



Unidade de Economia de Recursos

USO DE MATERIAIS PARA A DESCARBONIZAÇÃO DO SISTEMA ENERGÉTICO PORTUGUÊS

Webinar / Palestra LNEG ONLINE

11 maio 2021

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LNEG – Laboratório Nacional de Energia e Geologia

UER – Unidade de Economia de Recursos



Patrícia Fortes

NOVA School of Science and Technology

CENSE | Center for Environmental and Sustainable Research



O webinar não vai ser gravado, mas a apresentação será disponibilizada a quem solicitar por e-mail

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Colocar perguntas via chat / bate-papo do Zoom ou oralmente (após conclusão da apresentação)

Os slides estão em inglês mas a apresentação é feita em Português

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LNEG's RESOURCE ECONOMICS UNITS (UER)

The unit is **crosscutting the Energy and Geology areas** of LNEG.

Develops I&D&D activities and decision-support for both public policy-makers and the private sector on **energy and geology resource economics, towards carbon neutrality and sustainable resource exploitation and use**

UER applies techno-economic & social analytical approaches in the following I&D domains:



1

Sustainable energy systems (decarbonization, systems modelling, climate change impacts)



2

Resource use for energy production and consumption



3

Classification of geological deposits in a global economy



4

Economic and social impact of the energy transition



5

Circular economy, including design of products, services, systems and business models



6

Circular and sustainable public procurement

ENERGY AND CLIMATE

Energy Transition

Sustainable Urban Systems

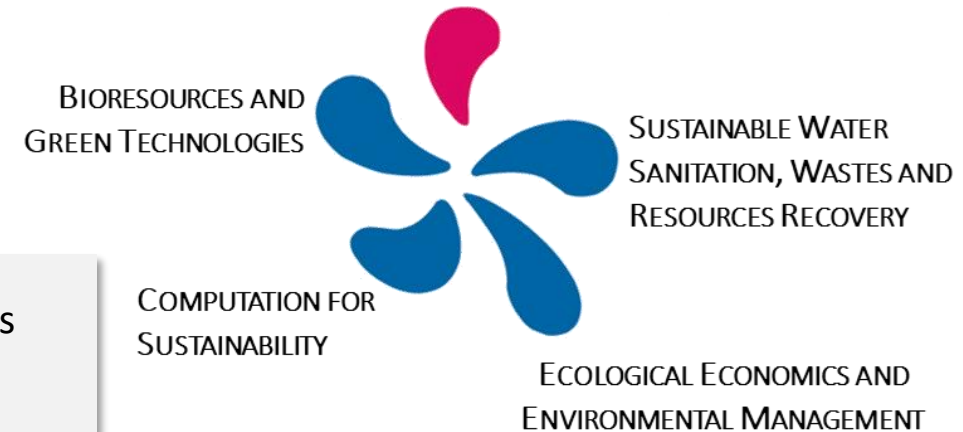
Climate Change Mitigation & Adaptation

Atmospheric Emissions & Air Quality

- › Long Term Energy and Climate mitigation Prospective Analysis
- › Energy Poverty and Buildings Energy Efficiency
- › Energy System Vulnerability to Climate Change
- › Resources for sustainable and carbon neutral energy system
- › Low Carbon Mobility Analysis
- › Integrated economic and energy systems technological modelling
- › Air Quality and Odors monitoring, assessment and management
- › Emissions Inventories

Policy support and Knowledge Transfer

ENERGY AND CLIMATE



Para a descarbonização dos sistemas energéticos é necessário investir massivamente em tecnologias de baixo carbono como turbinas eólicas, painéis fotovoltaicos e veículos elétricos, entre outros.

Todas estas tecnologias têm necessidades em materiais como o lítio ou terras raras que em muitos casos são comercializados por um pequeno grupo de países.

**Quais as quantidades de materiais necessários para a implementação do Roteiro para a Neutralidade Carbónica?
Até que ponto o comércio mundial destes materiais poderá condicionar a sua utilização para a descarbonização?**

Outline

- I. Critical Raw Materials (for energy) and EU at a glance***
- II. Materials needs for the Portuguese Carbon Neutrality Roadmap***
- III. Regional analysis of materials demand/supply for low-carbon energy***



Critical (and rare earth) metals

Rare earth minerals

Group of 17 elements used in a wide range of consumer products

Features:

▶ Gray to silvery metals

▶ Soft, malleable and ductile

China supplies at least 95 percent of world's rare earths

Some products that contain rare earth elements:

■ **iPods**
dysprosium, neodymium, praseodymium, samarium, terbium

■ **Wind turbines**
dysprosium, neodymium, praseodymium, terbium

■ **Hybrid vehicles**
dysprosium, lanthanum, neodymium, praseodymium

■ **Fibre optics**
erbium, europium, terbium, yttrium

■ **Energy-efficient fluorescent light bulbs**
europium, terbium, yttrium

Source: USGS

AFP

Reference: USGS – United States Geological Service

In 2013 - 14 metals identified as “likely to be needed in significant quantities for the deployment of low carbon energy technologies in Europe”:

Cadmium (Cd), Hafnium (Hf), Molybdenum (Mo), Nickel (Ni), Silver (Ag)

Niobium (Nb), Selenium (Se), Tin (Sn), Vanadium (V)

Tellurium (Te), Indium (In), Gallium (Ga).
Neodymium (Nd), Dysprosium (Dy)

R. Moss, E. Tzimas, P. Willis., J. Arendorf, and L. T. Espinoza. **Critical Metals in the Path towards the Decarbonisation of the EU Energy Sector. Assessing Rare Metals as Supply-Chain Bottlenecks in Low-Carbon Energy Technologies.** JRC Scientific and Policy Report EUR 25994 EN.” Luxembourg. 2013

<https://setis.ec.europa.eu/sites/default/files/reports/JRC-report-Critical-Metals-Energy-Sector.pdf>



several EU lists

2011⁽¹⁴⁾



2014⁽²⁰⁾



2017⁽²⁷⁾



2020⁽³⁰⁾

Raw materials are crucial to Europe's economy. They form a strong industrial base, producing a broad range of goods and applications used in everyday life and modern technologies. Reliable and unhindered access to certain raw materials is a growing concern within the EU and across the globe. To address this challenge, the European Commission has created a list of critical raw materials (CRMs) for the EU, which is subject to a regular review and update. CRMs combine raw materials of high importance to the EU economy and of high risk associated with their supply.

Why critical raw materials are important

- **Link to industry** - non-energy raw materials are linked to all industries across all supply chain stages
- **Modern technology** - technological progress and quality of life rely on access to a growing number of raw materials. For example, a smartphone might contain up to 50 different kinds of metals, all of which contribute to its small size, light weight and functionality.
- **Environment** – raw materials are closely linked to clean technologies. They are irreplaceable in solar panels, wind turbines, electric vehicles, and energy-efficient lighting.

https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en

4th EU list of 30 Critical Raw Materials – CRM (sept. 2020)

Antimony (Sb)**	Hafnium (Hf)*	Phosphorus (P)
Baryte (mineral BaSO ₄)	Heavy Rare Earth Elements	Scandium (Sc)*
Beryllium (Be)*	Light Rare Earth Elements	Silicon metal (Si)**
Bismuth (Bi)*	Indium (In)*	Tantalum (Ta)*
Borate (BO ₃ or BO ₄ compounds)	Magnesium (Mg)*	Tungsten or wolfram (W)*
Cobalt (Co)*	Natural Graphite (C)	Vanadium (V)*
Coking Coal (C)	Natural Rubber	<i>Bauxite rock (Al & Ga)</i>
Fluorspar (CaF ₂)	Niobium (Nb)*	<i>Lithium (Li)*</i>
Gallium (Ga)*	Platinum Group Metals*	<i>Titanium (Ti)*</i>
Germanium (Ge)**	Phosphate rock	<i>Strontium (Sr)*</i>

yttrium (Y)*, europium (Eu), gadolinium(Gd), terbium (Tb), **dysprosium (Dy)**, holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu)

lanthanum (La), cerium (Ce), praseodymium (Pr), **neodymium (Nd)**, promethium (Pm), samarium (Sm)

Not on CRM list, yet relevant for energy technologies:

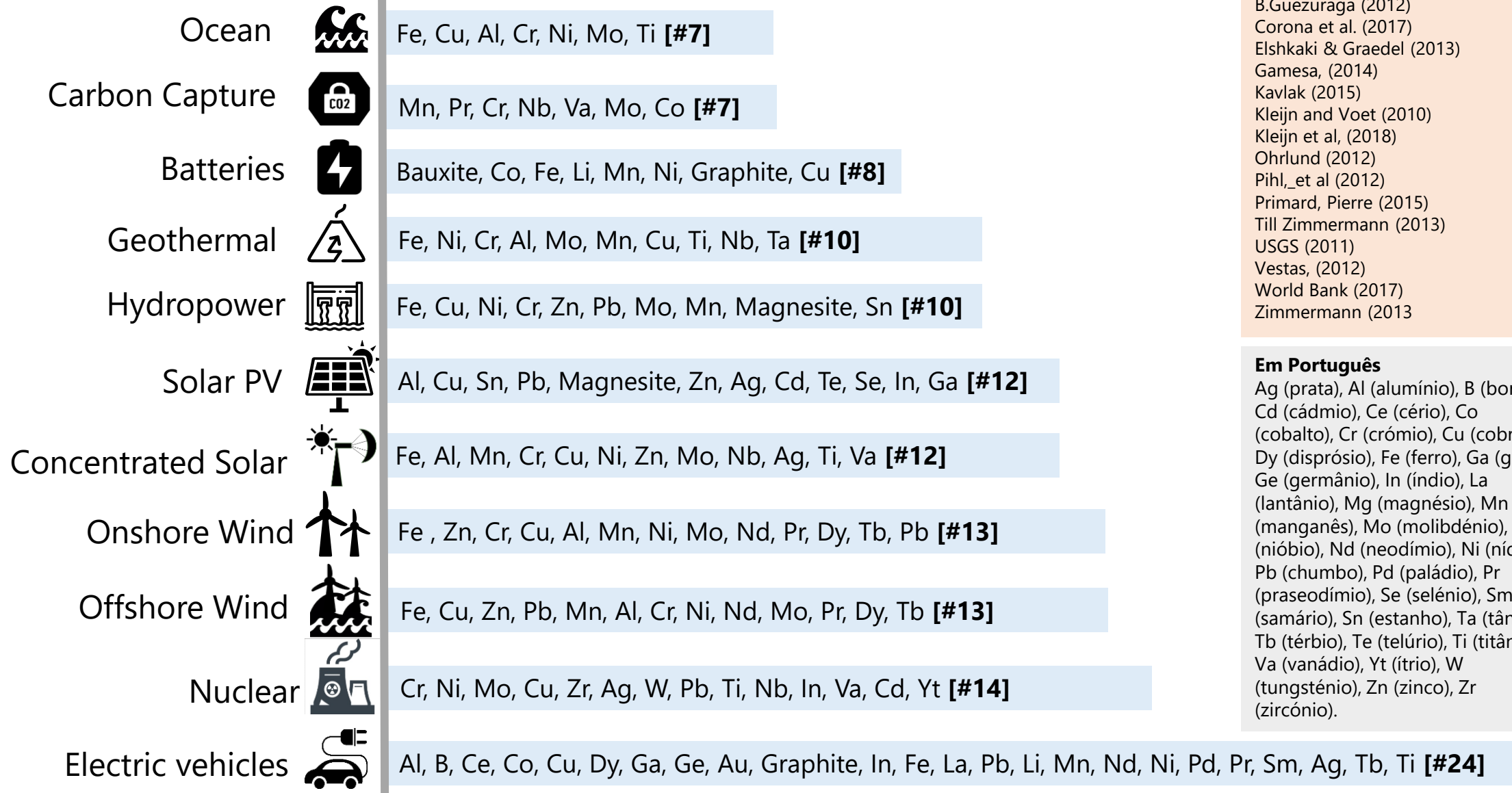
Tellurium (Te), Cadmium (Cd), Molybdenum (Mo), Nickel (Ni), Silver (Ag), Selenium (Se), Tin (Sn)

ruthenium (Ru), rhodium (Rh), palladium (Pd), osmium (Os), iridium (Ir), platinum (Pt)

*Italic – new materials in 2020 CRM list; * metal (or transition metal);** metalloid; purple – materials in 2013 JRC study for energy technologies*



Materials use per low carbon technologies



Literature review

JRC (2011, 2013, 2016)
 Garcia - Olivares et al. (2012)
 Ashby, Attwood and Lord, (2012)
 B.Guezuraga (2012)
 Corona et al. (2017)
 Elshkaki & Graedel (2013)
 Gamesa, (2014)
 Kavlak (2015)
 Kleijn and Voet (2010)
 Kleijn et al, (2018)
 Ohrlund (2012)
 Pihl,_et al (2012)
 Primard, Pierre (2015)
 Till Zimmermann (2013)
 USGS (2011)
 Vestas, (2012)
 World Bank (2017)
 Zimmermann (2013)

Em Português

Ag (prata), Al (alumínio), B (boro),
 Cd (cádmio), Ce (cério), Co
 (cobalto), Cr (cromo), Cu (cobre),
 Dy (disprósio), Fe (ferro), Ga (gálio),
 Ge (germânio), In (índio), La
 (lantânio), Mg (magnésio), Mn
 (manganês), Mo (molibdénio), Nb
 (nióbio), Nd (neodímio), Ni (níquel),
 Pb (chumbo), Pd (paládio), Pr
 (praseodímio), Se (selénio), Sm
 (samário), Sn (estanho), Ta (tântalo),
 Tb (térbio), Te (telúrio), Ti (titânio),
 Va (vanádio), Yt (ítrio), W
 (tungsténio), Zn (zinco), Zr
 (zircónio).



