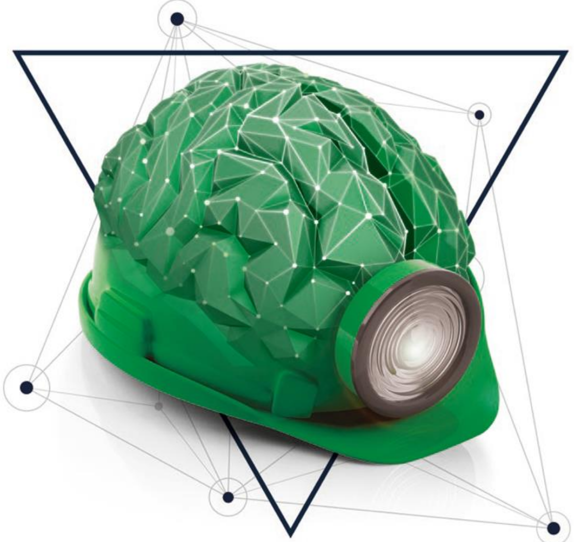
# DIM ESEE-2 innovative workshop

**Dubrovnik 20-22nd of Nov. 2021**



# Innovative solutions and challenges in underwater spaces: sensor development, robotization

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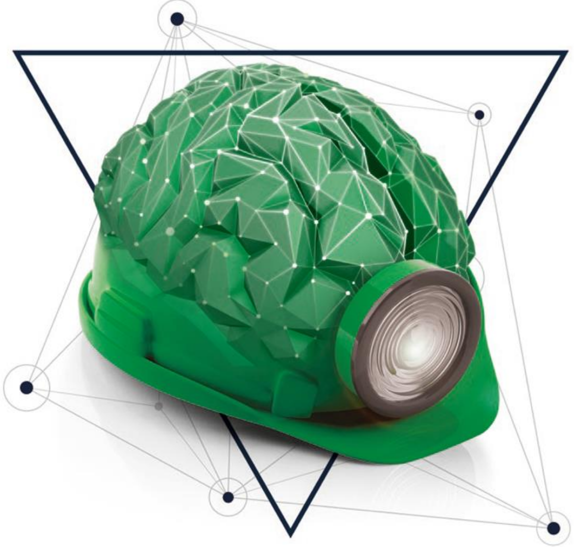

## Why we need solutions for underwater exploration and mining in responsible raw material supply in the future?

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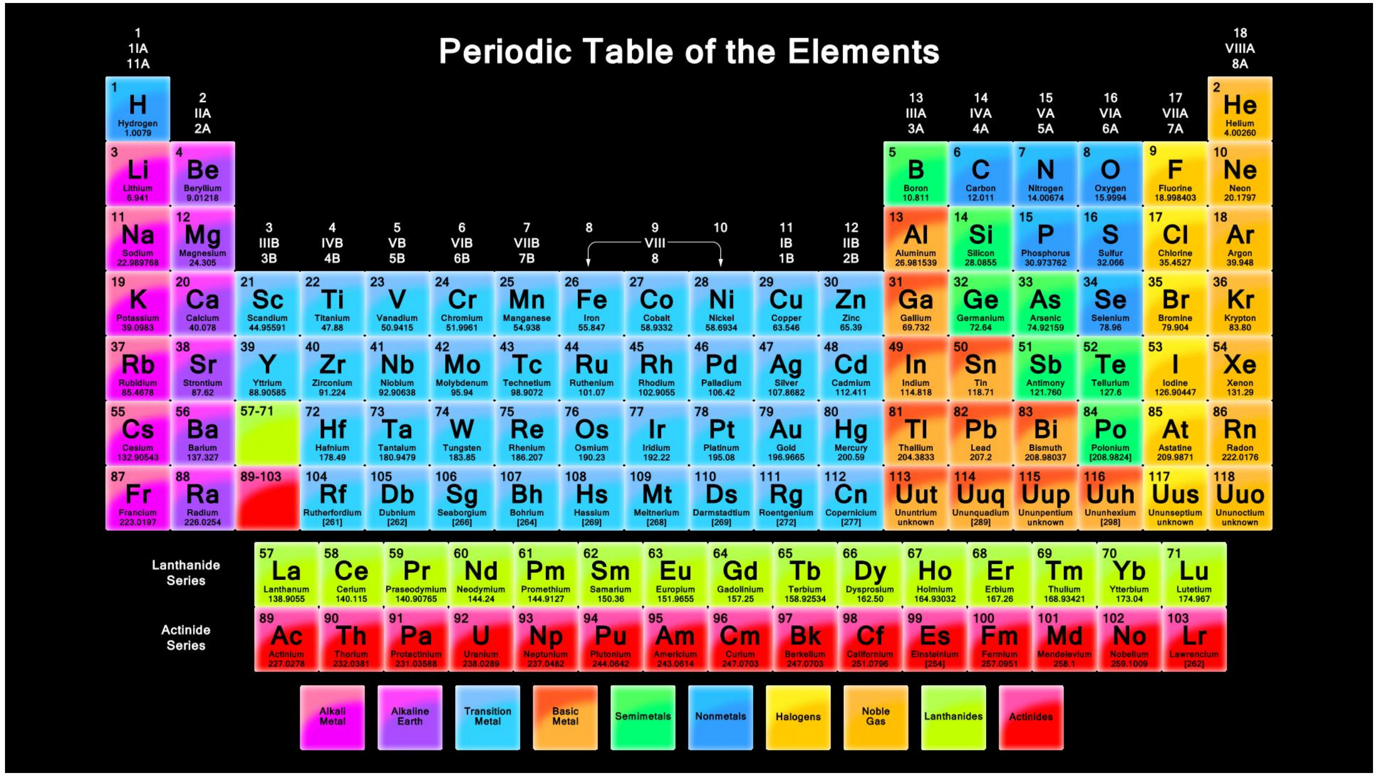
# Where are the things come from?

