From FineFuture to FINEST

Resource Supply for the Energy Transition and Sustainable Value Chains

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PART 1: FineFuture

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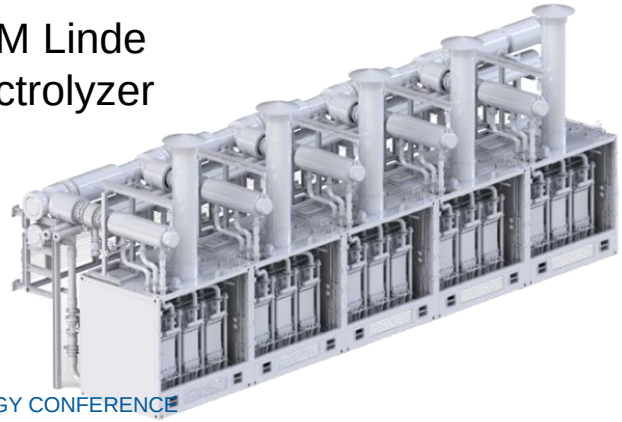
FineFuture: Resource technologies for base metals and CRMs

- Large amounts of base metals and CRMs are required to decarbonize industry and society
- Secure supply at manageable costs and acceptable CO_2 footprint is a challenge

Platinum
(Photo: Kalineri)

ITM Linde
electrolyzer



Copper

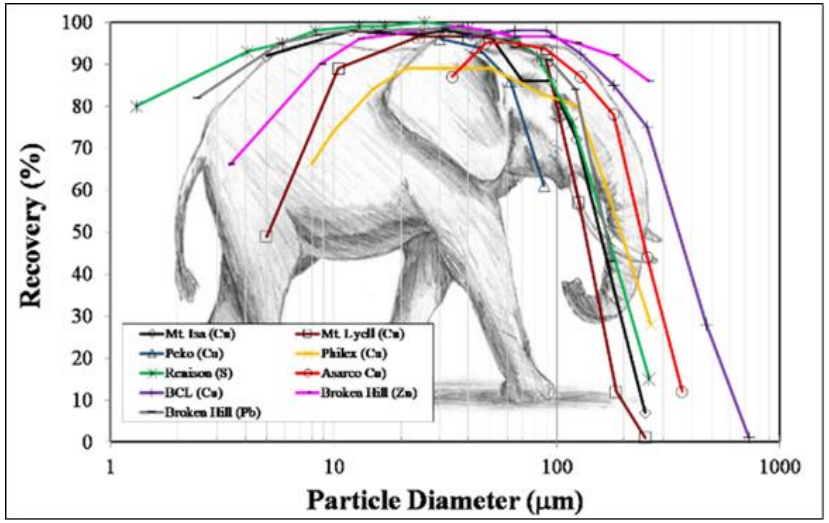
Mineral processing of base metals and and CRMs: The challenges

- Exhaustion of natural ore deposits:
  Cobalt: 0.5-2 kg Co/ t ore; PGMs: some g/t
- Complex composition of the ores:
  e.g.cobalt forms tiny structures (width: some µm, 10-50 µm long)

➔ more and more valuables are finely disseminated

➔ all mineral processing technologies have big problems with fine particles

- In addition:
  - High losses of valuables of up to **30%**
  - Large tailing ponds
    ➔ **huge environmental and safety problems**



©Eriez, MEI Flotation `17

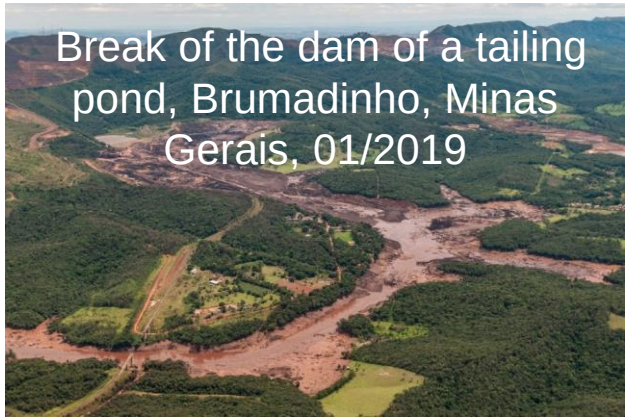


Photo: Vinícius Mendonça/Ibama Mais informações

Focus of FineFuture

Innovative flotation technology based on fundamental understanding

Complex ores, e.g.
Chalcopyrite with quartz

Mineral processing

Ore concentrate

Smelter & Refinery

Copper

Magnesite Ores

GRECIAN MAGNESITE
MAGNA

MAGNESITE IS A TRUE CELEBRITY MINERAL
Sculptures are not made of it. Almost everything else is, e.g.:
- Crucial and irreplaceable refractory material
- Various applications in the chemical industry
- Important for fertilizer production

Copper Ores

KGHM POLSKA MIEDŹ

COPPER – THE BASE METAL FOR ELECTRIC GRIDS, DIGITALIZATION…

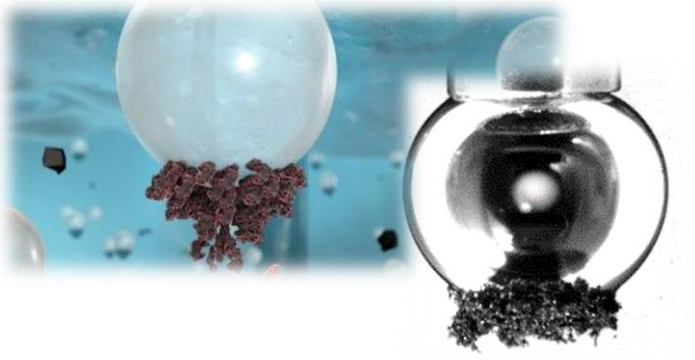
Manganese Ores (Gabun)

eramet

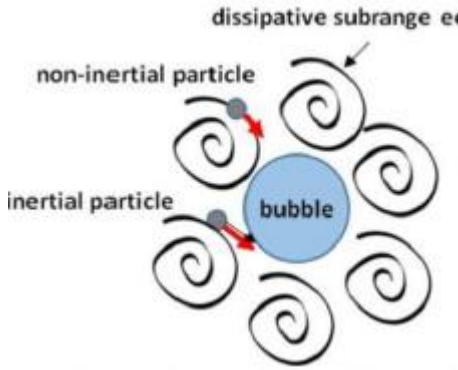
MANGANESE ORES – for steelmaking and foundry activities, chemical uses: batteries, animal feed, water treatment