<https://ec.europa.eu/docsroom/documents/42881>

Renewables

e-mobility

Defence & Space

Batteries

Fuel cells

Wind

Traction Motors

PV

Robotics

Drones

3D Printing

ICT

Electric and electronic equipment
Batteries
Automotive sector
Renewable energy
Defence industry
Chemicals and fertilisers

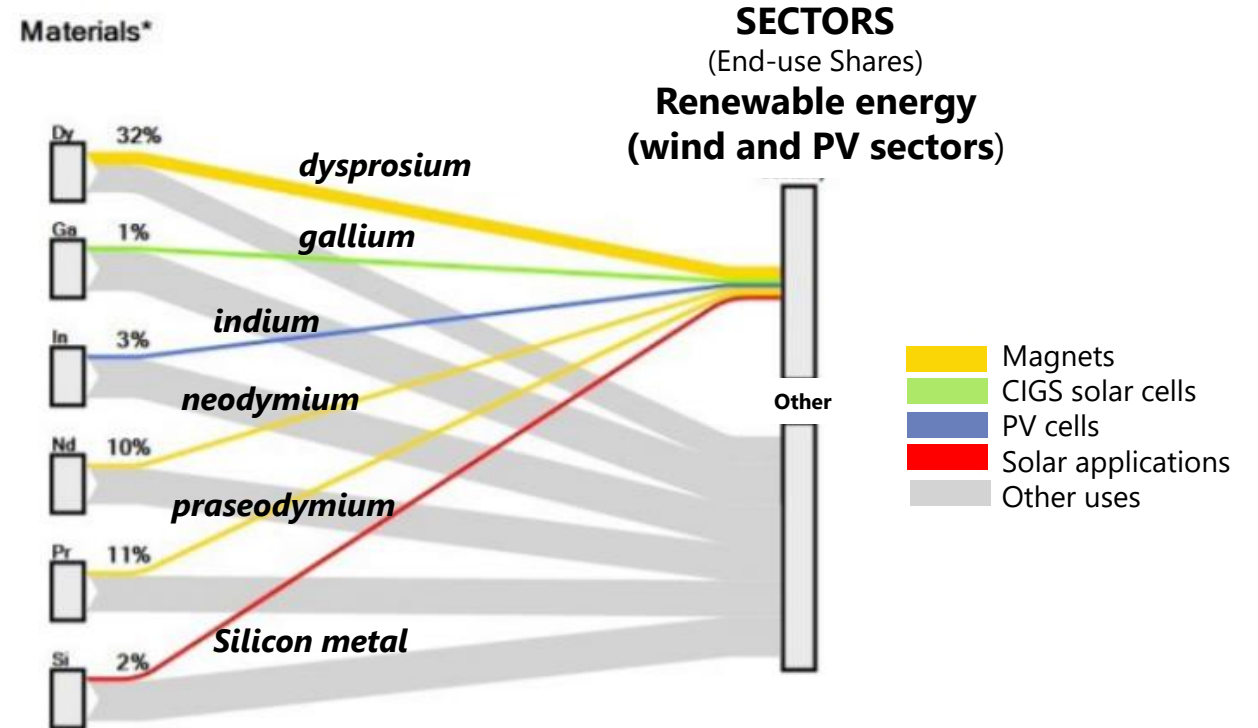
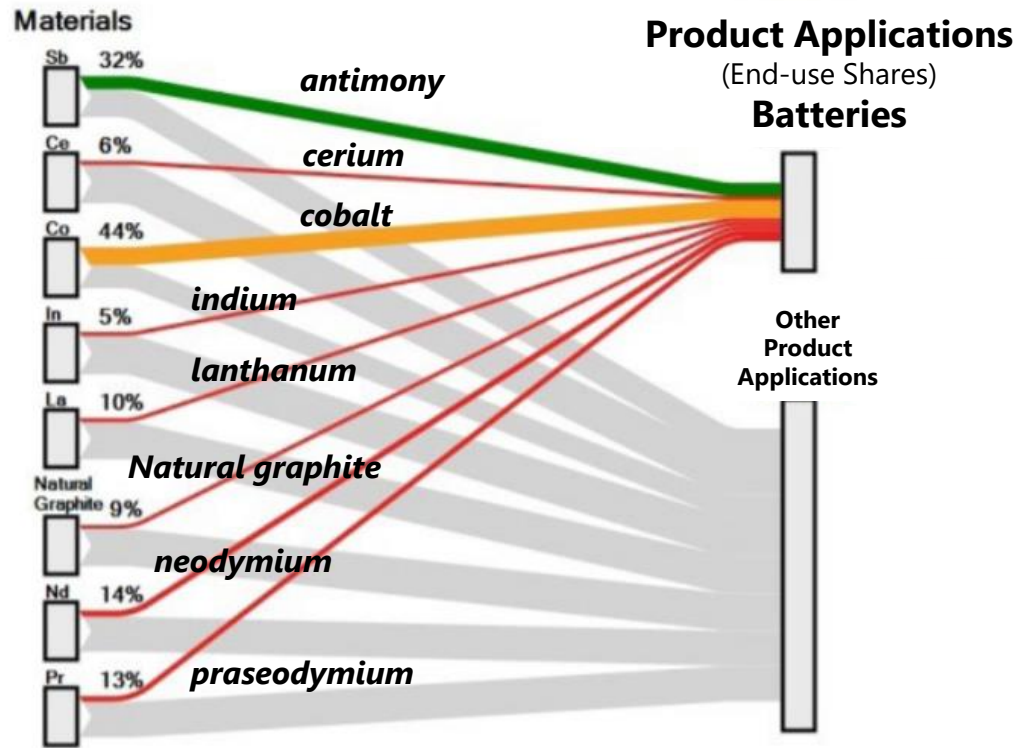
European Commission

Report on Critical Raw Materials and the Circular Economy

2018

https://ec.europa.eu/commission/publications/report-critical-raw-materials-and-circular-economy_en

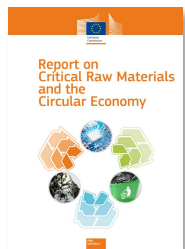
CRMs demand for batteries and solar and wind



- Magnets
- CIGS solar cells
- PV cells
- Solar applications
- Other uses

* Only a subset of all CRMs used in renewable energy sector is included.

CIGS – copper indium gallium selenide solar cells (thin film PV)



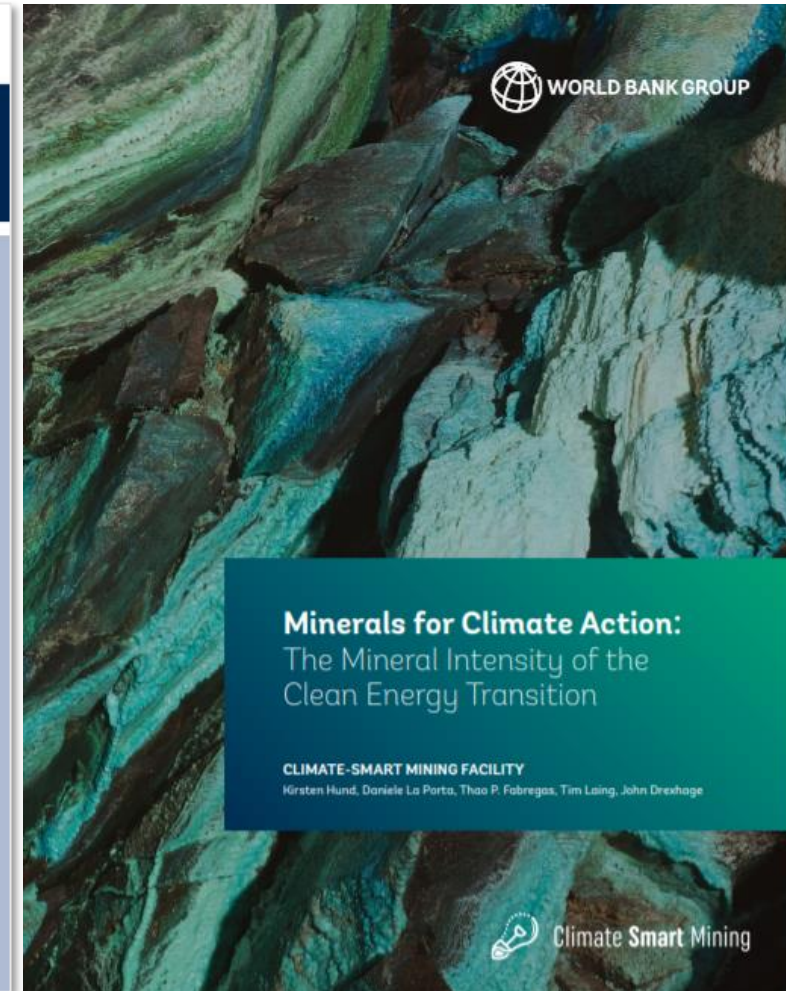
- Lead-acid batteries
- Batteries
- Batteries chemicals
- Other uses

Minerals & Metals for low carbon energy



July 2017

<http://documents1.worldbank.org/curated/en/207371500386458722/pdf/117581-WP-P159838-PUBLIC-ClimateSmartMiningJuly.pdf>



2020

<https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action>

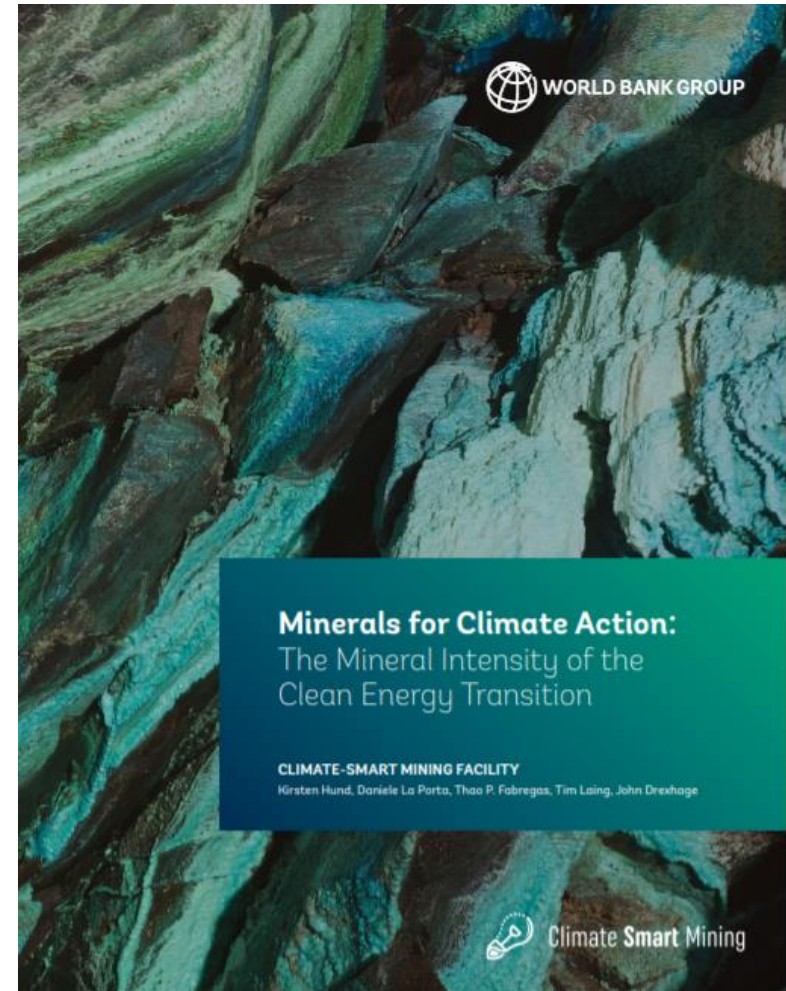
Minerals for climate action

“the production of minerals, such as graphite, lithium and cobalt, could **increase by nearly 500% by 2050** to meet the growing demand for clean energy technologies. It is estimated that over 3 billion tons of minerals and metals will be needed to deploy wind, solar and geothermal power, as well as energy storage, required for achieving a below 2°C future”

Highest growth for: Graphite, Lithium, Cobalt (in % of current demand) and Aluminium (in total terms)

“While the growing demand for minerals and metals provides economic opportunities for resource-rich developing countries and private sector entities alike, significant challenges will likely emerge if the climate-driven clean energy transition is not managed responsibly and sustainably.”

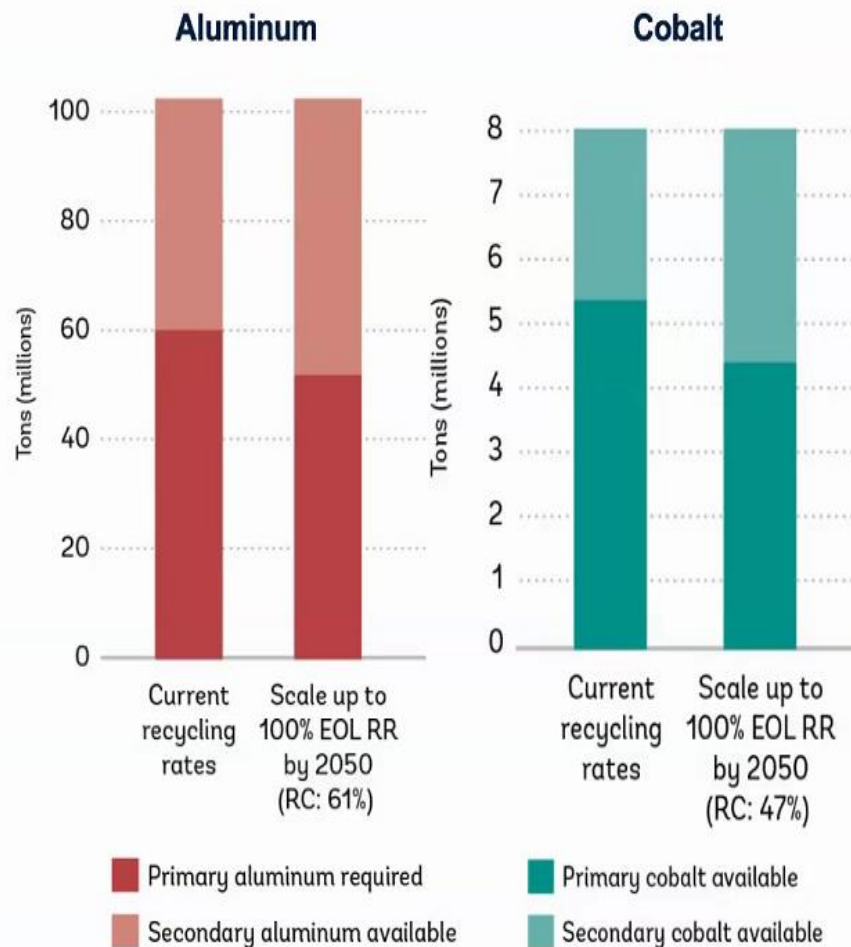
<http://pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf>



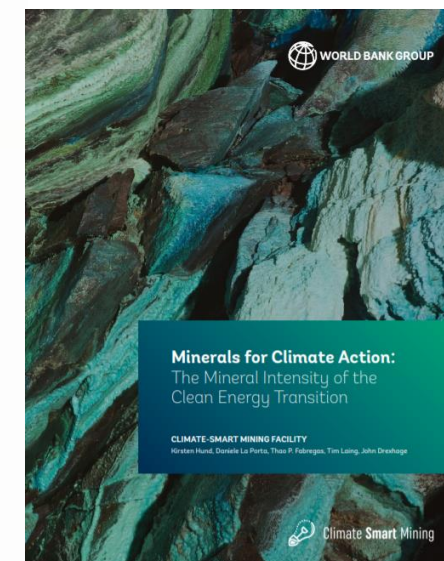
NEW FINDINGS:

THE ROLE OF RECYCLING IN MEETING DEMAND UNDER 2DS

- **Current recycling rates** refer to how many minerals are recycled at the end of a product's life (**EOL RR**)
- **Recycled content** refers to secondary minerals, which is the amount of recycled mineral that is used in new products
- Even if aluminum and copper from current products are recycled at **EOL at 100%**, it still wouldn't be enough to meet mineral demand under a 2DS
- While recycling can play an important role in meeting demand, **primary production** will still be needed



Note: 2DS = 2-degree scenario.

