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Material resources for the energy transition

Dr. Herena Torio

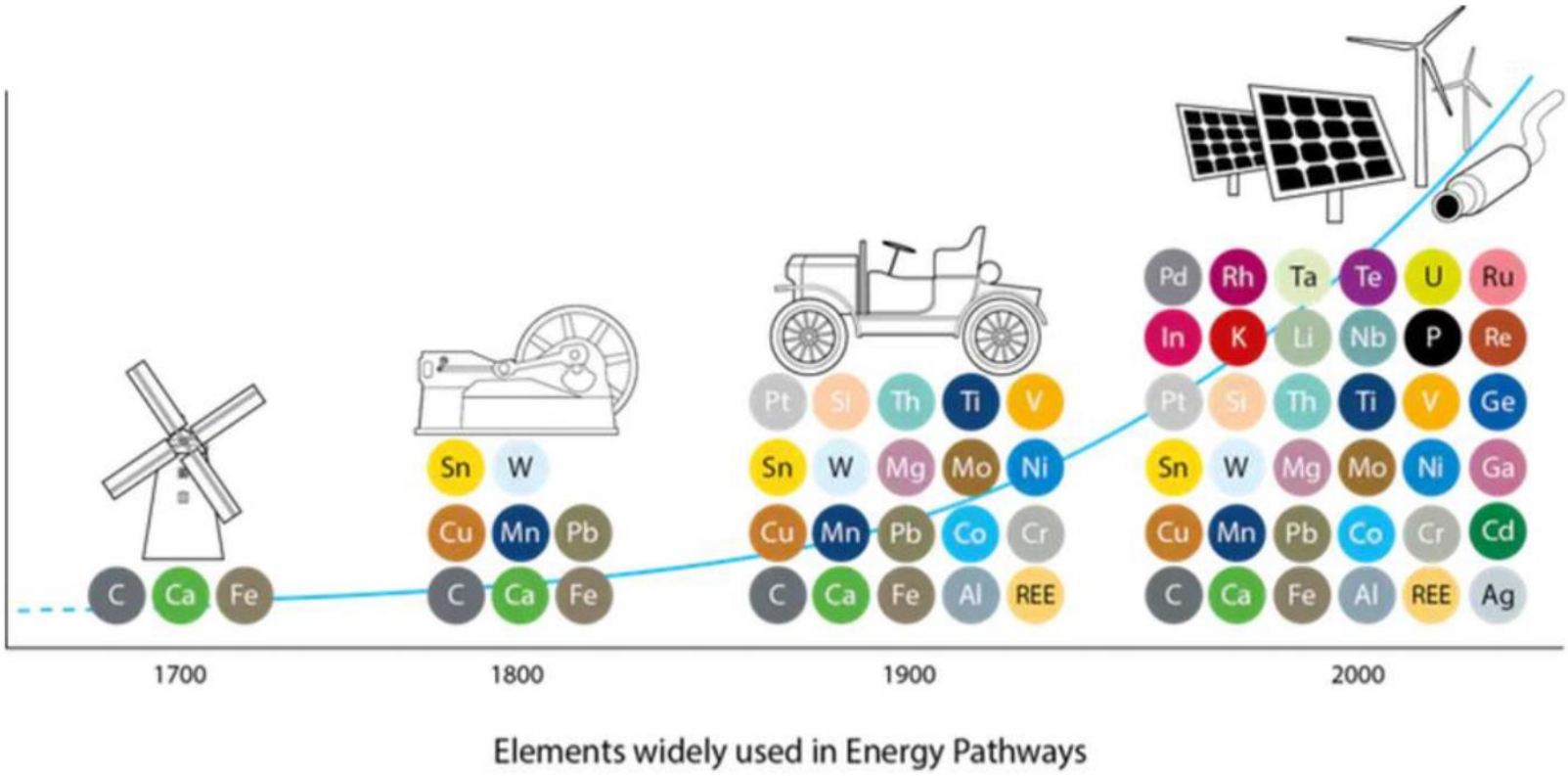
Agenda

- **Materials demands for energy transition**
- Critical materials
- Ways out
- Example: electric vehicles

Materials for the energy transition

Ages of energy

Higher amount and complexity of required materials

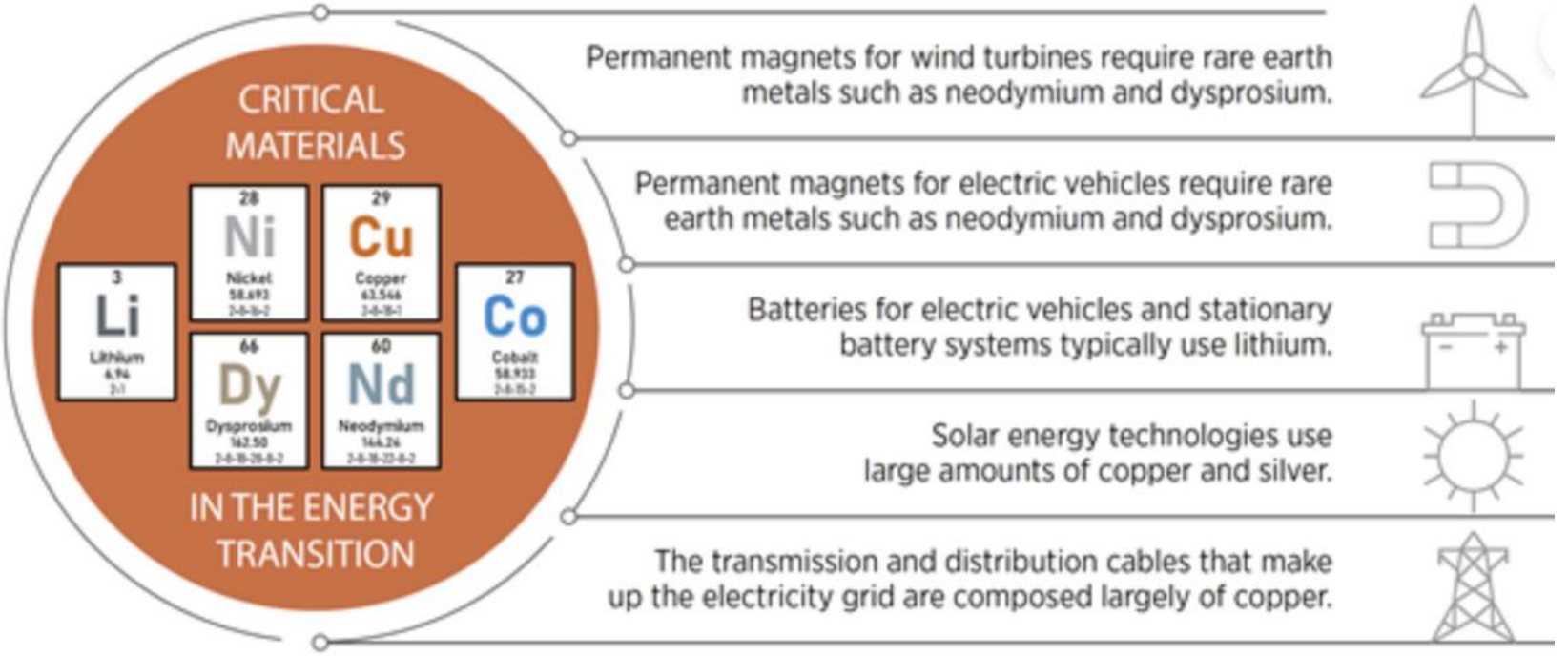


Source: Zepf et al. 2014. Materials critical to the energy industry.
Pehlken 2023. Lecture V01 – Hidden Champions for RE

Materials for the energy transition

Critical materials in the energy transition

Definition (IRENA, 2024): Critical materials are the resources needed to produce numerous key technologies for the energy transition, including wind turbines, solar panels, batteries for EVs and electrolysers.



Source: Critical materials (irena.org), https://www.irena.org/Energy-Transition/Technology/Critical-materials

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Agenda

- Materials demands for energy transition
- **Critical materials**
- Ways out
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Critical materials

Definition (IRENA, 2022)

Materials which…

Demand

- require a significant extraction effort
- a massive ramp-up of supply will be needed

Supply risk

- the production is concentrated in a few countries
- the quality of natural resources is declining
- prices have shown large fluctuations that reflect supply-demand imbalances.

Examples of non-critical materials

steel and concrete or aluminium: not considered to be critical, despite a need for a massive ramp-up of supply: the resource is in place and widely distributed

Critical Materials

Top of important materials for Energy transition

By categories

1. Lithium plays a crucial role in renewable energy technologies
2. four REEs (neodymium, praseodymium, terbium and cerium)
3. borates,
4. Gallium
5. natural graphite
6. cobalt.

The **critical raw materials** most in demand are:

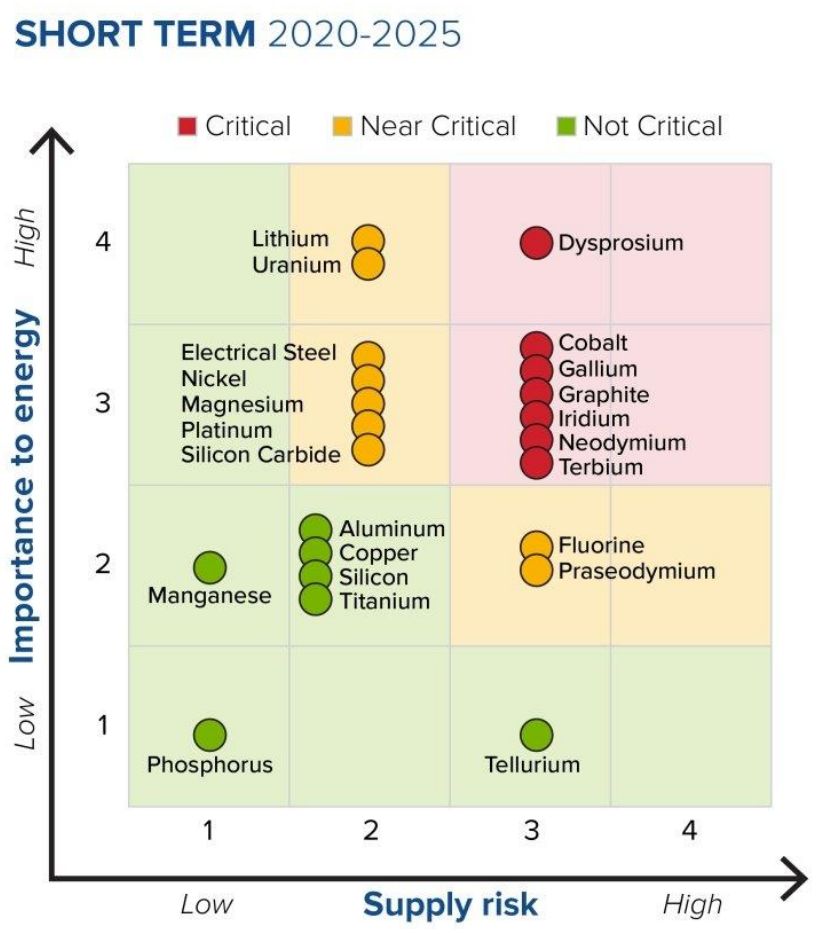
1. feldspar,
2. Strontium
3. lanthanum
4. phosphorus.

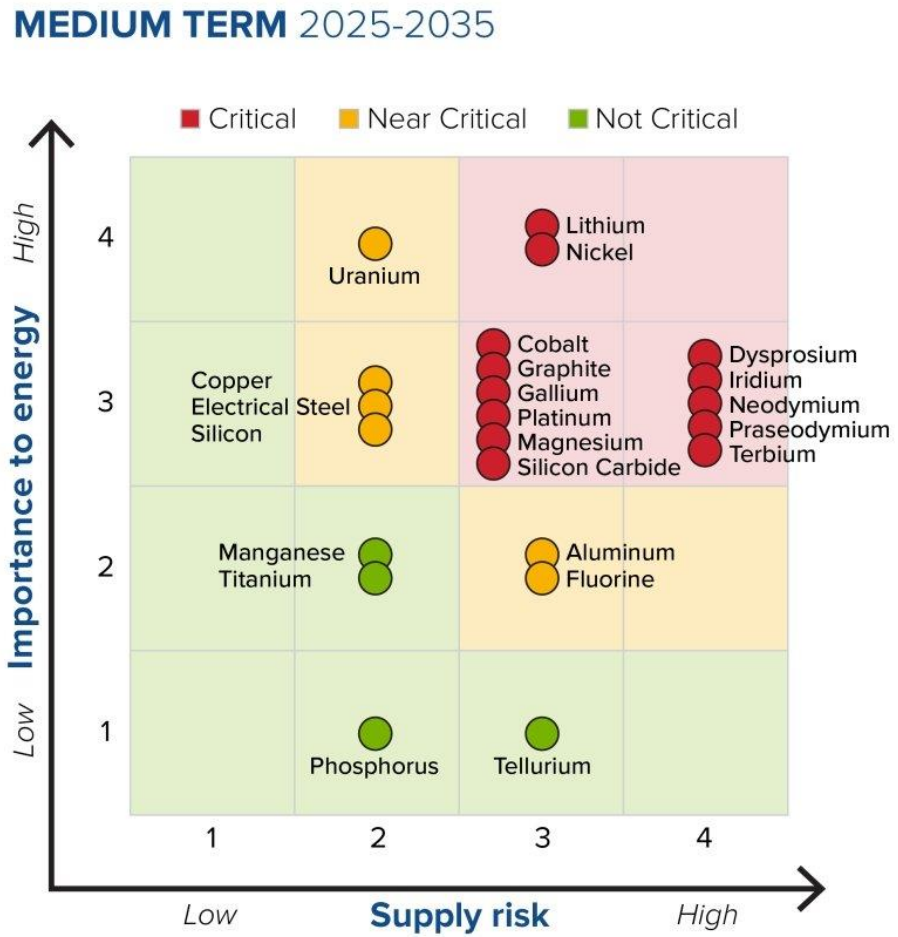
Gypsum, selenium and silica are the most required **non-critical raw materials**.