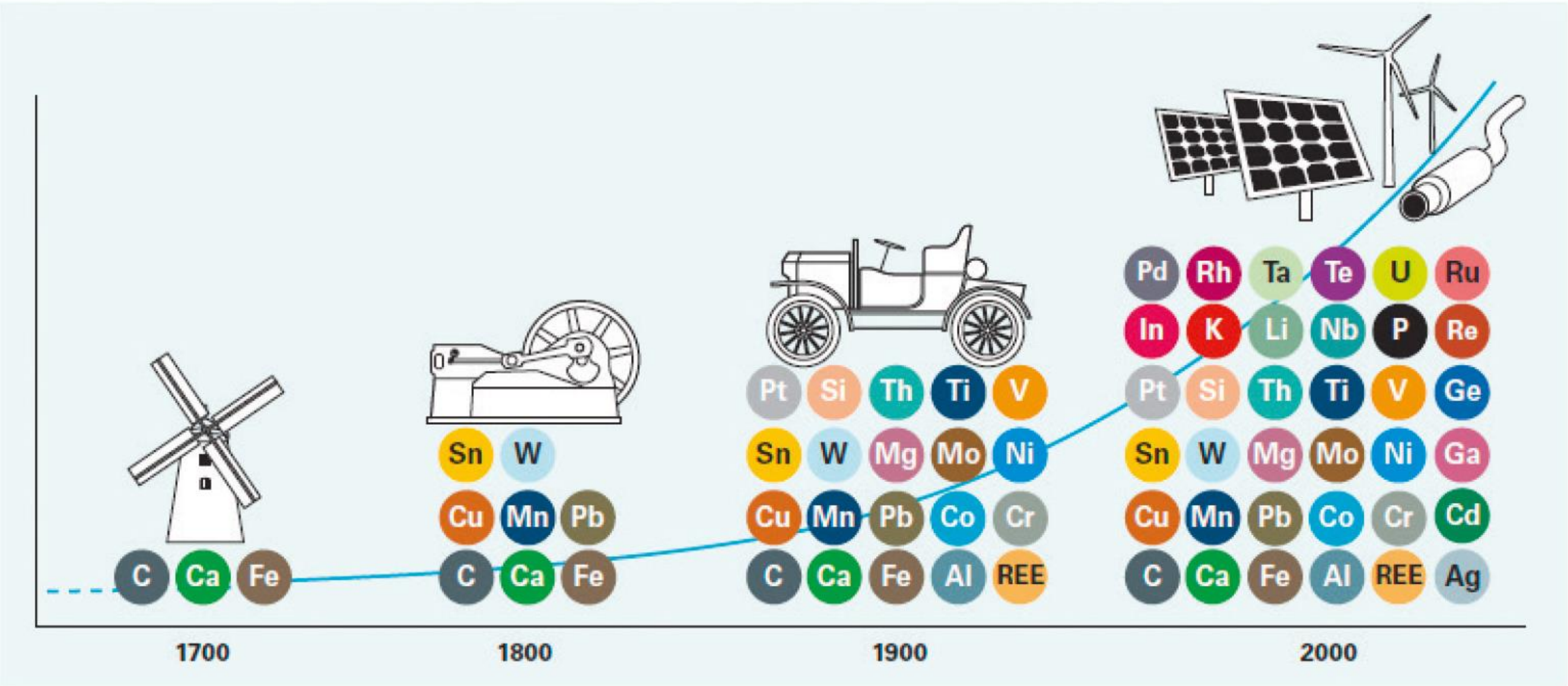



Almost everything comes from minerals

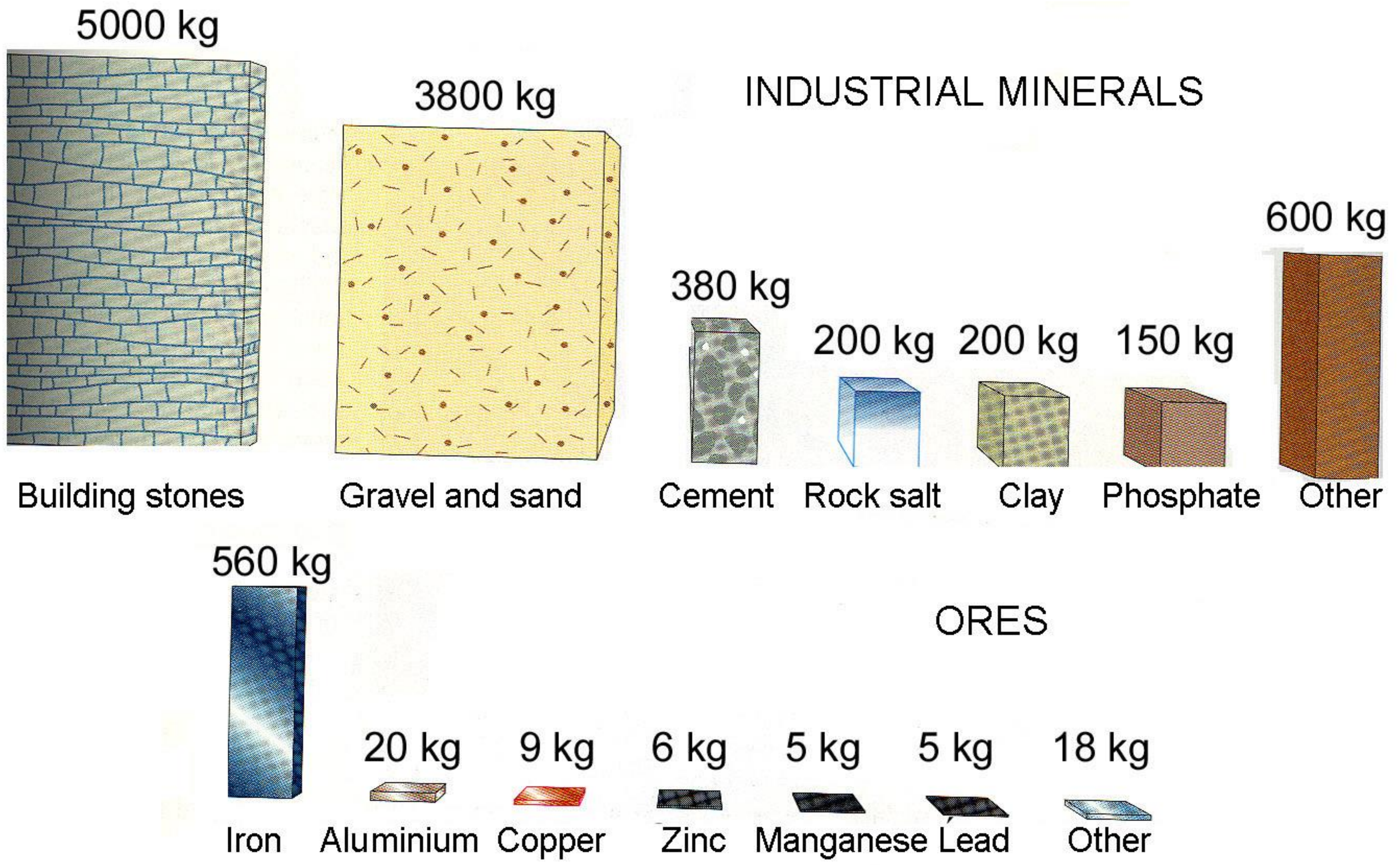
Where the minerals come from? → mining

# How many elements the humankind used in history (for energy)?

Figure 2: Materials widely used in energy technologies (1700-2000)[1]

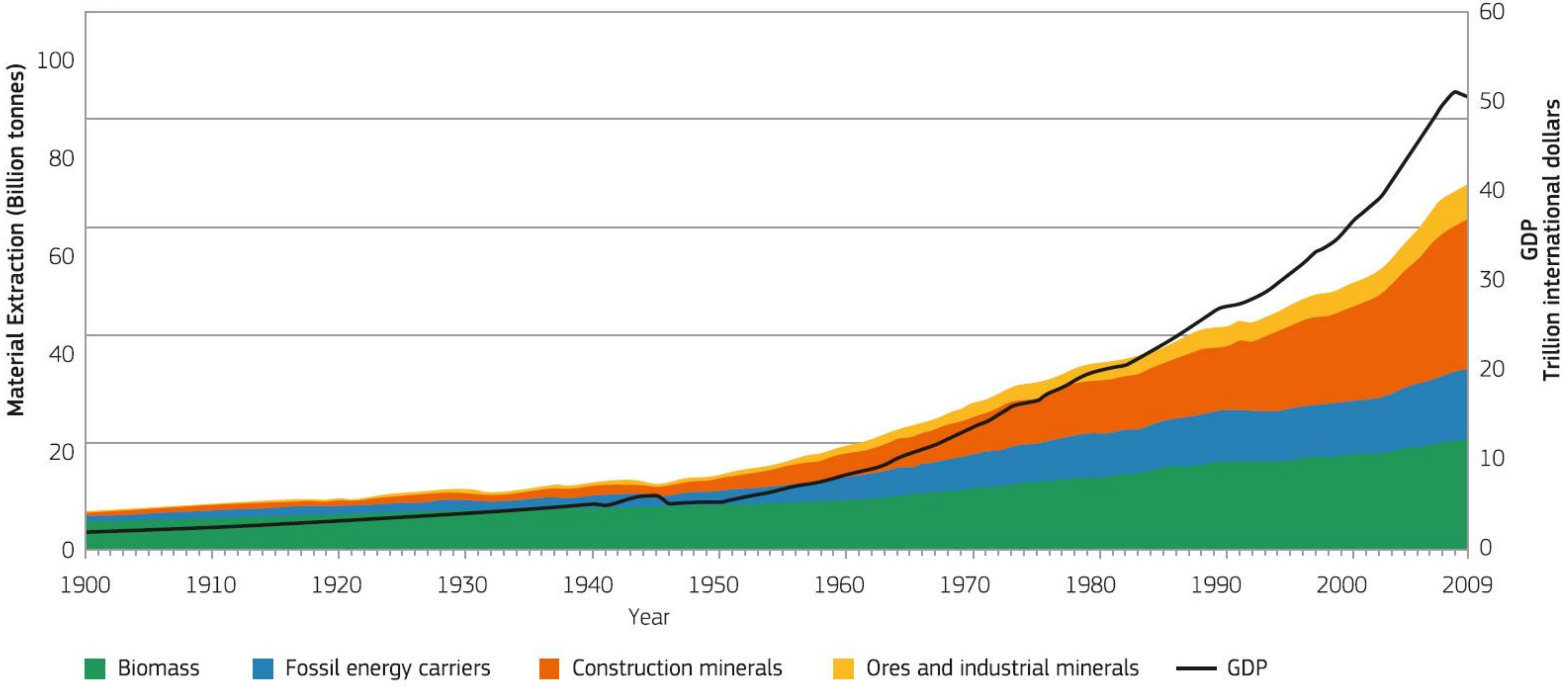


# Mineral consumption/ capita/year



# Global raw material extraction

Figure 3: Global material extraction by resource type and GDP (1900-2009)[4]



# E-mobility raw materials predictions 2030/2050

Figure 9. EU fleet of electric vehicles containing batteries according to the three explored scenarios

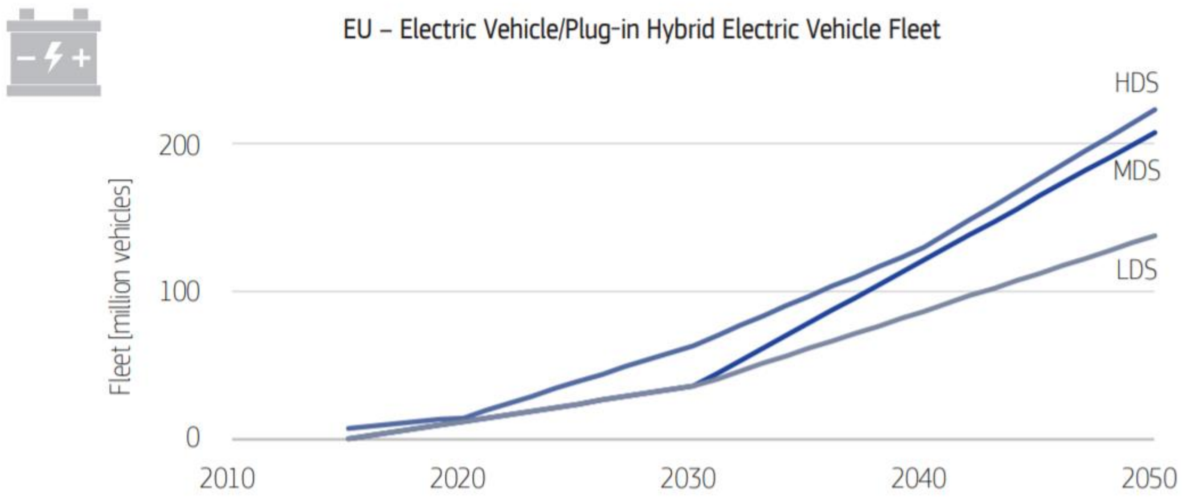
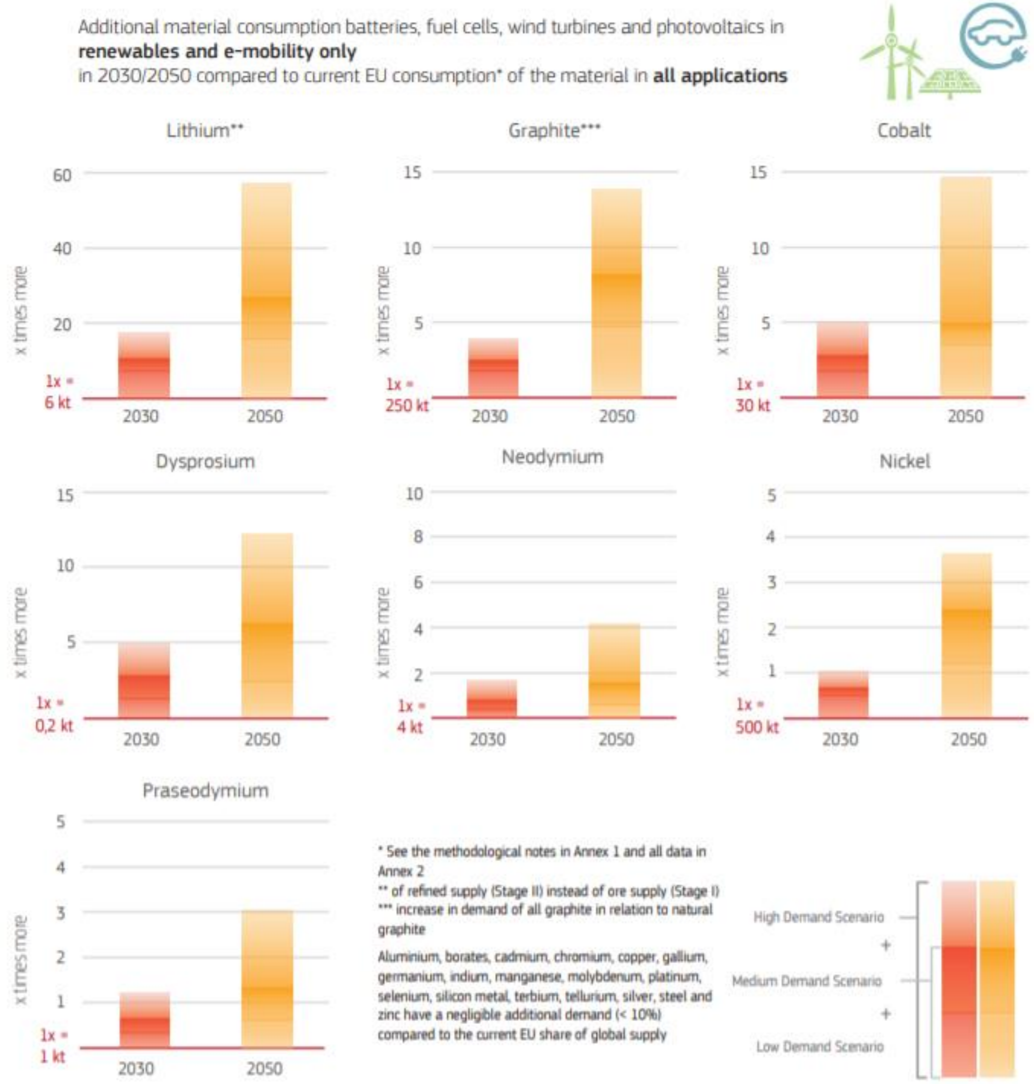
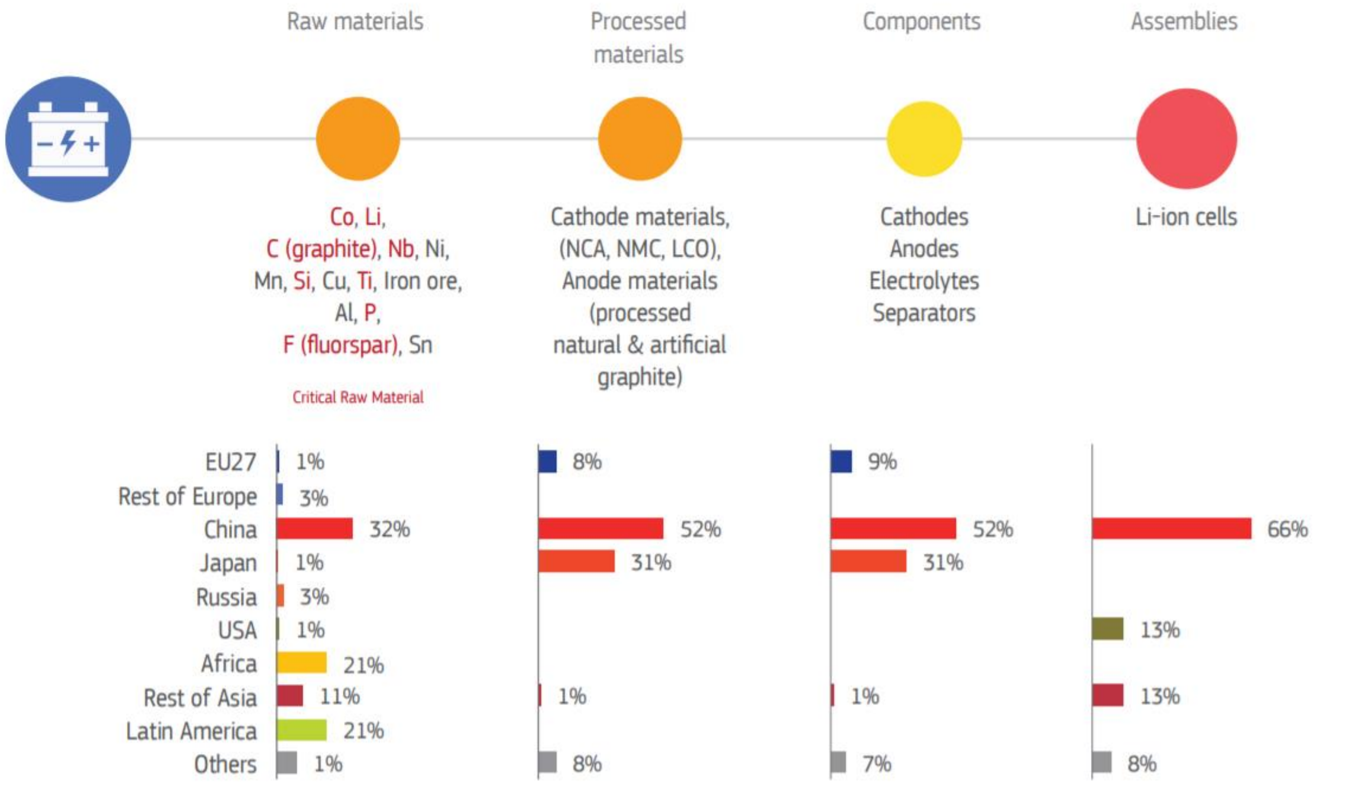