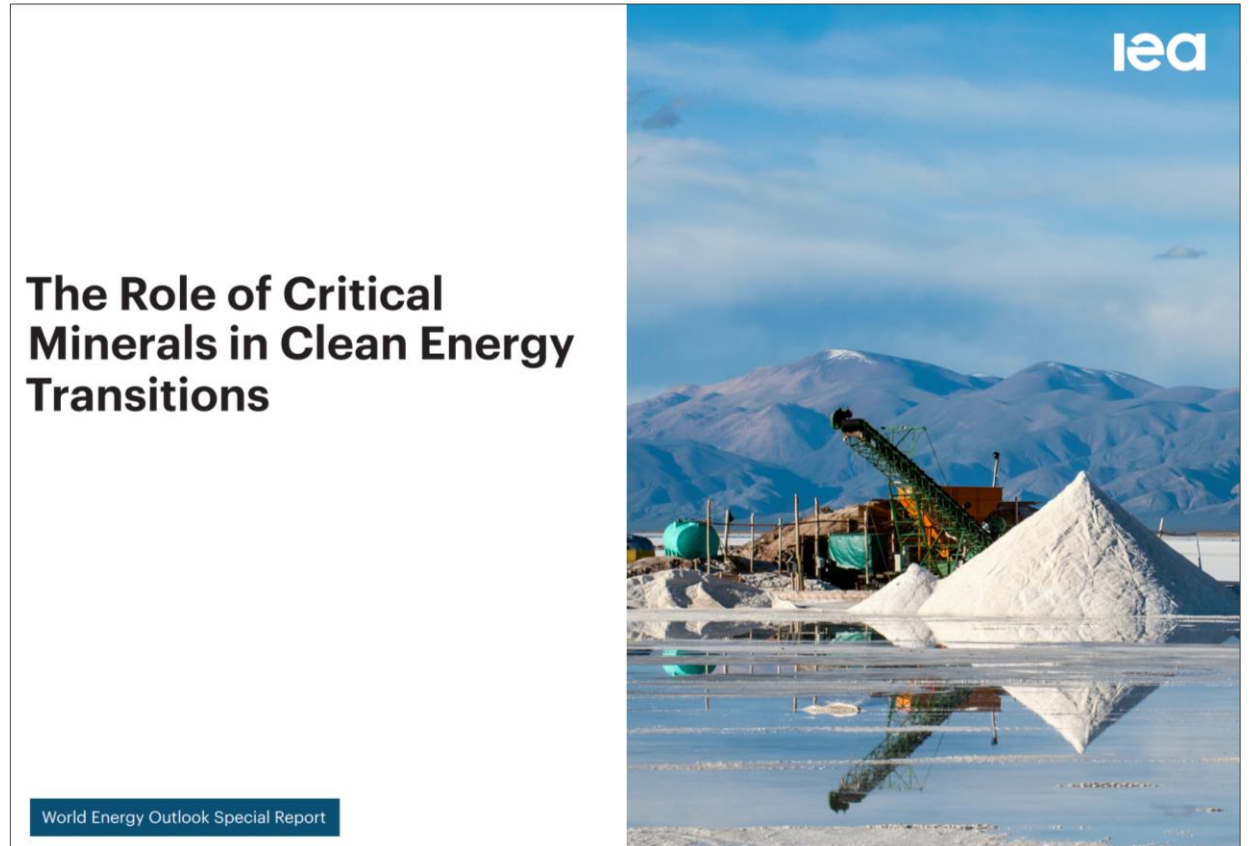


Minerals in Clean Energy Transitions



“A typical **electric car** requires **six times** the mineral inputs of a conventional car and an **onshore wind** plant requires **nine times** more mineral resources than a gas-fired plant. **Since 2010 the average amount of minerals needed for a new unit of power generation capacity has increased by 50%**”

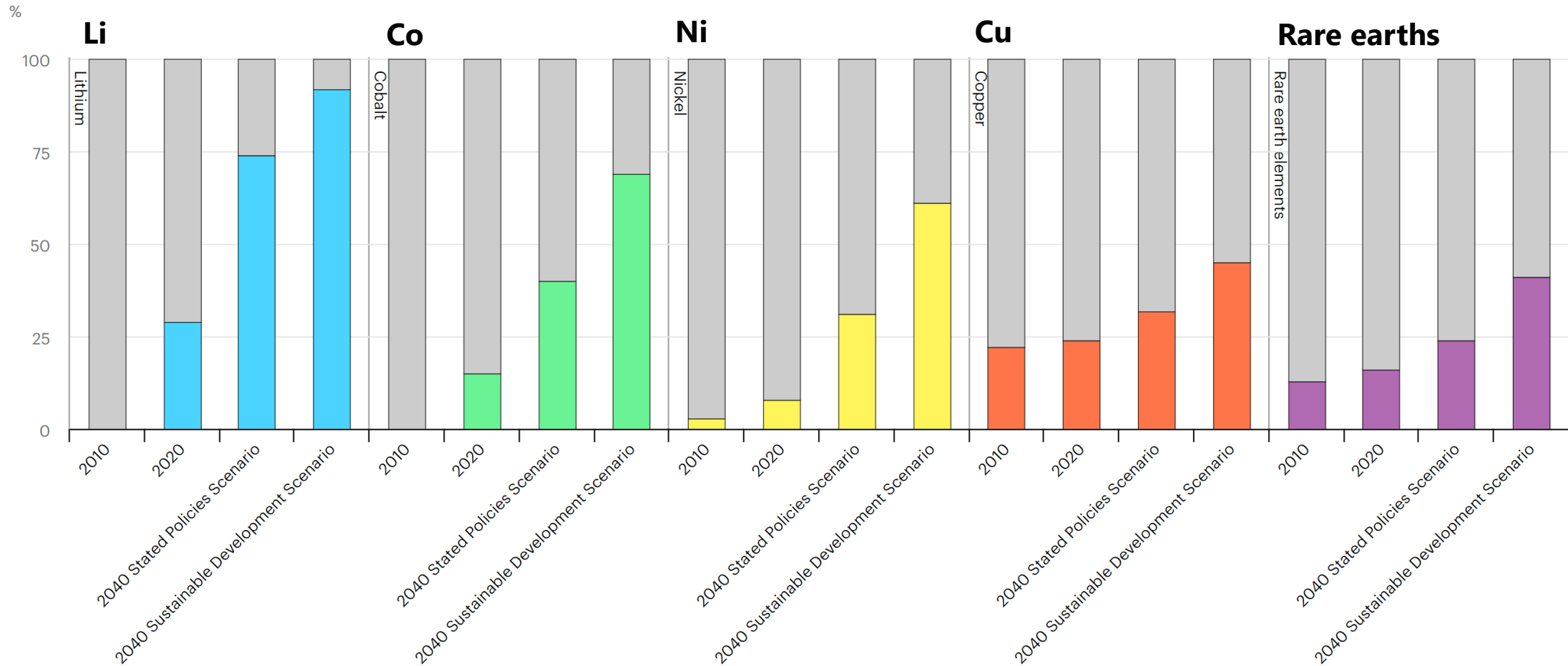
“The shift to a clean energy system is set to drive a huge increase in the requirements for these minerals, meaning that **the energy sector is emerging as a major force in mineral markets.**”



July 2021

IEA (2021), *The Role of Critical Minerals in Clean Energy Transitions*, IEA, Paris
<https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

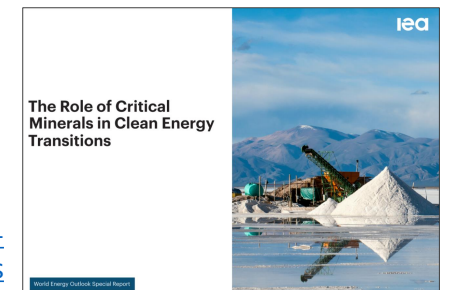
Share of minerals consumption by the energy system over total global mineral markets



% of total global minerals demand for the energy system will rise significantly over the next two decades up to more:

- > **40% for copper and rare earth elements,**
- > **60-70% for nickel and cobalt**
- > **almost 90% for lithium**

<https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



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- III. Regional analysis of materials demand/supply for low-carbon energy***



https://www.irishtimes.com/polopoly_fs/1.3717626.1543774008!/image/image.jpg_gen/derivatives/box_620_330/image.jpg

Energy Transition towards carbon neutrality

2015



2016



António Costa
Portugal Prime Minister
@COP22, dez-2016

“Portugal reaffirms its firm commitment to be neutral in GHG emissions by the end of the first half of the century”

2017

2018



Alternative pathways for all sectors of economy that allow the achievement of net carbon emissions by 2050



The European Parliament endorsed the net-zero carbon objective in its resolution on climate (March 2019)

2019

2020



National Energy and Climate Plan (NECP)
[Energy and GHG emission targets for 2030/2040]

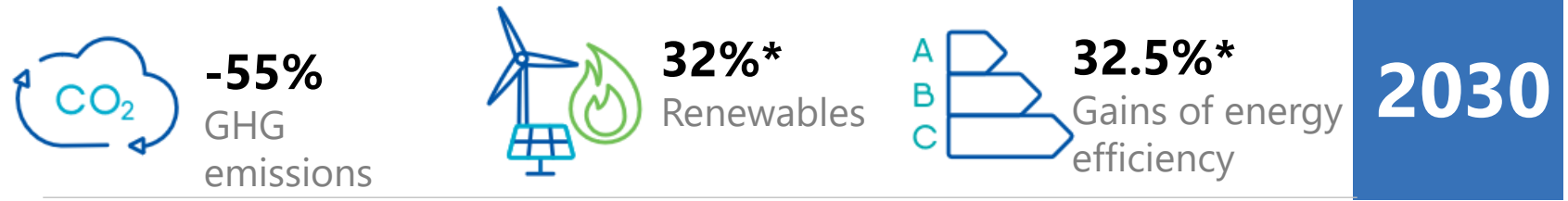


National Strategy for H2

2021

Energy Transition Goals in EU and Portugal

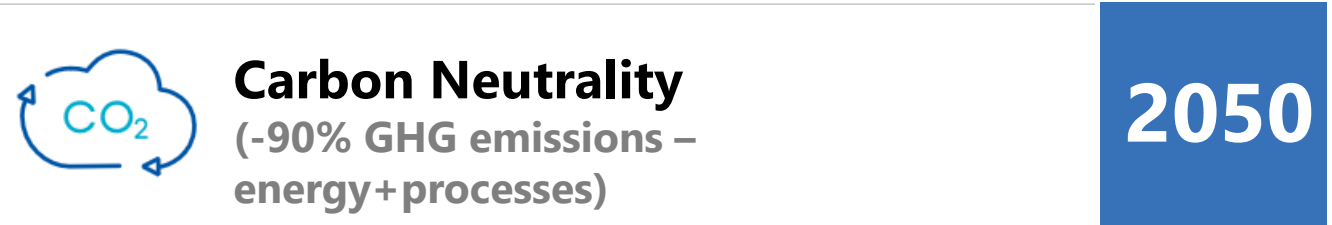
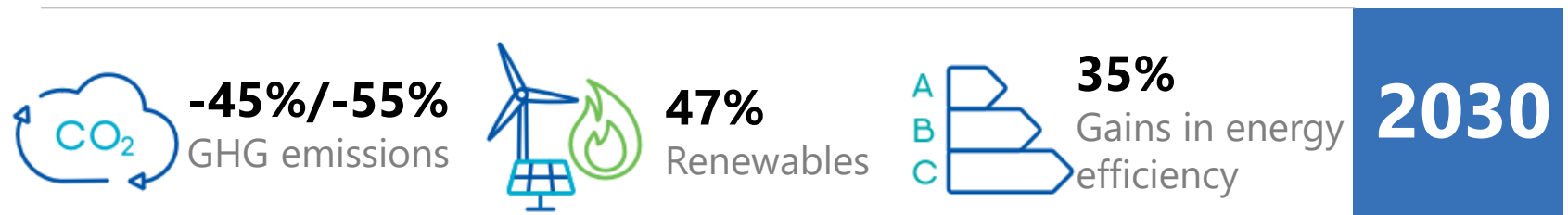
EU



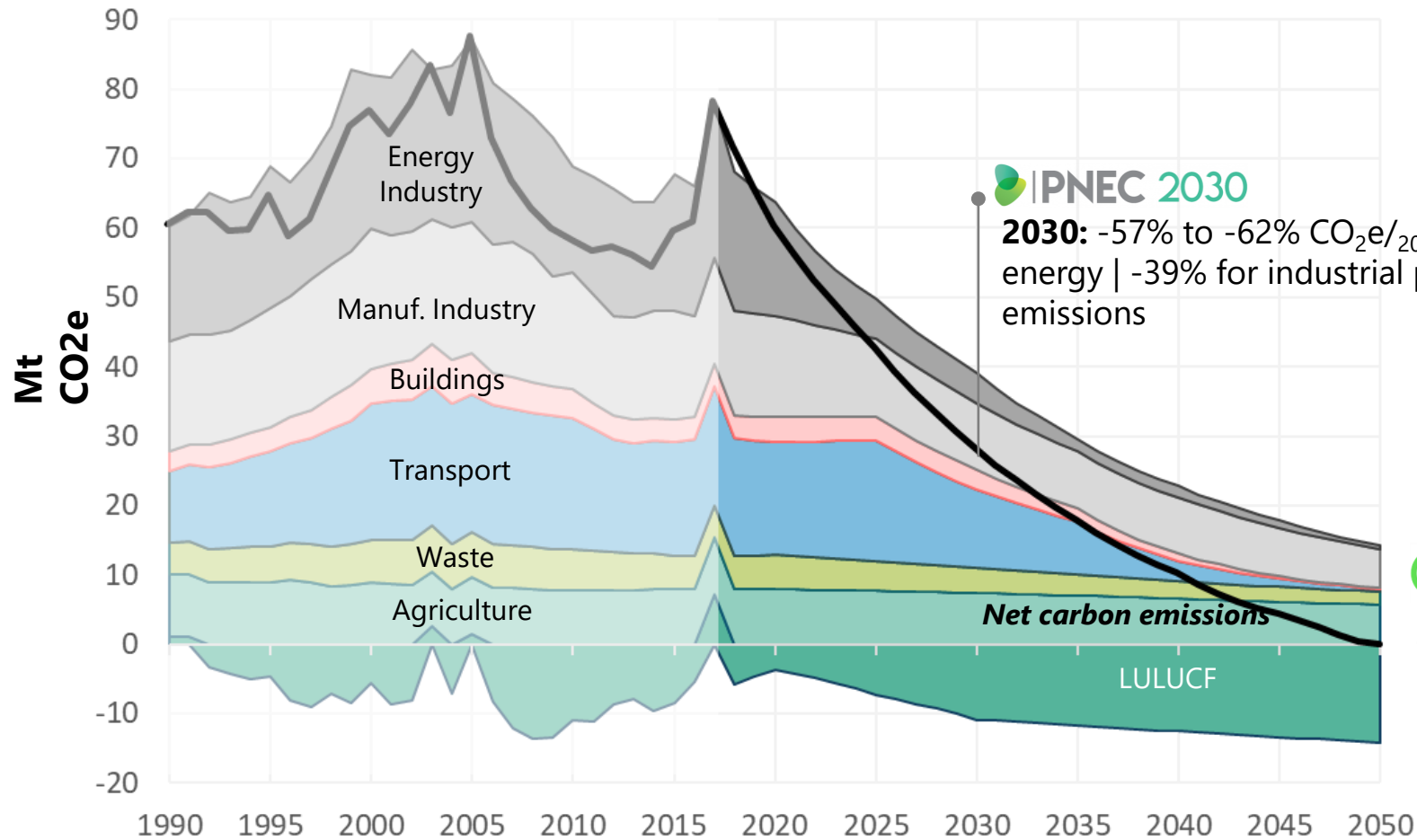
*New updates by Jun 2021



Portugal



Decarbonisation Pathways for Portugal



IPNEC 2030
2030: -57% to -62% CO₂e/2005 for energy | -39% for industrial process emissions