Knowledge-driven ➔ to industrial scale

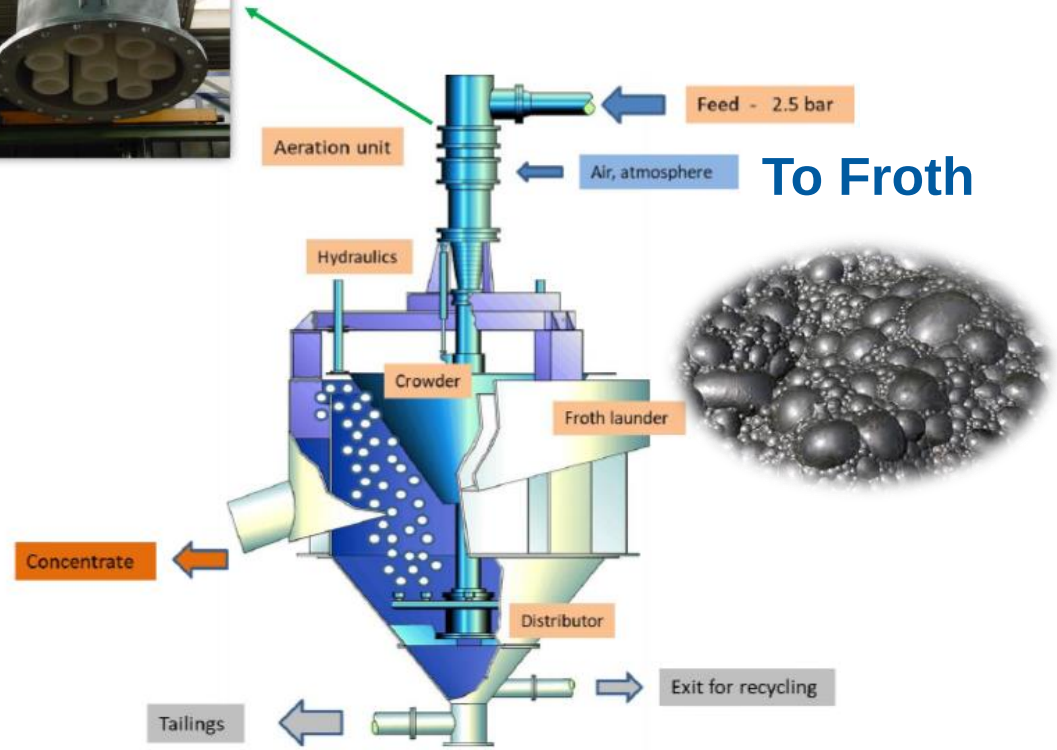
From mineral surfaces



via particle-bubble attachment in turbulent flows



Self aspirating Aerator
Multi Venturi system



To Froth

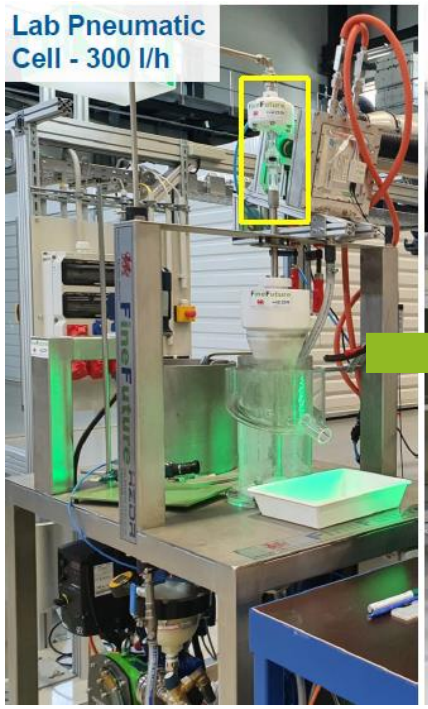
Maelgwyn Imhoflot™ Cells (second generation)