Source: https://rmis.jrc.ec.europa.eu/techprofiles/ind/5

Critical materials

Overview of critical materials





Source: https://www.energy.gov/cmm/what-are-critical-materials-and-critical-minerals

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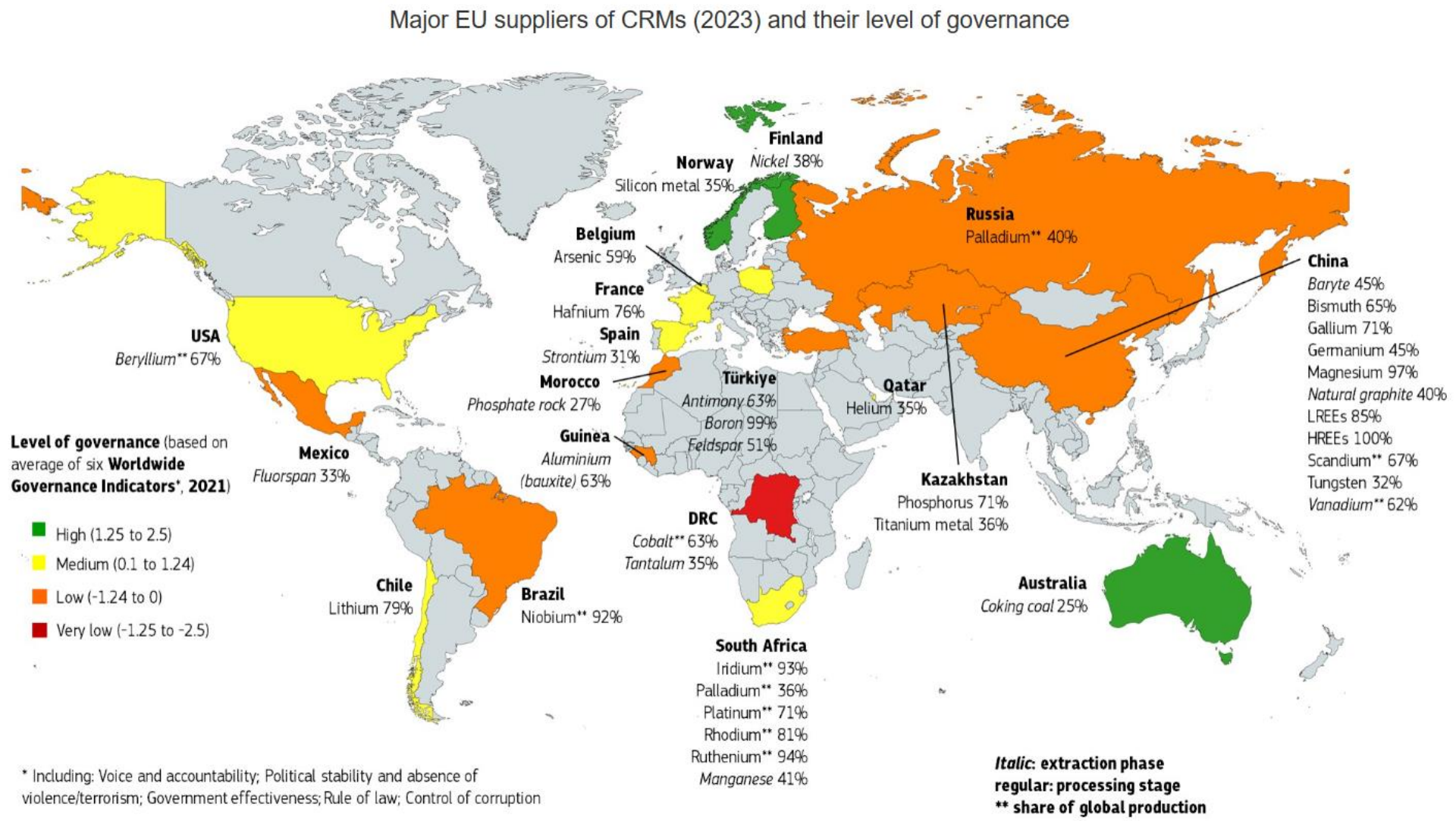
Critical materials

By countries and their „governance“



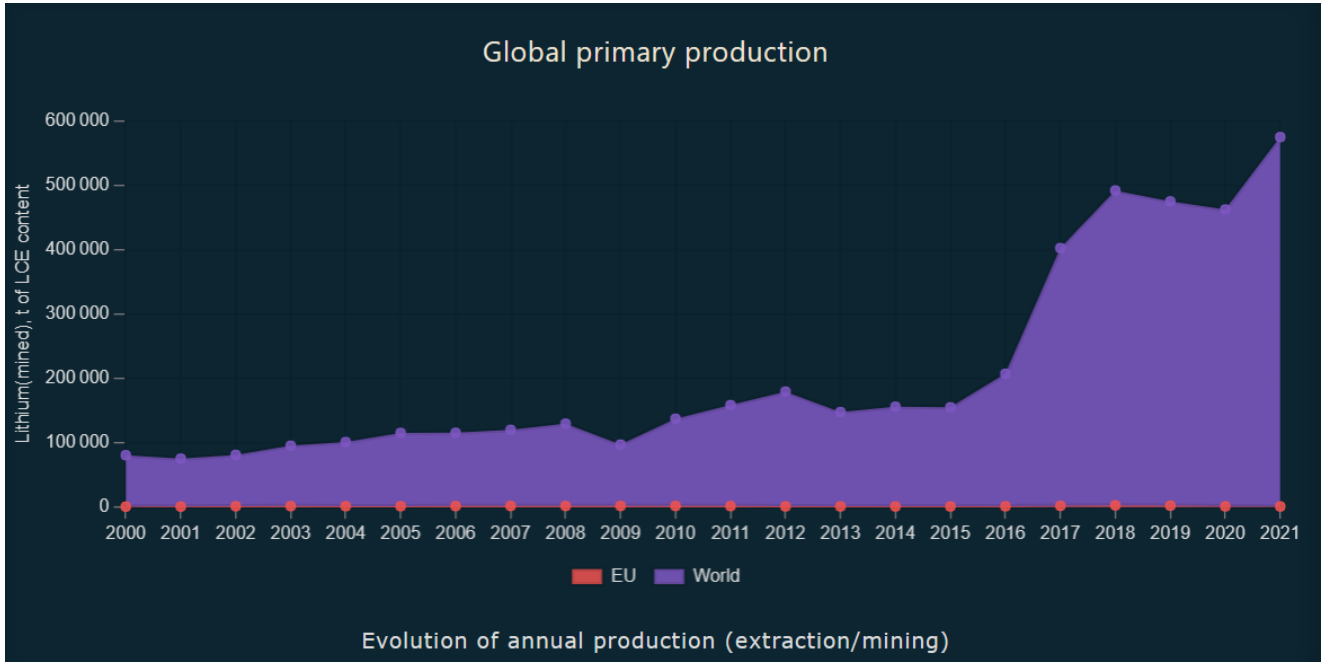
Source: https://rmis.jrc.ec.europa.eu/eu-critical-raw-materials

Critical materials

Production rates, historic data

Lithium

Currently, about 600 kt/a (per year!)



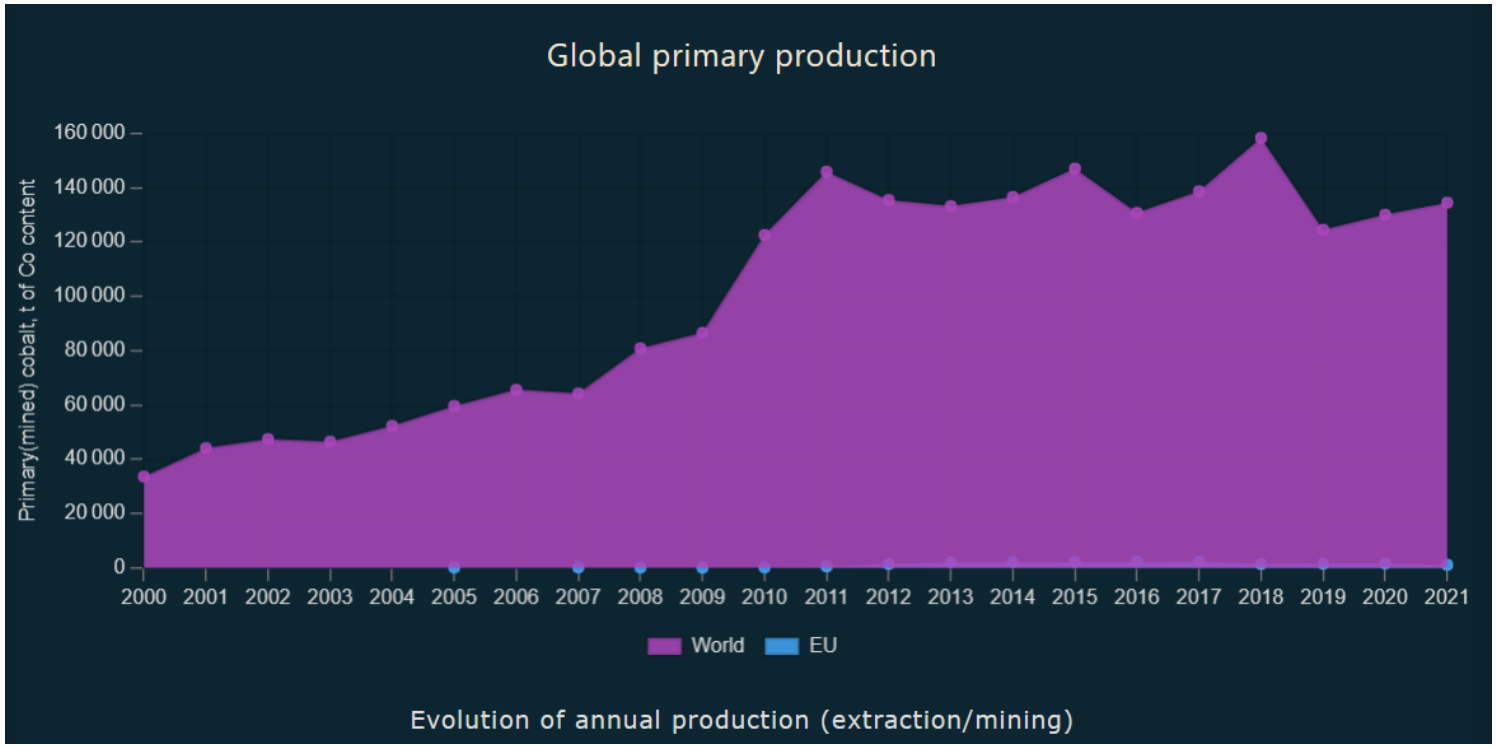
Source: RMIS - Raw materials' profiles (europa.eu), https://rmis.jrc.ec.europa.eu/rmp/Lithium

Critical materials

Production rates, historic data

Cobalt

Currently, about 160 kt/a (per year!)



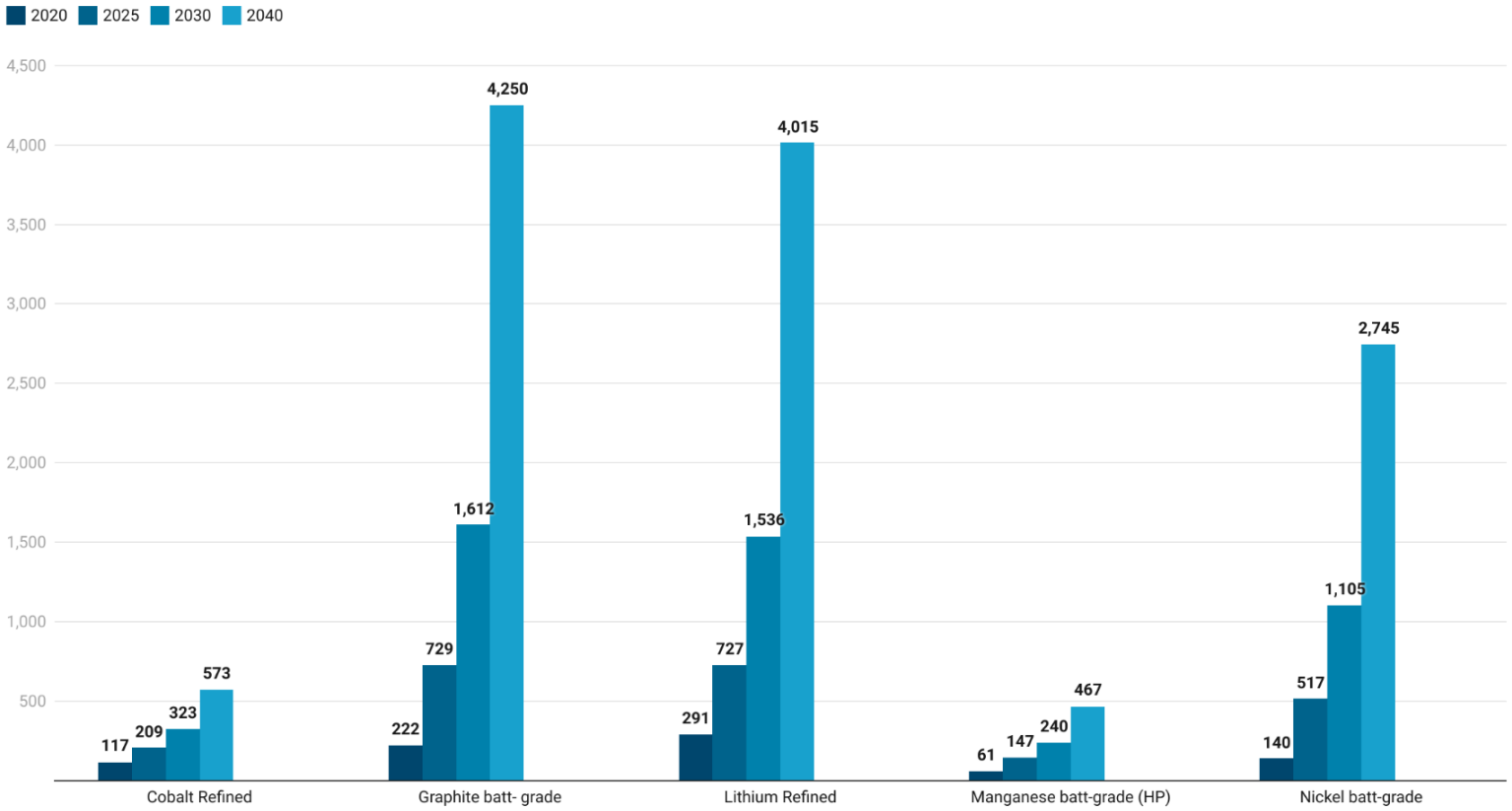
Source: RMIS - Raw materials' profiles (europa.eu), https://rmis.jrc.ec.europa.eu/rmp/Cobalt

Critical materials

Projected global demands for E-batteries

2020 - 2040

Figure 1 – Forecast of battery demand globally from processed raw materials [kt]



Source: JRC analysis.

Source: RMIS - Battery supply chain challenges (europa.eu)

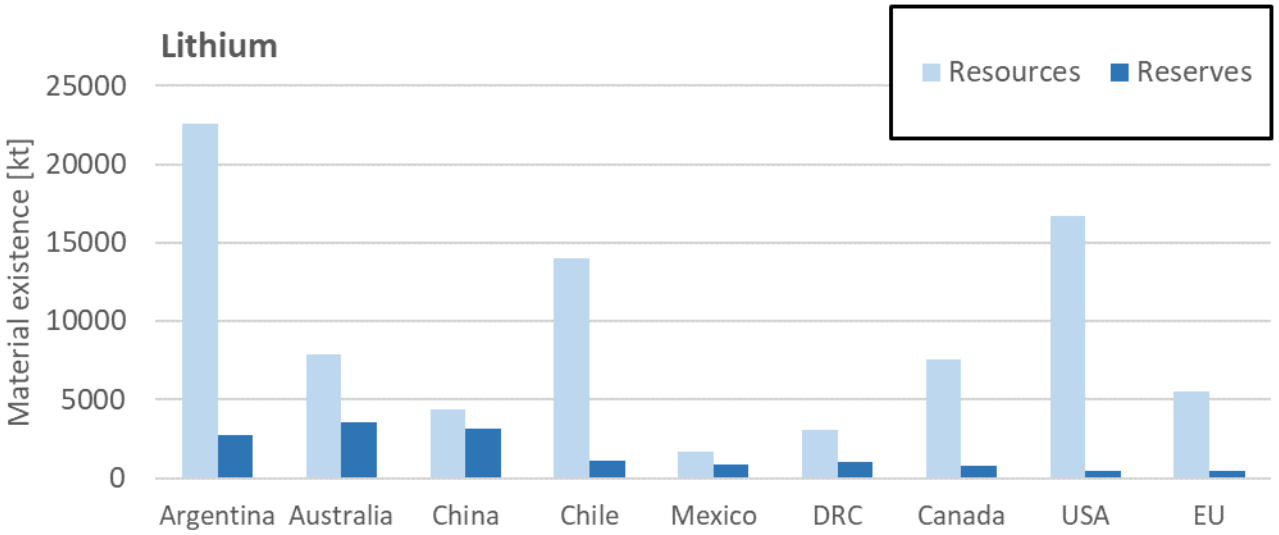
Critical materials

Resources and reserves

Lithium

Currently, about 600 kt/a (per year!), with current reserves: **ca. 25 years!**

- Projected demand 2030 for E-batteries! → 9 years!
- Projected demand 2040 for E-batteries! → 3 years!