Figure 1. Combined critical raw materials use in different technologies in the EU in 2030 and 2050



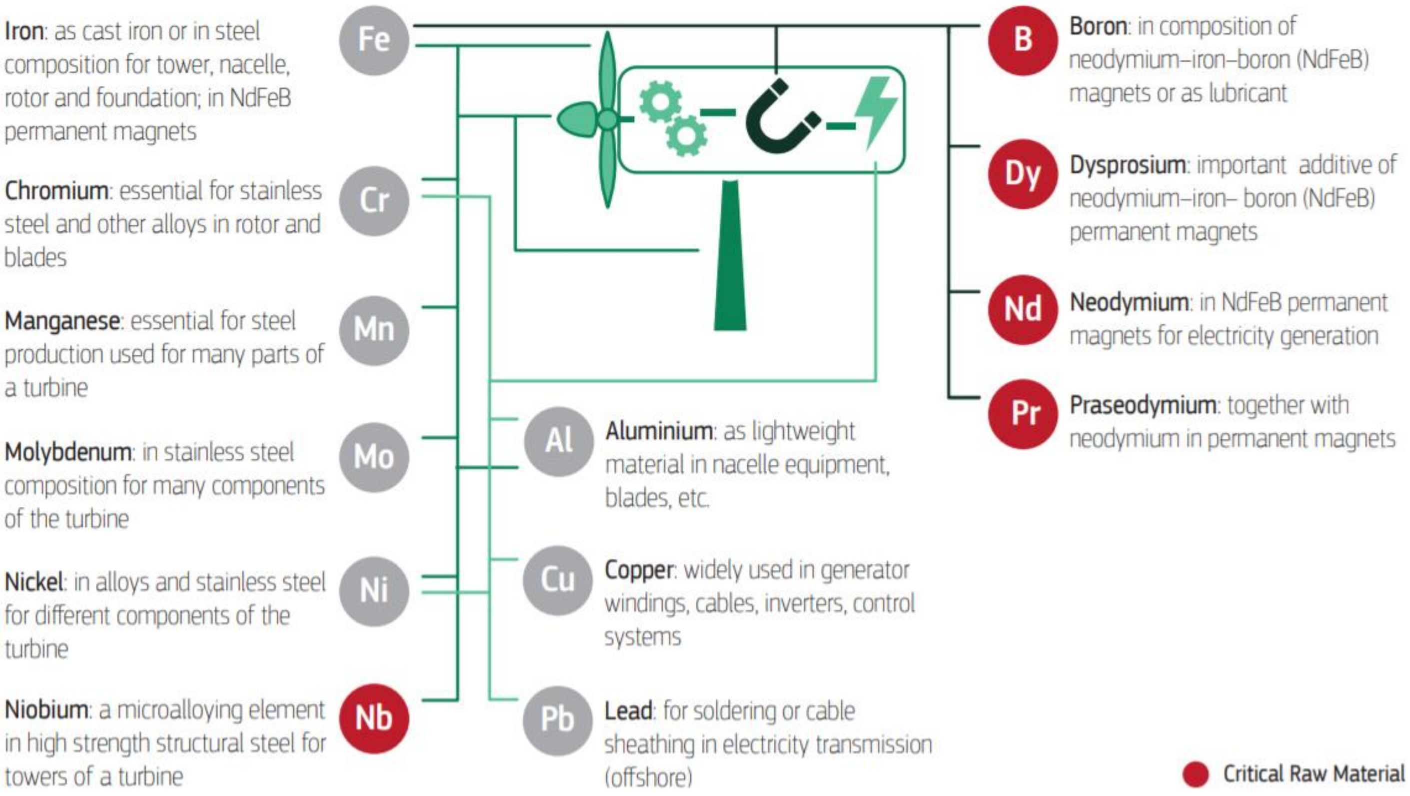
# E-mobility raw materials predictions 2030/2050

**Figure 8.** Li-ion batteries: an overview of supply risks, bottlenecks and key players along the supply chain. (See the Glossary for the acronyms used)



# Raw material need of wind turbines

Figure 18. Raw materials used in wind turbines



# Raw material need of defence industry

Figure 57. Relevant raw materials used in defence applications.

