

Permanent Magnet to REE metal or REE alloy. The **Dyscovery** project process routes



Daniel Vogt | DESY Workshop | Hamburg | 07.02.2023

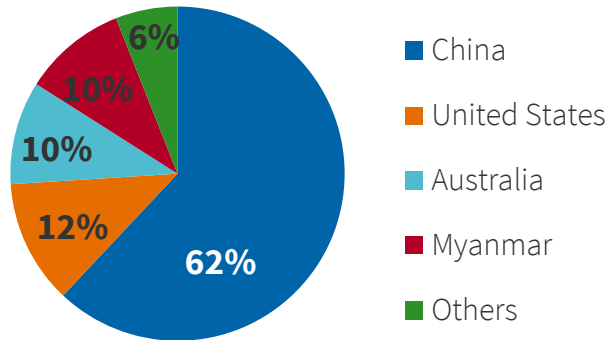
Critical Materials and Life Cycle Management
The Example of Rare Earths – Curse or Blessing?

Rare Earth supply – Critical situation?

Nd, Pr, Dy crucial for REPM (Rare Earth Permanent Magnets)

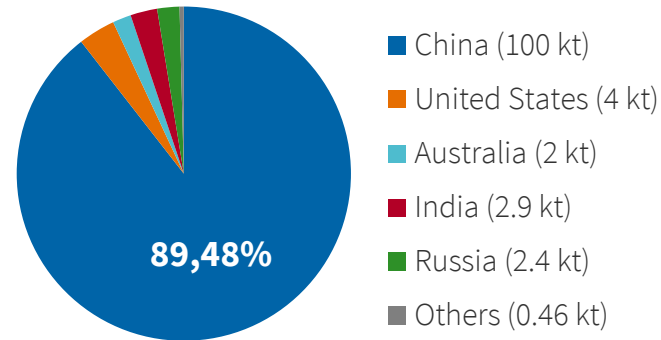
- ~ 25% REE ¹
 - ~ 75% Nd & Pr ²
- } used for **REPM**

Global REO production (2020)



³ USGS, 2020

Global REE production (2013)



⁴ J. Kuhn, H. Gevers, 2015

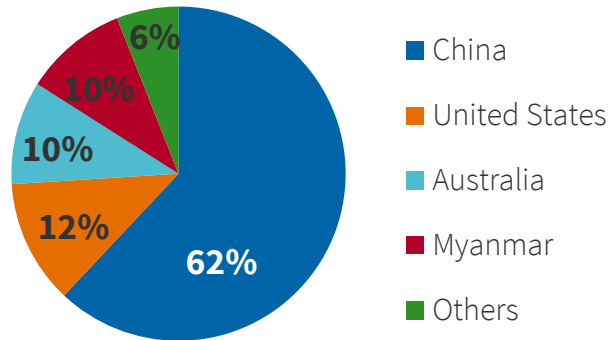
Rare Earth supply – Critical situation?

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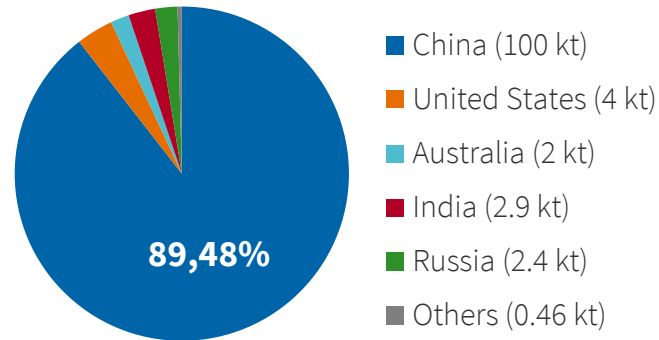
EU classified REE as „Critical Raw Material”

Global REO production (2020)



³ USGS, 2020

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NdFeB recycling



typical composition

Main elements	Nd	23-31	%
	Pr	0-7	%
	Dy	1.3-5	%
	Fe	65-70	%
	B	0.9-1.2	%
Coatings and additives	La	0-2	%
	Co	0-1	%
	Al	0-0.3	%
	Cu	0-0.3	%
	Ni	0-0.3	%
Contaminants	Nb	0-0.6	%
	C, Ca, N, Si, O		

