EU Green Week Partner Event

Quantifying Environmental Impact in Rare Earth Value Chains LCA Knowledge Sharing Roundtable

Badrinath Veluri

The Global Rare Earth Industry Association

Engaged in a more Sustainable, Responsible, Collaborative and Transparent Rare Earth Supply Chain, from Mining to Recycling

REIA

Who We Are?

- The Only Global Industry Association advocating the Rare Earth Industry
- A non-profit organization born in Brussels in 2019
- Originally founded with the support of EIT RawMaterials
- A multicultural and experienced Board and Advisory Board
- 40 members to date from all over the world, from all parts of the value chain.

Our Global Partners

Europe	America	Asia Pacific
European Commission	Critical Materials Institute, AN ENERGY INNOVATION HUB	ACREI, 中國稀土行業協會, ASSOCIATION OF CHINA RARE EARTH INDUSTRY
eit RawMaterials	Natural Resources Canada / Ressources naturelles Canada, Canada	JOGMEC, Japan Oil, Gas and Metals National Corporation
EUROPEAN RAW MATERIALS ALLIANCE ERMA		

TECHNICAL COMMITTEES
ISO/TC 298
Rare earth

REIA

Our Mission

Build and promote a more Sustainable, Responsible, Collaborative and Transparent Rare Earth Supply Chain from Mining to Recycling

- Gather and represent the global Rare Earth Industry stakeholders throughout the whole value chain
- Develop intelligent strategic partnerships with global influencers and experts
- Bridge the gap between our members and policy/decision makers
- Popularize Rare Earths to a larger audience: concentrate on the benefits of RE and best practices in terms of ESG – share success stories
- Become a well-regarded think tank in the sector

REIA

Sustainability as Focus!!

REIA, its members and global sponsors have acknowledged **sustainability** as the key priority for a healthy REE industry

Why REIA ?

Take part in shaping the Future of RE

Network and benchmark with key RE stakeholders

Make your voice heard/Influence policy makers

Commit to a more sustainable supply chain/
Showcase your engagement to sustainability

Access and share information, expertise and best practices and gain visibility via REIA events, online directory, weekly newsletter, social networks

Find partners (suppliers, clients, service providers)

REIA

We Give the Industry a Voice

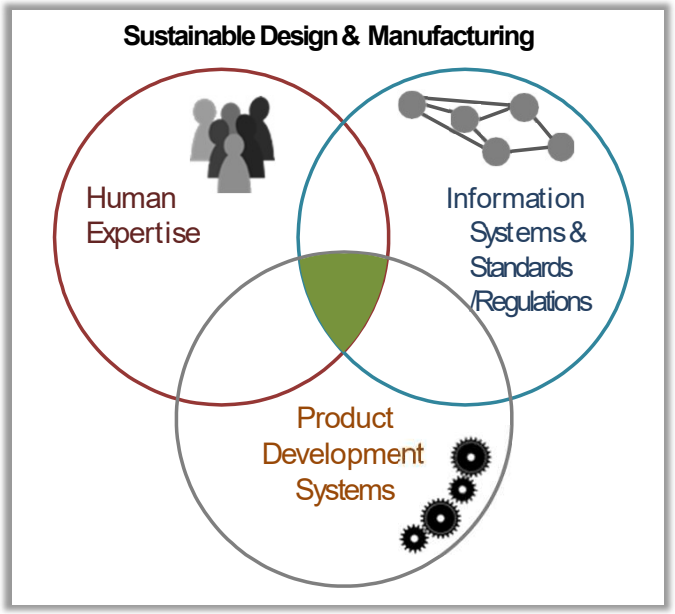
We polled our members on challenges to develop RE mines, separation and purification plants (REIA survey, 2021)

