This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

Critical Materials and Life Cycle Thinking

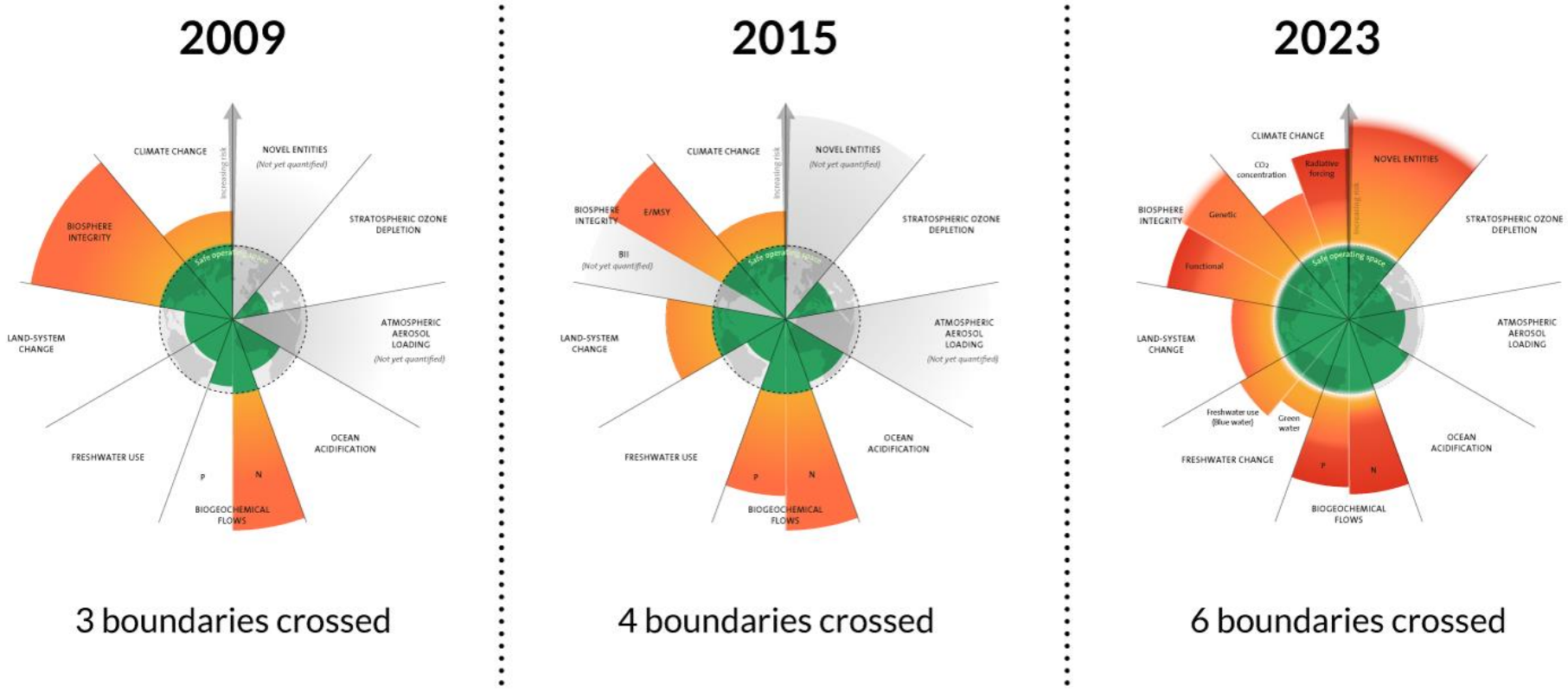
Low Emittance Ring – Permanent Magnets Workshop
November 14th 2023 / Trieste, Italy

Andrea Klumpp/ DESY / i.FAST WP 11

iFAST

The challenge

The challenge



The evolution of the planetary boundaries framework. Licenced under CC BY-NC-ND 3.0. You are free to share — copy and redistribute the material in any medium or format. (Credit: Azote for Stockholm Resilience Centre, Stockholm University. Based on Richardson et al. 2023, Steffen et al. 2015, and Rockström et al. 2009)

Public Perception

Sünden für die Forschung

Expeditionen, Teleskope und Großgeräte belasten das Klima. Langsam kommt es zum Umdenken

Von Ralf Nestler

Reisen oder nicht? Diese Frage stellen sich viele Forscherinnen und Forscher. Denn: Die pandemiebedingten Beschränkungen sind weitgehend abgeschafft, sie könnten wieder durchstarten zu Expeditionen, Speziallaboren und Konferenzen. Doch die Reisen belasten das Klima und vergrößern weiter den CO_2-Fußabdruck der je nach Disziplin ohnehin oft deutlich über dem Durchschnitt liegt.

Das liegt unter anderem an großen Forschungsbauten aus Beton und Stahl, die zudem viel Strom verbrauchen. Die Astronomie mit ihren Teleskopen und Rechenzentren gehört eindeutig zu den großen Emittenten. Doch auch die Teilchenphysik mit ihren Beschleunigern und die Umweltforschung – Stichwort Expeditionslogistik – tragen zum Klimawandel bei.

„Können Universum nicht auf Kosten des Planeten erforschen“

Wie viel, das lässt sich kaum fassen. Der „Klimaabdruck“ einer Spiegeloptik, einschließlich Herstellung, eines Gebäudes oder von Dienstreisen, kann geschätzt werden. Studien haben daher eine gewisse Unsicherheit, können Tendenzen jedoch deutlich machen.

Demnach sind in der Astronomie die Infrastrukturen der dominierende Fak-

Fahrt fürs Klima. *Der Polarstern hat auf der „Mosaic“-Expedition rund 7000 Tonnen Schiffsdiesel verbraucht.* Foto: dpa/AWI

Sins for research

https://infrasevent.presidencyeu.es/#event

DER TAGESSPIEGEL

Brandbrief für Klimaschutz

02.09.2020, 17:34 Uhr

Dicke Luft bei Helmholtz

Mitarbeiter der Forschungsorganisation fordern weitreichende Maßnahmen für sofortigen Klimaschutz. VON JAN KIXMÜLLER

Die Standorte, wie hier am GFZ Potsdam, sollen klimaneutral werden. FOTO: SEBASTIAN GABSCH PNN

Trouble‘s brewing @ Helmholtz

SPIEGEL Wissenschaft

Studie zu Emissionen

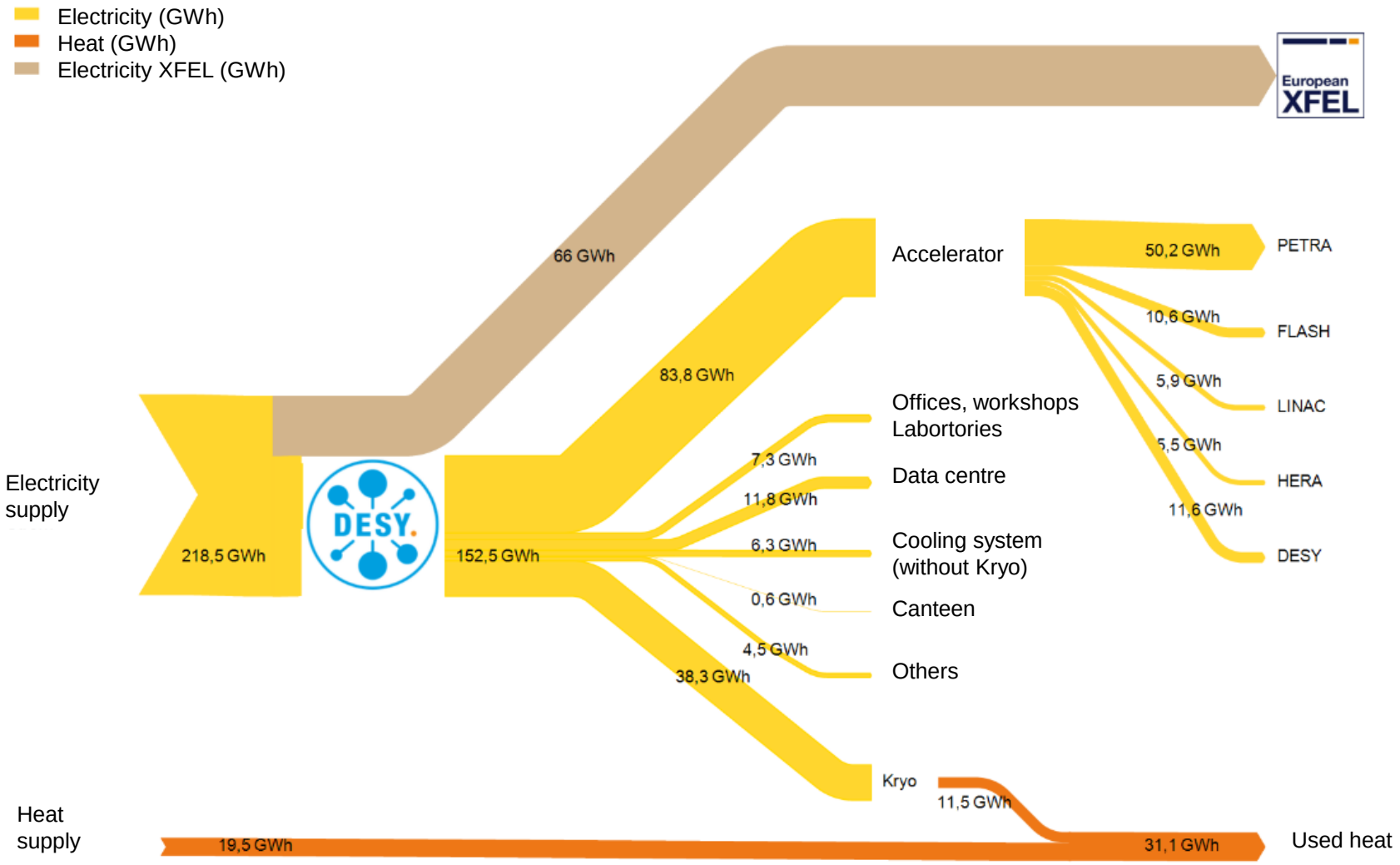
Wie klimaschädlich darf Grundlagenforschung sein?

