Fraunhofer IKTS

Critical Minerals & Tailings Valorisation series

MRIWA Webinars (2026)

Towards sustainable critical raw material production: lithium recovery from spodumene as a demonstration case

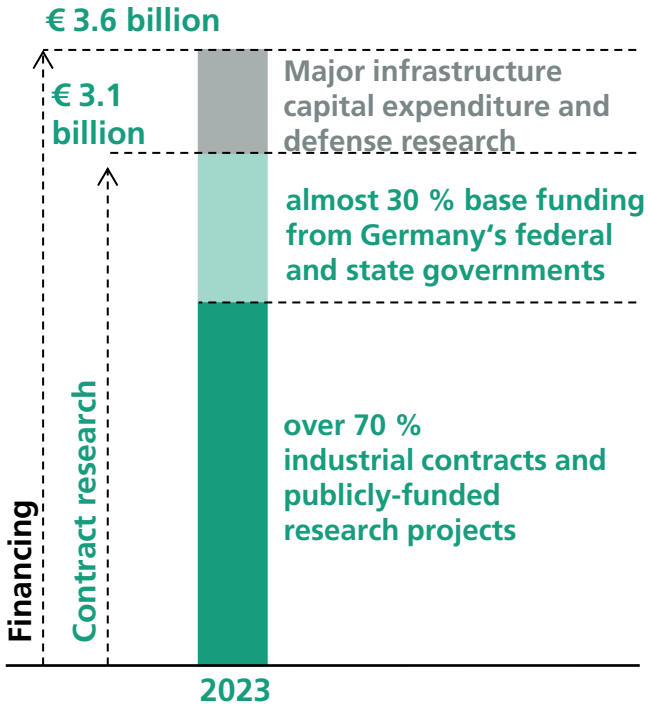
Dr.-Ing. Sandra Pavón

Fraunhofer-Gesellschaft

Applied research with a focus on key future-relevant technologies and the commercialization of findings in business and industry. A trailblazer and trendsetter in innovative developments.

32,000 employees

75 institutes and research units



Fraunhofer IKTS

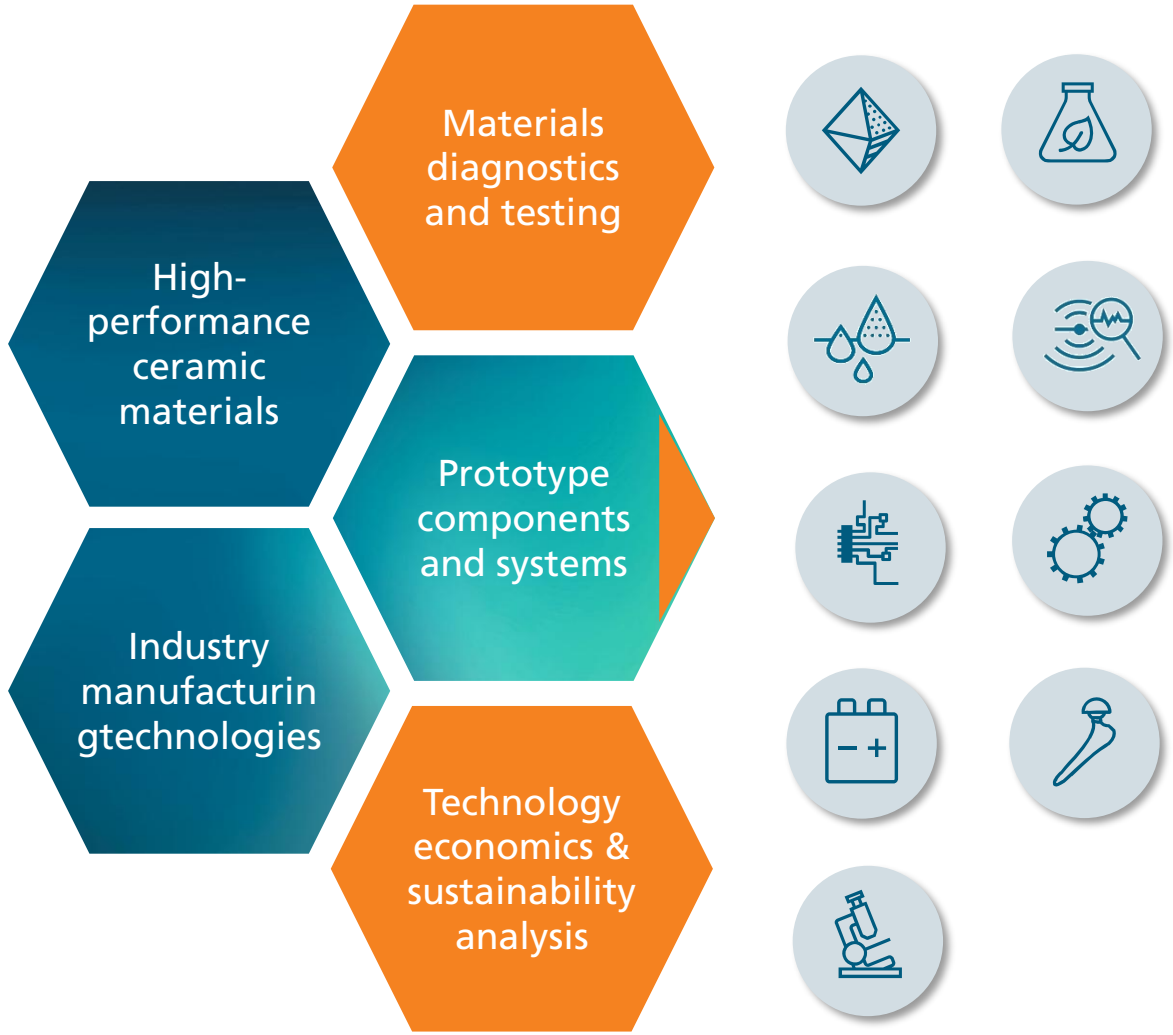
Fraunhofer Institute for Ceramic Technologies and Systems

Fraunhofer Institute for Ceramic Technologies and Systems IKTS

Europe’s leading R&D institute for ceramics

Research and technology service provider in the field of high-performance ceramics

- From materials to systems
- In complete production lines up to pilot-plant scale
- Incl. Materials diagnostics and testing
- Incl. analyses of economic viability and sustainability