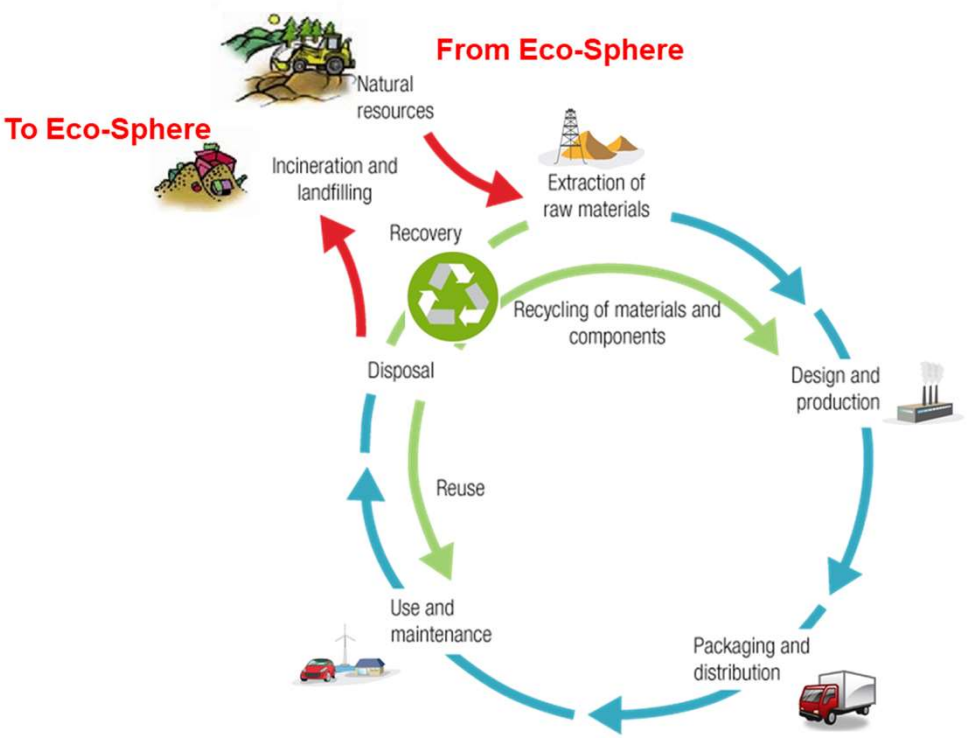
Areas of concern in order of importance:

- High Capital costs/Need for more support from investors/governments
- Uncertainty due to price volatility
- Complexity to establish separation and purification plants
- Need for a good technical mastery of REE processes
- Waste management Recycling
- Need for R&D on new processes

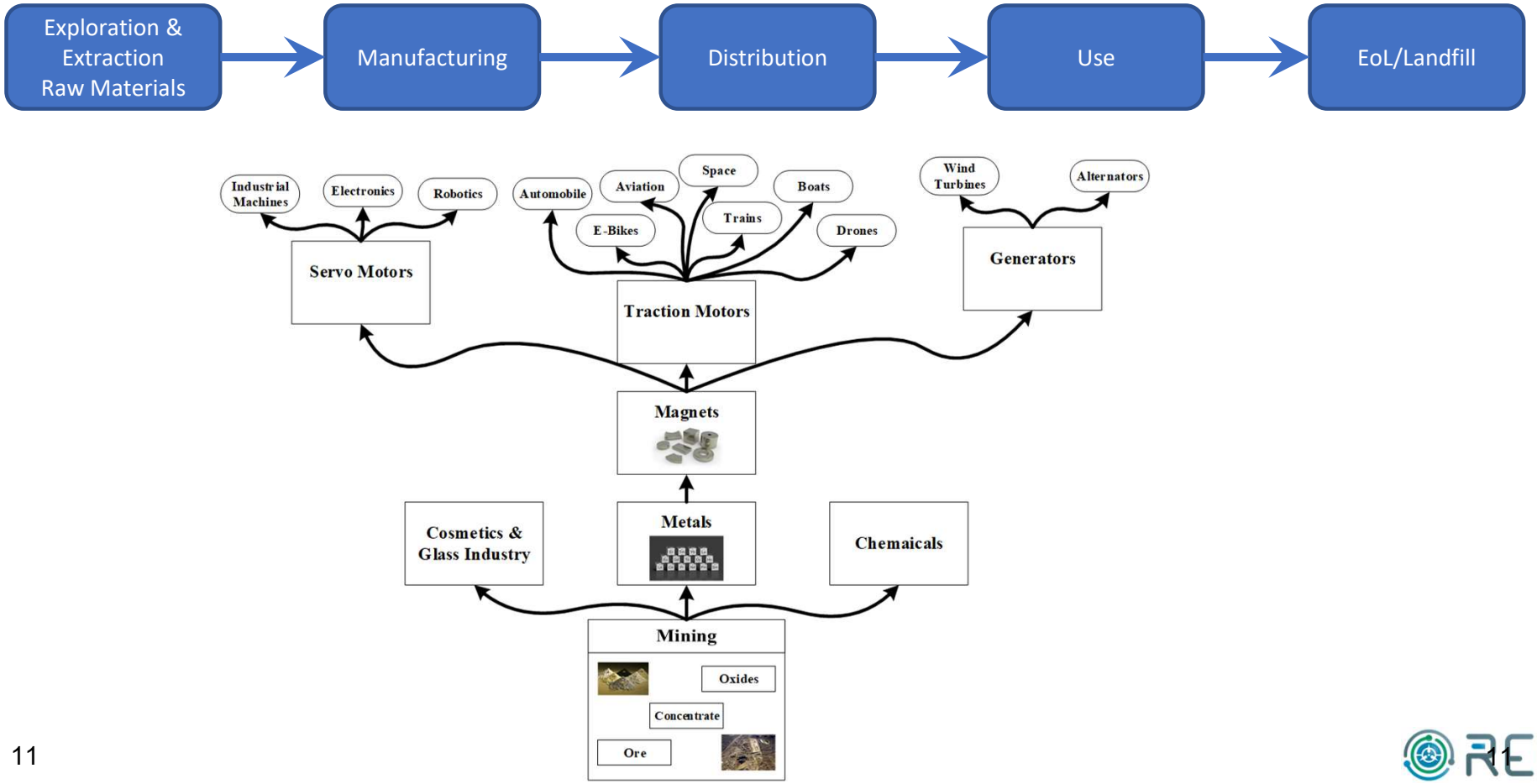
Why Quantification?