In China soll ein riesiges Neutrino-Obser
ökologische Auswirkungen diskutiert. Da
Astronomen und Astronominnen angeko

Von **Christoph Seidler**
16.01.2021, 19.12 Uhr

How climate-damaging is basic research allowed to be?

The challenge - energy consumption DESY 2021

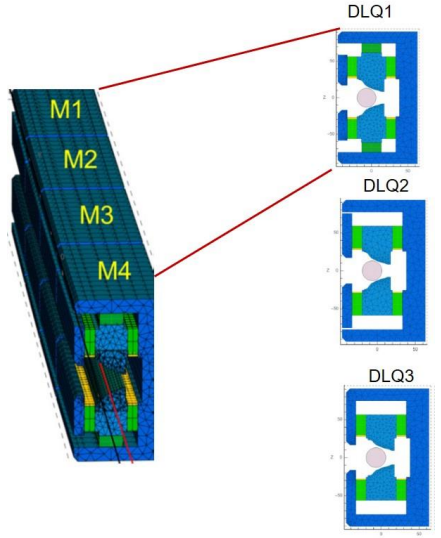


Energy Consumption in other accelerator facilities

- Increasing use of permanent magnets in new lattices
- Permanent magnets run without electricity

ESRF:	before upgrade	16.9 GWh / year	J.Chavanne Permanent accelerator magnets for light sources 5th ESSRI Workshop 2019, https://indico.psi.ch/event/6754/contributions/18013/
	after upgrade	8.5 GWh / year	
PSI:	SLS	6.4 GWh / year	M.Seidel Technologies for Sustainable Accelerators First I.FAST annual meeting 2022 https://indico.cern.ch/event/1138690/contributions/4782721/
	SLS2.0	2.6 GWh / year	
HZB:	BESSY II	5.1 GWh/ year	J.Völker Overview permanent magnets at accelerator facilities I.FAST REE workshop 2023 https://indico.desy.de/event/35655/timetable/#20230206.detailed
	BESSY III	<1.3 GWh/ year	

Bending magnets at PETRA IV



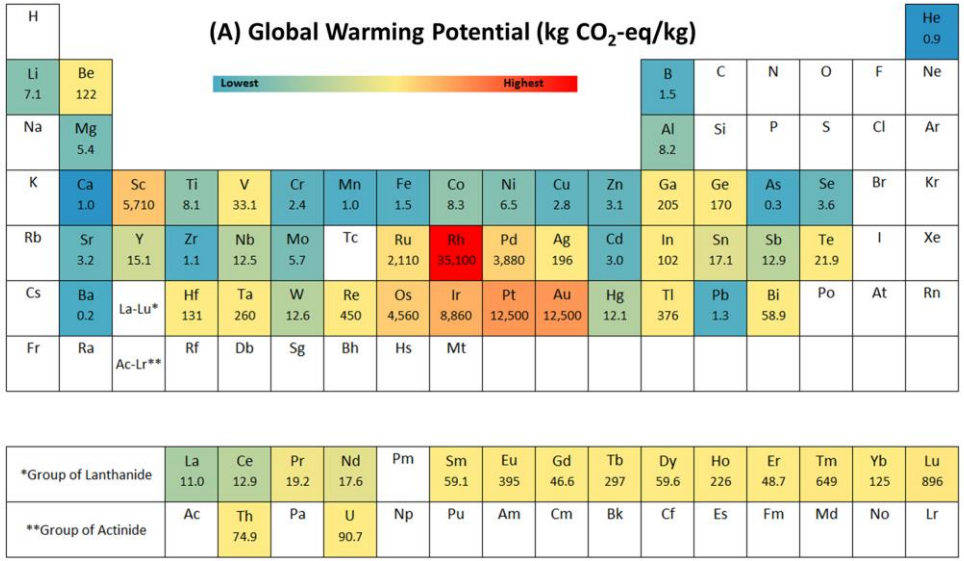
- H6BA lattice: DLQs combine the function of a dipole and quadrupole magnets to save space
- Soft iron poles and yoke; SmCo magnets
- Thermal shims for temperature compensation
- Energy savings: **nearly 2.87 GWh/year**

  (calculated with 6500 h operation time per year; without cooling and heating)

for all electromagnets in PETRA IV nearly 6.4 GWh per annum (6500 h operation time)

CO_2 footprint for bending magnets

- First calculations for material and energy:
  NO! production, transport and cooling in operation included
- Literature research for Global warming potential (GWP) for materials
- Depending from included processes (eg. mining, sintering …) and mining/production region
  but also from data base, program for calculation values for one material differ a lot
- Here only cradle to gate calculations (for SmCo only the raw material Sm and Co)



Life Cycle Assessment of Metals: A Scientific Synthesis
Philip Nuss1*, Matthew J. Eckelman
www.plosone.org 1 July 2014 | Volume 9 | Issue 7 | e101298

Energy GWP from UBA for renewable electricity

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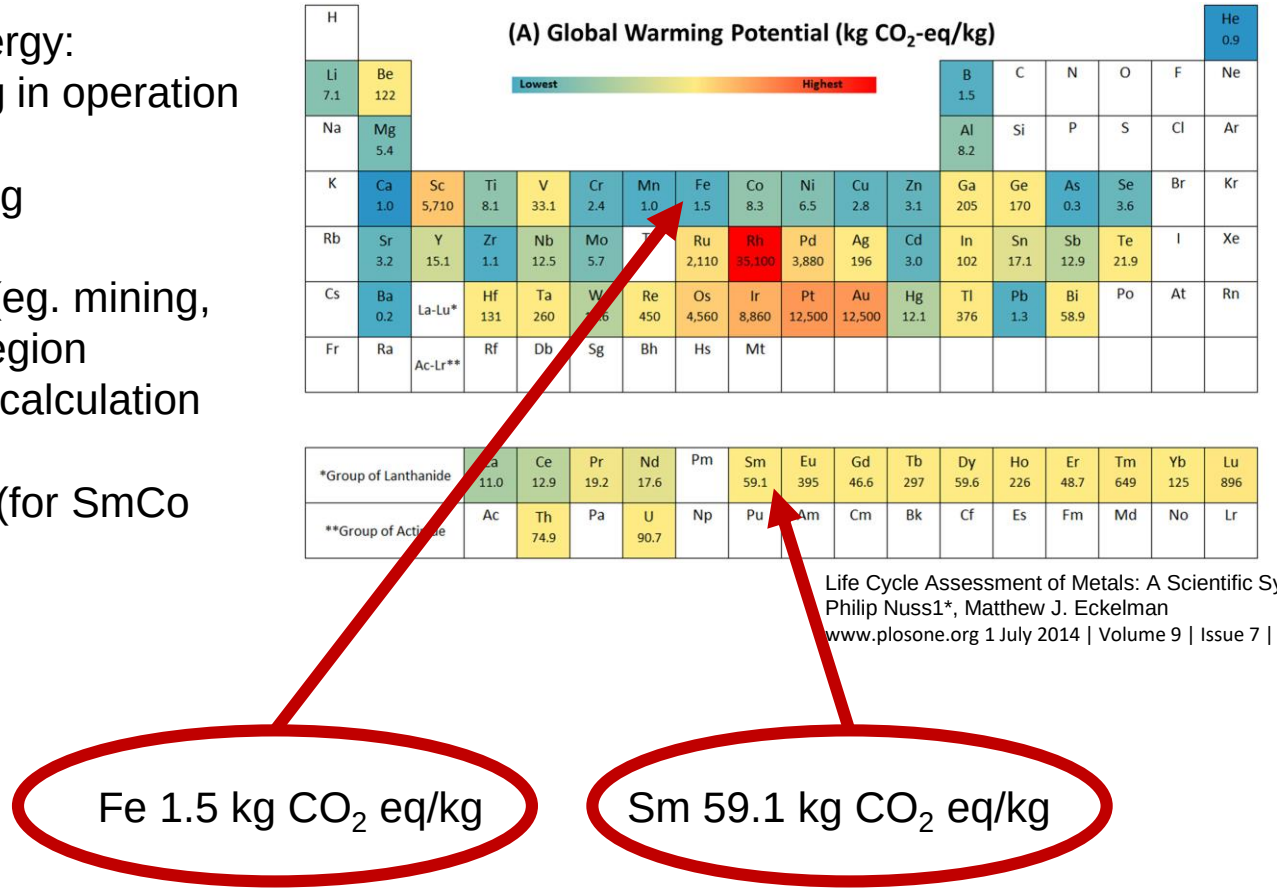