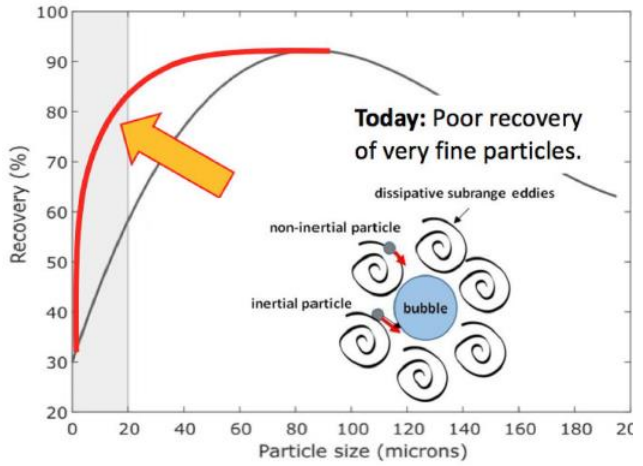
From lab scale

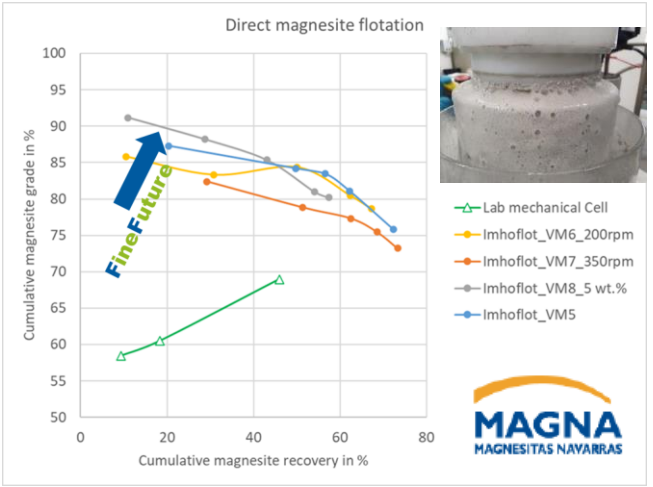
via pilot scale

to industrial scale

From lab scale ➔ via pilot scale ➔ to industrial scale







GRECIAN MAGNESITE

eramet

ТУРБОФЛОТСЕРВИС
TURBOFLOTSERVICE

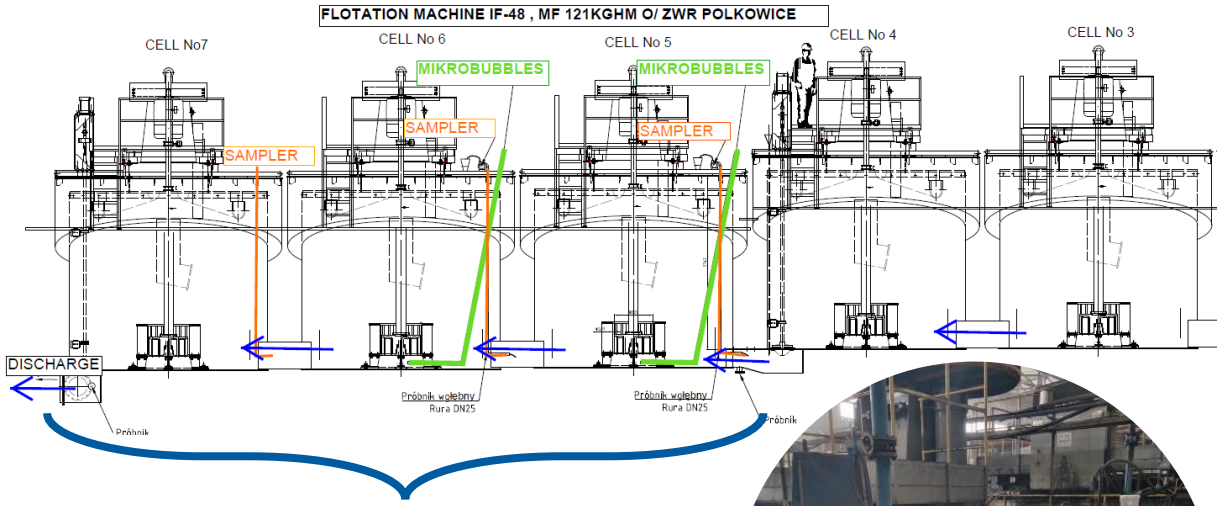
MAELGWYN MINERAL SERVICES

MAGNA
MAGNESITAS NAVARRAS

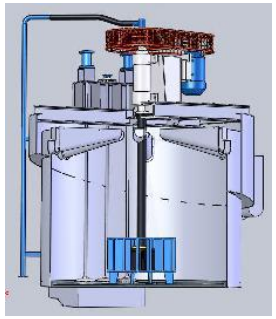
KGHM
POLSKA MIEDŹ

Industrial Scale Flotation – Case studies (Copper ore/Tailings)

I. Large scale injection of microbubbles

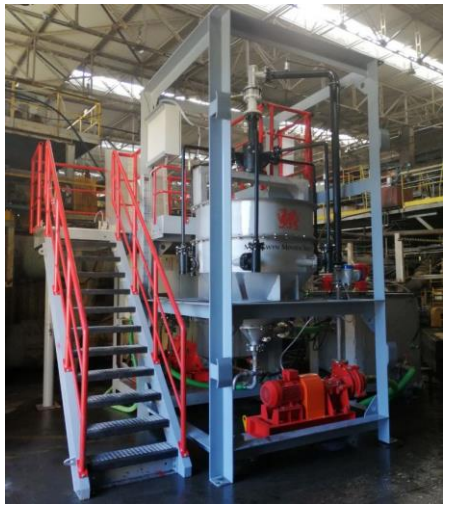


Last cascade of scavenger flotation (3 flotation cells)



IF type 48m³ flotation cell

II. Optimized pneumatic flotation reactor



KGHM POLSKA MIEDŹ

MAELGWYN MINERAL SERVICES

- Pilot (semi-industrial) plant 30 m³/h at KGHM copper concentrator

FineFuture…lots of Lessons Learned, e.g.

- There is **no single reagents** formulation that can be applicable and efficient **for** the recovery of **all minerals**.
- **Limited capability** of existing **advanced optical diagnostics** to study experimentally bubble-particle collisions under **turbulent conditions**.
- **Partly efficient CFD** (Computational Fluid Dynamics) **multiphase simulations** incorporating the innovative complex flotation kinetics developed in FineFuture.
- **Bubbles generation** is a **reactor dependent** process
- FineFuture **lab scale pneumatic cell** showed **promising** results for ultrafine particles …..

More work on **finetuning and refining** of theoretical and engineering features based on **large scale tests**.

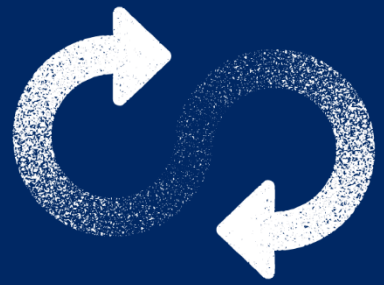
We are very grateful to the European Union's Horizon 2020 research and innovation programme for funding our works under grant agreement No. 821265.

HELMHOLTZ

HZDR HZB KIT TU BERGAKADEMIE FREIBERG UFZ

Spitzenforschung für
große Herausforderungen.

