# Perspectives on CRM extraction

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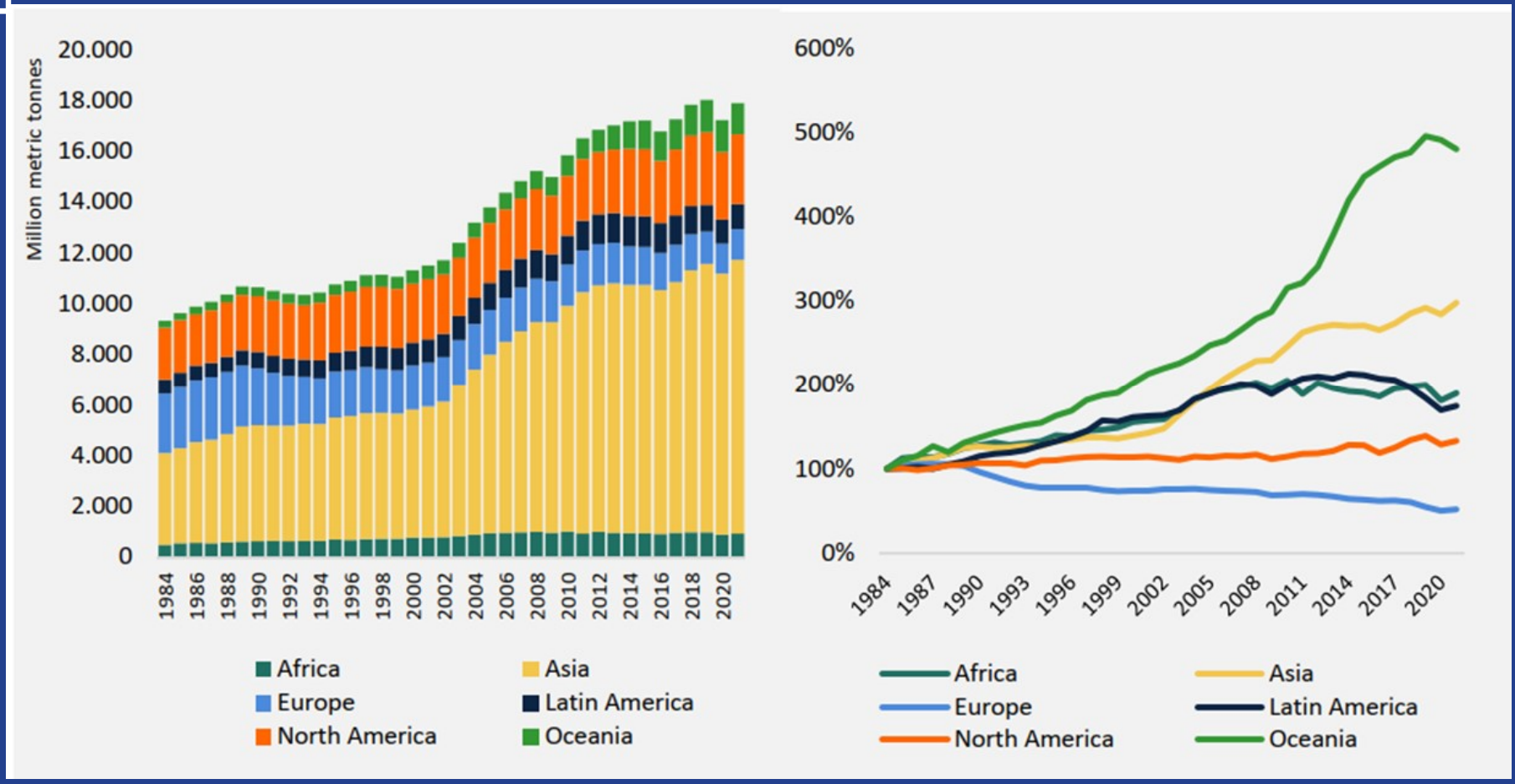
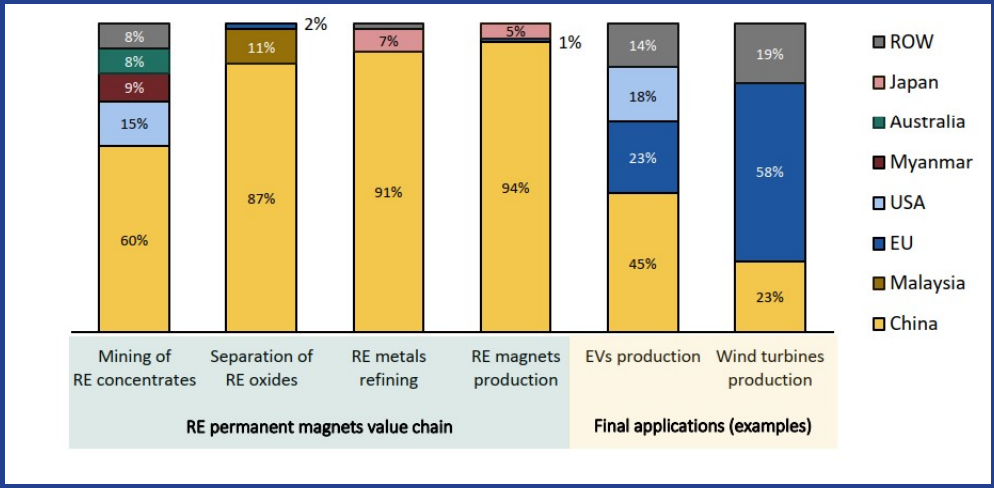
# Raw materials

- ✓ Raw materials will be at the center of decarbonization efforts and electrification of the economy.
- ✓ The transition to a net-zero economy will be metal and mineral-intensive.
- ✓ Economical and political changes impact on availability of minerals and metals.