Data source: RMIS - Raw materials' profiles (europa.eu), https://rmis.jrc.ec.europa.eu/rmp/Lithium

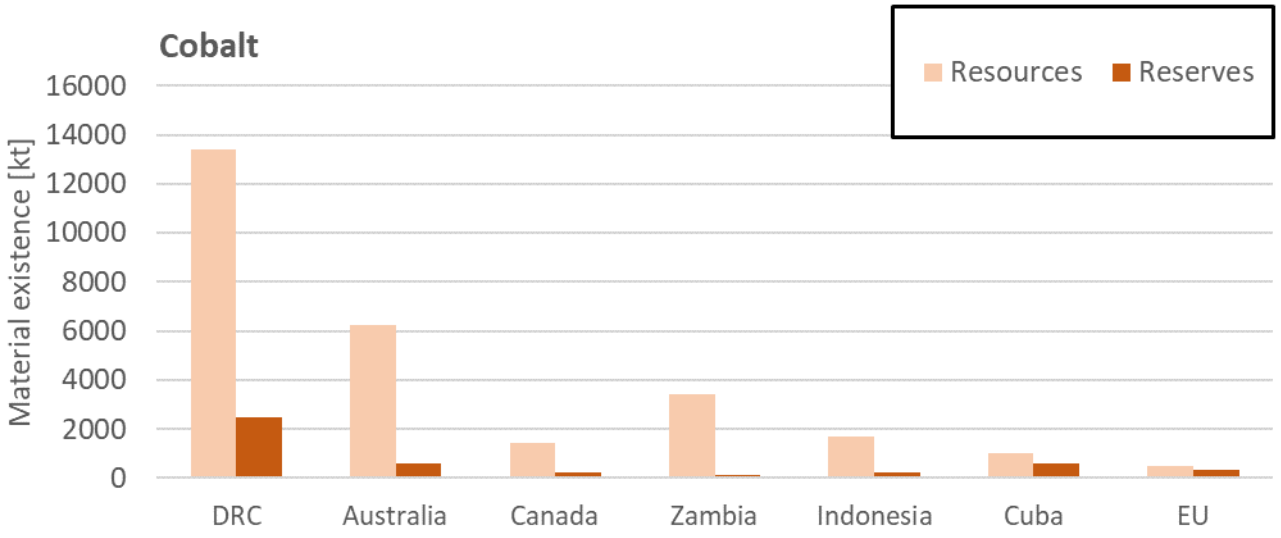
Critical materials

Resources and reserves

Cobalt

Currently, about 160 kt/a (per year!), with current reserves: **ca. 25 years!**

- Projected demand 2030 for E-batteries! → 14 years!
- Projected demand 2040 for E-batteries! → 8 years!



Data source: RMIS - Raw materials' profiles (europa.eu), https://rmis.jrc.ec.europa.eu/rmp/cobalt

Critical materials

Regional supply

Dependencies and fragilities

- Oligopolies concentrated in China
- Despite of diversification: expected to remain for Co, Ni, Graphite & Manganese)

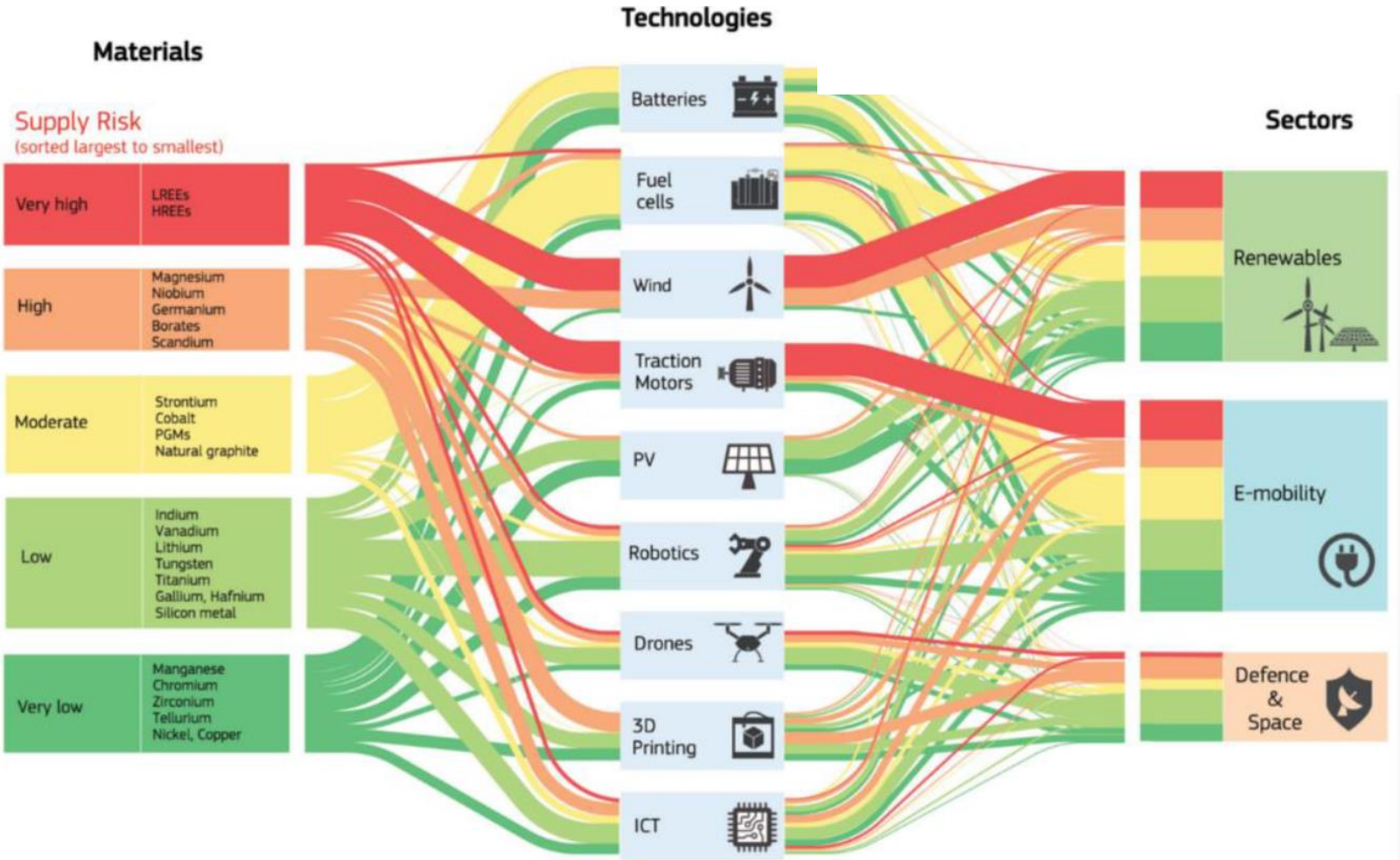
Country	Cobalt (Refined Co)	Graphite (Anode precursors from natural graphite+synthetic graphite)	Lithium (Refined Li)	Manganese (HP EMM+HP MSM)	Nickel (NiSO4)	Cells
	51%	87%	34%	56%	59%	65%
	7%	3%	4%	14%	8%	14%
	10%	1%	11%	7%	6%	0%
	3%	1%	0%	0%	6%	1%
	0%	6%	10%	0%	1%	14%
	6%	1%	5%	0%	1%	0%
	1%	0%	0%	10%	1%	0%
	0%	0%	2%	0%	2%	1%
	2%	1%	0%	0%	0%	2%
	1%	0%	0%	0%	9%	0%
	2%	0%	0%	0%	0%	0%
	1%	0%	2%	0%	0%	0%
	0%	0%	16%	0%	0%	0%
	0%	0%	0%	8%	0%	0%
	0%	0%	11%	0%	0%	0%

Source: RMIS - Battery supply chain challenges (europa.eu)

Critical materials

Supply required for different sectors

Dependencies and fragilities



Source: RMIS - Raw Materials Information System (europa.eu)

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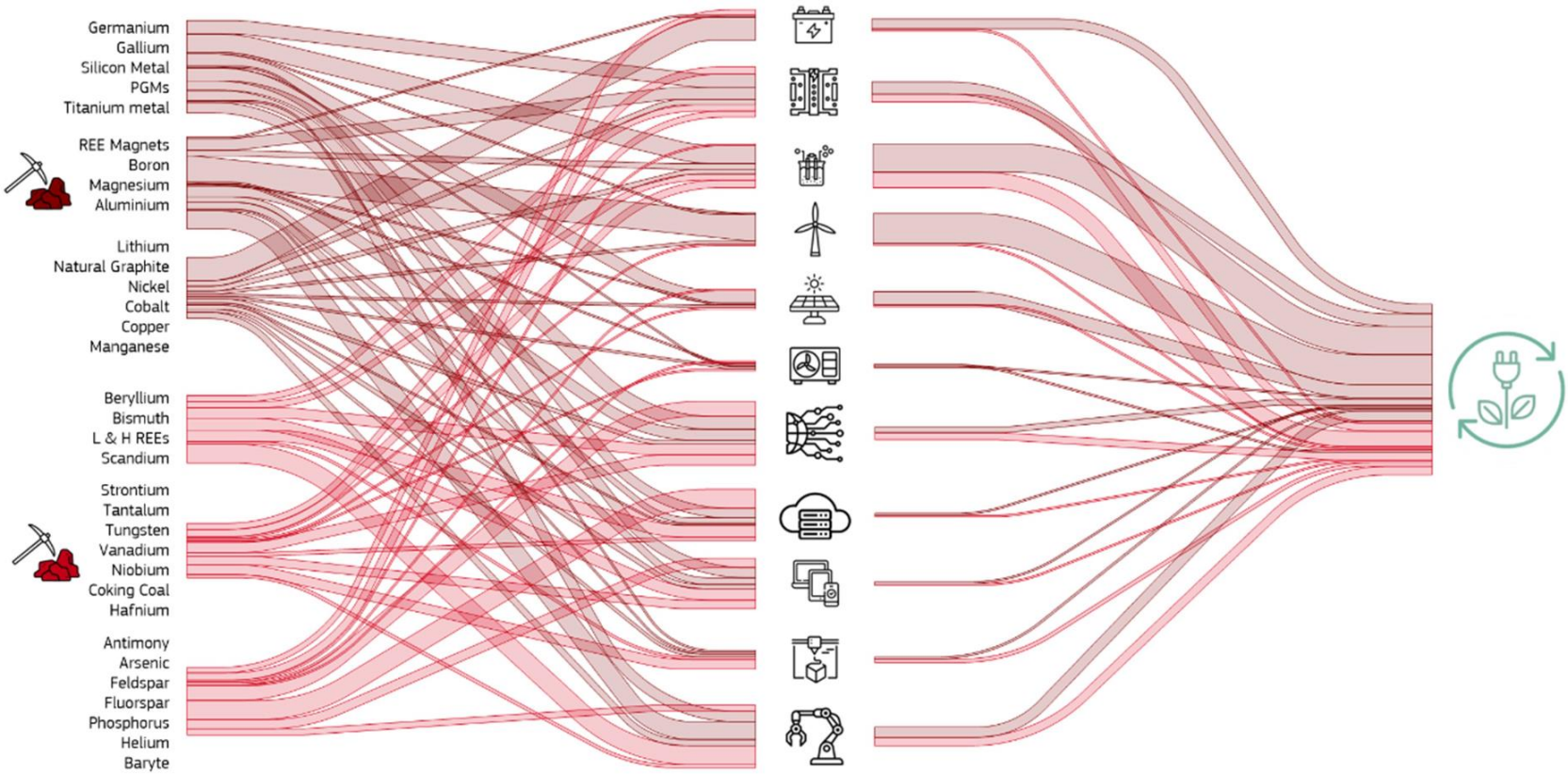
Critical materials

Supply required for different sectors

Dependencies and fragilities



Sankey diagram of the raw materials present in each technology of the renewable energy sector (critical = bright red; strategic = dark red)

Source: JRC, 2023.

Source: RMIS - Raw Materials Information System (europa.eu)

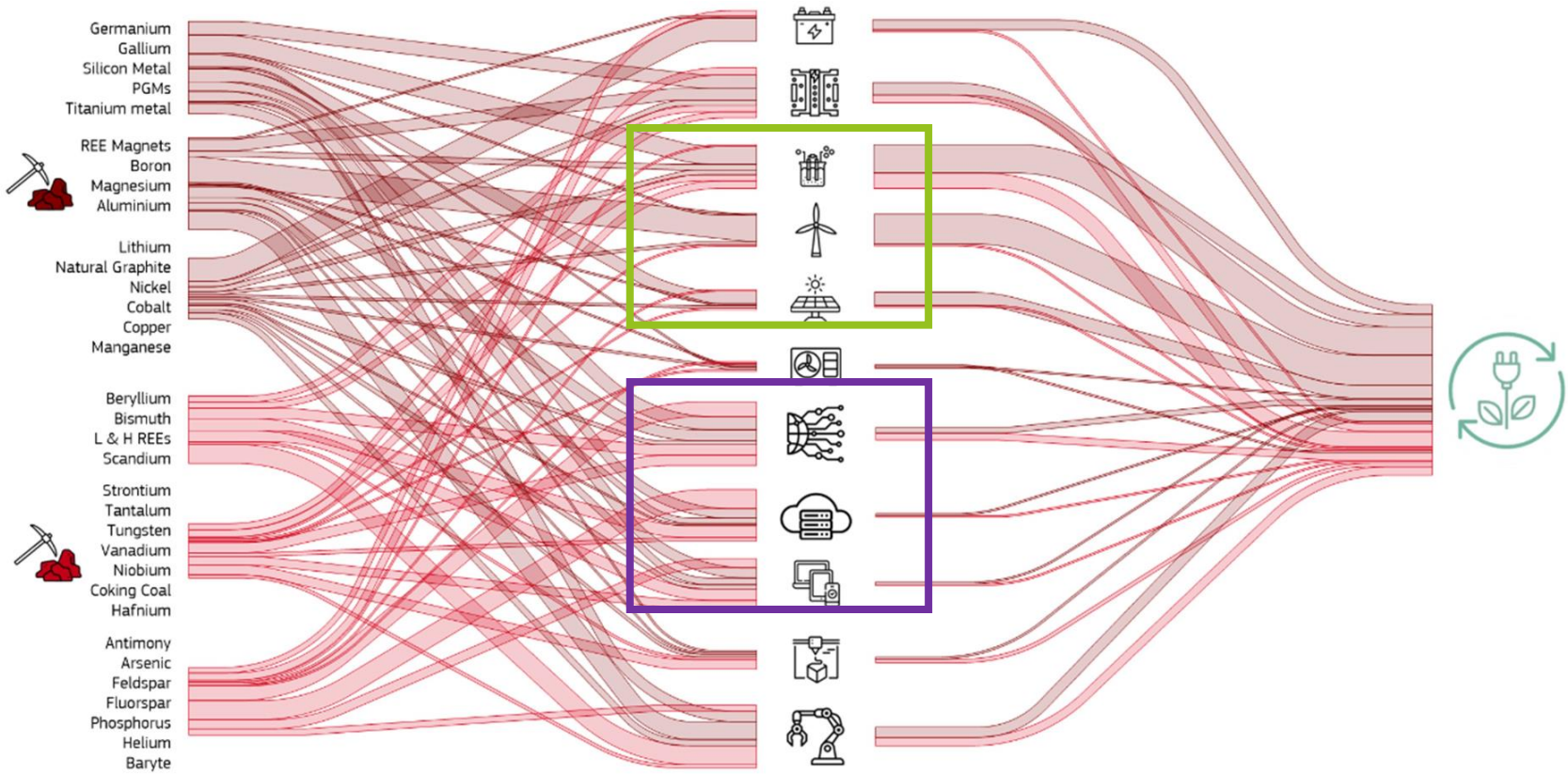
Critical materials

Supply required for different sectors

Dependencies and fragilities

Renewables

ICT, smart-grids



Sankey diagram of the raw materials present in each technology of the renewable energy sector (critical = bright red; strategic = dark red)