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First calculations - CO2 footprint for bending magnets

	DLQ1		DLQ2		DLQ3	
	Emag	Pmag	Emag	Pmag	Emag	Pmag
operation [kW]	1,27		0,67		1,11	
Fe [kg]	189,6	114,33	170,6	114,33	287,6	171,40
Cu [kg]	34		31		50	
Al [kg]		20		20		30
Sm_2Co_{17} [kg]		16,47		16,47		24,70
FeNi [kg]		1,2		1,2		1,8
Total weight [kg]	223,6	152,0	201,6	152,0	337,6	227,9

Material and energy consumption for DLQs

Energy GWP from UBA for renewable electricity

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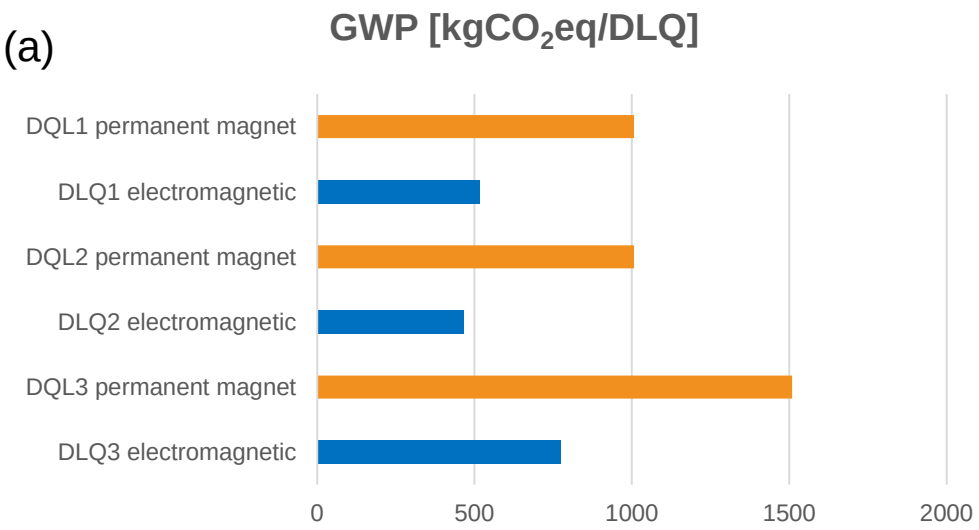
Material and energy consumption for DLQs

(a)



GWP for (a) material (electromagnets- blue and permanent magnets – orange)

Energy GWP from UBA for renewable electricity

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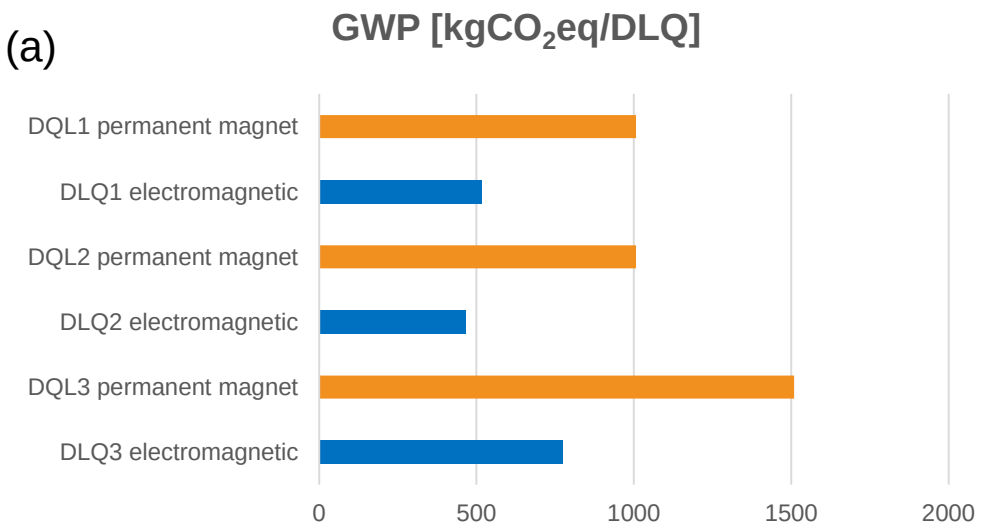
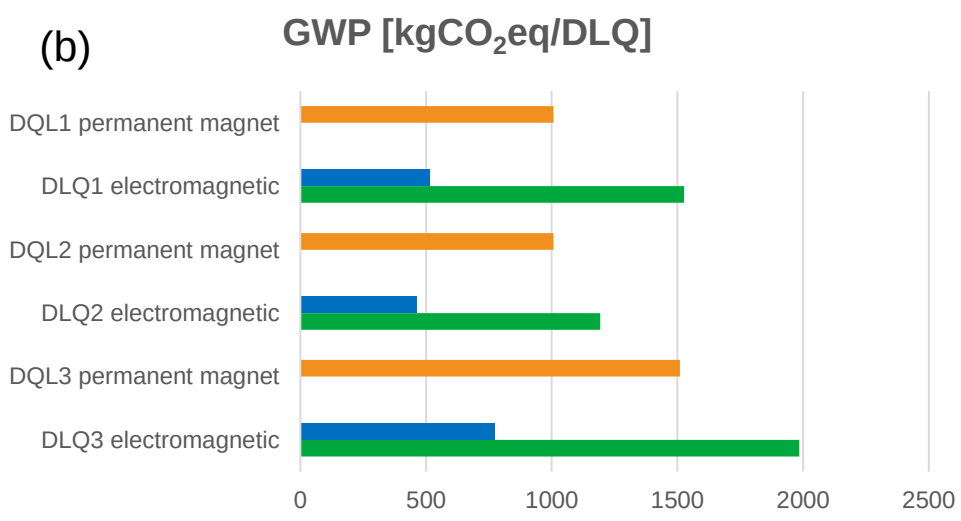


(b)



GWP for (a) material (electromagnets- blue and permanent magnets – orange)
and (b) including estimated energy consumption (material + renewable electricity for 2 years – green)

Energy GWP from UBA for renewable electricity

Problems and challenges of permanent magnets

Beginning of life cycle: Mining and Processing

- Rare earths are mined and processed under destructive social and environmental conditions
- No alternative sources or certified mining and processing available

In operation

- Temperature fluctuations and radiation damages reduce the life span
- Magnetic field is not adjustable, so changes in trajectories can not be compensated
- Magnetic field can not be switched off (Safety aspects like maintenance)

End of life cycle: Recycling

- So far no industrial recycling chain

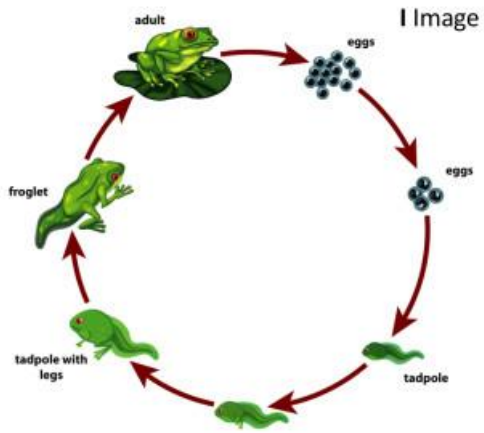
a) **Private, illegal minning in China**; http://www.chinahush.com/2009/10/21/amazing-pictures-pollution-in-china/; 2009 - 2011 ChinaHush is licensed under a Creative Commons License *Copyright:* Lu Guang;
b) **air pollution by heavy industries**; Quelle: china-digital-times *Copyright:* My Essentia com blog;
c) **In-Situ-Leaching**; Quelle: Web-Page Bellona
Copyright: Andrej Ozharovsky;
d) **Entrance to waste disposal for radioactive waste from REE production in Bukit Merah** in Kledang mountains; built for 20 years storage of radioactive waste (14 Mrd years radioactive half-life); 1985 *Copyright:* Consumer Assciation Penang

Beitrag: Collector
Lizenz: Creative Commons (CC-BY-NC-SA) V.3.0

What to do?