# Historical world mineral production



# Critical Raw Materials Act (CRMA)




Righetti, Rizos 2024

- ✓ The act focuses on sustainability and the circular economy.
  - ✓ at least 10% of the EU's annual consumption for extraction
  - ✓ at least 40% of the EU's annual consumption for processing
  - ✓ at least 25% of the EU's annual consumption for recycling
  - ✓ no more than 65% of the EU's annual consumption from a single third country

# CRMA and circular economy

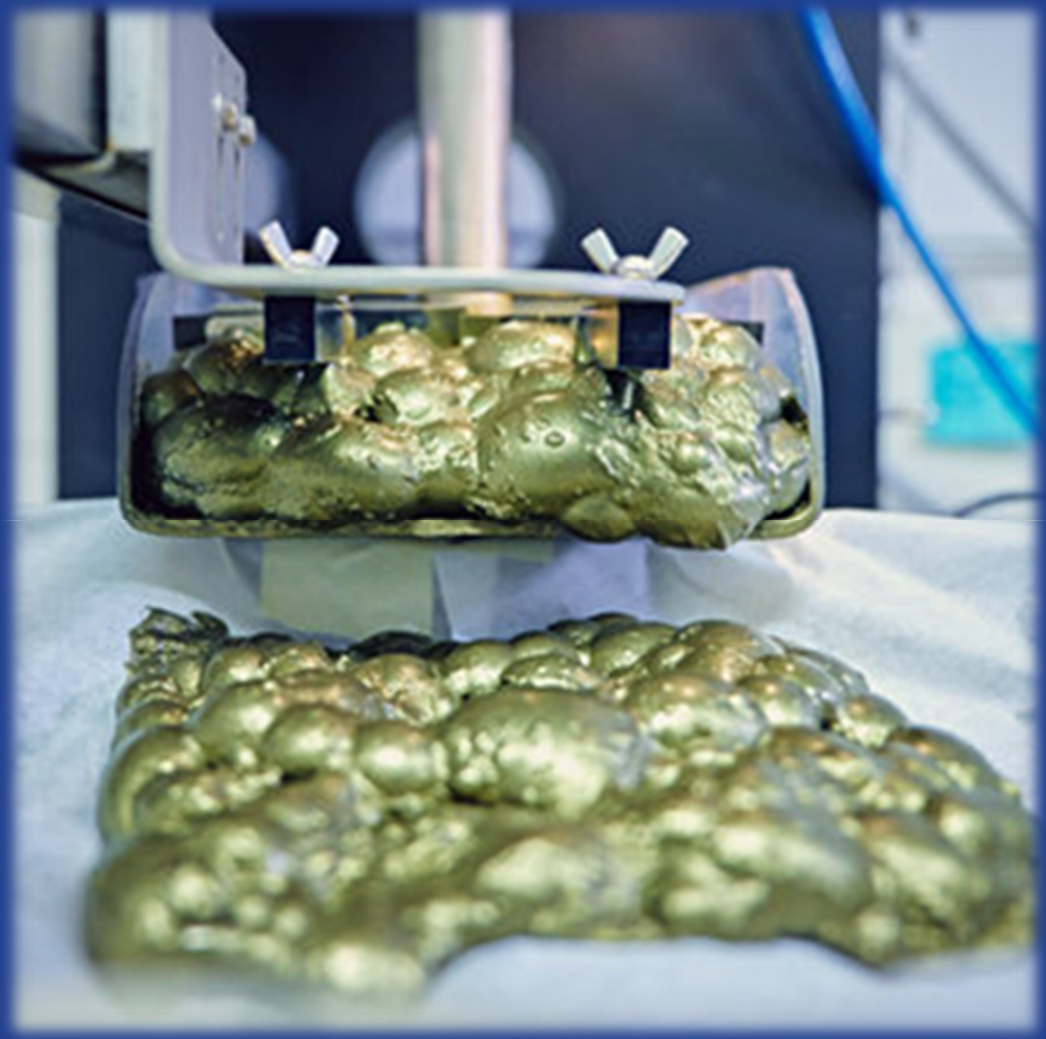
*In 2020, less than 1% of permanent magnets were recycled.*