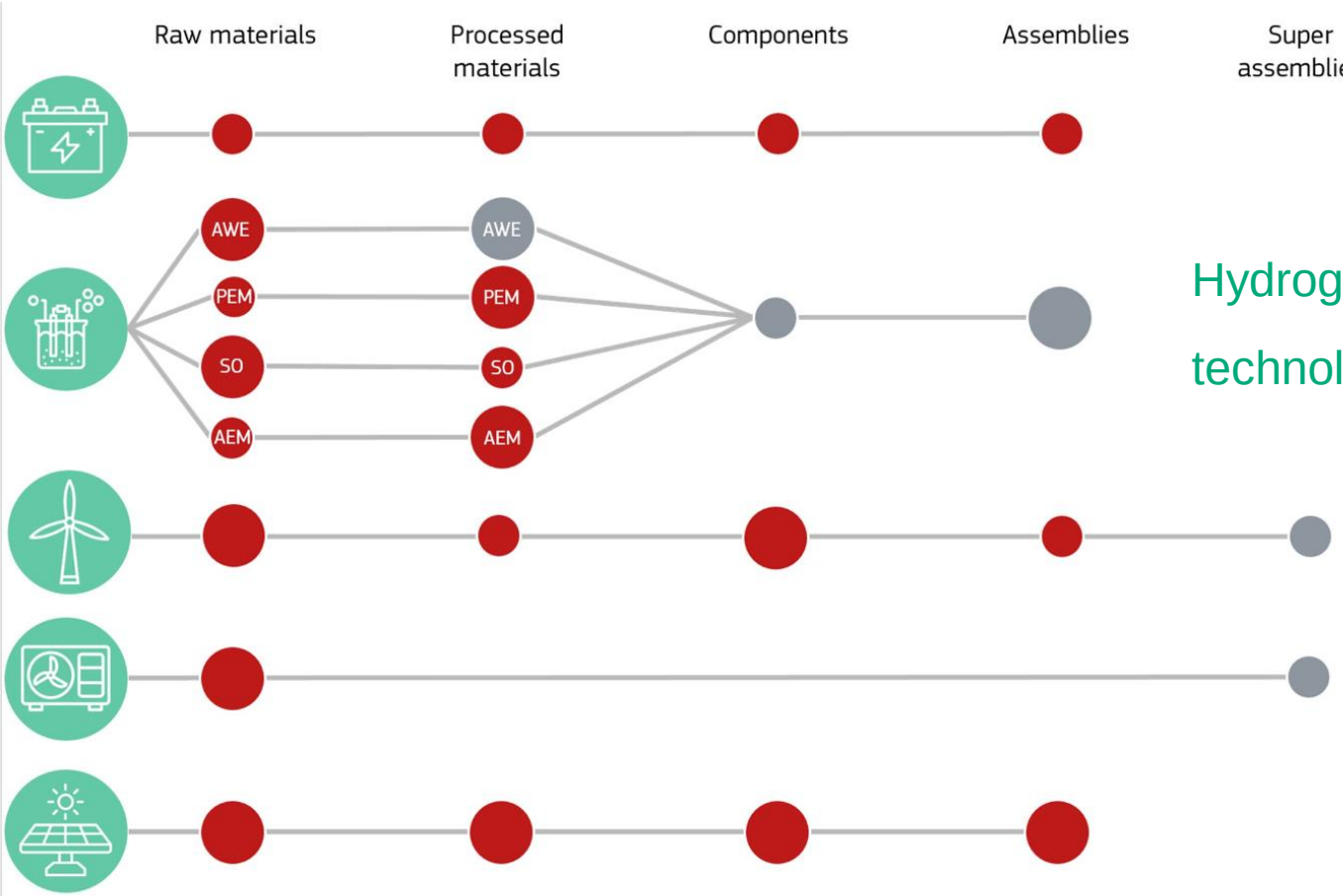
Source: JRC, 2023.

Source: RMIS - Raw Materials Information System (europa.eu)

Critical materials

Supply risks for RE

Supply chain bottlenecks



Hydrogen technologies

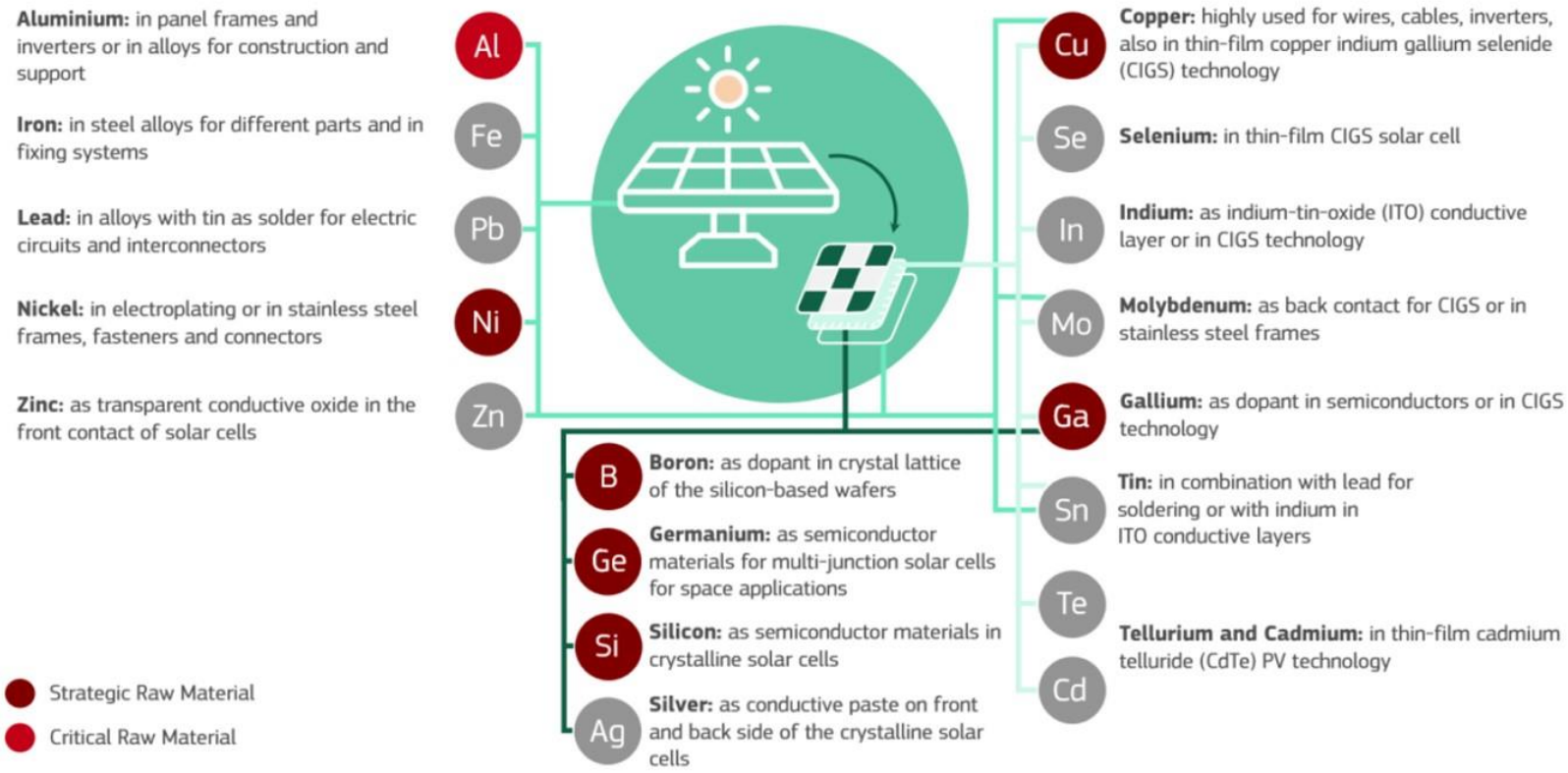
Overview of supply risks, bottlenecks, and supply patterns along the selected supply chains relevant to the renewable energy sector. Source: JRC, 2023.