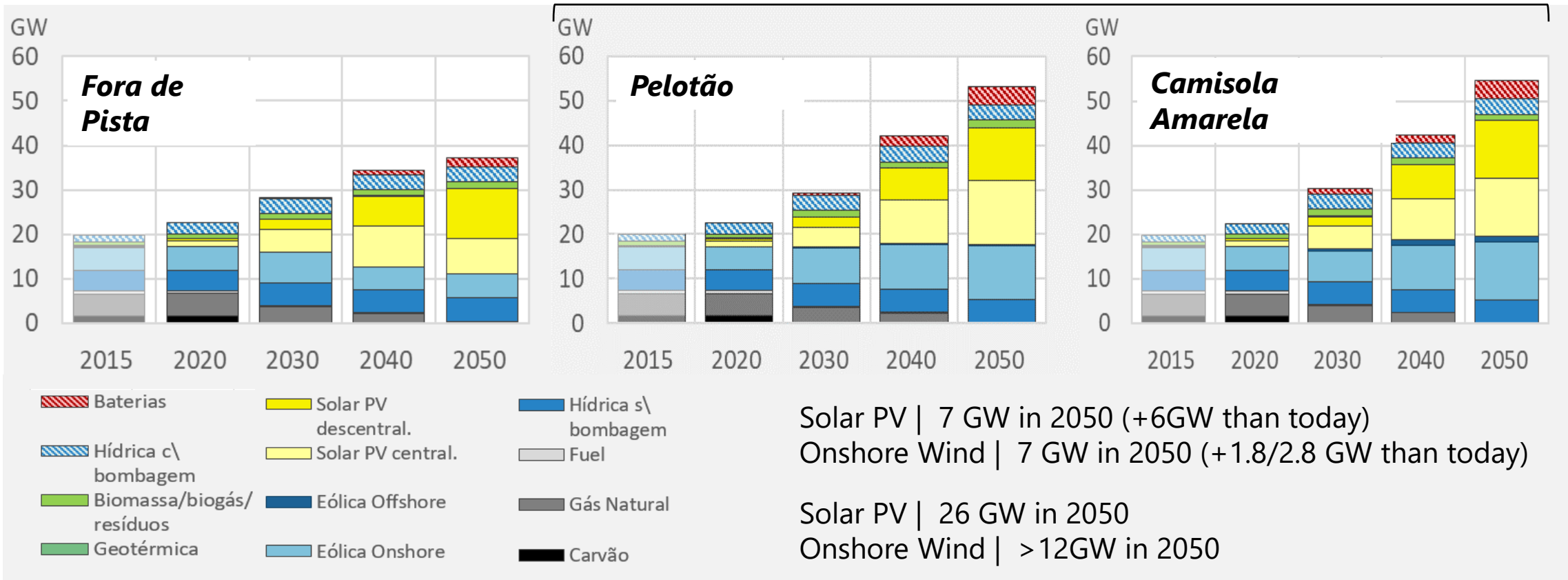
RNC2050
Carbon Neutrality Roadmap

2050: -90% CO₂e/2005 for the whole energy system (energy + process emissions)

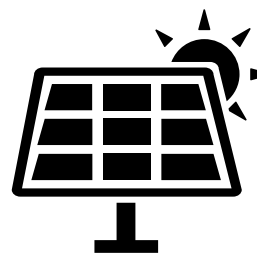
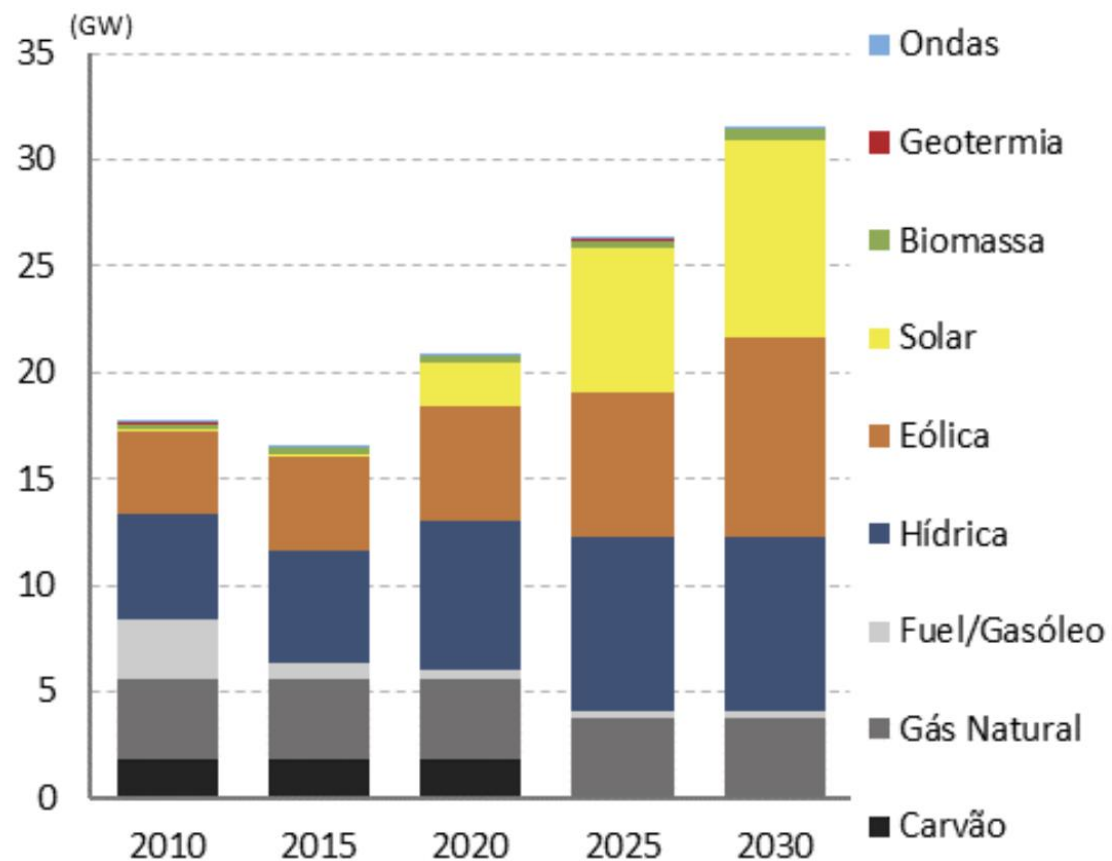
Carbon Neutrality Roadmap | Power Sector

No carbon neutrality

Carbon Neutrality



PNEC| National Energy and Climate Plan 2030 Power Sector



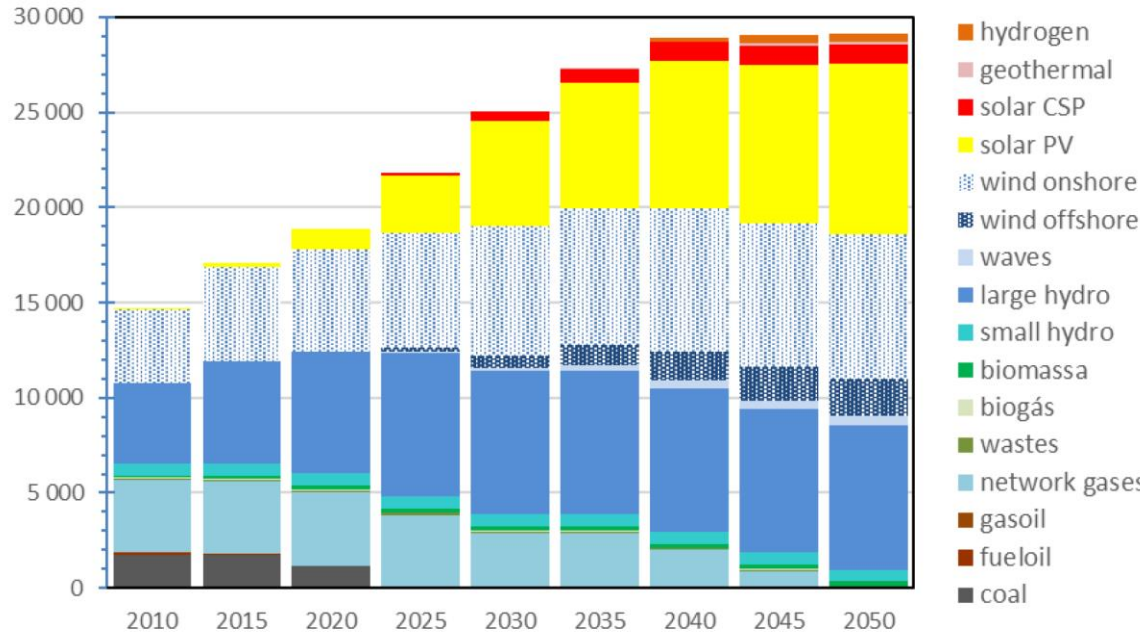
9 GW (+8GW than today)



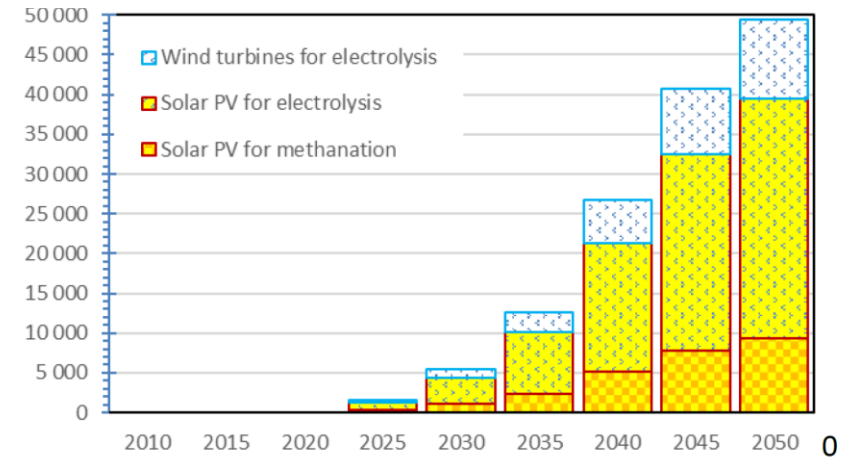
9GW (+3.5 GW than today)

EN-H2 support scenarios | Power Capacity

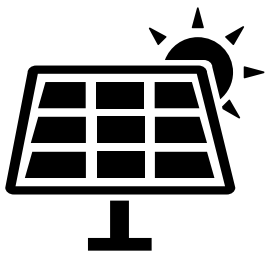
Power to the grid (centralized)



Power to produce green H2

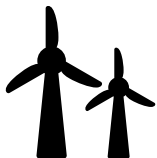


	2010	2015	2020	2025	2030	2035	2040	2045	2050
Wind turbines for electrolysis				318	1 100	2 550	5 400	8 250	10 000
Solar PV for electrolysis				954	3 300	7 650	16 200	24 750	30 000
Solar PV for methanation				299	1 034	2 397	5 076	7 755	9 400
Total				1 570	5 434	12 597	26 676	40 755	49 400



2030 /2050

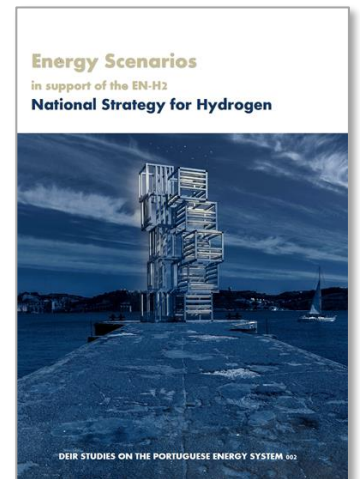
14.5 />50 GW (+13/+50 GW than today)



8 / 23GW (+2.5/+18 GW than today)

Energy Scenarios in support of the EN H2 National Strategy for Hydrogen
These are supporting scenarios and should not be considered as targets or goals!!!