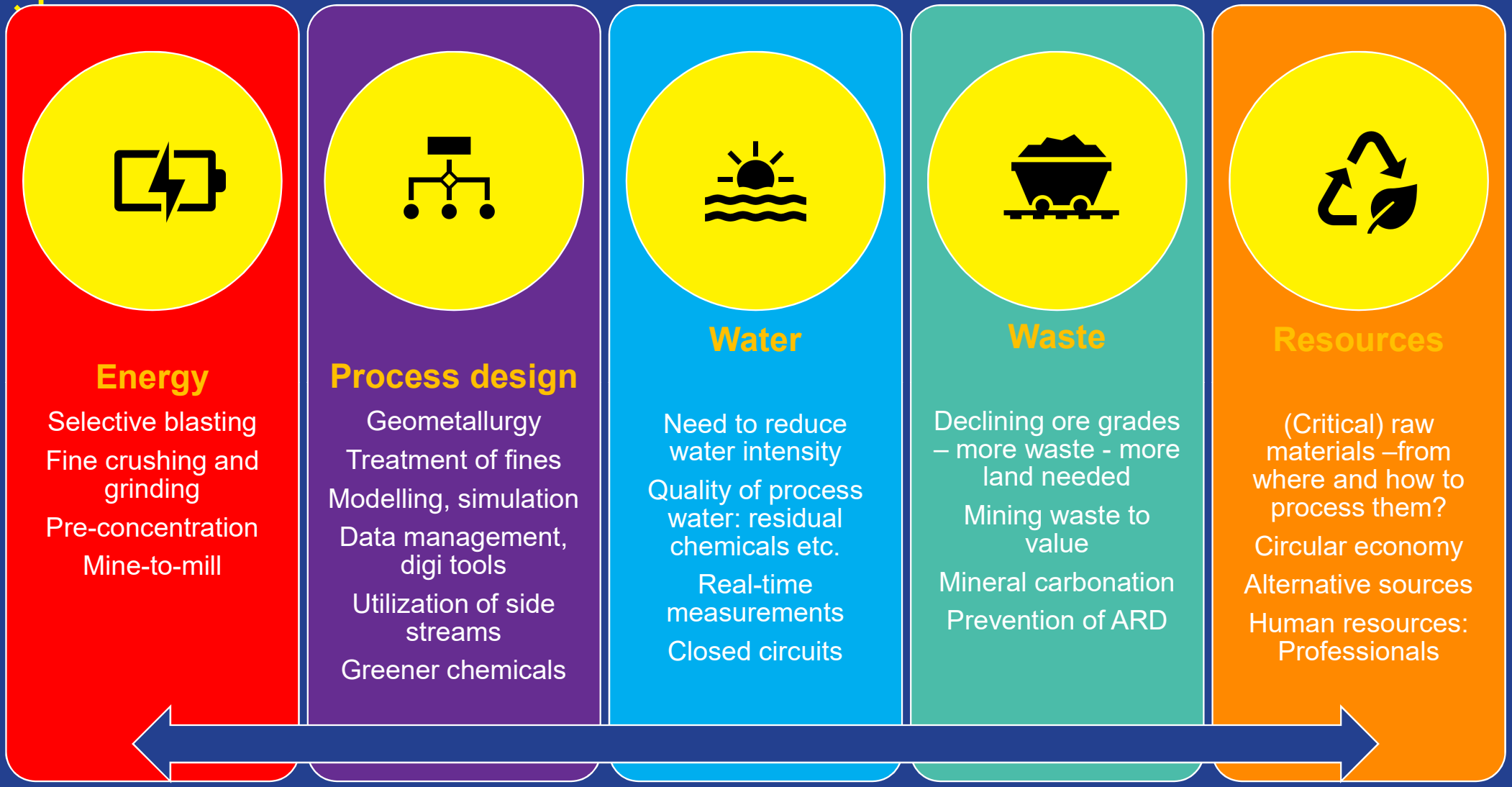
- ✓ The regulation lists measures such as
  - ✓ increasing the collection of used materials, sorting,
  - ✓ reuse,
  - ✓ substitutability,
  - ✓ and repair obligations to old products.
- ✓ Research in the sector is supported.
- ✓ Companies are required to list generated waste and prepare waste management plans.
- ✓ Potential old extractive waste sites for CRM must be identified, studied and their data collected into a dedicated database.

- ✓ **Decreasing ore grades** -> larger tonnages needed to be mined -> more water needed to produce same amount of concentrate.
- ✓ **Complex, disseminated ores** –> finer grinding required to liberate valuables for processing.
- ✓ Holistic and innovative solutions required to reduce negative impacts of processing.

# Resource efficiency

- ✓ Closed material cycles to reduce the demand of minerals from primary sources and reduce waste.
- ✓ **Maximize resource use efficiency** by extracting maximum value from mined products.
- ✓ **Maximize the materials use efficiency** through substitution, reuse and recycling.
- ✓ The increased demand for commodities still require increasing amounts of newly mined ores.




Energy
Selective blasting
Fine crushing and grinding
Pre-concentration
Mine-to-mill
Process design
Geometallurgy
Treatment of fines
Modelling, simulation
Data management, digi tools
Utilization of side streams
Greener chemicals
Water
Need to reduce water intensity
Quality of process water: residual chemicals etc.
Real-time measurements
Closed circuits
Waste
Declining ore grades – more waste - more land needed
Mining waste to value
Mineral carbonation
Prevention of ARD
Resources
(Critical) raw materials –from where and how to process them?
Circular economy
Alternative sources
Human resources: Professionals

**PRODUCE MORE**
- Larger capacities
- Better recovery

**IMPROVE SAFETY**
- Safe workplace
- Hygienic conditions

**MAINTAIN STABILITY**
- Reliable employer
- - Avoidance of cuts

**PRODUCE WITH LESS**
- Smaller fixed costs
- Smaller variable costs

**CONSUME LESS**
- Minimal water use
- Energy efficiency

The pursuit of sustainability is a strong driver for developing and using innovative technologies.

Ore exploration

Mining

Blasting

Mineral processing

Comminution (crushing, grinding) Separation

Product: mineral concentrate

Post-treatment

Pyrometallurgy:

Smelters, refineries

Hydrometallurgy

Tailings management

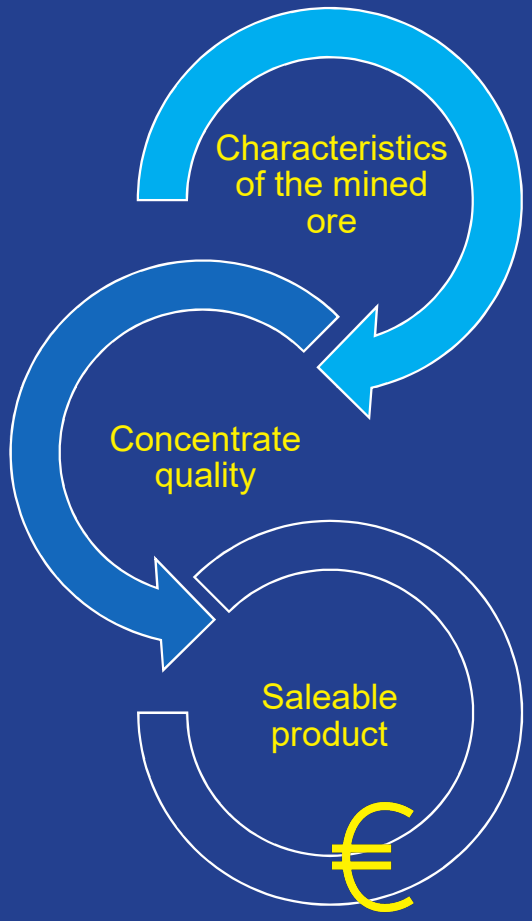
MINING PROJECT

# Life cycle of materials

- ✓ The part of the materials cycle during which natural resources are transformed into useful products -> value-adding.
- ✓ The stages through which material moves to the point of use in a product -> the value chain.