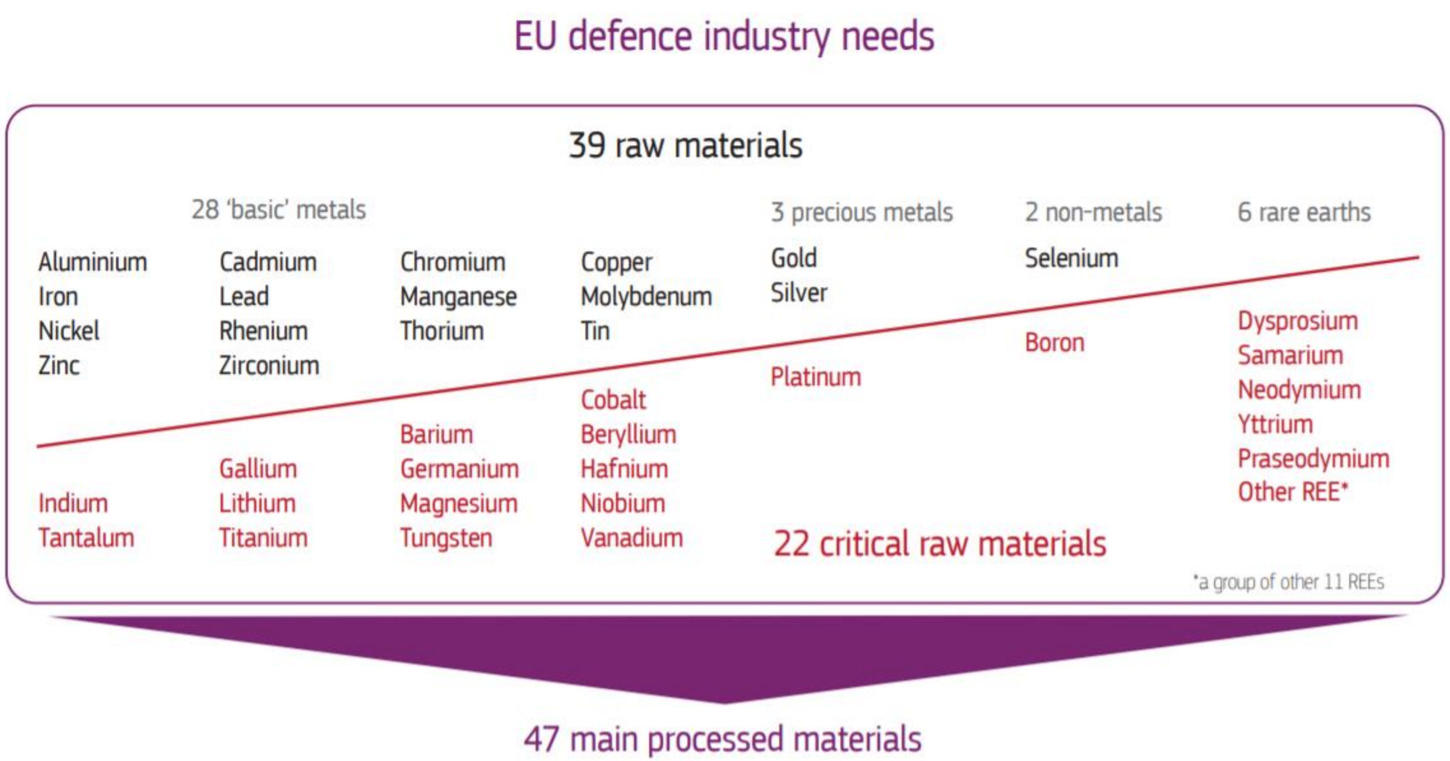
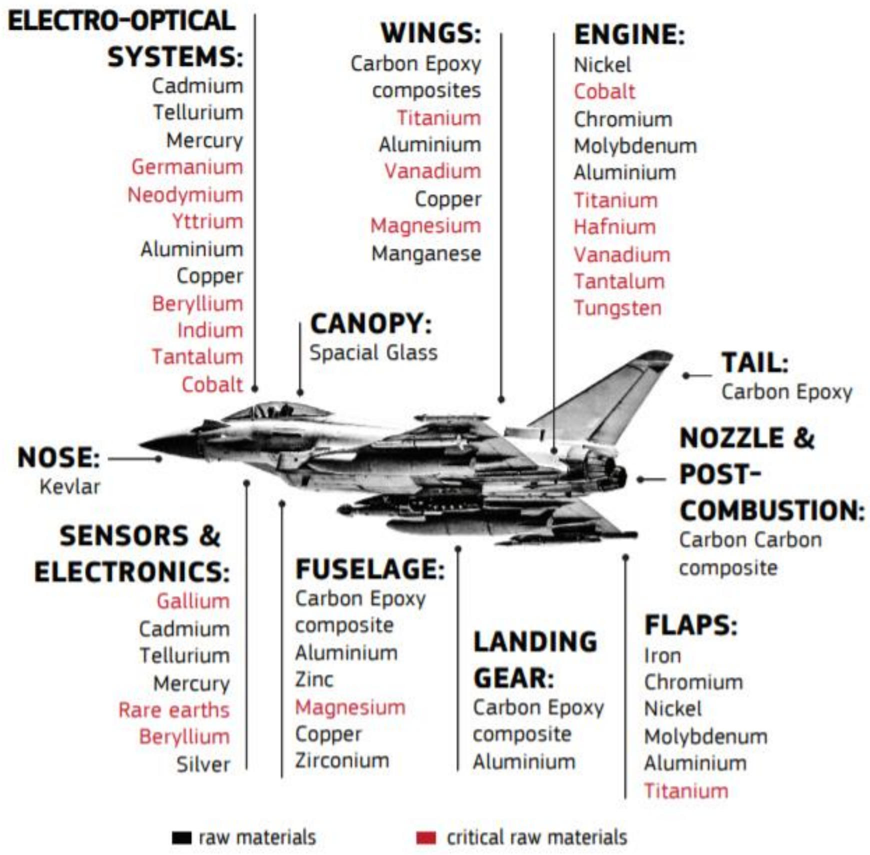
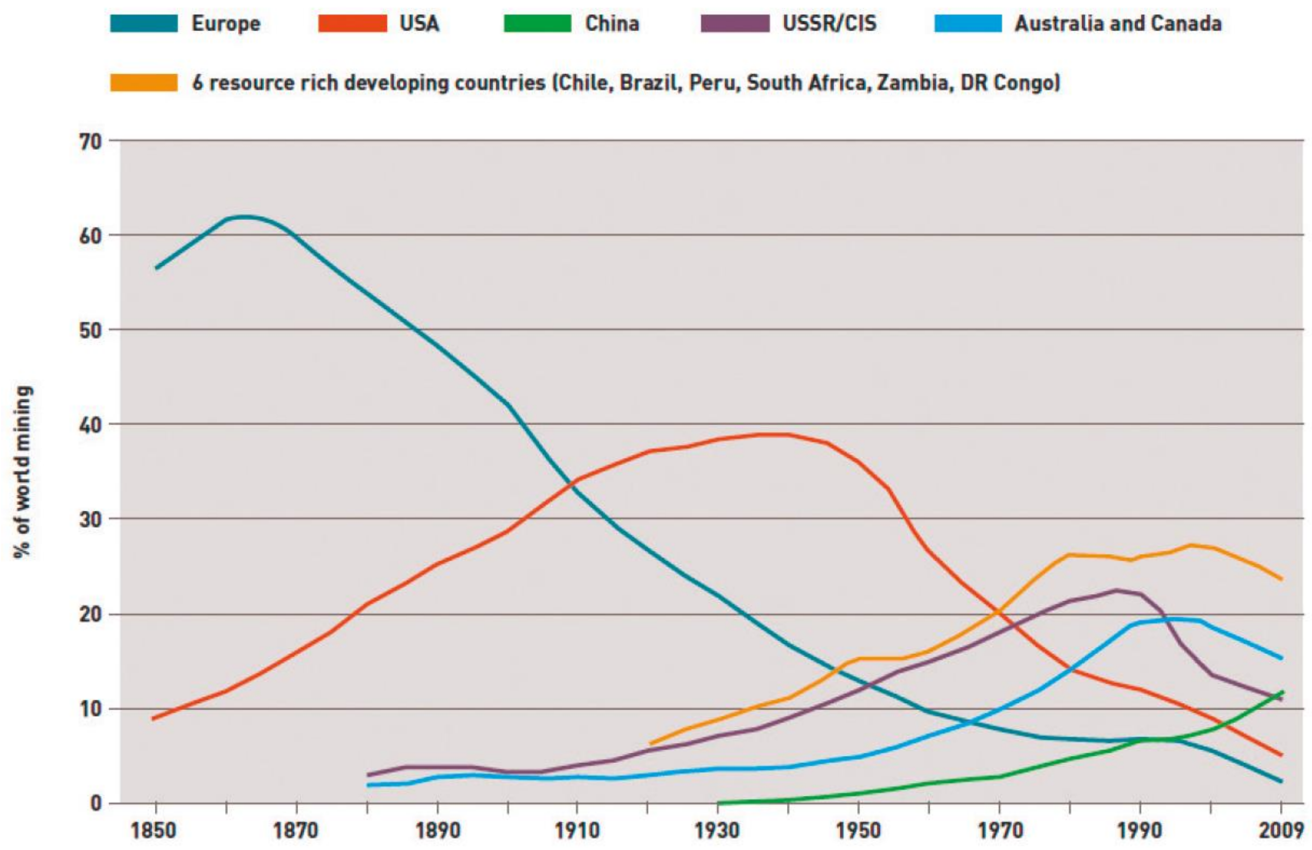



Figure 60. Materials used in different parts of the combat aircraft Rafale



# Where the humankind mined in history

Figure 9: Share of world metals mining by world region (1850-2009)[38]



# Raw materials supply risks / problems

## 96% of the raw materials are imported to EU

If (the majority of) the international trade of a raw material is controlled by one or few maybe even unreliable countries… **REE embargo of China**!!

Conflict minerals

**ColTan, Congo**
**Diamond Sierra Leone**

Isotope measurements, etc…

**COVID19 situations….**

Not help consolidated international raw material supply

**EU Raw Material Initiative (2008) →** Criticality assessment of raw materials supply regularly

# Economic importance and supply risk results of 2020 criticality assessment

Figure 2. Semi-quantitative representation of flows of raw materials and their current supply risks to the nine selected technologies and three sectors (based on 25 selected raw materials, see Annex 1 – Methodological notes)