833 employees*

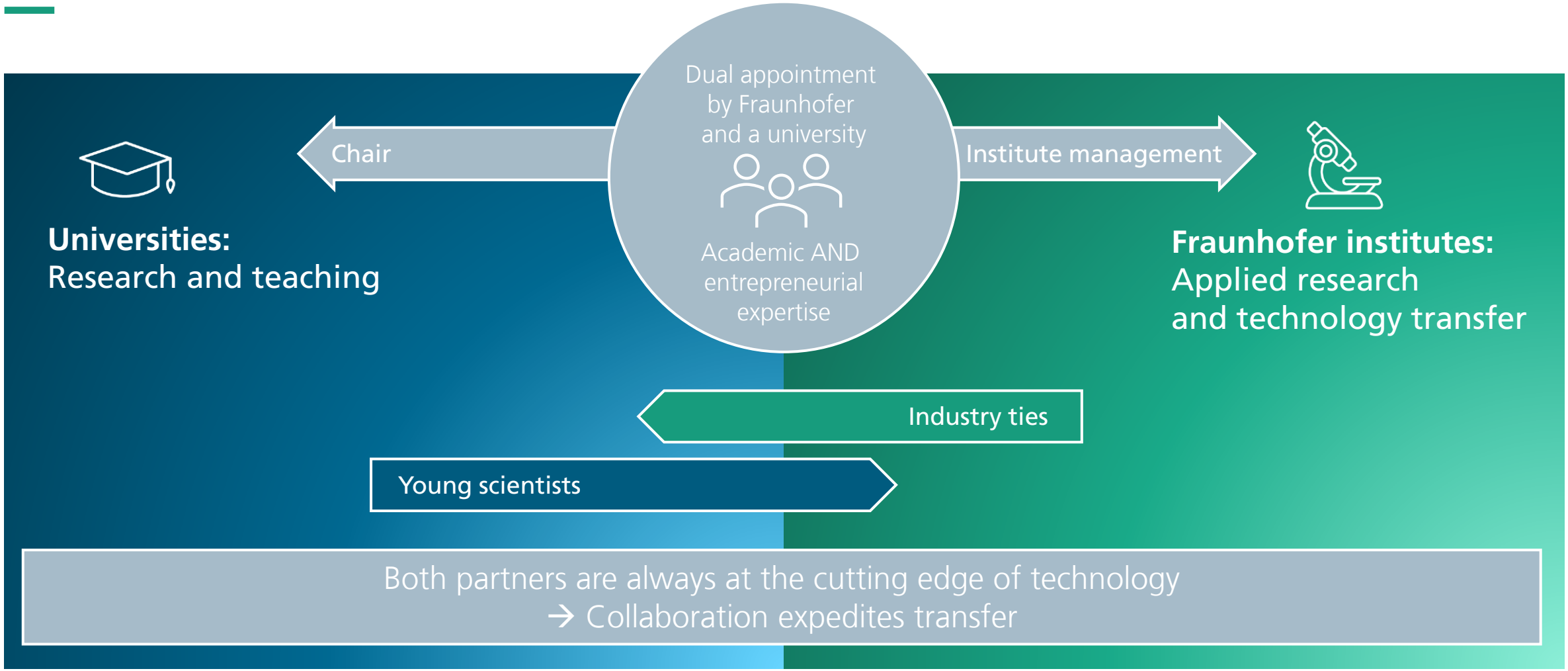
13 sites

106.2 million euro overall budget*

* as of December 31, 2025

Fraunhofer and Universities

Complementary synergies



Saxony: where competences meet to power industry

Complementary synergies

Turning Science into Solutions

Technische Universität Dresden

Founded: 1828 – one of Germany's oldest TU
Students: 29,000 students
Staff: 5,600 academics & 2,900 administrative
Academic breadth: 17 faculties, 119 degree programs

- A leading comprehensive technical research university; member of elite German TU9 network
- International profile; students from > 128 countries
- Recognized Excellence University under Germany's Excellence Strategy

Fraunhofer IKTS

Founded: 1992 – high-performance ceramic
Staff: 835 (84% scientists & administrative, 16% students)
Sites: 13

- Bridging materials science to industrial systems
- Tackling complex material and process challenges, from advanced diagnostics and analytics to complete system demonstrations, supporting industry adoption
- Multi-site setup and extensive partnerships

TU Bergakademie Freiberg · TUBAF Die Ressourcenuniversität. Seit 1765.

Founded: 1765 – oldest mining university
Students: 4,400 students
Staff: 2,100 academics & administrative
Academic breadth: 6 faculties, 90 degree programs

- Historically specialized in resource technologies, mining and circular economy
- Combines tradition with research on energy systems, environmental tech and recycling
- Research-intensive community with close industry link

Saxony: where competences meet to power industry

Complementary synergies

Fraunhofer IKTS

Turning Science into Solutions

Technische Universität Dresden

TU Bergakademie Freiberg

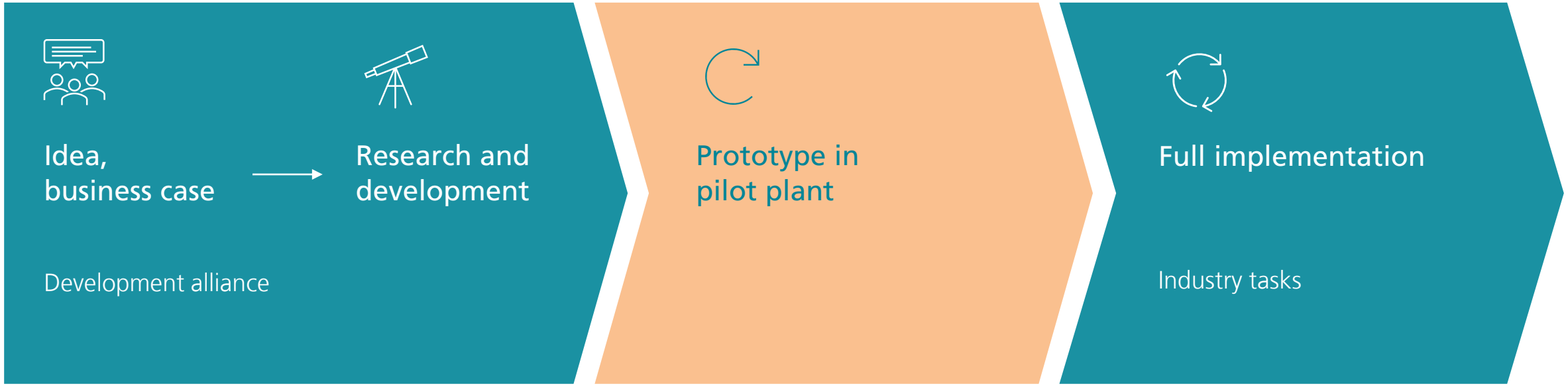
TUBAF
Die Ressourcenuniversität.
Seit 1765.

Saxony: where competences meet to power industry

Complementary synergies

Research partner from the idea to the product

Innovation phases



- Realization of R&D projects
- Guidance throughout the entire process chain

- Partner in the market launch
- Techno-economic balancing

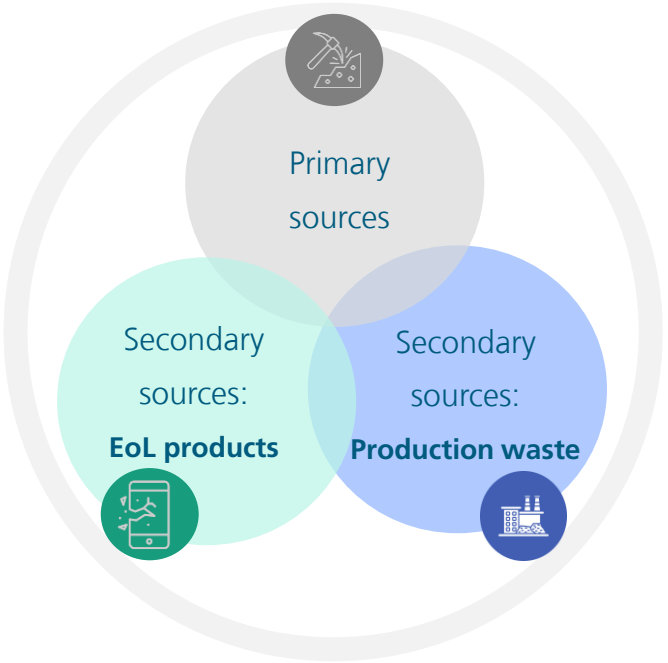
- IP licensing
- Transfer to full pilot scale

Raw materials & Recycling activities in Fraunhofer IKTS

Strategy

Make recycling strategies work

- **True recycling**
  - ✓ Primary product quality and specification conform materials
- **Planetary boundaries**
  - ✓ Zero-waste; Low carbon footprint
  - ✓ Energy and resource efficiency and use of renewable energies
- **Electrified processes**
  - ✓ Higher degree of automatization & Digitalization
- **Targeting the real needs of industry**



