

# Untapping the hidden resources:

Mining waste as a potential alternative source of critical raw materials



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Resource Engineering

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# Who we are?



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Delft

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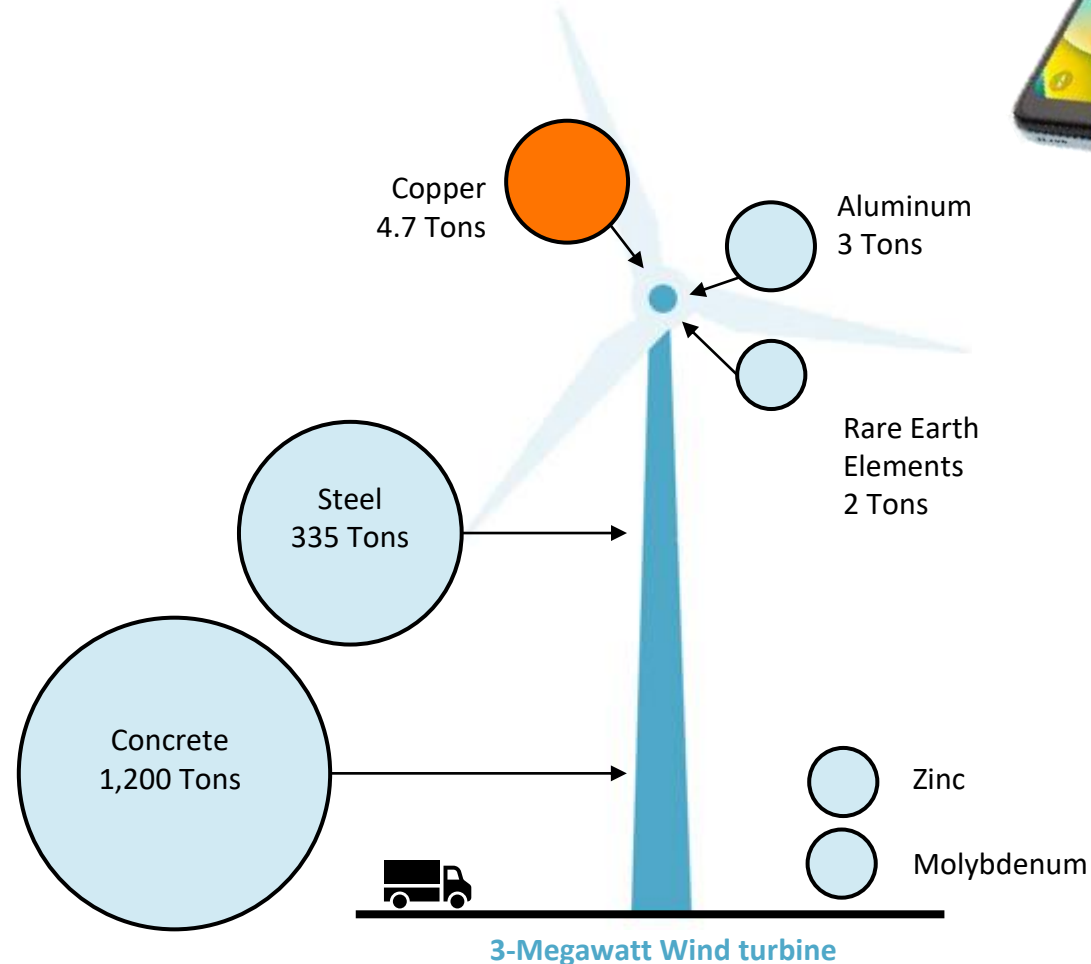
**Kiarash Pashna**

- Mining engineer



# Introduction

- Increasing demand for mineral products
  - Technological advancements
  - Energy transition
  - Emerging markets
- Critical raw materials (CRMs)
  - Supply risk – high import dependence
  - Economic importance in key sectors
  - Lack of alternatives to these materials