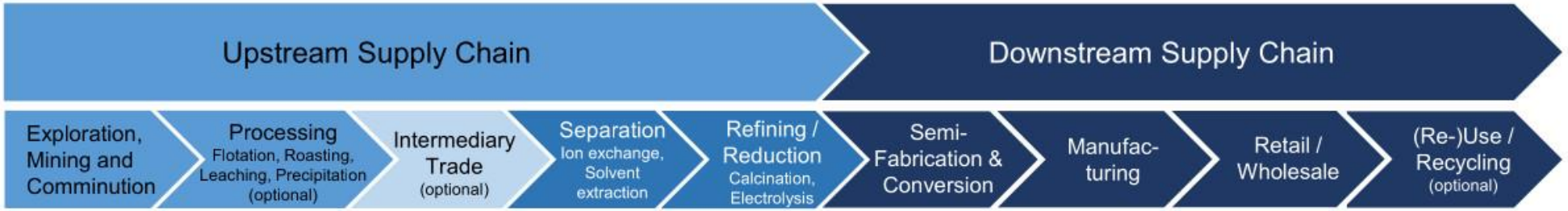
What to do?

- Awareness at accelerator community
- Implement life cycle management already in planning phase of new Ris
- Find best practice for recycling of these materials
- Support development of certification system for mining and processing of critical materials



I Image by brgfx on Freepik

I Image by juicy_fish on Freepik



I from M.Erdmann: https://indico.desy.de/event/35655/contributions/137541/

Awareness

Awareness

Workshop: Critical Materials and Life Cycle Management: The Example of Rare Earths – curse or blessing?

- Life Cycle Assessment (LCA) and Recycling for permanent magnets
- Certification and auditing for rare earth elements

All Presentations can be found at:
https://indico.desy.de/event/35655/overview

REPM 2023 in Birmingham
REPM 2023 (eventsair.com)

Life Cycle Assessment

Life cycle

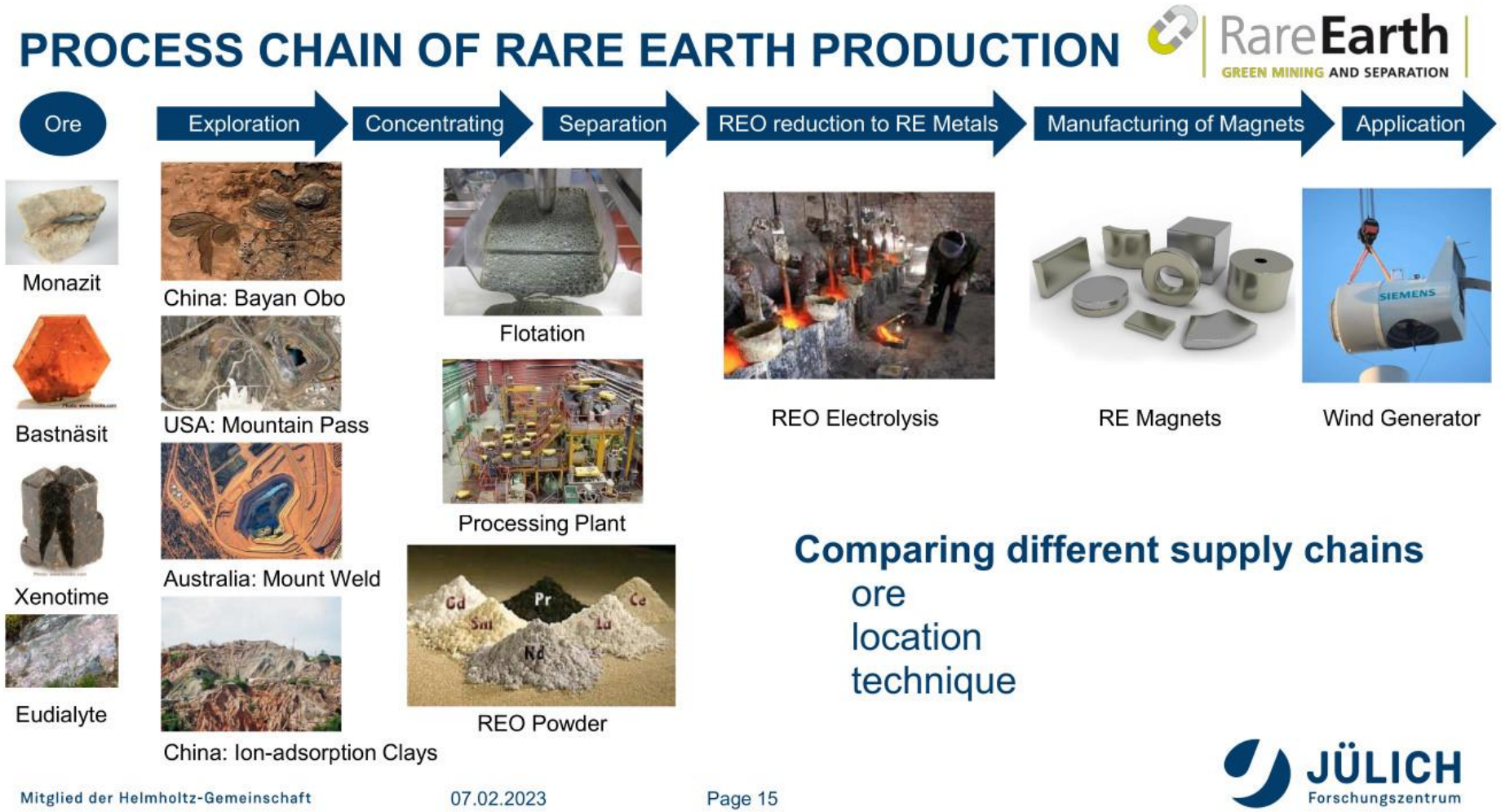
European Commission, Joint Research Centre, Cristobal-Garcia, J., Pant, R., Reale, F., et al., *Life cycle assessment for the impact assessment of policies*, Publications Office, 2017, https://data.europa.eu/doi/10.2788/318544

Life Cycle Assessment (LCA)

A tool for the analysis of the environmental burden of products at all stages in their life cycle

Indicator		Unit
▪ Climate Change Potential (Global Warming)	GWP	kg CO_2 eq.
▪ Eutrophication Potential (Over-fertilization)	EP	kg P eq./kg N eq.
▪ Photochemical Ozone Depletion Potential (Summersmog)	POCP	kg Ethene eq.
▪ Ozone Depletion Potential (Ozone hole)	ODP	kg CFC-11 eq.
▪ Acidification Potential land and ocean (Acid rain)	AP	kg SO_2 eq.
▪ Human toxicity	HTP	kg 1,4-DCB eq.
▪ Ecotoxicity	FAETP / MAETP / TETP	kg 1,4-DCB eq.
▪ Abiotic Resource Depletion (Resource scarcity)	ADP	kg Cu eq.
▪ Water scarcity		m^3 world eq.
▪ Land use		m^2a
▪	.....	

Process chain for REE



| from P.Zapp
https://indico.desy.de/event/35655/contributions/137451/

LCA for permanent magnets

SUMMARY OF LIFE CYCLE ASSESSMENT (LCA)

Challenges

- High energy demand
- High water consumption → Sinking of the groundwater level
- High chemical consumption (organic solvents, acids, flocculants, ammonia and nitrate compounds)
- High amount of emissions, effluents, and solid waste
- Discharge of radioactive elements (^{232}Th, ^{238}U) and their decay products into the environment
- Salinization and toxic and radioactive contamination of groundwater in mining/processing regions
- Land occupation for mining, processing plant(s), additional infrastructural facilities, waste disposals, tailings, dams, permanent storage of radioactive waste materials
- Transportation distances and routes (for separately located processing facilities)
- Accidents: uncontrolled leakage of contaminated wastewater (pipeline leaks, dam bursts) – not considered in LCA