  - ✓ Product(s) of value
  - ✓ By-products – substances of additional value.
  - ✓ Wastes – substances for which there are no **present** uses.

# Product




- ✓ Among the key factors affecting revenues in a mine are selling price and quality of a product – concentrate- produced.
- ✓ The quality of the concentrate has a major effect on the further downstream processing.
- ✓ Even relative small increases in return per tonne of ore treated can have a significant effect on economy, due to the very large tonnages that are often treated.

# Characterization

The fundamentals for any processing or trreatment of ore and tailings are initially dictated by the mineralogical and chemical characteristics.

- ✓ Chemical characterization:
- ✓ Concentration of valuable metals/ minerals and impurities
- ✓ -> is it feasible to recover metals? Is it feasible to remove impurities?

- ✓ Mineralogical characterization:
- ✓ How easily the metal/ mineral with value can be separated?

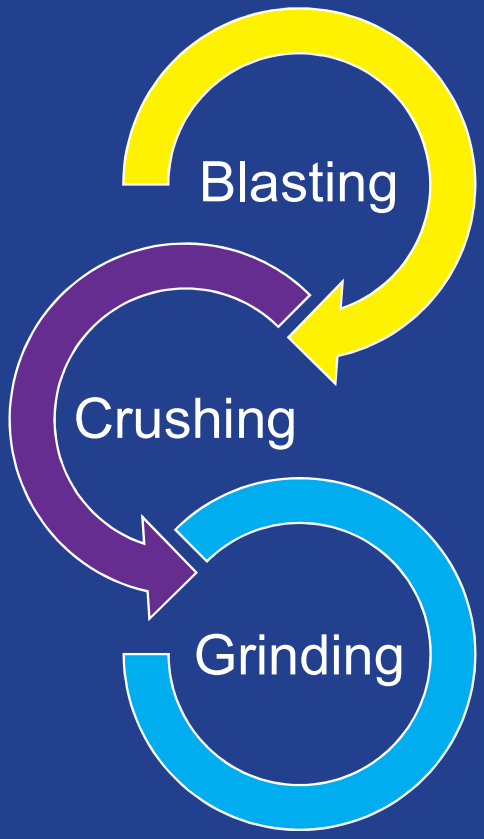
-> in what minerals metal occurs? Are there associations?

*Integrating mineralogy-based analysis early in the project development enables to generate a good understanding of the behaviour of material through process flowsheet options.*

# Mine, mill, metallurgy

- ✓ The integration of the value chain mining-milling- metallurgy enables removal of impurities and penalty elements when it is least harmful.
- ✓ More efficient mining. Mine site processing -> less waste rock,
- ✓ More efficient processing – pre-concentration etc. -> Less waste rock and tailings.
- ✓ Use for tailings -> secondary raw materials.
- ✓ Removal of penalty elements during processing -> better payment for concentrate.

# Size reduction




- ✓ Low grade complex ores require energy-efficient solutions for liberating material.
- ✓ From the energy-efficiency perspective it is essential to understand the associated size reduction mechanisms.
- ✓ Controlled optimisation of the rock fragmentation chain from the blasting to comminution.
- ✓ Efficient handling in the rock breakage chain from mine to mill requires a comprehensive view of the rock type and characteristics.

# Energy consumption

- ✓ Grinding mills typically the highest cost items at a mine site.
- ✓ Energy consumption of grinding very high compared with the preceding stages blasting and crushing.
- ✓ For example, the distribution of energy at copper mine site is 3-5% for blasting, 5-7% for crushing and 80-90% for grinding (*Jeswiet et al, 2016*).

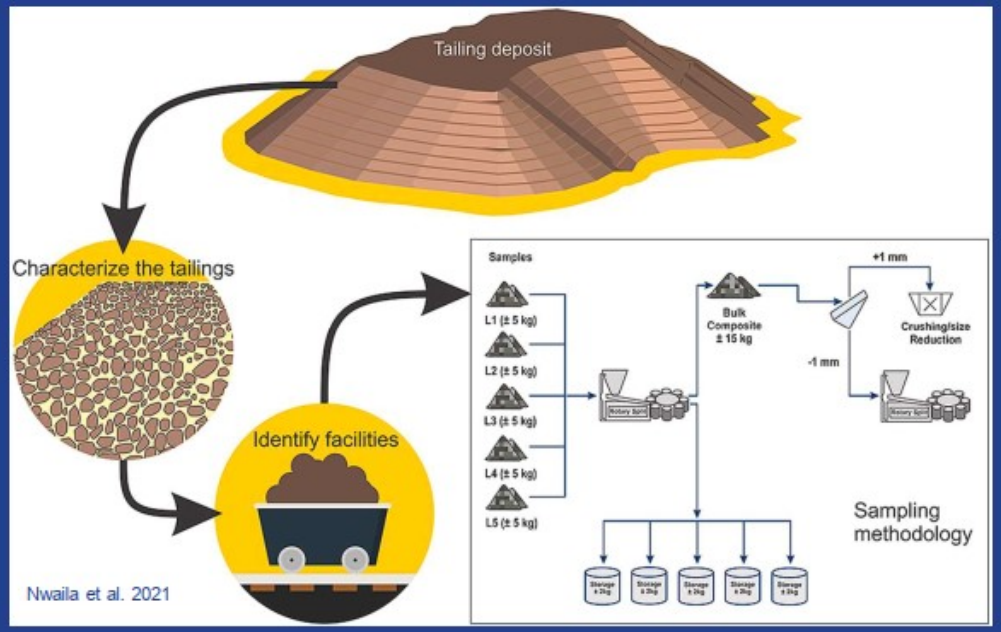
# Pre-concentration

- ✓ Removal of waste material from the size reduction stream prior to grinding has a positive impact on the overall process efficiency.
  - ✓ Reduced volume of waste material to be processed.
- ✓ Waste rock in the mill reduces the mill´s ore grinding capacity.
- ✓ In many cases waste rock is harder than the ore.
  - ✓ The harder the rock the longer the grinding time and the lower the mill input.
  - ✓ Hard rock results in overgrinding the ore.
  - ✓ Result: increased energy consumption, excessive amount of fines and major problems in processing.

