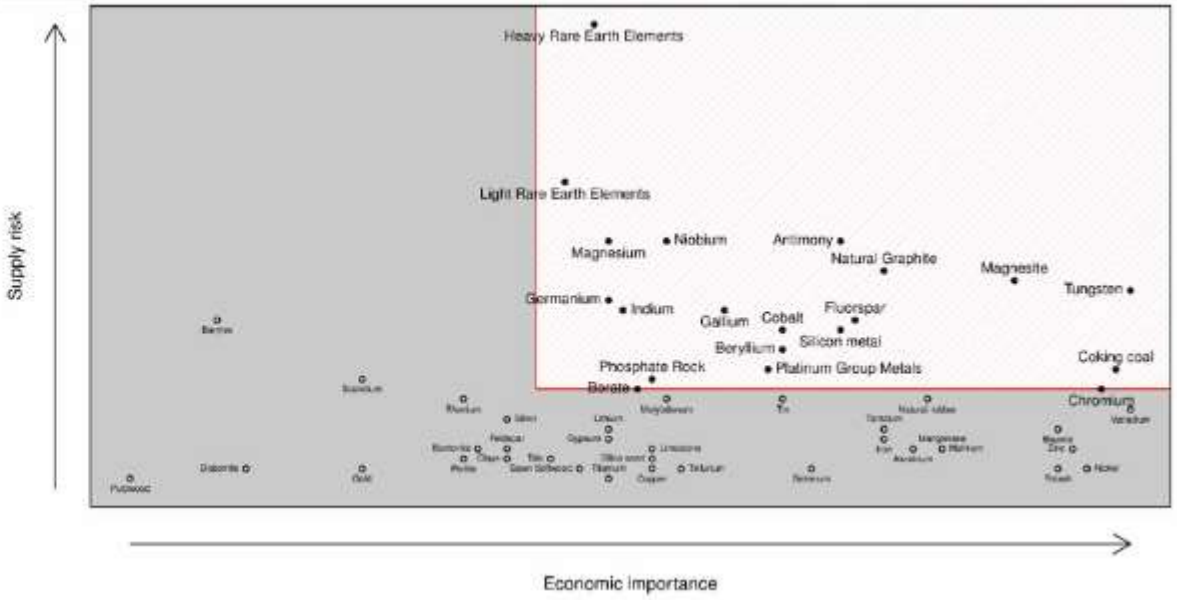
http://www.europe-geology.eu/map-viewer/

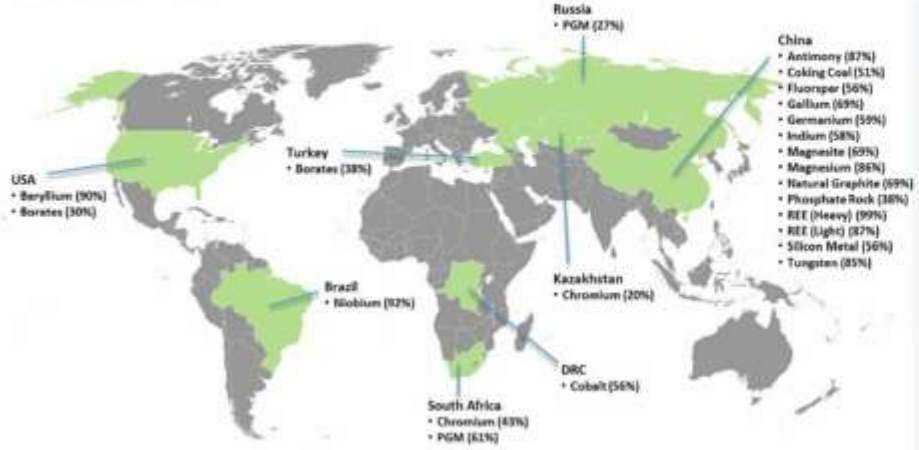
This project has received funding from the European Union's innovation programme under grant agreement No 731166

REPORT ON CRITICAL RAW MATERIALS FOR THE EU

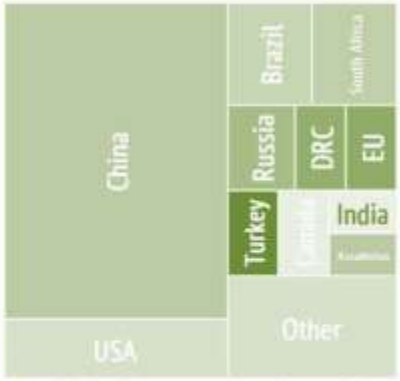
Report of the Ad hoc Working Group on defining critical raw materials

May 2014





World primary supply of the 54 candidate raw materials



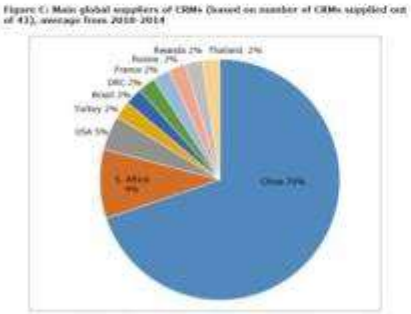
World primary supply of the 20 critical raw materials

2017

Study on the review of the list of Critical Raw Materials

Criticality Assessments

Deloitte.



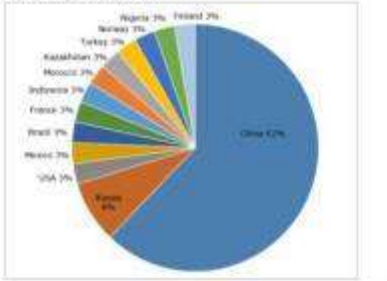
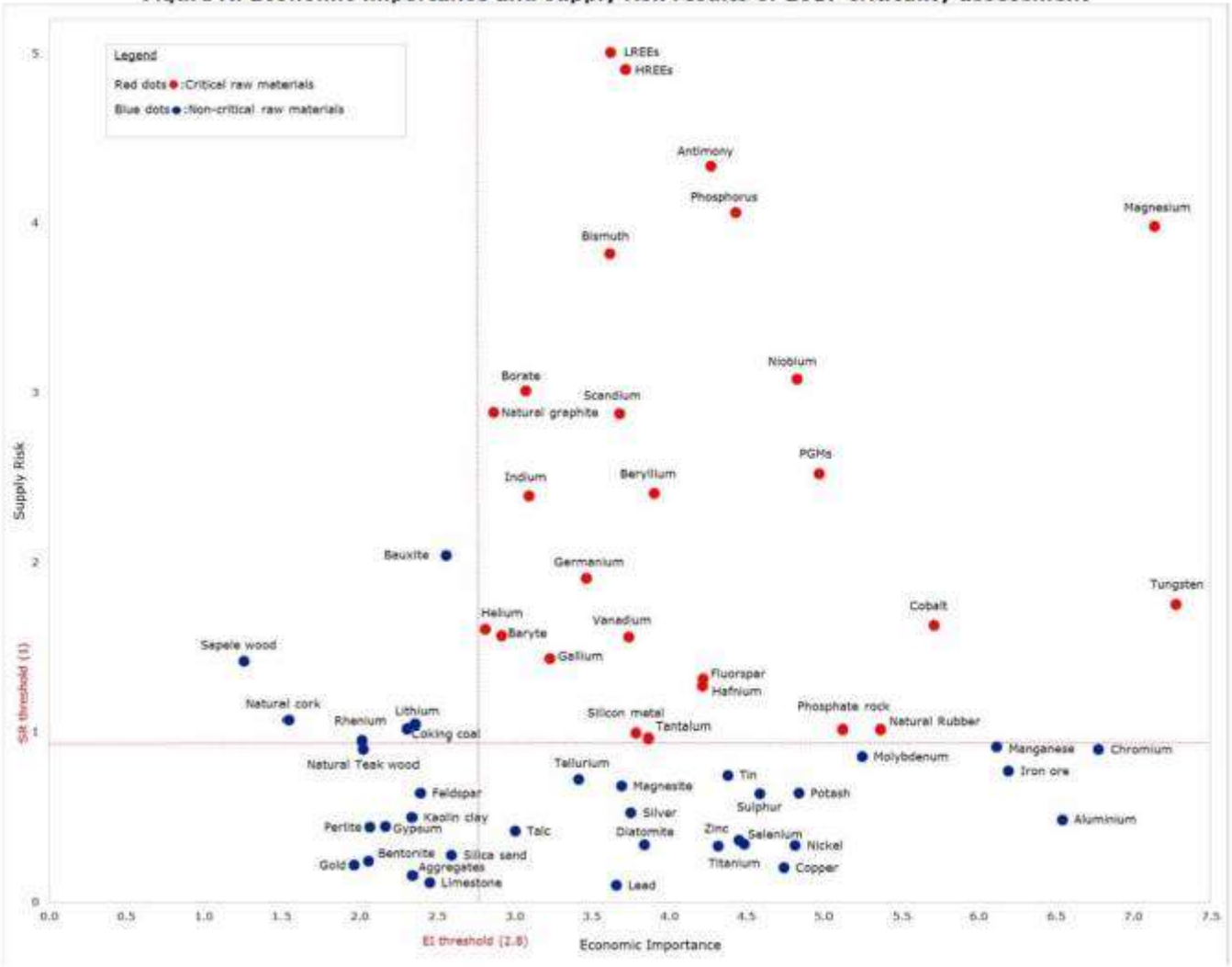


Figure A: Economic importance and supply risk results of 2017 criticality assessment



JRC Scientific and Technical Reports

Critical Metals in Strategic Energy Technologies

Assessing Rare Metals as Supply-Chain Bottlenecks in Low-Carbon Energy Technologies

R.L.Moss[1], E.Tzimas[1], H.Kara[2], P.Willis[3] and J.Kooroshy[3]

[1]JRC – Institute for Energy and Transport
[2]Oakdene Hollins Ltd
[3]The Hague Centre for Strategic Studies

Table 3: List of Rare Earth Elements and Platinum Group Metals Considered in this Study

Rare Earth Elements	Symbol	Wind
Lanthanum	La	×
Cerium	Ce	×
Praseodymium	Pr	(✓)
Neodymium	Nd	✓
Samarium	Sm	×
Europium	Eu	×
Gadolinium	Gd	×
Terbium	Tb	(✓)
Dysprosium	Dy	✓
Holmium	Ho	×
Erbium	Er	×
Thulium	Tm	×
Ytterbium	Yb	×
Lutetium	Lu	×

Platinum Group Metals	Symbol	Biofuels
Ruthenium	Ru	✓
Rhodium	Rh	×
Palladium	Pd	×
Osmium	Os	×
Iridium	Ir	×
Platinum	Pt	×

(Metals that have been ticked in brackets denote very small or occasional usage which has not been quantified)

Table 2: List of Metals Considered in This Study

Element Name	Symbol	Nuclear	Solar	Wind	Biofuels	CCS	Grids
Antimony	Sb	×	×	×	×	×	×
Barium	Ba	×	×	×	×	×	×
Beryllium	Be	×	×	×	×	×	×
Bismuth	Bi	×	×	×	×	×	×
Cadmium	Cd	✓	✓	×	×	×	×
Calcium	Ca	×	×	×	×	×	×
Caesium	Cs	×	×	×	×	×	×
Chromium	Cr	✓	×	✓	×	✓	×
Cobalt	Co	✓	×	×	✓	✓	×
Copper	Cu	✓	✓	✓	×	✓	✓
Gallium	Ga	×	✓	×	×	×	×
Germanium	Ge	×	✓	×	×	×	×
Gold	Au	×	×	×	×	×	×
Hafnium	Hf	✓	×	×	×	(✓)	×
Indium	In		✓	×	×	×	×
Lead	Pd	✓	×	×	×	×	×
Lithium	Li	×	×	×	×	×	×
Magnesium	Mg	×	×	×	×	×	×
Manganese	Mn	×	×	✓	×	✓	×
Molybdenum	Mo	✓	×	✓	×	✓	×
Nickel	Ni	✓	×	✓	(✓)	✓	×
Niobium	Nb	✓	×	×	×	✓	×
Platinum Group	PGM	×	×	×	✓	×	×
Potassium	K	×	×	×	×	×	×
Rare Earth Elements	REE	×	×	✓	×	×	×
Rhenium	Re	(✓)	×	×	×	(✓)	×
Rubidium	Rb	×	×	×	×	×	×
Scandium	Sc	×	×	×	×	×	×
Selenium	Se	×	✓	×	×	×	×
Silver	Ag	✓	✓	×	×	×	×
Sodium	Na	×	×	×	×	×	×
Strontium	Sr	×	×	×	×	×	×
Tantalum	Ta	×	×	×	×	(✓)	×
Tellurium	Te	×	✓	×	×	×	×
Thallium	Tl	×	×	×	×	×	×
Tin	Sn	✓	✓	×	×	×	×
Titanium	Ti	✓	×	×	×	×	×
Tungsten	W	✓	×	×	×	×	×
Vanadium	V	✓	×	×	×	✓	×
Yttrium	Y	✓	×	×	×	(✓)	×
Zinc	Zn	×	×	×	×	×	×
Zirconium	Zr	✓	×	×	×	×	×

(Metals that have been ticked in brackets denote very small or occasional usage which has not been quantified)

Renewable and Sustainable Energy Reviews 49 (2015) 655–671

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Renewable and Sustainable Energy Reviews

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

Assessing the need for critical minerals to shift the German energy system towards a high proportion of renewables

Peter Viebahn*, Ole Soukup, Sascha Samadi, Jens Teubler, Klaus Wiesen, Michael Ritthoff

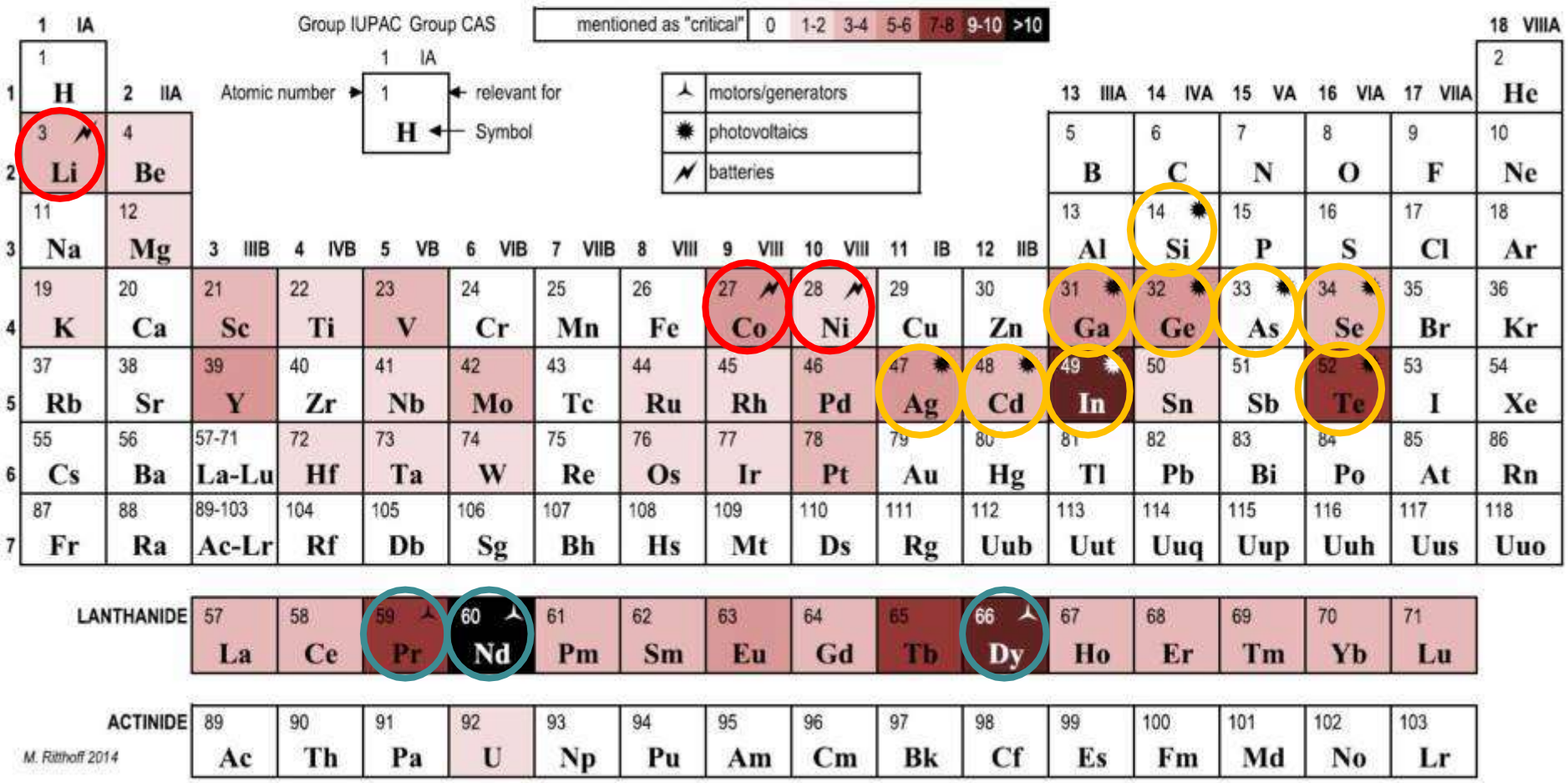

Fig. 1. "Criticality" and usage of elements according to an evaluation of 12 studies.

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Assessing the need for cri system towards a high pr

Peter Viebahn *, Ole Soukup, Sasc

Wuppertal Institute for Climate, Environment and Energy

2015

Table 1
Qualitative expert screening of renewable electricity production, storage and transmission technologies.

Energy source	Technology	Sub-technology	Main potentially critical element/ mineral resources and field of application	Preliminary classification as a result of combining with Fig. 2		
				"relevant" → Section 3.2	"potentially-relevant" → Section 3.3	"non-relevant"
Electricity generation						
Solar	Solar PV (photovoltaics) roof-top, ground-mounted, building-integrated	Crystalline	Ag (contact layer), but quantitatively not relevant and replaceable			X
		Thin film, CdTe	In, Ga, Se (absorber, buffer layer, TCO substrate), CdS (buffer layer) *****	X		
		Concentrating PV	See crystalline cells			X
		Organic PV	–			X
		Electrochemical PV	SnO_2 (semiconductor of dye-sensitised solar cells)			X
	Concentrating solar power (CSP) **	Parabolic trough, solar tower	Ag (mirrors)		X	
			$NaNO_3+KNO_3$ (thermal storage)		X *	
			Cu (wires)			X
			Cer (mirror production process)			X
			Ni, V (ferrous alloy)		X	
Wind	Wind power station	Onshore, offshore	Nd, Dy, Pr, Tb (permanent magnet)	X		
			Ni, Mo (ferrous alloy)		X	
Water	Hydropower	Run-of-river plant				X
Geothermal		Organic rankine Cycle (ORC)	Ni, V (ferrous alloy)		X	
Biomass ***	Combustion	Steam power plant, combined heat and power, ORC, Stirling				X
	Gasification ****		Ni, V (catalyst)		X	
	Fermentation ****		P (dedicated energy crops)			X
	Esterification ****		P (dedicated energy crops)			X
Electricity storage						
	Pumped hydro		Ni, V (ferrous alloy)		X	
	Compressed air energy storage (CAES)	Diabatic (CAES)				X
		Adiabatic (A-CAES)	Ni, V (ferrous alloy)		X	
	Hydrogen storage	Alkaline electrolysis	Ni (catalyst, electrical distribution)		X	
		H_2 storage				X
		Fuel cell	La, Y, Sc, Ni (SOFC)		X	
	Batteries (stationary)	Lithium-ion	Li		X	
		Redox flow	V (electrolyte)		X	
Electricity transmission						
	High-voltage alternating current (HVAC)	380 kV overhead line	Ni, V (ferrous alloy)		X	
	High-voltage direct current (HVDC)	HVDC overhead line	Ni, V (ferrous alloy)		X	

* Not derived from Fig. 2 but analysed additionally.
** CSP is not suitable for application in Germany, but several energy scenarios assume the import of CSP-based electricity from southern countries.
*** Producing intermediate products such as synthetic gas, biogas, bio-methane, vegetable oil and bio-diesel.
**** Regarding the assessment of dedicated energy crops, it should be pointed out that only mineral resources have been analysed. The availability of biomass itself and the associated problems, especially with regard to competing demand for land and biomass use [95,96], were not included in the scope of this study.
***** In addition, Ge is used in GaAs-Ge cells. These cells are neglected here because they will only be used in special appliances such as in space flights.