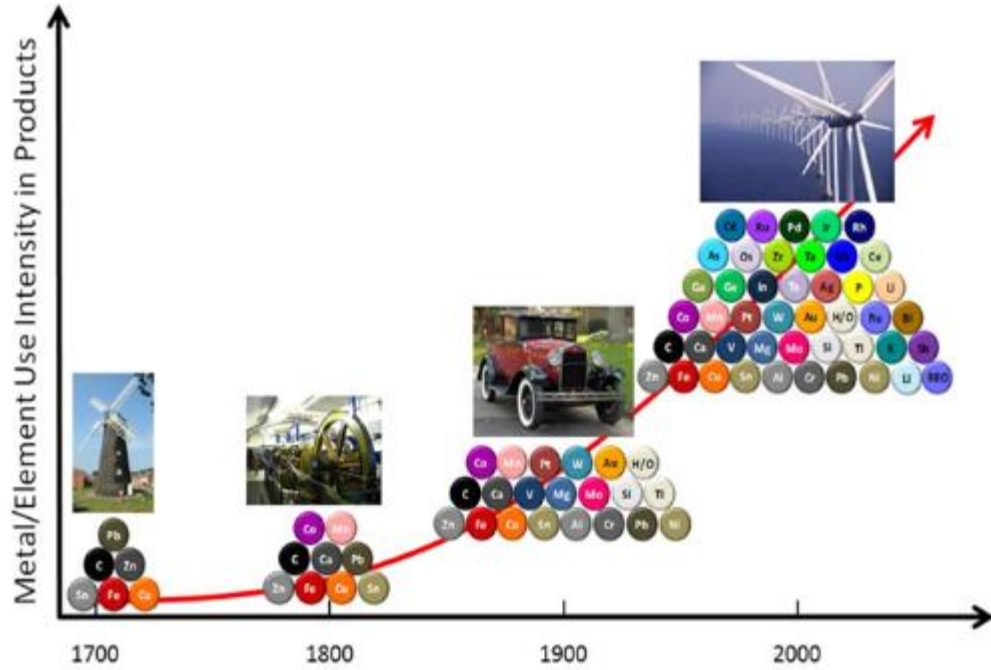
## Modern technologies



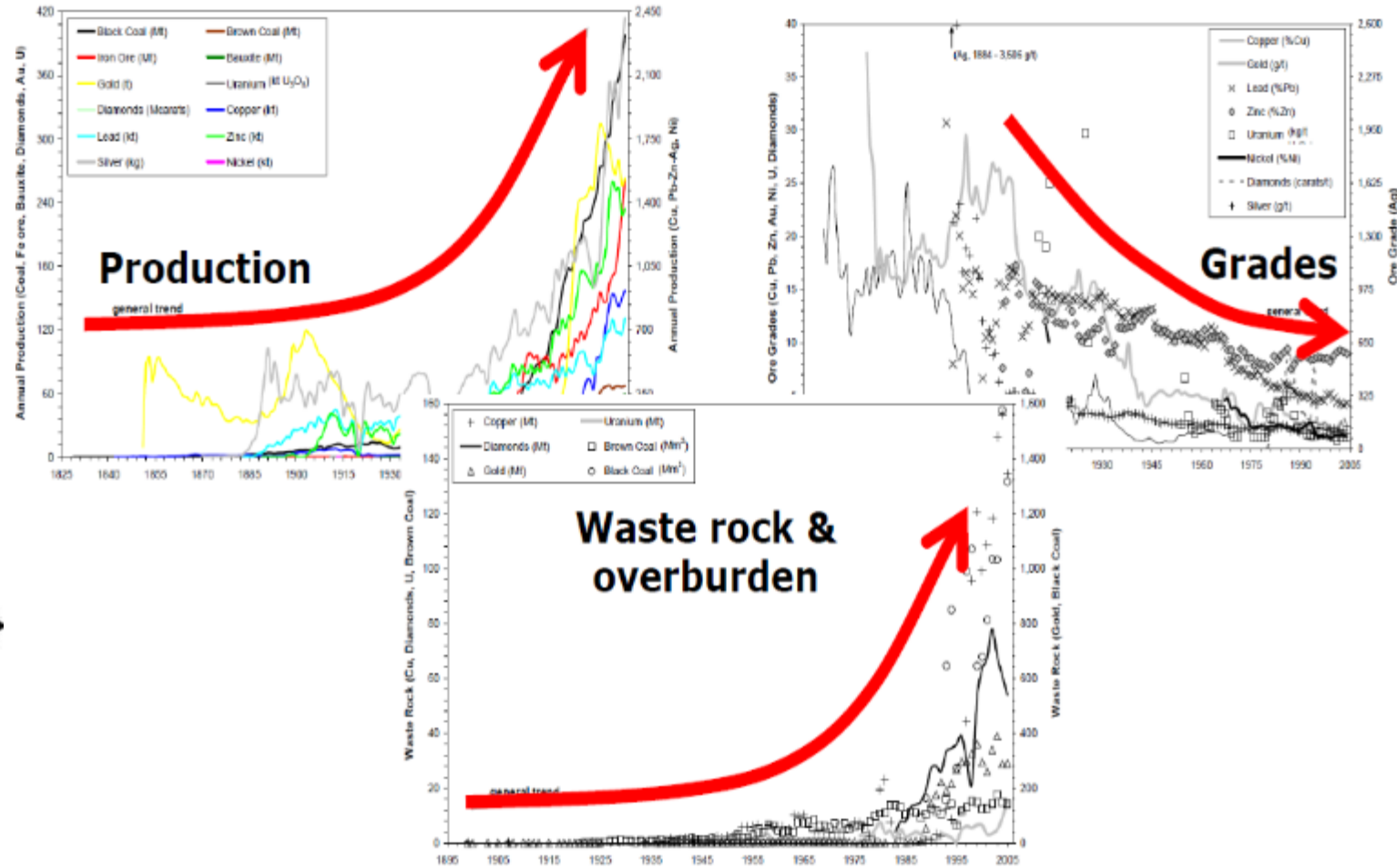
## Clean technologies



# Challenges



The need for raw materials as technology advances. Source: Markus A. Reuter, Ilkka V. Kojo, Outotec Oyj, Materia2/2012



(Source Mudd, 2007)

# How do we source raw materials?

**Gold Ore**



**Iron Ore**



**Ores** are naturally occurring rocks that contain metals or metal compounds



Gold



Iron metal

<https://www.luciteria.com>

**Metals** are the valuable parts of ores that can be extracted and sold

# Mining

- Mining is the process of extracting useful minerals from the surface of the Earth



- Resource distribution
- Growing demand
- Environmental issues
- Autonomy

One of the strategic actions to enhance the security of CRM supply is to diversify the sources

## Alternative sources

Mining operations produce various types of waste (e.g., tailings)

The waste could contain elements of economic interest



# Waste rock



- Consists of rock and target minerals in concentrations too low for economic recovery

- Size ranges from fine sand to large boulders



# Tailings





# What are tailings made of?



Metallic elements in red are **potentially toxic** but also **potentially economic**

## Sulphides and oxides

- Pyrite **FeS<sub>2</sub>**
- Pyrrhotite **Fe<sub>(1-x)</sub>S**
- Sphalerite **ZnS**
- Galena **PbS**
- Chalcopyrite **CuFeS<sub>2</sub>**
- Arsenopyrite **FeAsS**
- Magnetite **Fe<sub>3</sub>O<sub>4</sub>**

Processing fluids

## Silicates

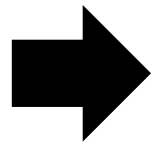
- Feldspars e.g., **NaAlSi<sub>3</sub>O<sub>3</sub>**
- Olivin **(Mg,Fe)<sub>2</sub>SiO<sub>4</sub>**