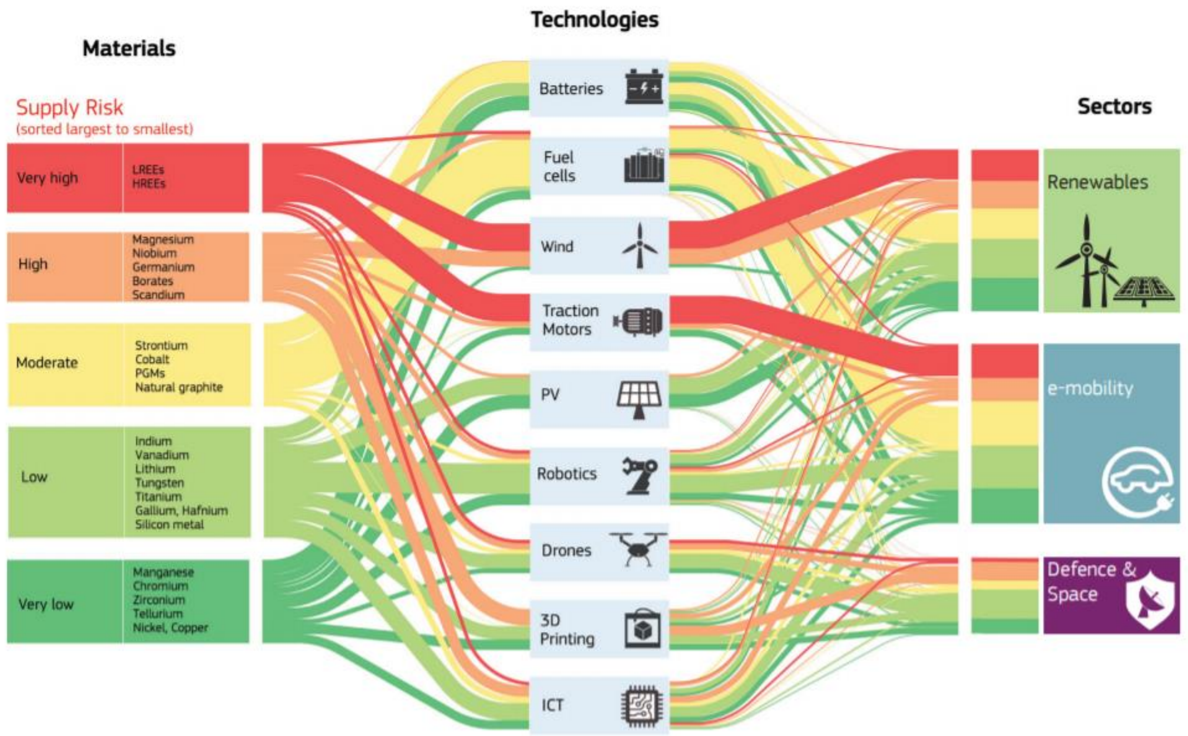
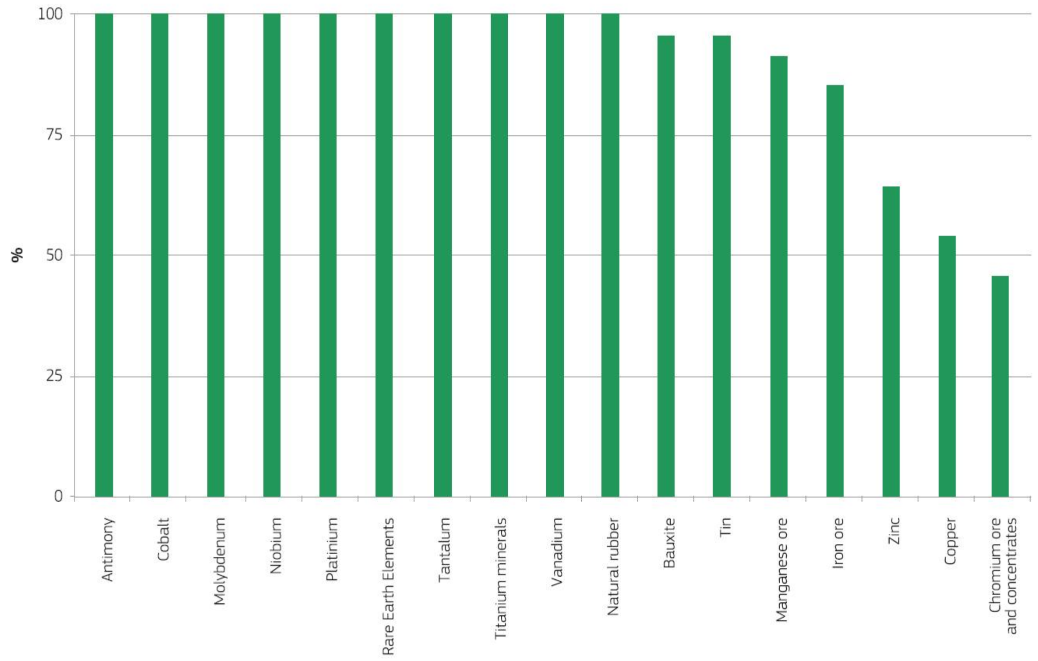
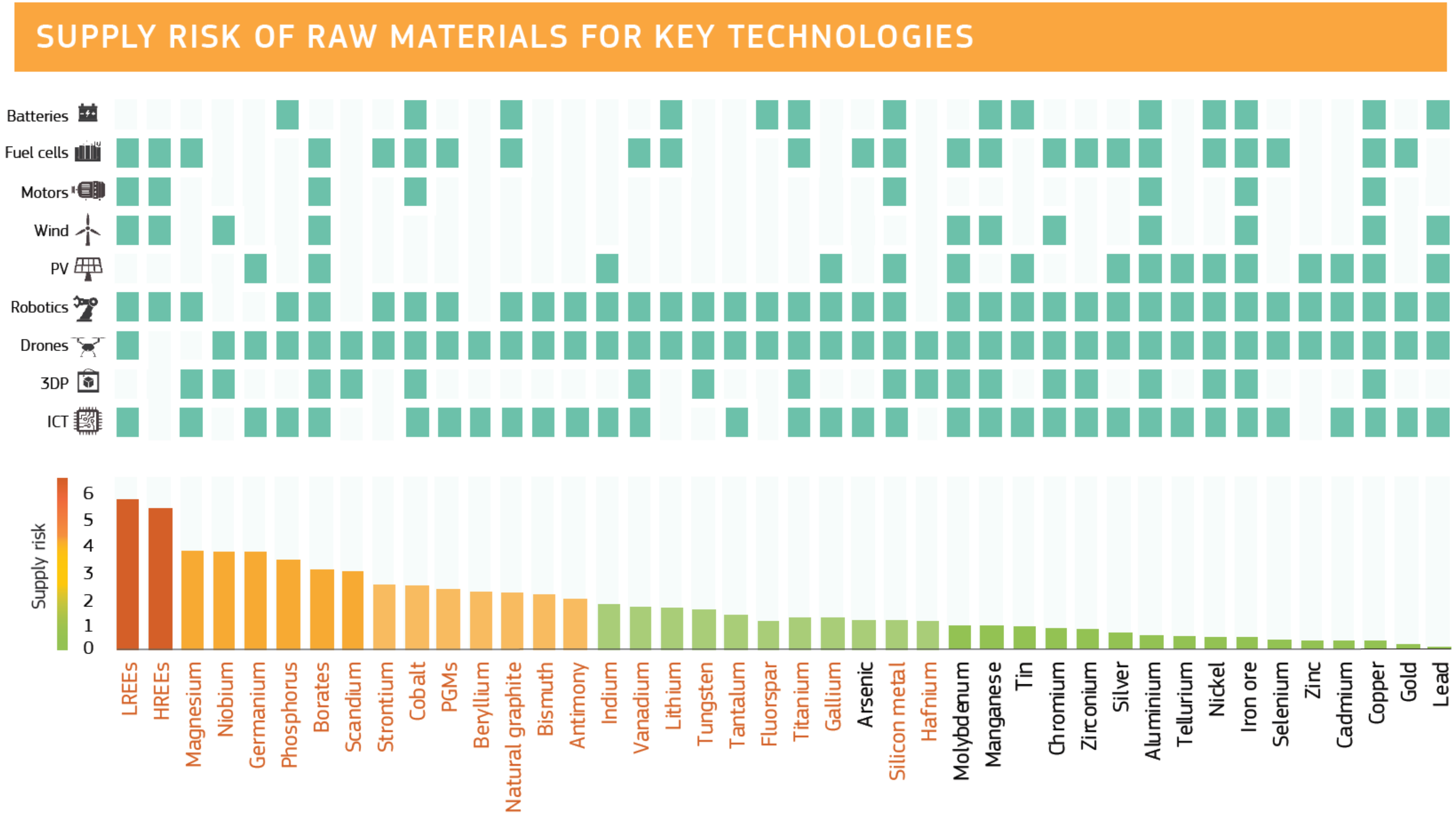


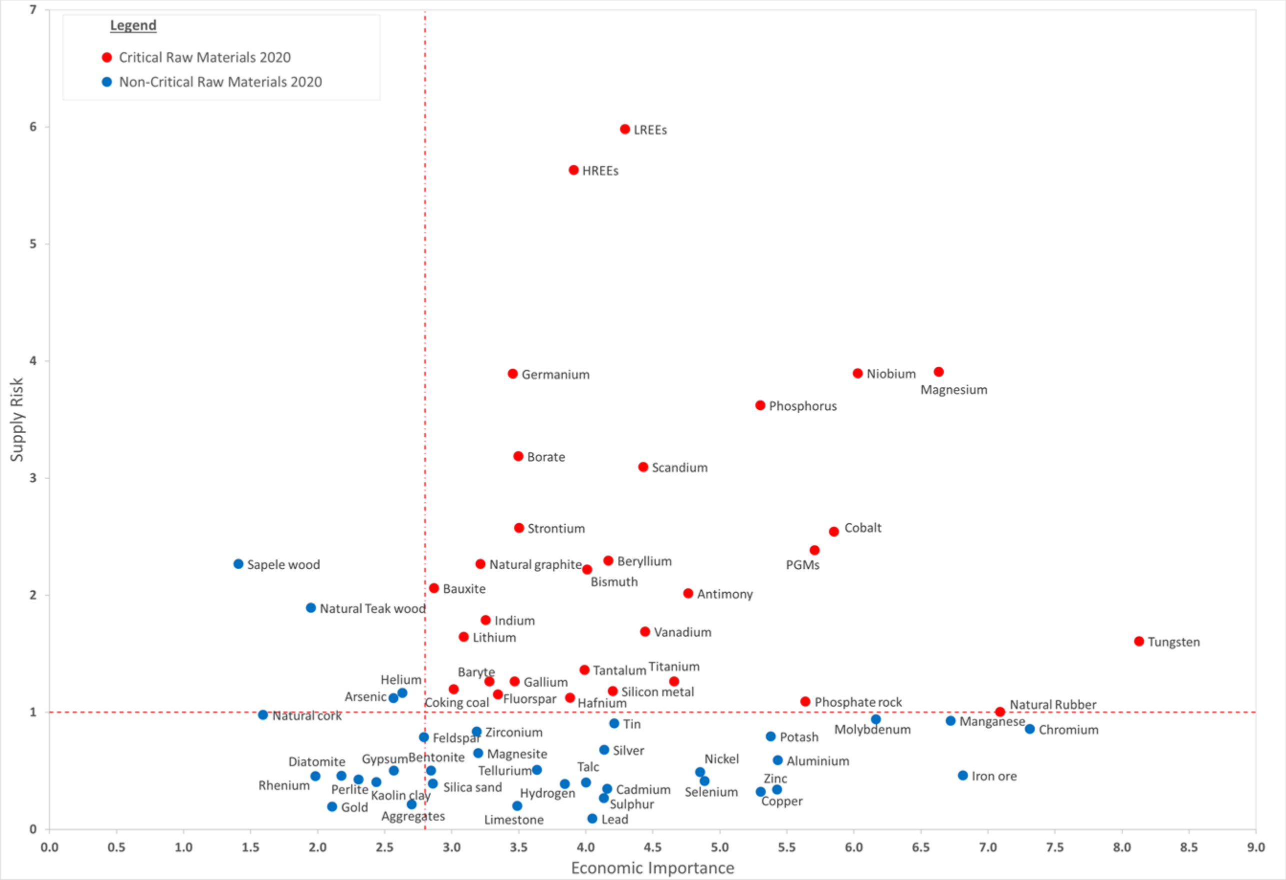

Figure 12: Import dependence for selected raw materials[53]



# Economic importance and supply risk results of 2020 criticality assessment



# Economic importance and supply risk results of 2020 criticality assessment




Introduced list of 14 Critical Raw Materials (CRM) in 2010
updated 20 CRMs in 2014
updated 27 CRMs in 2017

## Updated 30 CRMs in 2020

**2020 CRM list:**

Antimony, Baryte, Bauxite, Beryllium, Bismuth, Borates, Cobalt, Coking coal, Fluorspar, Gallium Germanium, Hafnuim, HREEs Indium, Lithium, LREEs, Magnesium, Natural graphite, Natural rubber, Niobium, PGMs Phosphate rock, Phosphorus, Scandium, Silicon metal, Strontium,Tantalum, Titanium, Tungsten, Vanadium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## Economic importance and supply risk results of criticality assessment

**Growing demand on raw materials**

Size of humankind + growing economy

Best resources are exploited

**Possibilities: Primary production, recycling, substitution**

Recycling: Pt vs. In, Sb… and how many times?