Sustainability Building Blocks





Linear Value Chain (Cradle to Grave)



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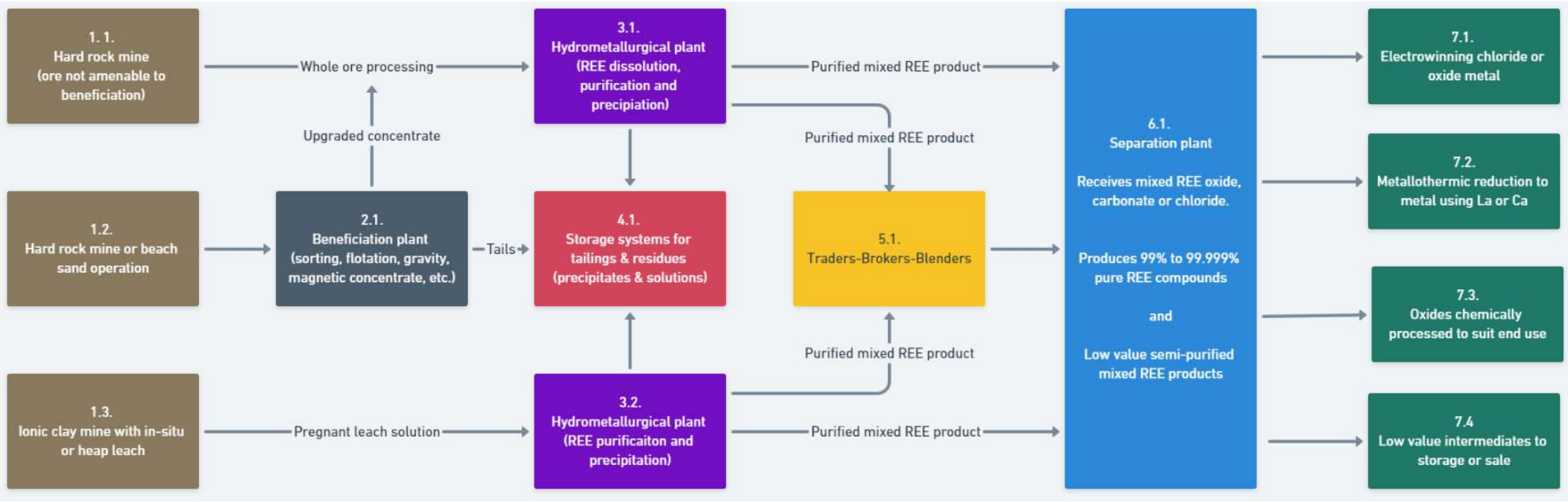
Mine to Separated Products/Compounds & Metals