<https://www.dgeg.gov.pt/pt/areas-transversais/investigacao-e-inovacao/publicacoes-relatorios-estudos/02-energy-scenarios-in-support-of-the-en-h2-national-strategy-for-hydrogen/>



Scope











39 materials

- | | |
|----------------------|------------------------|
| 1. Ag (silver) | 20. Mg (magnesium)** |
| 2. Al (aluminium) | 21. Mn (manganese) |
| 3. Au (gold) | 22. Mo (molybdenum) |
| 4. Bauxite | 23. Nb (niobium) |
| 5. B (boron) | 24. Nd (neodymium)* |
| 6. C (graphite) | 25. Ni (nickel) |
| 7. Ce (cerium)* | 26. Pb (lead) |
| 8. Cd (cadmium) | 27. Pd (palladium) |
| 9. <i>Cement</i> | 28. Pr (praseodymium)* |
| 10. Co (cobalt) | 29. Sm (samarium)* |
| 11. Cr (chromium) | 30. Se (selenium) |
| 12. Cu (copper) | 31. Sn (tin) |
| 13. Dy (dysprosium)* | 32. Ta (tantalum) |
| 14. Fe (iron) | 33. Tb (terbium)* |
| 15. Ga (gallium) | 34. Te (tellurium) |
| 16. Ge (germanium) | 35. Ti (titanium) |
| 17. In (indium) | 36. Va (vanadium) |
| 18. Li (lithium) | 37. W (tungsten) |
| 19. La (lanthanum)* | 38. Zn (zinc) |
| | 39. Zr (zirconium) |

*Rare Earth elements (RE);

** Proxy for magnesite $MgCO_3$

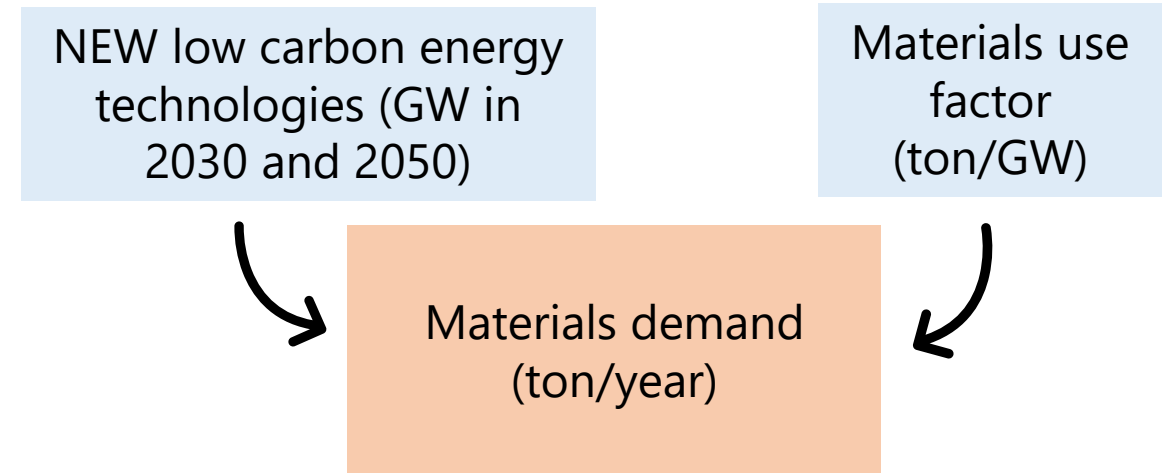
10 Low carbon technologies

-  Wind onshore
-  Wind offshore
-  Solar PV
-  CSP
-  Hydropower
-  Ocean (*not applicable for Portugal*)
-  Geothermal
-  CCS (*not shown today*)
-  Electricity Storage (*not shown today*)
-  Hybrid and electric vehicles (*partially shown today*)



Methods

- NEW installed capacity from RNC2050, PNEC and ENH2 support scenarios for 2030 and between 2030 and 2050
- The **materials use factors** compiled based on similar studies and life cycle assessments of specific technologies
- **Material's intensity** is assumed constant till 2050
- Assumptions on **technologies' deployment**:
 - PV is 80% c-SI, 10% a-si, 5% CdTe and 5% CIGS or 80% c-SI and 20% thin film
 - CSP is 50% Trough and 50% Tower
 - Wind Onshore is 100% without permanent magnet (NdFeB) and Offshore 50% as a permanent magnet (PM)

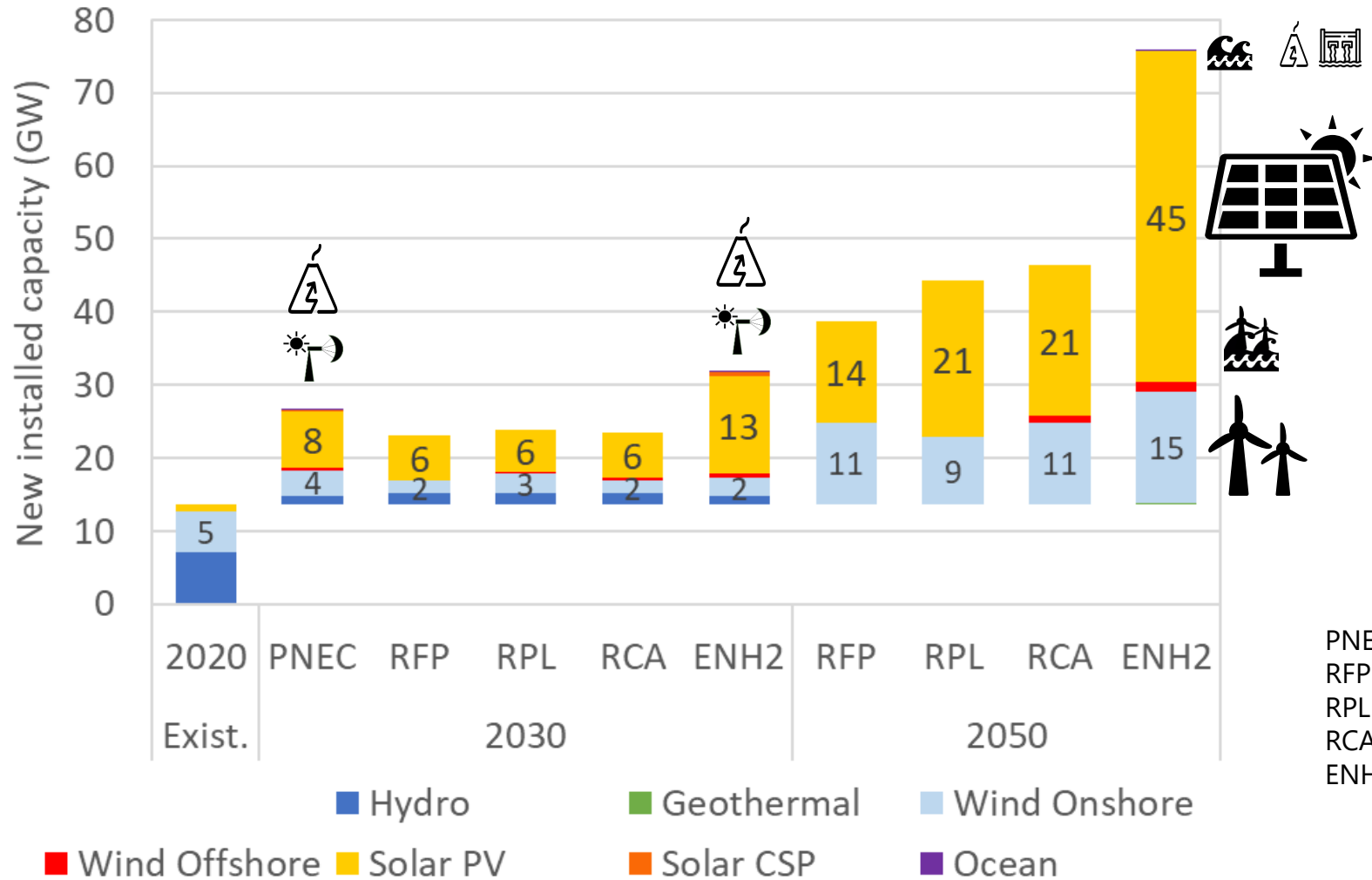


Stilwell, T. (2019) **Mapping necessary resources for the transition to a low carbon energy system and analysis of associated environmental impacts**. MSc in Environment Engineering - Environment Systems. FCT-NOVA University: https://run.unl.pt/bitstream/10362/71029/1/Stilwell_2019.pdf

Adapted from Stilwell, T., Simoes, S.G. (n.d.) Mapping necessary resources for the transition to a low carbon energy system. *(in preparation)*



Evolution of NEW electricity installed capacity in Portugal



PNEC – National Energy and Climate Plan 2030
 RFP - RNC2050 "Fora de Pista" Scenario
 RPL - RNC2050 "Pelotão" Scenario
 RCA - RNC2050 "Camisola Amarela" Scenario
 ENH2 – National Hydrogen Strategy

Some considered materials use factors – power sector

t /GW = 1g/kW	Wind		Solar		Hydro	Geothermal	Ocean	(Nuclear)	(CCS)
	Onshore	Offshore	PV	CSP					
Ag (silver)			15	17				8	
Al (aluminium)	1,585	1,073	9,534	8,247		11,894	14		
Cd (cadmium)			14					1	
Co (cobalt)								0	8
Cr (chromium)	3,158	676		2,950	13	64,405	0.31	427	326
Cu (copper)	1,823	7,750	1,765	2,238	69	2,218	446	60	
Dy (dysprosium)	8	24							
Fe (iron)	130,908	177,373		591,000	25,000	261,431	2,956		
Ga (gallium)			1						
In (indium)			4					2	
Mg (magnesium)			43		2				
Mn (manganese)	1,191	1,191		3,850	2	4,325			3,761
Mo (molybdenum)	184	136		128	3	7,209	0.1	71	8
Nb (niobium)				70		128		2	100
Nd (neodymium)	39	188							
Ni (nickel)	748	387		1,370	31	120,155	0.2	256	
Pb (lead)	0	5,255	216		5			4	
Pr (praseodymium)	20	54							1,145
Se (selenium)			5						
Sn (tin)			372		0.003				
Ta (tantalum)						64			
Tb (terbium)	1	7							
Te (tellurium)			8						
Ti (titanium)				13	0	1,634	0.01	2	
Va (vanadium)				2				1	100
W (tungsten)								5	
Zn (zinc)	5,150	5,750	24	1,025	5				
Cement	94,503	106,080		161,000	1,528,800	106,233			
Zr (zirconium)					0			31	

Literature review

JRC (2011, 2013, 2016)
 Garcia - Olivares et al. (2012)
 Ashby, Attwood and Lord, (2012)
 Guezuraga (2012)
 Corona et al. (2017)
 Elshkaki & Graedel (2013)
 Gamesa, (2014)
 Kavlak (2015)
 Kleijn and Voet (2010)
 Kleijn et al, (2018)
 Ohrlund (2012)
 Pihl, et al (2012)
 Primard, Pierre (2015)
 Till Zimmermann (2013)
 USGS (2011)
 Vestas (2012)
 World Bank (2017)
 Zimmermann (2013)

Stilwell. T., Simoes. S.G. (n.d.) Mapping necessary resources for the transition to a low carbon energy system (*in preparation*)

Materials needs for the Portuguese power sector

(ton)	2030					2050			
	RNCFP	RNCPL	RNCCA	PNEC	ENH2	RNCFP	RNCPL	RNCCA	ENH2
Ag (silver)	93	86	93	120	210	208	208	308	687
Al (aluminium)	61,905	59,469	62,308	81,866	137,041	149,960	149,960	214,775	463,089
Cd (cadmium)	87	80	87	107	188	194	194	288	633
Cement	10,862,030	10,992,360	10,911,841	8,631,557	8,387,915	1,059,418	1,059,418	1,159,452	1,765,642
Cr (chromium)	5,669	8,992	5,923	16,088	9,675	35,403	35,403	36,040	63,102
Cu (copper)	14,294	17,208	17,200	23,127	34,163	44,909	44,909	64,029	119,968
Dy (dysprosium)	14	28	23	35	34	90	90	112	155
Fe (iron)	269,247	443,321	335,795	734,238	751,122	1,467,533	1,467,533	1,634,796	2,578,569
Ga (gallium)	6	6	6	8	13	14	14	21	45
In (indium)	25	23	25	31	54	55	55	82	181
Mg (magnesium)	269	250	269	330	581	596	596	884	1,944
Mn (manganese)	2,134	3,614	2,580	5,968	5,576	13,352	13,352	14,475	22,484
Mo (molybdenum)	333	550	384	1,163	602	2,063	2,063	2,191	4,481
Nd (neodymium)	70	155	140	194	209	437	437	614	854
Ni (nickel)	1,382	2,224	1,527	10,404	2,793	8,385	8,385	8,750	36,580
Pb (lead)	1,346	2,527	3,316	3,231	6,067	2,995	2,995	9,396	17,124
Pr (praseodymium)	36	69	56	87	82	224	224	275	378
Se (selenium)	31	29	31	38	67	69	69	103	226
Sn (tin)	2,305	2,138	2,305	2,839	5,009	5,158	5,158	7,647	16,820
Tb (terbium)	2	4	4	6	7	11	11	18	25
Te (tellurium)	50	46	50	61	108	111	111	164	362
Ti (titanium)	0	0	0	102	7	-	-	-	333
Zn (zinc)	9,372	15,910	11,528	20,359	16,980	58,066	58,066	63,649	87,598

Cement



Fe



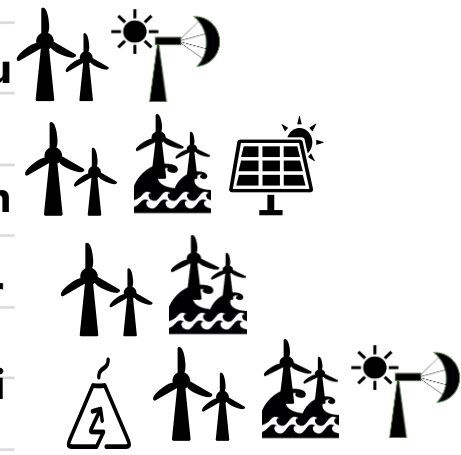
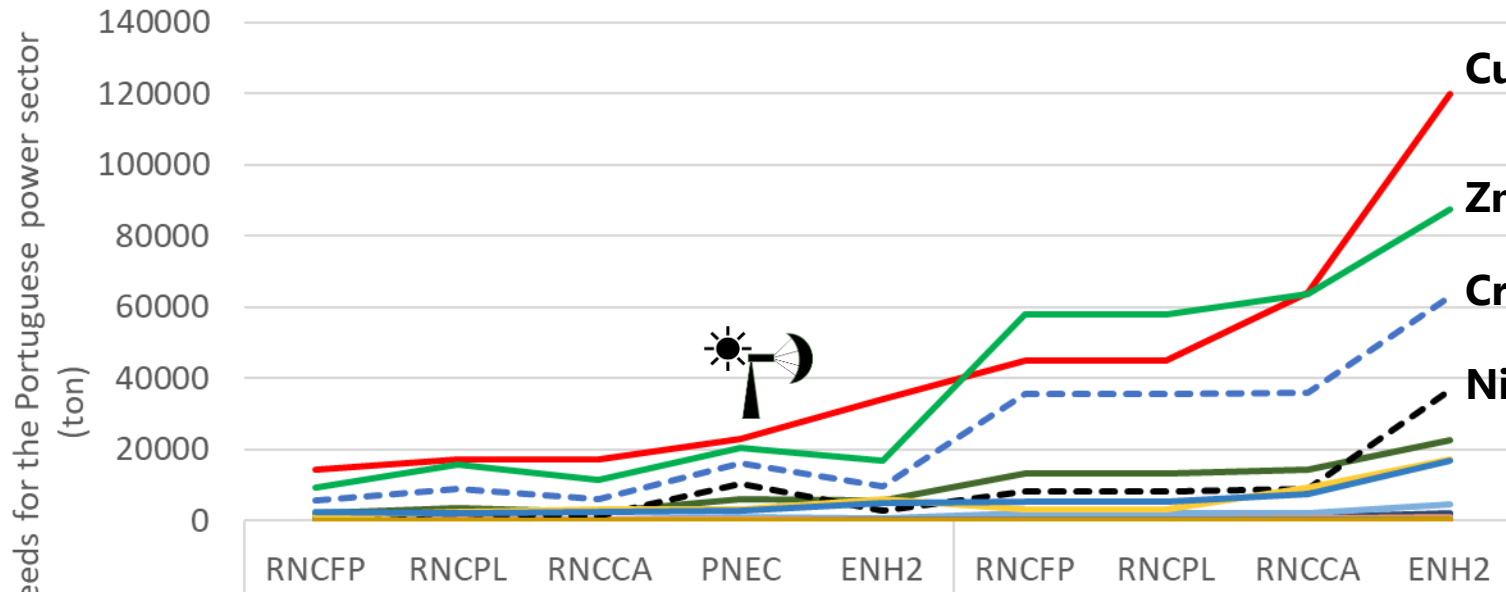
Al