Renewable and Sustainable Energy Reviews 49 (2015) 601–621
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Assessing the need for critical minerals to shift the German energy system towards a high proportion of renewables

Peter Viebahn *, Ole Soukup, Sascha Samadi, Jens Teubler, Klaus Wiesen, Michael Ritthe
Wuppertal Institute for Climate, Environment and Energy, Doeppersberg 19, 42103 Wuppertal, Germany

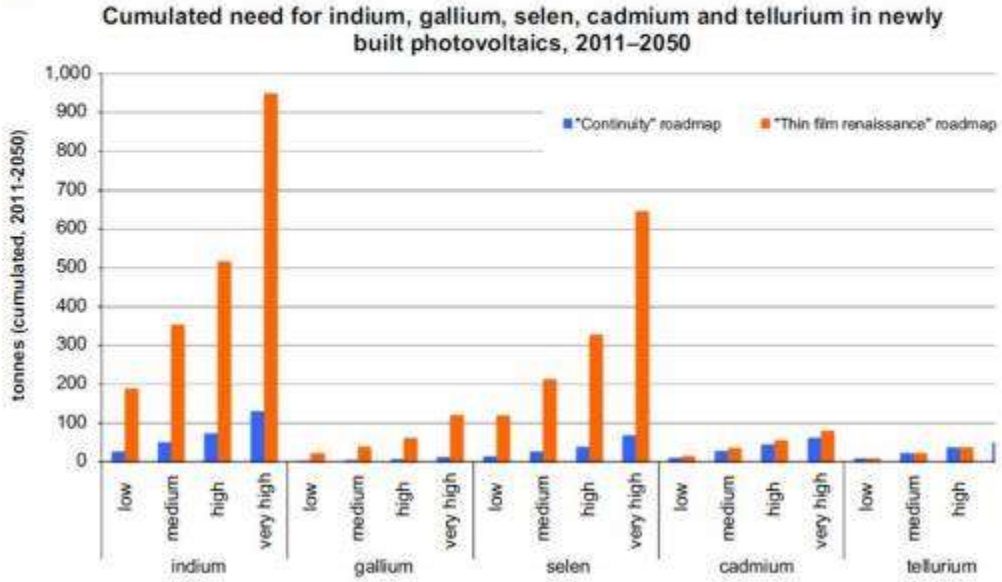

Fig. 11. Estimated cumulative critical mineral demand for photovoltaics deployment in Germany between 2011 and 2050.

"**continuity" roadmap**: estancamiento en la tendencia a un mayor tamaño del molino

"**upscaling" roadmap**: incremento en el tamaño de los generadores

"**HTS" roadmap**: tiene en cuenta la incertidumbre asociada con una posible entrada al mercado de generadores de superconductores de alta temperatura (HTS)

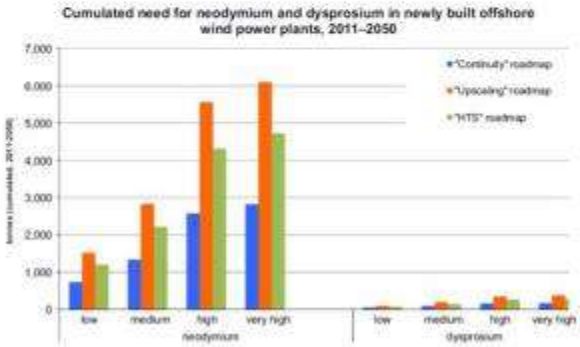

Fig. 13. Estimated cumulative critical mineral demand for offshore wind deployment in Germany between 2011 and 2050.

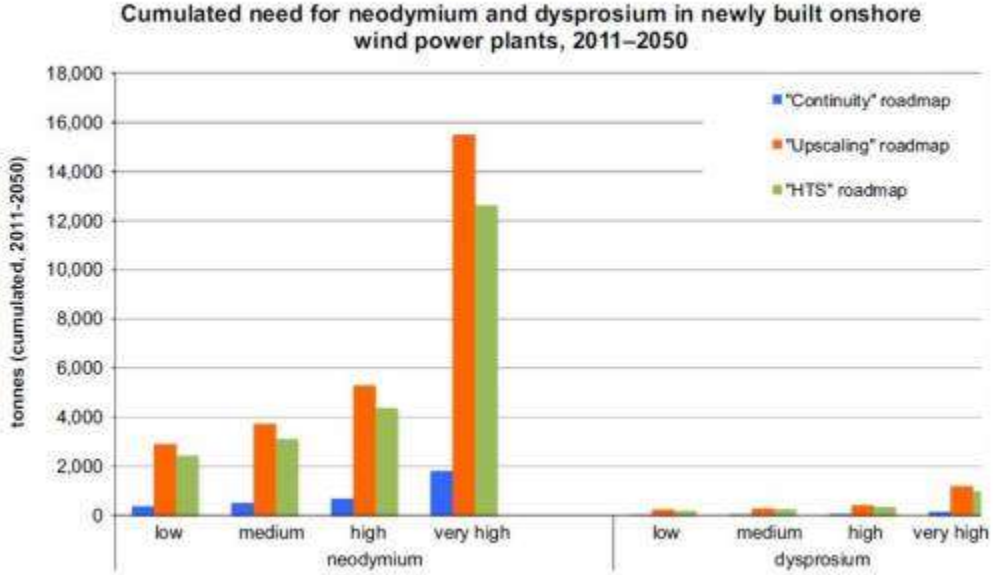

Fig. 12. Estimated cumulative critical mineral demand for onshore wind deployment in Germany between 2011 and 2050.

The Use of Potentially Critical Materials in Passenger Cars

KLAS CULLBRAND
OLOF MAGNUSSON

Department of Energy and Environment
Division of Environmental Systems Analysis
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden, 2011
Report No. 2012:13
ISSN: 1404-8167

Figure 5. Summary of the results from the detailed analysis in terms of distribution by subsystem. Showing where the 24 materials' main masses where identified. The figure is a summary of all 4 analyzed cars.

The Use of Potentially Critical Materials in Passenger Cars

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ISSN: 1404-8167

CMH = Conventional Midsize Car, High-Specified
CML = Conventional Midsize Car, Low-Specified
HMM = Hybrid Midsize Car, Medium-Specified
CLM = Conventional Large Car, Medium-Specified

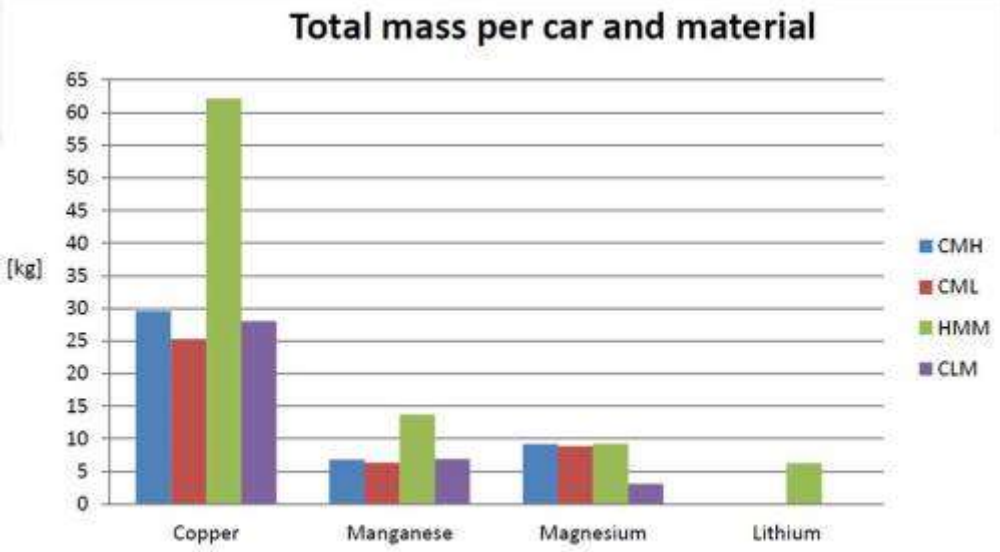

Figure 6. Total mass per car and material for materials with more than 1 kg identified in at least one of the cars.

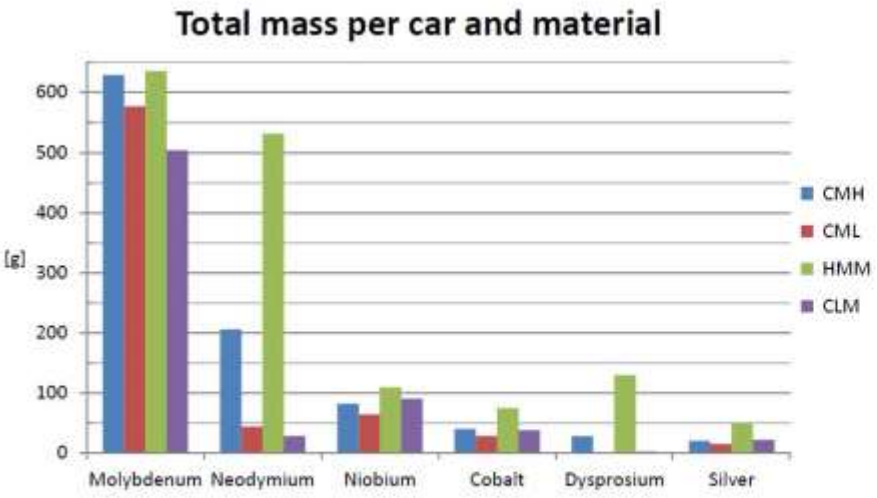

Figure 7. Total mass per car and material for materials with identified mass greater than 45g but less than 1kg in at least one of the cars.

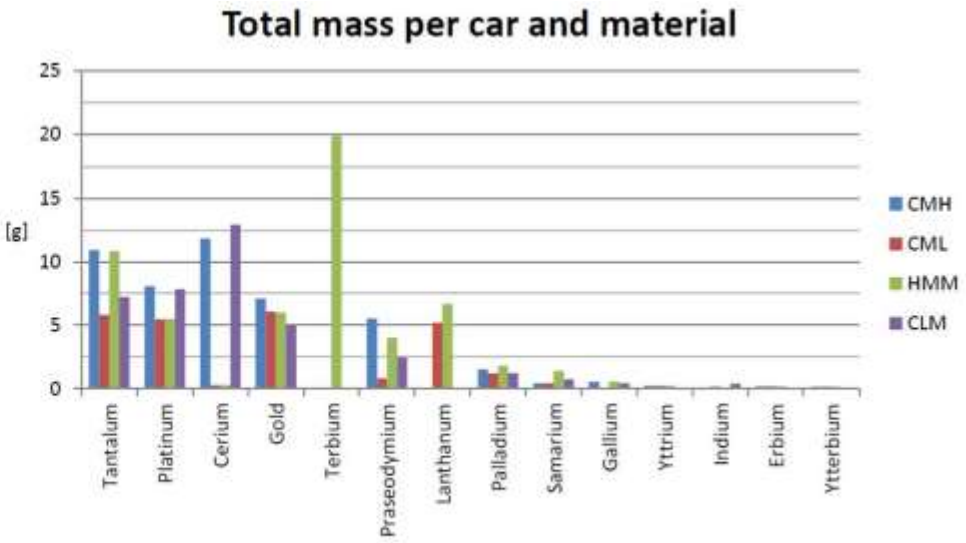

Figure 8. Total mass per car and material for materials with identified mass greater than 0.5 g but less than 45 g in at least one of the cars.

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Renewable Energy

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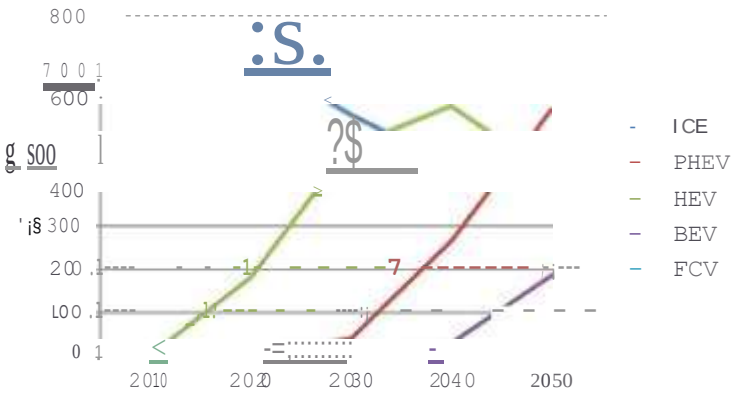
Role of crit ic al me ta ls in the fut ure markets of clean ene rgy techno lo g ies

Leena Grande ll [a], Antti Lehtila [b], Mari Kivinen[b], T iin a Koljonen [b], Su sanna Kihlman [b], Laura S. Lauri[b]



fjg. **4.** Privare car s in use.

Table 3
Various types of electric vehicles.

HEV	hybrid vehicle
PHEV	plug in hybrid vehicle
BEV	battery ele ctric vehicle
CEV	fuel cell elect ric vehicle

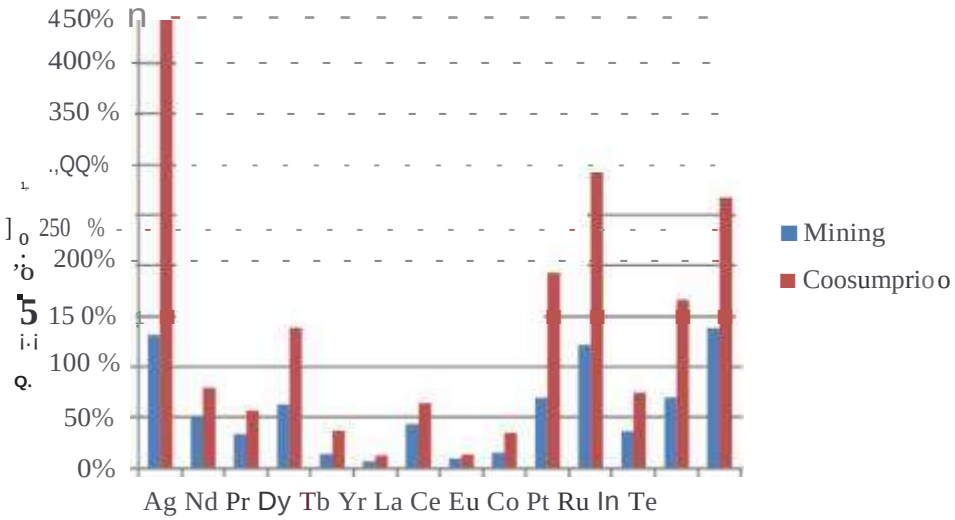


Fig. 6. Metals cu mu lat ive need for clea n ene rgy technologies u ntil 2050 in relation to global mine ral rese1ve s.

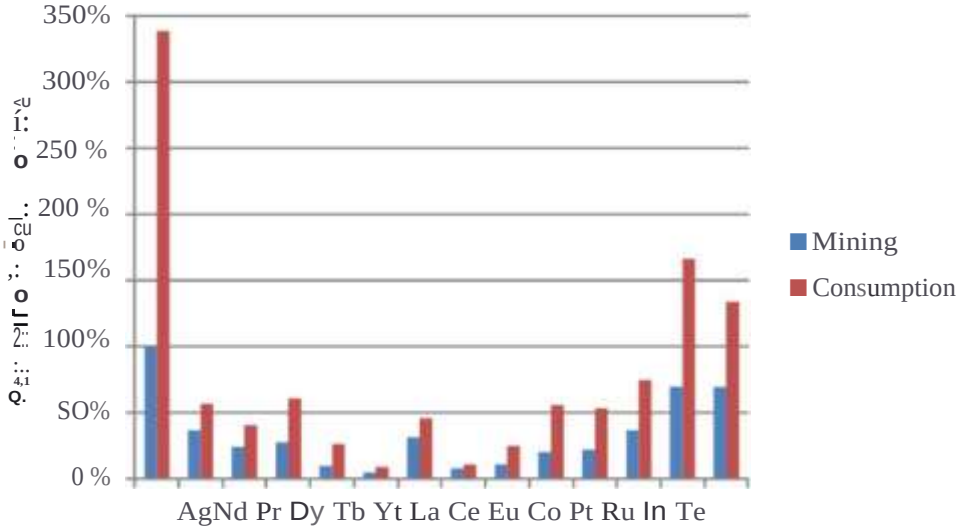
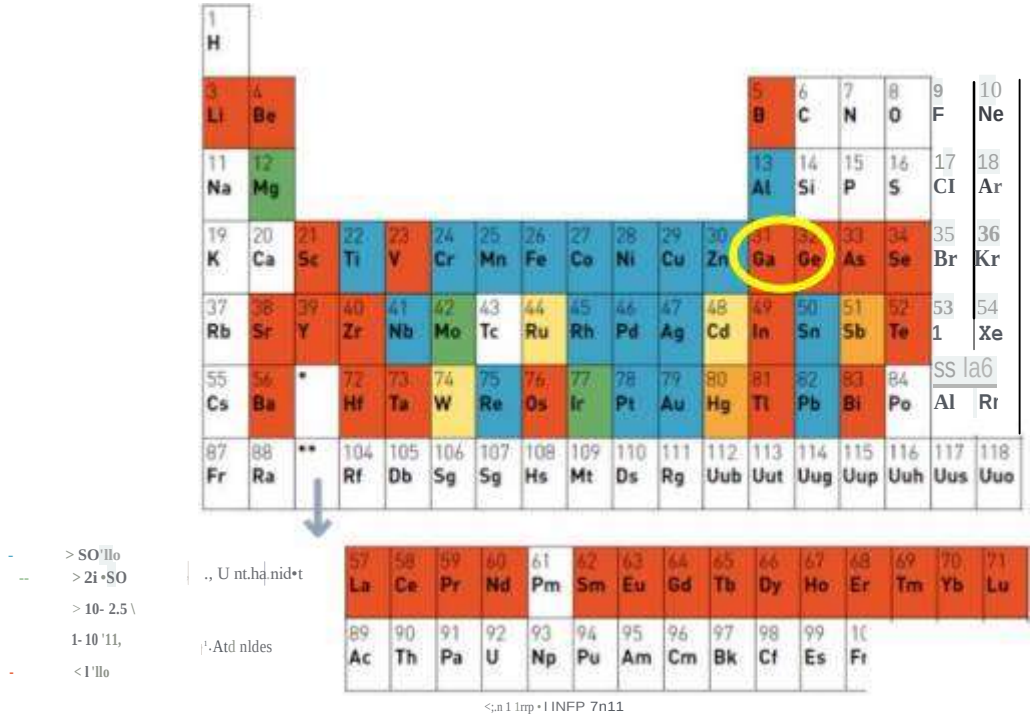


Fig. 7. Metals cum u lat ive need for cle an ener gy technolo gy until 2050 i n relation to global mine ral re sources.