- REE Value Chain (Mine → Oxides→ Metals)



Source: ISO TC298

REIA

Rare Earths' Value Chain Challenges

Lack of Transparency

Volatility

-ISO-TC 298 ☺

REIA

Where is the REE Industry today?

- Unclear/ambiguous **definitions & quantification methodologies** throughout the value chain
- No framework and no system definition for the **collection of data and modeling.**
- No **factual data**
- Risk of **data tampering/manipulation**
- Insufficient **collaboration and consensus** within the industry (esp. between up- and downstream)

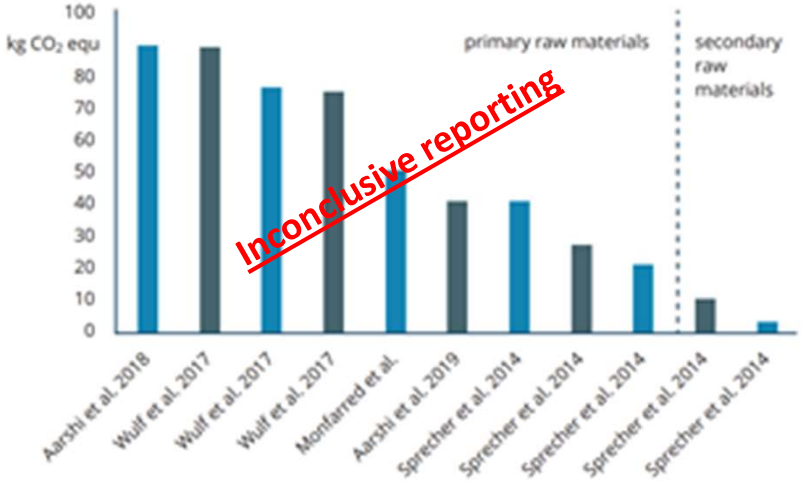
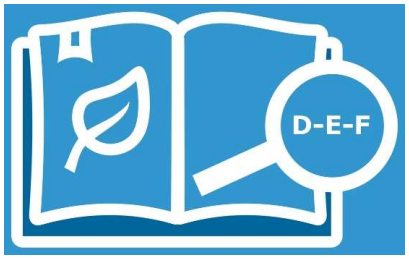


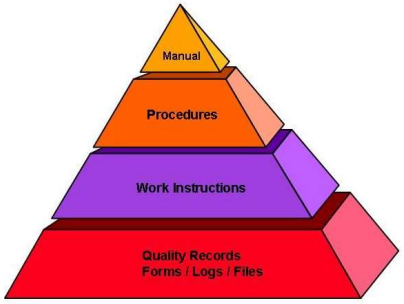
Figure 2: Global warming impacts of 1 kg of a REE-containing magnet according to various LCA reports.
Source: Roland Gauss presentation from Euromat, Stockholm, 2019

REIA

Building Sustainable & Transparent REE Value Chains..



Glossary



Standards and Guidelines

Data Security & Protocol

Transparency

Sustainability Quantification

Traceability

Thank You for Your Attention!

Questions?

QUANTIFYING ENVIRONMENTAL IMPACT IN RARE EARTH VALUE CHAINS

Pauline Chrobot / Quantis

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for healthier people and planet