Helmholtz Sustainability Challenge



FINEST

Use and management of **finest** particulate anthropogenic material flows in a sustainable circular economy

Part II: FINEST

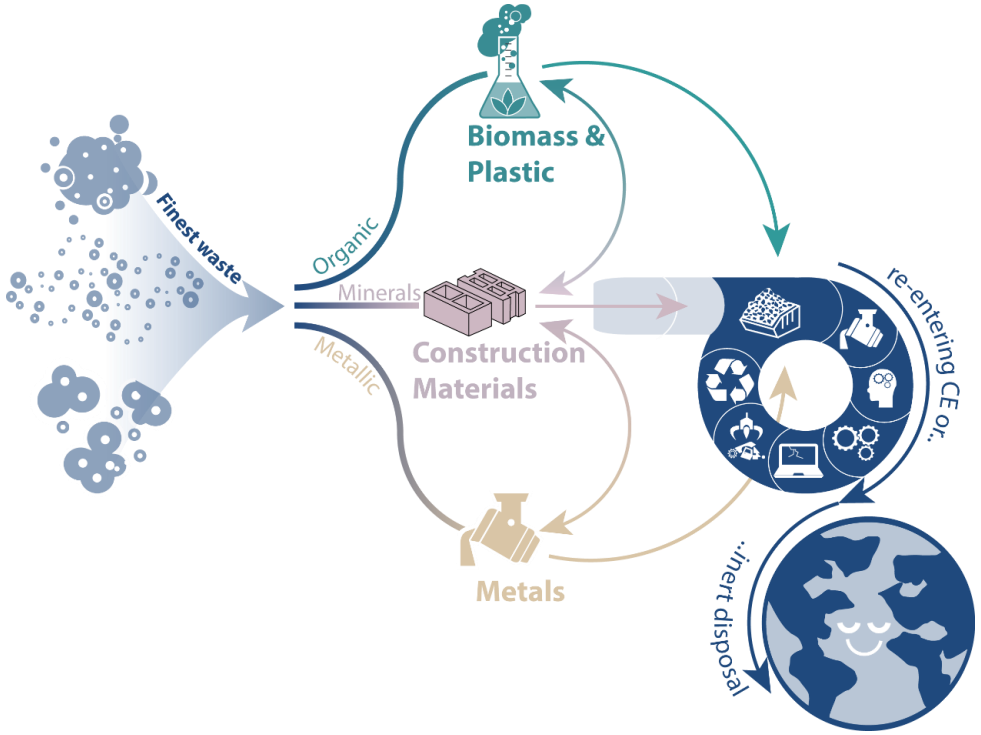
Central research question & research approach

Central research question

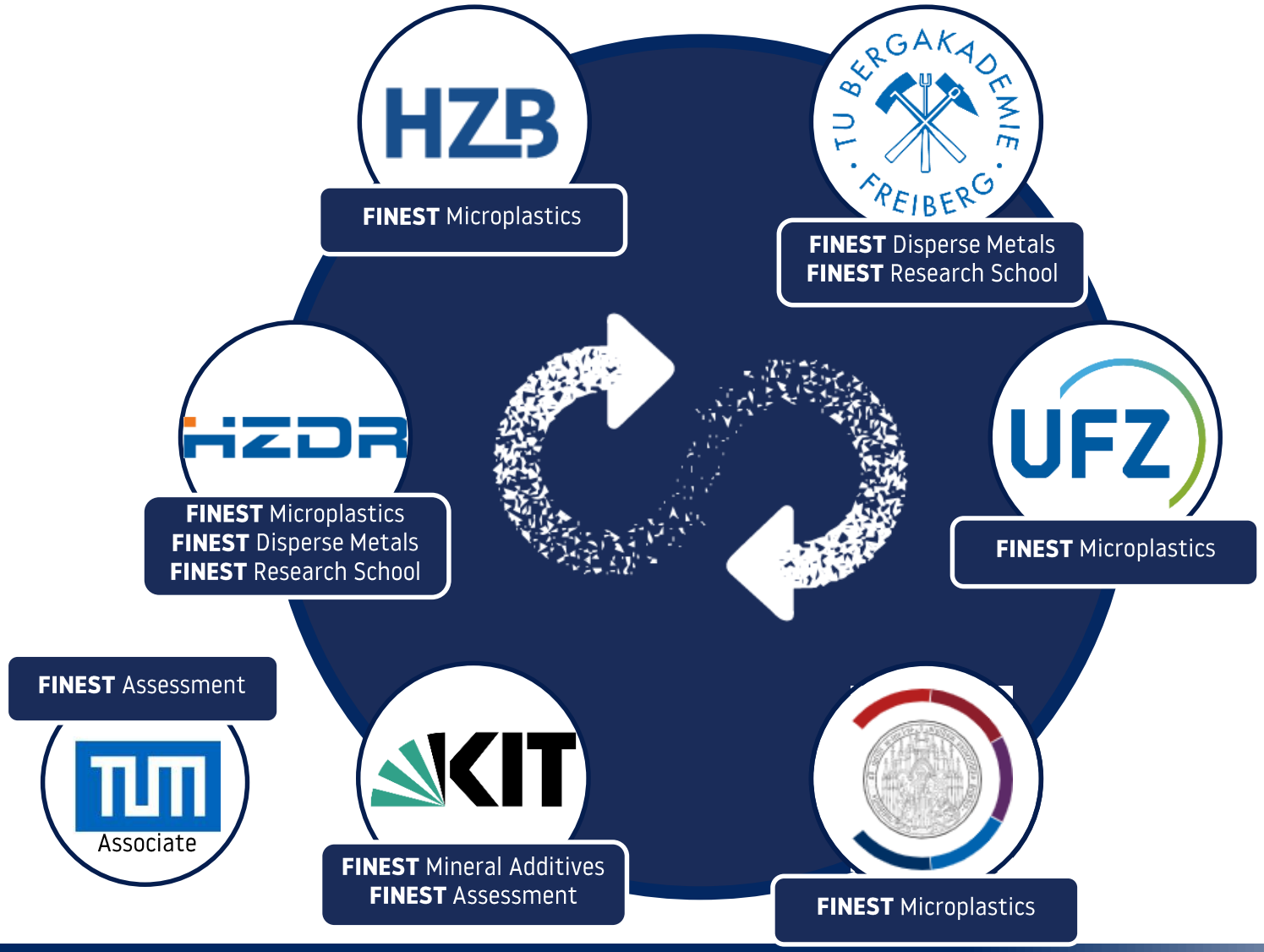
FINEST will find sustainable solutions for fine-grained residues from various sources that are currently only disposed of and not utilized