Figure 32: End-of-life recycling rates for 60 metals



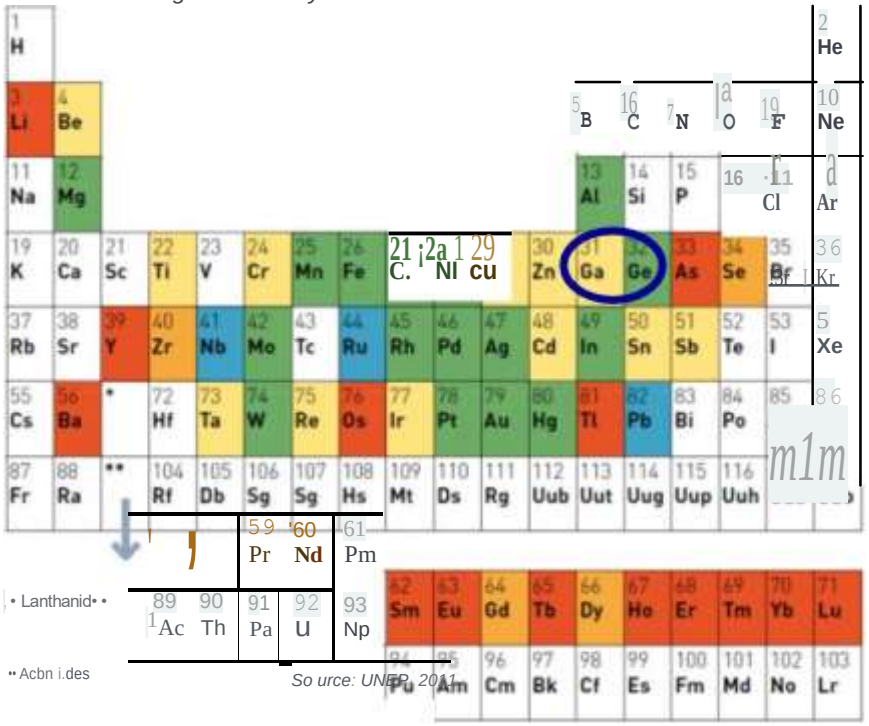
JR C SCIE N TI FI C A N O POLICY REPORTS

Critica! Metals in lhe Path towards the Decarbonisation of the EU Energy Sector

Table 155: Summary af the high-, medium-high- and medium-rated meta/s with their associated technolagy

Element	Rating	Associated Techno lo gy
Rare Earths: Dy, Pr, Nd	Hlgh	vehicles, wind
Rare Earths: Eu, Tb, Y	Hlgh	lighting
Gallium	Hlgh	lighting, solar
Tellurium	HI	so lar
Graphite	Medium-High	vehicles
Rhenium	Medium-High	fossil fuels
Hafnium	Medium-High	nuclear
Germanium	Medium-High	lighting
Platinum	Medium-High	fuel cells
Indium	Medium-Hi h	solar, lighting, nuclear
Rare Earths: La, Ce, Sm	Medium	vehicles
Rare Earth: Gd	Medium	lighting
Cobalt	Medium	vehicles, fossil fuels
Tantalum	Medium	geothermal, fossil fuels
Niobium	Medium	ces
Vanadium	Medium	ces
nn	Medium	so lar
Chromium	Medium	desa lination

Figure 33: Recycled contentfor 60 metals



So urce: UNEP, 2011

Sustainable Materials and Technologies 15 (2018) 9–18

Contents lists available at ScienceDirect

Sustainable Materials and Technologies

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

Improving supply security of critical metals: Current developments and research in the EU

Amund N. Løvik[a,*], Christian Hagelüken[b,c], Patrick Wäger[a,c]

[a] Empa, Swiss Federal Laboratories for Materials Science and Technology, St. Gallen, Switzerland
[b] Umicore, Hanau, Germany
[c] ESM Foundation, Bern, Switzerland

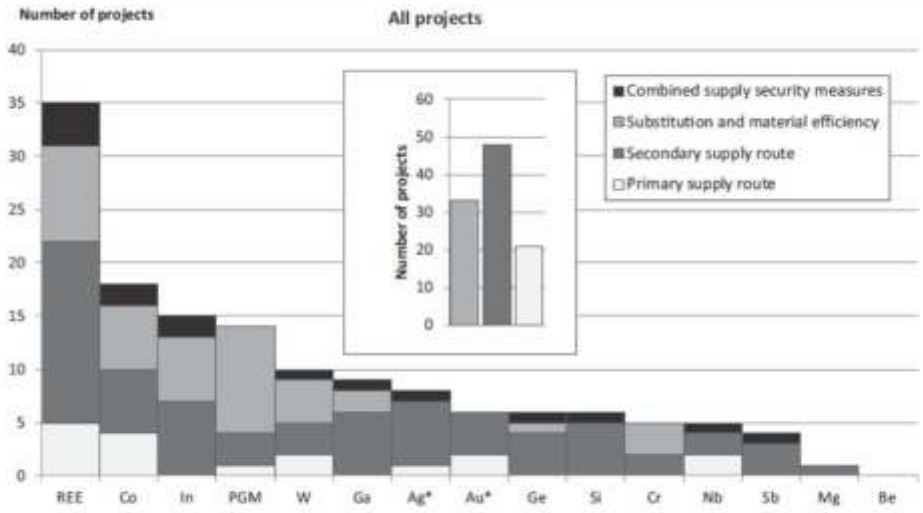


Fig. 3. Number of research projects and commitments addressing each metal. The colours of the stacked bars indicate which of the three supply security measures is being investigated. The inset shows the total number of projects within each supply security measure, including those that cover several measures. Rare earth elements (REE) and platinum group metals (PGM) are presented as groups, since project objectives usually do not specify which of these elements are considered. The total number of projects is 92. *Not considered critical by the EC.

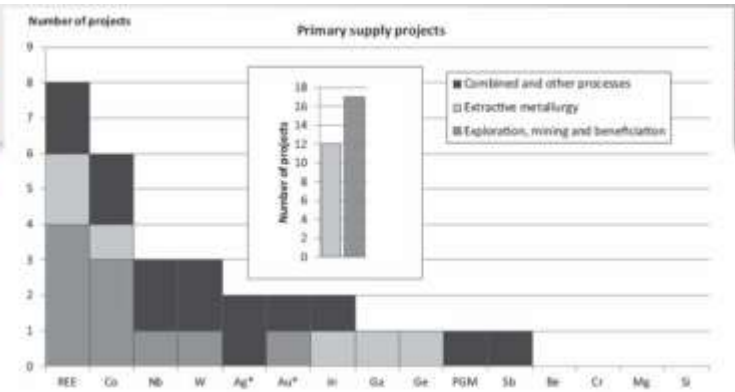


Fig. 4. Number of primary supply related projects by element. The patterns of the bars indicate in which process improvements are sought. The inset shows the total number of primary supply projects by process type. *Not considered critical by the EC.

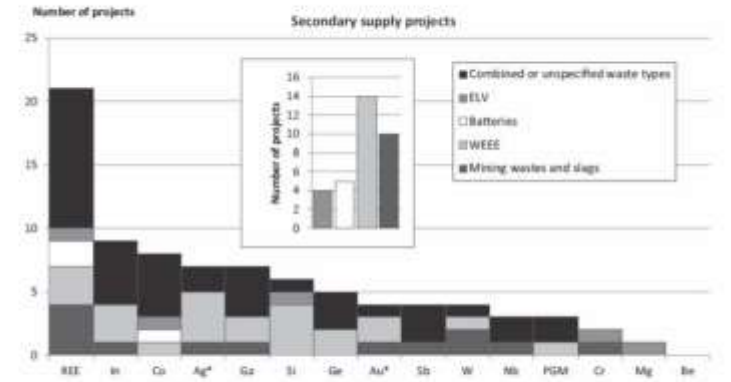


Fig. 5. Number of secondary supply related projects per metal. The patterns of the bars indicate the type of waste addressed. The inset shows the total number of secondary supply projects by waste type. *Not considered critical by the EC.

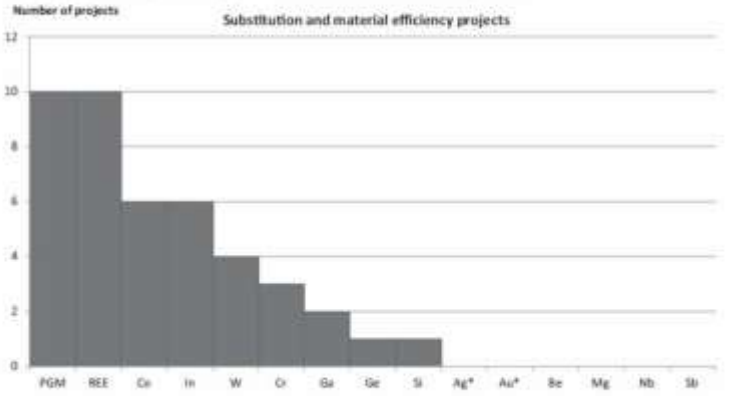


Fig. 6. Number of substitution and material efficiency related projects by element. *Not considered critical by the EC.

Sustainable Materials and Technologies 3 (2015) 7–13

Contents lists available at ScienceDirect

Sustainable Materials and Technologies

ELSEVIER

Electric vehicle traction motors without rare earth magnets

James D. Widmer *, Richard Martin, Mohammed Kimiabeigi

Centre for Advanced Electrical Drives, School of Electrical and Electronic Engineering, Newcastle University, Newcastle-upon-Tyne, UK

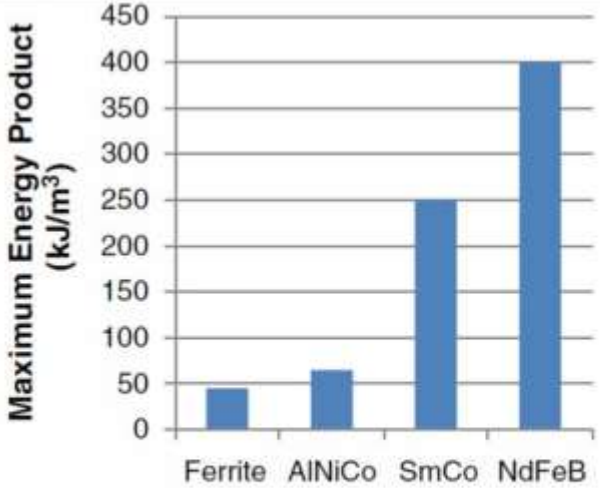


Fig. 2. Comparison between the Maximum Energy Product of differing hard magnetic materials.

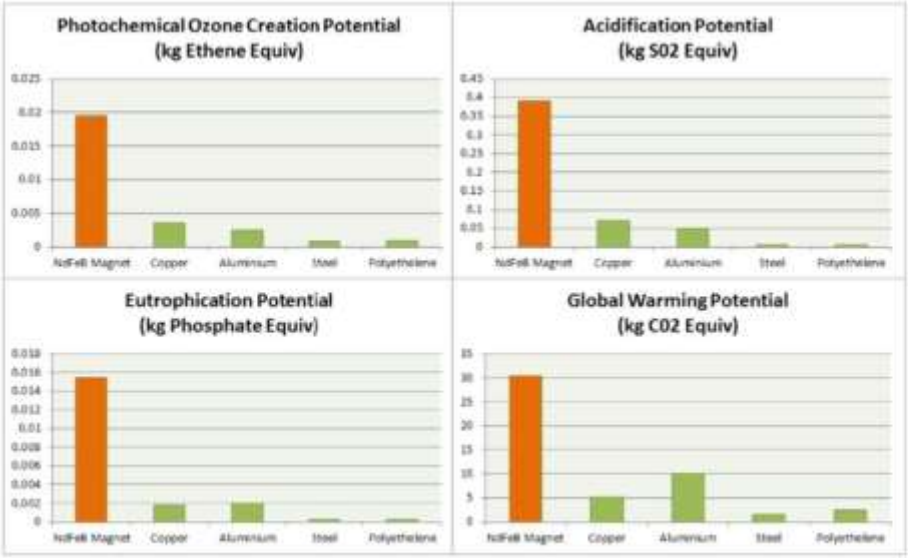


Fig. 7. Showing lifecycle data for the production of the different materials used in electric motors (reference withheld at the request of the provider).

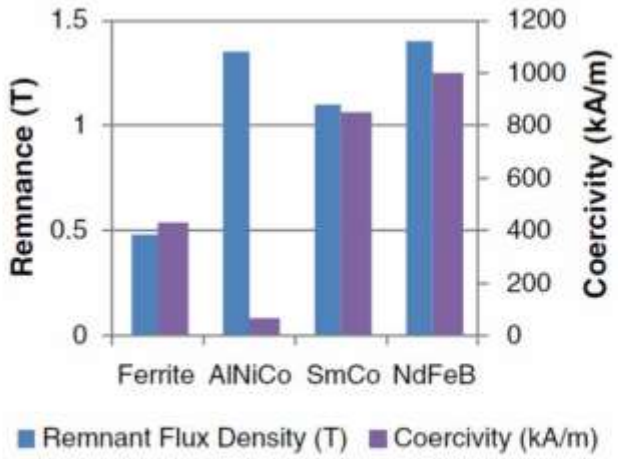


Fig. 3. Comparing remnant flux density (magnetic strength) and coercivity (resistance to demagnetisation) for different hard magnetic materials.

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Global Flows of Critica! Meta ls Necessary for Low-Carbon Technologies: The Case of Neodymi um, Cobalt, and Platinum

Kcisuke Nansai,*' Kcnich.i Nakajima/ Shigcmi Kagawa/ Yasushi Kondo ,* Sangwon Suh,[||]
Yosuke Shige tomi ,u and Yu ko Oshit}

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[1]F3CUlty of Po libc al Scicnce .1.nd Economics, \.Y:isccb Univc. ity, 1-6-1 Nis h.a-\-VJsed.1, Shinjuku-ku, Tok, ·0169 -S0.,50 J,1.PJ
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En vironm ental Science & Technolo .y

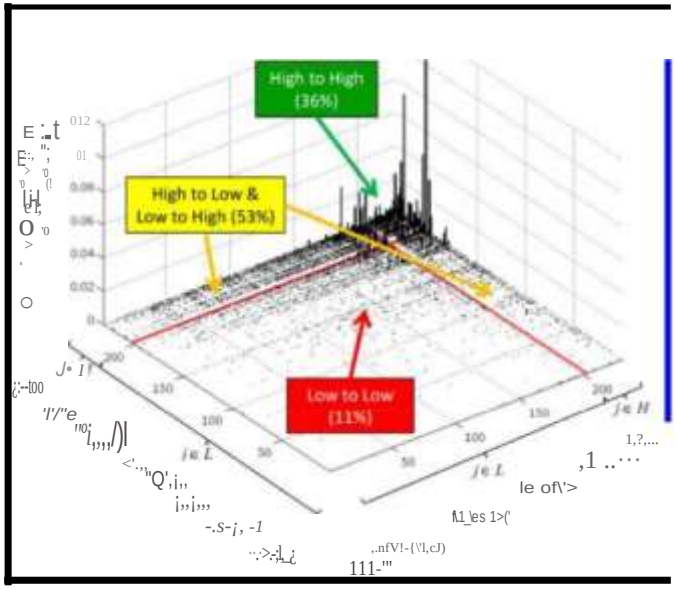
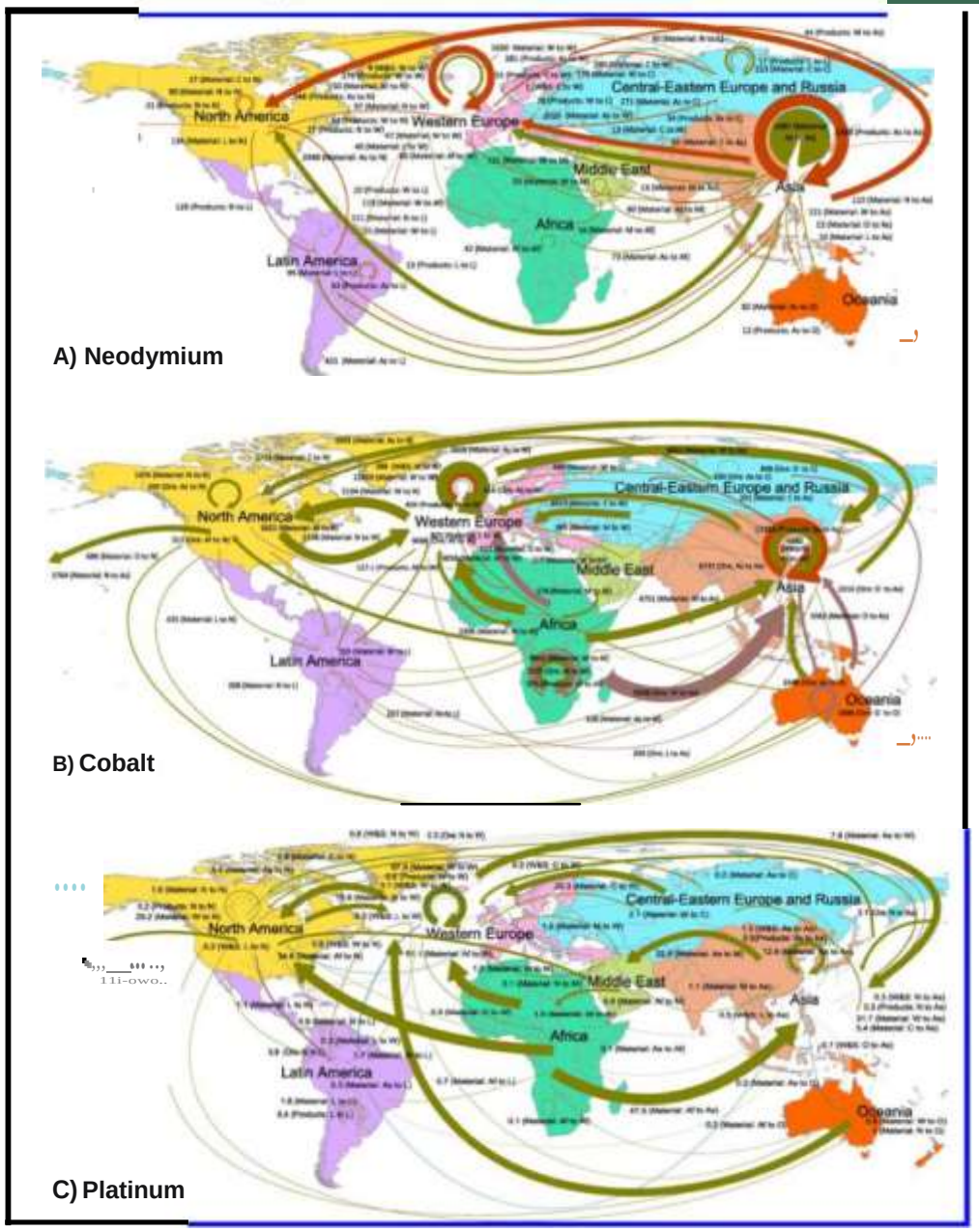


Figure 3. Glo bal Jlows of neodymium contained in transmission ap parat us for radiotelep hony i.nco rpora ting reccption app aratus (HS-852520); an e.xample of thc trade commod ity characterizatio n (red, ycUo w, and green-flow commodities) based on the relative shares of red, yellow, and green flows ofthe commod it y in qu estion. Hig h, Low refer to the technological lev el of the count ry (see text).