Firdaus et al., 2016

NdFeB recycling



typical composition

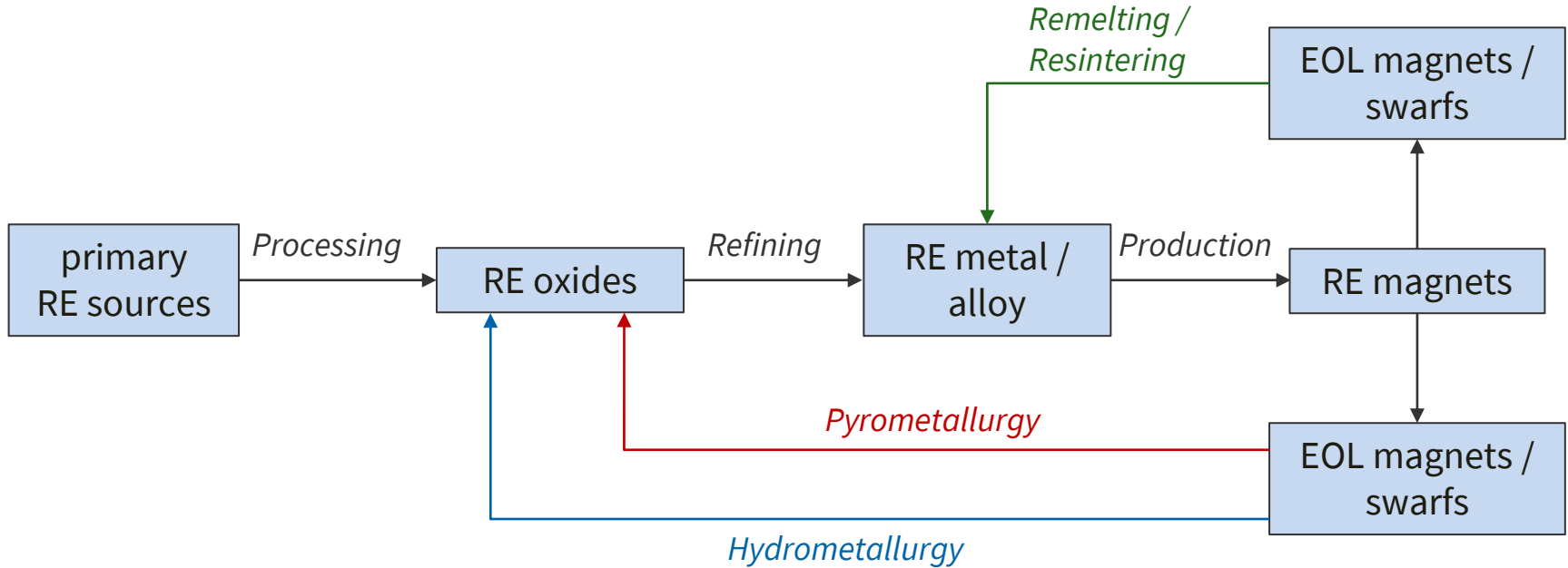
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Critical for direct reuse of EoL magnets