## Carbonates

- Calcite **CaCo<sub>3</sub>**
- Dolomite **CaMg(Co<sub>3</sub>)<sub>2</sub>**

# Large quantities of waste

- 10 grams per ton
  - ~ 0.001% gold
  - ~ **99.999% of the material is waste**



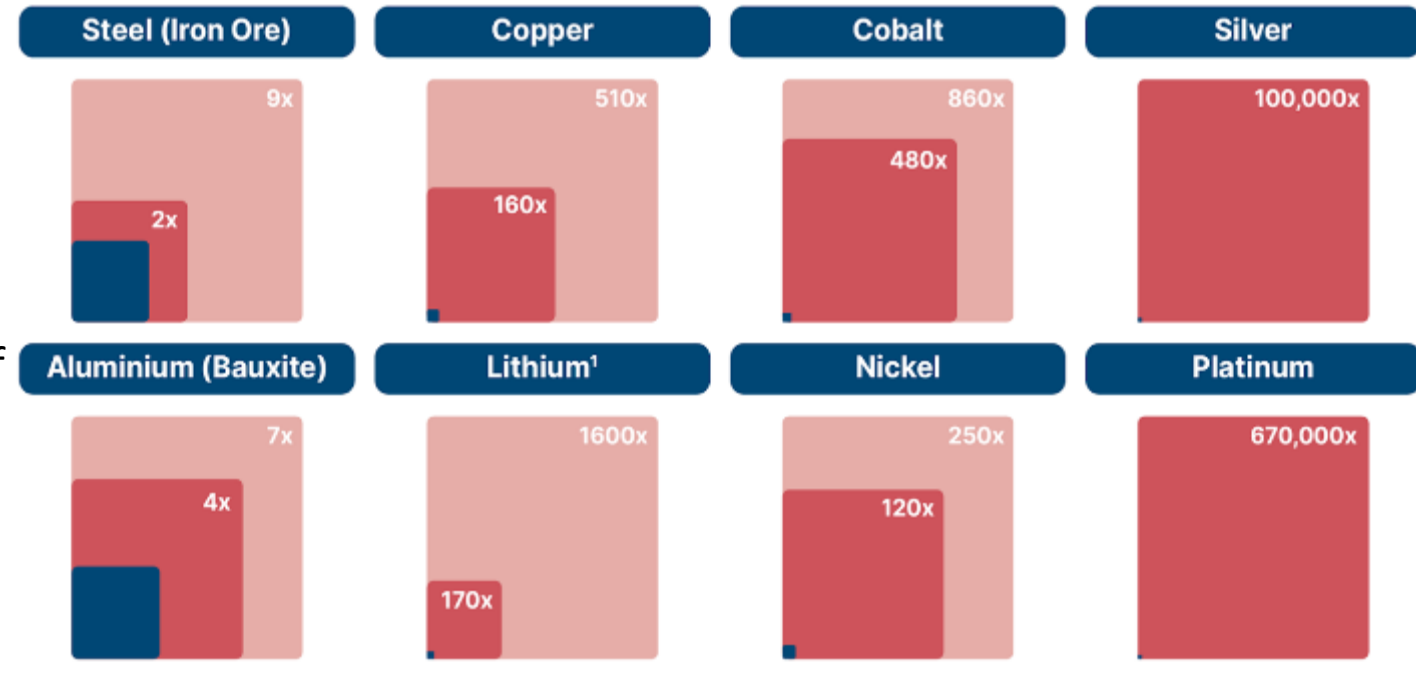
2-3 tons of tailings



Waste rock

Materials and associated ore grades and total material moved

1kg of commodity Total ore mined Total material moved



<sup>1</sup> For hard-rock mining of lithium.

SOURCE: Nassar et al. (2022), Rock-to-metal ratio: A foundational metric for understanding mine wastes.

According to the global tailings review, there is about **282.5 billion tonnes** of tailings worldwide (based on 8,500 tailings)



# Why valuable minerals in mining residues?

Mine waste often holds minerals of economic interest for several reasons

- Inefficient recovery
- Commodity-specific extraction
- Low economic value
- Natural process
- Geology
- Technological advancement
  - High-tech
  - Historic mining practices

# Benefits of re-mining



**Security of supply**



**Economics**



**Environment**



**Resource efficiency**



**Circular Economy**



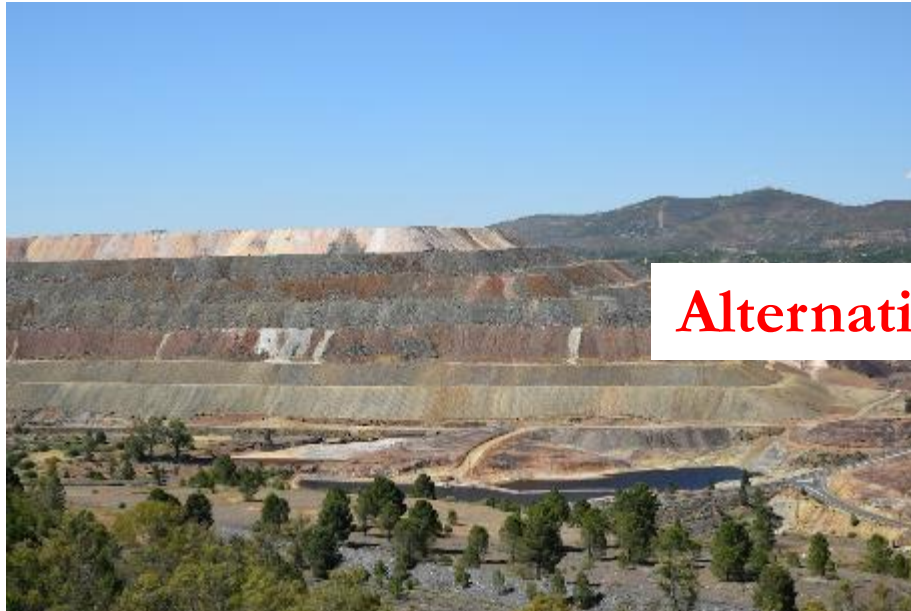
**Could reduce the need to open new mines**



