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Seit 1765.

(CRITICAL) RAW MATERIALS AND THEIR RECYCLING AS A KEY ENABLER FOR CLEAN ENERGY TECHNOLOGIES

Estonia and Saxony – on the way forward to Clean Energy. Research – Innovation – Realization

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Clean Energy – Technology

Bundesministerium
für Bildung
und Forschung

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Wasserstoff
Leitprojekte
Grün. Groß. Global.

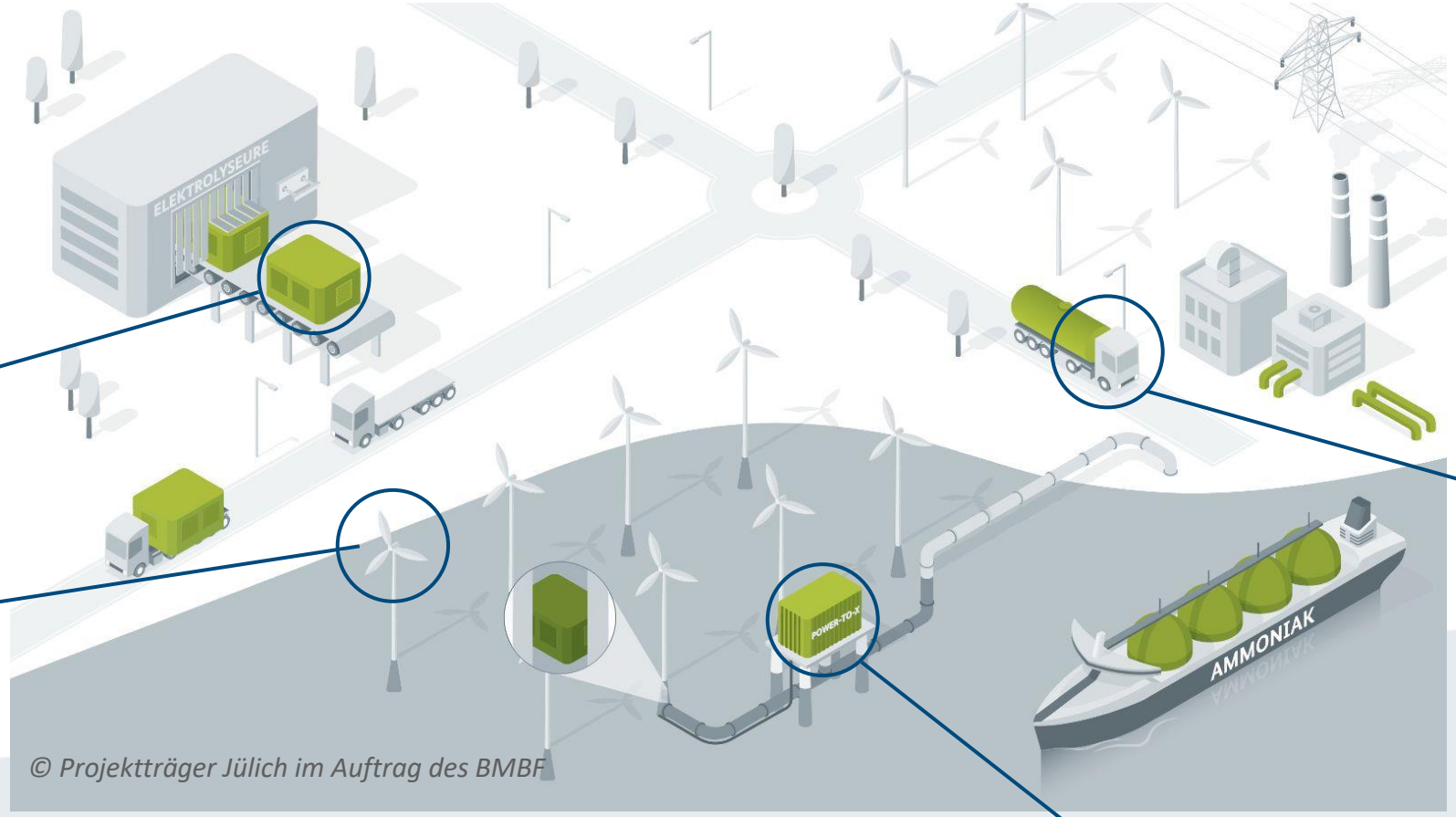
Clean Energy – Technology:
Functional chemical elements = critical raw materials

Bundesministerium für Bildung und Forschung

Wasserstoff Leitprojekte
Grün. Groß. Global.