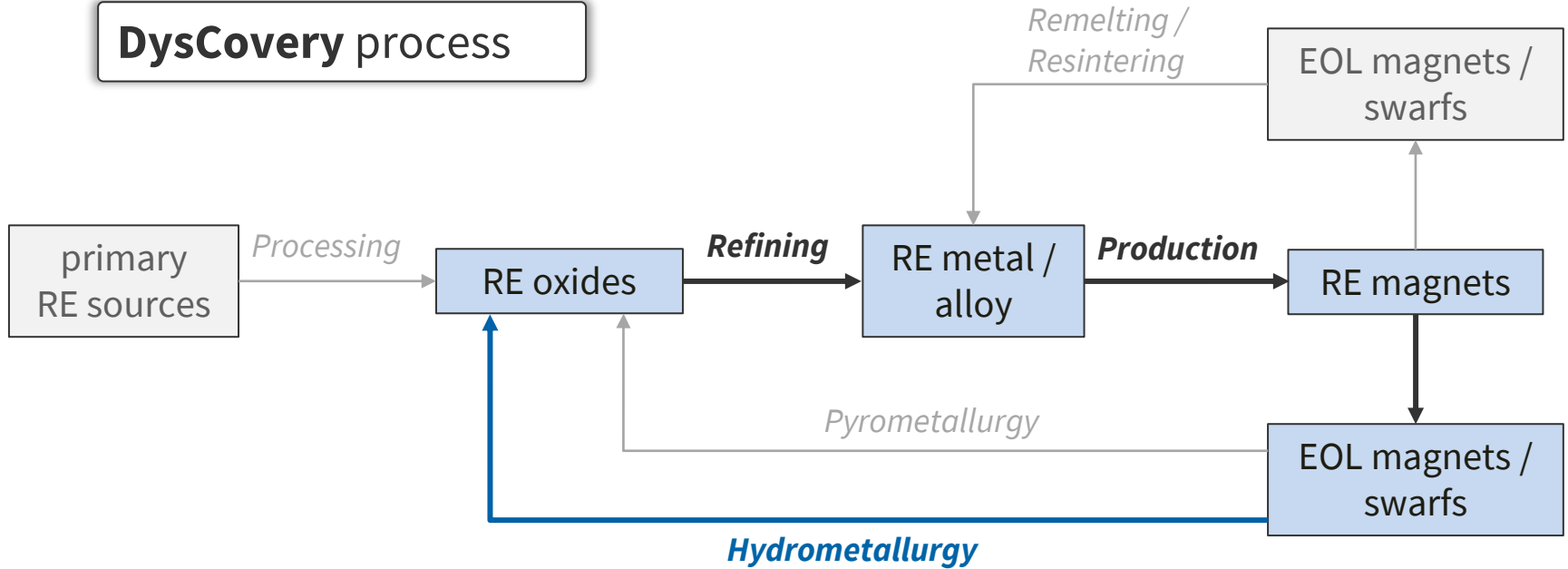
Firdaus et al., 2016

NdFeB recycling - Flow Sheet



NdFeB recycling - Flow Sheet

Dyscovery process



The Dyscovery process



Pre-Processing

H₂-free leaching

Precipitation

Extraction chromatography

Nd Electrowinning

Magnet production / testing

1) Demagnetizing

- Above Curie temperature
- Inert atmosphere



The Dyscovery process



Pre-Processing

H₂-free leaching

Precipitation

Extraction chromatography

Nd Electrowinning

Magnet production / testing

2) Crushing

- Air or inert atmosphere