Source: https://rmis.jrc.ec.europa.eu/techprofiles/ind/5

Critical materials

Technology profiles

Photovoltaics

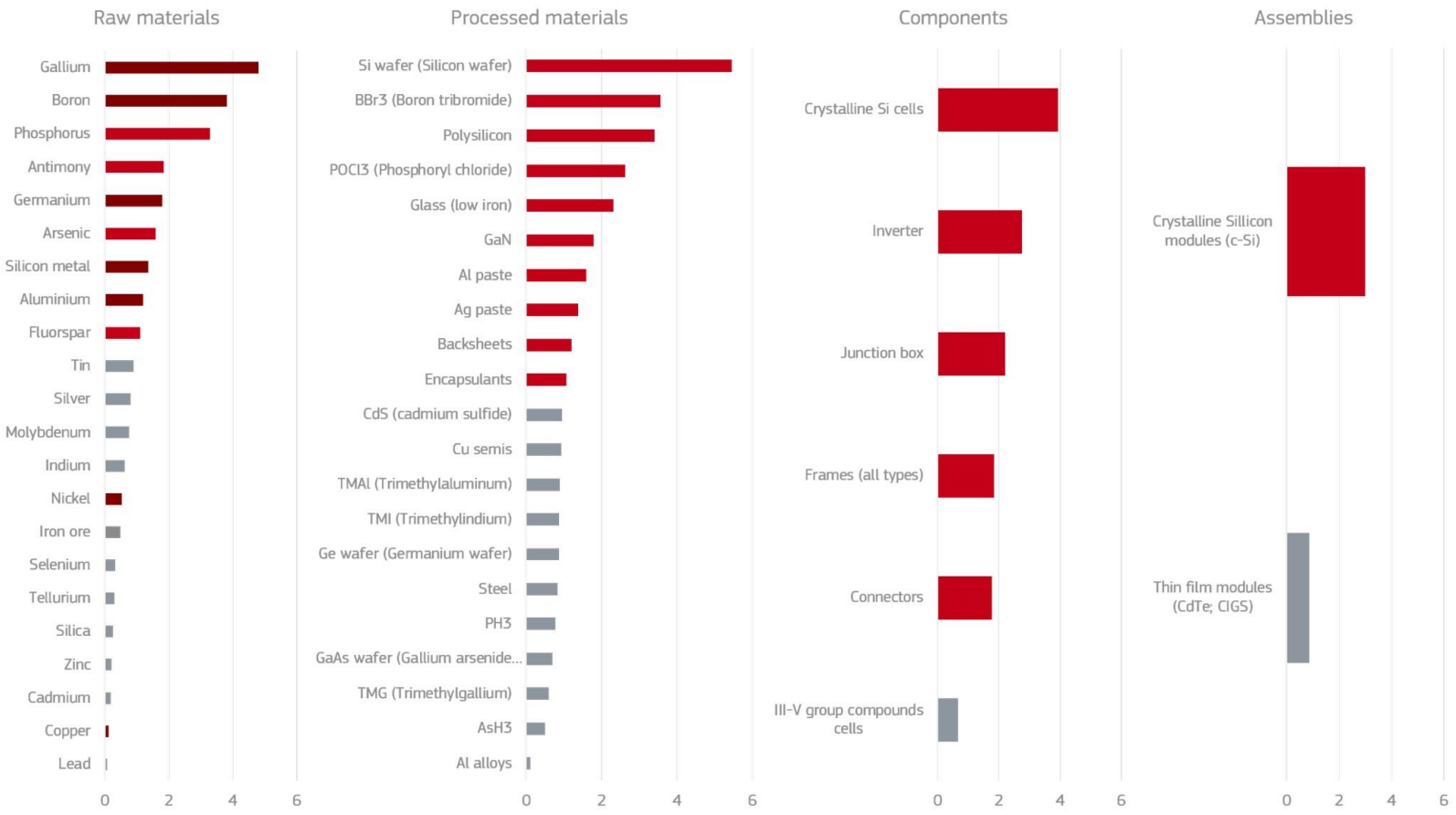


Source: https://rmis.jrc.ec.europa.eu/techprofiles/ind/7

Critical materials

Technology profiles

Photovoltaics

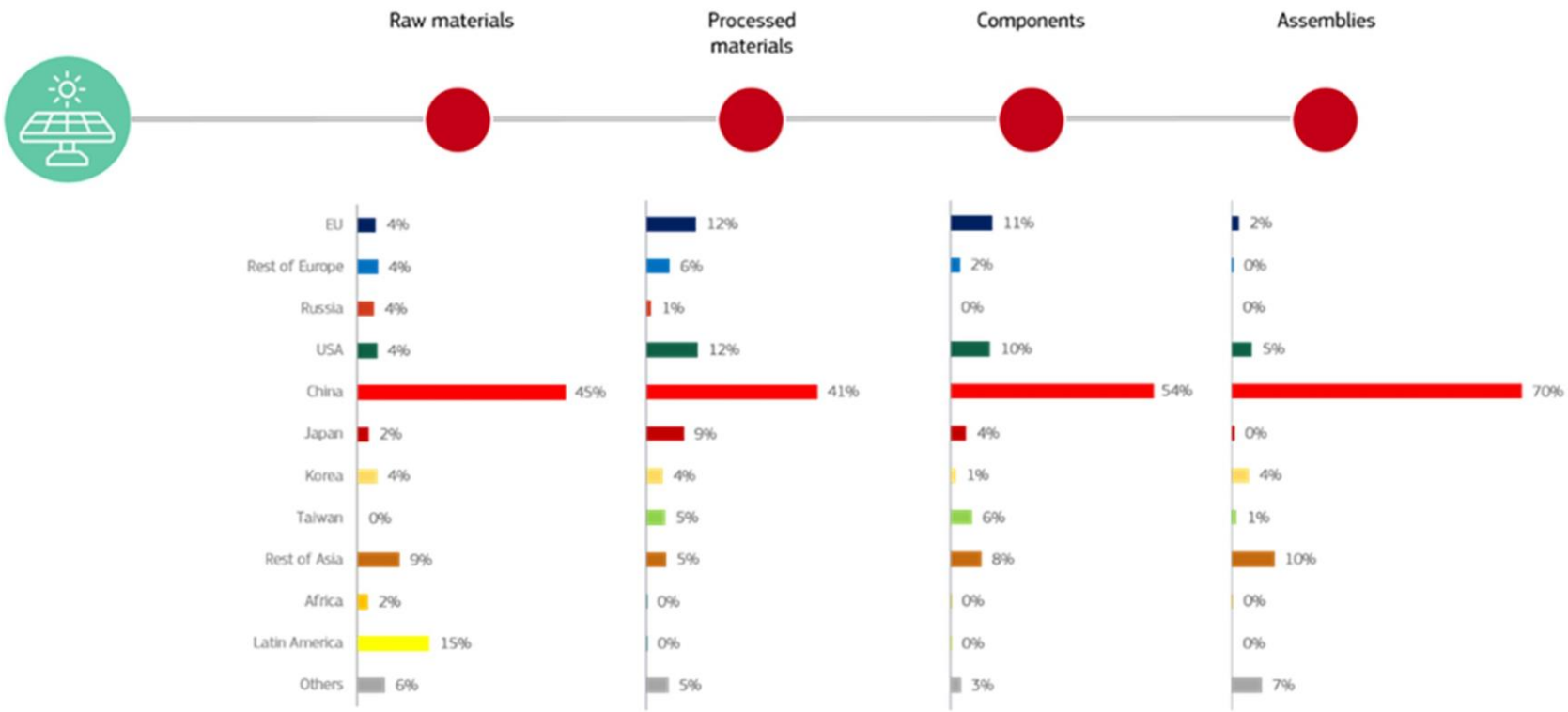


Source: https://rmis.jrc.ec.europa.eu/techprofiles/ind/7

Critical materials

Technology profiles

Photovoltaics

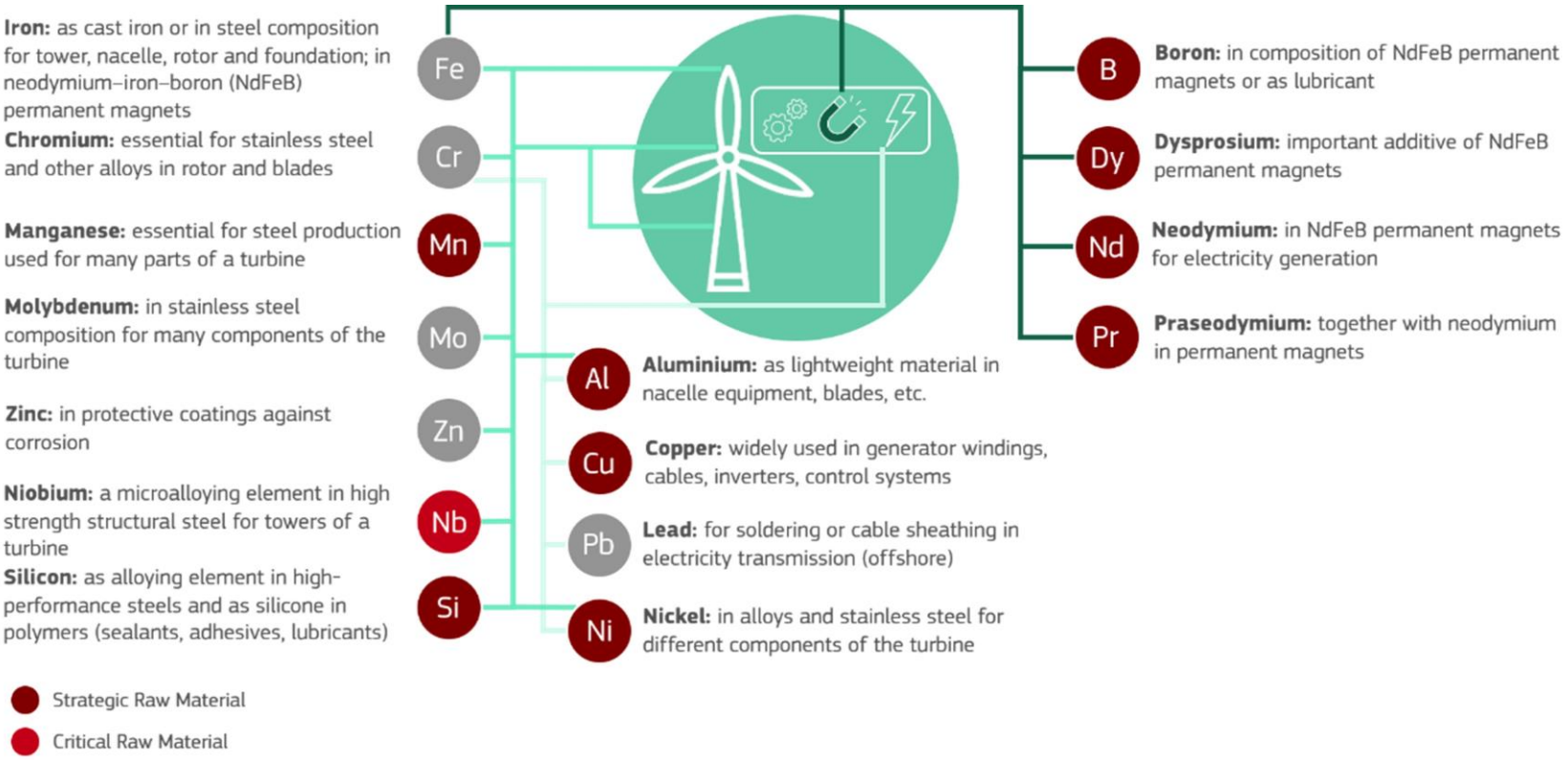


Source: https://rmis.jrc.ec.europa.eu/techprofiles/ind/7

Critical materials

Technology profiles

Wind turbines



Source: https://rmis.jrc.ec.europa.eu/techprofiles/ind/7

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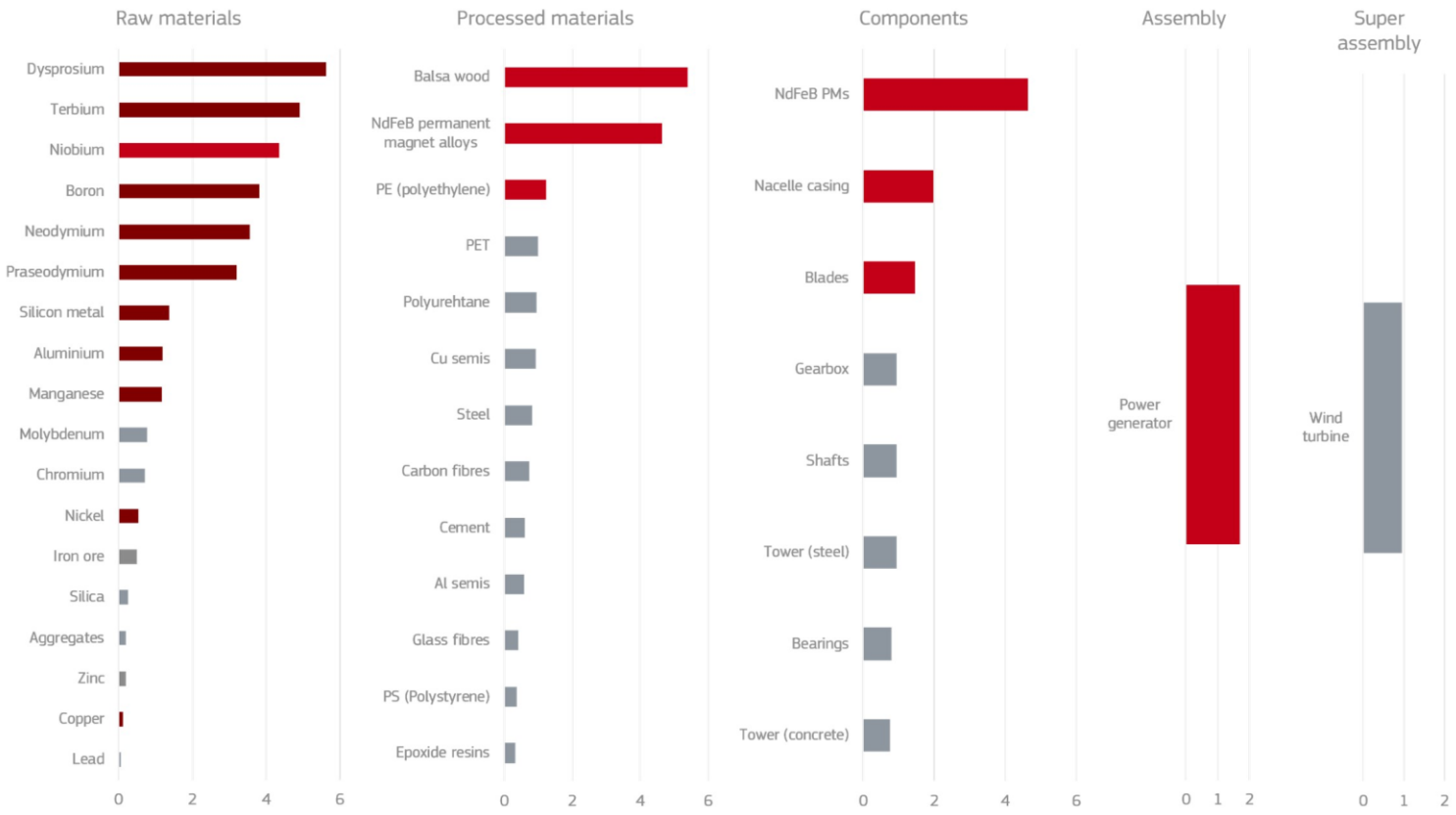
Critical materials

Technology profiles

Wind turbines

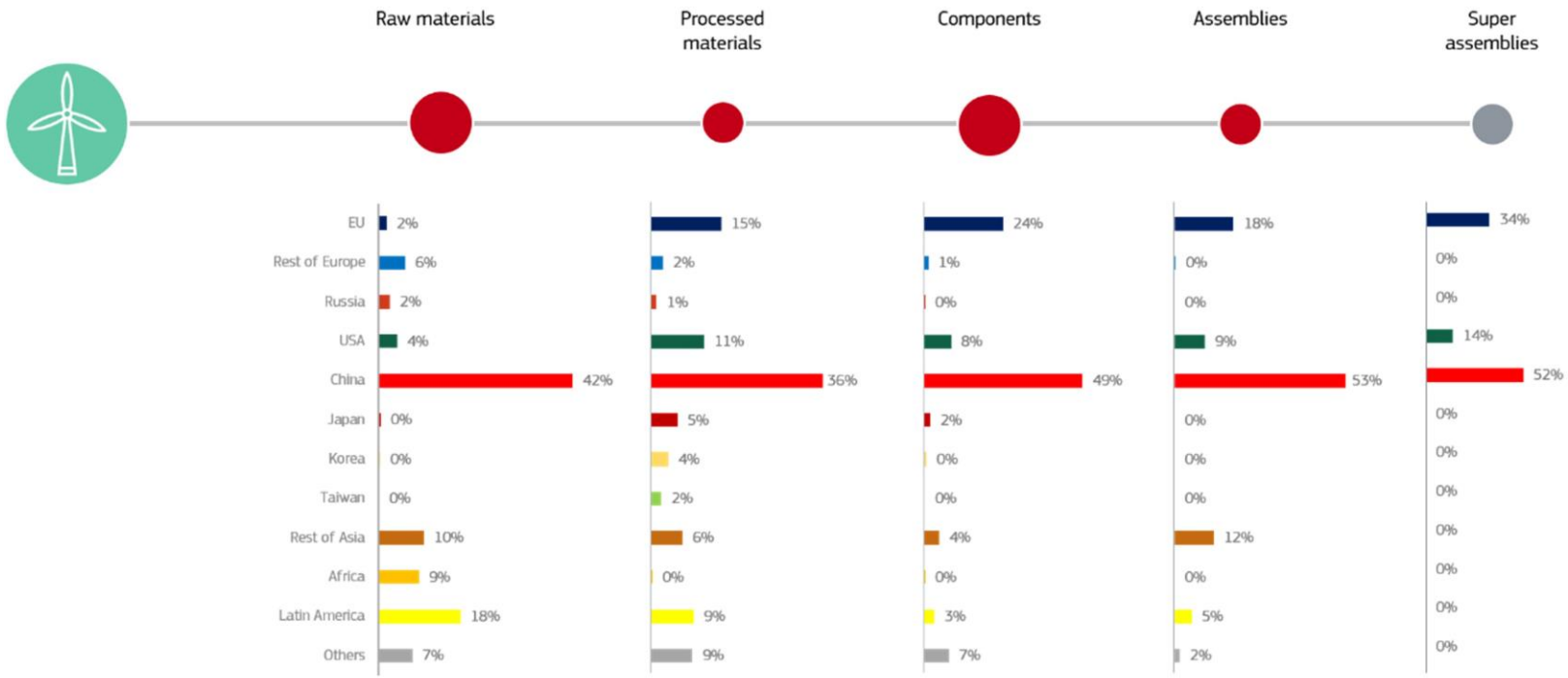


Source: https://rmis.jrc.ec.europa.eu/techprofiles/ind/6

Critical materials

Technology profiles

Wind turbines



Source: https://rmis.jrc.ec.europa.eu/techprofiles/ind/6

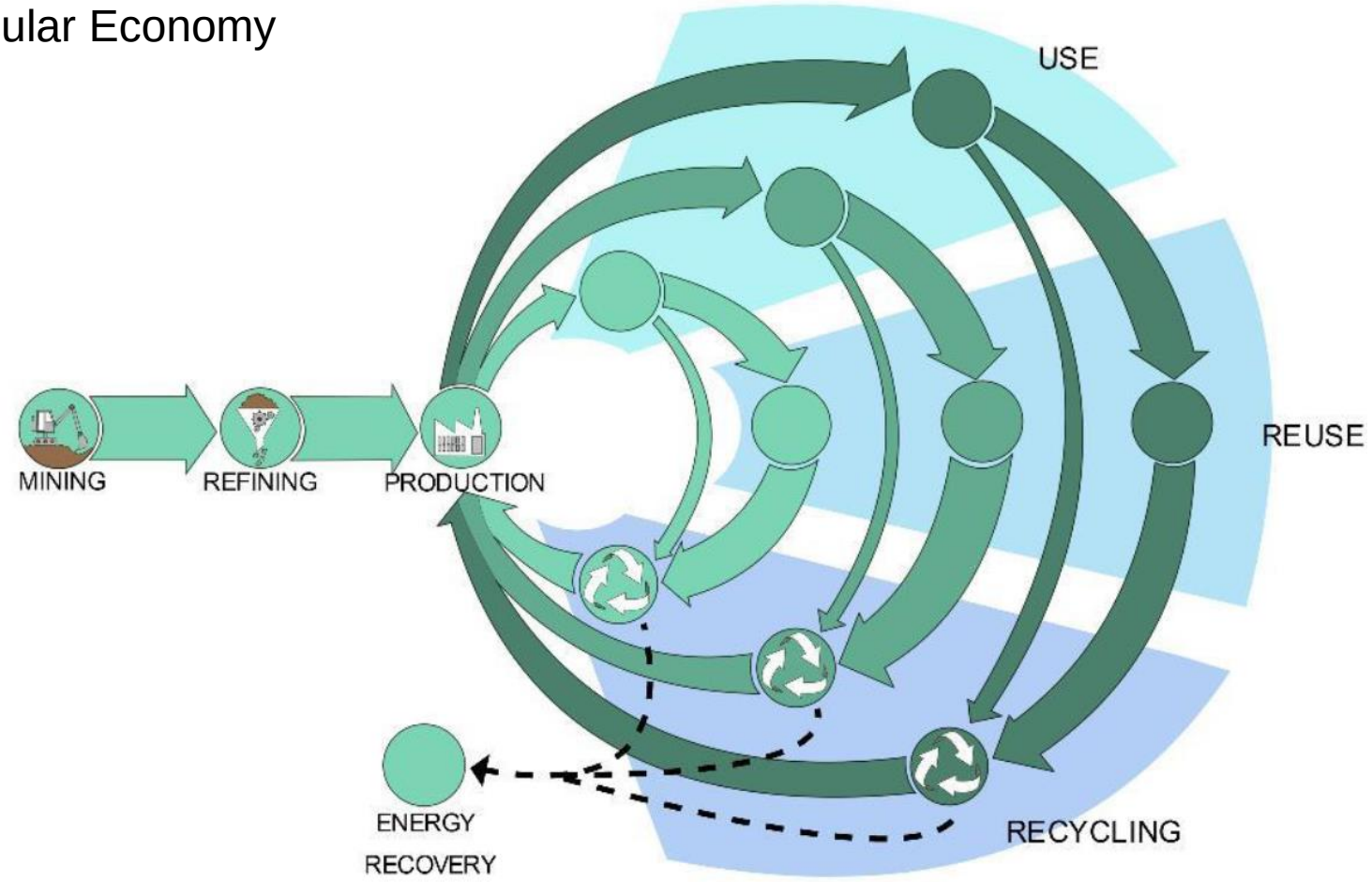
Agenda

- Materials demands for energy transition
- Critical materials
- **Ways out**
- Example: electric vehicles