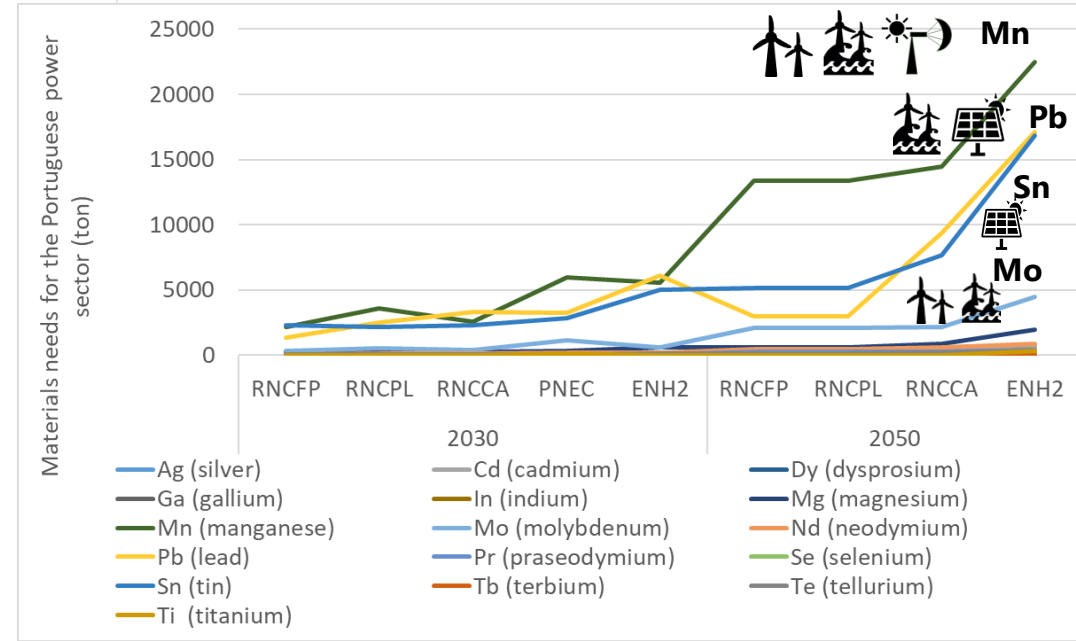
Cu



Materials needs for the Portuguese power sector (II)

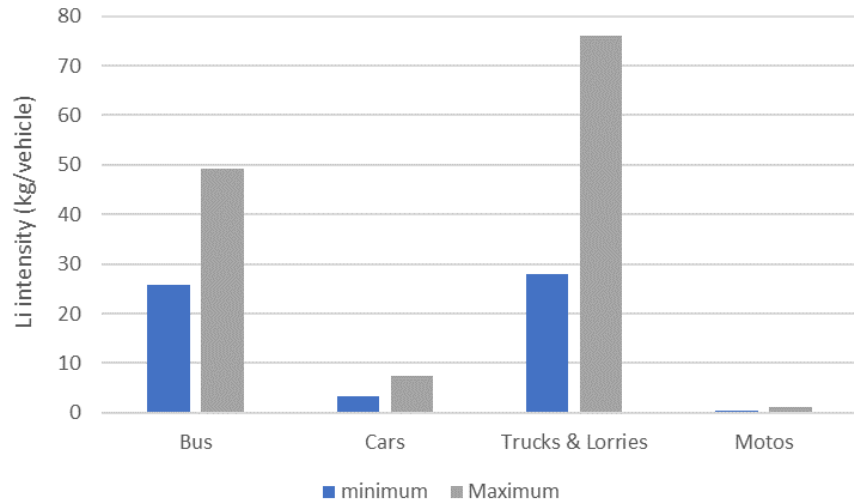


- | | | |
|-------------------|---------------------|---------------------|
| — Ag (silver) | — Cd (cadmium) | - - - Cr (chromium) |
| — Cu (copper) | — Dy (dysprosium) | — Ga (gallium) |
| — In (indium) | — Mg (magnesium) | — Mn (manganese) |
| — Mo (molybdenum) | — Nd (neodymium) | - - - Ni (nickel) |
| — Pb (lead) | — Pr (praseodymium) | — Se (selenium) |
| — Sn (tin) | — Tb (terbium) | — Te (tellurium) |
| — Ti (titanium) | — Zn (zinc) | |



- | | | |
|------------------|---------------------|-------------------|
| — Ag (silver) | — Cd (cadmium) | — Dy (dysprosium) |
| — Ga (gallium) | — In (indium) | — Mg (magnesium) |
| — Mn (manganese) | — Mo (molybdenum) | — Nd (neodymium) |
| — Pb (lead) | — Pr (praseodymium) | — Se (selenium) |
| — Sn (tin) | — Tb (terbium) | — Te (tellurium) |
| — Ti (titanium) | | |

Lithium for electric vehicles in RNC2050



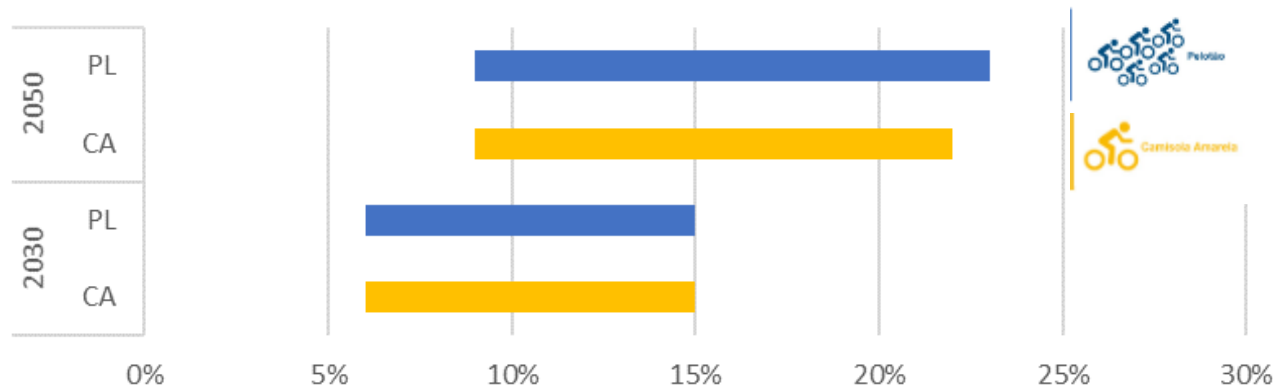
Li intensity (kg/vehicle) Maximum and minimum scenarios

- Li intensity considered constant until 2050;
- Recycling potential of Li in batteries not available in the period;

Sources:

doi.org/10.1016/j.rser.2018.03.002
 doi.org/10.1016/j.rser.2014.04.018
zeeus.eu/uploads/publications/documents/zeeus-ebus-report-internet.pdf
www.proterra.com/vehicles/zx5-electric-bus/range/

% national reserves of Li to satisfy national mobility needs in 2030 and 2050



Outline

- I. Critical Raw Materials (for energy) and EU at a glance*
- II. Materials needs for the Portuguese Carbon Neutrality Roadmap*
- III. Regional analysis of materials demand/supply for low-carbon energy**

Regional mining production in 2016

Regions of the planet

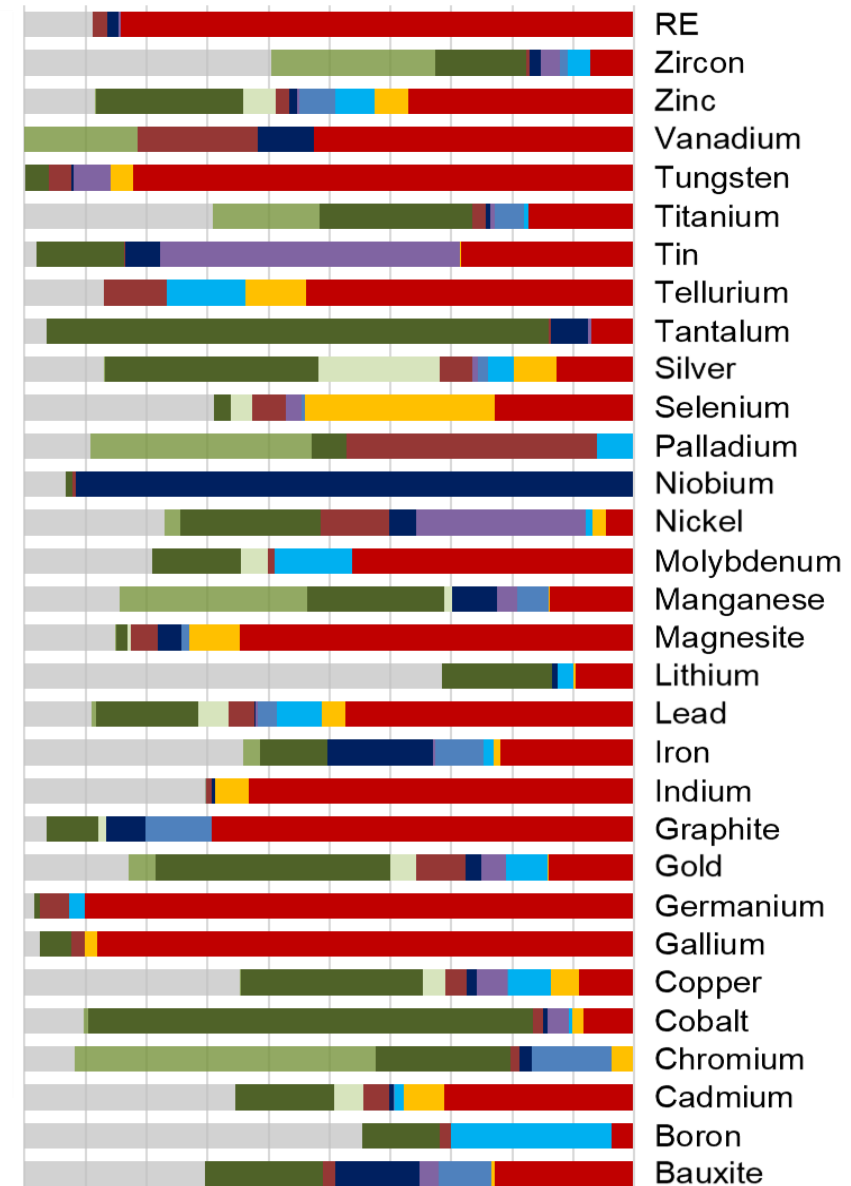
1. Africa+ (a)
2. ASEAN (b)
3. Brazil
4. China
5. EU
6. India
7. Mexico
8. Rest of the World (c)
9. Russia
10. South Africa
11. USA

(a) All of Africa + Argentina, Peru, Bolivia, Colombia, Venezuela, Saudi Arabia, Iran, Iraq, Kazakhstan, Mongolia, Pakistan, Ukraine;

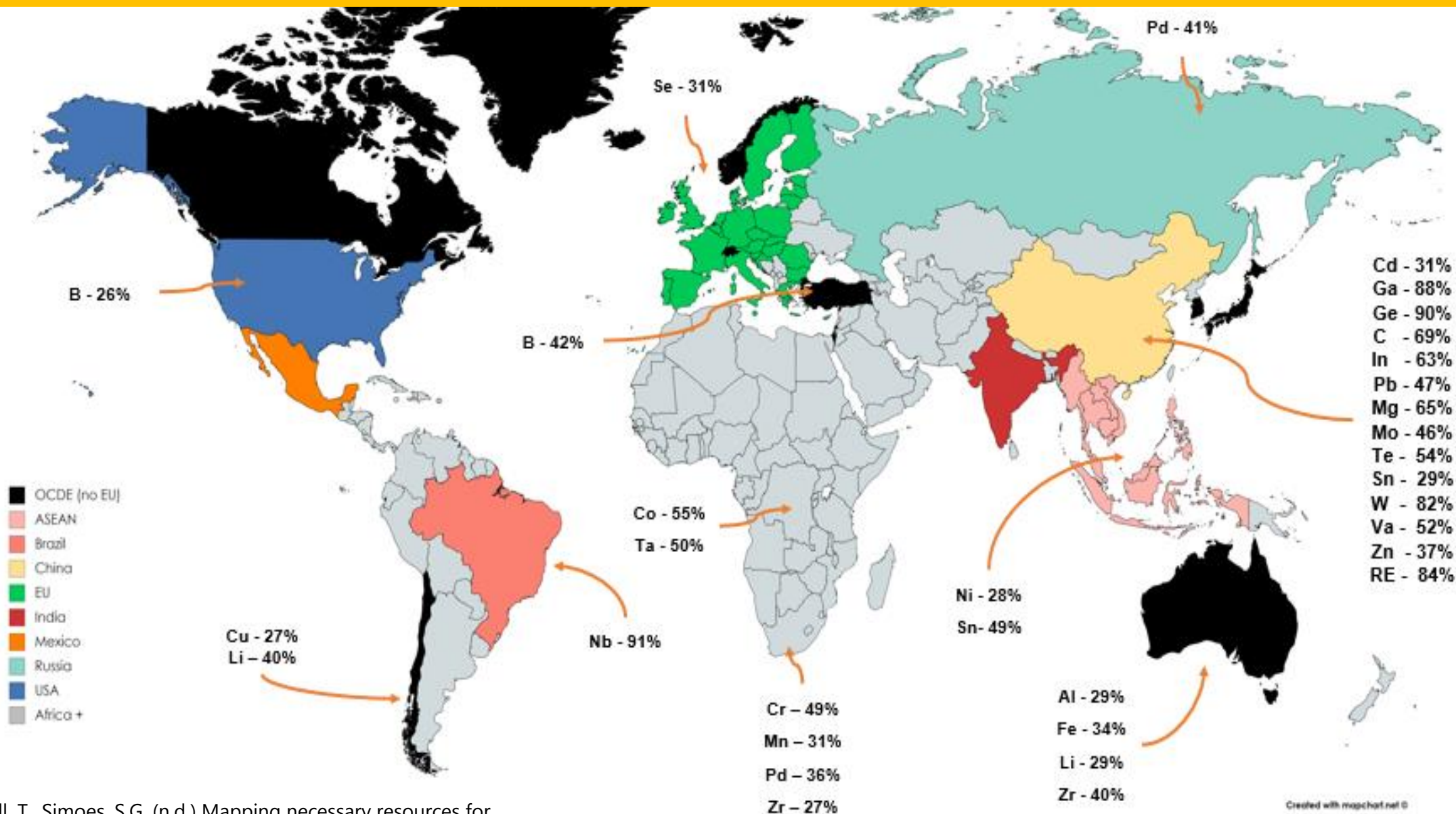
(b) Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam;