The Dyscovery process



Pre-Processing

H₂-free leaching

Precipitation

Extraction chromatography

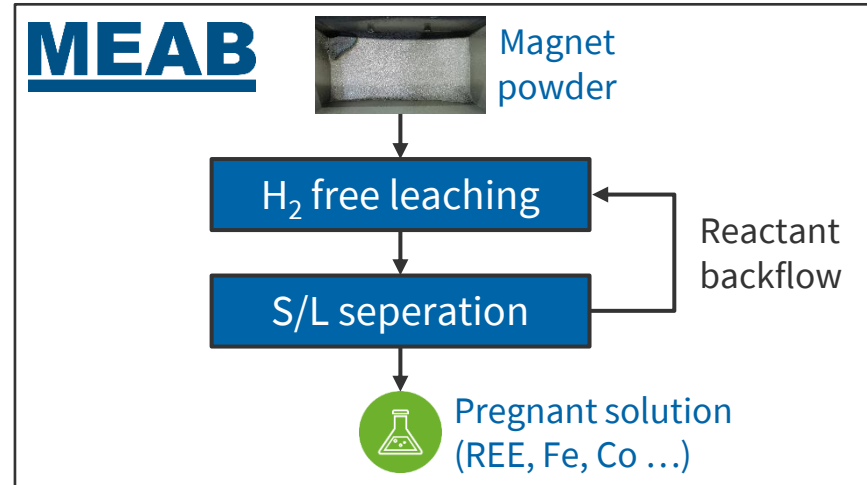
Nd Electrowinning

Magnet production / testing

Innovative dissolution process

Avoid hydrogen evolution

- low operation risk
- closed loop process



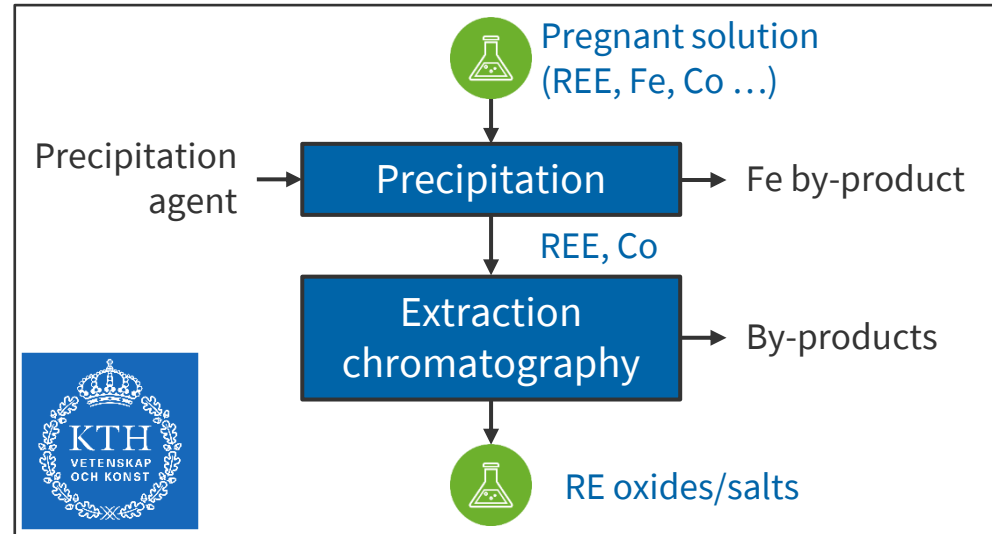
The DysCOVERY process



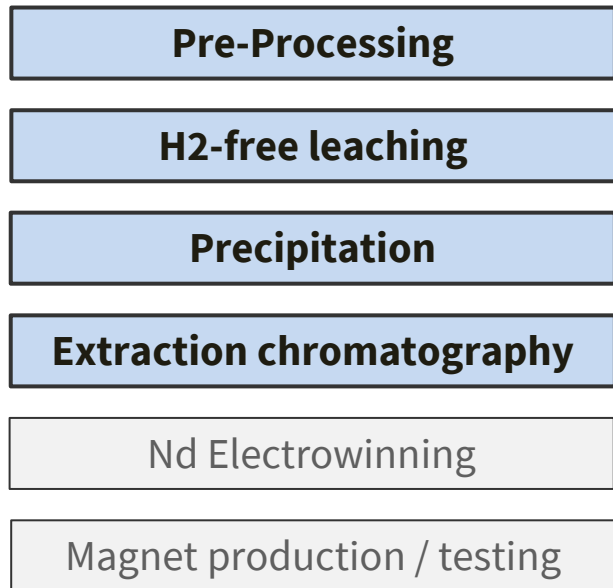
- Pre-Processing
- H₂-free leaching
- Precipitation**
- Extraction chromatography**
- Nd Electrowinning
- Magnet production / testing