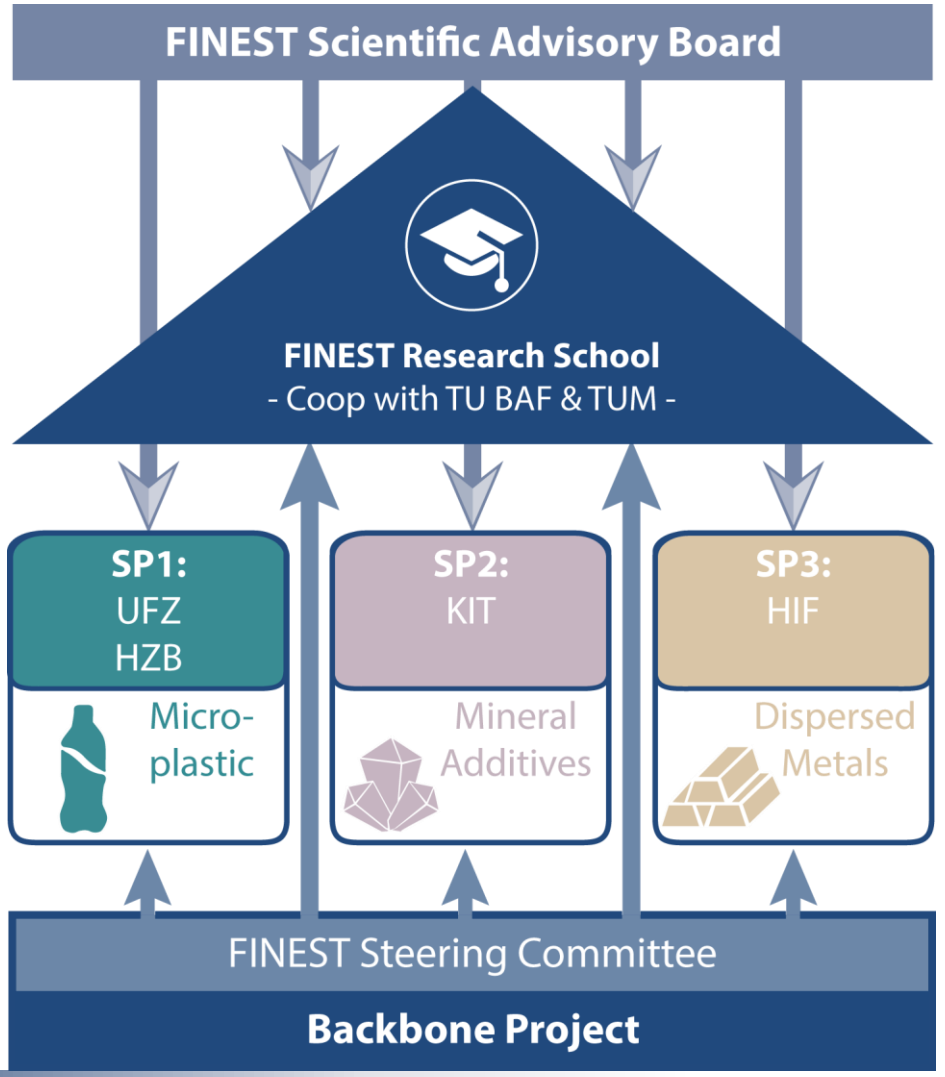
FINEST Approach

Through cleaning, separation, and blending processes several types of valuables and inert residues will be generated economically viable and ecologically benign.



FINEST Consortium and Project Structure



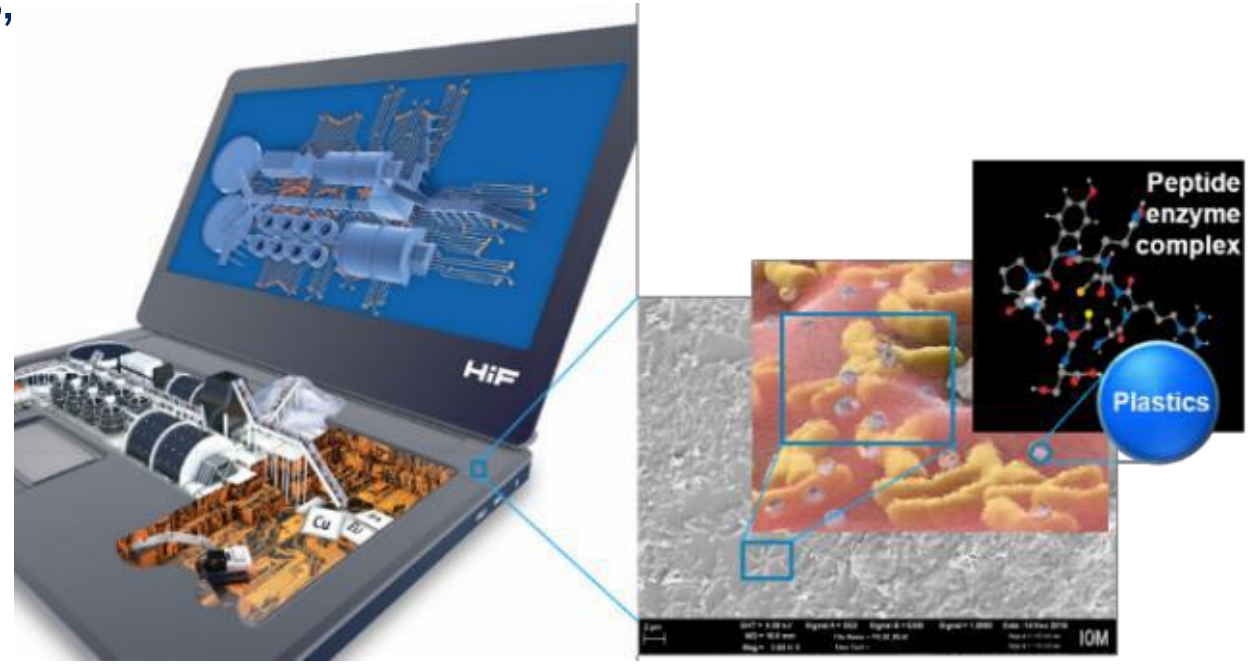


Subproject 1: **FINEST** Microplastics

General objective ➞ Bio-based recycling of (micro-) plastic residues

Goals - products:

- **Biocatalysts** to convert plastics fractions to yield
  - specific mono-/oligomers for product synthesis,
  - microbial biomass amenable to further microbial fermentation and
  - inert and safe residues for deposition
- **Anchor peptide arrays** enabling improved accessibility of microplastics for degrader enzymes and separation/detection of plastics
- **Novel thermal sensors** for non-invasive process monitoring

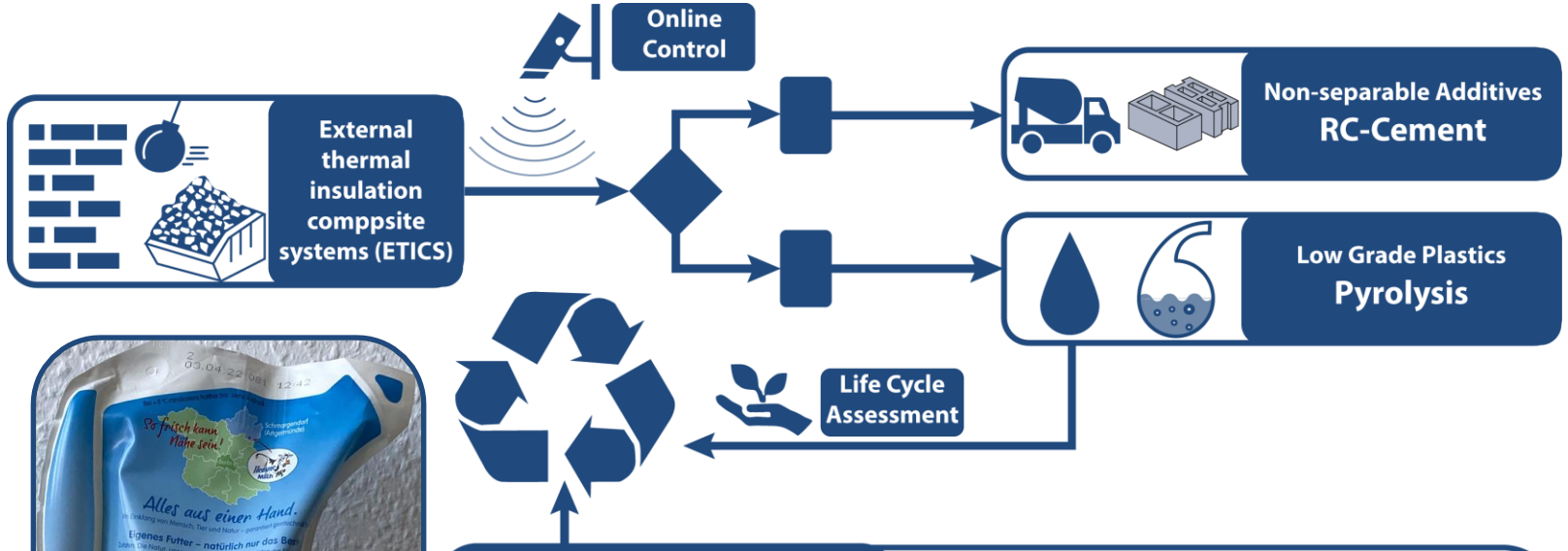


Subproject 2: **FINEST** Mineral Additives

General objective ➡ Recovery of mineral additives during chemical recycling

Goals:

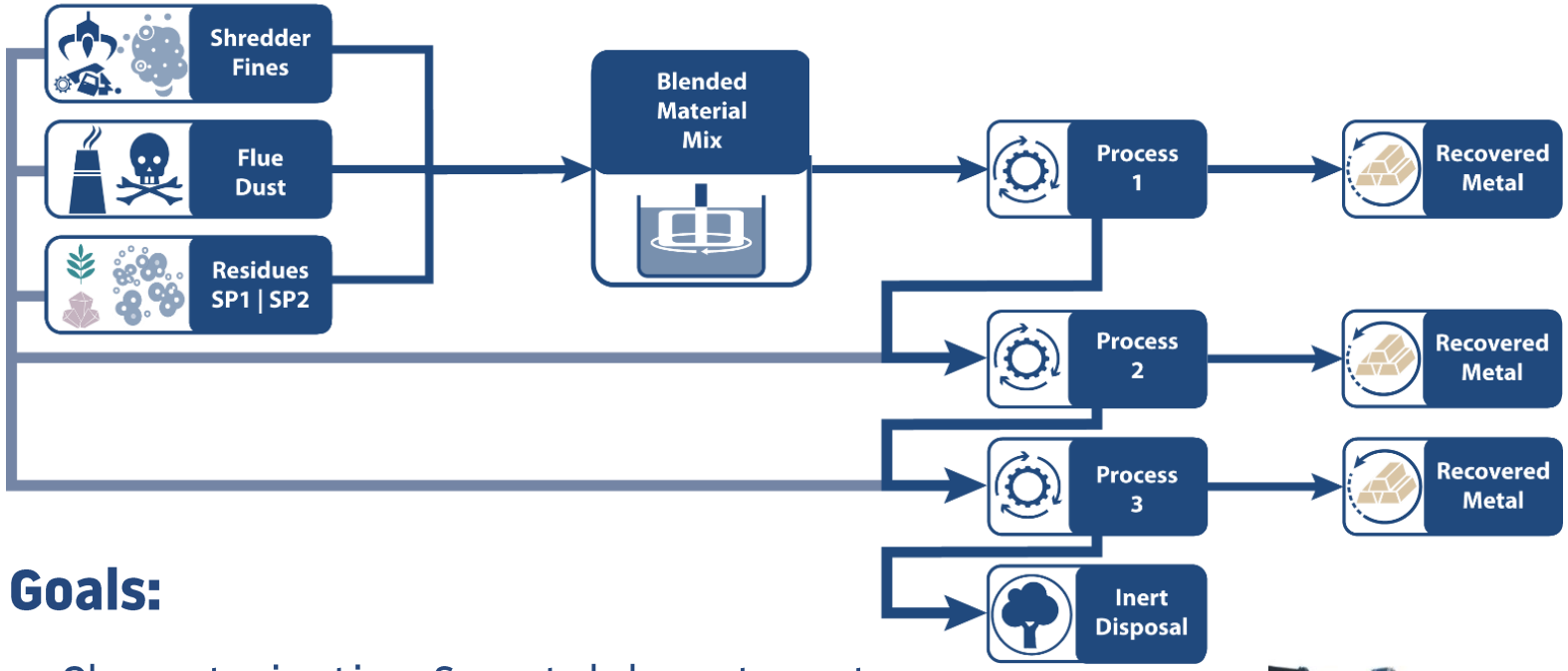
- Mapping & Characterization
- Sensors (process control)
- Monitoring during pyrolysis
- Use in RC-Cement
  - Additive partitioning
  - Effects on products
- LCA for decentralized recycling plants