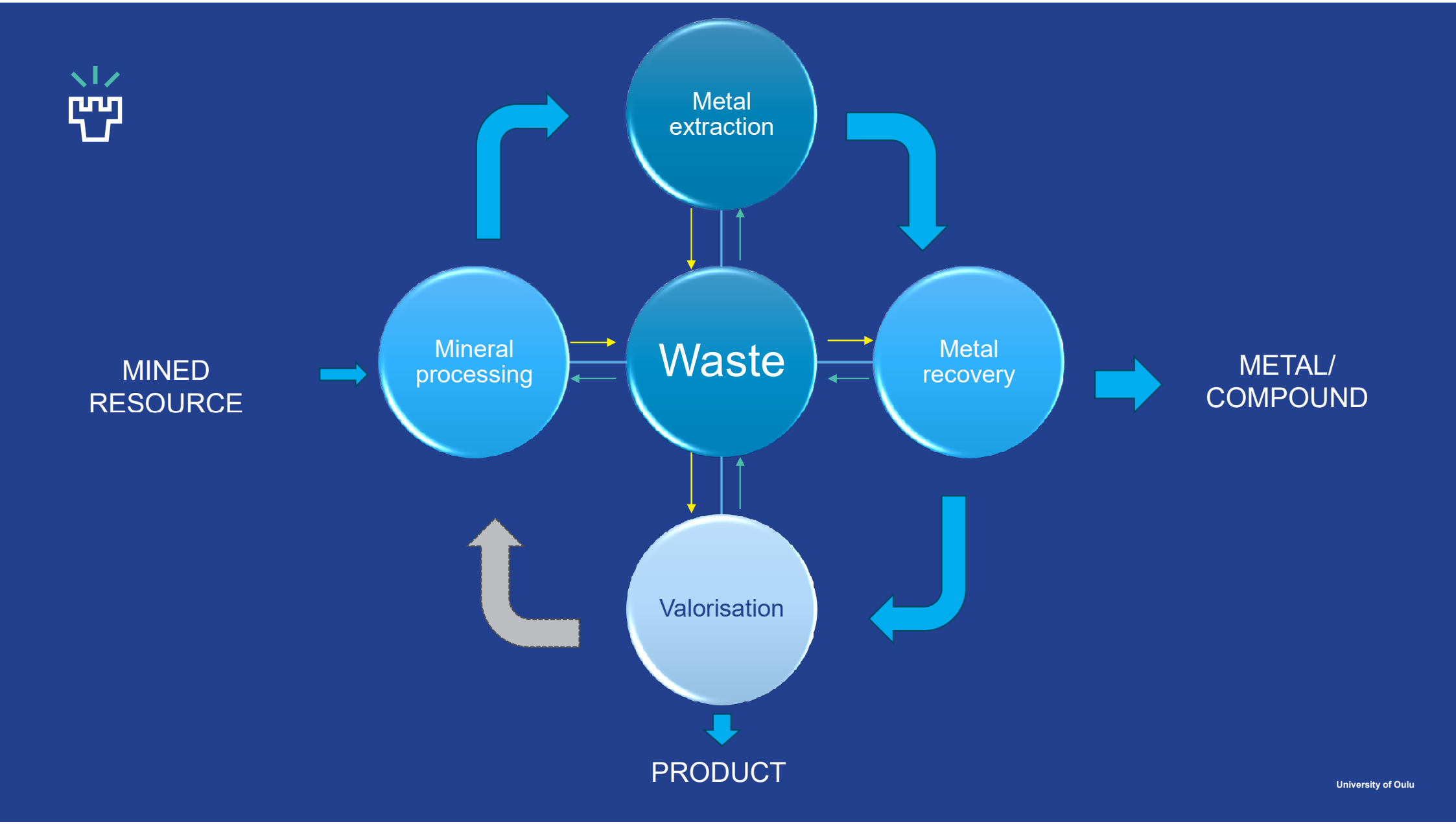
# Circular economy


- ✓ **Linear economy:** ”take, make and dispose”
- ✓ **Circular economy:** an economic system that is based on expanding the life cycle of products.
- ✓ The concept of waste is dynamic: what was considered a waste in the past may now been considered a product, and what is a waste now may become a raw material in the future.

# Reduce, reuse, recycle




- "Reduce" - efficient exploitation of resources, enhanced recovery rate improving the total recovery of resources and reducing pollutants.
- "Reuse" – e.g. recycling of mine wastewater and changing tailings and mineral waste into valuables. Valuable metals can be recovered and the mineral matrix be utilized in producing new substances such as building materials.
- "Recycle" - reusing the resources again from secondary materials.