Figu re 2. (A) Global ílow s of ncodymiu m among cight rcgions by four lyp cs oftradc commodity (ore , matcria ls, products and W&S (, va.si c and scra p)) in 2005; each lc g|end indkatcs th e volu mc of neodymium in lonnc s, th c co mmodit y lypc and thc region.s driving thc flow (Ali: Asia, Af: Africa, C: Cc ntral -Eástcm Europc and Russia, L:, L. tin Amcrica, M: Middlc East, N: North Amcrica, O : O ceanía, W: Western Europc). (B) Global ílows of cobalt among eig ht regions by the trade commodity type in 2005; each lege nd ind icates the volum e of cobalt in kt largor th an 200 kt. (C) Global Ho ws of platinum among eig ht rcgion s by tradc comm odi ty typc in 2005; each legend ind.icates thc volu mc of platinum in tonn e la.rgc r than 0.2 ton ne.

GLOBAL MINING RISK FOOTPRINT

(Japon)

Environmental Science & Technology
Policy Analysis
pubs.acs.org/est

Global Mining Risk Footprint of Critical Metals Necessary for Low-Carbon Technologies: The Case of Neodymium, Cobalt, and Platinum in Japan

Keisuke Nansai,[*,†] Kenichi Nakajima,[†] Shigemi Kagawa,[‡] Yasushi Kondo,[§] Yosuke Shigetomi,[†,∥,⊥] and Sangwon Suh[#]

Environmental Science & Technology
Policy Analysis

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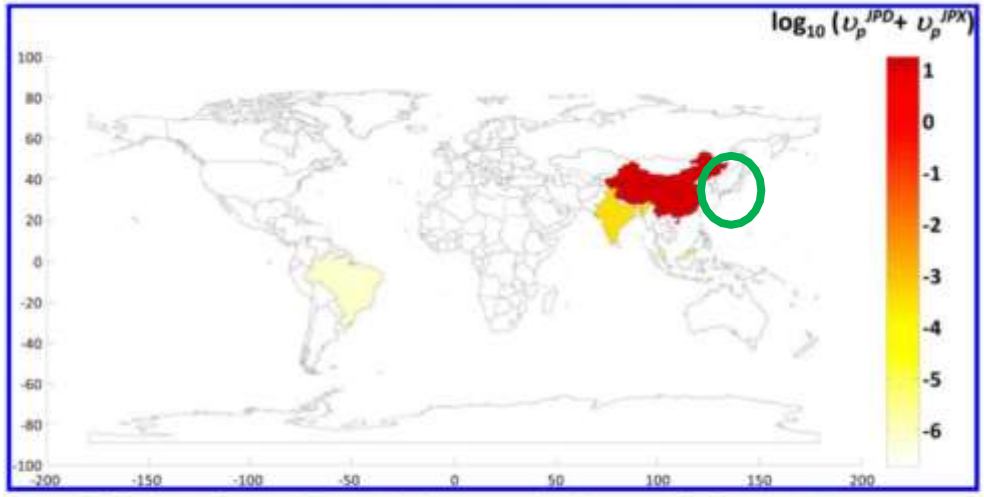

Figure 1. Global distribution of mining risk footprints of neodymium associated with Japanese total final demand in 2005.

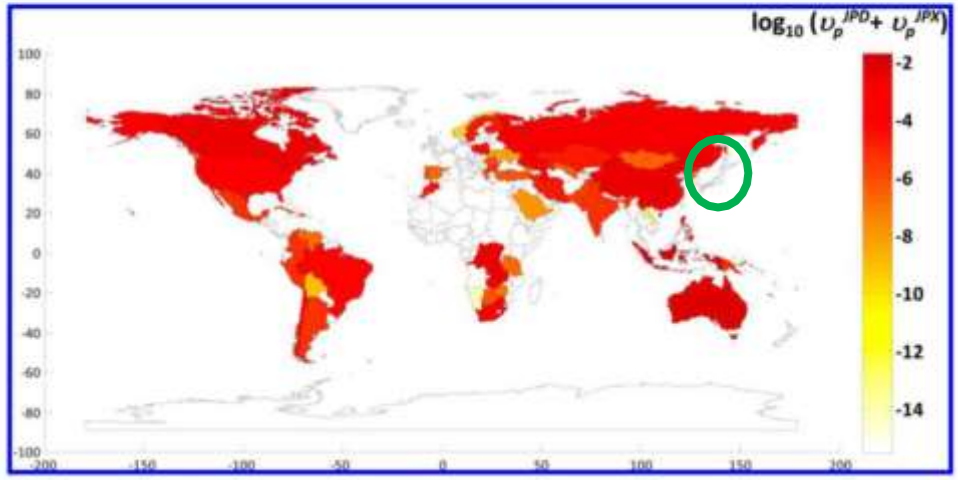

Figure 2. Global distribution of mining risk footprints of cobalt associated with Japanese total final demand in 2005.

Environmental Science & Technology
Policy Analysis

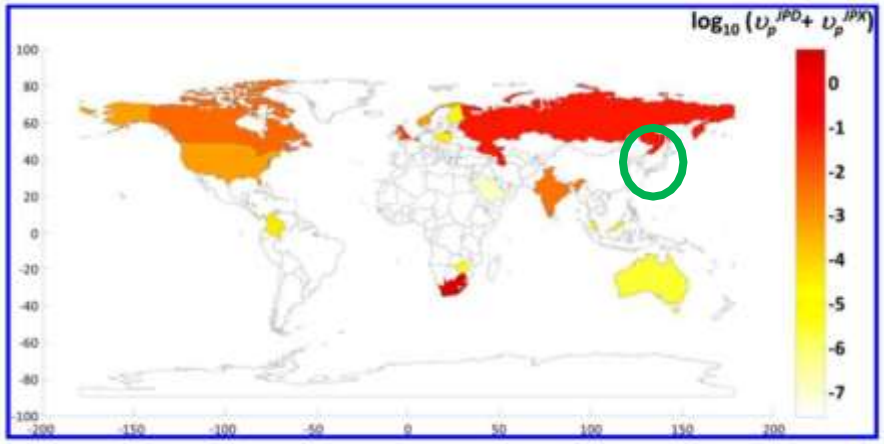

Figure 3. Global distribution of mining risk footprints of platinum associated with Japanese total final demand in 2005.

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Energy Policy 119 (2018) 226–241

Contents lists available at ScienceDirect

Energy Policy

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

Global metal flows in the renewable energy transition: Exploring the effects of substitutes, technological mix and development

André Månberger[a,*], Björn Stenqvist[b]

[a] Environmental and Energy Systems Studies, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden
[b] Physical Chemistry, Lund University, P.O. Box 124, SE-221 00 Lund, Sweden

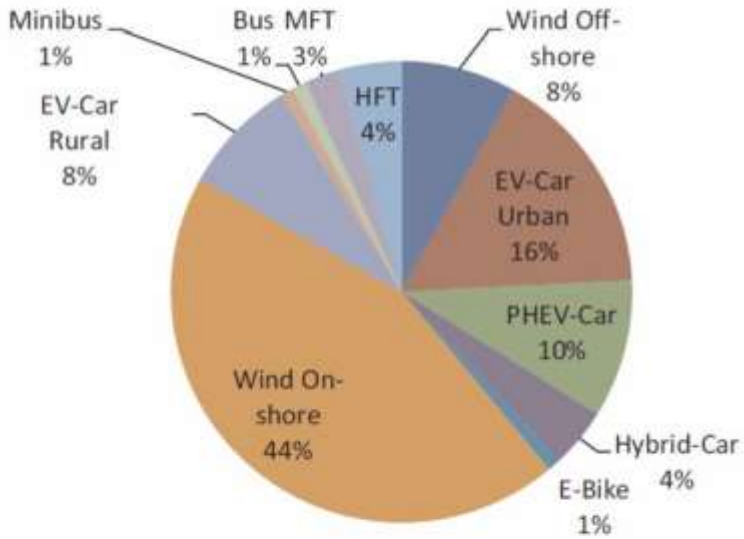

Fig. 4. Relative demand for permanent magnets per sector in Scenario 3.

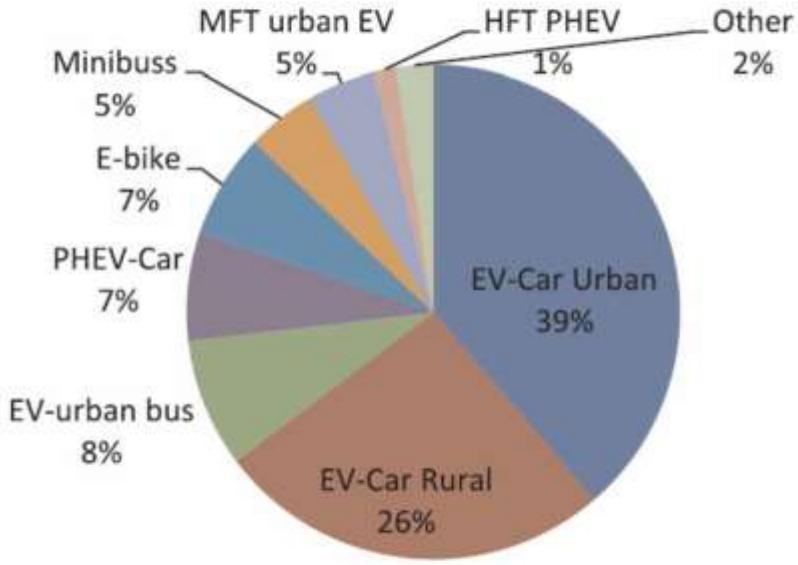

Fig. 8. Relative demand for batteries per sector, assuming moderate-size batteries.

Table 2
Summary of assumptions made in the four scenarios studied.

	Colour in figures	Technology mix	Battery size	Recycling rates	Metal intensity improvement
Scenario 1: Current technology and intensity	Black	Back-stop	Moderate	Current	None
Scenario 2: Current technology and improved intensity	Red	Back-stop	Moderate	Current	Between 2% and 5%
Scenario 3: New technology mix and improved recycling	Blue	Novel	Big	Improved recycling rates	None
Scenario 4: New technology mix and improved intensity	Green	Novel	Big	Current	Between 2% and 5%

Sustainable Materials and Technologies 12 (2017) 62–72

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Sustainable Materials and Technologies

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Role of substitution in mitigating the supply pressure of rare earths in electric road transport applications

Claudiu C. Pavel [a,*], Christian Thiel [b], Stefanie Degreif [c], Darina Blagoeva [a], Matthias Buchert [c], Doris Schüler [c], Evangelos Tzimas [a]

[a] Energy, Transport and Climate Directorate, Joint Research Centre, European Commission, Westerduinweg 3, 1755 LE Petten, The Netherlands
[b] Energy, Transport and Climate Directorate, Joint Research Centre, European Commission, Enrico Fermi 2749, I – 21027 Ispra, (VA), Italy
[c] Öko-Institut e.V., Rheinstrasse 95, 64295 Darmstadt, Germany

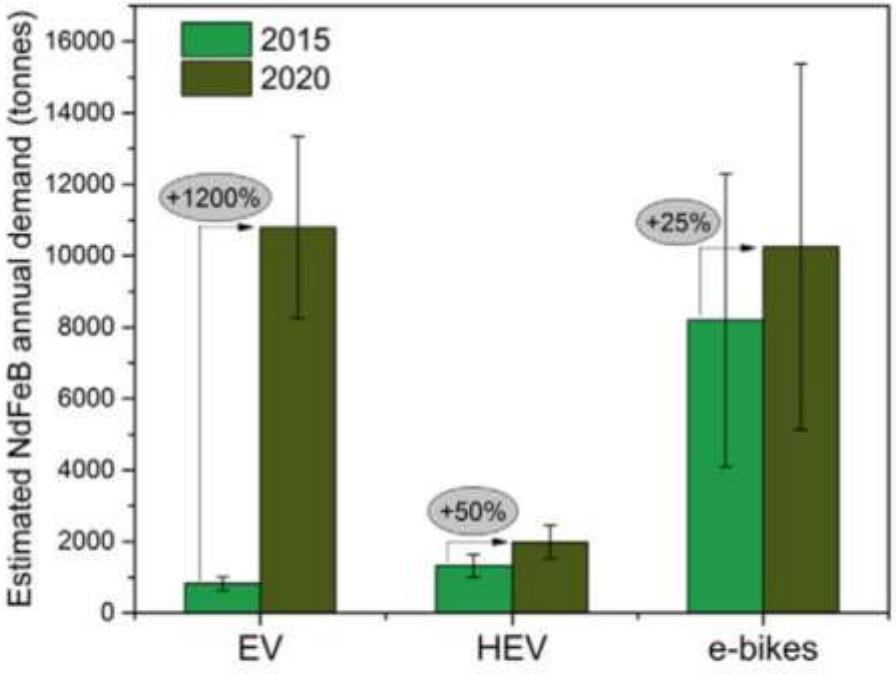

Fig. 5. Estimation of global annual demand for NdFeB magnet in EV, HEV and e-bike applications in 2015 and 2020 and the percentage increase assuming that all traction motors are based on NdFeB-PSM technology. Bars correspond to average values. The error bar represents the standard error calculated based on the minimum and maximum amount of NdFeB magnet used in PSM for each application.

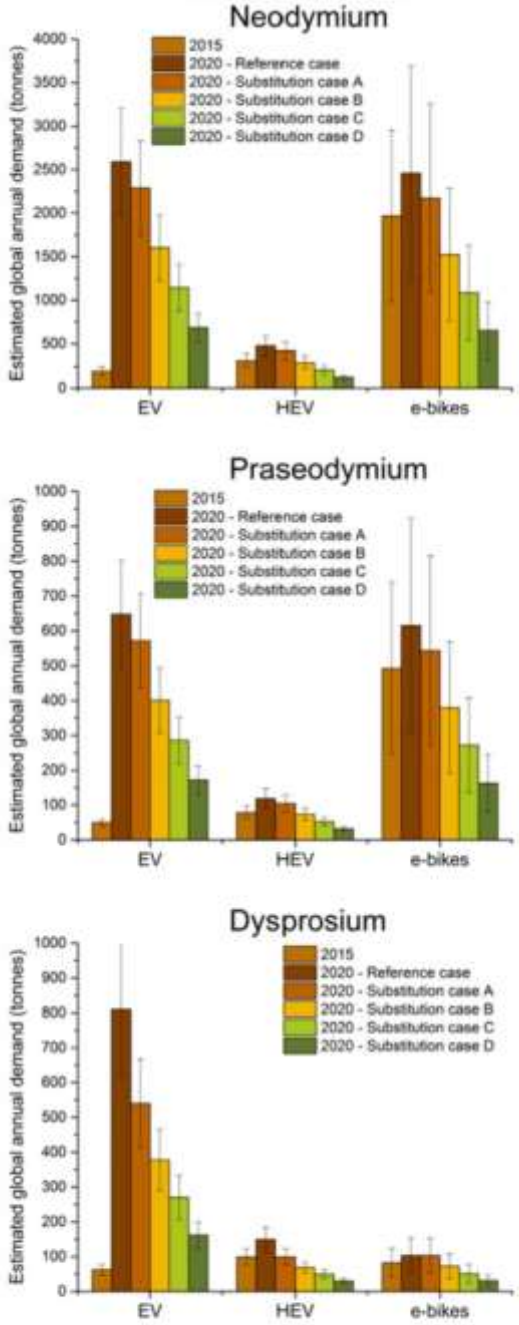

Fig. 6. Estimation of global annual demand for Nd, Pr and Dy in 2015 and 2020 in electric traction motors for H&EVs and e-bikes under different substitution scenarios. Bars correspond to average values. The error bar represents the standard error calculated based on the minimum and maximum amount of NdFeB magnet used in PSM for each application.

Resources, Conservation & Recycling 124 (2017) 50–61

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

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

Full length article

Tracing global lithium flow: A trade-linked material flow analysis

Xin Sun, Han Hao*, Fuquan Zhao, Zongwei Liu

State Key Laboratory of Automotive Safety Energy, Tsinghua University, Beijing 100084, China

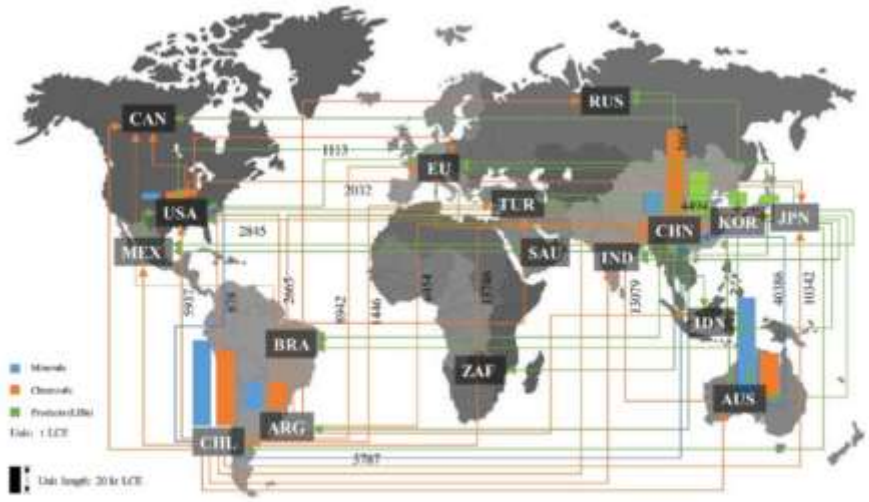

Fig. 3. Overview of global lithium commodity production and trade.