Electrolysis:
Ir, Sc, Ru, Pt, LREE, Ni,

Wind turbine:
LREE / HREE

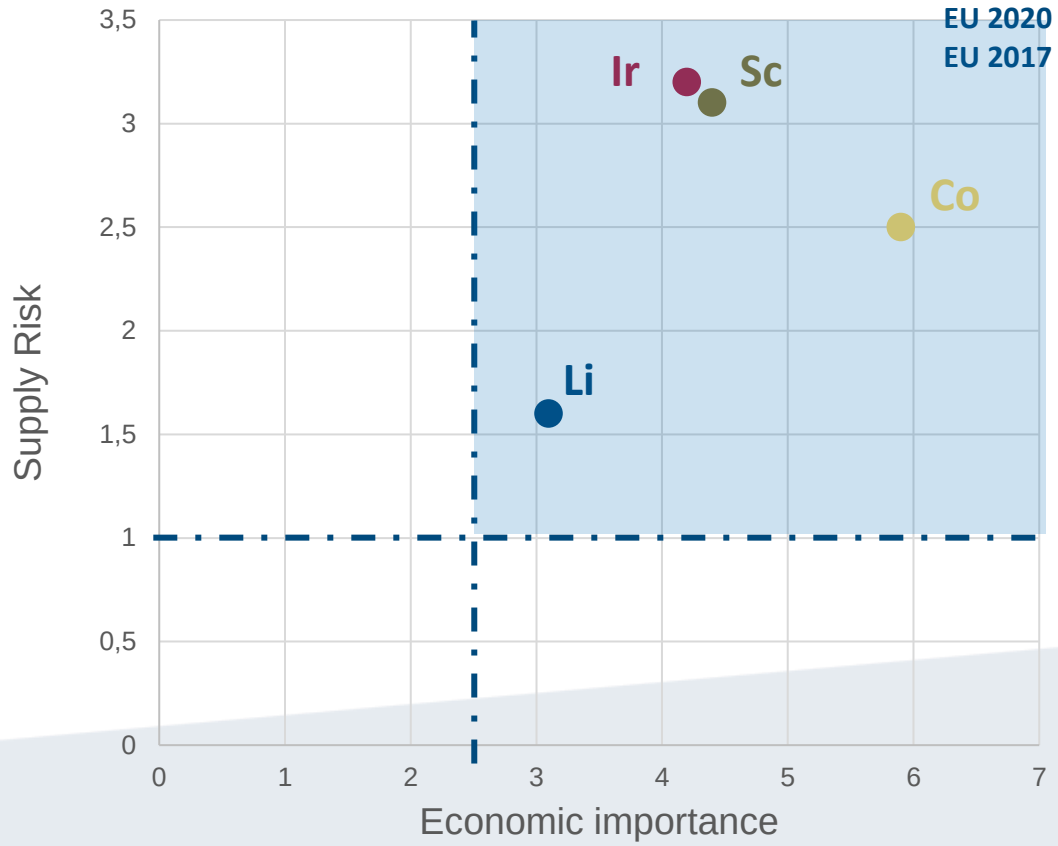


ELV:
Li, Co, Ni, Cu, Graphite

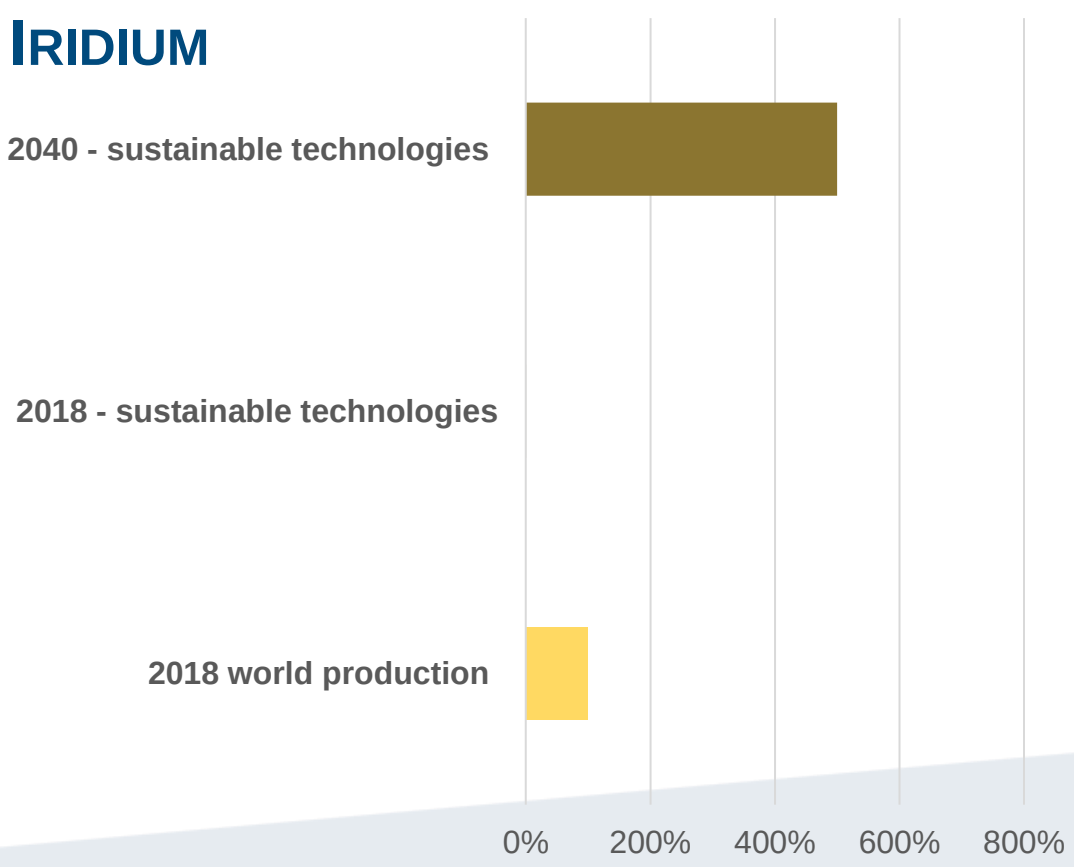
Catalysts:
Pt, Ru,

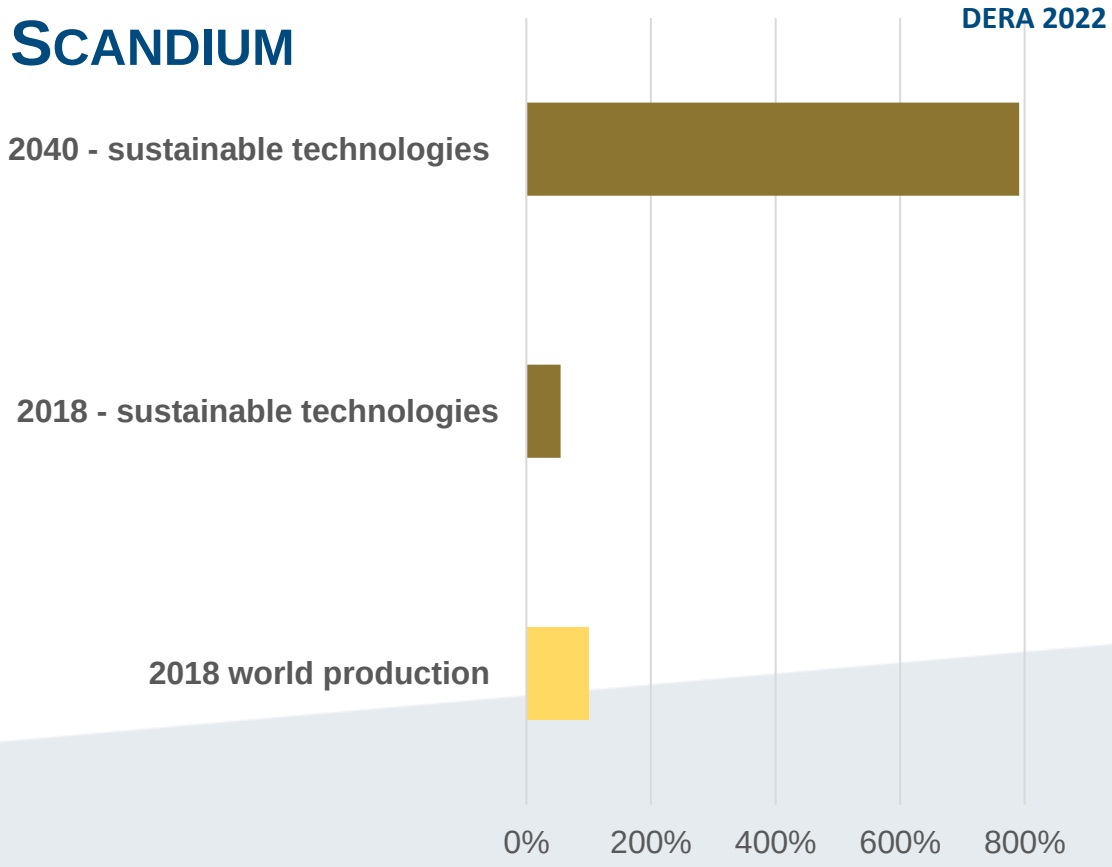
Criticality of raw materials

The EU Green Deal Communication adopted on 11 December 2019 recognizes access to resources as a strategic security question to fulfil its ambition towards 2050 climate neutrality and increasing our climate ambition for 2030



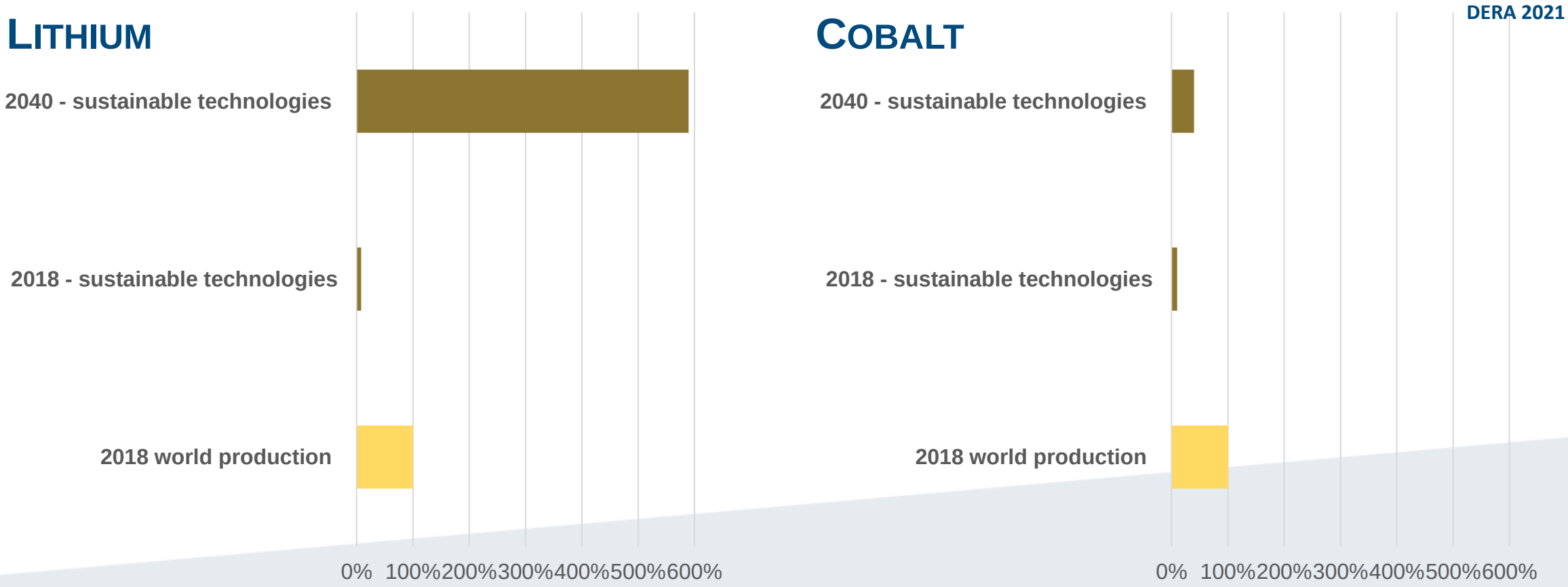
Availability of selected relevant critical raw materials for battery manufacturing (electrolysis technology PEM-EL / HT-EL)