SecREEts
Secure European Critical Rare Earth Elements

SUSMAGPRO

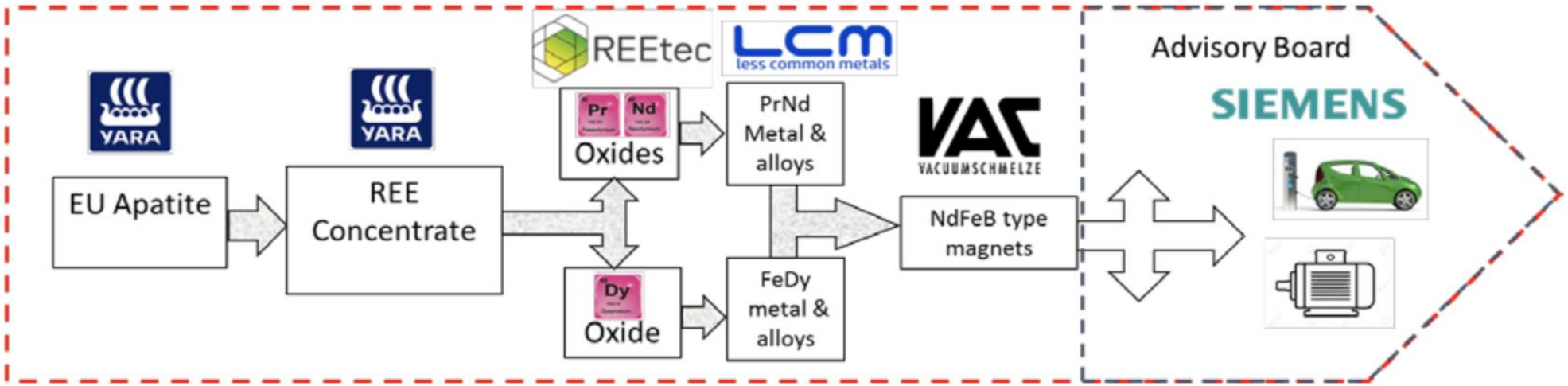
Quantis

The organisers SecREEts and SUSMAGPRO have received funding from the European Union's Horizon 2020 research and innovation programme under Grant agreement No 776559 and No 821114.

About SecREETs

Secure European Critical Rare Earth Elements

Objective > Produce european permanent magnets, from REEs sourced as co-products of an existing fertiliser production process and based on innovative production processes.



How does the environmental impact of SecREEts compare with the conventional production processes?

LCA Approach & Activities

Quantis is performing the life cycle assessment for:

1. SecREETs' production processes
2. Conventional production processes (China)

Data is the fundation of any life cycle assessment:

1. Primary data through contact with SecREETs partners
2. Secondary data from literature and expert assumptions for the assessment of the baseline

Key Conclusions

>> At this stage of the project, SecREEts LCA results show lower environmental impact than the baseline.

Challenges

- No standardized datasets (REIA)
- Data available from literature:
  - Limited availability of primary data from production plants in China
  - A lot of variability in data and results
  - Lack of transparency
  - Missing flows and data (wastewater treatment, radioactivity, losses through different steps)

Solutions

Short-term

- Exchange of best practices among practitioners
- Involve experts from industry for review

Long-term

- Building consistent datasets
- Harmonization in data used / common data fundation