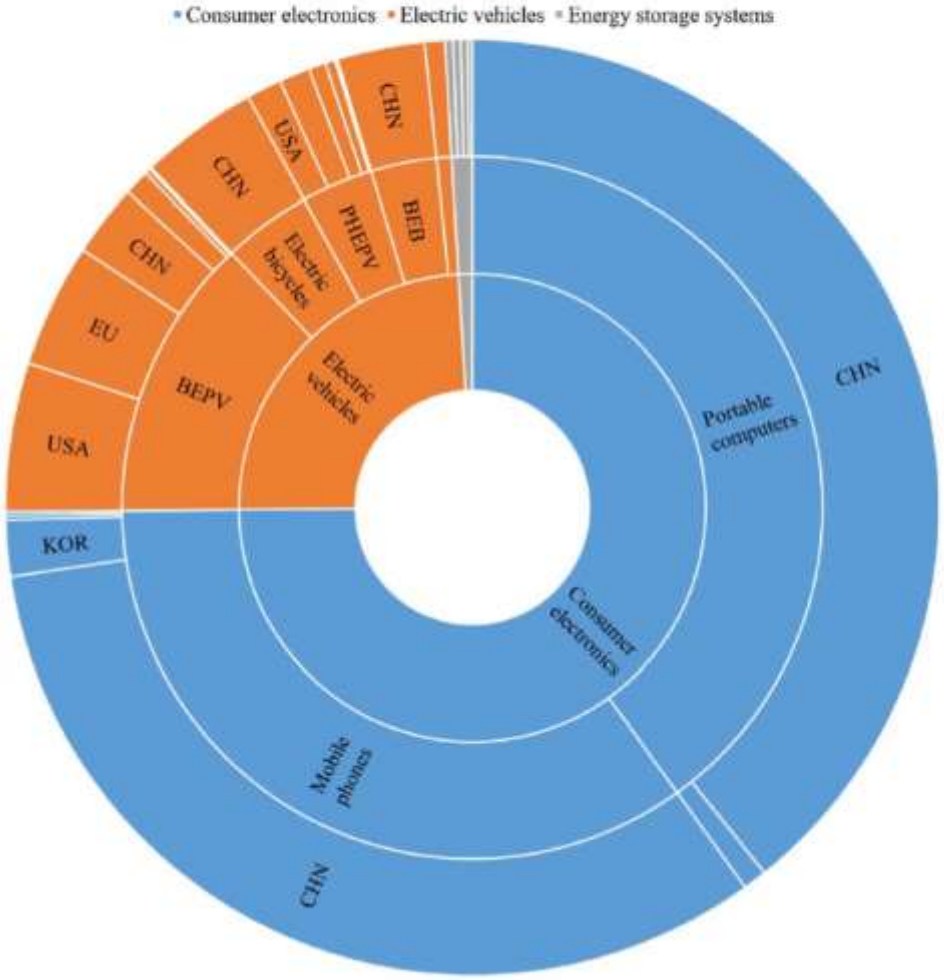

Fig. 7. Breakdown of LIB consumption by applications.

Resources, Conservation & Recycling 129 (2018) 202–208

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

Universidad Politécnica de Madrid
ETS de Ingenieros de Minas y Energía

Full length article

Metal supply constraints for a low-carbon economy?

Arjan de Koning[a,*], René Kleijn[a], Gjalt Huppes[a], Benjamin Sprecher[a], Guus van Engelen[a,c], Arnold Tukker[a,b]

[a] Institute of Environmental Sciences (CML), Leiden University, Leiden, Netherlands
[b] Netherlands Organisation for Applied Scientific Research TNO, Delft, Netherlands
[c] Currently employed at: Newpublic, Utrechtseweg 93, 3818 EC Amersfoort, Netherlands

Business-as-usual (BAU) scenario

Technological Scenario (TS)

Blue Map electricity supply (BMES) scenario
(IEA, 2008: 23% nuclear, 26% fosil con CCS, y 44% renovables)

Rare Earth Metals (REM) scenario
(similar al escenario BMES pero asume además que todos los automóviles eléctricos de nueva fabricación están equipados con imanes de Nd, no de Dy)

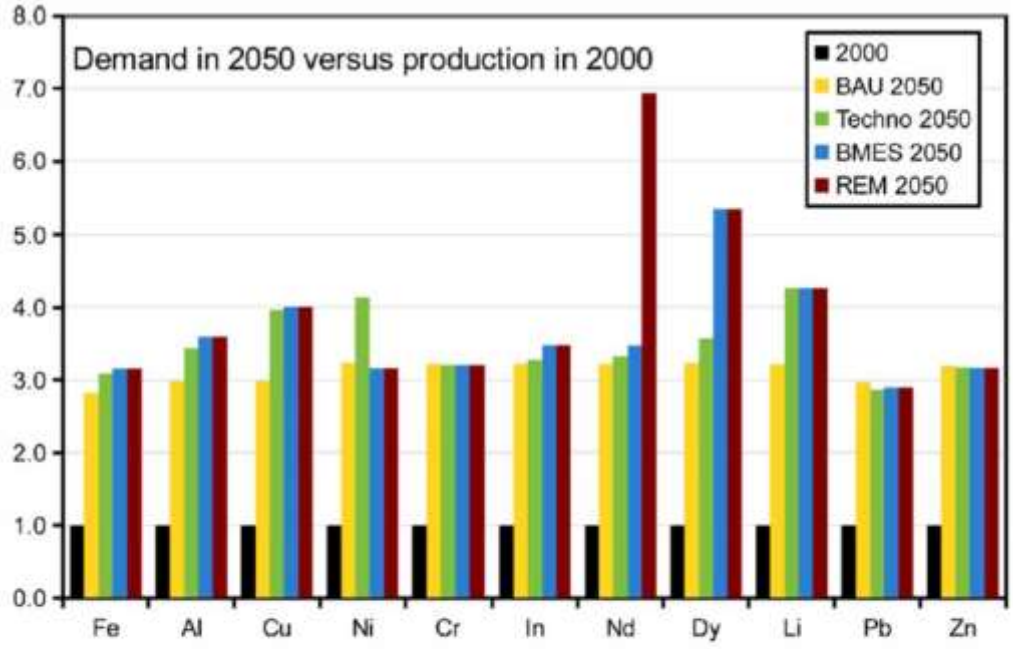


Fig. 2. Annual supply of metals in 2000 versus demand for metals in 2050 in the BAU, Techno, BMES and REM scenarios in 2050. Indexed values; annual supply of the metal in 2000 = 1.

Metals for a low-carbon society

Olivier Vidal, Bruno Goffé and Nicholas Arndt

Renewable energy requires infrastructures built with metals whose extraction requires more and more energy. More mining is unavoidable, but increased recycling, substitution and careful design of new high-tech devices will help meet the growing demand.

NATURE GEOSCIENCE | VOL 6 | NOVEMBER 2013
www.nature.com/naturegeoscience

Figure 1 | A row of wind turbines.

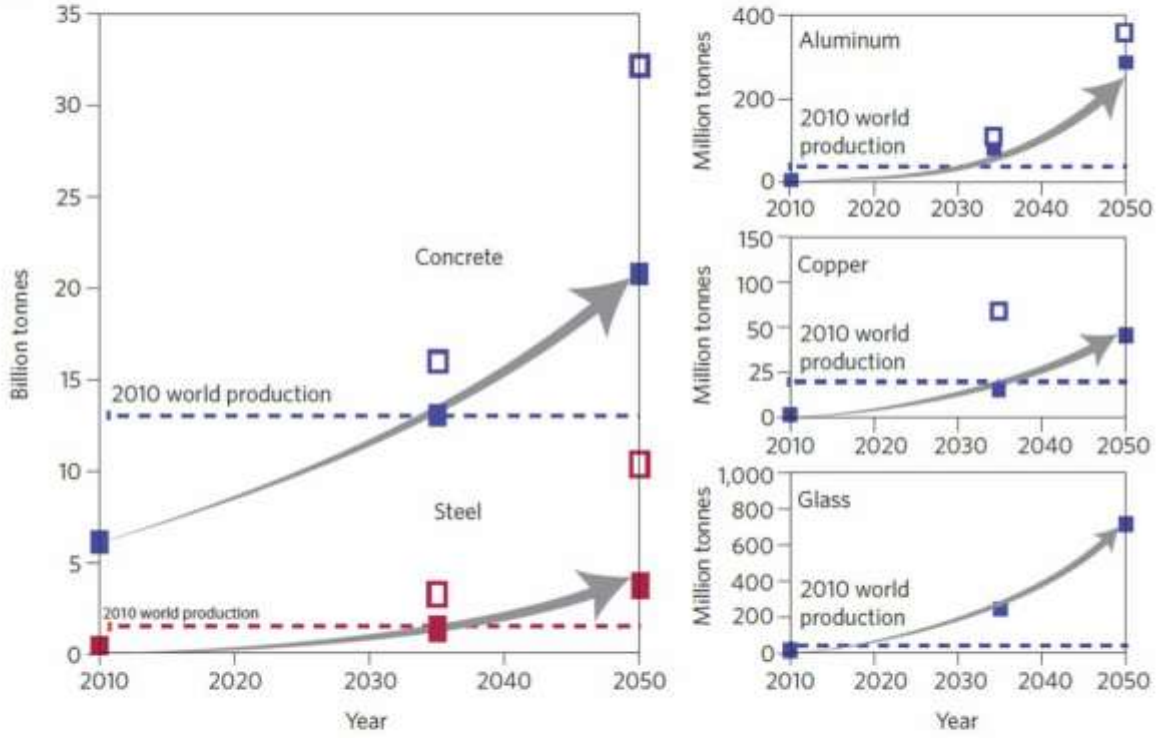


Figure 2 | Increasing global consumption of raw materials. The World Wide Fund for Nature (WWF) predicts that the contribution from wind and solar energy to global energy production will rise to 25,000 TWh in 2050[7]. To meet this demand, the global production of raw materials such as concrete, steel, aluminium, copper and glass will need to significantly increase. Open and filled symbols correspond to different volumes of raw material required to construct different types of photovoltaic panels (PV1 and PV2, respectively, in Supplementary Table 1).

POLITÉCNICA CAMPUS DE EXCELENCIA INTERNACIONAL

Environmental Science & Technology

The Water Footprint of California's Ener

Julian Fulton*,† and Heather Cooley‡

Table 1. Factors Used to Calculate California's Blue Electricity[a]

fuel	location	fuel cycle (l water/MWh)	generation (l water/MWh)
coal	all	96	1895
natural gas	all	24[b]	737
nuclear	all	212	1017

Environmental Science & Technology

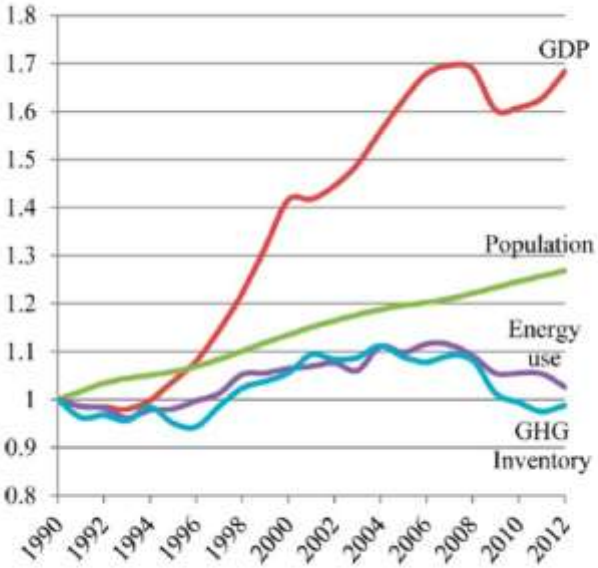
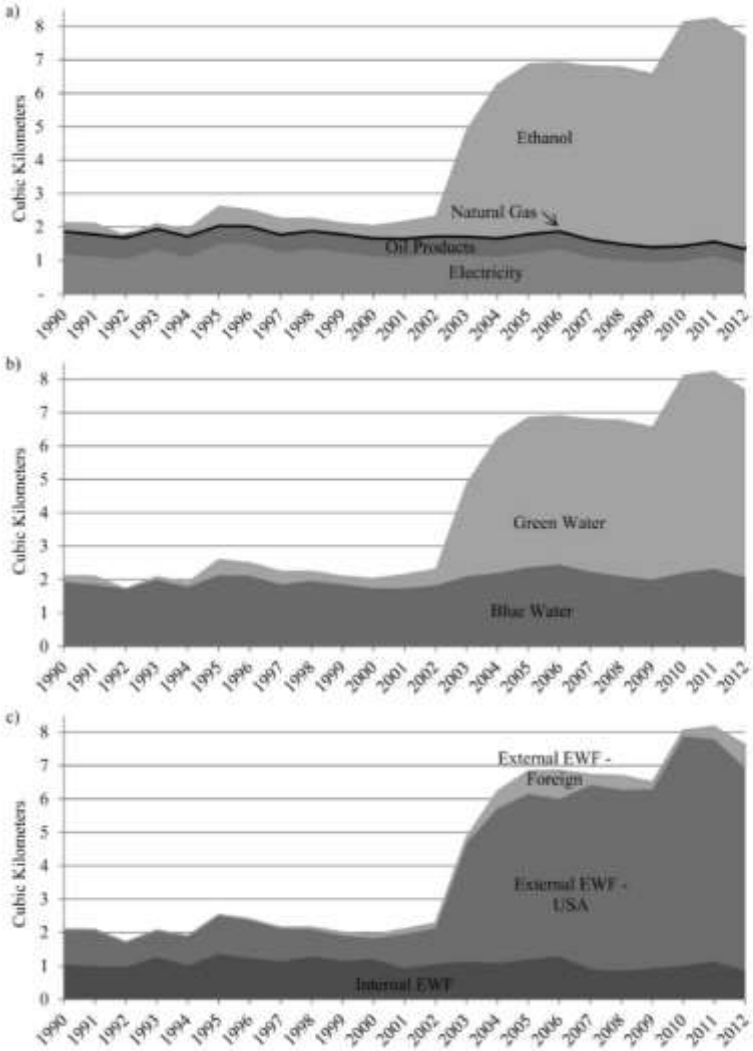


Figure 1. Changes in California GDP, population, energy use, and energy greenhouse gas inventory from 1990 to 2012.[20−23]

Environmental Science & Technology Policy Analysis



ilifornia's energy-water footprint between 1990 and 2012, broken down by energy type (a), by green and blue water (b), and by internal locations (c).

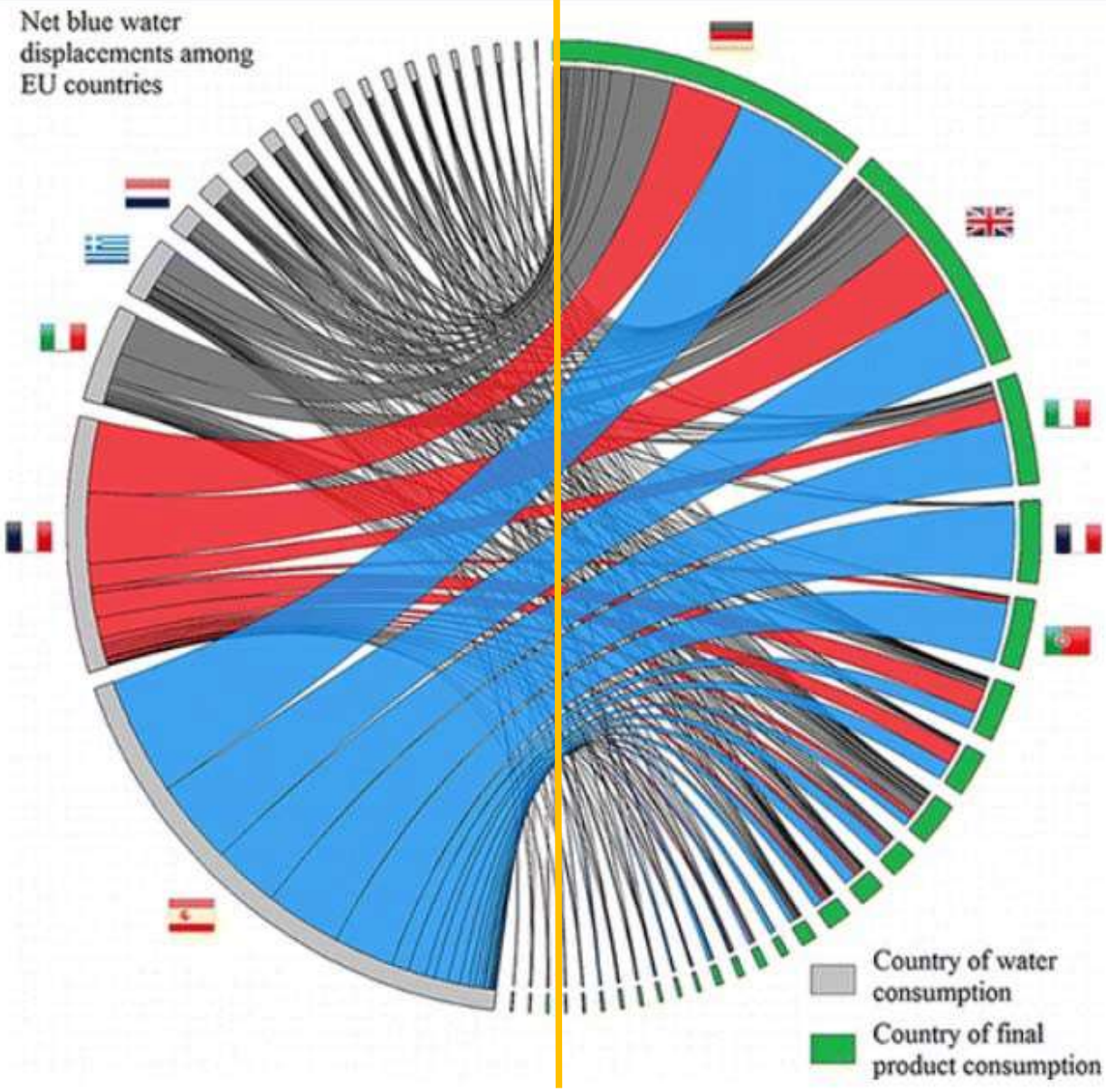
(EWF) Energy-related Water Footprint

Environmental Science & Technology

Carbon, Land, and Wate
Union: Consumption, Pr
International Trade

Kjartan Steen-Olsen,*,† Jan Weinzett

†Industrial Ecology Programme and Departm
Technology (NTNU), Trondheim, Norway
‡Global Footprint Network, Geneva, Switzerl
§University of Twente, Enschede, The Nethe