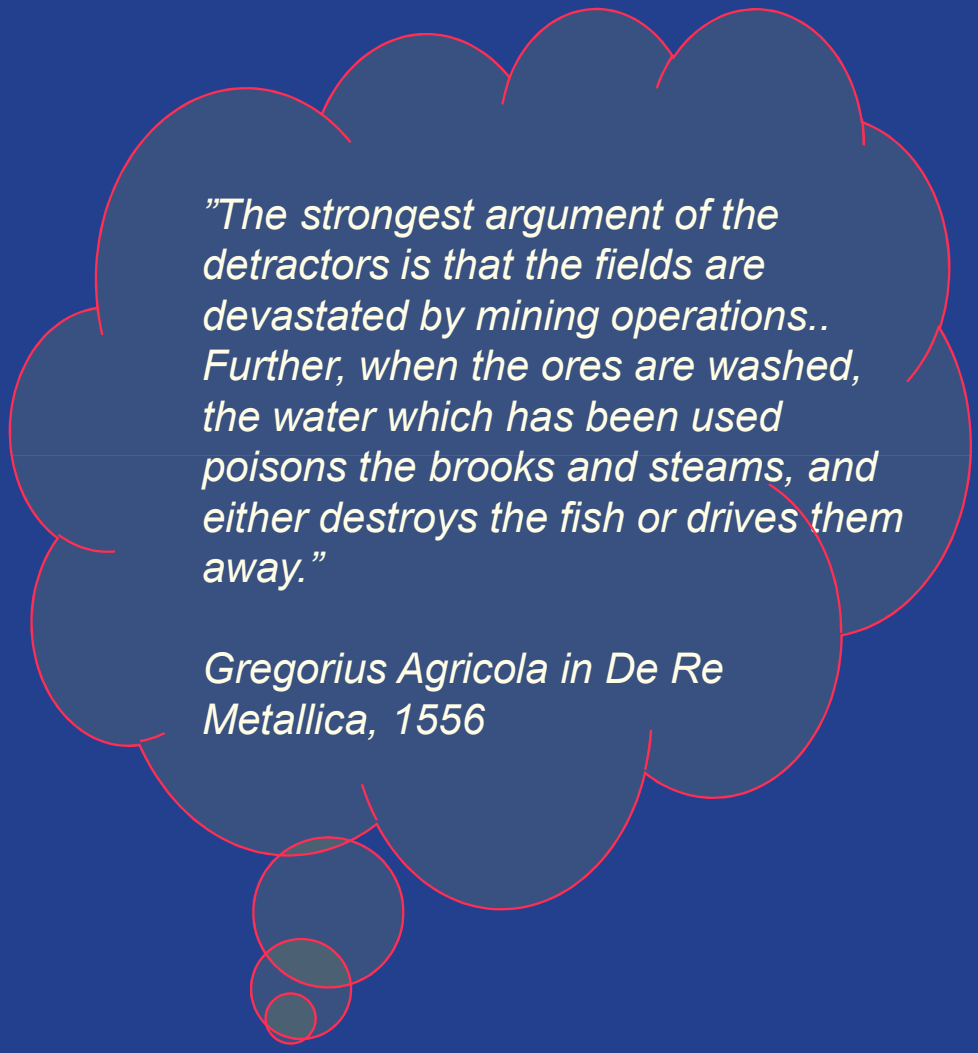

Metal extraction
MINED RESOURCE
Mineral processing
Waste
Metal recovery
METAL/ COMPOUND
Valorisation
PRODUCT

# Mining and processing waste

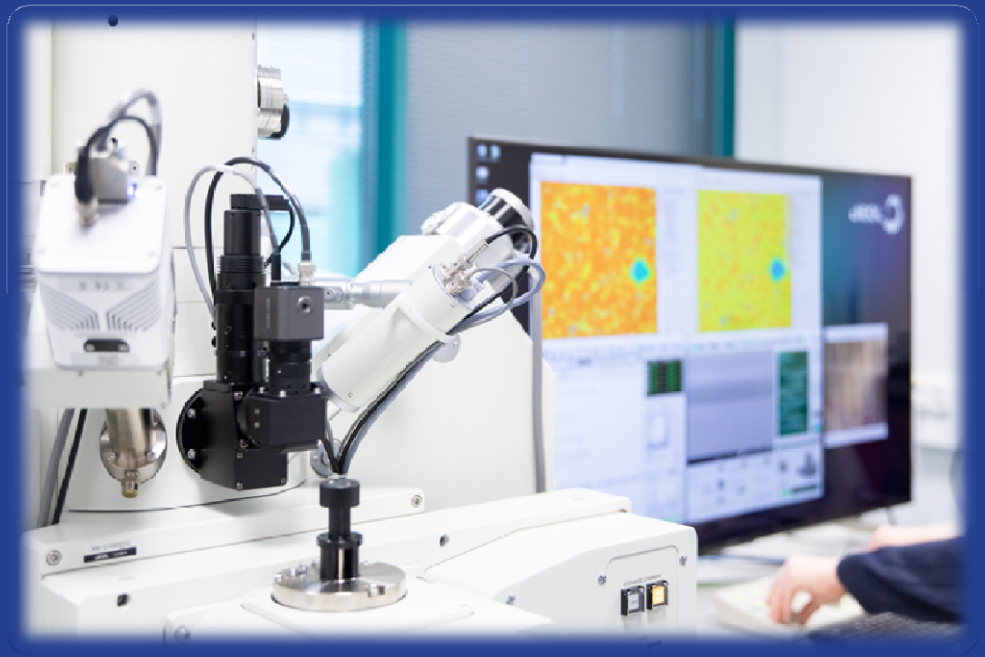

- ✓ Globally over 100 billion tons of mining wastes are generated annually and this is likely to grow.
- ✓ Mining wastes, processing wastes and metallurgical wastes.
- ✓ Mine wastes: waste rock, overburden and mining waters.
- ✓ Processing wastes: tailings. Slurries and mill water.
- ✓ Metallurgical wastes: generated during the extraction and recovery of metals from mineral concentrates – slags, roasted ore, flue dust, ashes, leached ores and process water.