Verpackung:
Durch den 40 %igen Kreideanteil reduziert sich der Kunststoffbedarf auf ein Minimum. Zur Herstellung ist nur sehr wenig Wasser und Energie erforderlich.

Subproject 3: **FINEST** Disperse Metals

General objective ➡ Blending of complex residues, metal recovery or benign storage



WORK PACKAGES	MILESTONES
① knowledge management	database for mass balances – modelling – technology ready
② inline process control (sensors + simulations)	software for inline process control developed
③ high-temperature processes	metal recovery and inertisation raised from TRL 3 to 4
④ mixing and agglomeration	safe mixing possible at TRL 3 to 5
⑤ assessment economic, ecological and social	inline and offline assessment of processes (incl. SP1 and SP2)

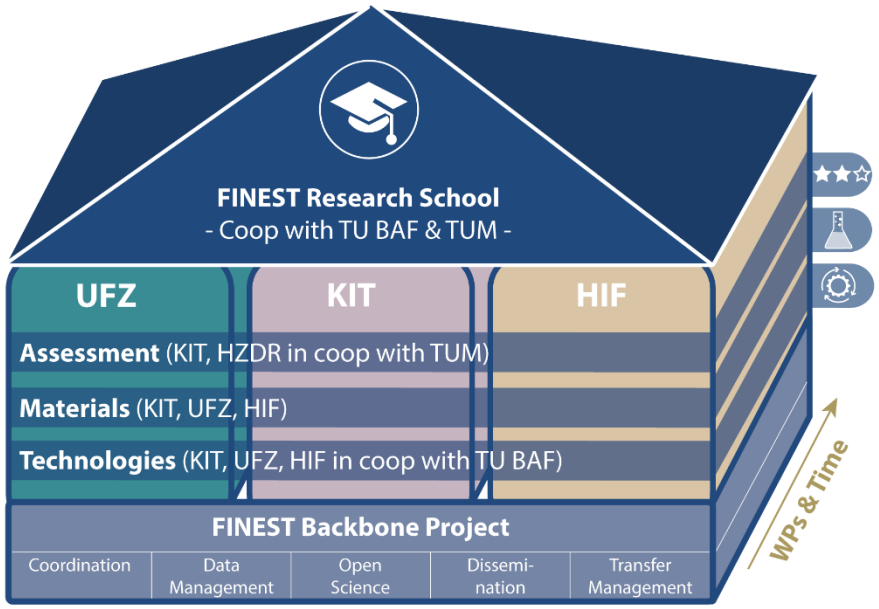
Goals:

- Characterization & metal deportment
- Blending and agglomeration technologies
- Metal recovery
- Comprehensive sustainability assessments

FINEST Satellite Projects

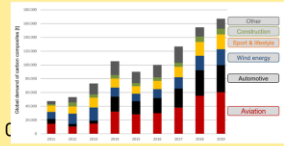
Goals:

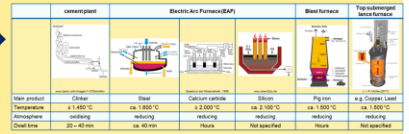
- Short-term projects diversifying the campaign
- High risk-high gain approaches
- Linking to core projects or filling gaps



Objective: Utilization of end-of-life carbon fibers (no solution so far and high hazardous risk)

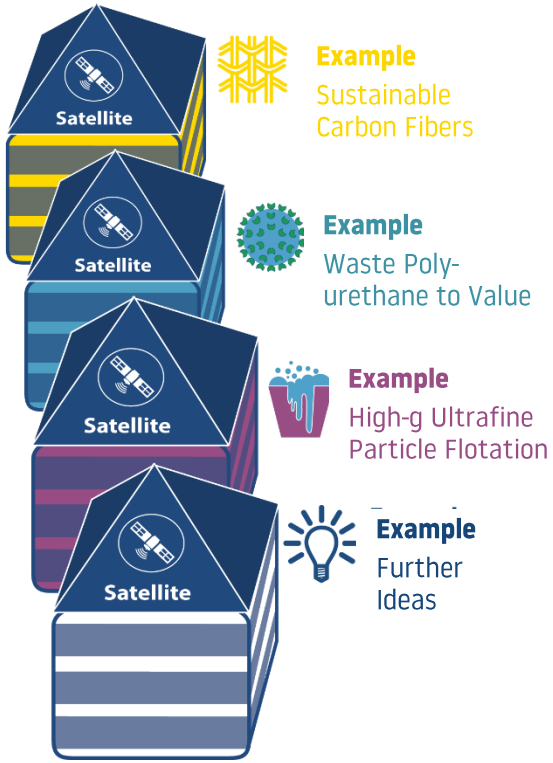
- Increasing demand for carbon fiber reinforced plastics CFRP;
- Downcycling issue
- Generation of respirable fiber fragments during treatment of C
- **Degradation of CF in thermal processes** with sufficient temperature, residence time and back-mixing – industry processes