# Project

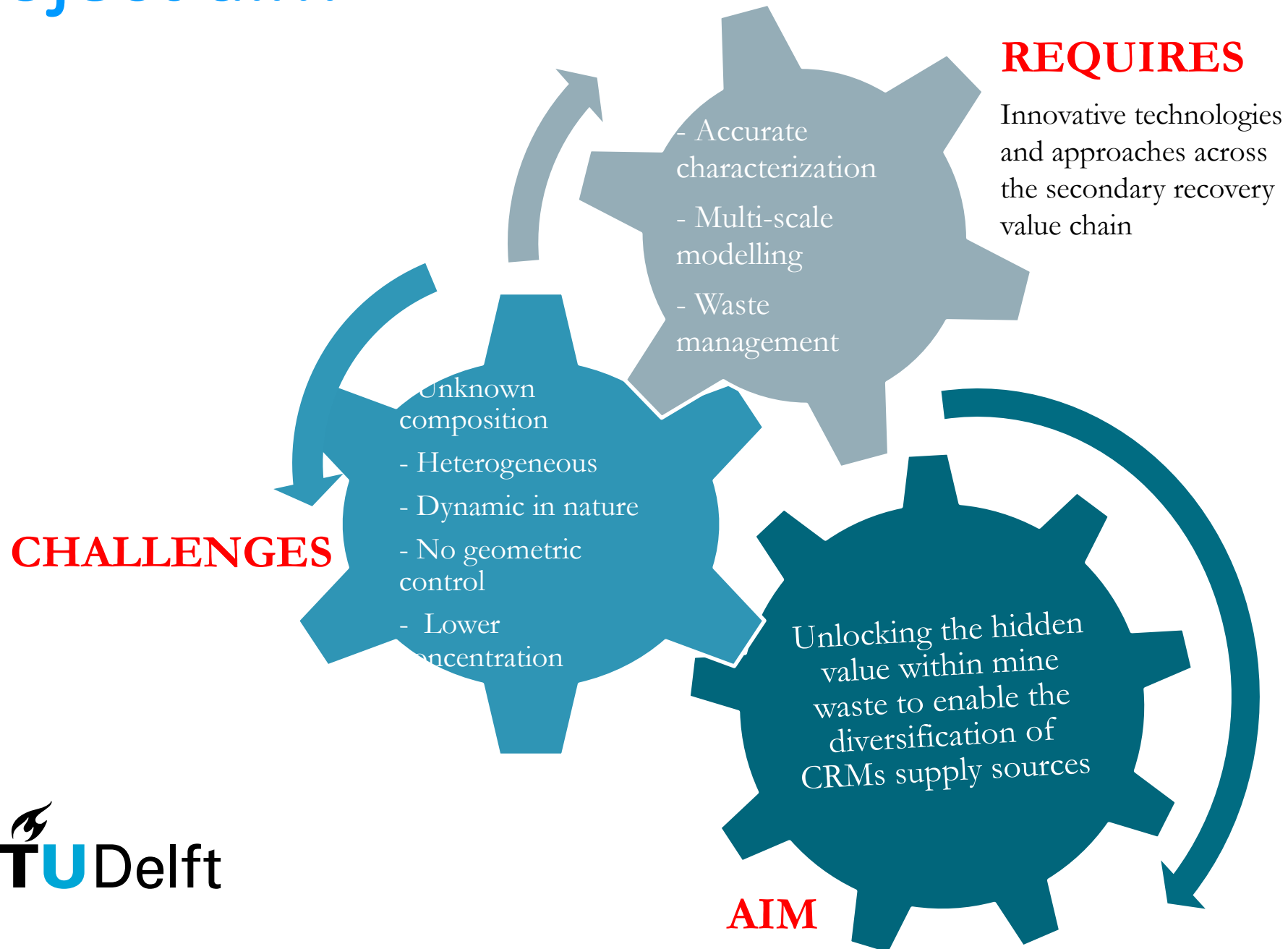
Sourcing of CRMs from extractive waste such as