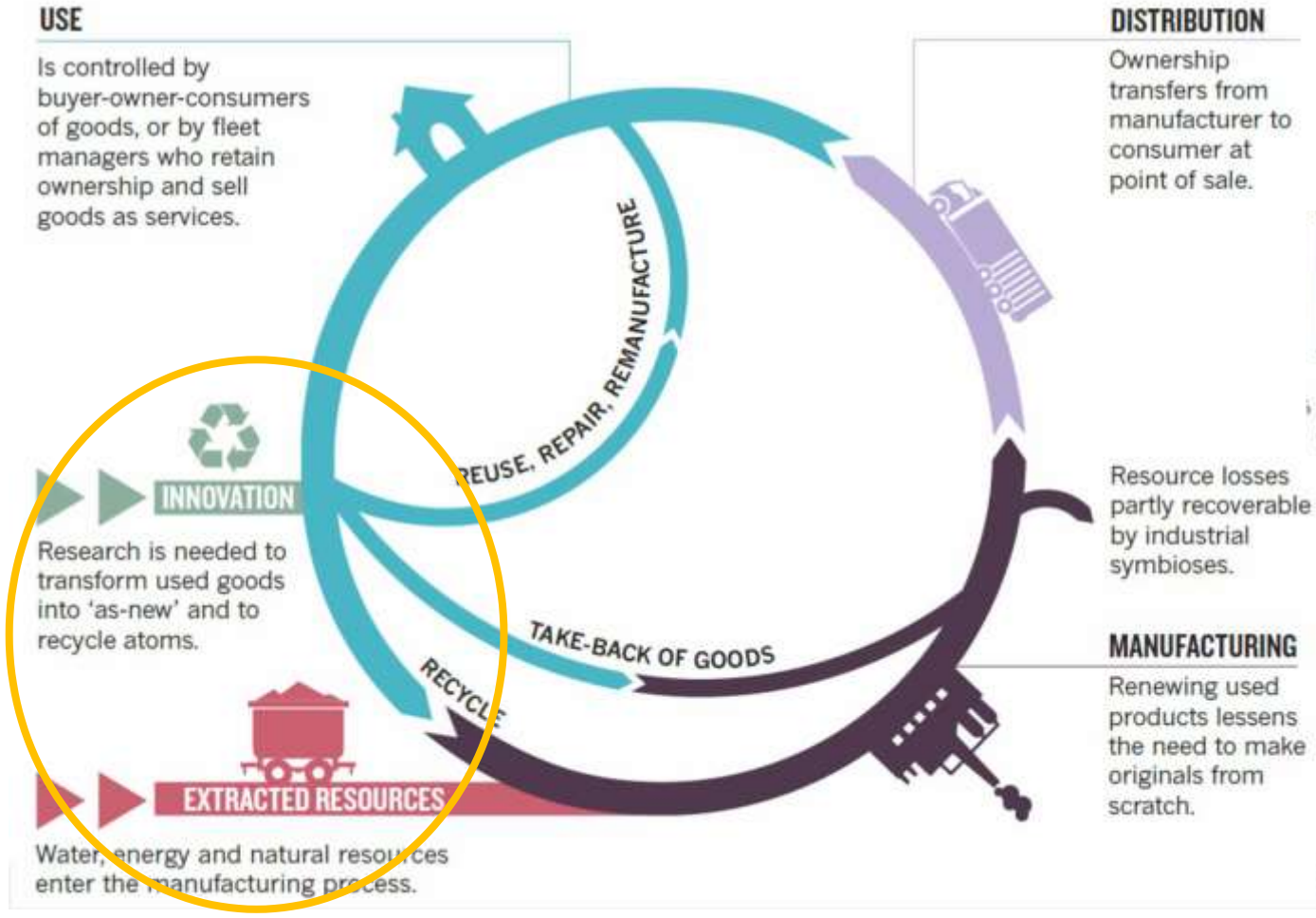
Circular economy

CLOSING LOOPS

Using resources for the longest time possible could cut some nations' emissions by up to 70%, increase their workforces by 4% and greatly lessen waste.

facture, upgrades and retrofits; and those that turn old goods into as-new resources by recycling the materials. People — of all ages and skills — are central to the model. Ownership gives way to stewardship; consumers become users and creators[3]. The remanufacturing and repair of old goods, buildings and infrastructure creates skilled jobs in local workshops. The experiences of ▶

24 MARCH 2016 | VOL 531 | NATURE | 435



THE CIRCULAR ECONOMY
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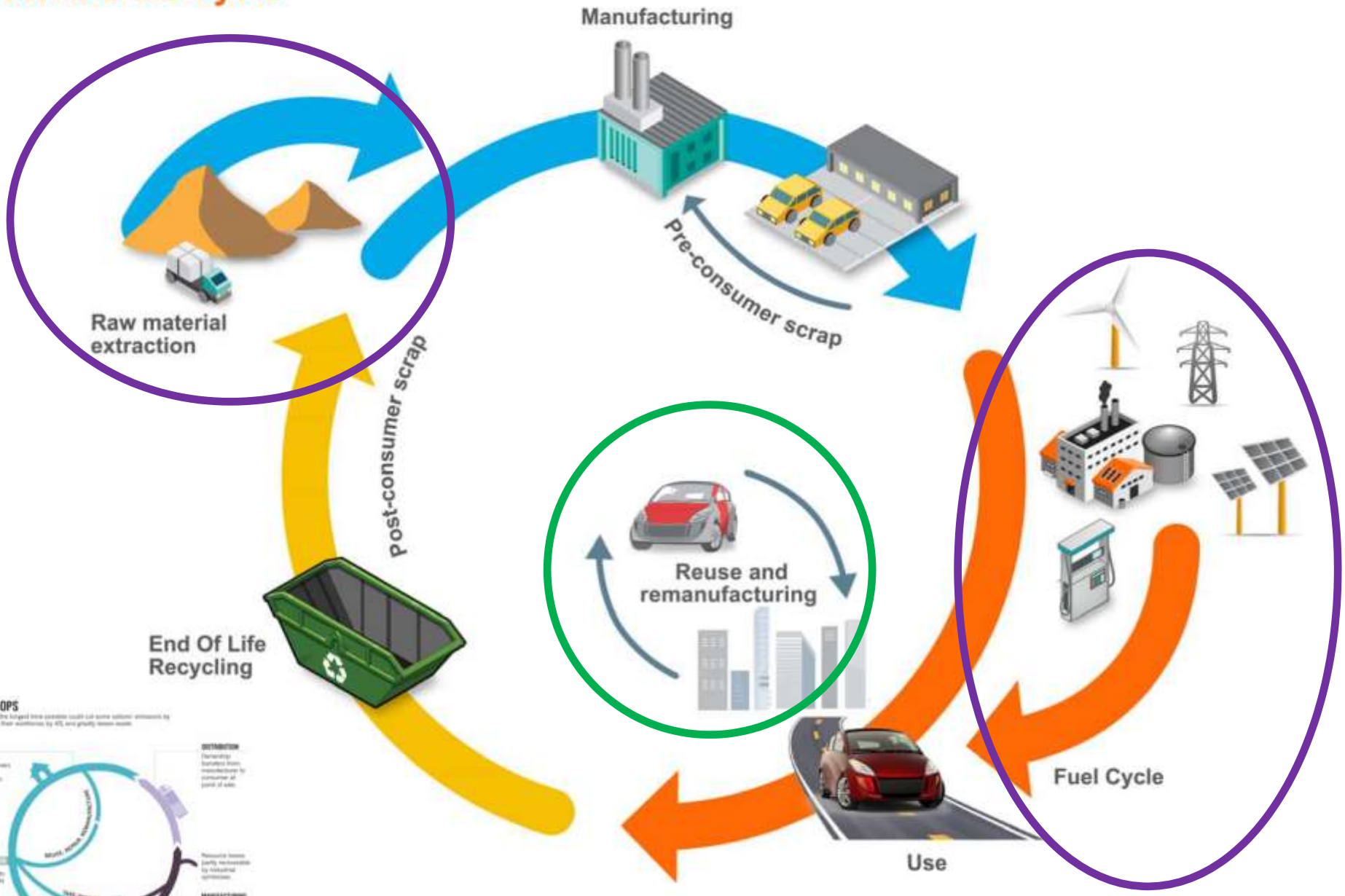
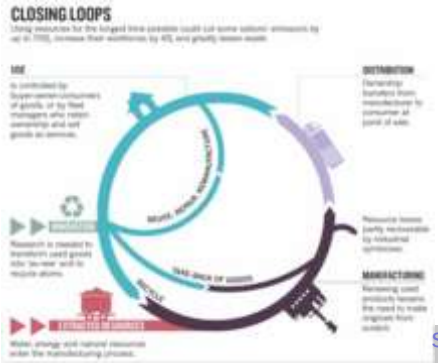
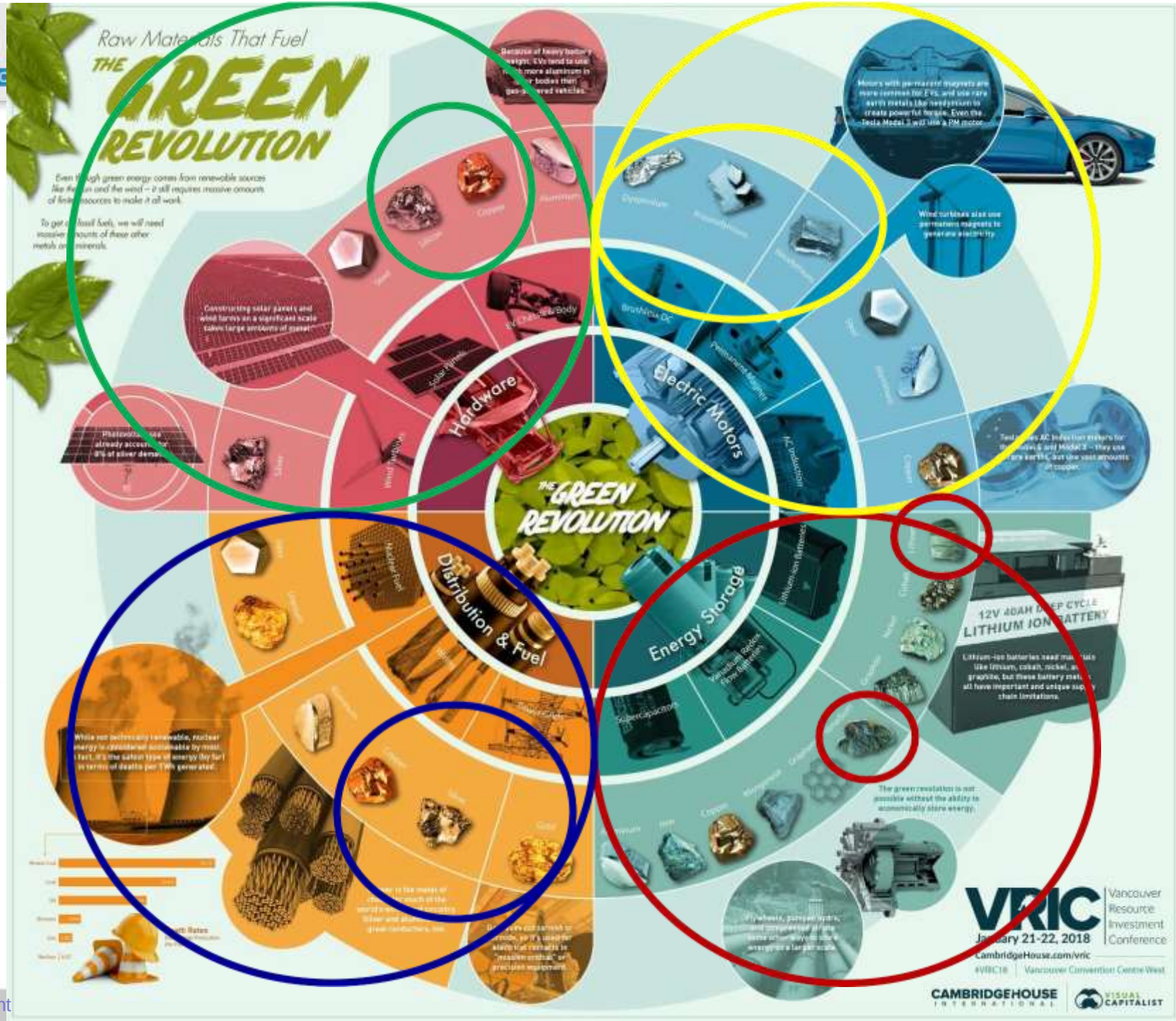
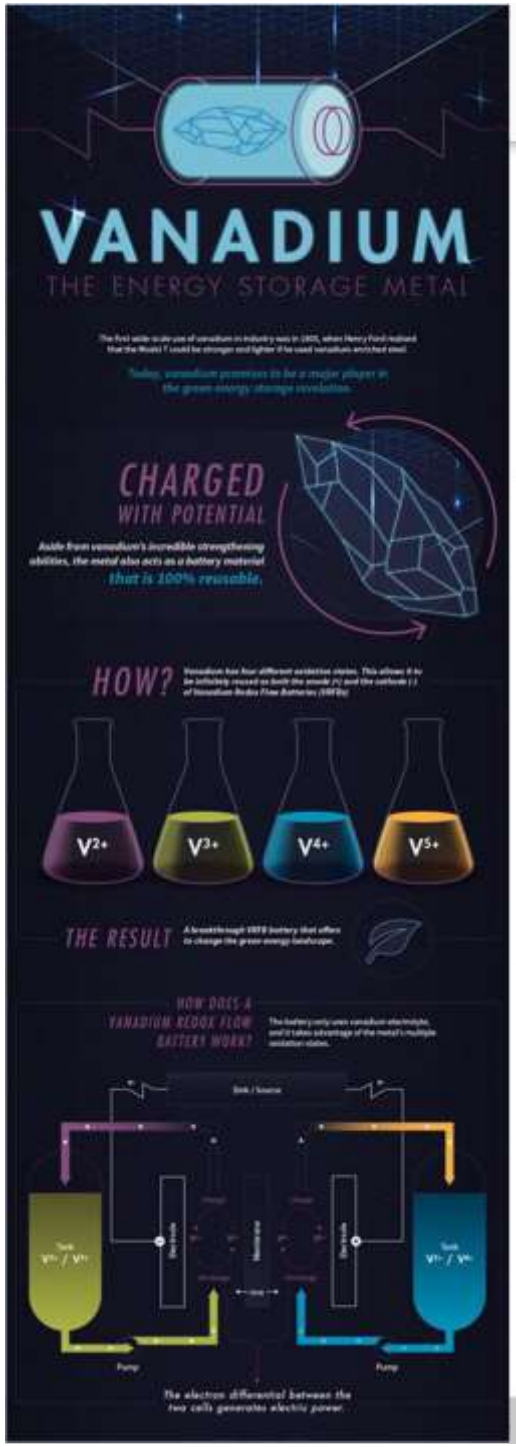
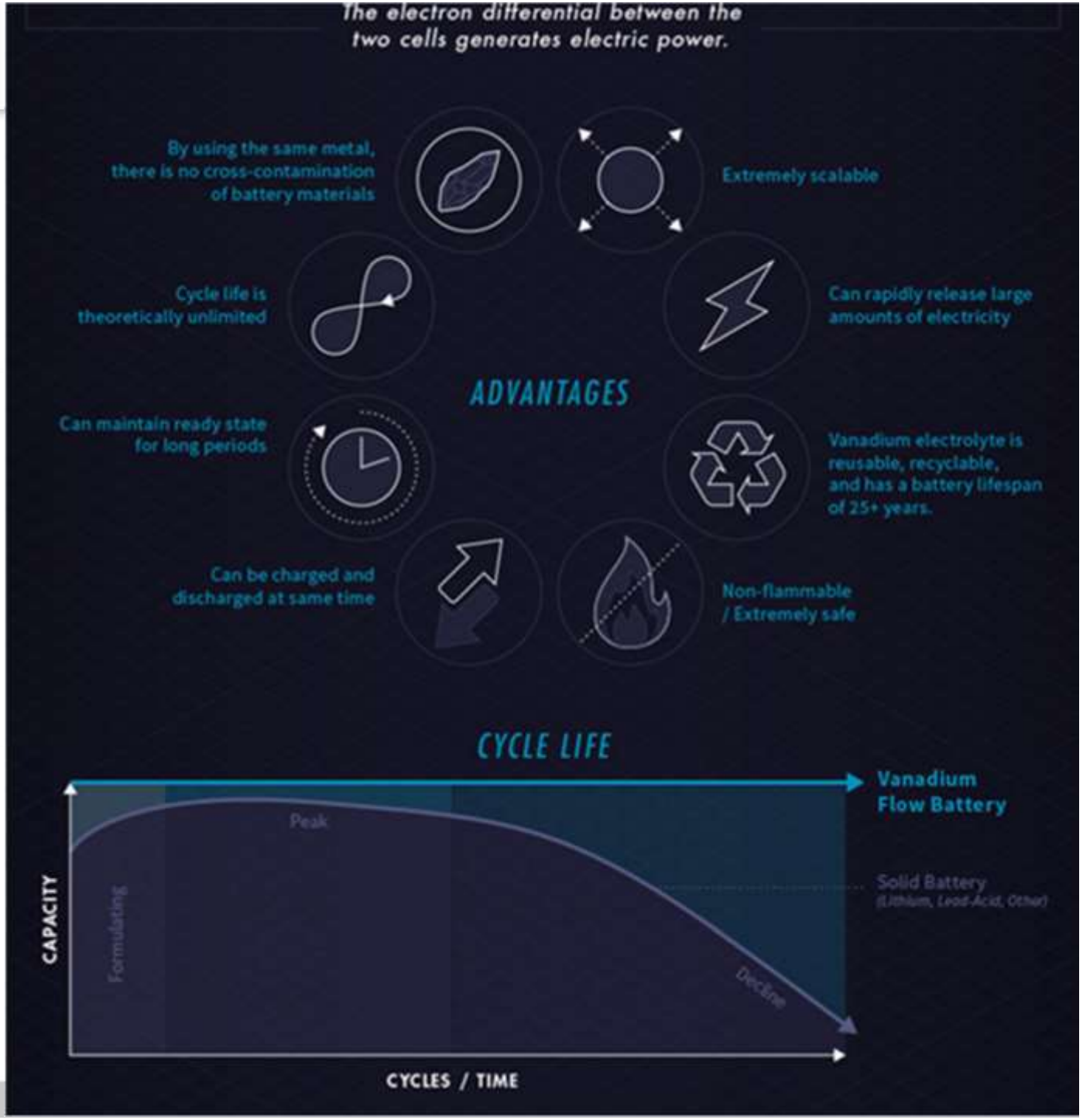
Vehicle life cycle