Mitglied der Helmholtz-Gemeinschaft 07.02.2023 Page 28

JÜLICH Forschungszentrum

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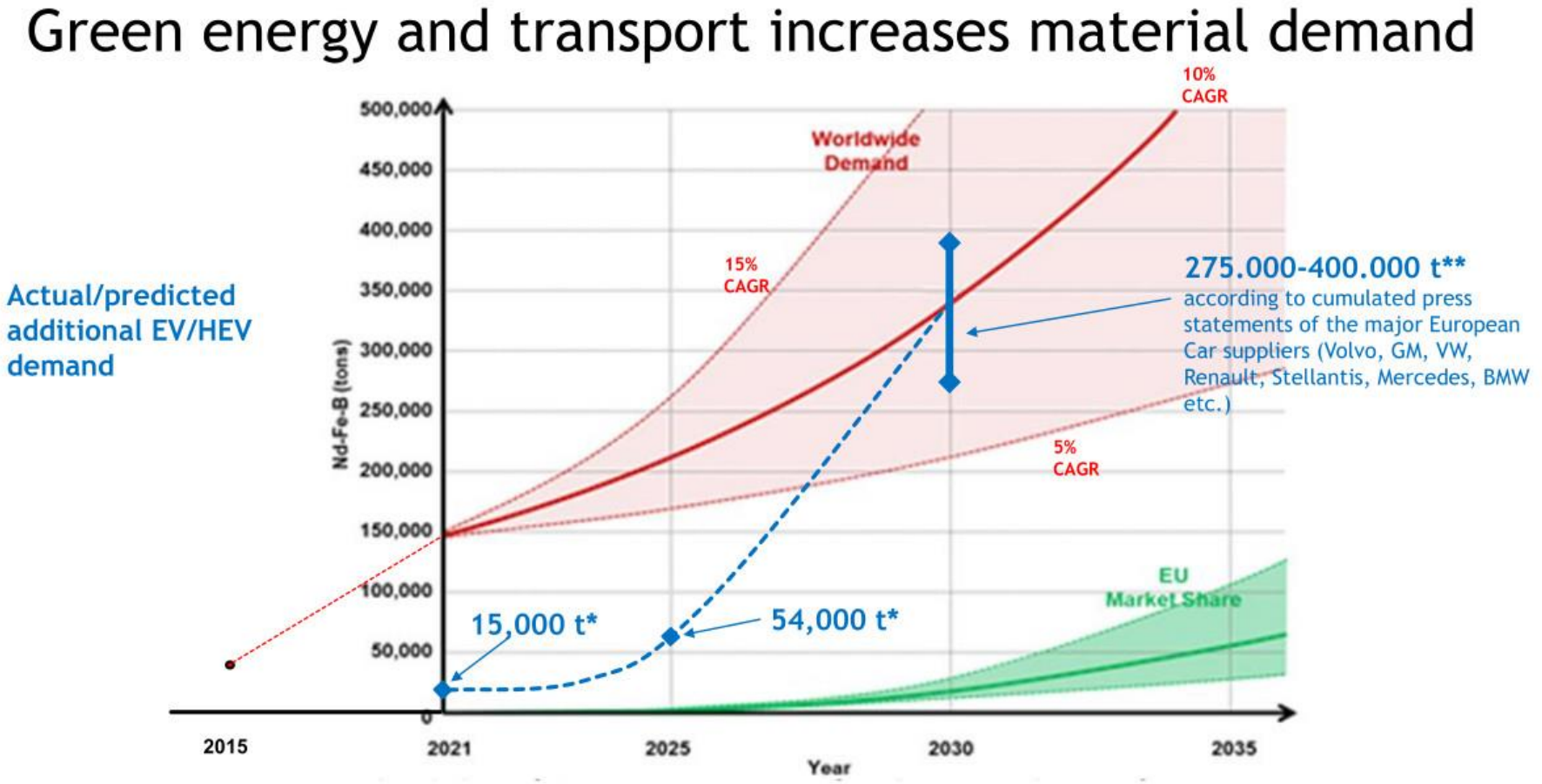
| from P.Zapp https://indico.desy.de/event/35655/contributions/137451/

Magnet recycling

Future material demand



*Source: *REIA (2022)*

**Source: *IEA (2021), Global EV Outlook 2021, IEA, Paris https://www.iea.org/reports/global-ev-outlook-2021*

I from C.Burkhardt: https://indico.desy.de/event/35655/contributions/137453/

The recycling chains

The challenge

Permanent Magnets

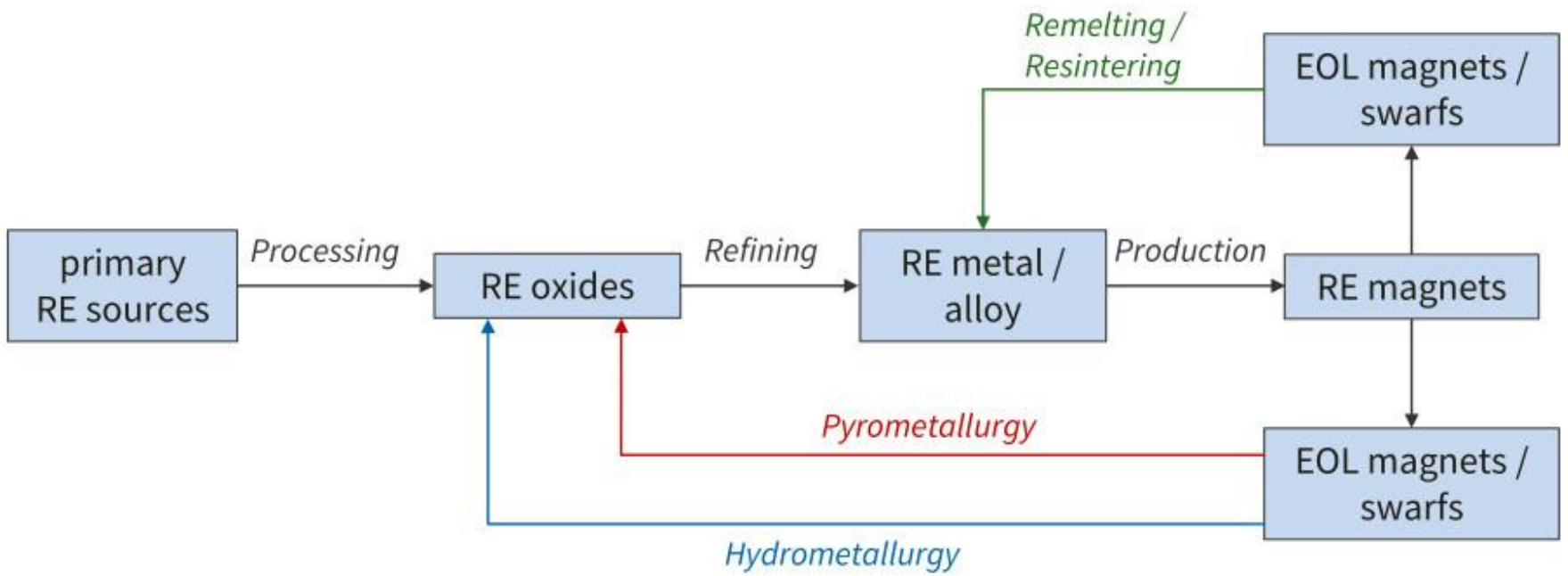
Awareness

Life Cycle Assessment

Recycling

Certification

Next steps



| from D. Vogt
https://indico.desy.de/event/35655/contributions/137462/

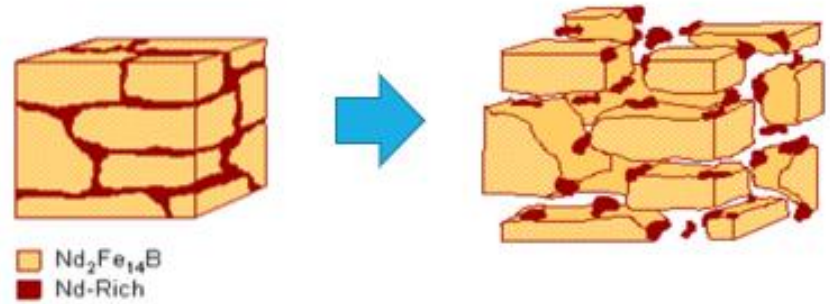
The short loop

Rare Earth Recycling

Short loop

Recycling is technically feasible

- High yield
- High quality
- Low carbon footprint



kshop - Critical Materials and LCA: Rare Earths, © Prof. Dr. Carlo Burkhardt

Source: Speight, J.; Climate Change from a Materials Perspective, The University of Birmingham, 02.08.2019