QUANTIFYING ENVIRONMENTAL IMPACT IN RARE EARTH VALUE CHAINS

Spomenka Kobe/Jožef Stefan Institute

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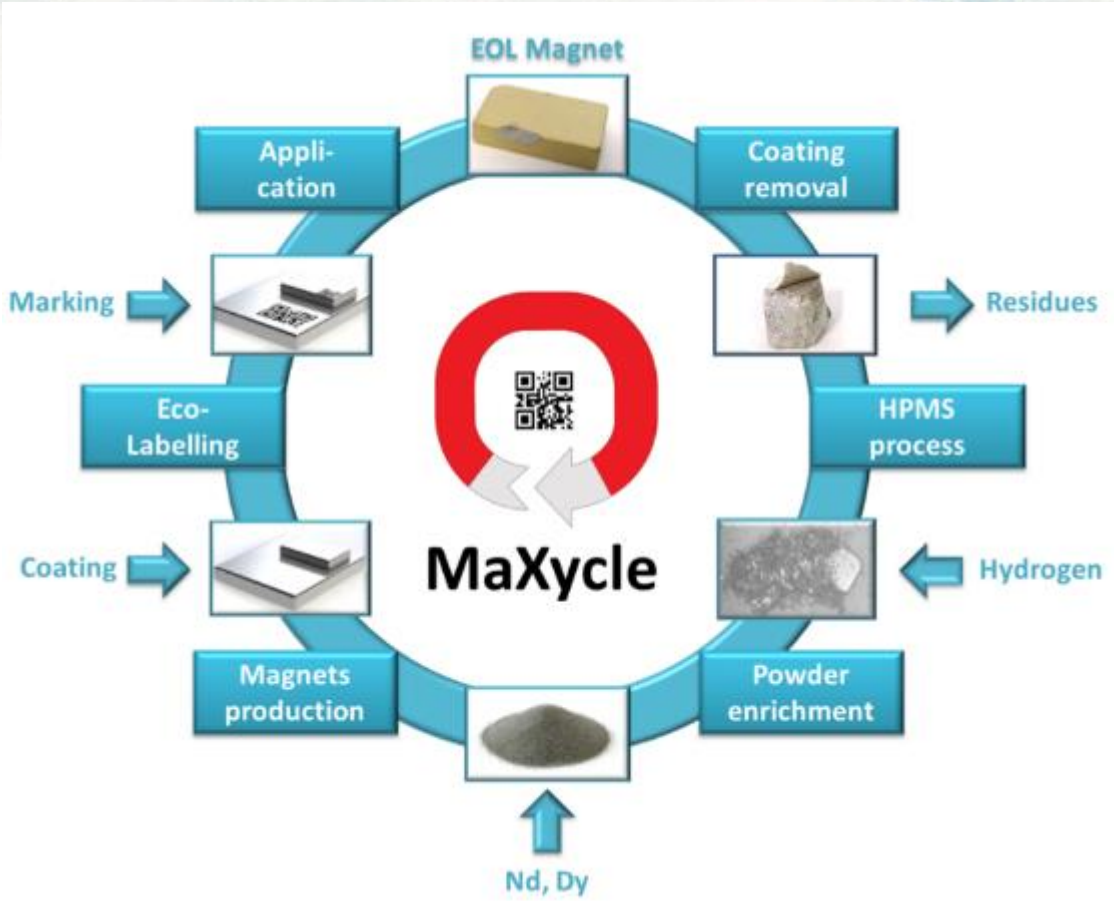
MaXycle

The organisers SecREEts and SUSMAGPRO have received funding from the European Union's Horizon 2020 research and innovation programme under Grant agreement No 776559 and No 821114.

MaXycle - A novel circular economy for sustainable RE-based magnets/Jožef Stefan Institute

IJS Ljubljana Slovenia
HS PF
ivl
mimplus
MAGNETI LJUBLJANA d.d.
UNIVERSITY OF BIRMINGHAM
RockLink Rare Metals Recycling



Goals

- **Definition of standardised quality criteria** for EOLM and a classification system for contamination levels to categorise products by pre-processing requirements.
- Development of a **labelling system** for newly produced RE magnets to identify different magnet types and qualities, including provision of reliable and durable marking methods.