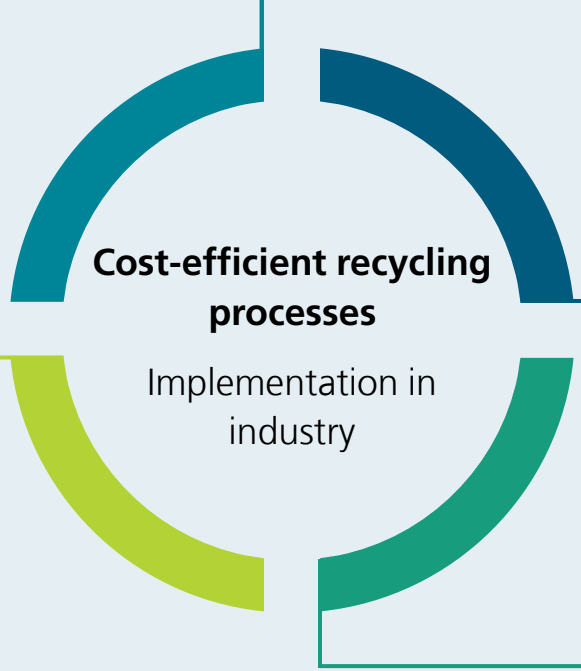
Securing the raw material base for the provision of tomorrow's solutions

Sustainability

Cross-sector solutions for water, energy and food security

Close the loop, integrate recycling across the full process to maximise resource recovery and minimise losses including **waste management**.

Smart Processes
Leverage digital monitoring to optimize process efficiency and material recovery



Adapt existing processes before starting from scratch, leverage what already works to reduce costs and complexity.

Implement **Safe-by-Design (SSbD) principles** from the very beginning, even at production scale, to ensure sustainable, scalable recycling.

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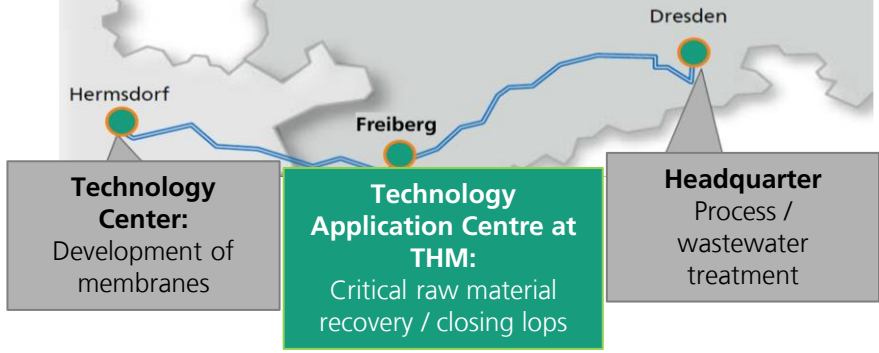
Recycling inorganic raw materials for the energy transition



Getting insights in our working areas

YouTube – Link

Breakdown technologies

…applied science…

Technology portfolio

…ongoing development…

- **Lithium recovery from primary & secondary sources**
  - COOL-Process: Validation through 230 L autoclave & patented by TU Bergakademie Freiberg
  - FEEL-Process: patented IKTS & TU Bergakademie Freiberg
- **Metal separation**
  - Solvent extraction – continuous modus (Mixer settler) & membrane contactors
  - Ionic exchange
  - Precipitation/Complexation/Crystallization
- **Purification & refining**
  - Diffusiondialysis/electrodialysis and electrowinning
  - AOP (applying photocatalysis, plasma treatment, electrochemical oxidation) – removal of organic components (trace amounts)
- **Waste valorization: *Geopolymers***
  - Validation together with German company & patented by TU Bergakademie Freiberg

Purification & Refining: water as a valuable resource

…Water reuse is the indisputable necessity for sustainable process chains…

1. **Detailed analyses of process water resources/demands**
   including characterization of (physico-)chemical properties of process media as basis for preliminary mass balances and selection of treatment strategies/processes

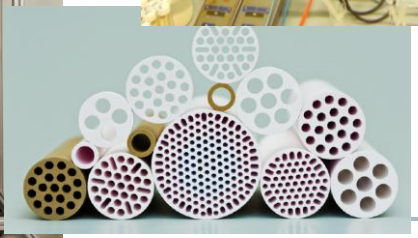
2. **Development of concepts for process water treatment and recycling**
   including aspects of sustainability (reduction of chemical consumption, heat recovery strategies etc.)

3. **Validation of application-focused process combinations/ treatment trains aiming (complete) process media recycling**
   based on data derived from process modelling or/and experimental studies (specific laboratory scale tests)

4. ***Definition of adapted/enhanced concepts for closing process water circuits***
   including up- and downstream process steps (e.g. separation/further treatment of by products)

Development/adaption of analytical methods
(rheology, granulometry; spectrometry, chromatography)

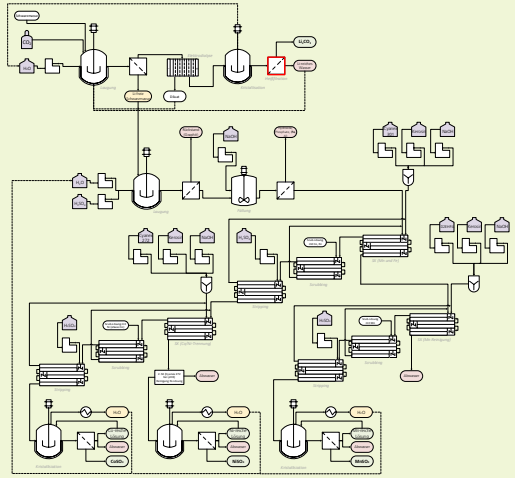
Application of membrane/electrochemical processes (studies in laboratory and semi-pilot scale)
(membrane filtration, reverse osmosis; electrodialysis, selective precipitation, ion exchange)



Sustainability assessments

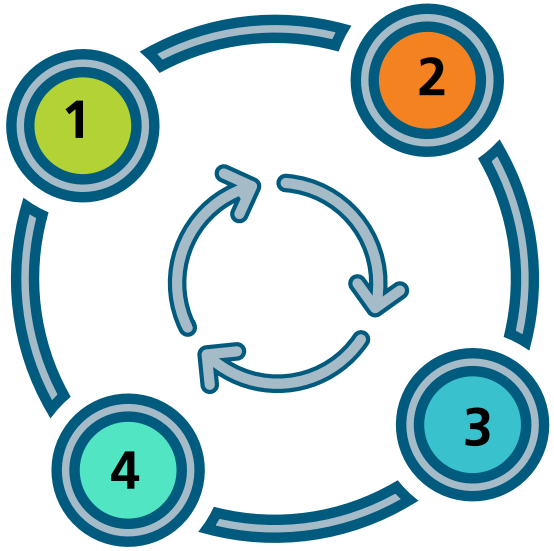
LCA, s-LCC, TEA

System/process monitoring (material and energy requirements)

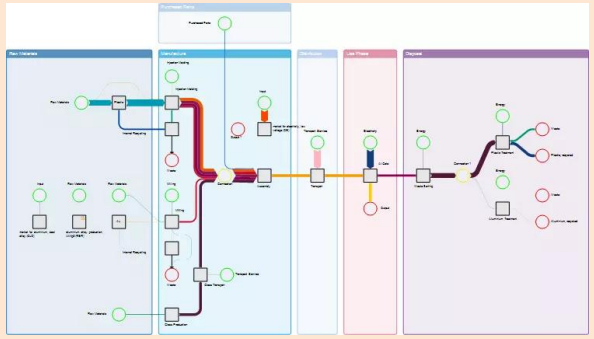


Process adaptation / optimisation

Identification of the process step modules with the greatest effect on the target value