**Primary production will be needed even in long term**

# How the robotic projects fit to the raw materials strategy of the EU

- Raw Materials Initiative (RMI) 2008 → Raw materials strategy of the EU → Based on 3 pillars
  - Fair and sustainable raw material import from the global market
  - **Sustainable raw material supply from inside EU**
  - Effective resource management and use of secondary raw materials with recycling
- Second Pillar
  - Improve of legal framework of exploration and exploitation of raw materials
  - **Improve the knowledge of raw materials inside of EU with the development of innovative exploration and exploitation methods**

    → which „the biggest economic profit and environmental advantage can be achieved *with*"
- → Action plan: Strategic Implementation Plan (SIP) for the European Innovation Partnership on Raw Materials (2013)
  - **I.2 and I.3: development of exploration and extraction methods of raw materials**
    - New exploration technologies
    - Automated mining technologies
    - Utilization of small deposits with economic and environmentally sound technologies
- → Horizon 2020 programmes: **UNEXMIN** (2016–2019), **VAMOS** (2015–2018), **ROBOMINERS** (2019–2022), **CHPM2030** (2016–2019)
  - FP9 is called Horizon Europe (2021–2027)
- → EIT Raw Materials (foundation 2015): the biggest association in the raw materials sector: **UNEXUP** (2020–2022)

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# Environmentally sound exploration and exploitation technologies

- New exploration, new methods technologies (for new targets)
  - Low concentration (till now uneconomic) but large deposits
  - Ultra deep seated deposits (land and sea)
  - Small but high grade deposits
- Intensive development needed: Remote sensing, robotization, automatization, machine learning (AI) in exploration and mining
- Solutions without the need of dewatering
  - Less social confrontation with the other areas of society (e.g. agriculture, living environment…)
  - No sulphide (pyrite) oxidation
  - Quick, economic decision to further explore / exploit or not
  - Smaller infrastructure / economic footprint on the surface
  - Increase human safety (mining is a dangerous environment)

# Already existing robotization and automatization, autonomy in raw materials exploration and mining

**Own experience in Horizon2020 and EIT RawMaterials projects**

UNEXMIN / UNEXUP
VAMOS
Robominers
CHPM2030

# ¡VAMOS!

¡Viable Alternative Mine Operating System!

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642477".

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*What is ‘VAMOS’?*

‘**V**iable **A**lternative **M**ine **O**perating **S**ystem’

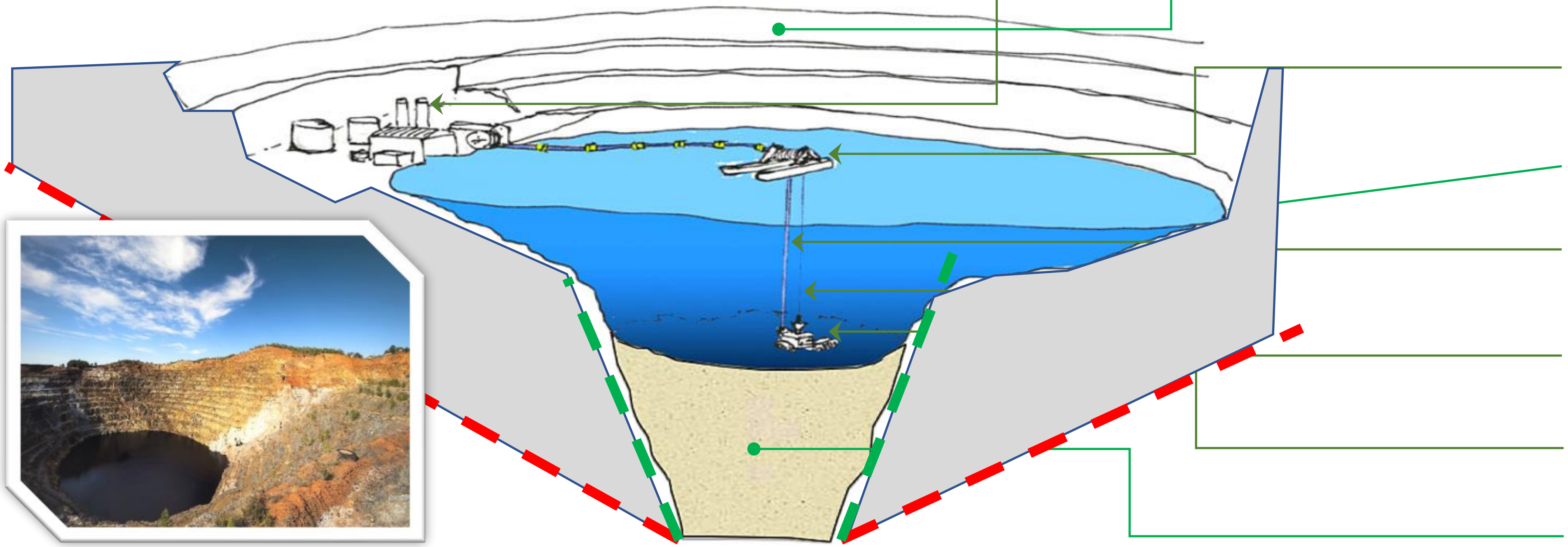
An EC-funded novel mining methodology for inland mining

Custom-built multi-component submerged inland-mining robotics system

Environmentally considerate and hopefully viable mining technique

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 642477”.

# *System Overview*





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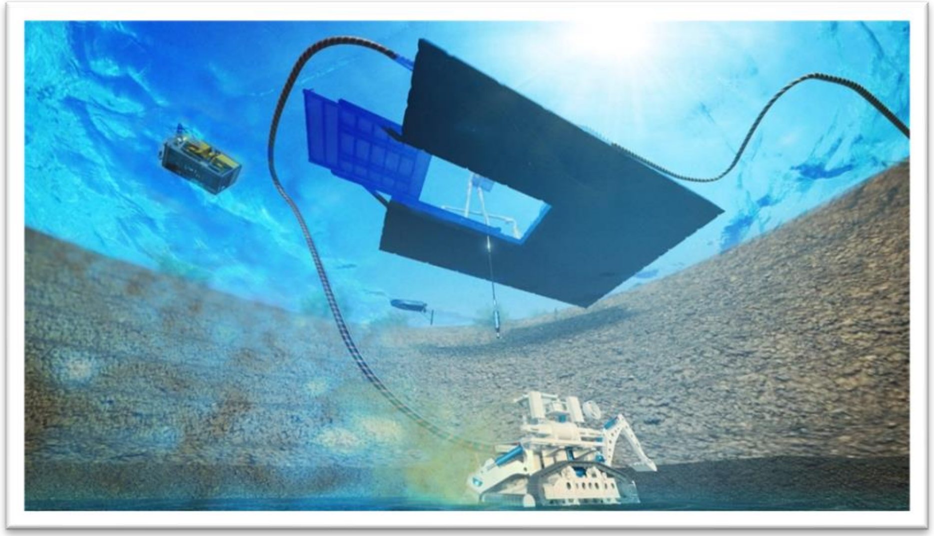
# Anticipated benefits of ¡VAMOS!



Easily transportable modular system

No need to spend money on dewatering

Cheaper alternative to underground conversion

Lower stripping ratio achievable: less waste material processed

Primary crushing costs removed: material already crushed to <50 mm

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642477".

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# *Anticipated benefits of ¡VAMOS!*

No mine dust or blasting to harm or kill workers and disturb nature

No aquifer draw-down and associated risks for adjacent land

No blasting or fleet operation noise to disturb surroundings

No worker exposure to underground roof collapse

Proven publicly acceptable methodology

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 642477”.

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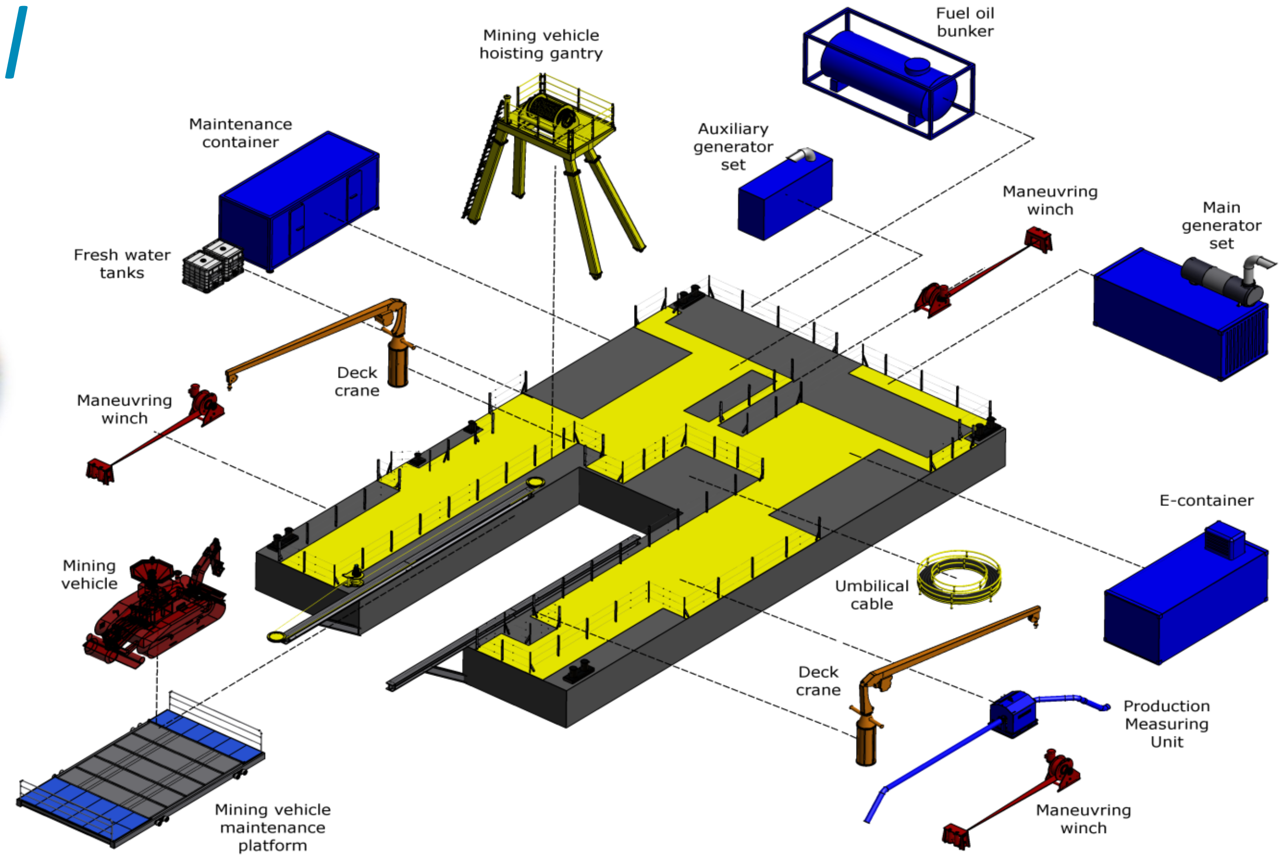
# Launch and Recovery Vessel