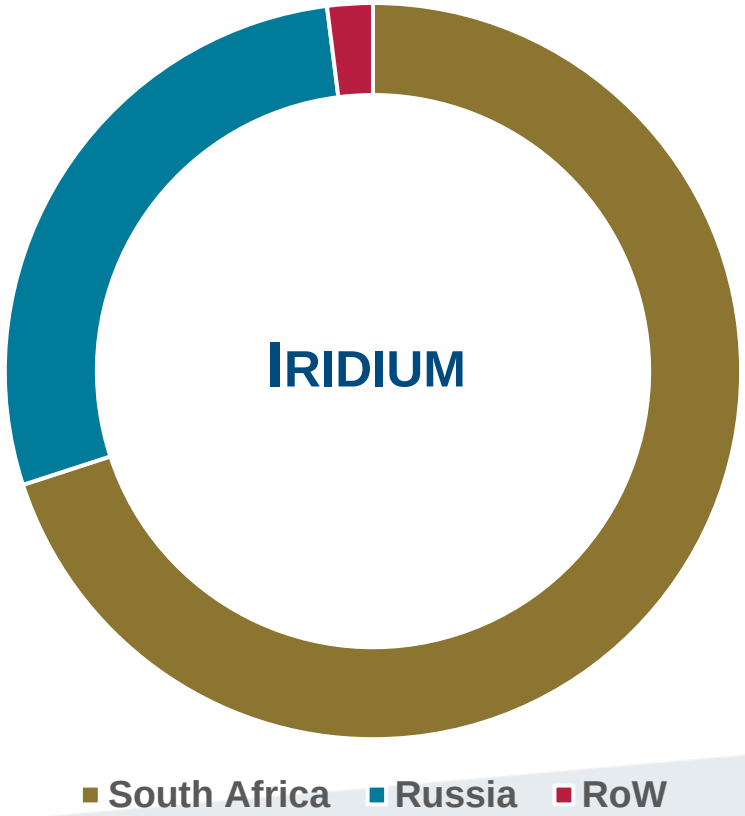
DERA 2022

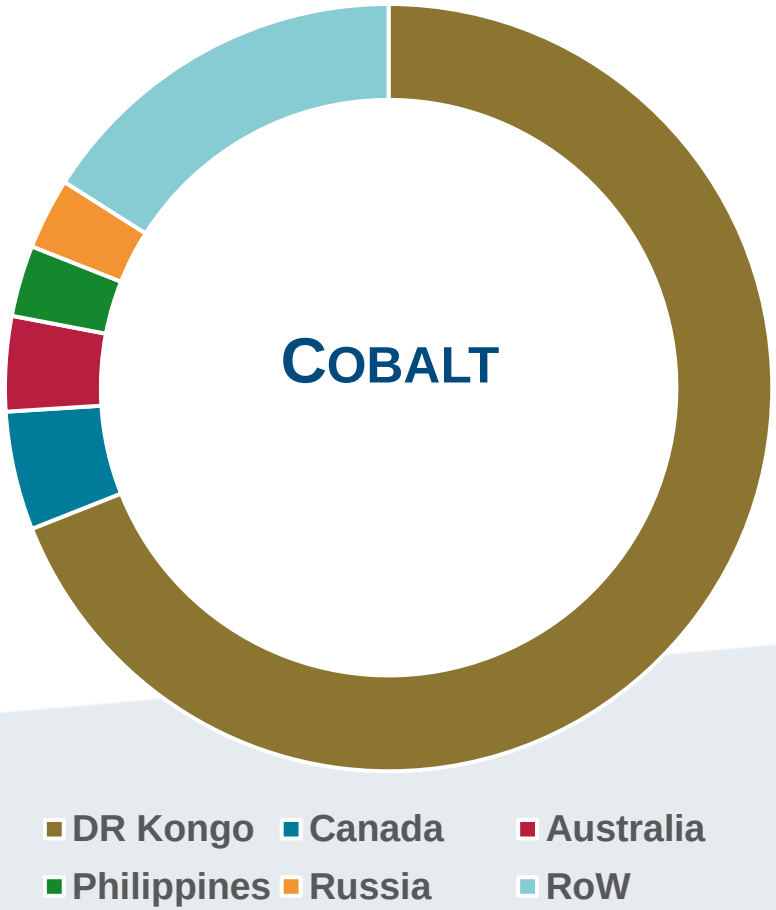
Availability of selected relevant critical raw materials for battery manufacturing (lithium-ion-batteries)



Geostrategic aspects of raw materials: restricted number of potential suppliers – location in political / economic unstable regions