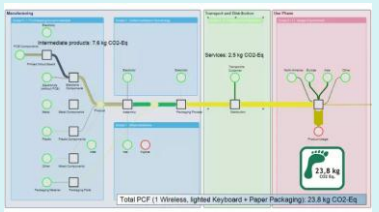


Modelling/ visualisation



- Division into process sub-units

Evaluation/scenario analysis



Use Case: Lithium

Demonstration of battery metals recovery from primary and secondary resources through a sustainable processing methodology

To boost the green transition, the availability of CRM needs to be ensured. The battery sector has been experiencing increasing demand for raw materials for years and is vulnerable for supply risks. Various strategies are being pursued to meet the growing demand for critical raw materials and to build up viable, sustainable and innovative value chains. Waste valorization by recovery and recycling plays a central role.

Objectives

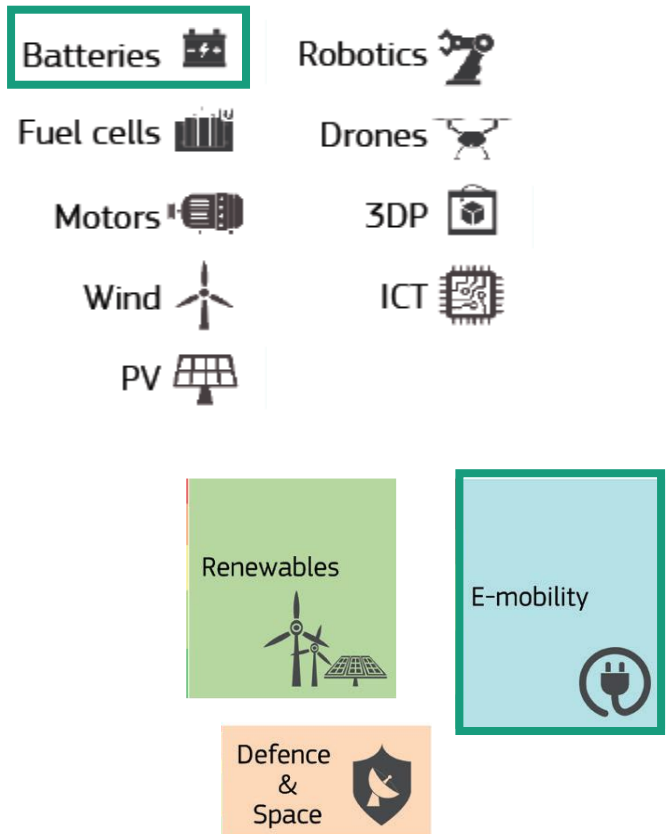
- Recover valuable materials from primary and secondary resources (tailings)
- Demonstrate sustainable production and recovery of critical battery metals
- Assess End-use of the recovered critical battery metals
- Identify and characterize the critical battery metals with innovative technologies
- Enable social participation, stakeholder engagement and networking

https://metallico-project.eu/

Development of high-tech applications

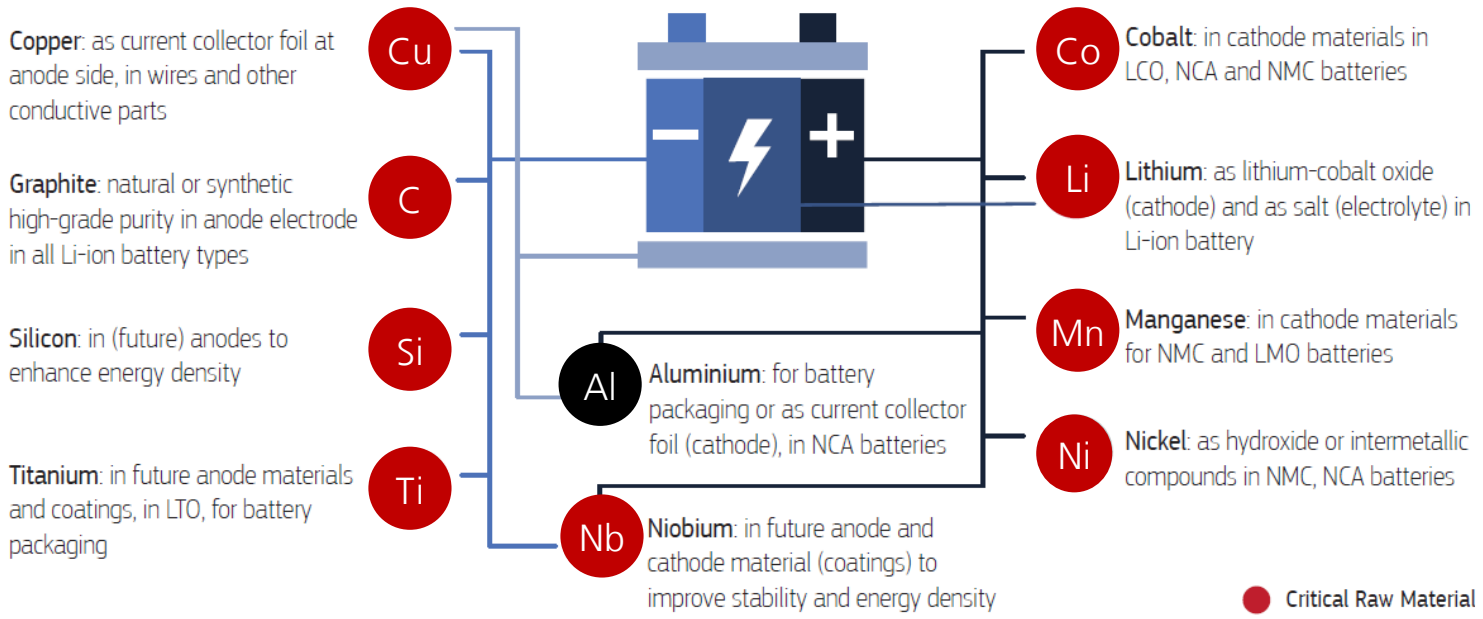
Safeguarding the raw material basis

Key technologies & sectors



Critical Raw Materials for the EU (2023)