Innovative extraction chromatography

Separation of REE and Co



The Dyscovery process



MEAB



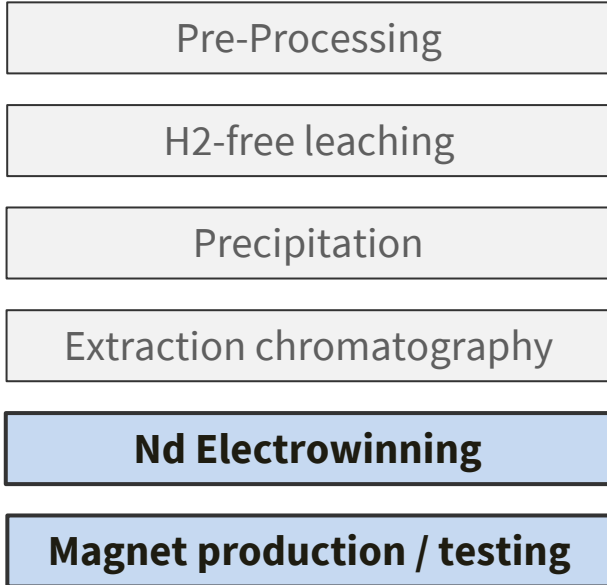
MONOLITHOS
CATALYSTS - RECYCLING - INNOVATION

Process Upscaling to TRL8

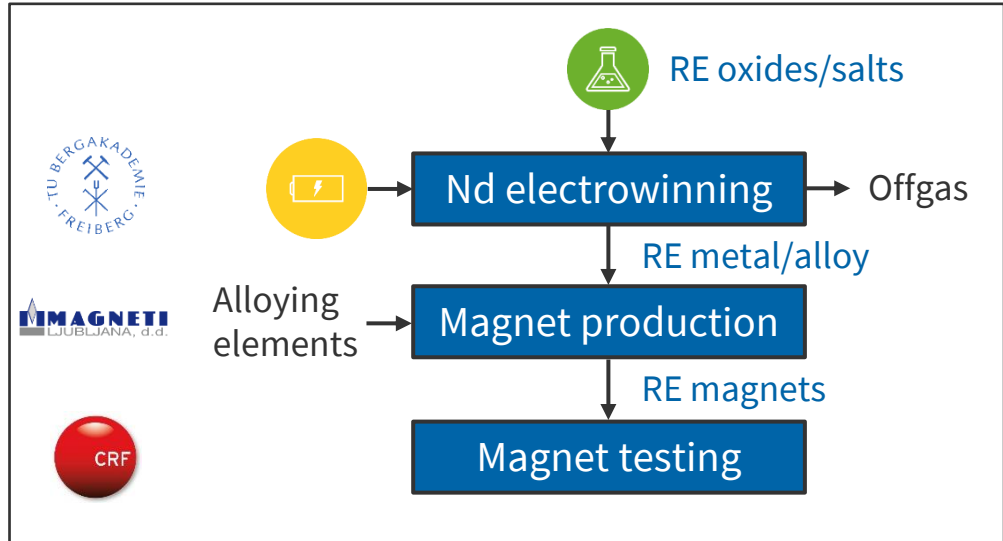
- Recycling of **630 t/a** EoL material by **2025**
- Enhancing **EU recycling capacity** by **23%**