Critical materials

Ways out

Circular Economy



Source: Pehlken 2023. Lecture V01 – Hidden Champions for RE

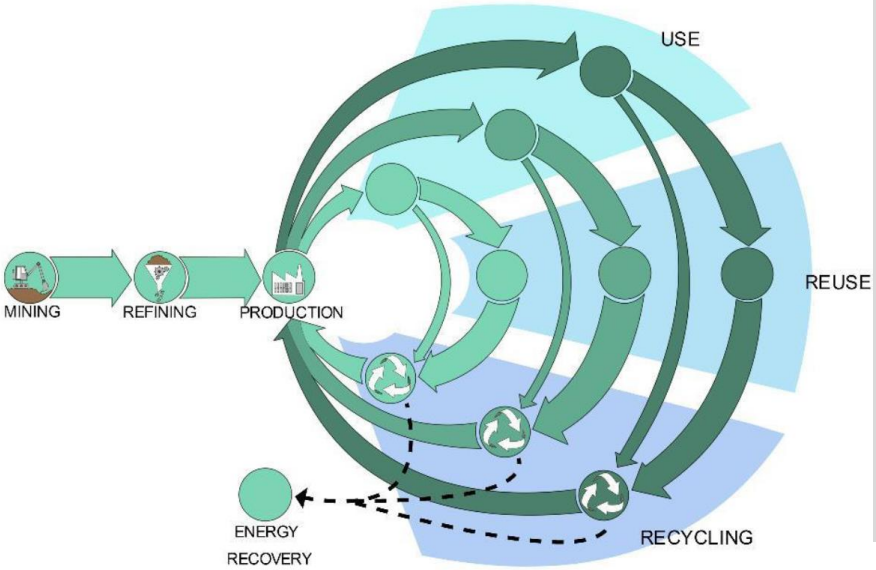
Critical materials

Ways out

Circular Economy

Methods

- **Life-cycle Assessment (LCA)**
- **Material Flow Analysis (MFA):** a great data base for MFA can be found in the link here: RMIS - Material system analysis (MSA) (europa.eu)



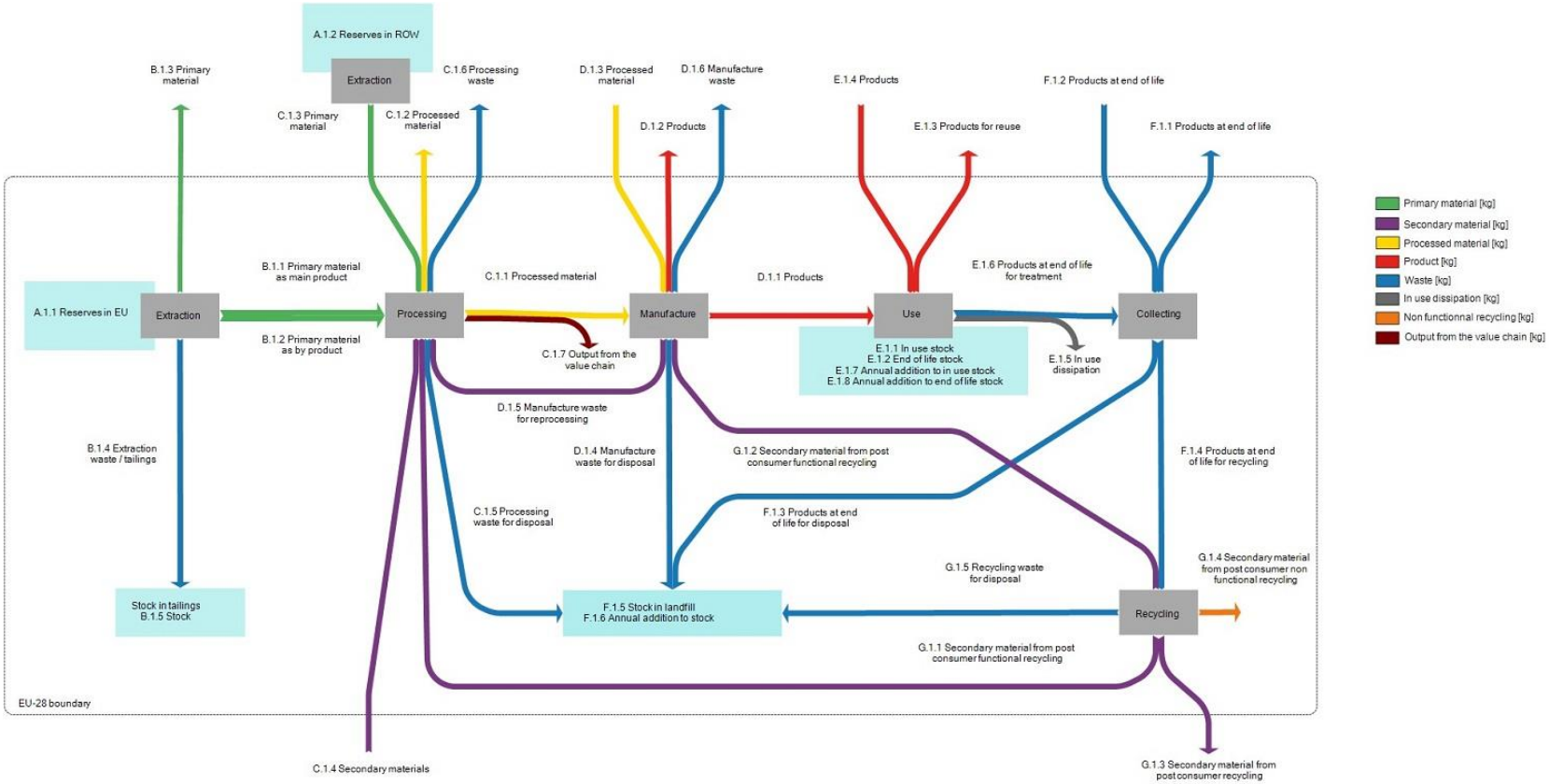
Source: Pehlken 2023. Lecture V01 – Hidden Champions for RE

Critical materials

Global demand and supply

Primary sources → directly obtained from nature, raw materials

Secondary sources → are any processed materials at any stage of the subsequent material use

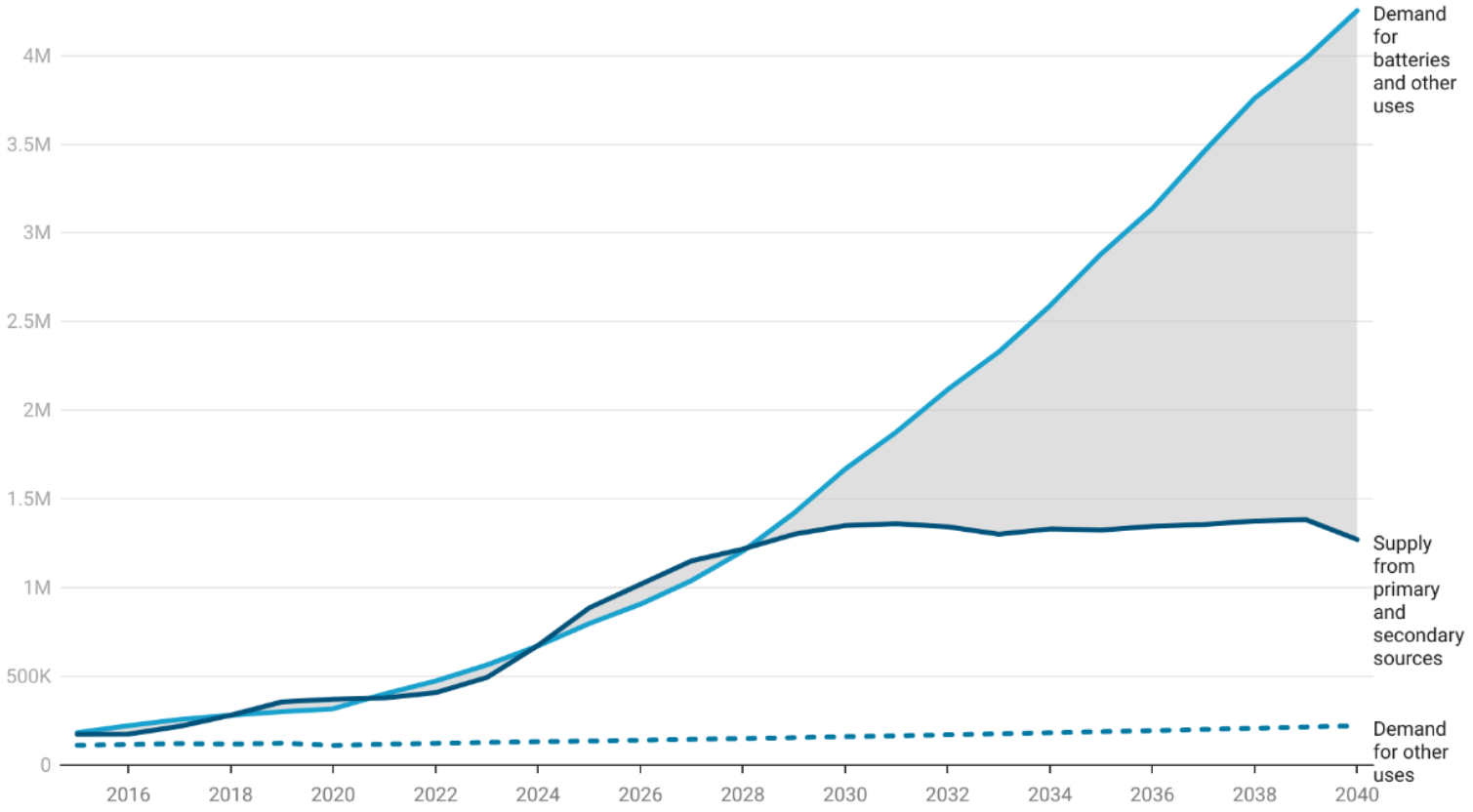


Source: https://rmis.jrc.ec.europa.eu/msa

Critical materials

Global demand and supply
Primary and secondary sources

Forecast of global Supply-Demand balance for **lithium** [t LCE]



Source: RMIS - Battery supply chain challenges (europa.eu)

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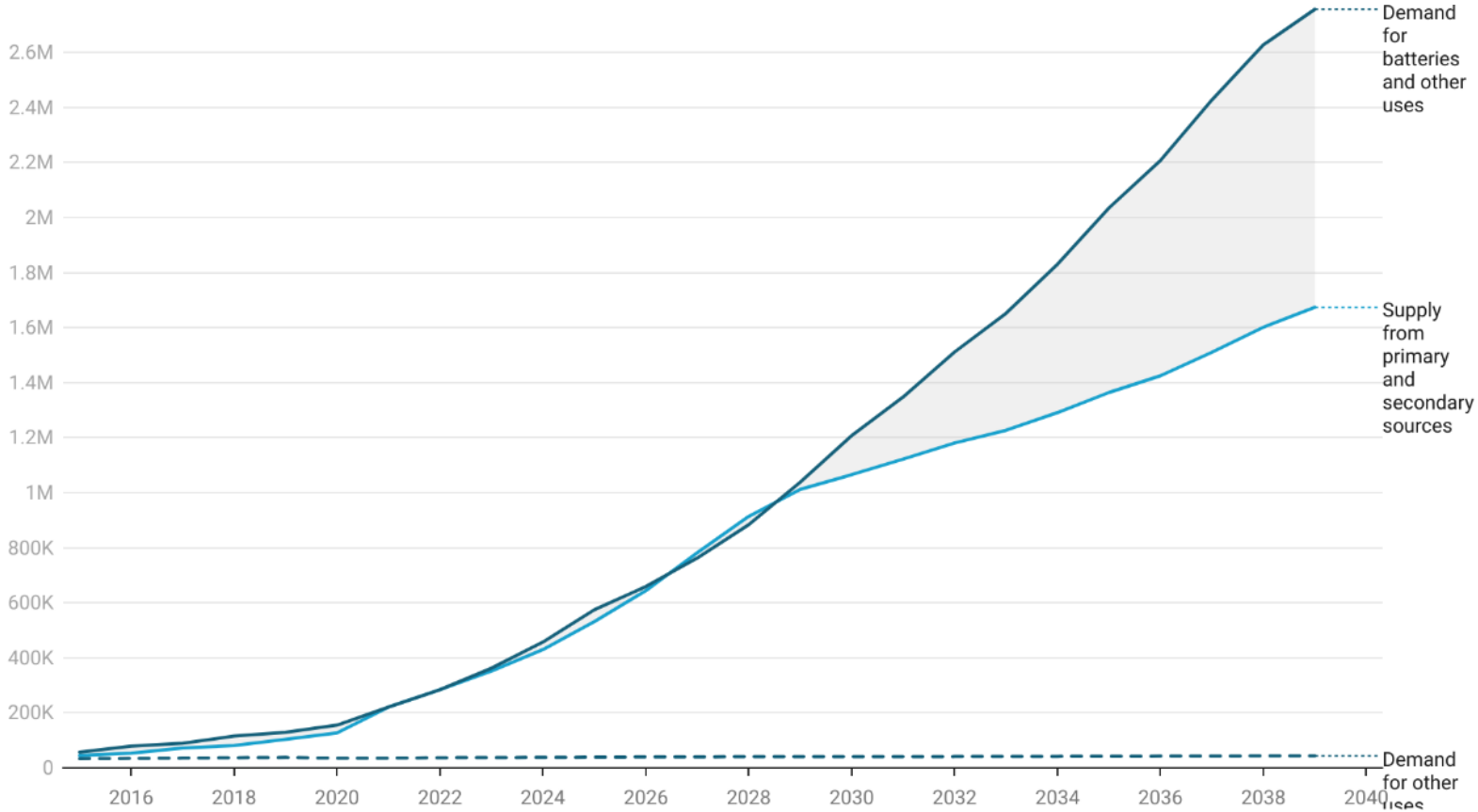
Critical materials

Global demand and supply
Primary and secondary sources

Forecast of global Supply-Demand balance for **nickel** [t]



Source: RMIS - Battery supply chain challenges (europa.eu)