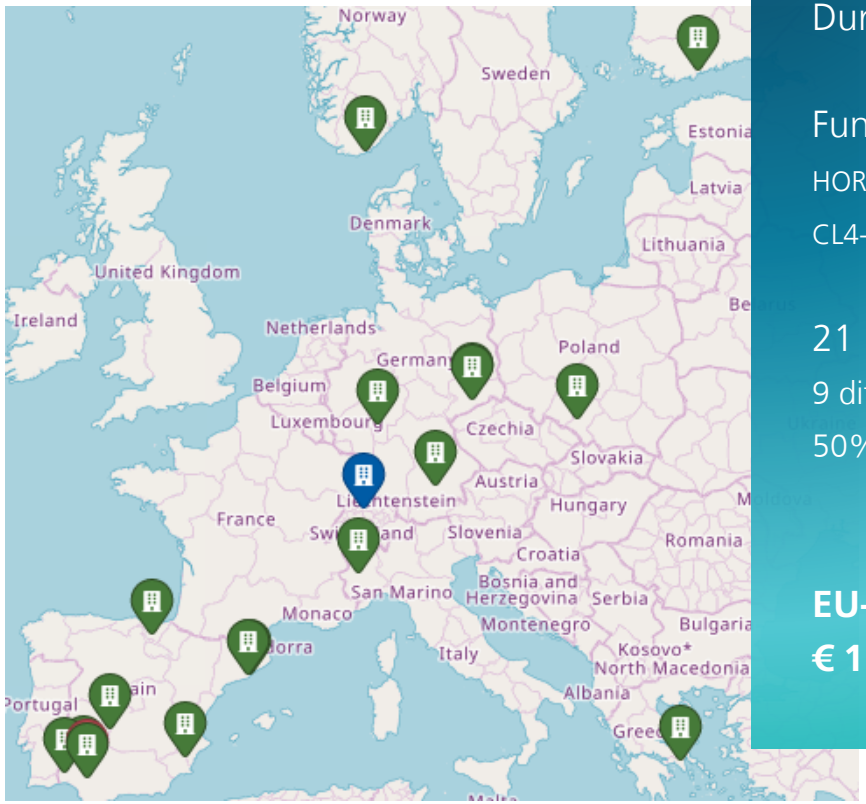
34 CRMs including **Lithium, Manganese, Copper, Nickel, Cobalt, Graphite**



S. Bobba, S. Carrara, J. Huisman, F. Mathieux, C. Pavel. Critical Raw Materials for Strategic Technologies and Sectors in the EU: A Foresight Study (**2020**)

Five different processes for metal recovery from primary and secondary raw materials

- **COOL+**
  - **Li** recovery and **waste valorization**
- **TAILCO**
  - **Co** recovery from tailings in Cu hydrometallurgical plants
- **PURGES**
  - **Co** recovery from purges generated in pyrometallurgical refining processes
- **CONI**
  - **Co**, **Ni** and **Co** recovery from waste alloys (Fe-As) generated in Pb hydrometallurgical processes
- **COMAN**
  - **Co**, **Cu** and **Mn** recovery from tailings generated in ore concentration plants.



Duration: 4 Years

Funding program:
HORIZON EUROPE– HORIZON-CL4-2022-RESILIENCE-01

21 Partners
9 different countries
50% Companies

EU-Contribution:
€ 11 798 783,25 €

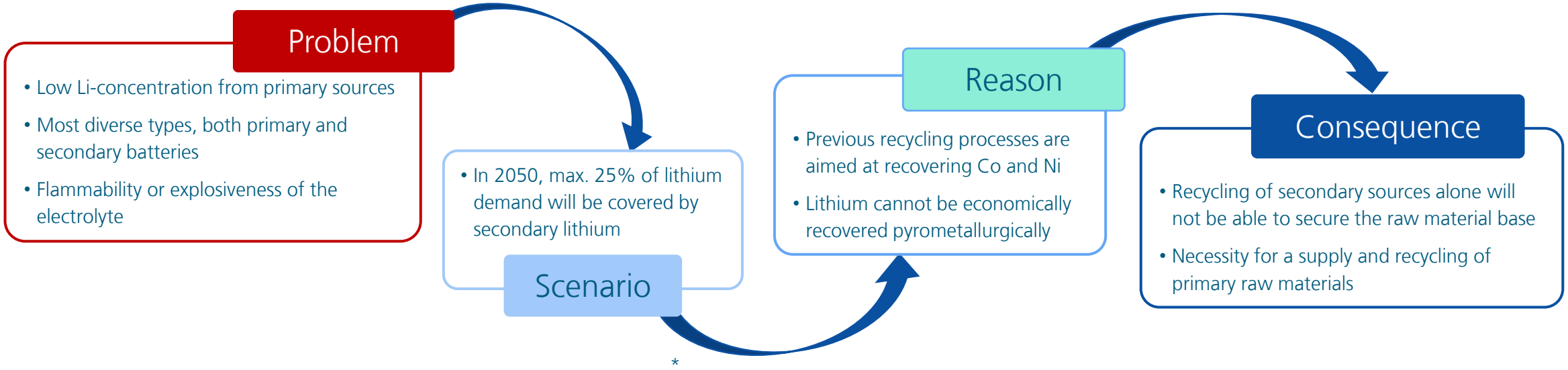
Lithium

Raw material situation

Li Increase the supply risk → **Critical Raw Material**

Li Need for action to secure the raw material base for domestic industry.

- Lithium is considered one of the **essential metals** for future technologies
- Continuous **increase** in lithium **demand** in the coming years
- **Production** (290,000 t/year) and **Reserves** (37 mill. t) placed mainly in Australia, Chile, Argentina, China.



*

U.S. Geological Survey, Mineral Commodity 2026, **2026;** Trading Economics, Resilience: Charting a Path towards greater Security and Sustainability, Belgium, **2020**

Lithium recovery: COOL+ Process

…Validation in TRL 5…

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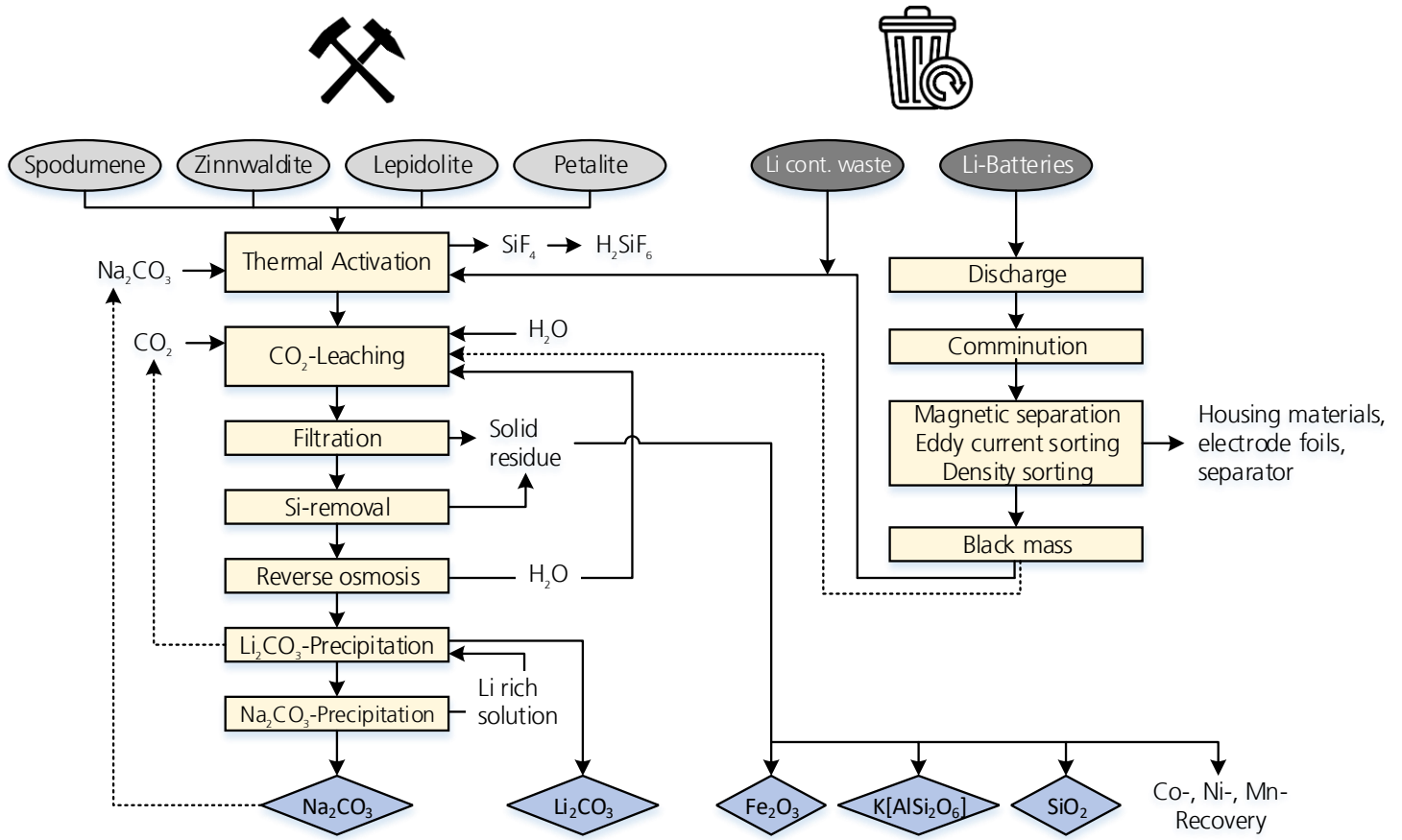