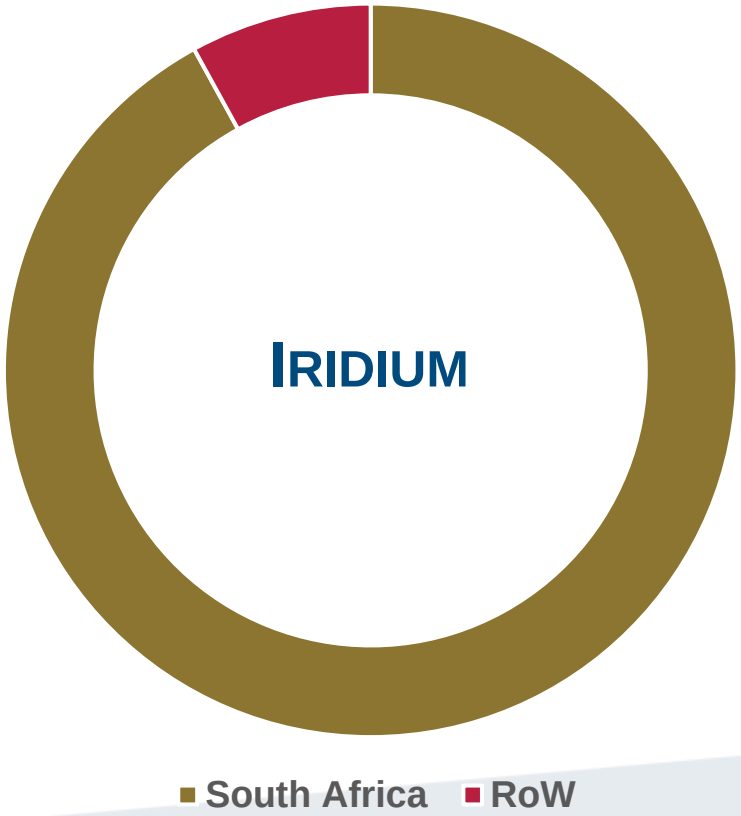
Minke, C. 2021
DERA 2021

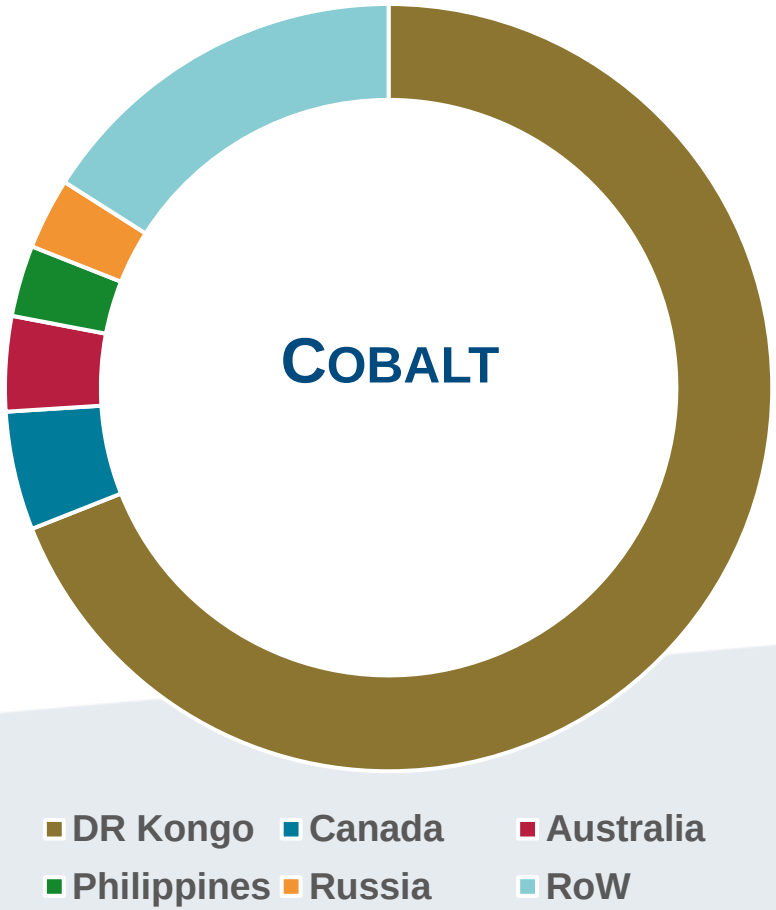




Geostrategic aspects of raw materials: restricted number of potential suppliers – location in political / economic unstable regions

EU 2020
DERA 2021





Recycling and Recovery of critical raw materials

- Raw material are not ubiquitous
- Raw materials are an key factor for future technology development (and economic strength)
- Raw materials become a strategic aspect for future development
- The production (mining / processing refining) the of raw materials to introduce them into the materials cycle has a significant CO_2-impact

Keep the raw materials in the cycle!

- If there are no economic drivers – legislation can create drivers

Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning batteries and waste batteries, repealing Directive 2006/66/EC

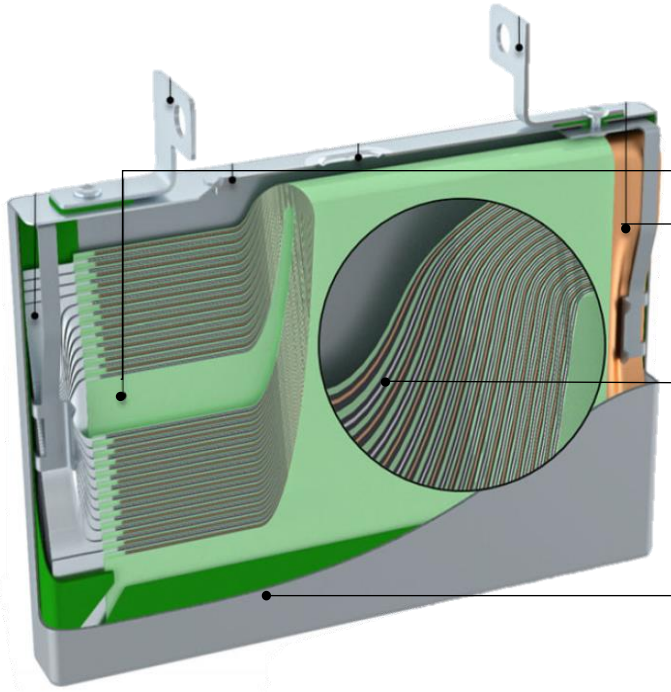
Measures	Option 2 - medium level of ambition	Option 3 - high level of ambition
5. Recycling efficiencies and recovery of materials	Lithium-ion batteries and Co, Ni, Li, Cu: • Recycling efficiency lithium-ion batteries: 65% by 2025 • Material recovery rates for Co, Ni, Li, Cu: resp. 90%, 90%, 35% and 90% in 2025	Lithium-ion batteries and Co, Ni, Li, Cu: • Recycling efficiency lithium-ion batteries: 70% by 2030 • Material recovery rates for Co, Ni, Li, Cu: resp. 95%, 95%, 70% and 95% in 2030

Green Deal: EU agrees new law on more sustainable and circular batteries to support EU's energy transition and competitive industry

….. This will guarantee that **valuable materials are recovered** at the end of their useful life and brought back in the economy by adopting stricter **targets for recycling efficiency and material recovery** over time. Material recovery targets for lithium will be 50% by 2027 and 80% by 2031.