- Waste rock, tailings, and metallurgical slags



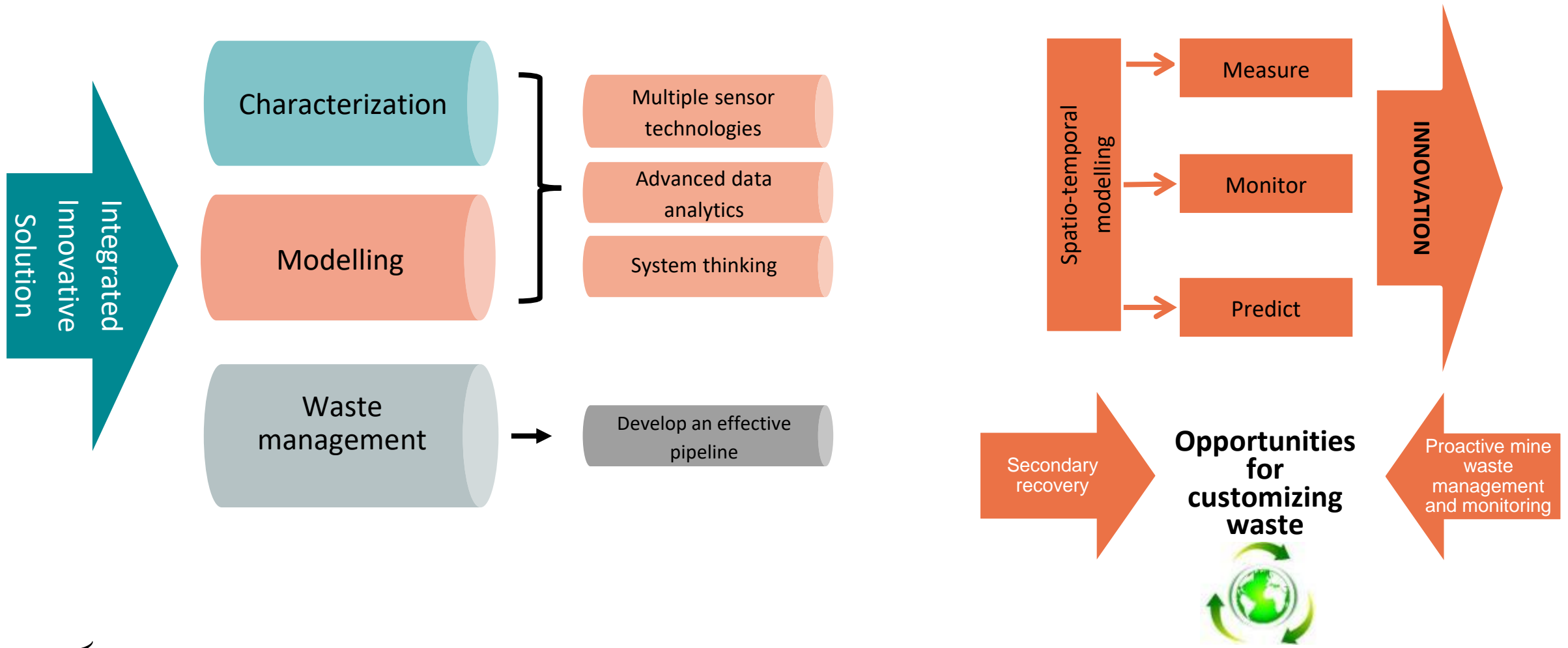
**Alternative sources?**

# Project aim





# Research concept



# Sensor Technologies

- Various technologies
- Diverse properties
- Different platforms
- Multi-scale data