# Variable properties

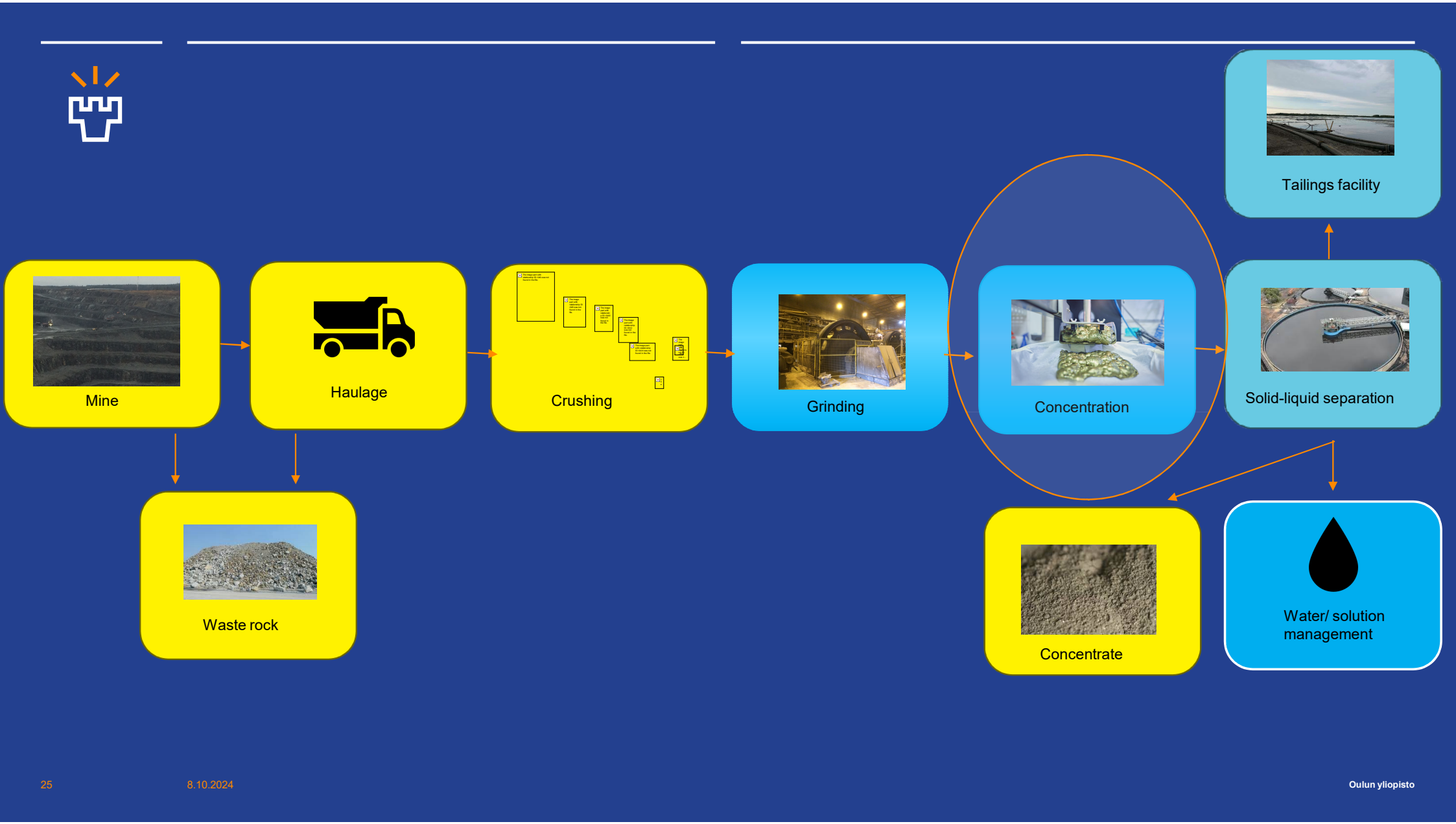
- ✓ Mining and processing waste have variable chemical and physical properties that can make recovery of potential valuables challenging.
- ✓ Can contain primary ore in subeconomic concentrations, gangue minerals, secondary minerals formed during weathering, compounds formed during mineral processing or waste disposal.
- ✓ Waste particles may be poorly liberated and particle sizes can vary significantly.



# Composition



- ✓ The mineralogical and chemical characterizations are necessary in forecasting geotechnical properties of the waste and leachability of potentially harmful compounds.
- ✓ The mineralogical composition of processing waste, tailings, can be very complex and heterogeneous.
- ✓ The most important mineralogical considerations are those that influence mineral recovery, decontamination and acid rock drainage.


Mine
Haulage
Crushing
Grinding
Concentration
Solid-liquid separation
Tailings facility
Waste rock
Concentrate
Water/ solution management