EU 2022

Challenges in recycling: Lithium-ion-batteries



anode

10-18 µm

33-125 µm

separator

15-50 µm

cathode

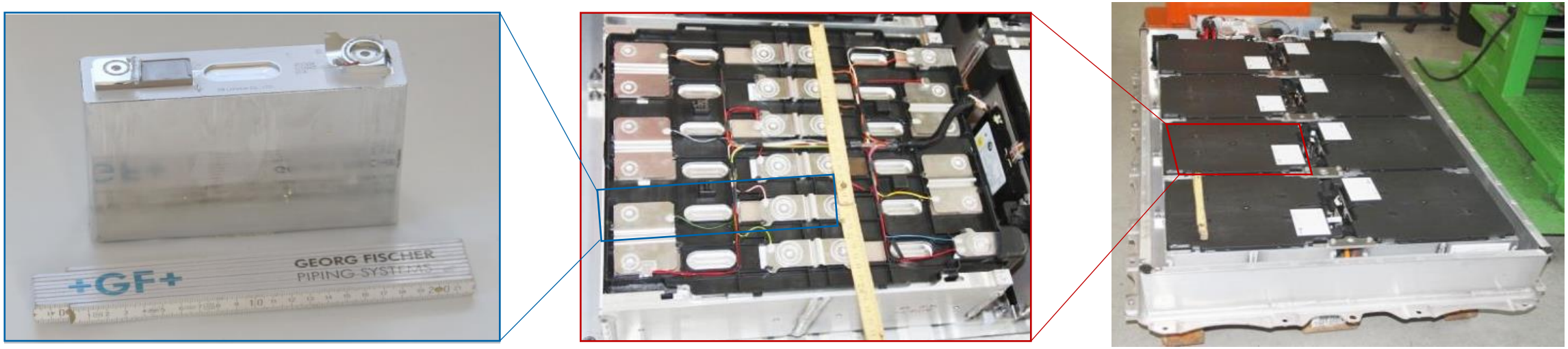
10-25 µm

27-130 µm

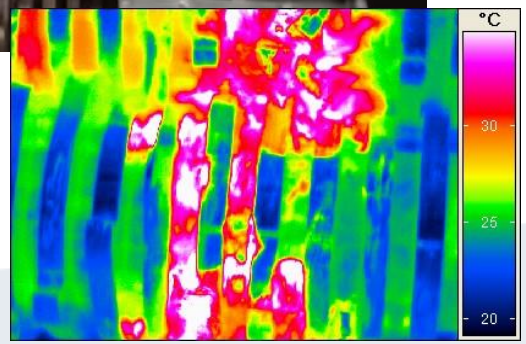
cell housing

0,5-1,5 cm

Batteries internal structure and setup



Crushing, sorting, re-crushing, sorting,… generation of secondary raw materials



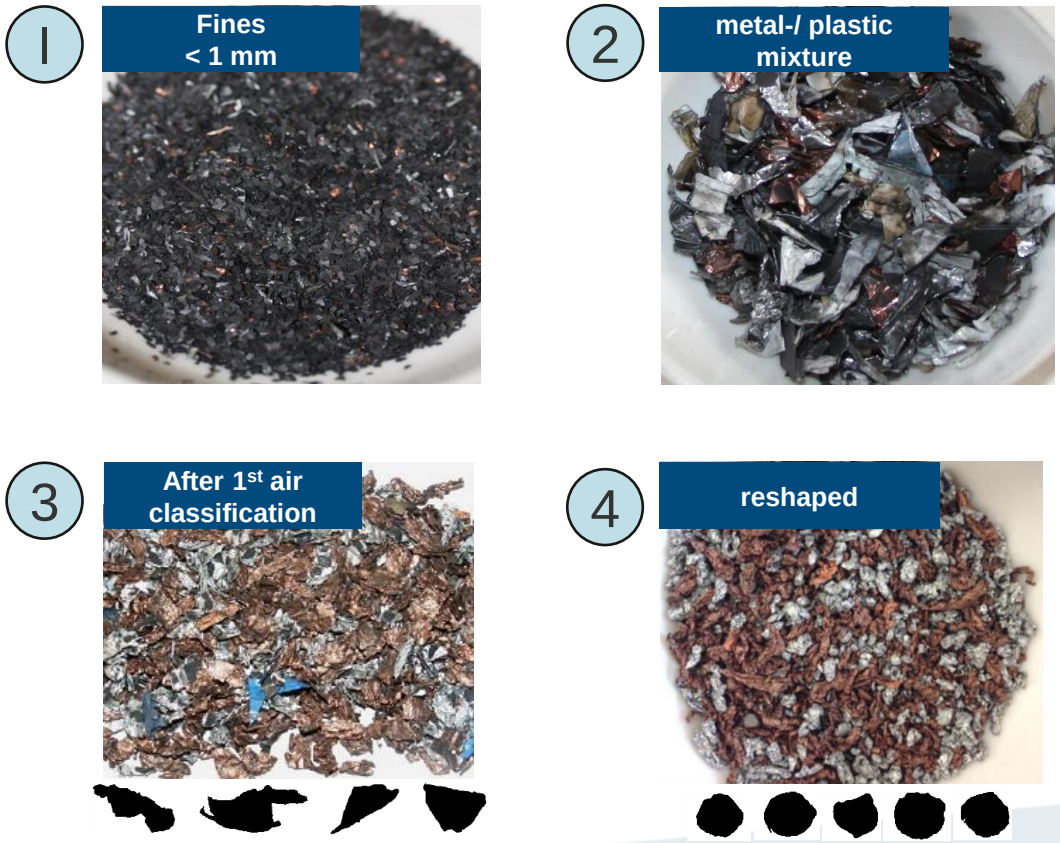
Fe / Al

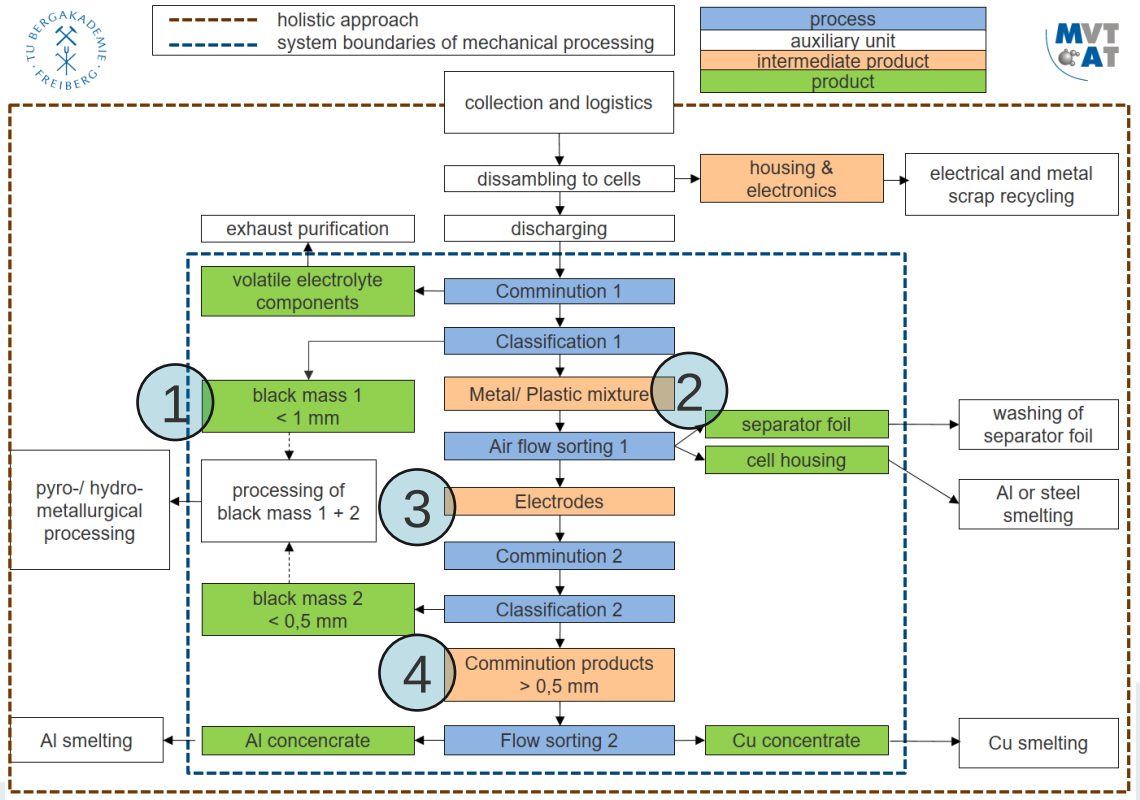
Ni, Co, Li

Al

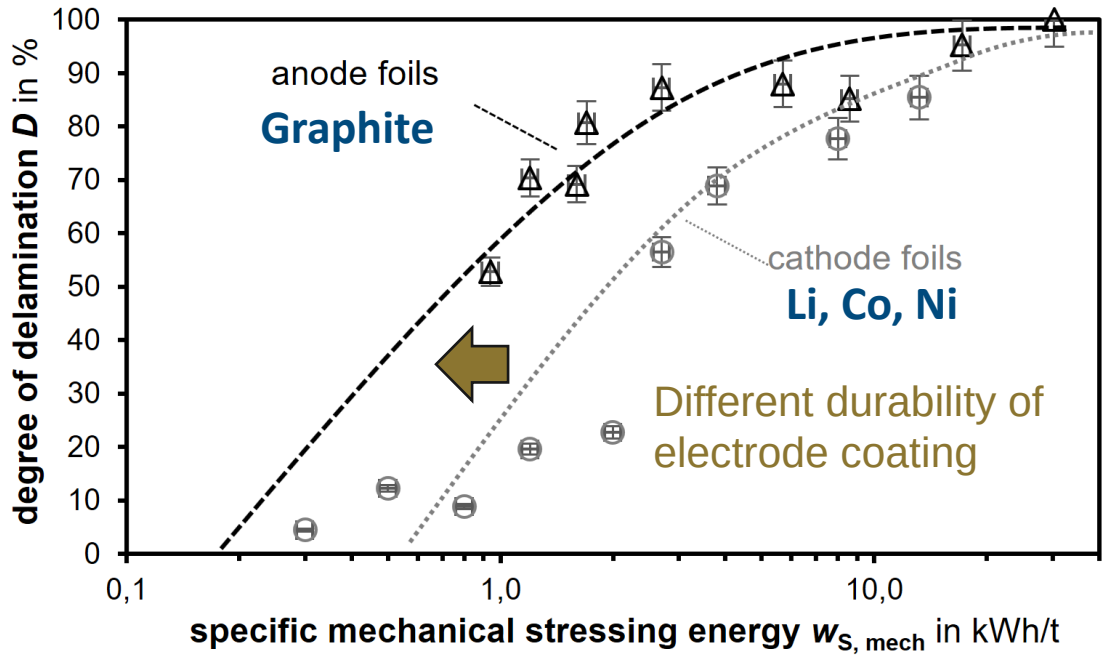
Cu

Mechanical battery recycling process





Effects of Selective comminution (foils only)