The Dyscovery process



Production of new magnets from EOL waste RE refining + magnet production/testing



The Dyscovery process



Pre-Processing

H₂-free leaching

Precipitation

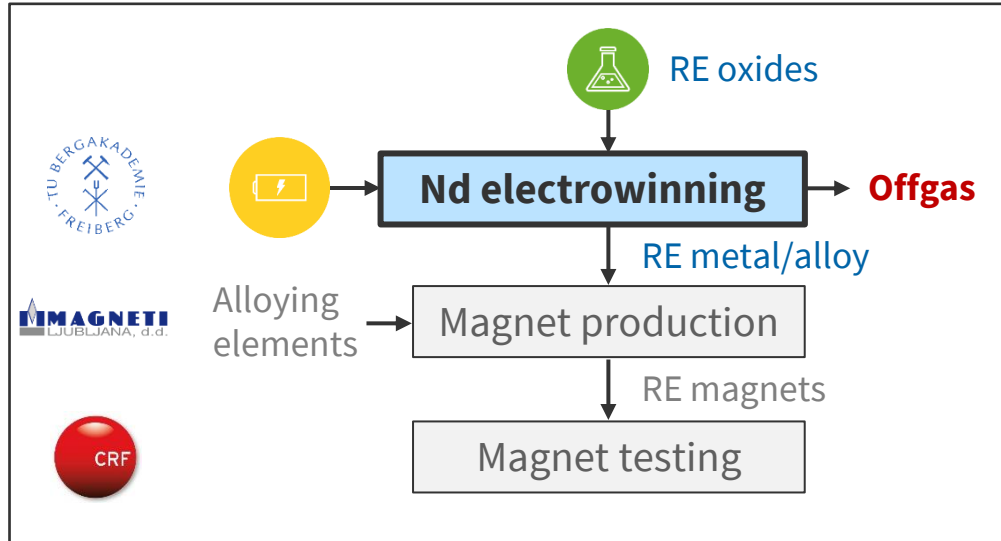
Extraction chromatography

Nd Electrowinning

Magnet production / testing

Neodymium electrowinning

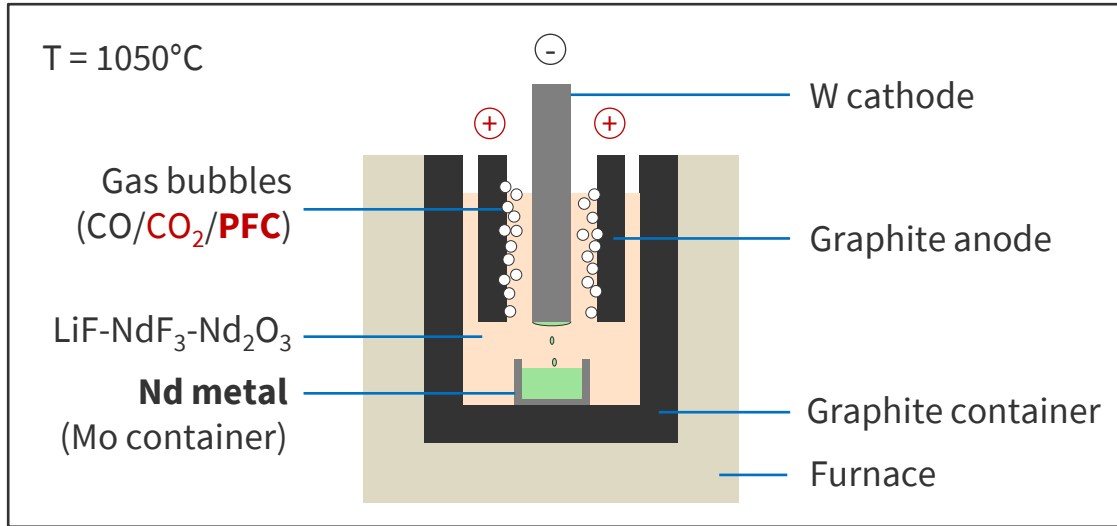
How about sustainability?



Challenges of neodymium electrowinning

Neodymium Molten Salt Electrowinning

Process schematic



Anode:



Cathode:



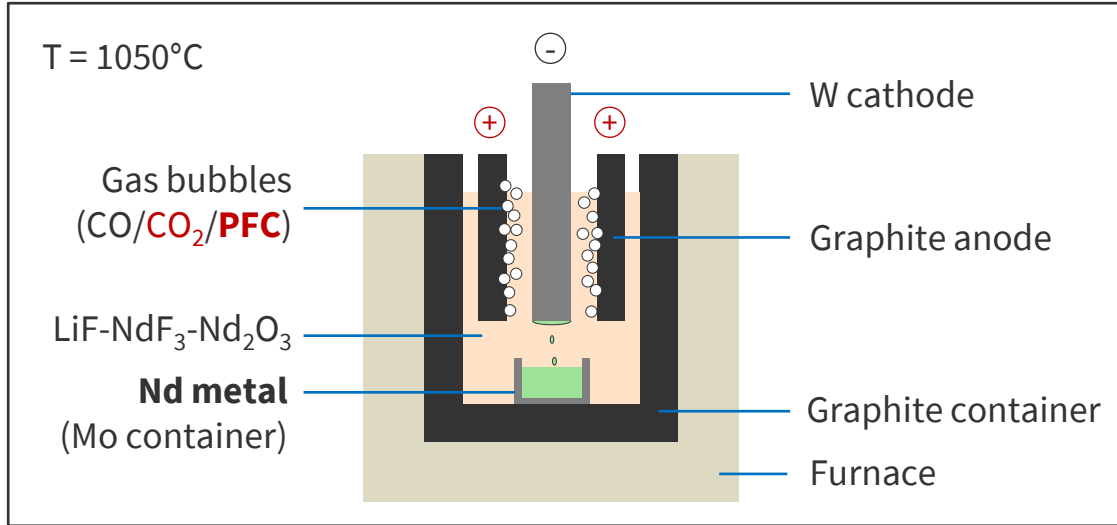
Overall:



Challenges of neodymium electrowinning

Neodymium Molten Salt Electrowinning

Process schematic



Anode effect:

low Nd_2O_3 concentration

Anodic overpotentials lead to **PFC** emission

→ GWP = **12.200 CO₂-eq**

Anode:



Challenges of neodymium electrowinning

Pilot Plant Manufacturing

Nd molten salt electrowinning



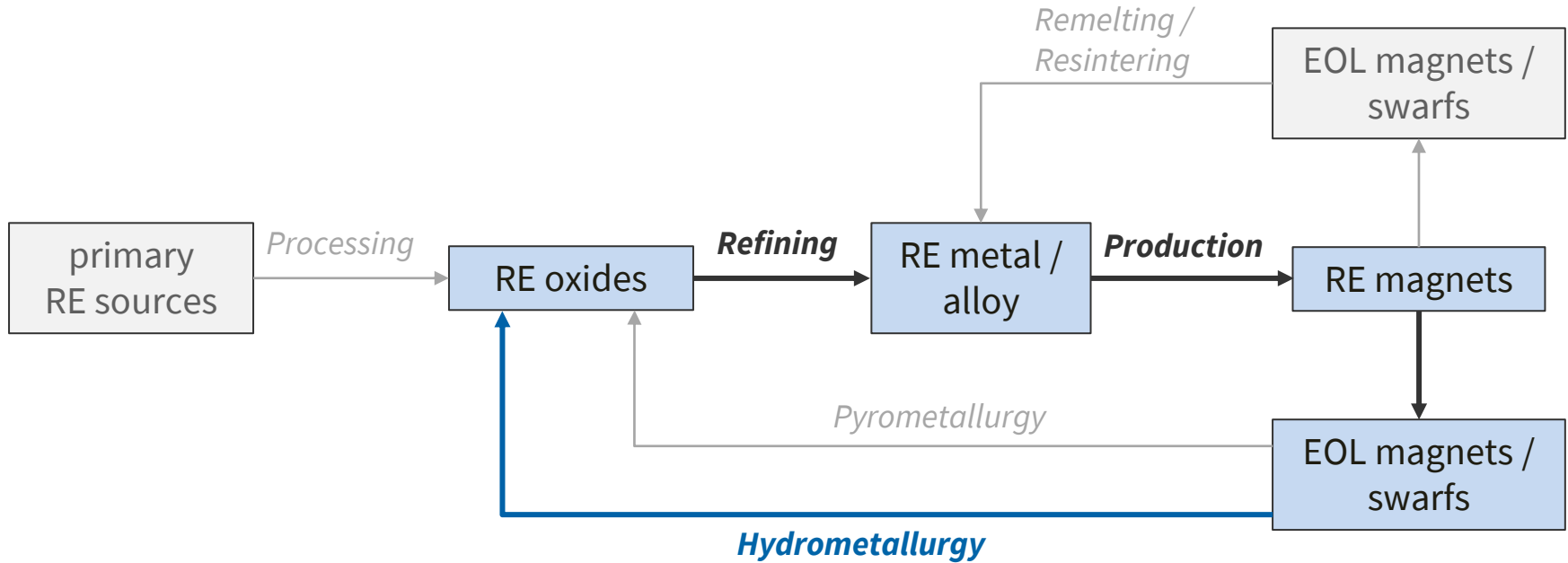
Research challenges:

- Reduce PFC emissions
 - Electrochemical measurements
 - Online gas measurement
- Evaluate Nd production from EOL magnets
- Optimize cell design & parameters

Cell design based on existing Aluminum electrowinning cell

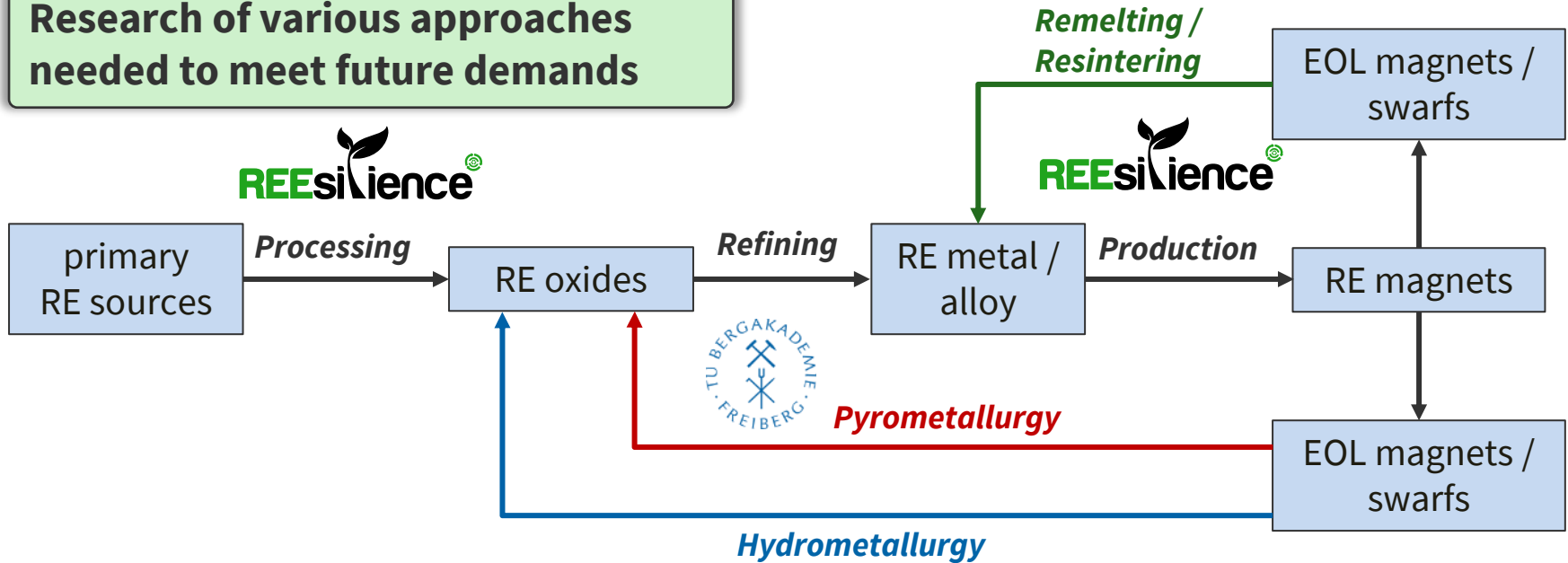
Future of RE recycling ? ...

NdFeB recycling - Flow Sheet



NdFeB recycling - Flow Sheet

Research of various approaches needed to meet future demands



RE supply in Europe

- Nd, Pr, Dy demand may rise by 700-2600 % until 2037¹
- Use collaborations (DysCoverly, REEsilience ...) to research, upscale and implement recycling technologies in EU
- High interest of industry (producers and end-users)

Nd electrowinning

- Nd metal/alloy production from various RE streams
- Control over PFC emissions

Pyrometallurgical recycling

- Optimization of RE slag systems (3 Master thesis since 2021)



Thank you for listening!



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