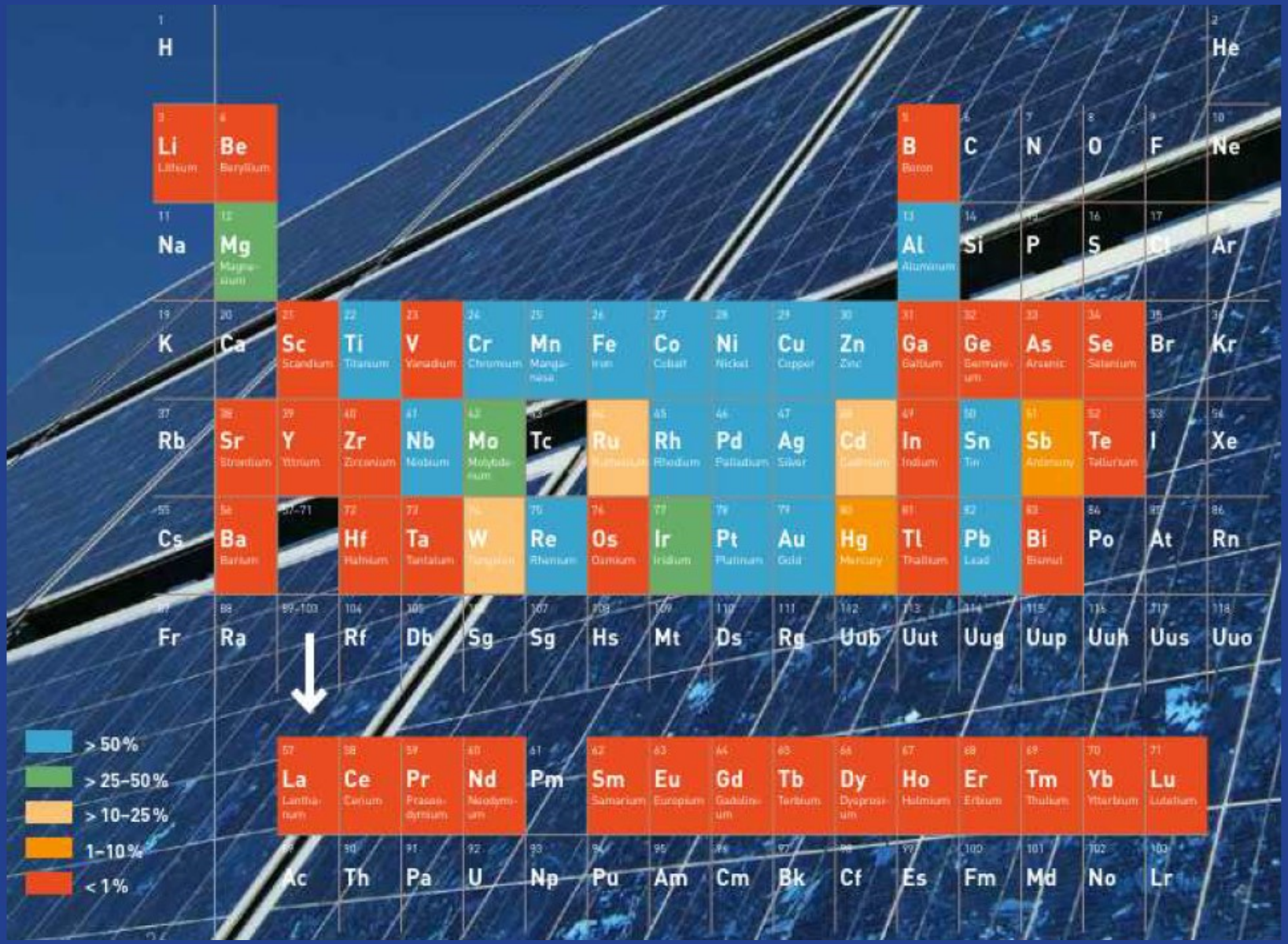
# Water management

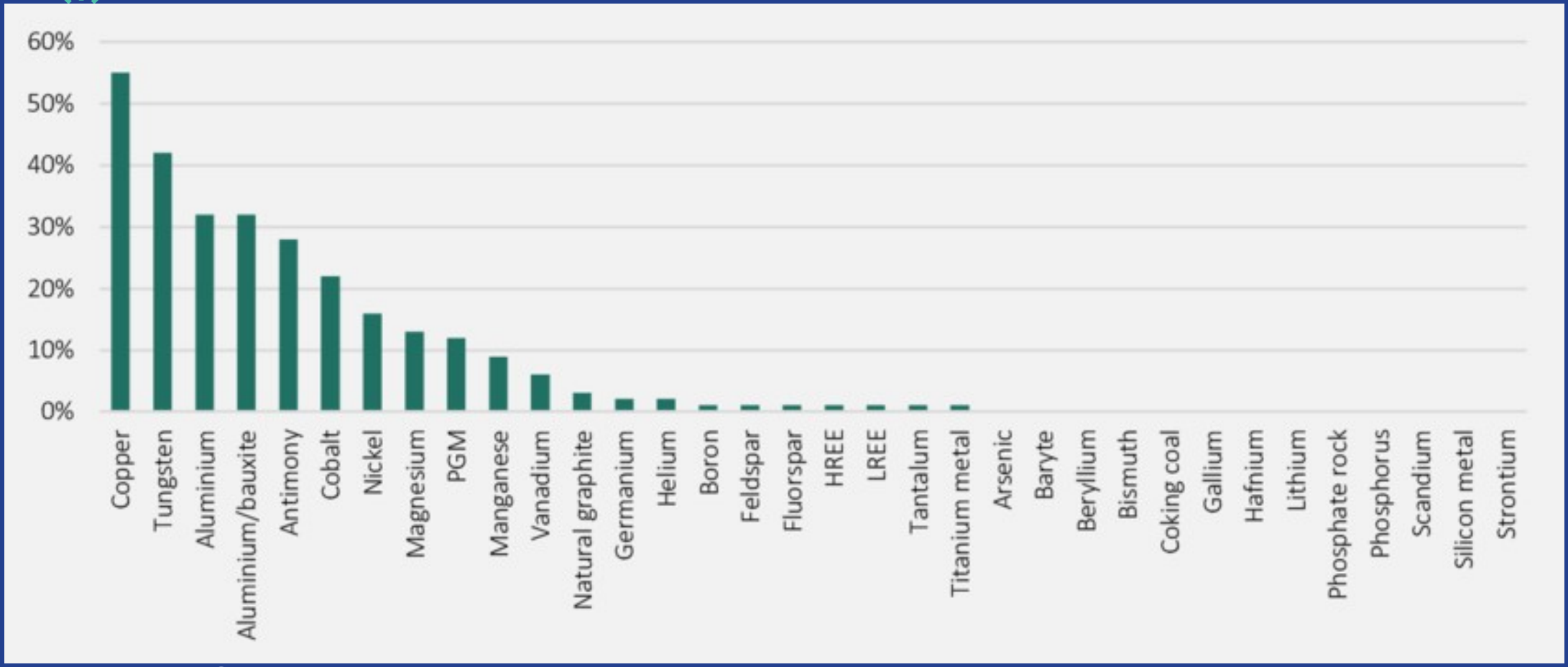
- ✓ Average water consumption at the mine site ~1.5-3.5 $m^3$/ processed ore.
- ✓ Recirculation of water is becoming more important: as much water as possible must be reclaimed from the tailings pond for a reuse in the mill and the volume of fresh make-up water must be kept to a minimum.
- ✓ The main disadvantage of water reclamation is the recirculation of pollutants in the mill which may interfere with processes -> water treatment.
- ✓ Extraction of potential valuables from the streams.

# Recycling of metals

- ✓ Recycling of metals considered as a sustainability strategy.
- ✓ Limitations:
- ✓ Still relatively low efficiencies in the collection and processing of most metal-bearing discarded products.
- ✓ Primary material often relatively abundant and low-cost
- ✓ End-of-life recycling rate low for most of the metals.

End-of-life recycling rates for metals (Reuter et al).






Source: Righetti, Rizos 2024

# Thank you!