(c) Australia, Canada, Chile, Iceland, Japan, Norway, Turkey, South Korea, Switzerland

Stilwell. T., Simoes. S.G. (n.d.) Mapping necessary resources for the transition to a low carbon energy system. (in preparation)



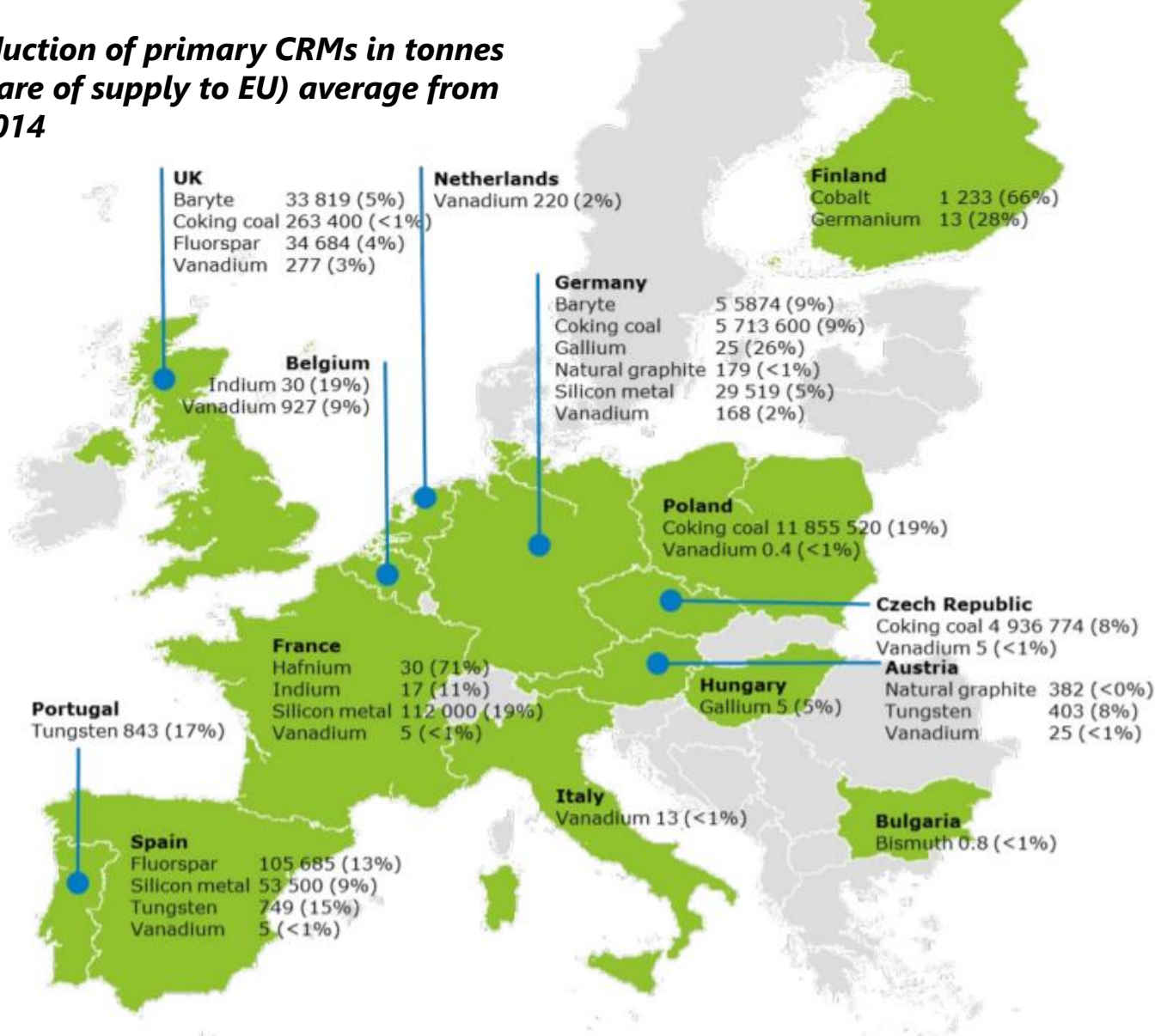
World largest producers (2016)



Stilwell. T., Simoes. S.G. (n.d.) Mapping necessary resources for the transition to a low carbon energy system. (in preparation)

EU production of CRMs

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



Report on Critical Raw Materials and the Circular Economy

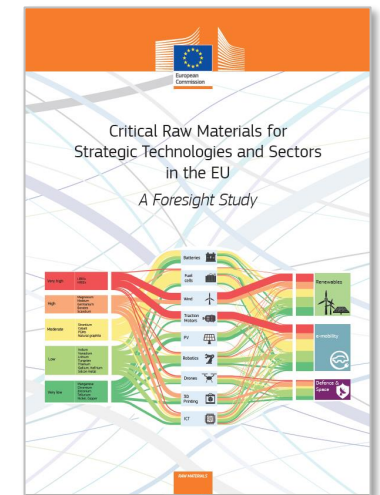
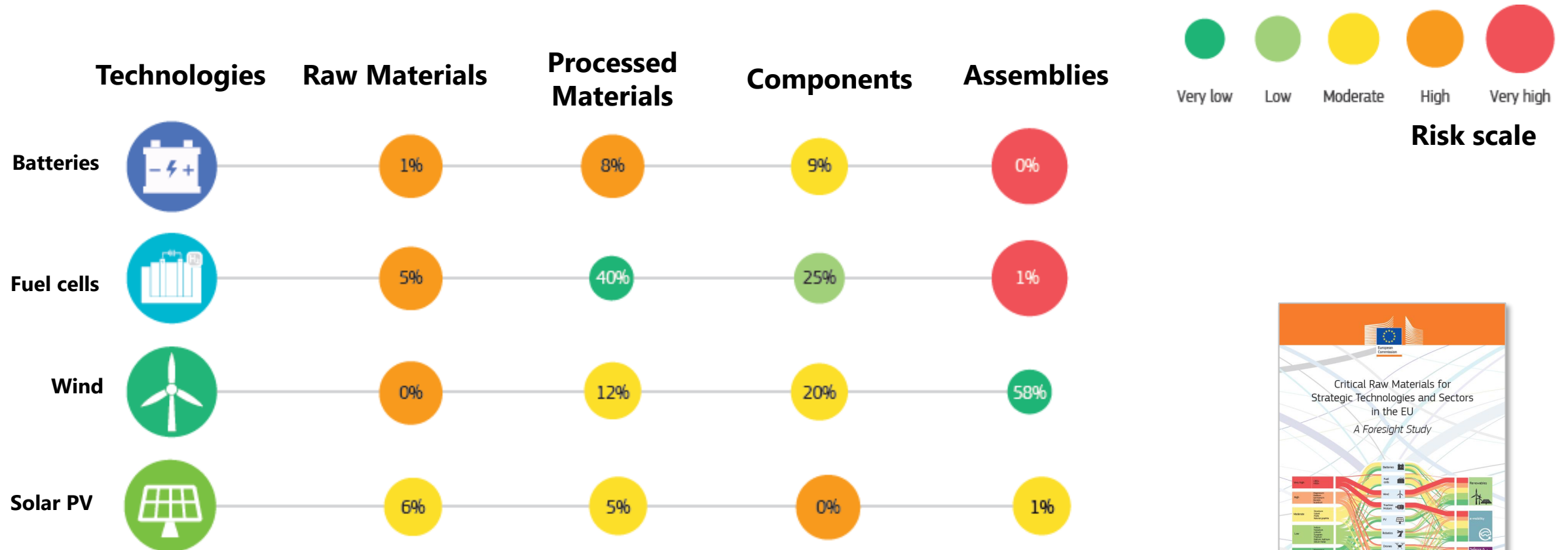


RAW MATERIALS

2018

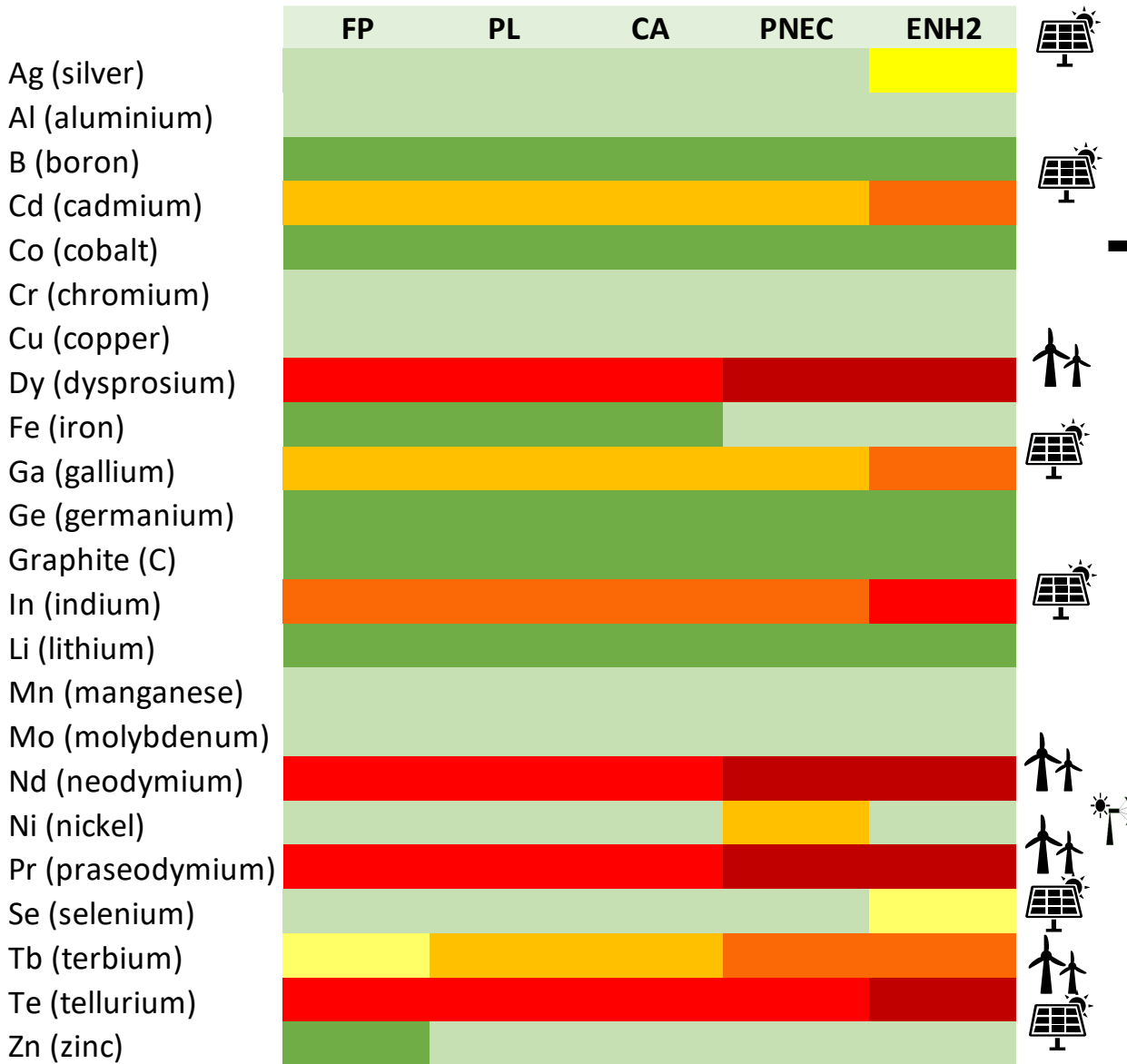
https://ec.europa.eu/commission/publications/report-critical-raw-materials-and-circular-economy_en

Supply risks for the EU and EU shares of production



<https://ec.europa.eu/docsroom/documents/42881>

Relative importance of Portuguese materials needs



2030

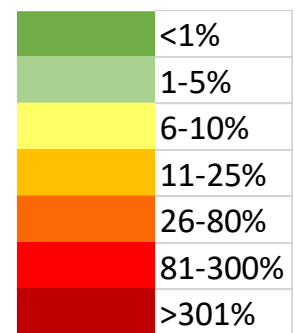
this assessment →

🇵🇹 **material needs for Portugal for power sector**

current total material use in EU (2012-2017)