Wuschke 2016

HM 340
Gebr. Jehmlich

Challenges in recycling: PEM-Electrolyzer stack

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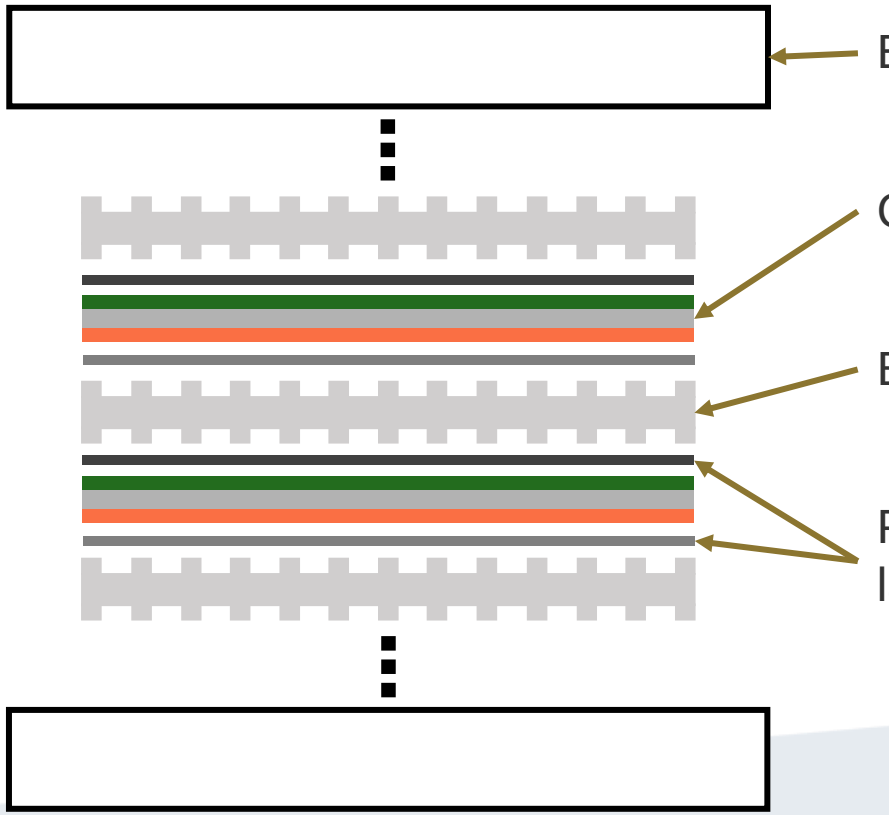
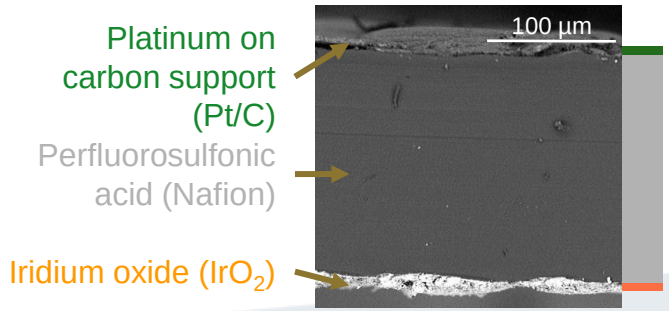
Federal Ministry of Education and Research



Valuable materials:

77	78	44
Ir	**Pt**	**Ru**
192,22	195,08	101,07

22
Ti
47,88



PEM Water Electrolyzer (WE)

Mechanical recycling approaches

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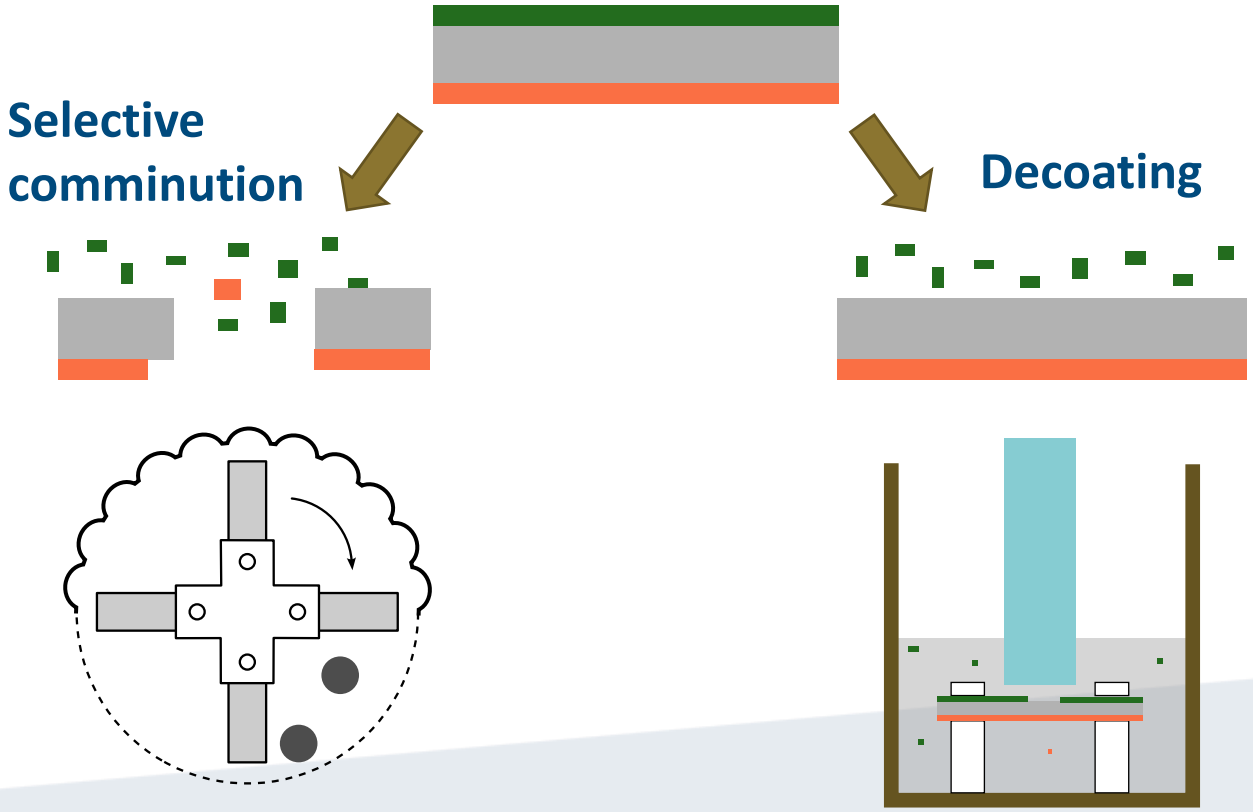
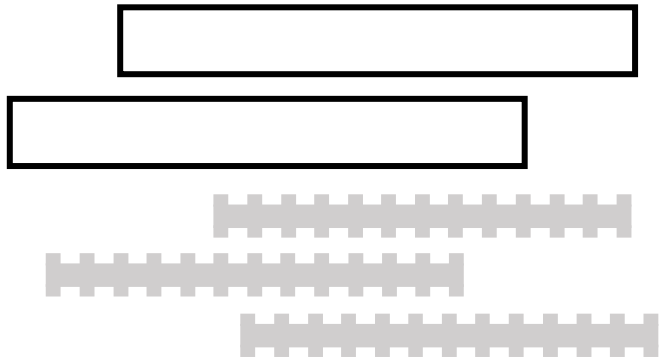
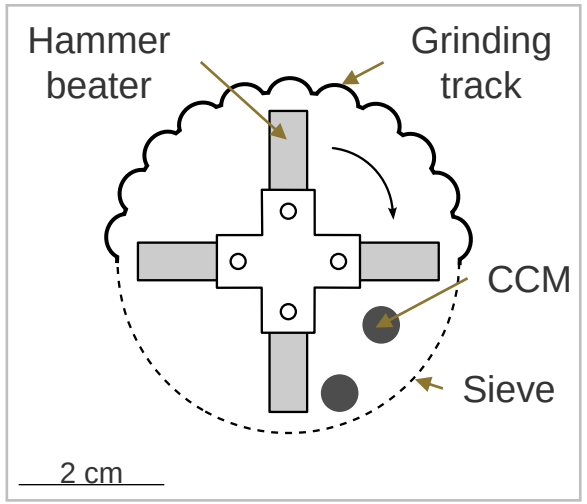