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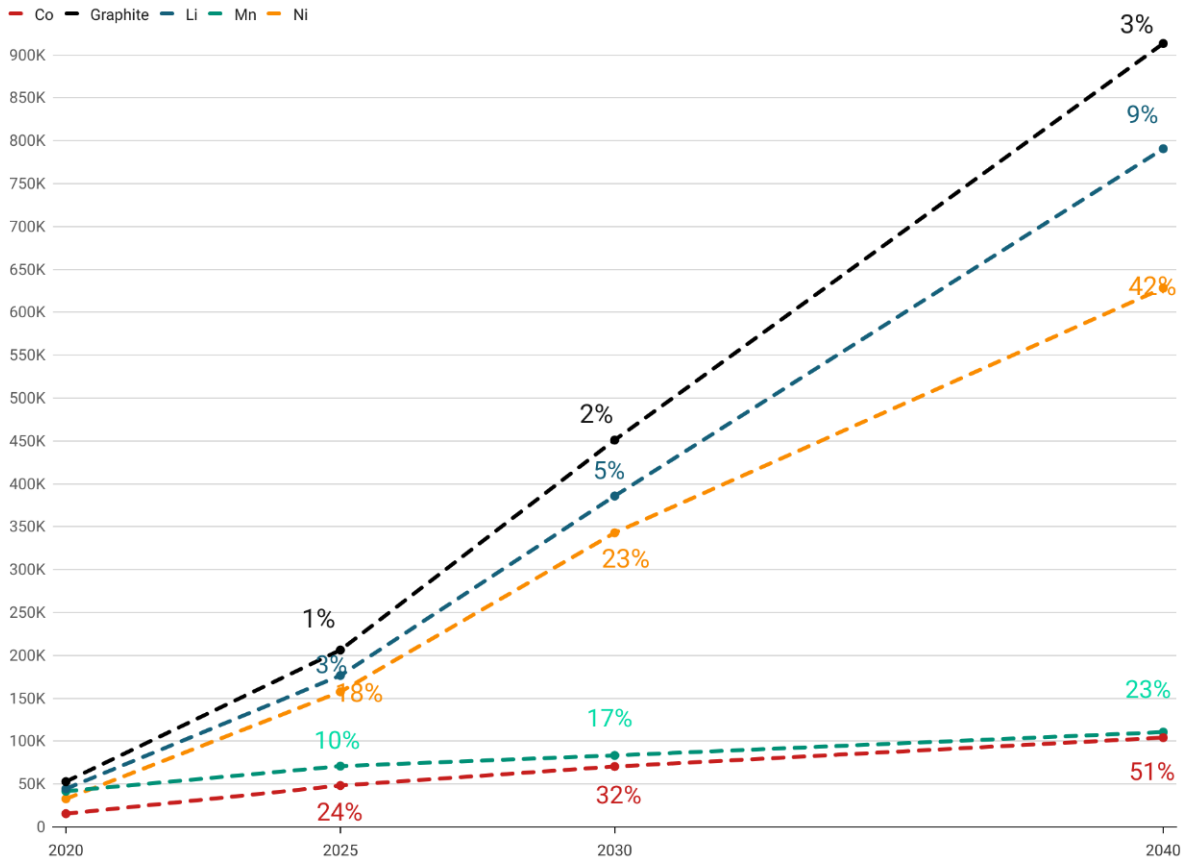
Critical materials

Potential secondary sources

Forecast of global Supply-Demand balance for nickel [t]

Figure 4 – Estimated consumption of battery raw materials [t] and supply potential from secondary raw materials (old+new scrap) [%] in the EU (2020-2040)



Source: RMIS - Battery supply chain challenges (europa.eu)

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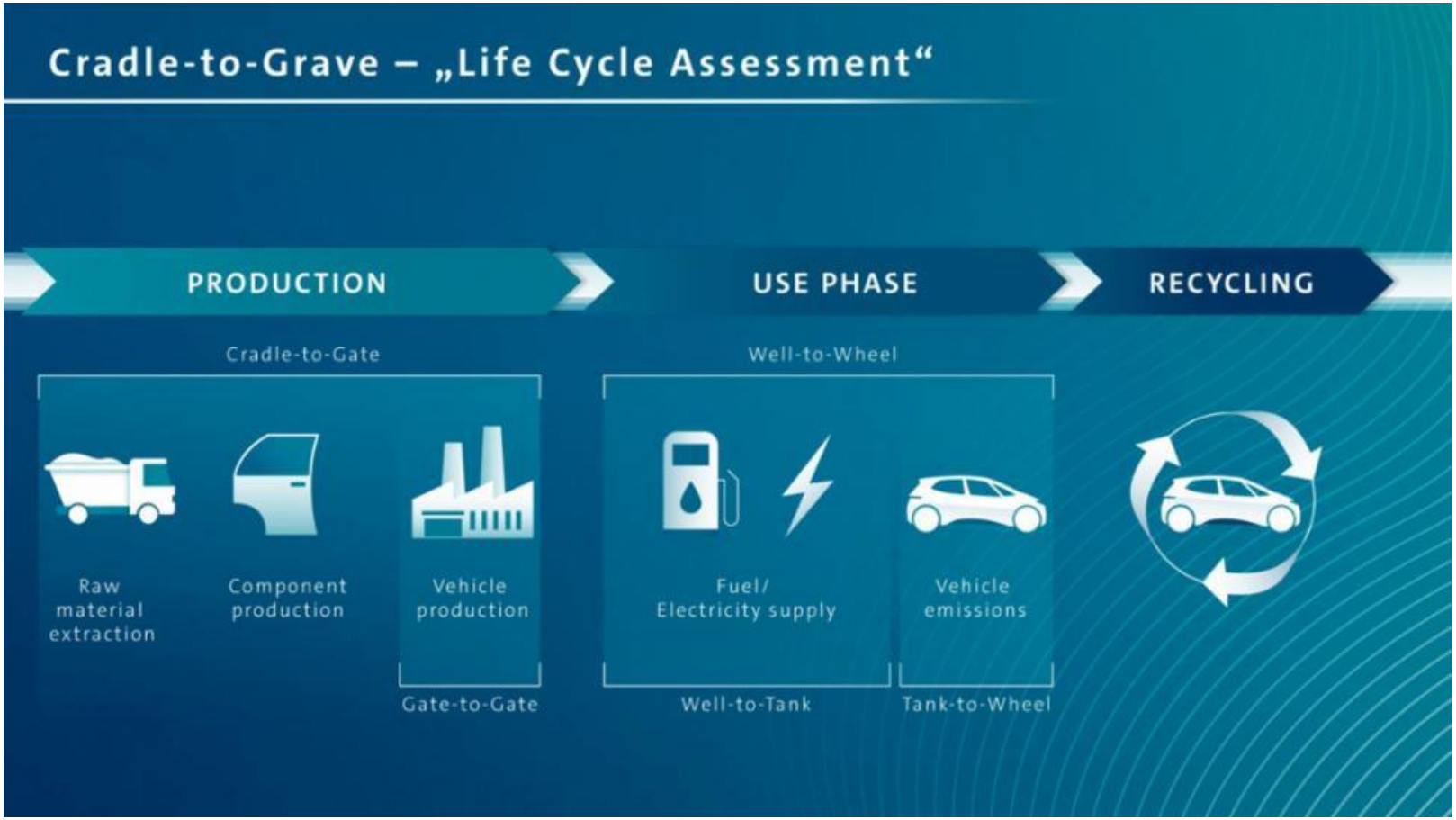
Agenda

- Materials demands for energy transition
- Critical materials
- Ways out
- **Example: electric vehicles**

Critical materials

Example: E-vehicles

Circular Economy



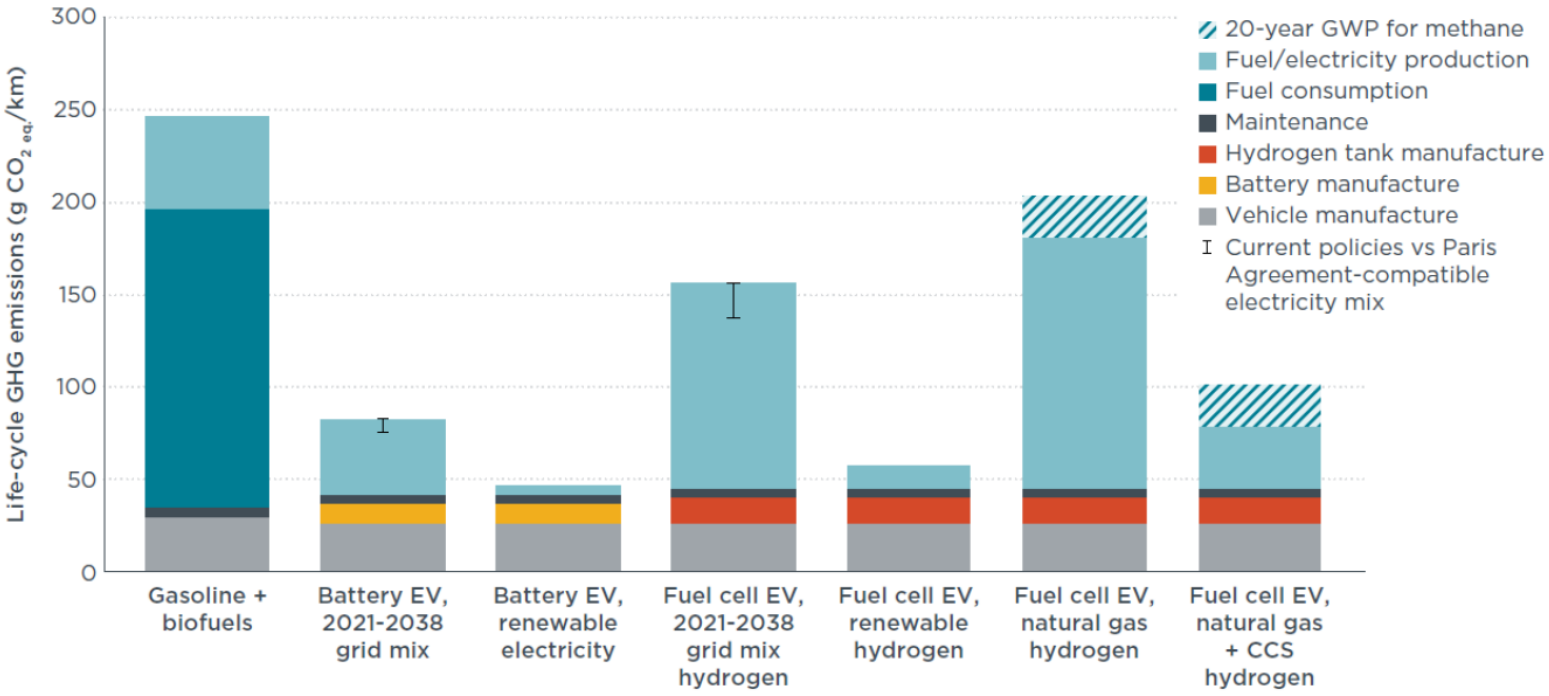
Source: https://www.volkswagengroup.it/ita/media/comunicati-stampa/i-veicoli-elettrici-hanno-il-miglior-bilancio-di-co2

Critical materials

→ Tank-to-wheel analysis

Example: E-vehicles

Circular Economy



Reference: ICCT WHITE PAPER, GLOBAL COMPARISON OF THE LIFE-CYCLE GREENHOUSE GAS EMISSIONS OF PASSENGER CARS, 2021

Source: Pehlken 2023. Lecture V02 – Hidden Champions for RE

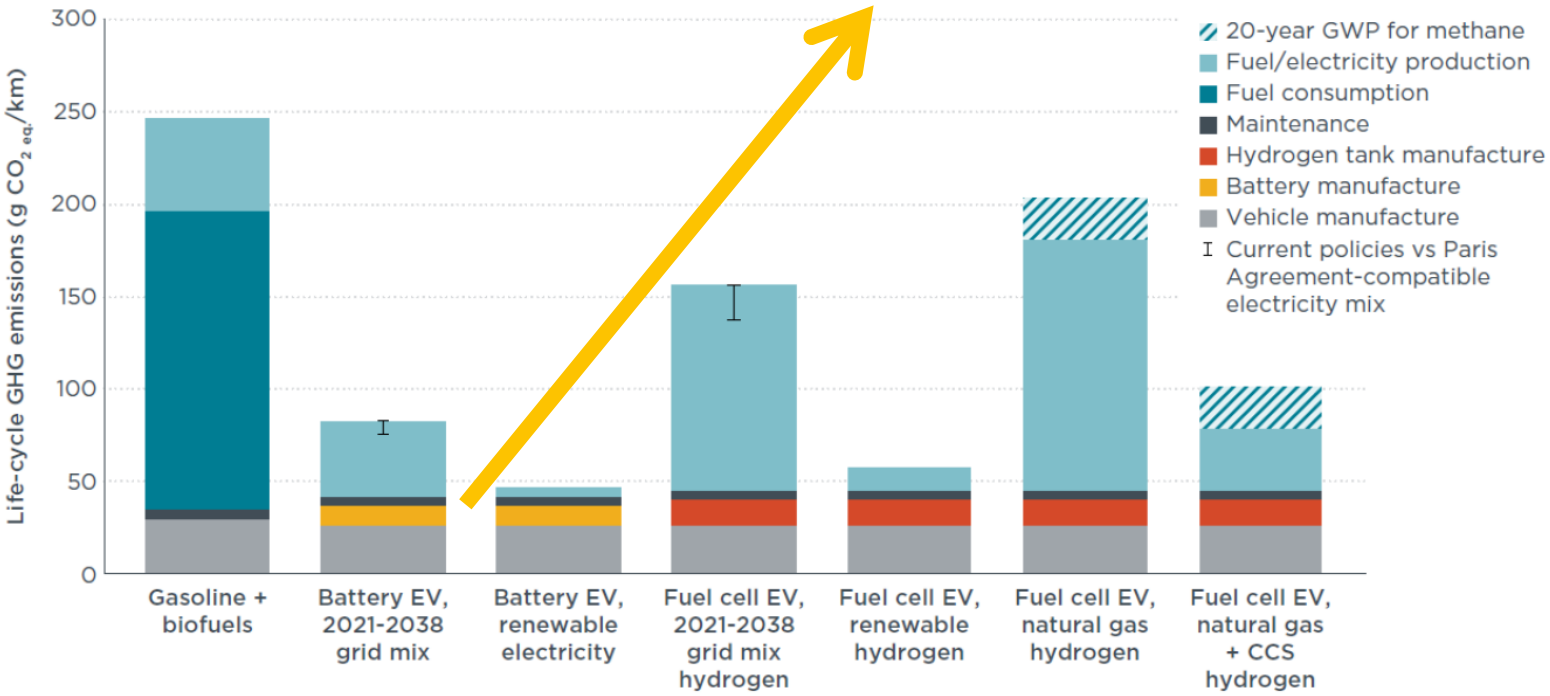
Critical materials

Example: E-vehicles

Circular Economy

→ Tank-to-wheel analysis

→ CO2 is not the only relevant indicator!