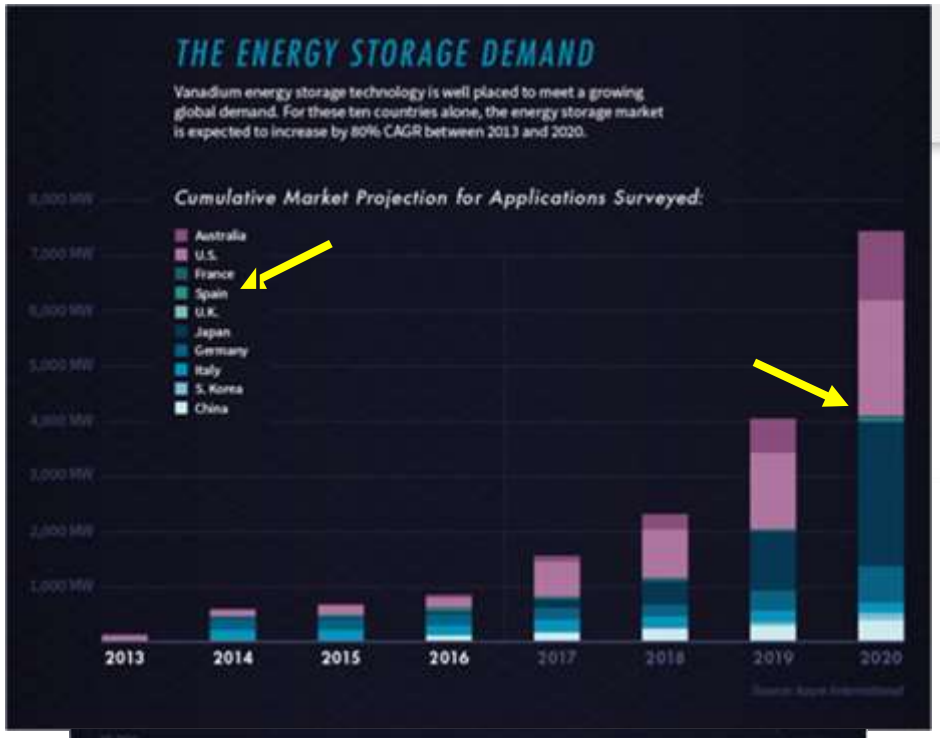




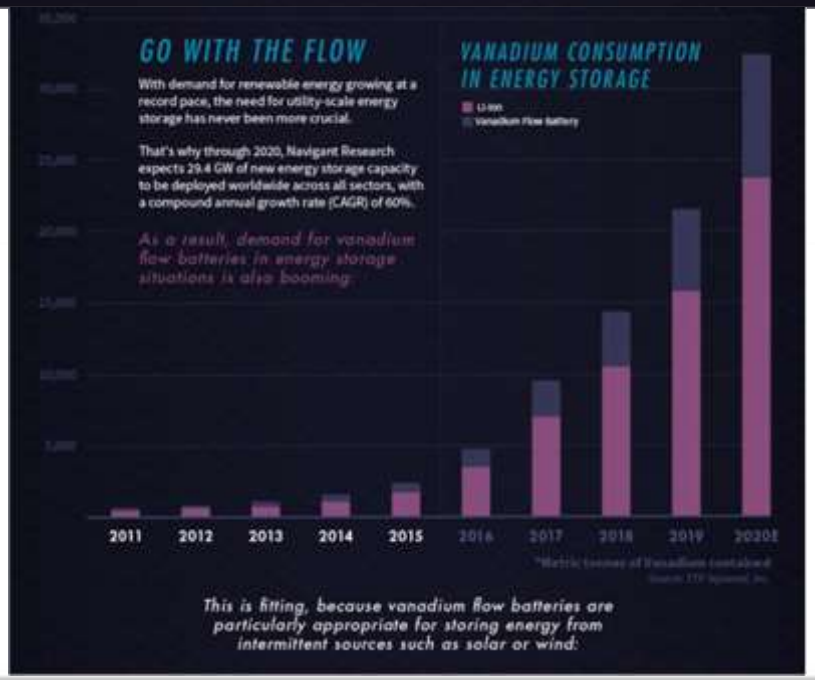

Raw Materials That Fuel
THE GREEN REVOLUTION
Hardware
Electric Motors
Distribution & Fuel
Energy Storage
THE GREEN REVOLUTION
12V 40AH DEEP CYCLE
LITHIUM ION BATTERY
VRIC
Vancouver Resource Investment Conference
January 21-22, 2018
CambridgeHouse.com/vric
CAMBRIDGEHOUSE INTERNATIONAL
VISUAL CAPITALIST

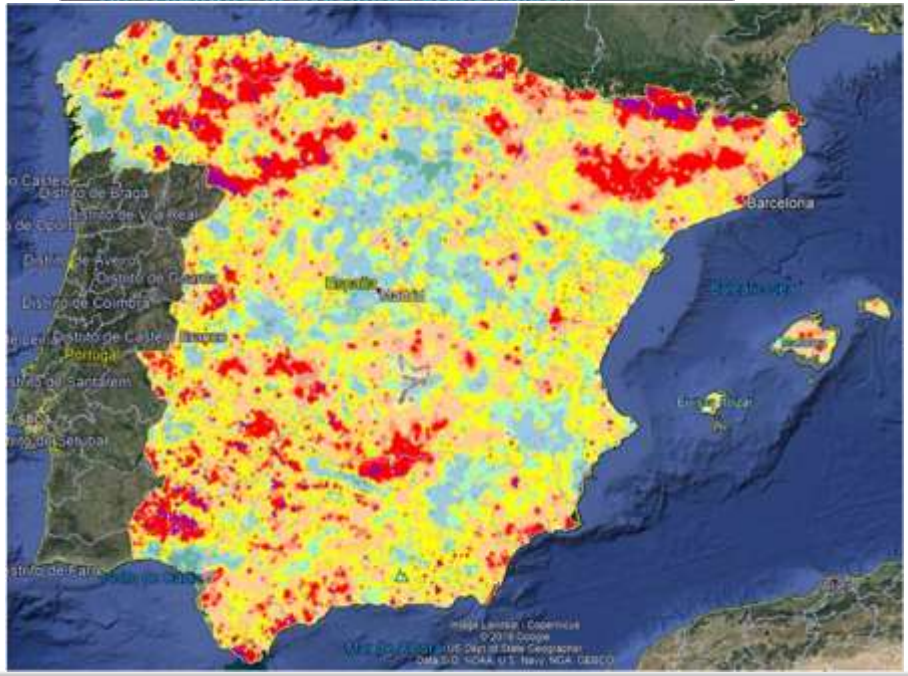

VANADIUM
THE ENERGY STORAGE METAL
CHARGED WITH POTENTIAL
HOW?
V^{2+}
V^{3+}
V^{4+}
V^{5+}
THE RESULT
HOW DOES A VANADIUM REDOX FLOW BATTERY WORK?
Pump
Pump
The electron differential between the two cells generates electric power.


The electron differential between the two cells generates electric power.
By using the same metal, there is no cross-contamination of battery materials
Extremely scalable
Cycle life is theoretically unlimited
Can rapidly release large amounts of electricity
ADVANTAGES
Can maintain ready state for long periods
Vanadium electrolyte is reusable, recyclable, and has a battery lifespan of 25+ years.
Can be charged and discharged at same time
Non-flammable / Extremely safe
CYCLE LIFE
Vanadium Flow Battery
Peak
Solid Battery
(Lithium, Lead-Acid, Other)
CAPACITY
Formulating
Decline
CYCLES / TIME


THE ENERGY STORAGE DEMAND
Vanadium energy storage technology is well placed to meet a growing global demand. For these ten countries alone, the energy storage market is expected to increase by 80% CAGR between 2013 and 2020.
Cumulative Market Projection for Applications Surveyed:
Australia
U.S.
France
Spain
U.K.
Japan
Germany
Italy
S. Korea
China
2013
2014
2015
2016
2017
2018
2019
2020

VANADIUM FLOW INSTALLATIONS
As the energy storage market blooms, vanadium flow batteries are being installed around the world. Here are some of the most noteworthy projects:
CANADA
CHINA
The largest grid-scale battery system in the world is being built on the Dalian peninsula in China, and it will serve about 7 million residents. The battery will be able to peak-shave approximately 9% of Dalian's expected load in 2020.
200 MW
800 MW/h
15 MW
USA
DRC
JAPAN

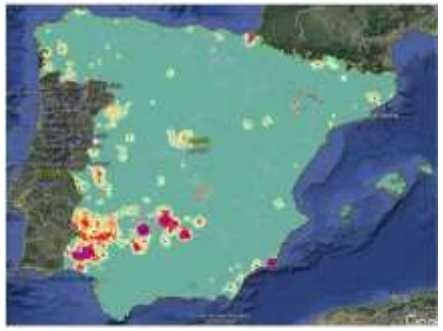

GO WITH THE FLOW
With demand for renewable energy growing at a record pace, the need for utility-scale energy storage has never been more crucial.
That's why through 2020, Navigant Research expects 29.4 GW of new energy storage capacity to be deployed worldwide across all sectors, with a compound annual growth rate (CAGR) of 60%.
As a result, demand for vanadium flow batteries in energy storage situations is also booming.
VANADIUM CONSUMPTION IN ENERGY STORAGE
Li-ion
Vanadium Flow Battery
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020E
This is fitting, because vanadium flow batteries are particularly appropriate for storing energy from intermittent sources such as solar or wind:


Barcelona

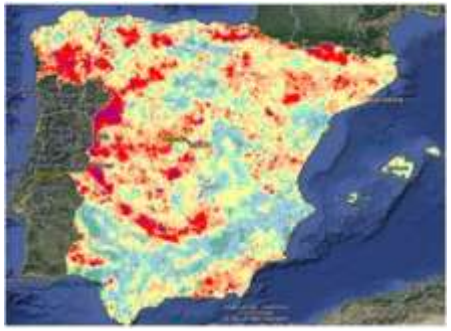
Pr
59
Praseodymium

Nd
60
Neodymium

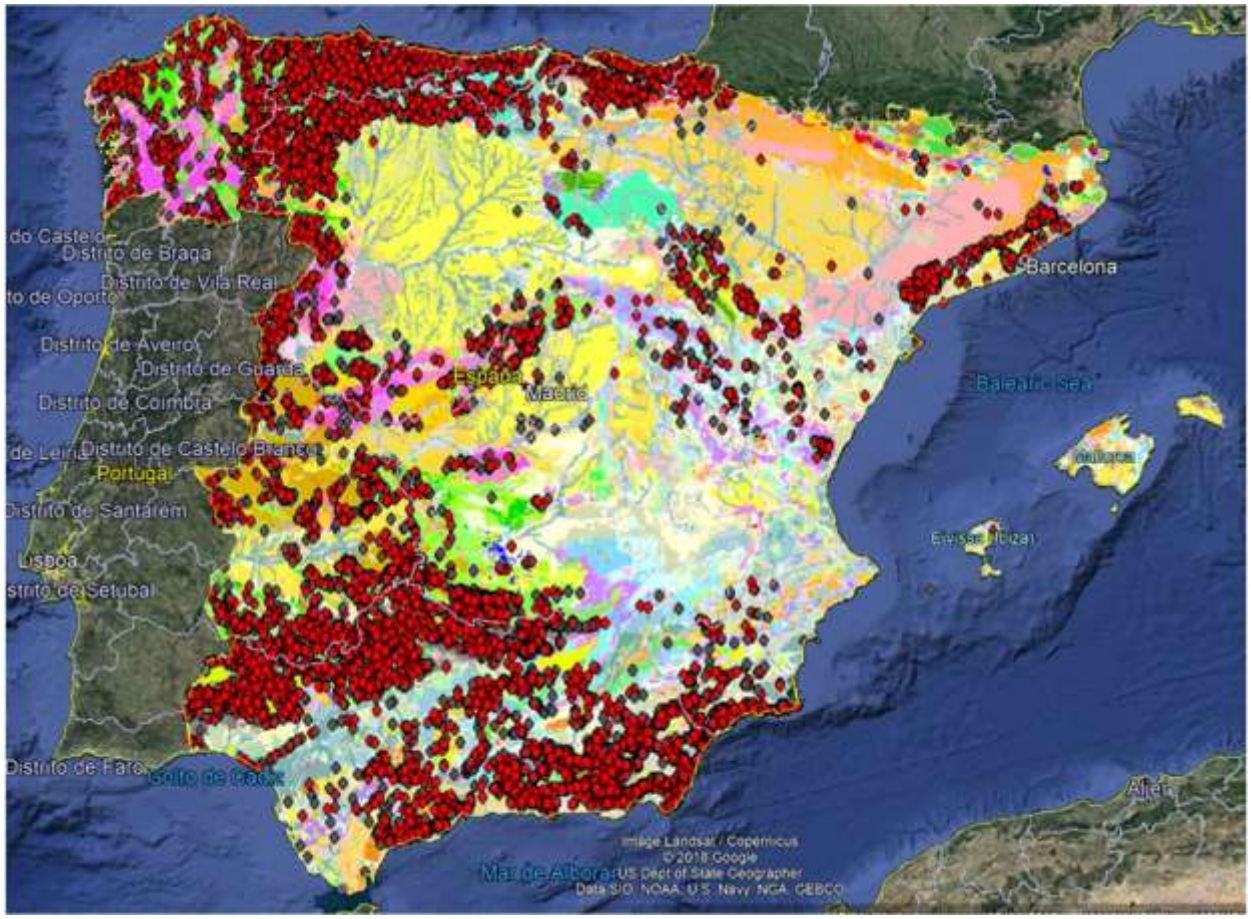
Dy
66
Dysprosium

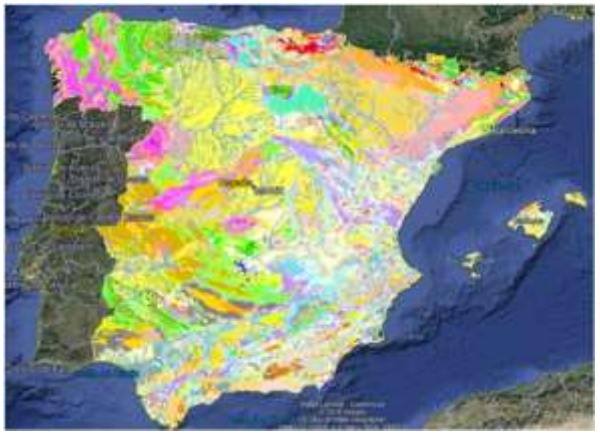


Li
3
6.941

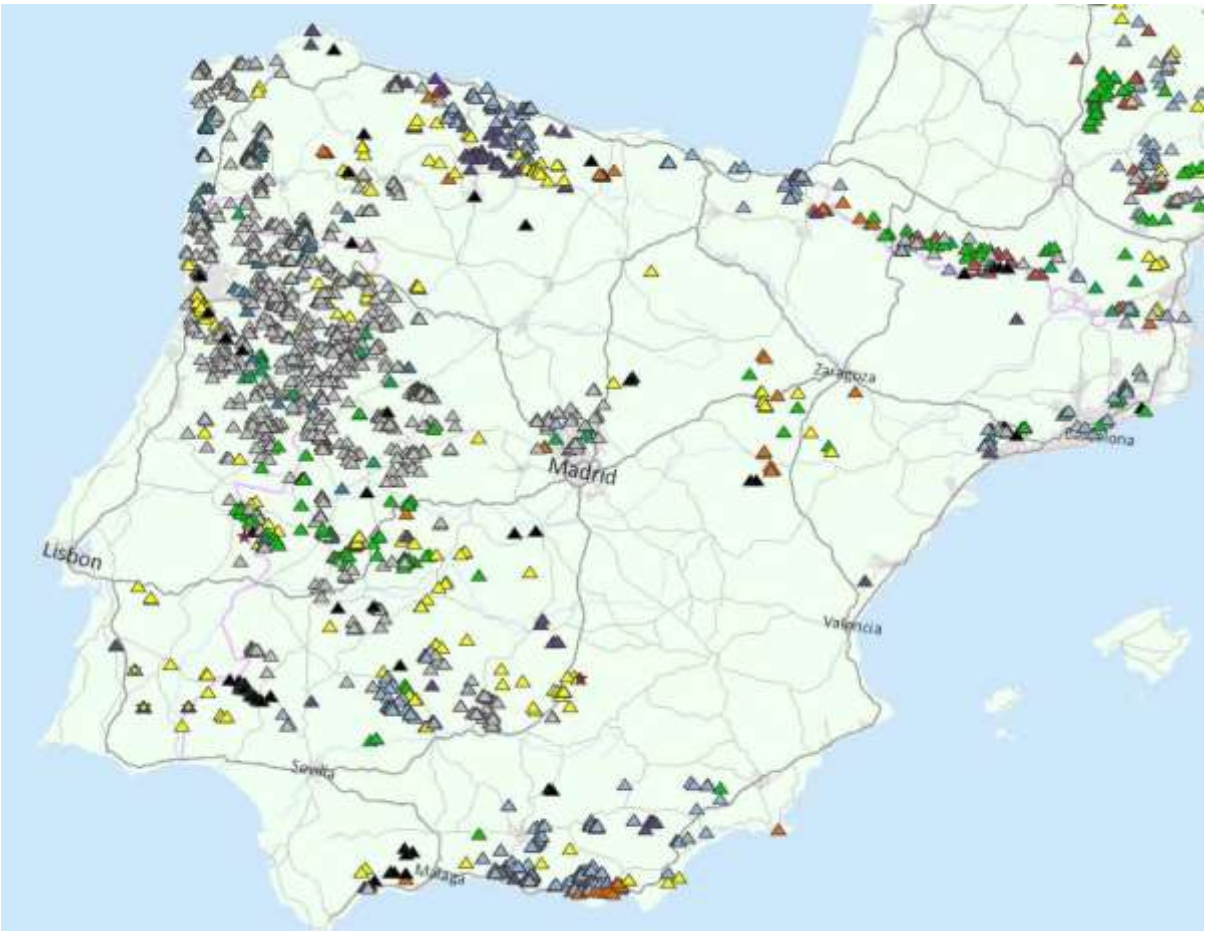


Mapa Metalogenético





Minerales críticos en España



Fuente: EGDI: Critical raw Materials Map (parcial)

GeoERA - European Geological Surveys joint action to improve Data Management

- Existen diversas iniciativas desde la CE y EGS para homogeneizar y actualizar las bases de datos de la Unión sobre indicios de materias primas minerales
- El Proyecto Minerals4EU y el Proyecto ProMine han alimentado la plataforma EGDI que proporciona una base sólida de información
- Actualmente la llamada GeoERA desarrolla estudios de mayor detalle e incluye el potencial de los fondos marinos

Criticality of metals and metalloids

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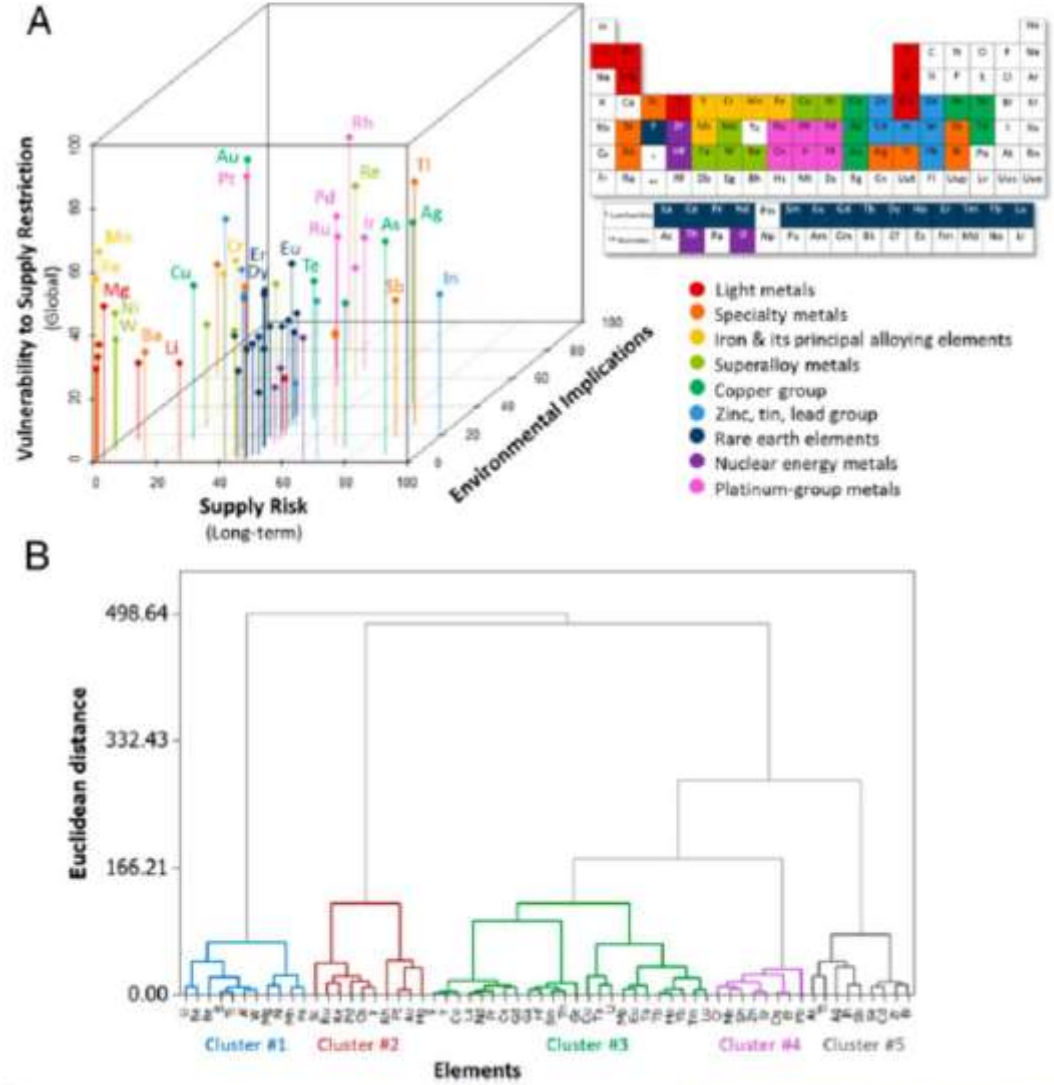