Partial de-mounting / reverse manufacturing

Comminution – Scale Down in Hammer mill

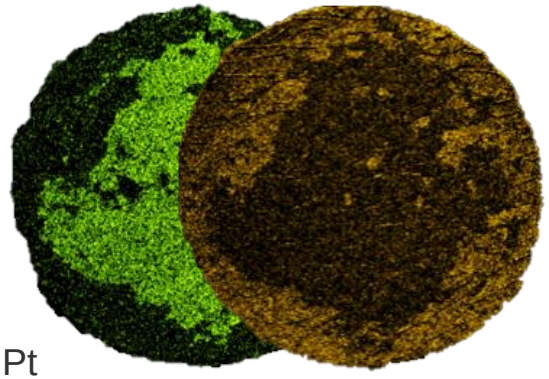
Feed: CCM
Ø 5,6 mm



Laboratory hammer mill on machine platform *Picoline* from *Hosokawa Alpine*

Delaminated and ruptured CCM + electrode powder

Sample holder with CCM for analysis



EDX: Pt

Conclusions - (Critical) Raw Materials and their Recycling as a Key Enabler for Clean Energy Technologies.

Challenges are ahead:

- Criticality of related (raw) materials
- Supply and need differ for certain elements / materials
- Recycling has to keep the critical materials in the life-cycle.
- Are we able to keep the precious materials in the cycle?
    - Suitable technologies
    - Political and legislative boundary conditions
    - Industrial involvement

- Availability of skilled labor force?

Start working on the challenges – success is possible

Activities to boost circular technology in Saxony and esp. in Freiberg

The work on the recycling challenges need concerted actions and the right infrastructure

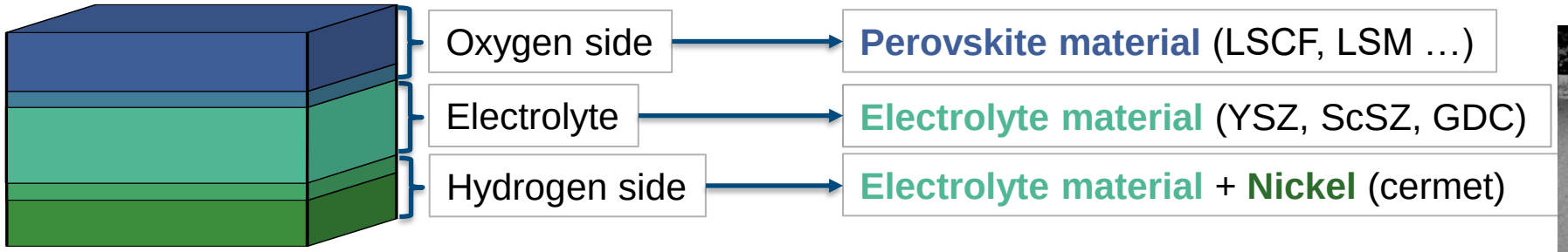
Infrastructural activities:

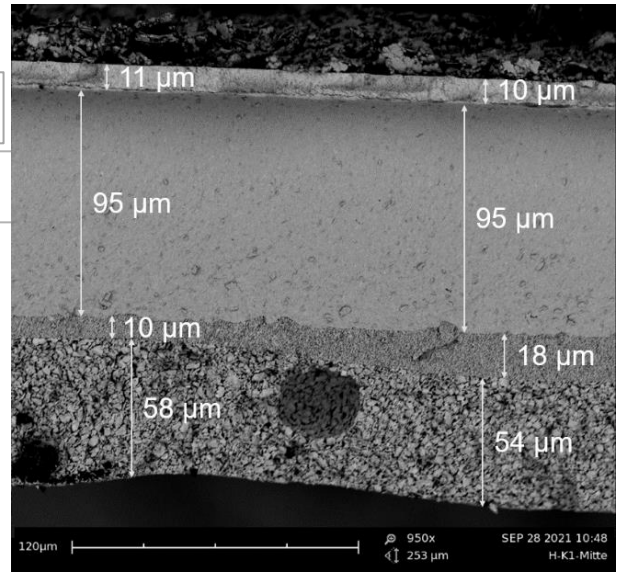
- **CircEcon** - pilot scale recycling and de-mounting plant (TU Dresden, TUBAF, TU Chemnitz; HS Zittau-Görlitz)
- **FlexiPlant** – digitalized recycling plant (HZDR, TUBAF)
- **Data Mining Lab Freiberg** – digitalized recycling and re-synthesis network (TUBAF, HZDR, FhG IKTS)

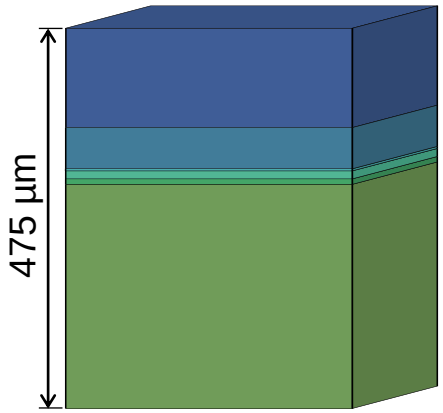
Education and integrated projects:

- Sächsische Wasserstoffunion (TU Chemnitz, TU Dresden, TUBAF)
- Participation in and lead of high level national projects
- Continuous development of teaching content
- Active participation in European activities, i.e. EIT RM, ERMA, Battery Alliance,…

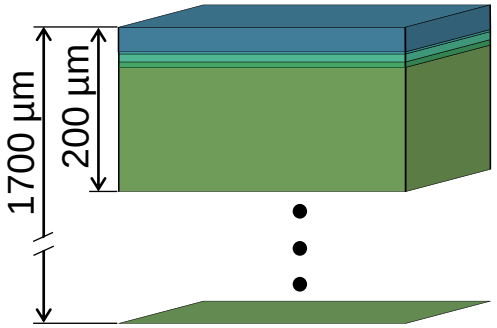
Challenges in recycling: Solid oxide cells – Designs and materials



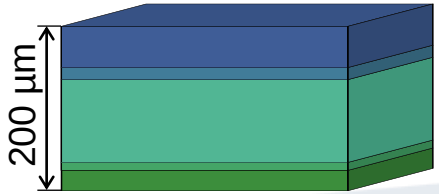




Cell type 1



Cell type 2



Cell type 3

Hydrogen (fuel gas) electrode supported cells

Electrolyte supported cells

Sonomechanical-decoating – decoating efficiency

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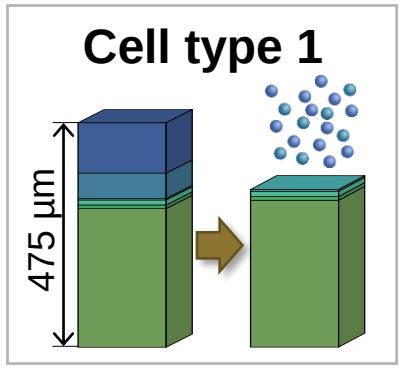
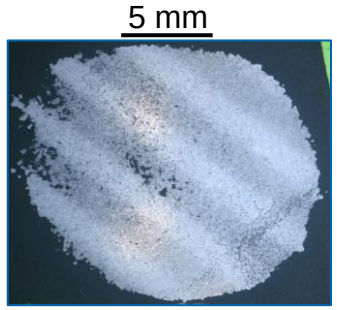
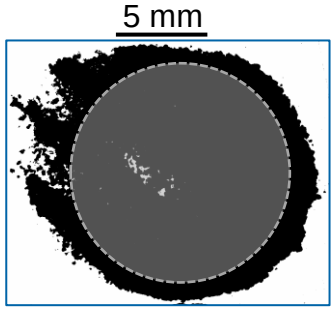