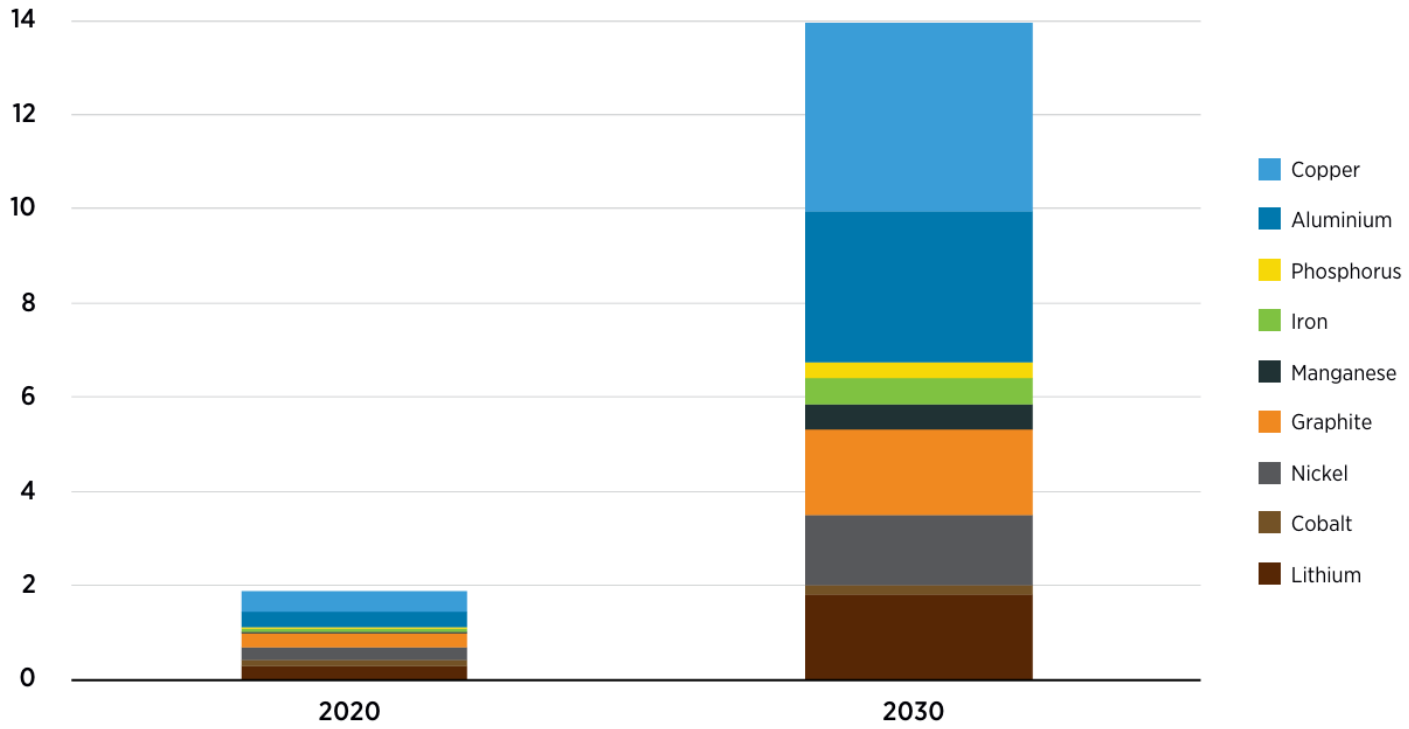
Reference: ICCT WHITE PAPER, GLOBAL COMPARISON OF THE LIFE-CYCLE GREENHOUSE GAS EMISSIONS OF PASSENGER CARS, 2021

Source: Pehlken 2023. Lecture V02 – Hidden Champions for RE

Critical materials

Example: E-vehicles

Projections of demand for **battery** materials (IRENA 2022)



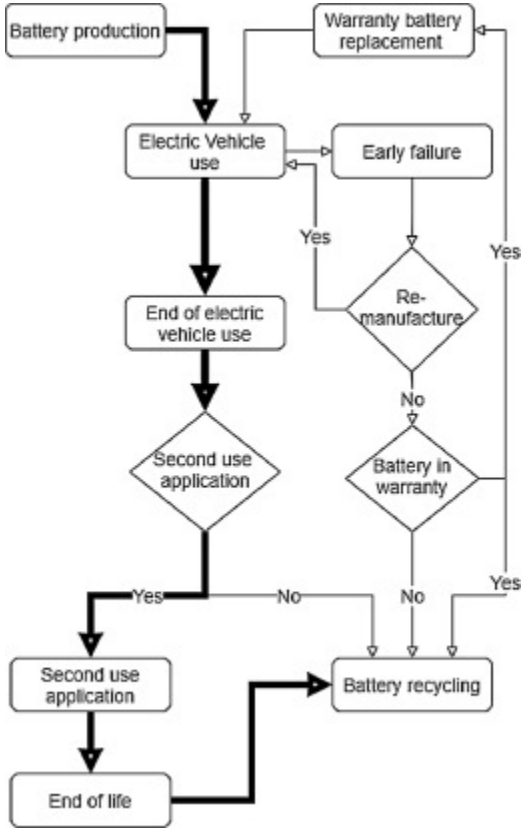
Adapted from: BloombergNEF, 2021a.

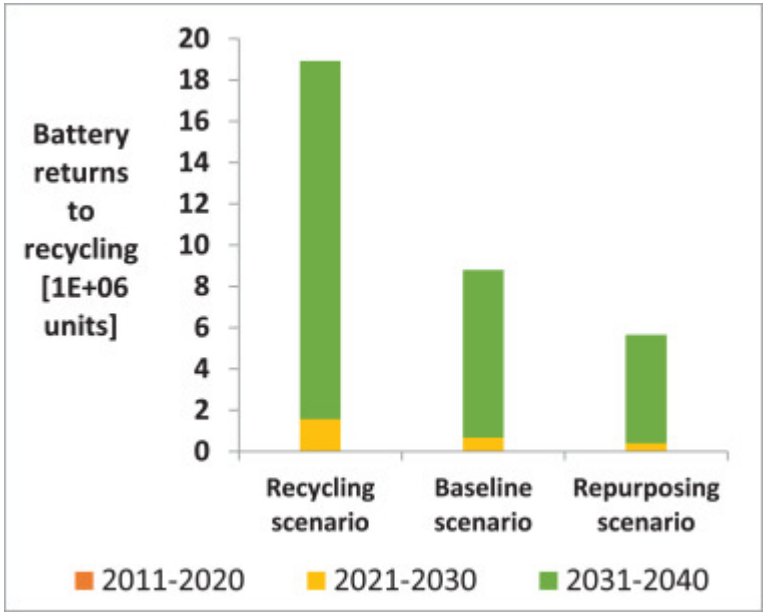
Source: Pehlken 2023. Lecture V02 – Hidden Champions for RE

Critical materials

Example: E-vehicles

Second-life, reusing, refurbishing and recycling…
…for battery materials



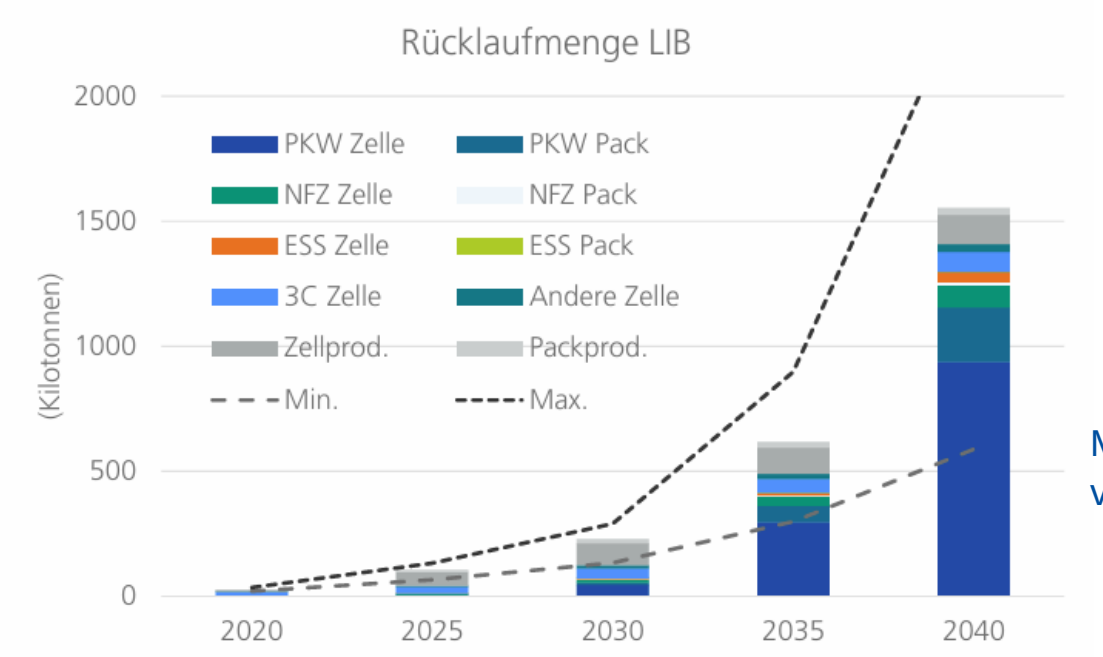


Source: *Forecasting the EU recycling potential for batteries from electric vehicles.* https://doi.org/10.1016/j.procir.2020.01.109 , 2020.

Critical materials

Example: E-vehicles

Second-life, reusing, refurbishing and recycling…
…for battery materials



Mostly e-vehicles!

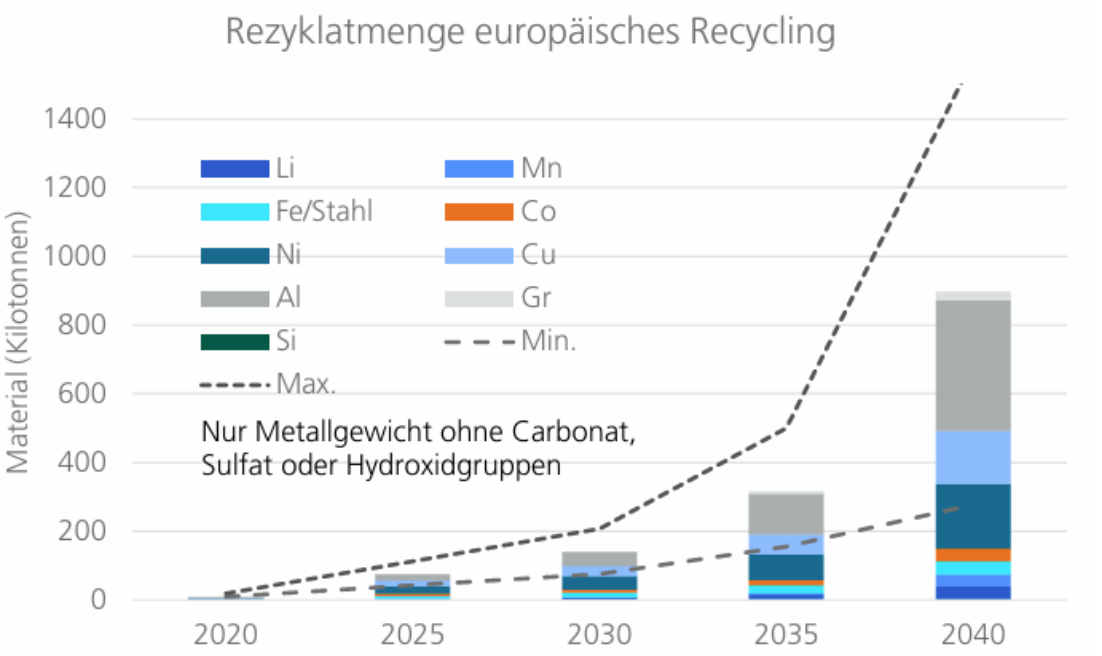
Abbildung 4: Prognose zur Rücklaufmenge gebrauchter LIB aus unterschiedlichen Anwendungen (PKW, Nutzfahrzeuge: NFZ, stationäre Speicher: ESS, „Computing, consumer, communication“: 3C) und von Zellproduktionsschrotten in ein europäisches Recycling. Die Balken bilden das Basis-Szenario ab.

Source: https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2021/VDMA_Kurzstudie_Batterierecycling.pdf

Critical materials

Example: E-vehicles

Second-life, reusing, refurbishing and recycling…
…for battery materials



Li… ☹

Abbildung 6: Entwicklung von Rezyklatmengen aufgeteilt nach unterschiedlichen Metallen und Rohstoffen bis 2040. Die Balken bilden das Basis-Szenario ab.

Source: https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2021/VDMA_Kurzstudie_Batterierecycling.pdf

Critical materials

Example: E-vehicles

Recycling processes and their outcomes

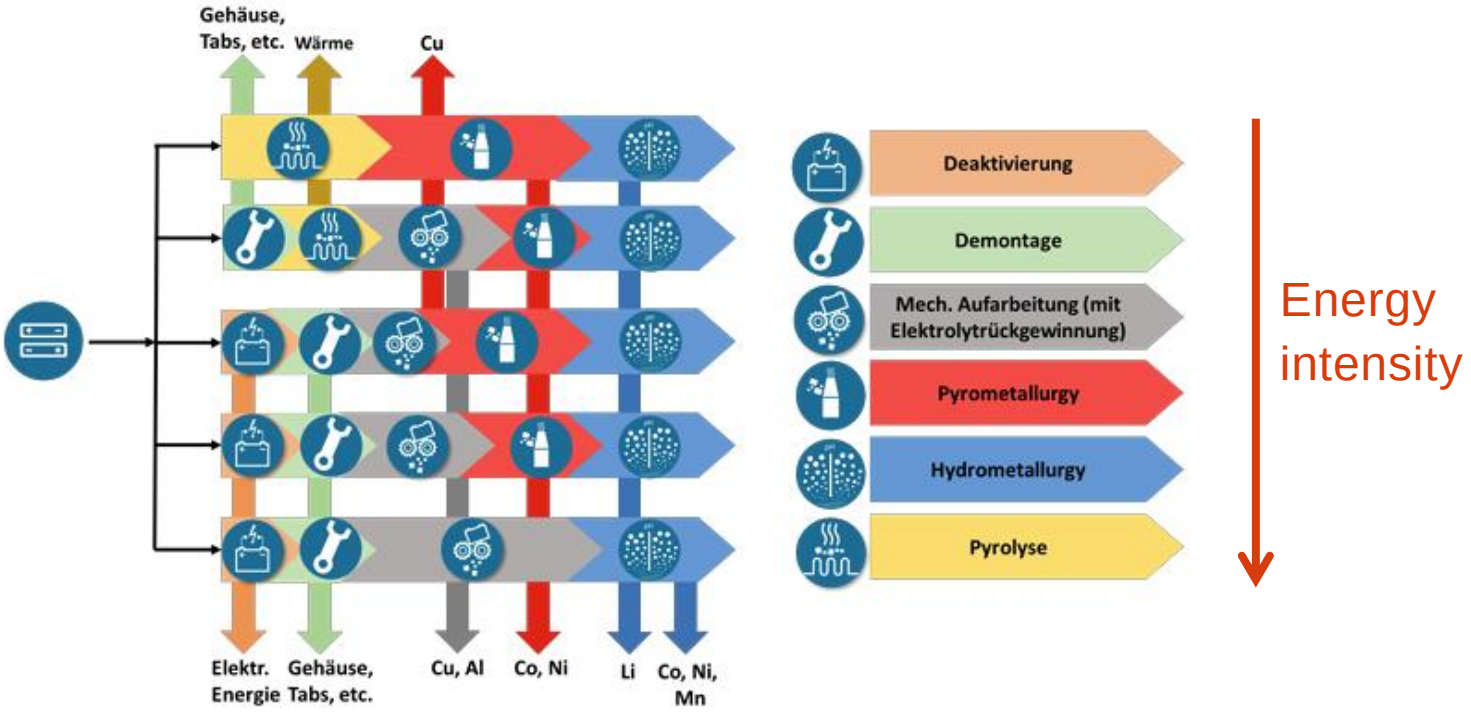


Abbildung 8: Mögliche Prozessrouten des Recyclings von Lithium-Ionen-Batterien. [Doose2021]

Source: https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2021/VDMA_Kurzstudie_Batterierecycling.pdf

Critical materials

Take aways

- **Critical materials** (amount or origin) are required for many technologies within the energy transition:
  - Wind, PV, batteries, smart-grids
- Demands for these materials are expected to „sky-rocket“ as compared to current demands
- **Depletion times** in the range of a decade for future demands and current reserves!
- Recycling and second life:
  - Possible but:
    - Energy intensive!
    - Low recyclability rates for some materials
    - Potential for yearly supplies from recycling processes in the EU: 40% for Cobalt and ca. 15% for Lithium, Nickel und Copper for new batteries.