Recycling in primary product quality

Recycling of the residual materials

Holistic processing of primary and secondary raw materials

M. Bertau, G. Martin, C. Pätzold, DE 1020152217590; M. Bertau, G. Martin, DE102016204360.9; H.-G. Jäckel,, U.A. Peuker, L. Wuschke, *Chem. Ing. Tech.* **2014**, *86*, 806-813; G. Martin, C. Pätzold, M. Bertau, *Int. J. Min. Process.* **2017**, *160*, 8-15; G. Martin, A. Schneider, W. Voigt, M. Bertau, *Min. Eng.* **2017**, *110*, 75-81; D. Kaiser, S. Pavón, M. Bertau, *Chem. Ing. Tech.* **2021**, *93*, 1833-1839; S. Pavón, D. Kaiser, M. Bertau, *Chem. Ing. Tech.* **2021**, *93*, 1840-1850; 30. S. Pavón, D. Kaiser, R. Mende, M. Bertau. *Metals* **2021**, *11*, 259.

  Confidential

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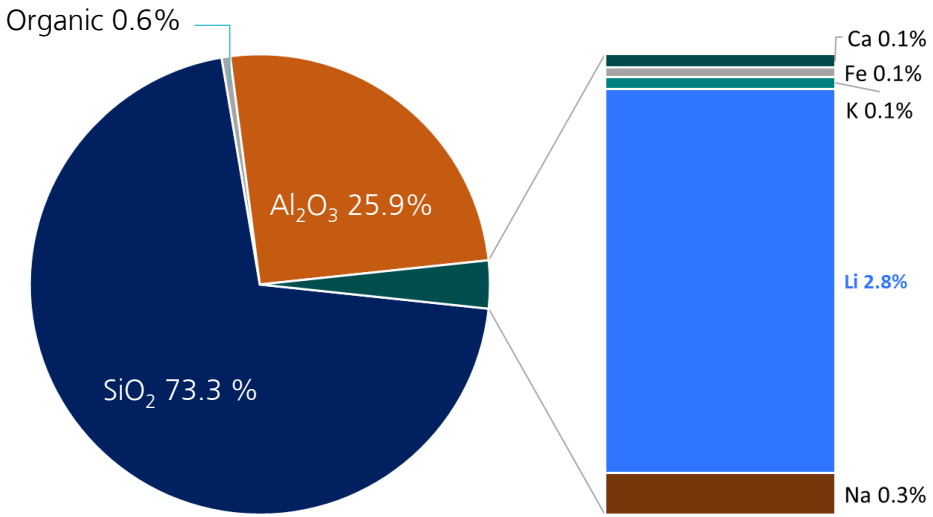
Lithium recovery: COOL+ Process

…Validation in TRL 5…

Addition of Na_2CO_3

- Spodumene from Nigeria
- Li content. 2.8 wt.%



- Thermal activation

  Mineral phase transformation (β-spodumene)

750 °C

3 h

Spodumene +

30 wt.% Na_2CO_3

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Lithium recovery: COOL+ Process

…Validation in TRL 5…

230 L pressure reactor

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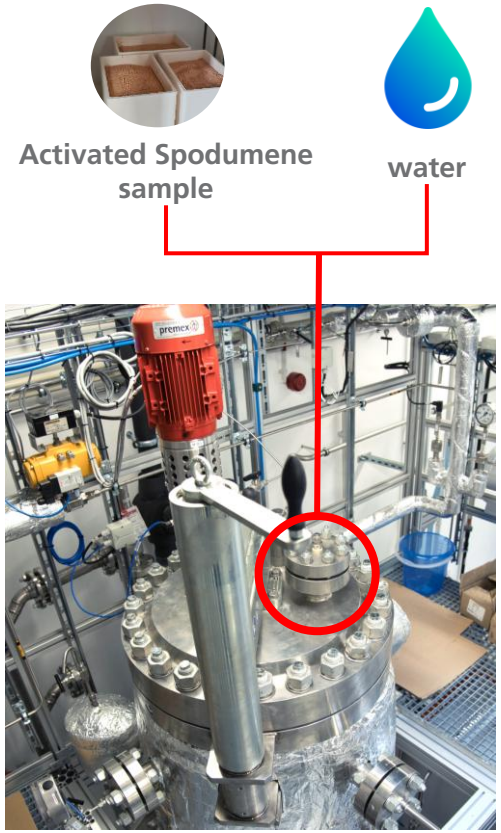

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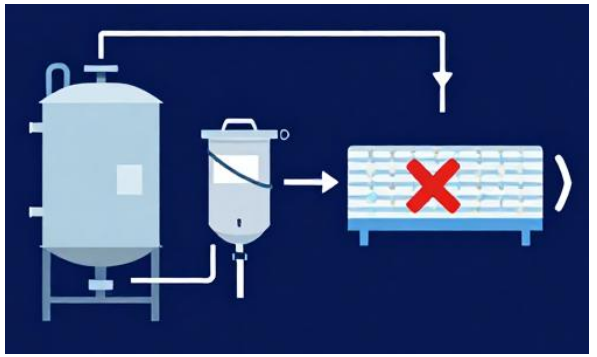
- 230 °C; 100 bar; s/L ratio = 80; 3 h
- Li recovery: 75%

Lithium recovery: COOL+ Process

…Validation in TRL 5…

Li-rich solution

Chemical composition [g/L]		
Li	Na	Si
659.22	2172.3	205.47



- × ED membrane scaling
- × Non selectivity monovalent/monovalent

Replacement of technology:

- Si removal by adding MgO
- Reverse Osmosis

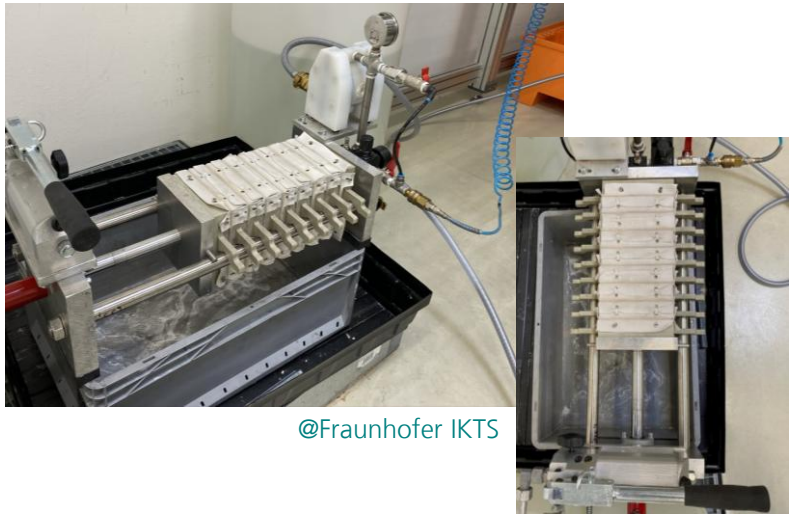
	V [mL]	Li [ppm]	Na [ppm]	Si [ppm]
Permeate	93.88	32.69	108.02	3.29
Retentate	290.2	864.88	2732.1	131.8