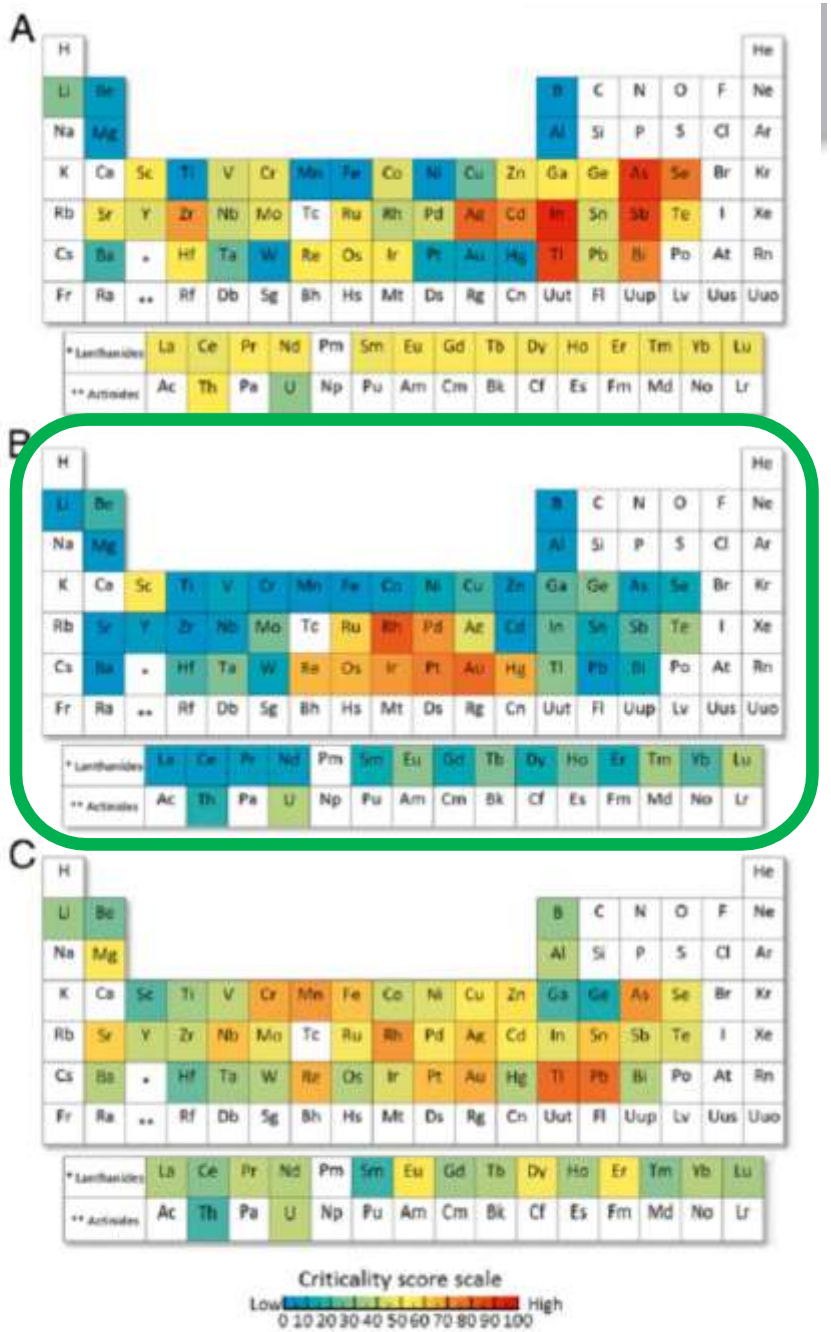
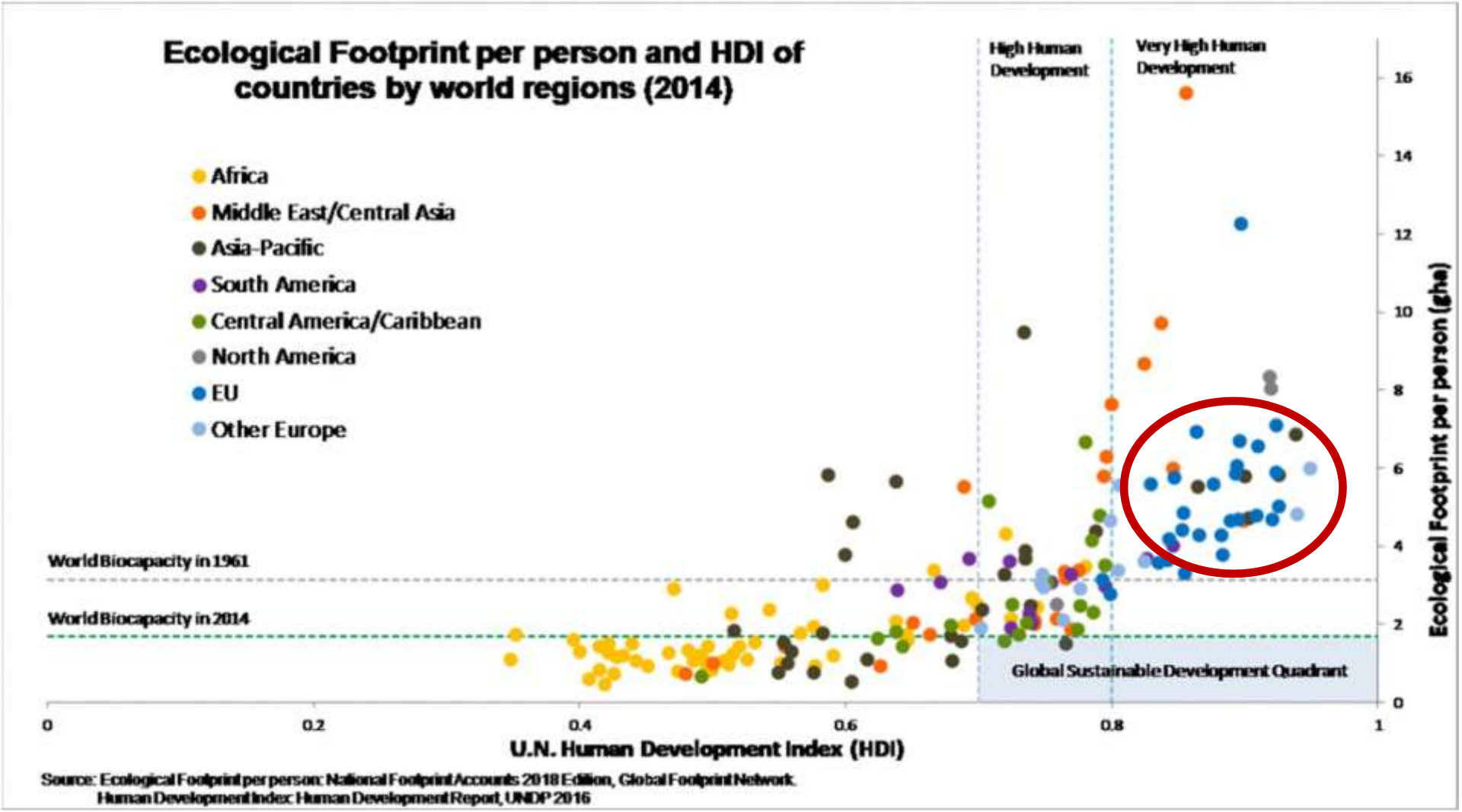


Fig. 6. Periodic tables of criticality for 62 metals, 2008 epoch, global level for (*A*) supply risk, (*B*) environmental implications, and (*C*) vulnerability to supply restriction.


Ecological Footprint per person and HDI of countries by world regions (2014)
Africa
Middle East/Central Asia
Asia-Pacific
South America
Central America/Caribbean
North America
EU
Other Europe
High Human Development
Very High Human Development
World Biocapacity in 1961
World Biocapacity in 2014
Global Sustainable Development Quadrant
0
0.2
0.4
0.6
0.8
1
U.N. Human Development Index (HDI)
0
2
4
6
8
10
12
14
16
Ecological Footprint per person (gha)
Source: Ecological Footprint per person: National Footprint Accounts 2018 Edition, Global Footprint Network.
Human Development Index: Human Development Report, UNDP 2016

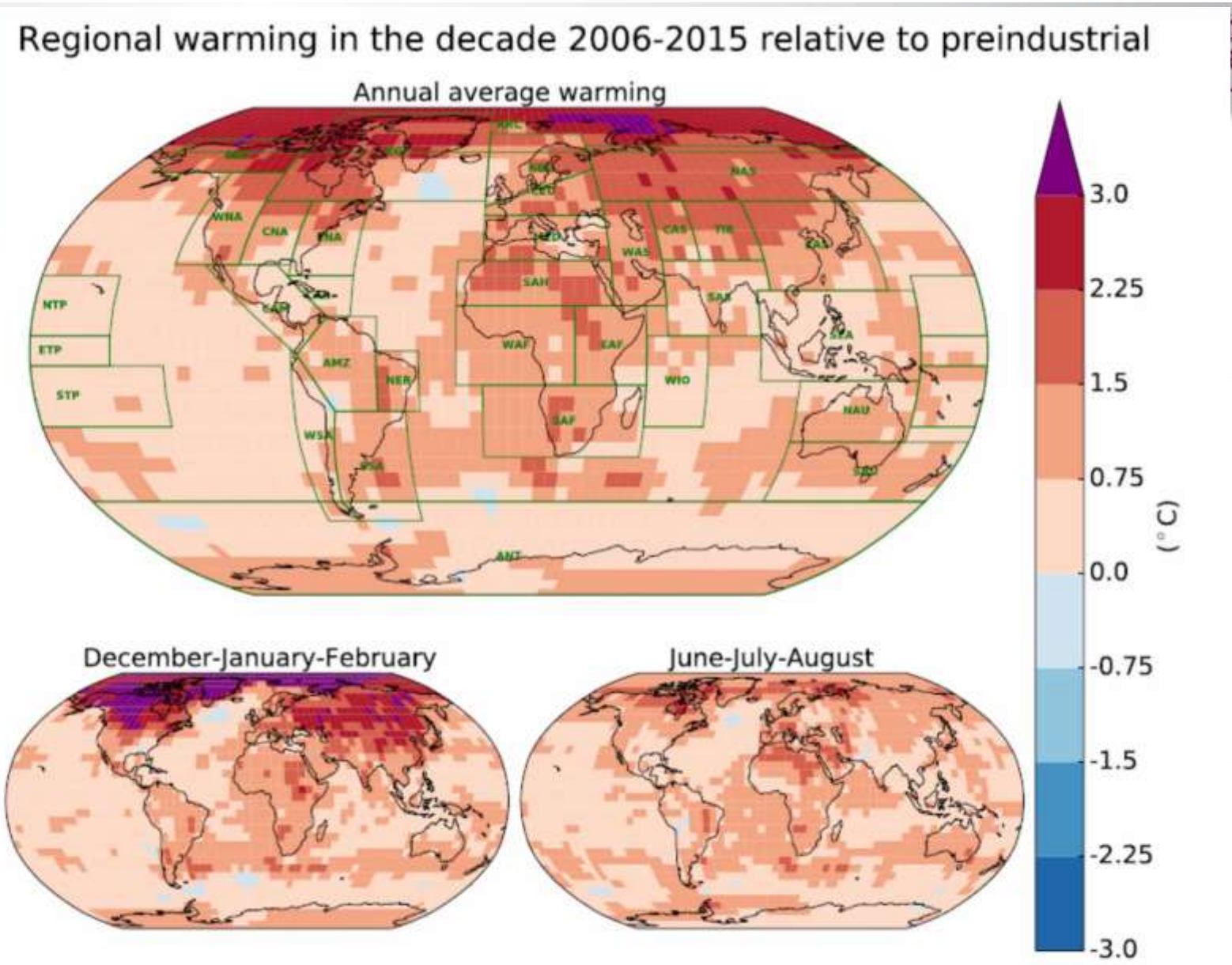
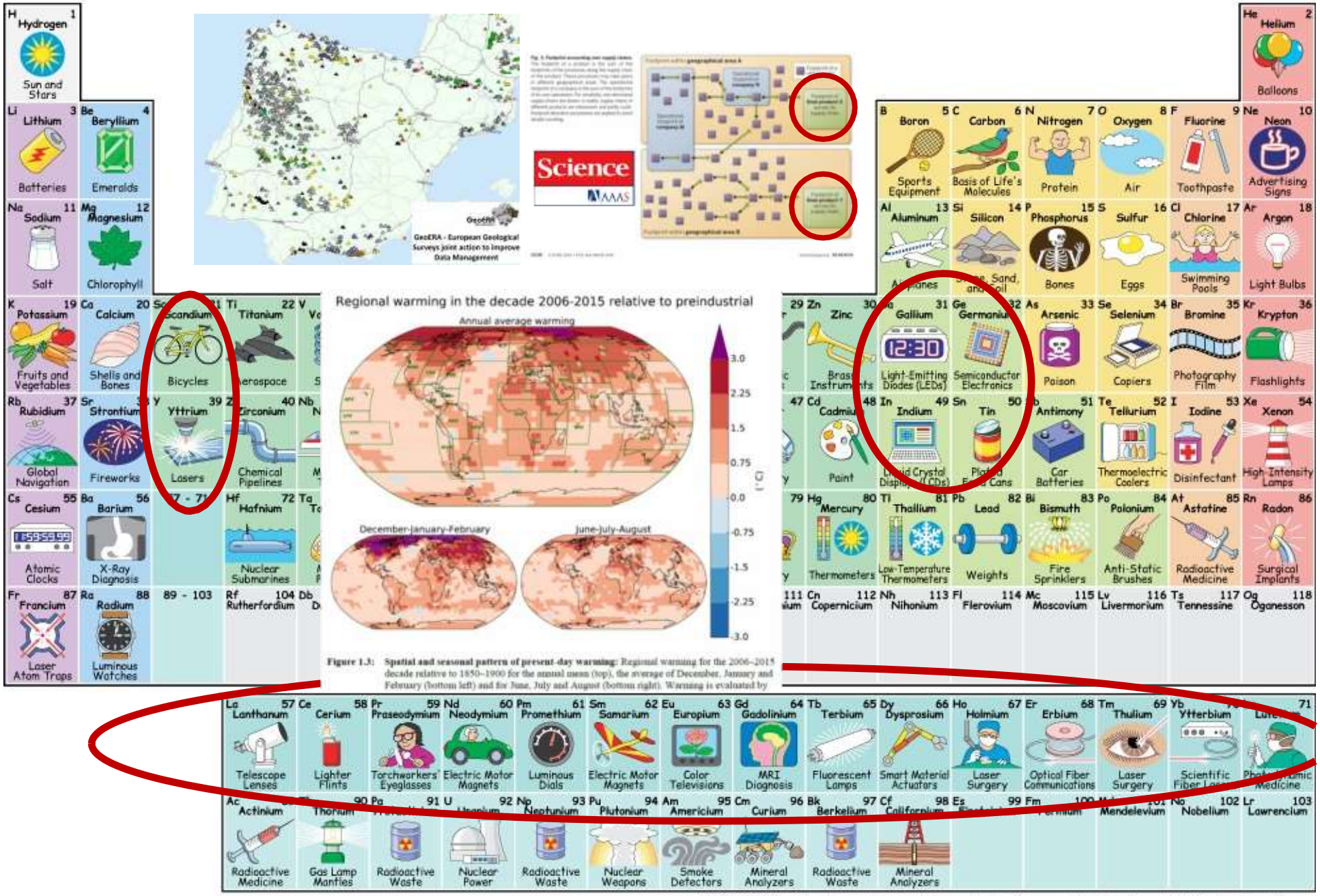
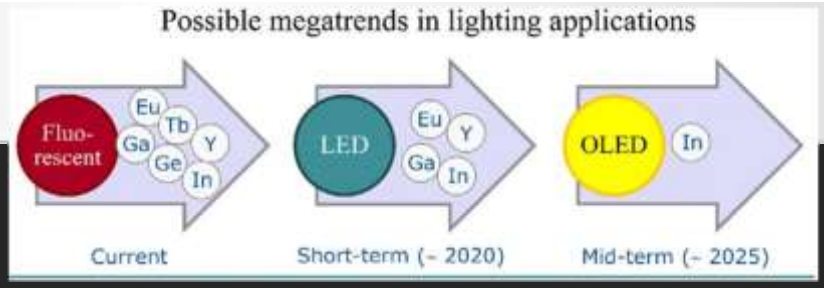
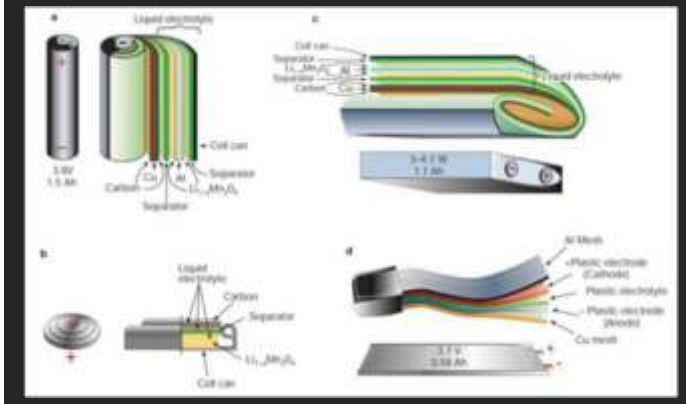


Figure 1.3: **Spatial and seasonal pattern of present-day warming:** Regional warming for the 2006–2015 decade relative to 1850–1900 for the annual mean (top), the average of December, January and February (bottom left) and for June, July and August (bottom right). Warming is evaluated by

The Periodic Table of the Elements, in Pictures and Words







Muchas Gracias por su atención