Research proposal:

- Basic investigations on fiber degradation scale-up, process integration, demo, evaluation
- Potential industry partners: fiber suppliers (e.g. CU), applicants pyrometallurgy (e.g. BSW)

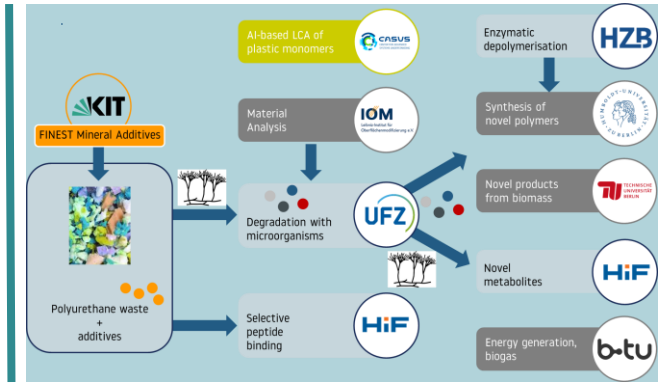


Example
Sustainable Carbon Fibers

Example
Waste Poly-urethane to Value

Example
High-g Ultrafine Particle Flotation

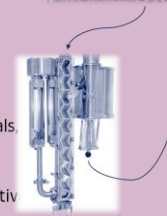
Example
Further Ideas

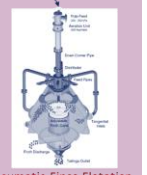


Objective: Multi-step flotation separation with special focus on variable selective hydrophobization and depression of the anthropogenic particles (*innovative challenge*)

Approach:

- PhD study on effective **ultrafine particle pneumatic froth flotation** separation
- Material focus: Waste Dust from air classified shredder fine fractions containing valuable metals, plastic components and complex inorganics
- Fluid dynamic enhancements to enable efficient particle-bubble coalescence and reduced unselectiv ultrafine particle entrainment

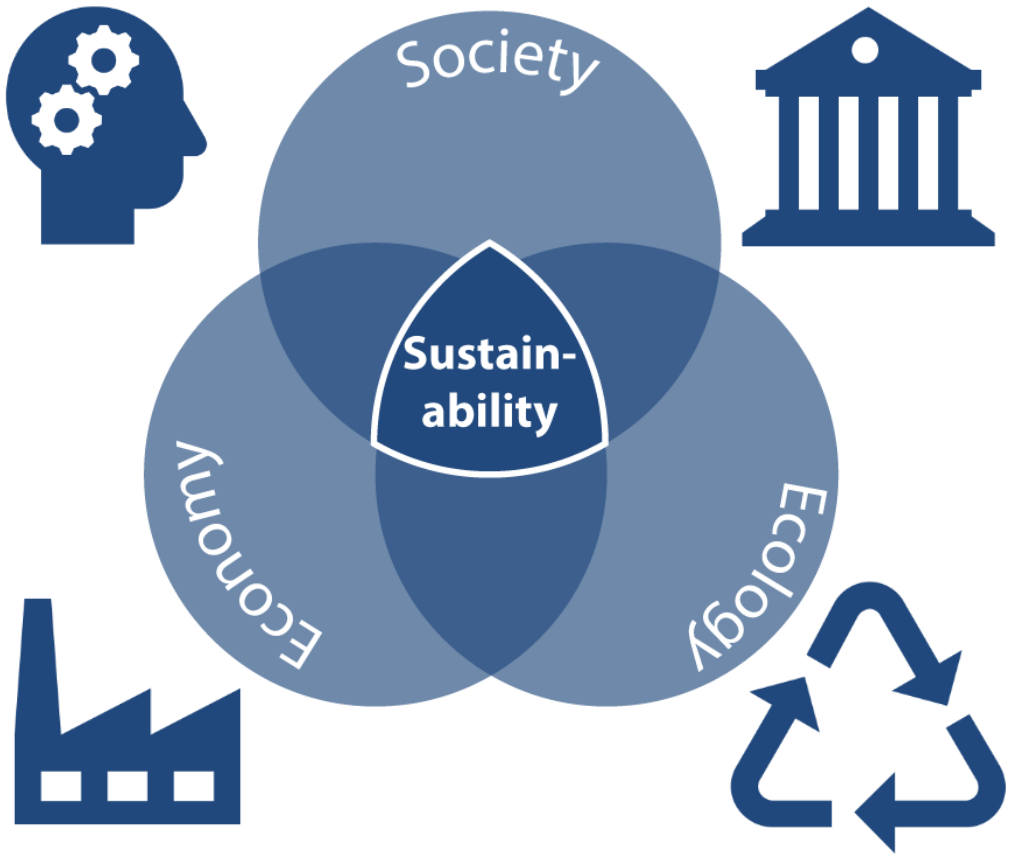

Air classification of shredder fractions


Pneumatic Fines Flotation of Waste Dust from Air Classifier

Societal relevance & impact

Impact on education

- Interdisciplinary expertise
  - Resource management
- Life-cycle thinking
- Industrial ecology



Impact on decision-makers

- Adaptation of regulations
- Shift in research funding
- CE thinking in procurement

Impact on industry

- Reduction of waste
- Valorisation of residues
- Knowledge transfer
  - Skilled personnel
- Tech transfer

Impact on ecology

- Resource recovery ⇧
- Materials kept in the loop
- Amount disposed ⇩
- Environmental risks ⇩

The Future is Circular.

This work was performed as part of the project ‘Use and management of **finest** particulate anthropogenic material flows in a sustainable circular economy’ (**FINEST**), which is funded by the Initiative and Networking Fund of the Helmholtz Association (grant agreement number KA2-HSC-10).

Hans Carl von Carlowitz
(1645-1714)