**Plenty of options!**

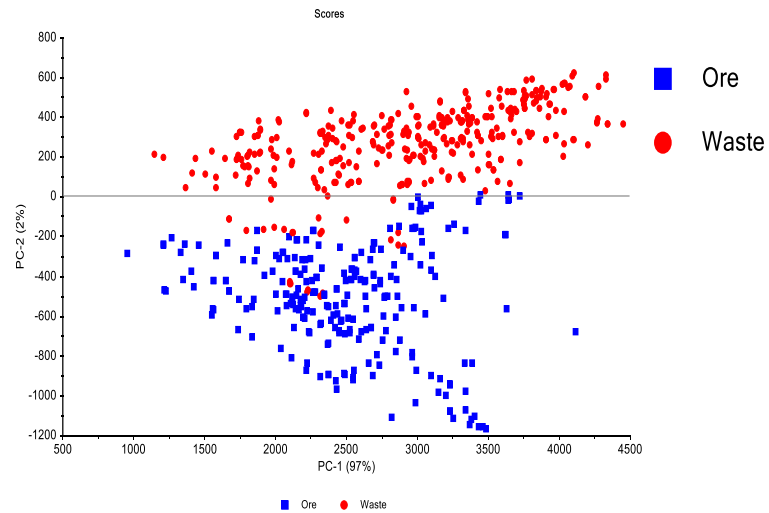


Figure: A PCA model computed using MWIR data

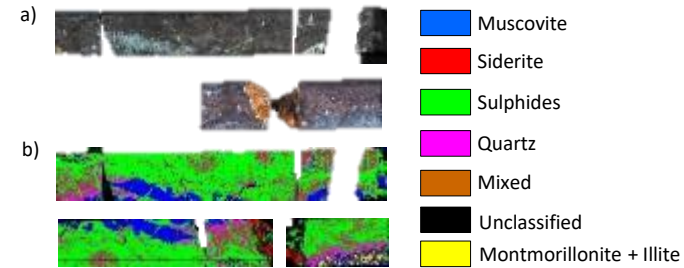


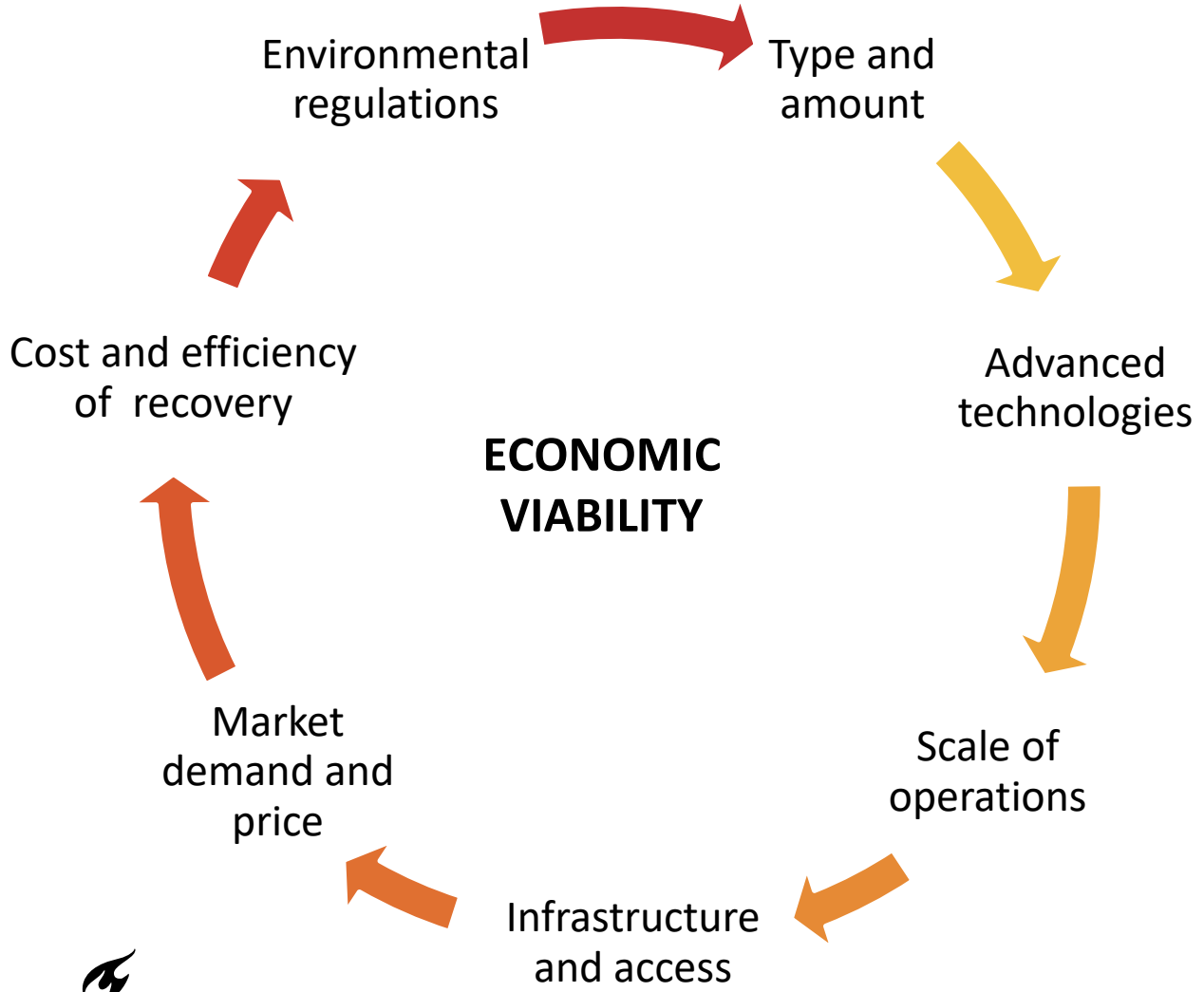
Figure: Mineral mapping using Hyperspectral imaging