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MaXycle

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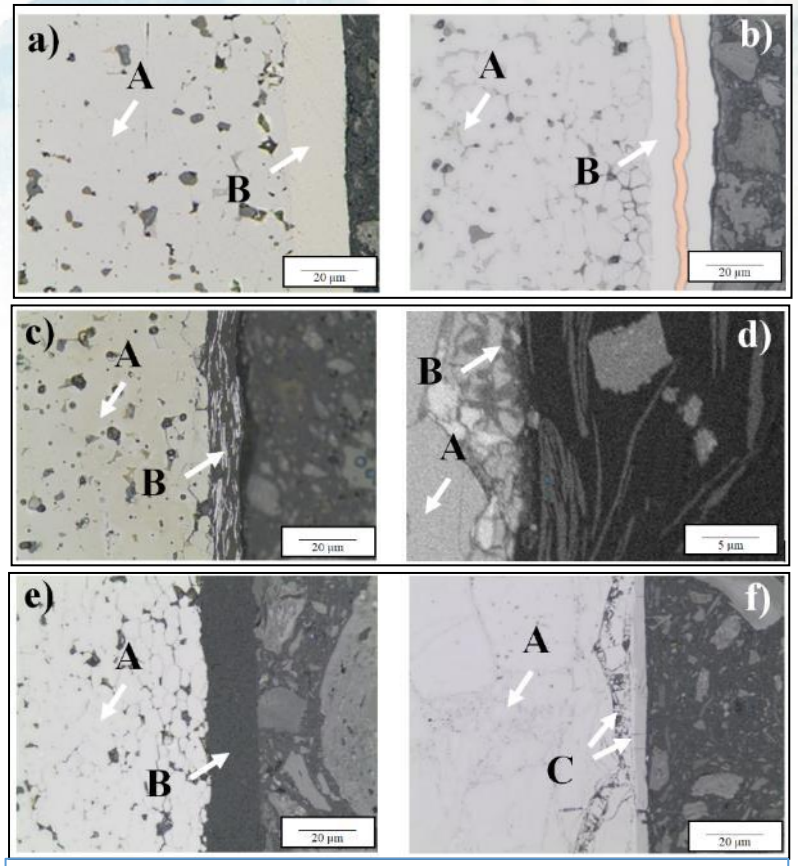
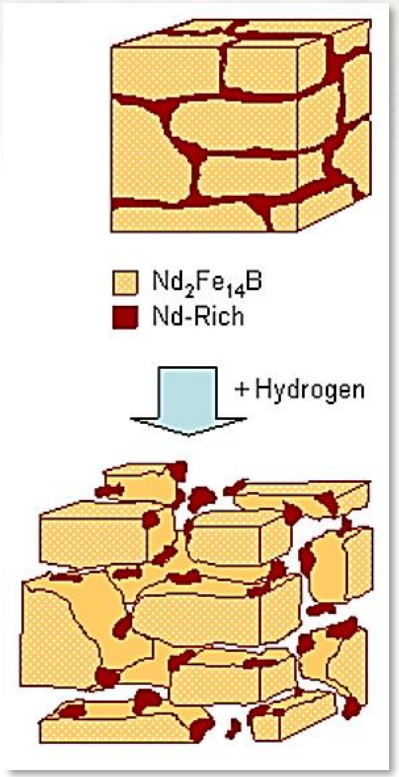
Approach: Not based on conventional recycling by chemical or pyrometallurgical processes



a): Ni (electroplated)
b): multilayer Ni-Cu-Ni (electroplated)
c) and d): polymer with fibers (different magnifications)
e): single layer polymer,
f): uncoated



Recycling of EOL Nd-Fe-B magnets is based on the **highly effective HPMS process** (Hydrogen Processing of Magnetic Scrap)

Using hydrogen for recycling of EOL magnets enables **88% energy efficiency** and is **98% less toxic** as the standard hydrometallurgical process

- C. Burkhardt, A. Lehmann, B. Podmiljšak, S. Kobe, A systematic classification and labelling approach to support a circular economy ecosystem for NdFeB-type magnet. *Journal of materials science and engineering. B.*, ISSN 2161-6221, **2020**, vol. 10, no. 7/8, str. 125-133

SecREEts
SUSMAGPRO
MaXycle

Key conclusions: HPS processing followed by sieving

S1: Passivated "Normal"	**S5: Electroplated Ni+Ni**	**S9: Electroplating blue Zn**
Magnet: Large chunks	Magnet: Small chunks	Magnet: small chunks
Coating: Small flakes	Coating: Nt disintegrated	Coating: Mixed size
Sieving likely not helpful	Sieving likely helpful	Sieving possibly helpful
S2: Passivated Phosphate	**S6 Electroplated Ni+Cu+Ni**	**S10: Electroplating color Zn**
Magnet: Large chunks	Magnet: Small chunks	Magnet: Medium chunks
Coating: Small flakes	Coating: Not disintegrated	Coating: Medium flakes
Sieving likely not helpful	Sieving likely helpful	Sieving possibly helpful
S3: Passivated NT1	**S7: Electroplated Ni+Cu+Sn**	**S11: Ni+Cu+Epoxy**
Magnet: Large chunks	Magnet: Medium chunks	Magnet: Small chunks
Coating: Small flakes	Coating: Oblong flakes	Coating: Not disintegrated
Sieving likely not helpful	Sieving possibly helpful	Sieving likely helpful
S4: Passivated M-coating	**S8: Chemical Ni**	**S12: Single Epoxy**
Magnet: Mixed size	Magnet: Medium chunks	Magnet: Small chunks
Coating: Mixed size	Coating: Not disintegrated	Coating: Not disintegrated
Unclear	Sieving likely helpful	Sieving likely helpful