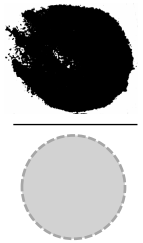
Cell type 1 after ultrasonication

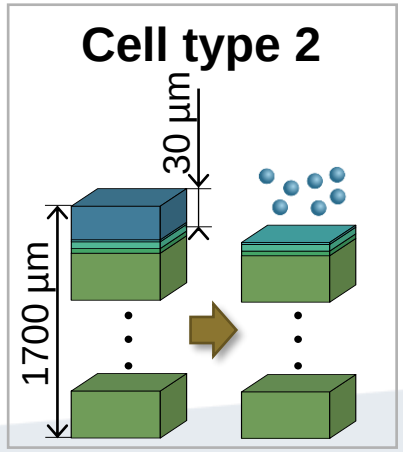
Thresholding

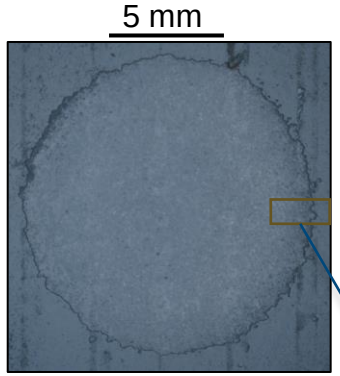


Decoated cell area

$$Decoating\ efficiency = \frac{Area_{\mathrm{Decoated}}}{Area_{\mathrm{Sonotrode}}} =$$

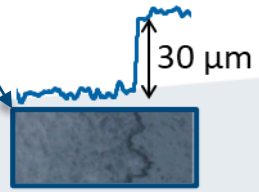


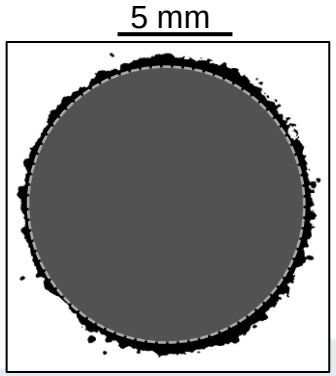




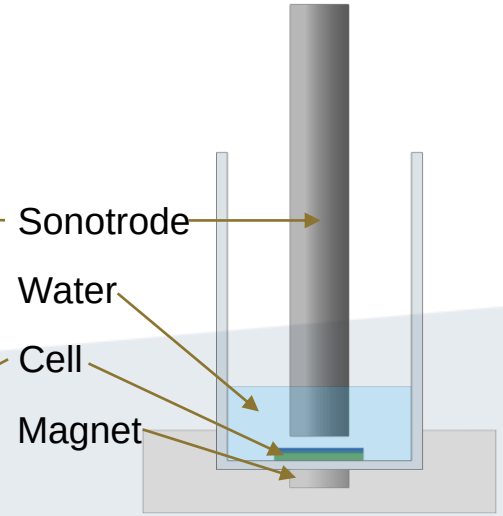
Cell type 2 after ultrasonication

Contour-extraction





Decoated cell area



Quantitative results – de-coating technology

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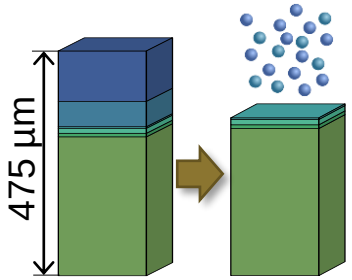
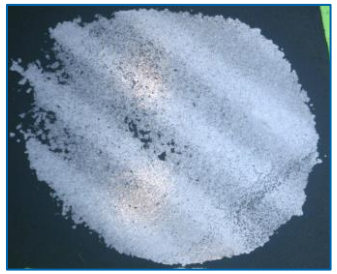
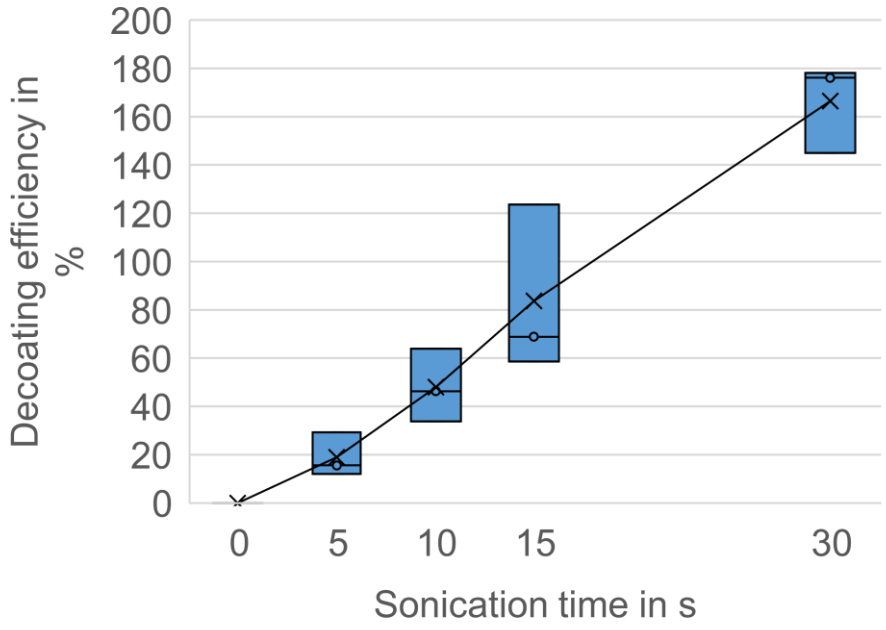
Cell type 1

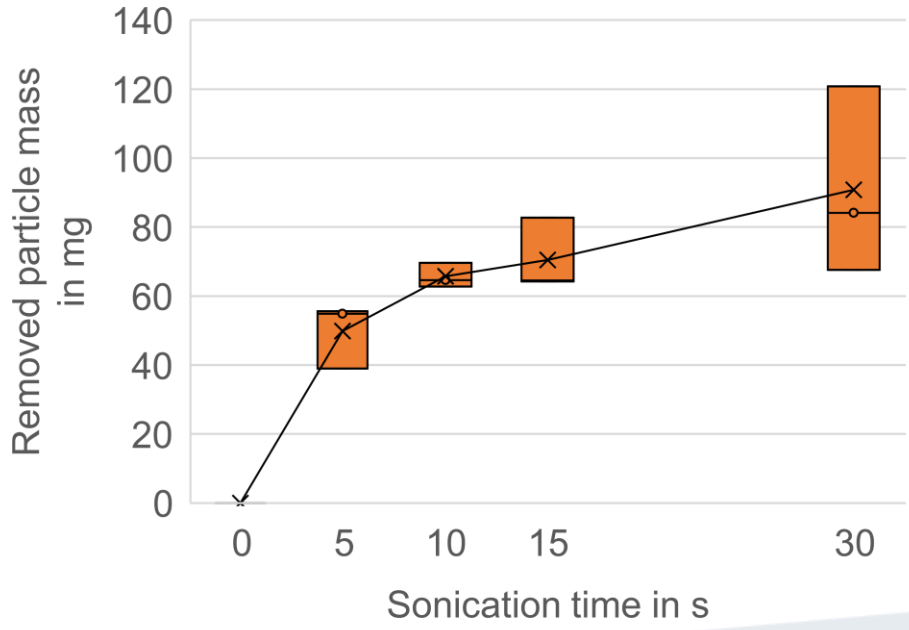


Decoating



5 mm





$$Decoating\ efficiency = \frac{Area_{\mathrm{Decoated}}}{Area_{\mathrm{Sonotrode}}}$$

Impurities from other layers in particle product < 1 Wt.-%