Production Measurement Unit: ρ + Q

Slurry bypass + LIBS unit




**INSite: In-situ ore grading system using LIBS in harsh environments**

**EIT RM project!!!!**

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https://www.youtube.com/watch?v=XALp8YniNiI

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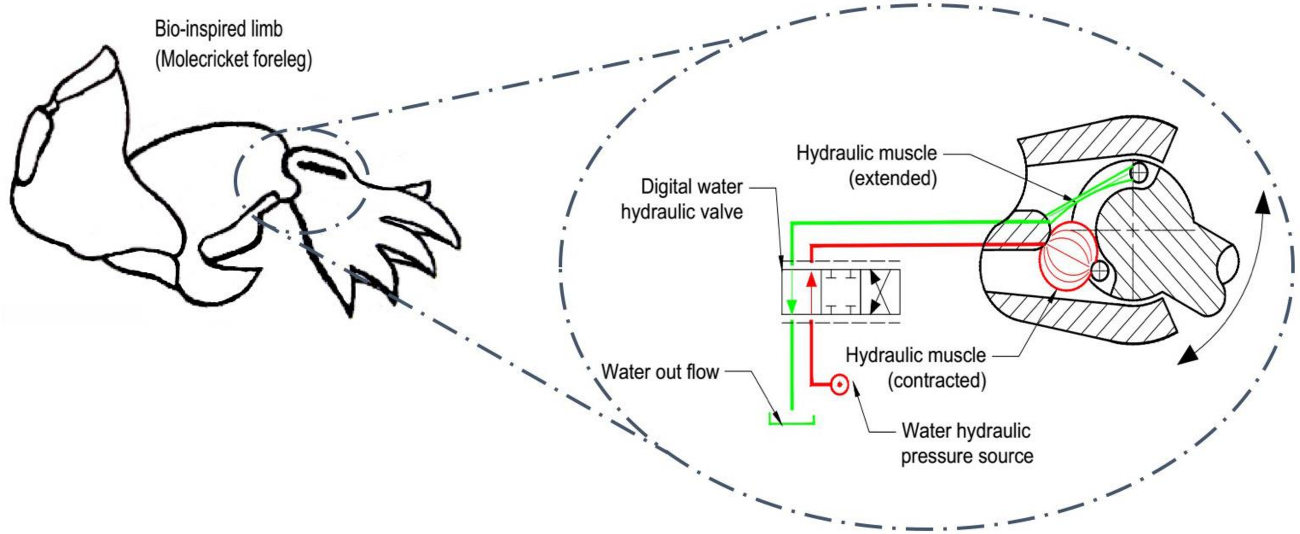
# ROBOMINERS

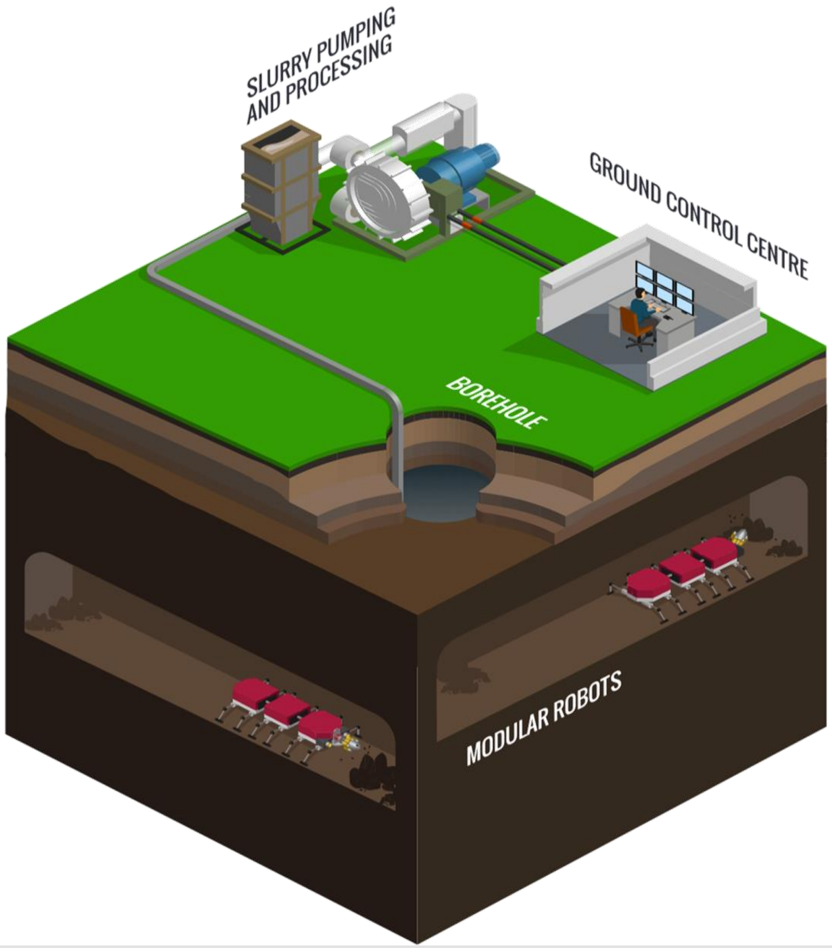
Resilient Bio-inspired Modular Robotic Miners




Tech specs:

- 0.5-1 ton
- 20-30 kW
- Hydraulic
- Tethered

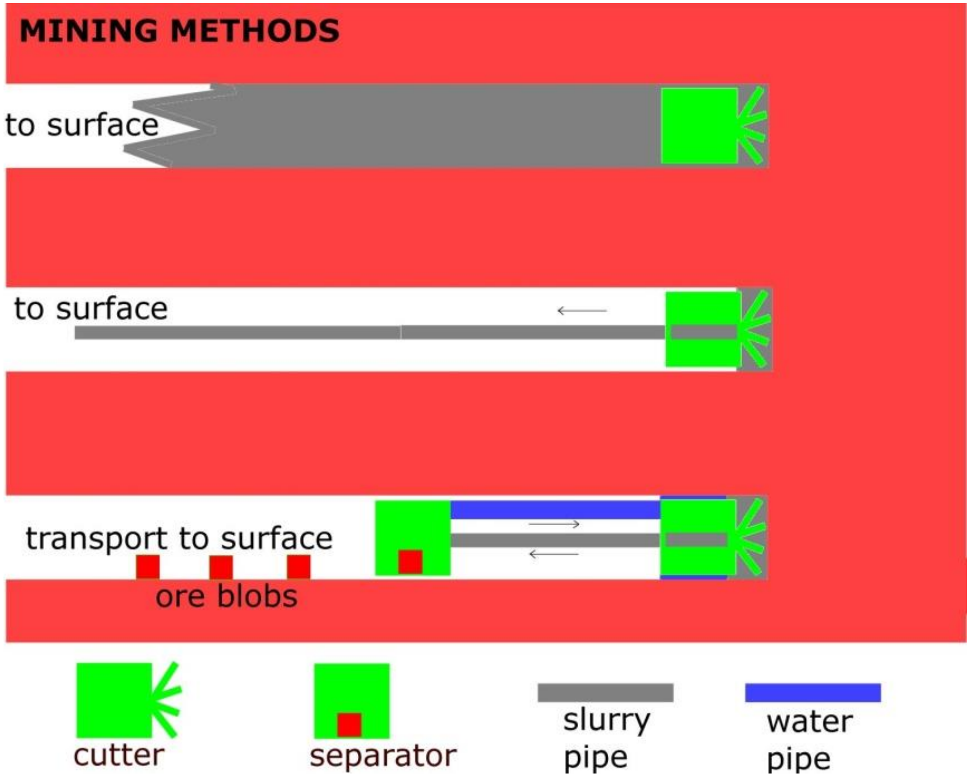
# Concept




1. Robot parts (modules) are sent underground via a borehole
2. They self-assemble to form a fully funcional modular robot
3. Using specialised sensing devices, they detect ore
4. Using ad-hoc production devices, they produce slurry that is pumped out
5. They can re-configure on-the-job

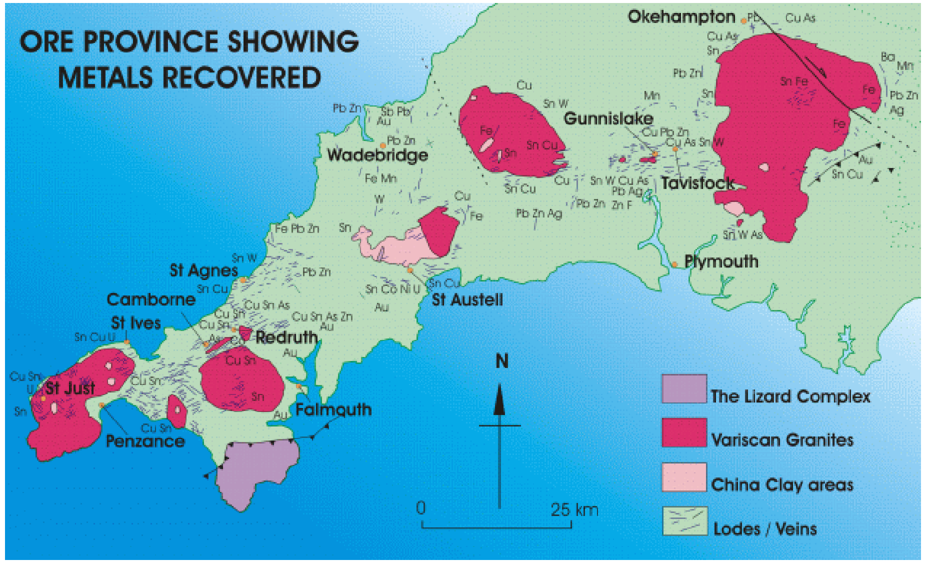
# Mining system

- Need of a **new approach to mining strategy and mine design**
- Studying and simulating the various systems components in future mining scenarios
- Creating a **simulated environment for the entire mining operation,** considering
  - drilling methods
  - mineral exploration
  - minerals processing and transport options
  - power supply scenarios
  - mine design and mine geometry