I from C.Burkhardt: https://indico.desy.de/event/35655/contributions/137453/

The long loop

The challenge

Permanent Magnets

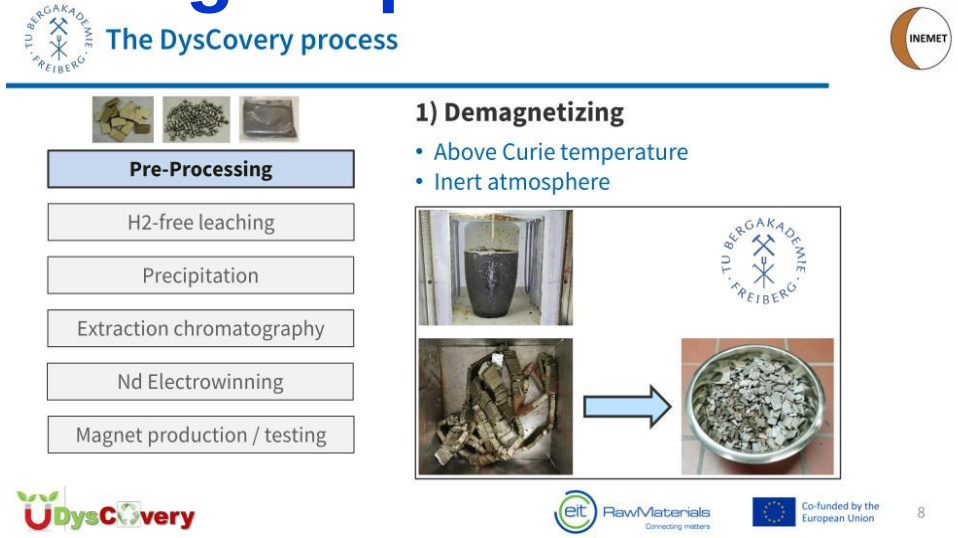
Awareness

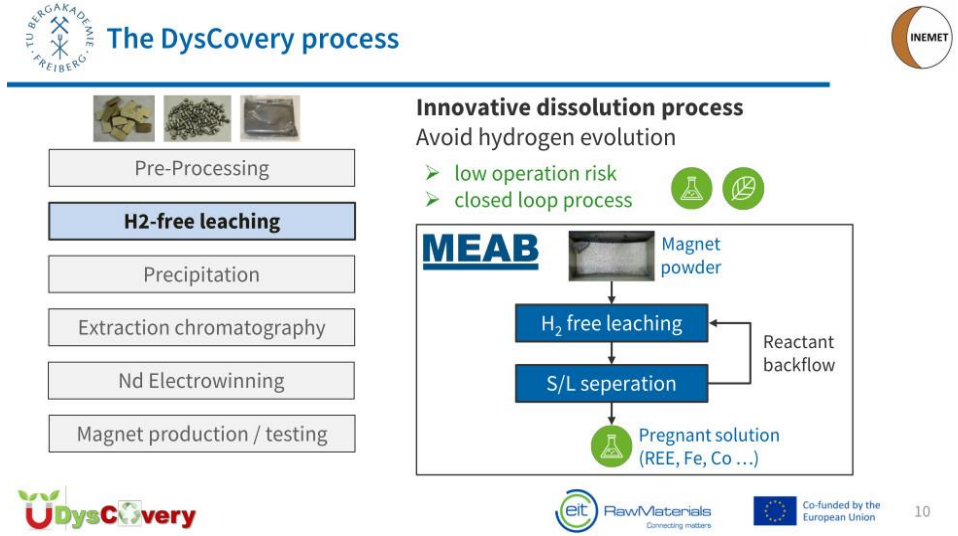
Life Cycle Assessment

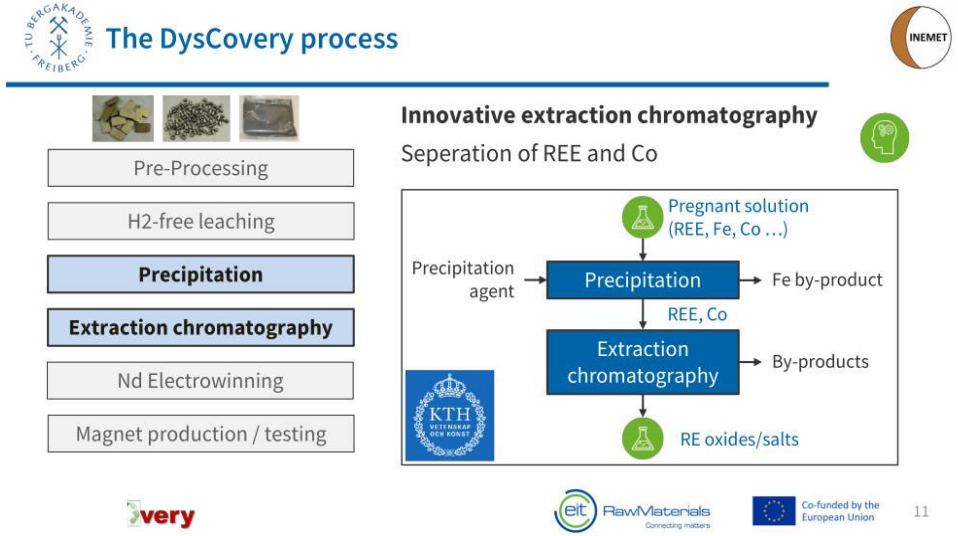
Recycling

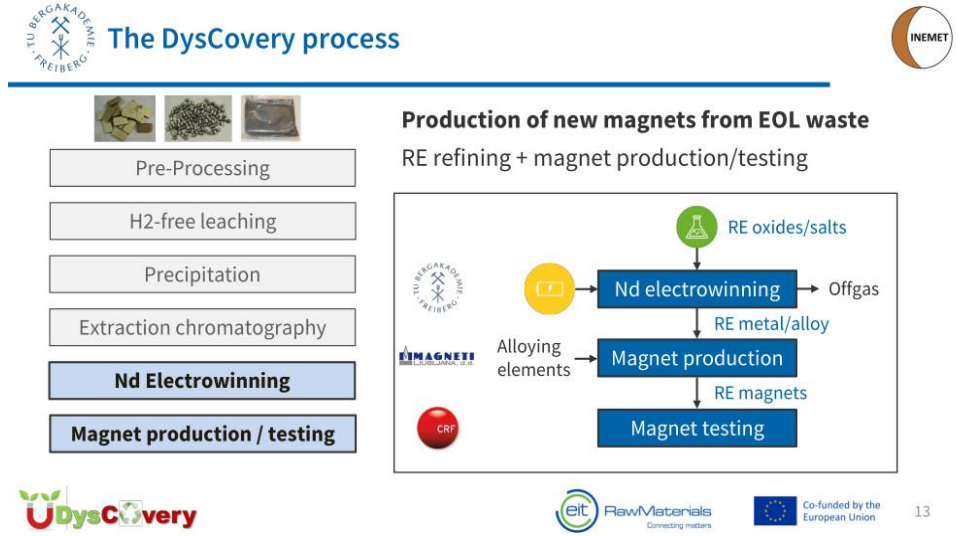
Certification

Next steps









| from D. Vogt https://indico.desy.de/event/35655/contributions/137462/

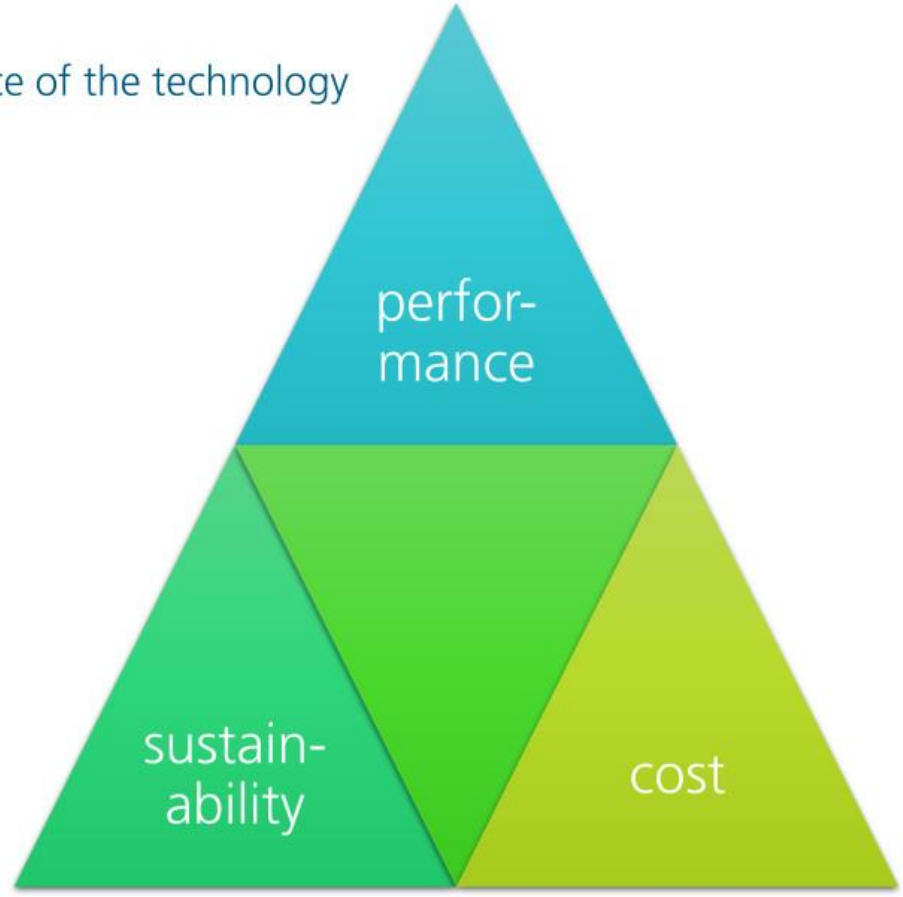
Balancing in recycling

Rare-earth permanent magnet recycling

Options for the use of recycled magnets in dependence of the technology

Performance | Sustainability | Cost

- For the use of recycled RE permanent magnets a materials tradeoff needs to be used
- **Elemental recycling**
  - With elemental recycling the highest magnetic performance can be adjusted → equivalent to magnets from primary elements
  - Cost for the recycling process is high
  - Sustainability is low → better than magnets from primary elements
- **Functional recycling**
  - Magnetic performance is dependent on the EoL magnets
  - Sustainability is potentially highest
  - Pretreatment of EoL magnets is needed