Lithium recovery: COOL+ Process

…Validation in TRL 5…

Filtration I – Chamber filter press

Separation of Li-free spodumene and aqueous solution rich in Li



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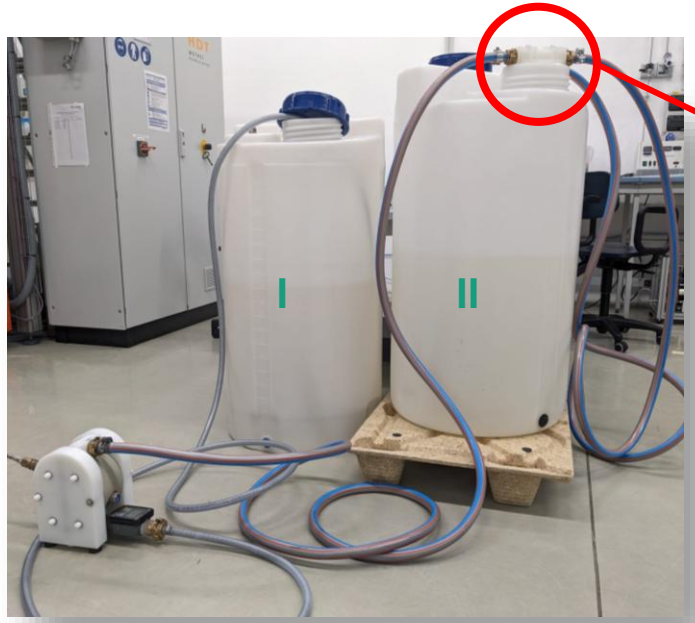

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Filtration II: fine-filtration

Membrane filter 0.2 µm to avoid blocking the membrane in the RO

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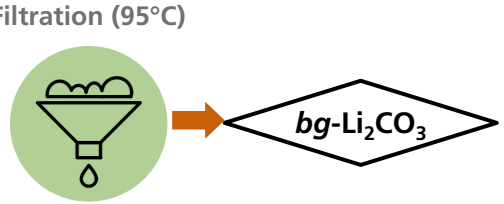
Lithium recovery: COOL+ Process

…Validation in TRL 5…



- **Crystallization & Filtration at 95 °C and washing**
  - Solubility $Li_2CO_{3\ (95°C)}$ = 7.5 g/L
  - Solubility $Na_2CO_{3\ (95\ °C)}$ = 436 g/L

- **Product:**
  - Li_2CO_3 in battery grade quality (≥ 99.5%)

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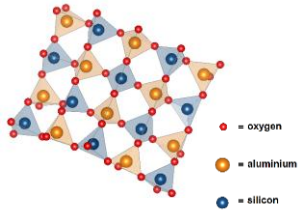
Waste valorization

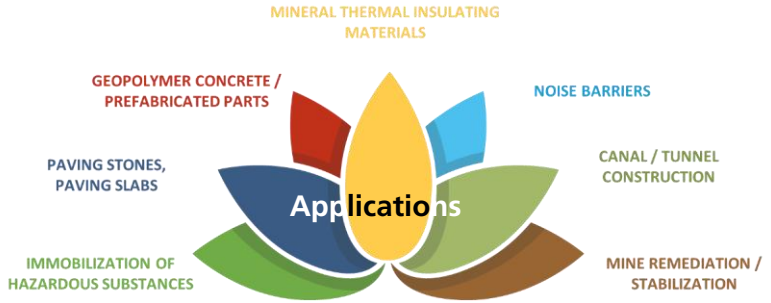
…Geopolymers production…

Inorganic and calcium-free polymers based on silicon and aluminum oxide

Properties

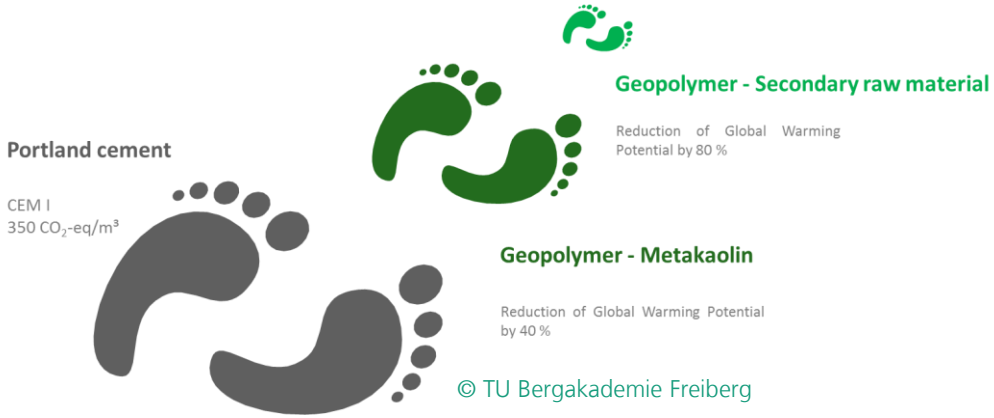
- Rapid hardening, shrink-proof, high compressive strengths, stable against leaching
- Non-flammable, temperature-resistant, dimensionally stable and resistant to all inorganic and organic acids (except HF).





Advantages

- ✓ Building materials made from 100 % secondary raw materials
- ✓ Economic competitiveness with conventional building materials
- ✓ Recycling of residues and overburden materials
- ✓ Saving landfill space and costs and natural resources
- ✓ Savings of up to 80 % of climate-damaging CO_2 emissions
- ✓ Achievement of the climate protection goals



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M.. Bertau, P. Fröhlich, M. Kraft, K. Dombrowski-Daube, J. Sachl, H. Lange, R. Huber (2020) Reststoffbasierte Zusammensetzung zur Herstellung eines Geopolymer-Leichtsteins, sowie ein Verfahren zu dessen Herstellung und deren Verwendung. Deutsche Patentanmeldung DE102020134133.4; M. Bertau, M. Kraft (2020) Verfahren zur Herstellung eines Geopolymerbetons oder -mörtels. Deutsche Patentanmeldung DE102020107138.8

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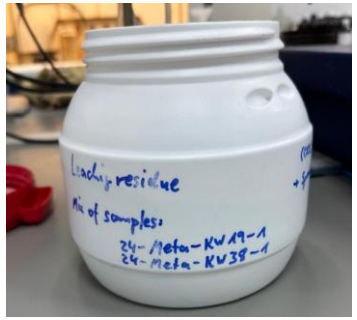
Waste valorization