# Targeted mines

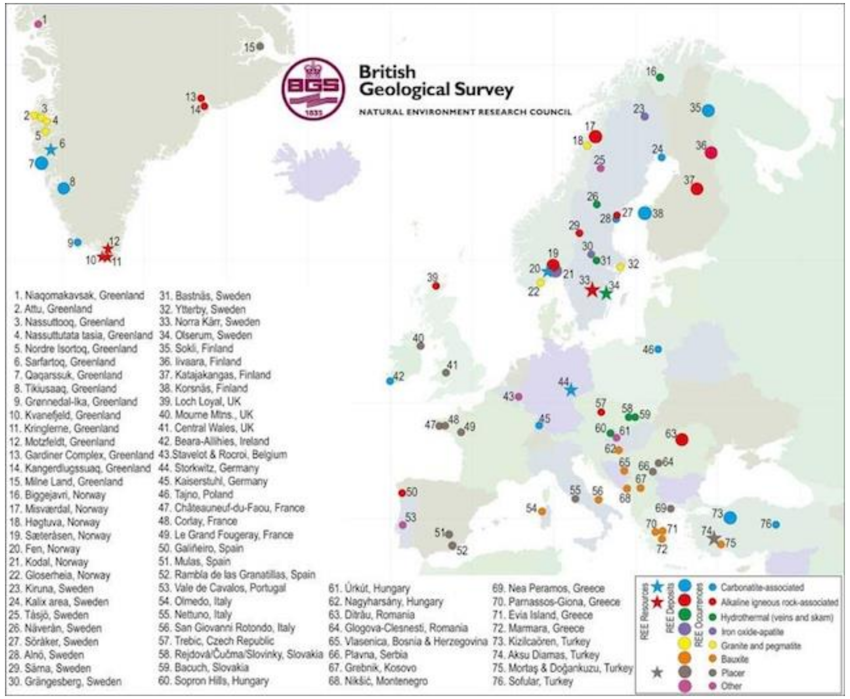
- **Abandoned mines.** ROBOMINERS presents a solution for reopening many of Europe’s abandoned underground mines, **without the need for a full recommissioning and in particular without the need to dewater the mine**.

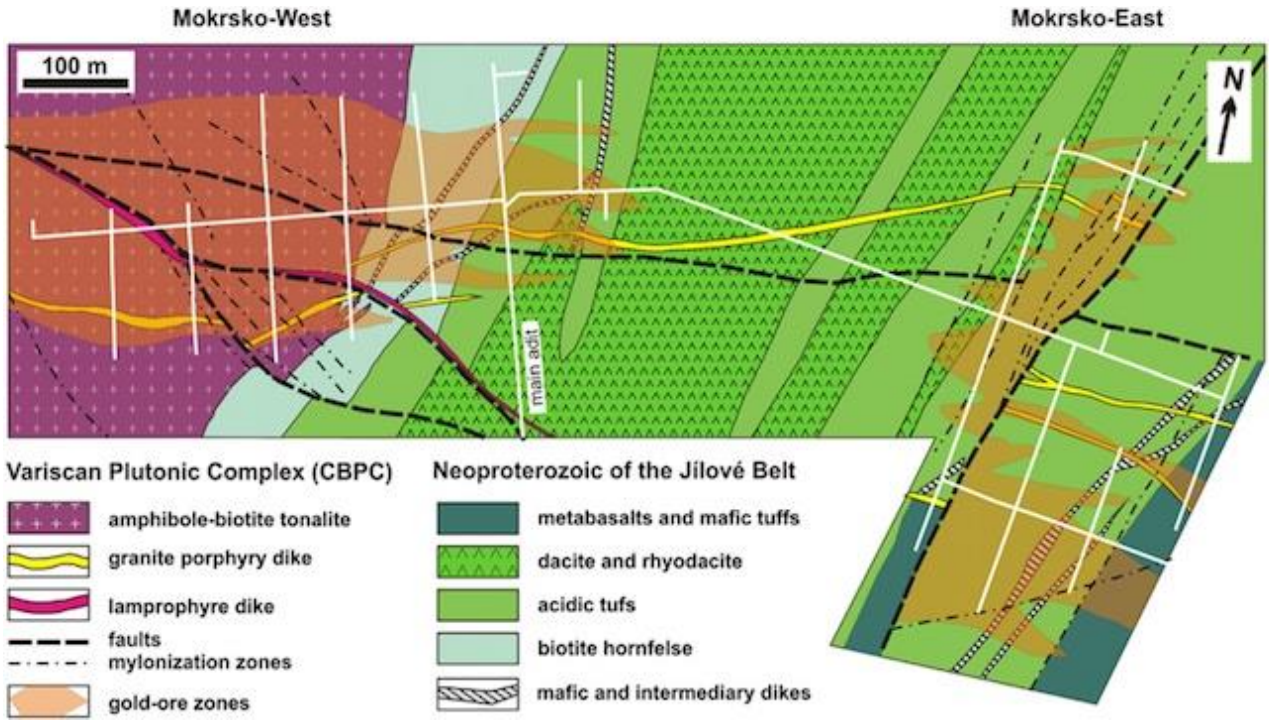



*Left: Metals mined from the Cornwall mineralised belt. Right: Ruins of the abandoned Botallack Mine in Cornwall. Operating from the 1500s to 1895, Botallack was once one of the greatest copper and tin mines in England*

# Targeted mines

- **Small but high grade mineral deposits.** *The proposed technology does not require the development of any mine infrastructure and even very small deposits can be mined.*

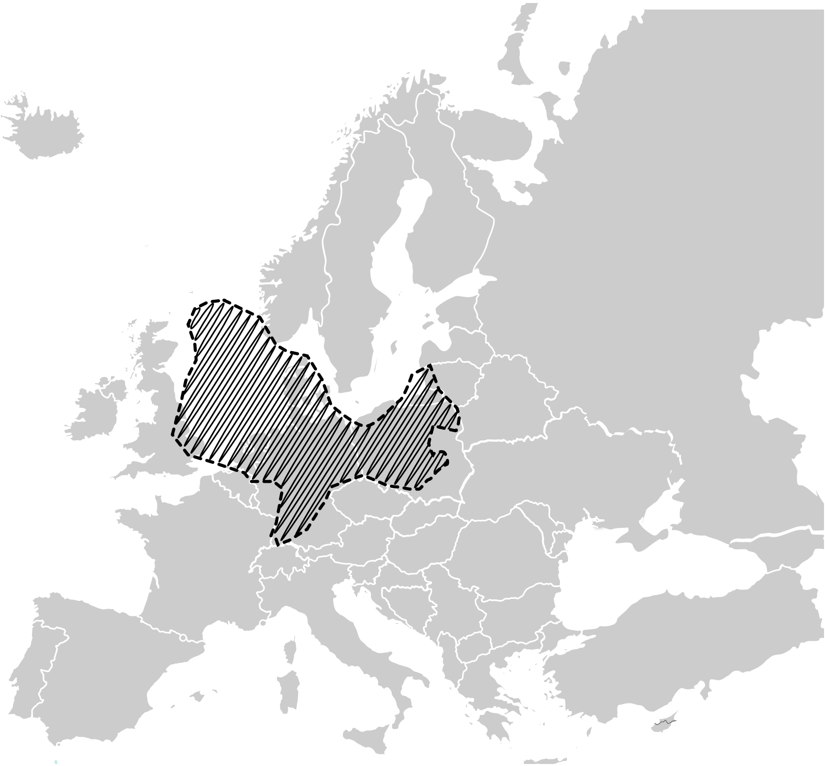



*Geological map of the Mokrsko-West and Mokrsko-East deposits (horizontal section at ca. 300 m a.s.l.)*

# Targeted mines

- **Ultra depth.** *Under this application scenario a large diameter borehole will be drilled from the surface to the deep-seated deposit.*



*Extension of the Kupferschiefer Formation in NW Europe*

# Specific objectives

**Build a fully functional modular robot-miner prototype** capable of operating, navigating and performing selective mining

Validate all key functions of the robot-miner to a level of TRL-4

**Design a mining system of expected future** upstream/downstream raw materials processes via simulations, modelling and virtual prototyping

Use the prototypes to study and advance future research challenges on

- scalability, resilience, re-configurability, self-repair, collective behaviour, operation in harsh environments,
- selective mining,
- production methods,
- necessary converging technologies on an overall mining system level

**New mining concept, proven in laboratory conditions, capable of changing the scenario of mineral exploitation**

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# CHPM2030 - Combined Heat, Power and Metal extraction from ultra-deep ore bodies

## Concept

→ Identifying ultra deep metalliferous formations

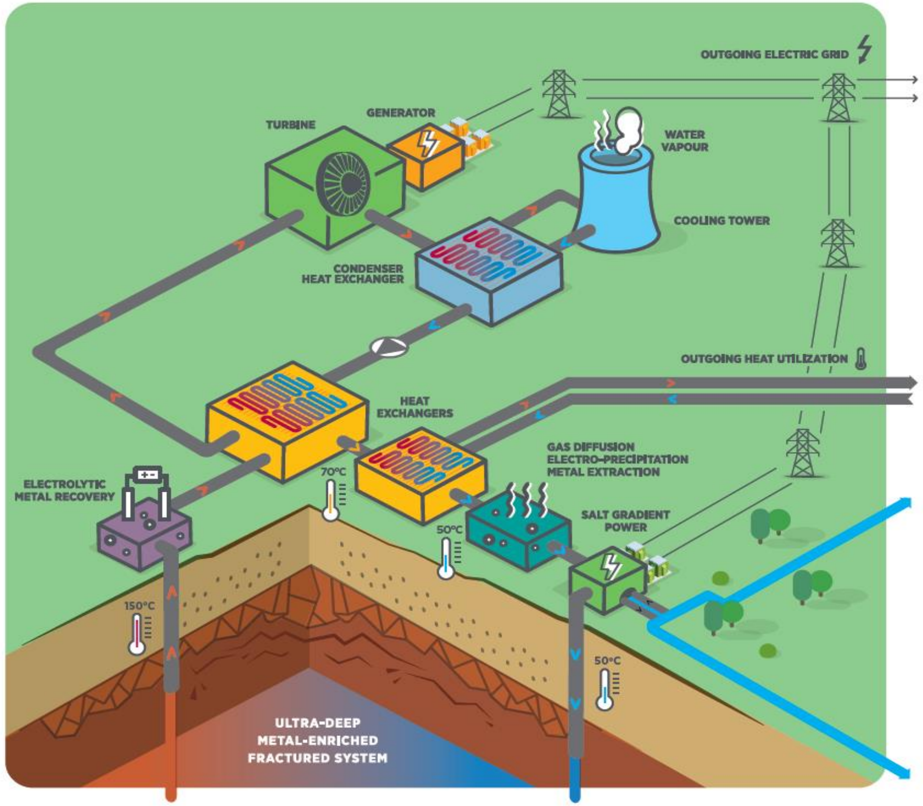
→ Establishment of EGS

→Enhance the interconnected fracture systems within the orebody

→ Leaching metals from the orebody

→ Production of heat and electricity

→ Metal extraction from the geothermal brine



# Schematic overview of the envisioned CHPM Facility