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I from J.Gassmann: https://indico.desy.de/event/35655/contributions/137452/

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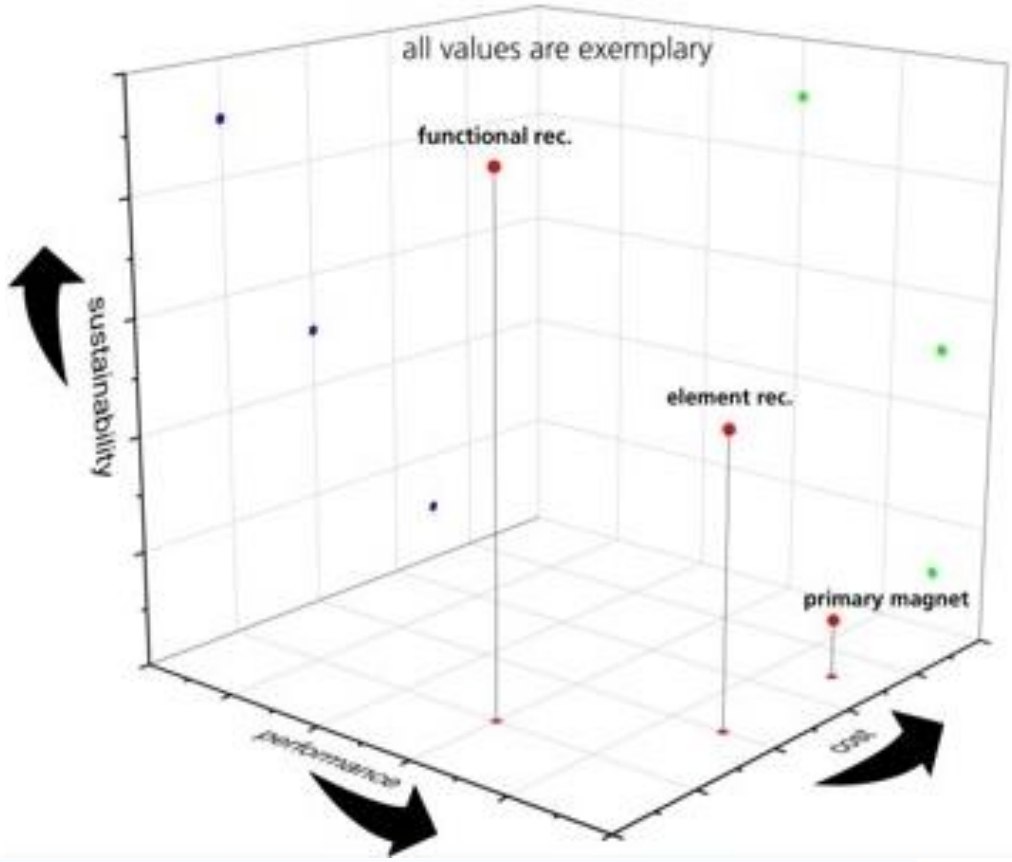

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Challenges in recycling process

RE Magnets Recycling

Technical issues

Other technology metals (Ag, Pt, Pd) have recycling rates of ~30%

- Recycling rate of Nd is <1%

→ Large diversity of End-of-Life Magnets:

– SmCo, Ferrite, NdFeB....

– no design for recycling

→ Underdeveloped recycling schemes

Workshop - Critical Materials and LCA: Rare Earths, © Prof. Dr. Carlo Burkhardt

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Challenges in recycling in accelerator facilities:

Designed for recycling ?

Example old DORIS undulators: At the workshop - initiation of recycling of some DESY undulators

Problem 1: how to disassemble the magnet structures/ undulators?

T.Vielitz, DORIS undulator

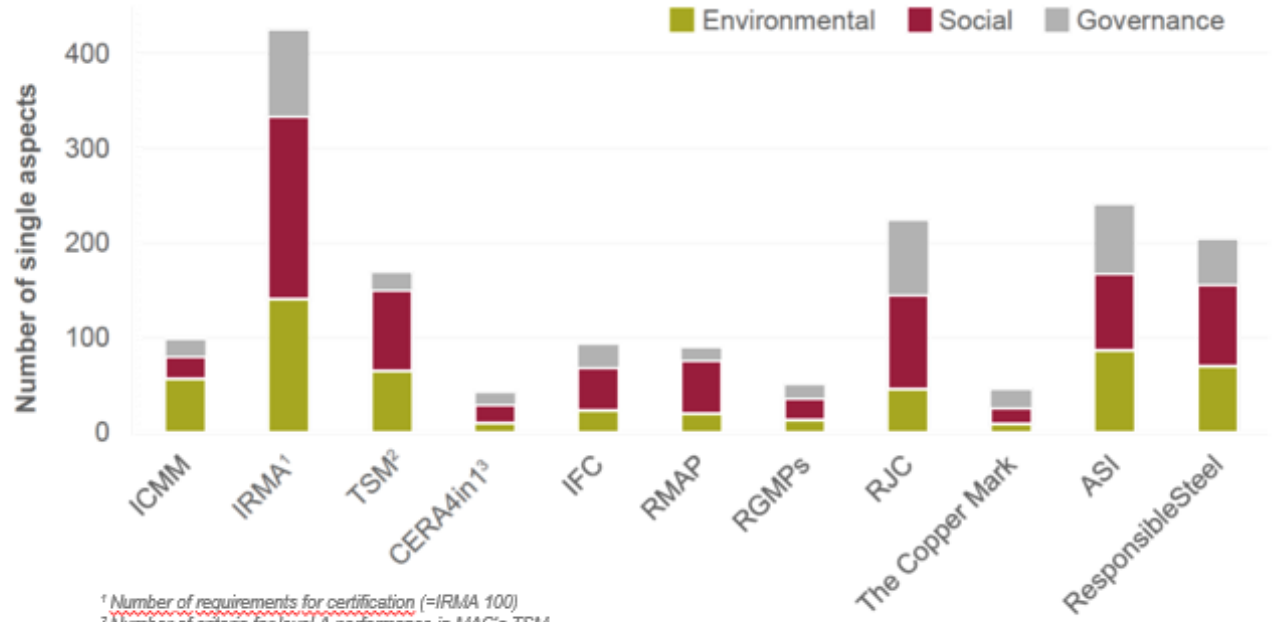
Problem 2: Magnets are glued and coated (to avoid rusting), this pollute the material in short loop recycling with HPMS

HPMS is a hydrogen based process which is used to extract NdFeB magnets from electrical products such as hard disk drives. The extracted NdFeB powder is in the form of an alloy which can be re-processed into different forms which can be sold back into the supply chain for rare earth magnets. Source: Speight, J.; Climate Change from a Materials Perspective, The University of Birmingham, 02.08.2019

Certification and audit

Certification

Voluntary Sustainability Standard Systems for Mineral Resources



¹ Number of requirements for certification (=IRMA 100)
² Number of criteria for level A performance in MAC's TSM
³ More requirements in CERA 4in1 Audit Check List

© BGR (2022) – Sustainability Standard Systems for Mineral Resources – A Comparative Overview

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ICMM International Council on Mining & Metals
IRMA Initiative for Responsible Mining Assurance
The Mining Association of Canada
IFC International Finance Corporation
CERA4in1
Responsible Minerals Initiative
World Gold Council
Responsible Jewellery Council
The Copper Mark – Responsibly Produced Copper
asi Aluminium Stewardship Initiative
Responsible Steel
BGR Bundesanstalt für Geowissenschaften und Rohstoffe
GEOZENTRUM HANNOVER