…Characterization…



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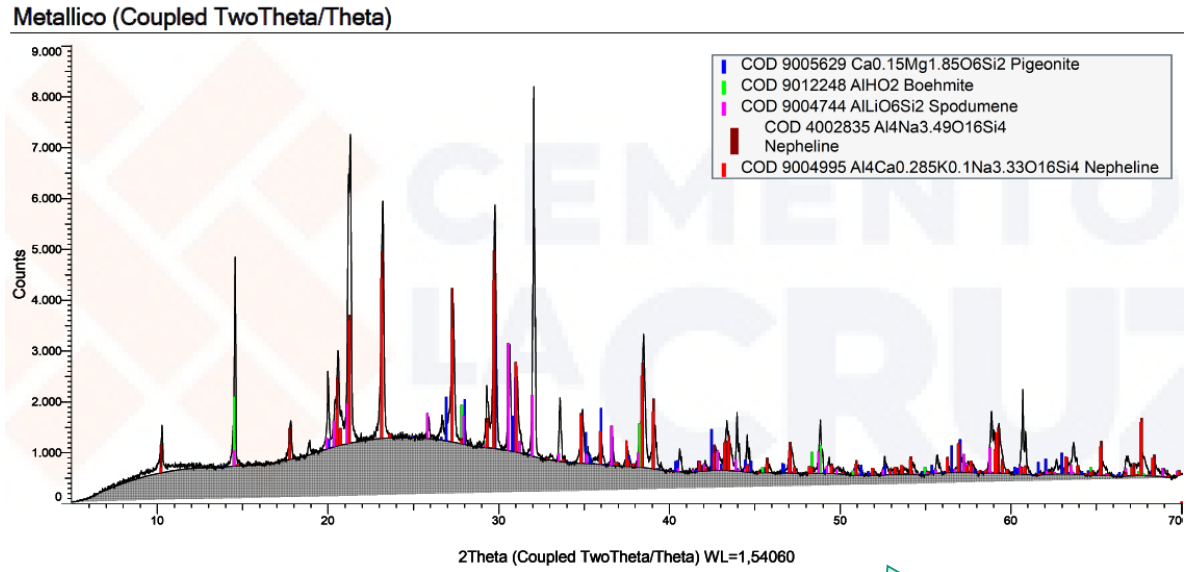
Results Table

Z	Formula	Concentration	
14	SiO2	46,728	%
13	Al2O3	20,126	%
26	Fe2O3	0,743	%
20	CaO	2,183	%
12	MgO	0,187	%
16	SO3	0,167	%
11	Na2O	4,927	%
19	K2O	0,170	%
22	TiO2	0,033	%
15	P2O5	0,049	%
30	ZnO	0,010	%
25	Mn2O3	0,230	%
24	Cr2O3	0,060	%
38	SrO	0,011	%

Interesting components for geopolymers: Si, Al, Na



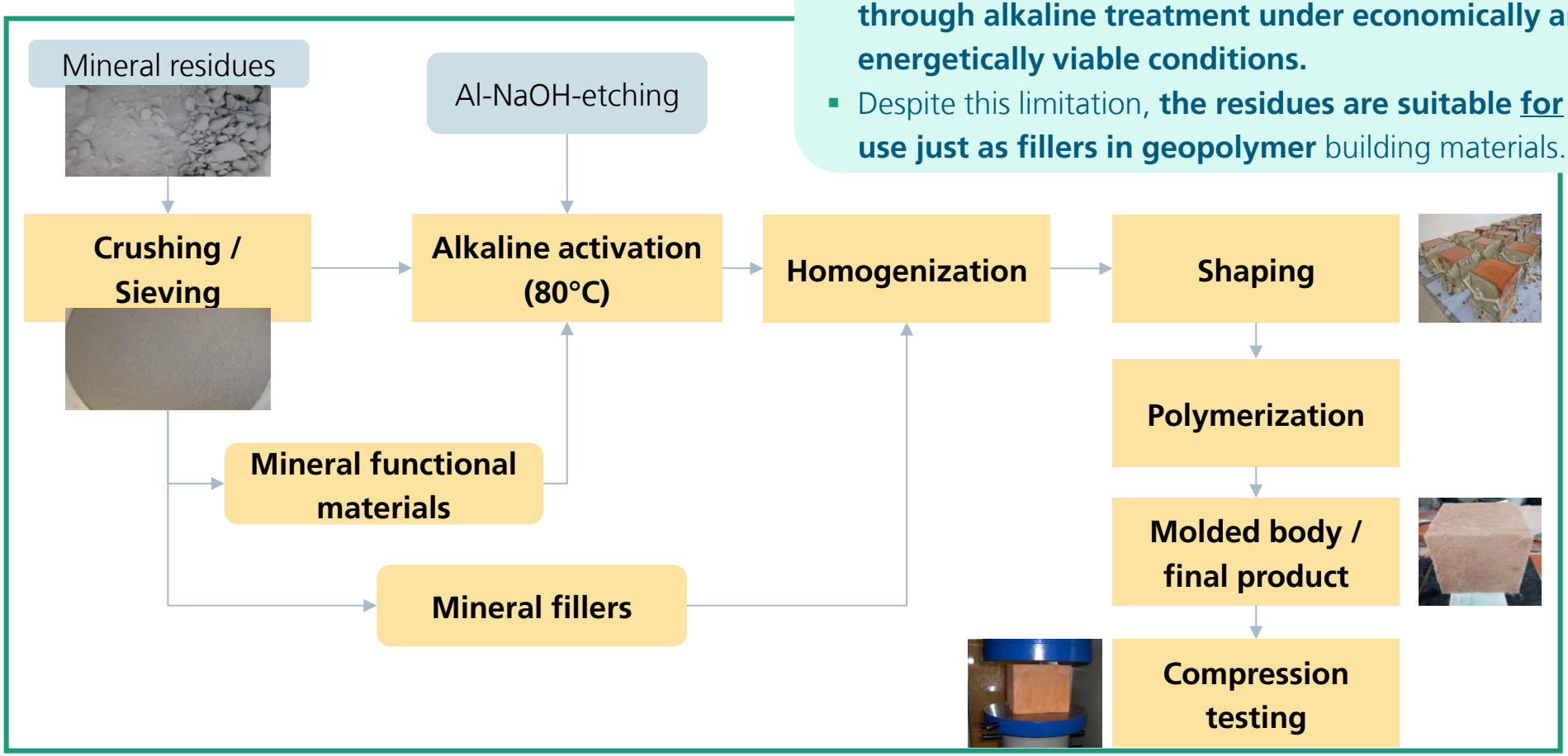
High content of amorphous phase

Waste valorization

…Geopolymers production…

Results

- Mineral residues from lithium extraction **could not be efficiently activated for Al–Si monomerization through alkaline treatment under economically and energetically viable conditions.**
- Despite this limitation, **the residues are suitable for use just as fillers in geopolymer** building materials.



LAUTECH Lausitzer Technologiezentrum

Waste valorization

…Construction materials industry…

- Reactive activity index

Compressive strengh (Mpa)	Reference	Clinker 75% + 25% residue	Reactive activity index
2 days	29.2	21.5	98%
7 days	42.5	36.7	118%
28 days	47.2	48.8	138%

High reactivity index

- Potential reactivity (ASTM C618, R3 protocol)

SCM*	Heat release (J/gSCM)	
	3 days	7 days
Residue from COOL+	205.2	303.1
Fly ashes	210.2	323.6
GGBFS	116.4	150.9

**Supplementary Cementitious Materials*

High reactivity (>300 J/g SCM 7 days)

Outlook

…Closing material loops…

- Growing demand for secure and sustainable metals supply chains creates strong opportunities for innovative processing technologies.
- Process development of technologies capable of meeting market requirements regardless of input material → Holistic approaches
- Process intensification and selective recovery strategies offer potential for:
  - Integration into existing flowsheets
  - Modular implementation
  - Scalable industrial deployment
- Collaboration between industry, technology providers, and research institutions will be essential to accelerate commercialization and market readiness.

The transition toward sustainable critical raw material production is not only an environmental necessity, but also a strategic industrial opportunity.

Fraunhofer IKTS

Thank you for your attention!

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