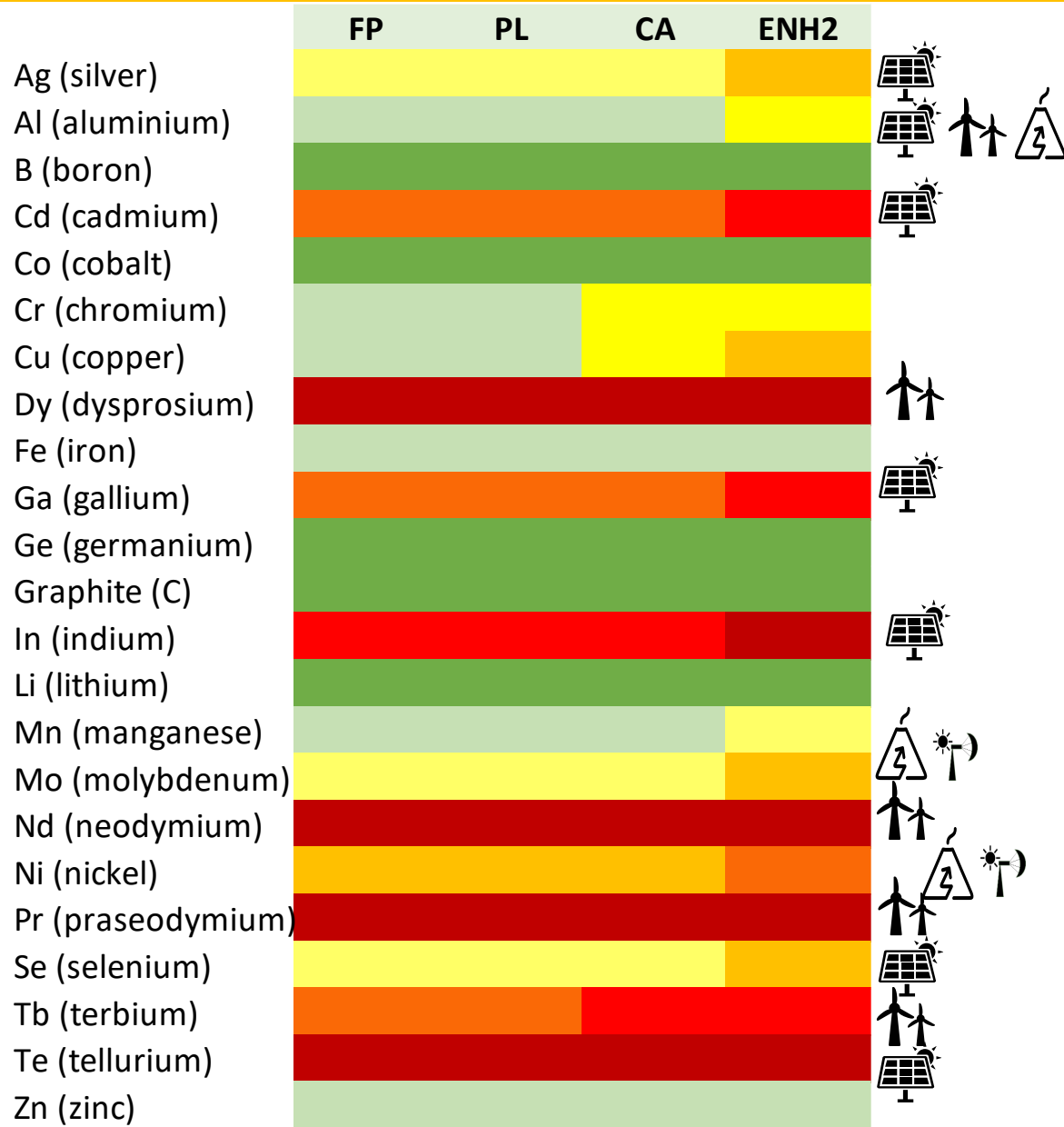
<https://ec.europa.eu/docsroom/documents/42881>



Potential higher supply risk with #9 materials
Cd, Dy, Ga, In, Nd, Ni, Pr, Tb and Te (> 10% total current EU demand)

Relative importance of Portuguese materials needs

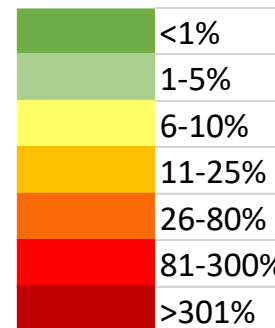
2050



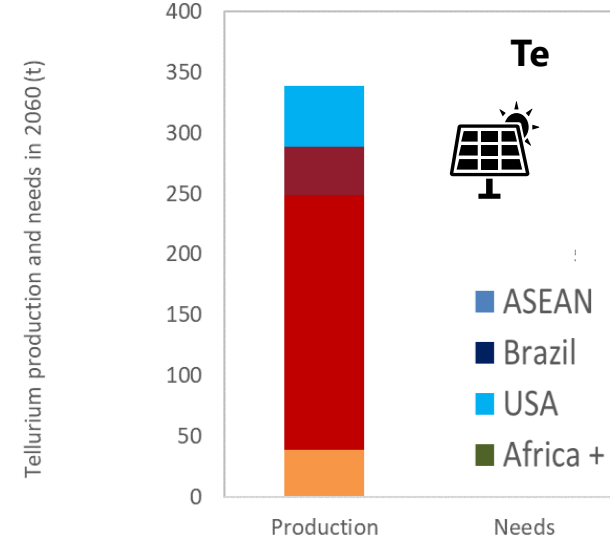
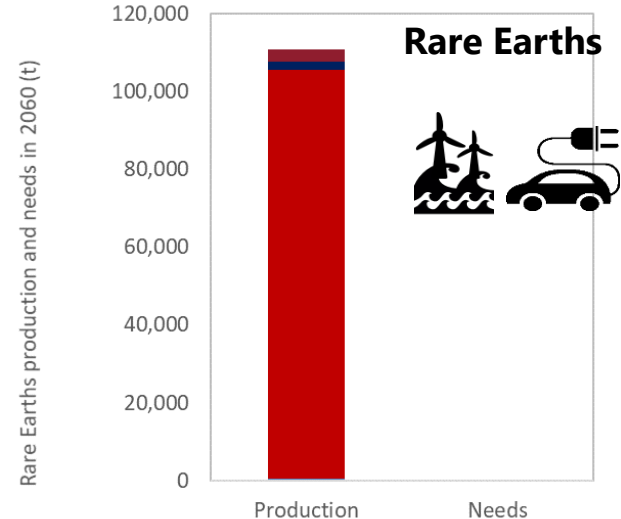
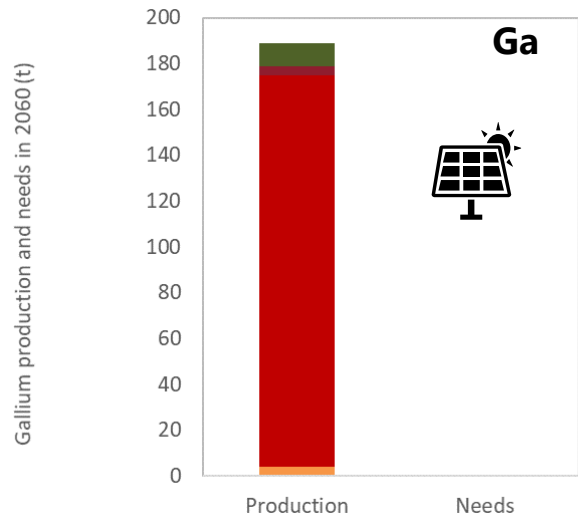
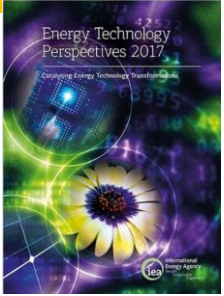
Potential higher supply risk with #13 materials
Ag, Cd, Dy, Ga, In, Nd, Ni, Pr, Mo, Se, Tb and Te (>10% total current EU demand)
In bold new materials from 2030

Al, Cr, Mn close to 10% threshold

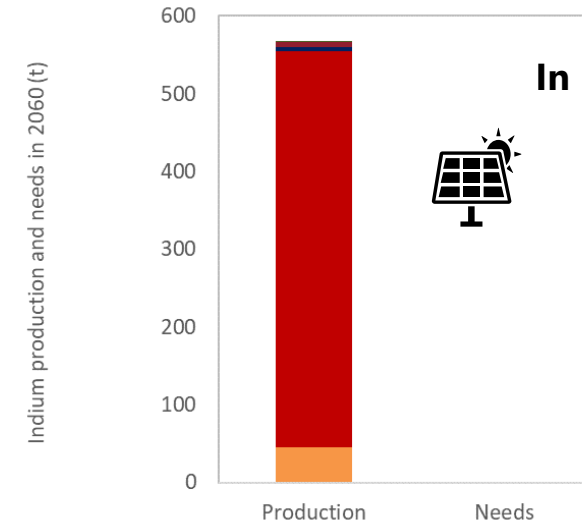
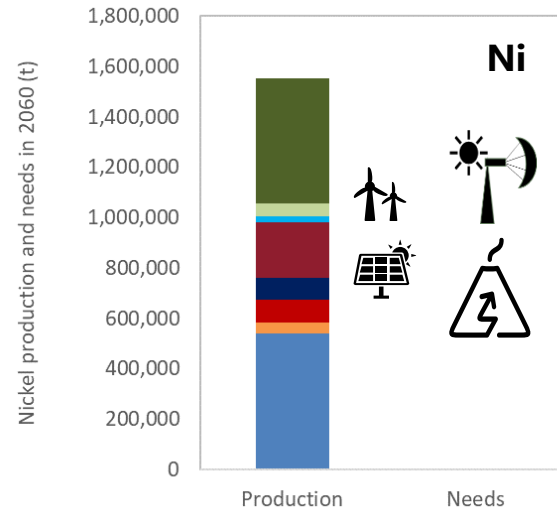
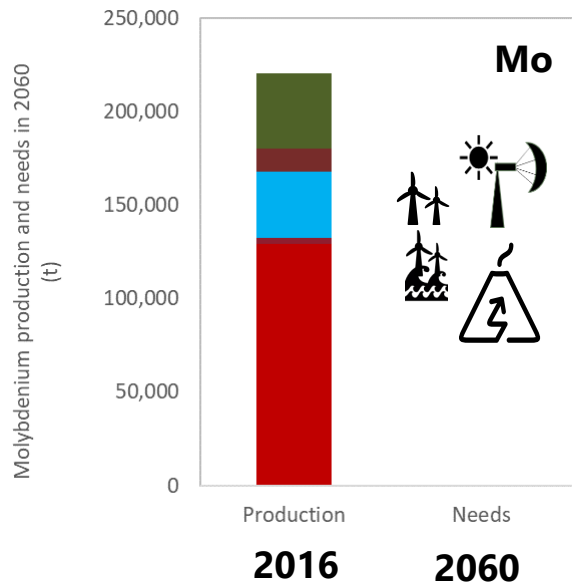
- > From 2030 to 2050 **relative importance of Portuguese needs increases** with 3 more materials above 10% threshold and other 3 close, depending on considered scenario
- > Potential risk of supply **consistently higher with ENH2** strategy scenarios



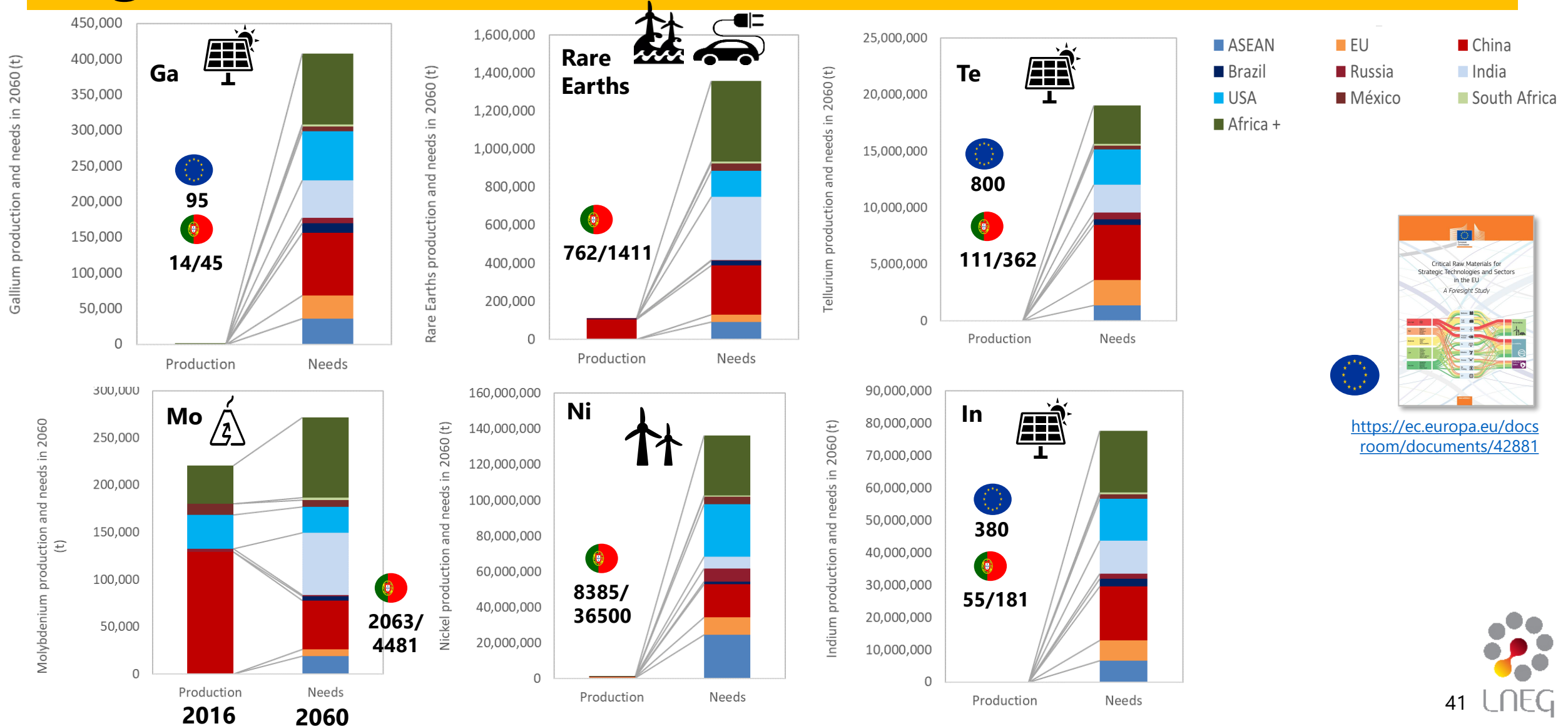
8 Most Critical Materials: Production vs Needs of 10 Regions of the Globe in 2060 (IEA ETP B2DS 2017)



- ASEAN
- EU
- China
- Brazil
- Russia
- India
- USA
- México
- South Africa
- Africa +



8 Most Critical Materials: Production vs Needs of 10 Regions of the Globe in 2060 (IEA ETP B2DS 2017)



SOME LIMITATIONS

Production is relative to the reported mine production for 2016 – *needs to be updated*

Does not have into account:

- production of the same materials in other regions of the world
- other needs for the same materials
- Efficiency improvements and recycling

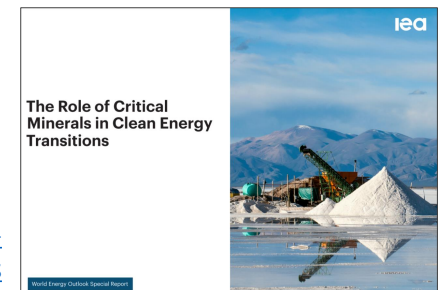
Next steps

- Include improving material usage efficiency
- Compare totals accounting also with batteries and electric vehicles
- Include materials for electrolysis, fuel cells and synthetic fuels
- Include recycling
- Land use and water needs
- Compare with minerals and materials available in Portugal - both primary sources and from materials recovery
- ...



“New and more diversified supply sources will be vital to pave the way to a clean energy future. A strong focus on recycling, supply chain resilience and sustainability will be essential”

<https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>





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 Geology and Geological Risk	 Mineral Technology	BUILDING A STRONGER AND CLEANER FUTURE	
 Resource Economics	 Geo-Information		 Geological Resources
 Bioenergy and Biorefineries	 Energy in the Built Environment		 Integration of Renewable Energies in the Energy System
	 Materials for Energy		 Renewable Energies



<http://www.lneg.pt>



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