## LIBS

	Correct classification rate %
Into 2 classes (at 2000 ppm cut-off grade)	95

Figure: Classification of Li ore samples using LIBS data

# Economic viability of re-mining?



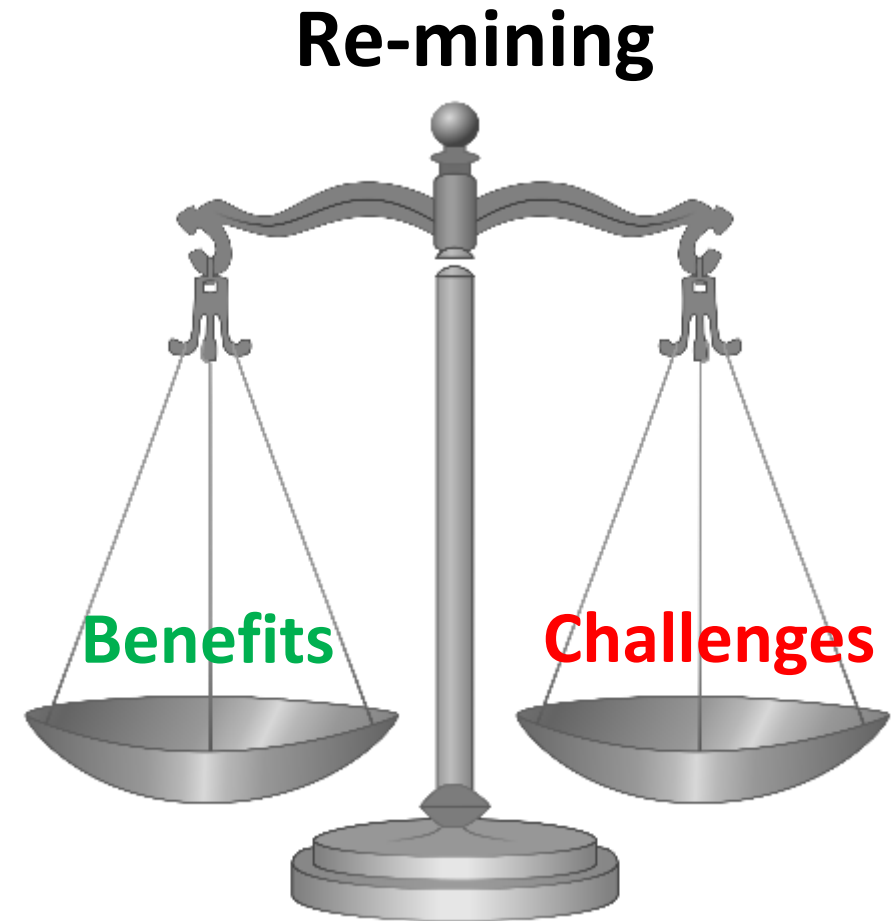
**IMPORTANT NOTE**

Vary significantly depending on site-specific factors and market conditions



# Re-mining requires environmental permit

- Social license: community consent and involvement
- Long-term environmental impact
- Transparency and accountability
- Reclamation and rehabilitation obligations



# Mine waste projects in the Section of Resource Engineering

- Tailings from old Pb\_Zn mine, from **Slovenia**
- Coal mine waste, **Germany**
- Tailings and waste rock characterization, **Spain**
- Metallurgical Slag, **Colombia**



Mine waste dump site in Spain

Desta, F., Kamps, O., and Buxton, M.: Sensor-based Multi-Level Analysis of Ferronickel Furnace Slag: Exploring Economic Opportunities, EGU General Assembly 2024, Vienna, Austria, 14–19 Apr 2024, EGU24-5645,

Kamps, O., Maghsoudi, F., Desta, F., and Buxton, M.: Fourier Transform Infrared data analysis to analyse the environmental impact of coal mine waste, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023

Maghsoudi Moud, F., Kamps, O., Desta, F., and Buxton, M.: Multi-sensor approach for modeling rare earth elements within the lignite waste dumps, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-16360

# Significance & future impact

## Significance & future impact

- Recovery of CRMs
- Diversification and security of supply source
- Reduced environmental impact
- Promote efficient resource utilization



- Scalable and adaptable framework
- Technological development
- Collaboration – multidisciplinary approach

 **TU Delft** The end of mine life is the beginning of something new!



**Thank you for your attention!**