I from M.Erdmann: https://indico.desy.de/event/35655/contributions/137541/

Certification

Summary: Process for Certification

BERNERSCONSULTING Bridging China & Europe

Initial Process

1. Sign NDA & Declaration of Participation
2. CSR introduction, basic training & Baseline Audit by Nanjing University EHS
3. **Certification: Bronze – Basic supplier qualification**
4. Training & Improvement
5. Audit
6. **Certification: Bronze / Silver / Gold / Platinum – CSR Improvement Fund participation**

Ongoing 3-year cycle

- Continuous Improvement & CSR improvement projects (with CSR fund support)
- Third-party assessment / pre-audit and audit preparation
- Certification Audit
- **Certification: Bronze / Silver / Gold / Platinum – CSR Improvement Fund participation**

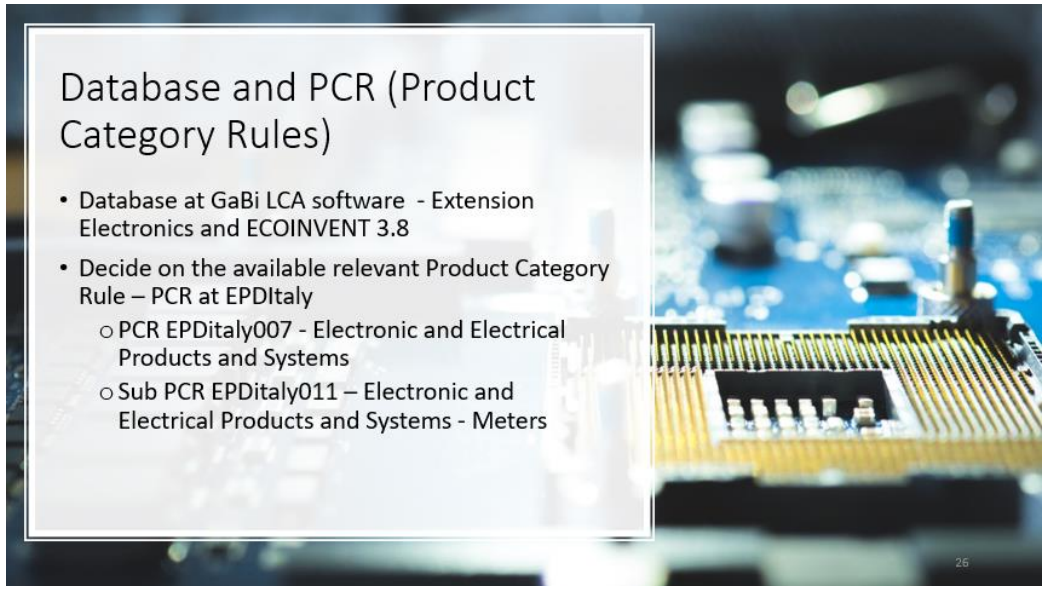
Lutz Berners | 07 February 2023 | DESY Workshop on Magnets
ers Consulting GmbH. All rights reserved

| from L. Berners https://indico.desy.de/event/35655/contributions/137504/

Next steps

LCA

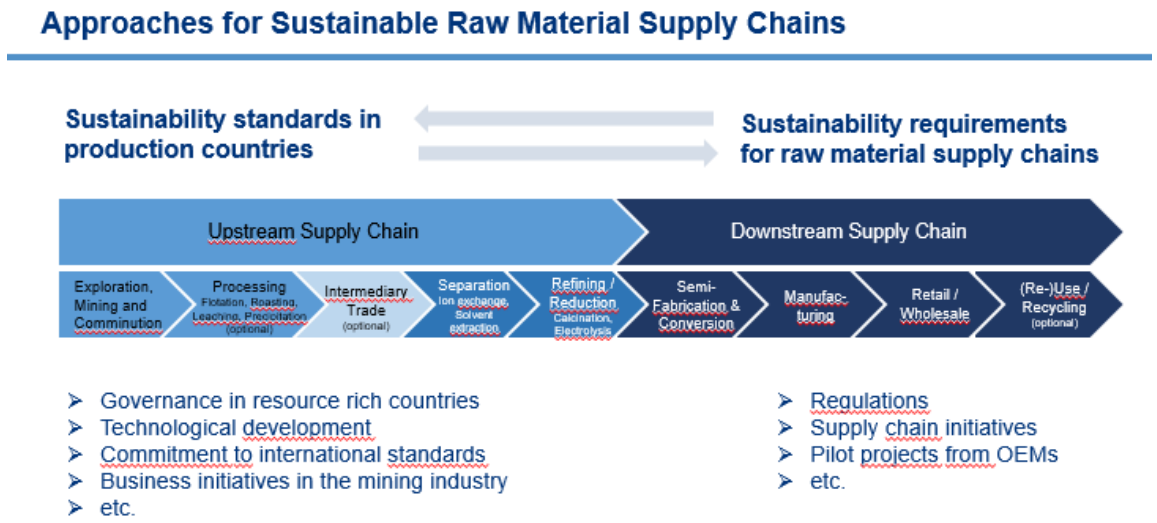
- Analyse existing LCA on rare earth
- Develop further down the supply chain
- Start LCA on other (easier) technical components with better data available → electronics



I from A.Lotan: https://indico.desy.de/event/35655/contributions/137465/

Certification

- Raise awareness
- Get better data/transparency
- develop and establish a first set of criteria to be specified in the procurement tenders → together
- start with transparency, auditability and initial questions on the biggest issues
- become more stringent over time
- Support political processes for CoC Certification



I from M.Erdmann: https://indico.desy.de/event/35655/contributions/137541/

Recycling

- Include questions of RC already in design
- Help make REE recycling a successful business case
- Cooperation with institutes and industry developing REE RC

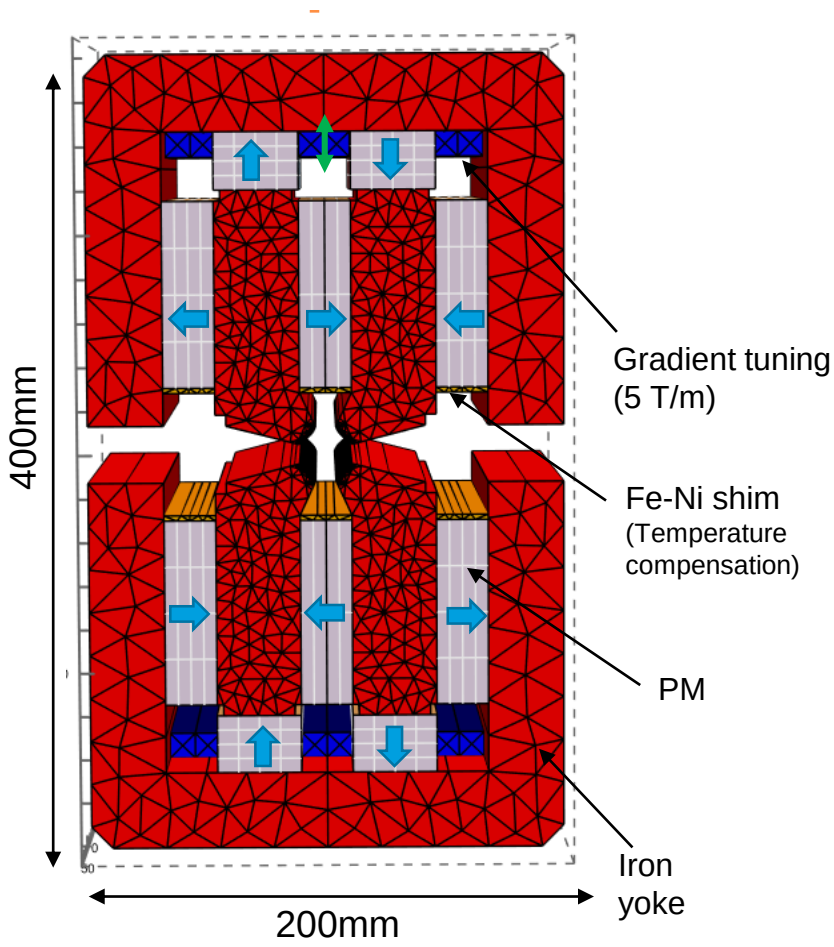
Source: Speight, J.; Climate Change from a Materials Perspective, The University of Birmingham, 02.08.2019

At DESY

- Discussions about permanent magnets for focussing electron beam (Quadrupole)
  → First design studies are done

- Development of a procurement scheme for sustainable magnets (in cooperation with other accelerator facilities)
  → Cooperations with consultant is planned
  → iFAST Workshop

- In the design phase, the recycling has to be in mind!



P. Ngotta

Sources

Infos taken from several presentations given at the iFAST Workshop

“Critical Materials and Life Cycle Management: The example of Rare Earths – curse or blessing”

06.-08.02.2023 at DESY;

indico: https://indico.desy.de/e/ree

iFAST

Thank you for your attention!

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