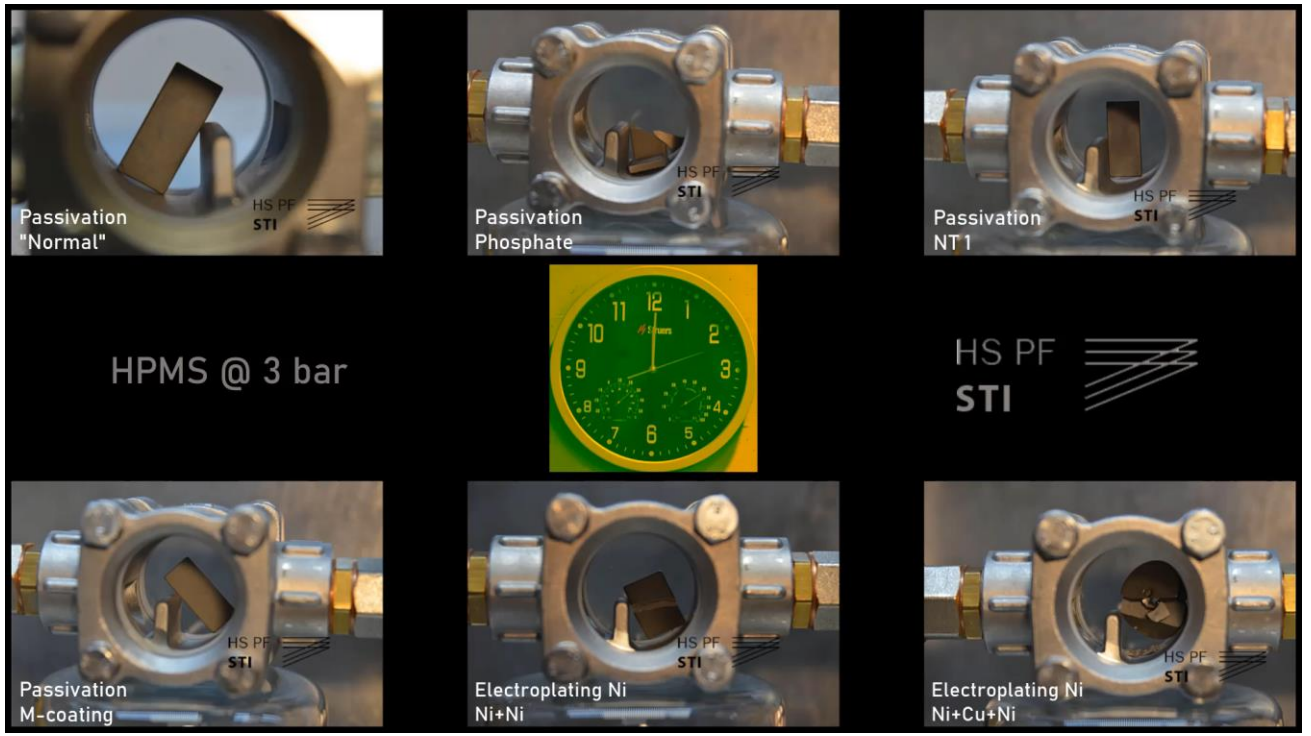
H2-permeable

Assumption, if sieving may separate magnetic and coating materials.
Colours indicate if the observed properties are recycling friendly or not.

Labelling of Nd-Fe-B magnets

Type of Magnet (select from drop down list)	Type of Coating (select from drop down list)	Heavy RE-Content [%] (enter value in mass%)	Magnet Grade (select from drop down list)	Certified Producer Code (select from drop down list)
NdFeB_sintered	Zn	0,30	N27 EH	Magneti

MAXYCLE MAGNET CODE: A 2 003 N27 EH P123M



SecREEts SUSMAGPRO MaXycle

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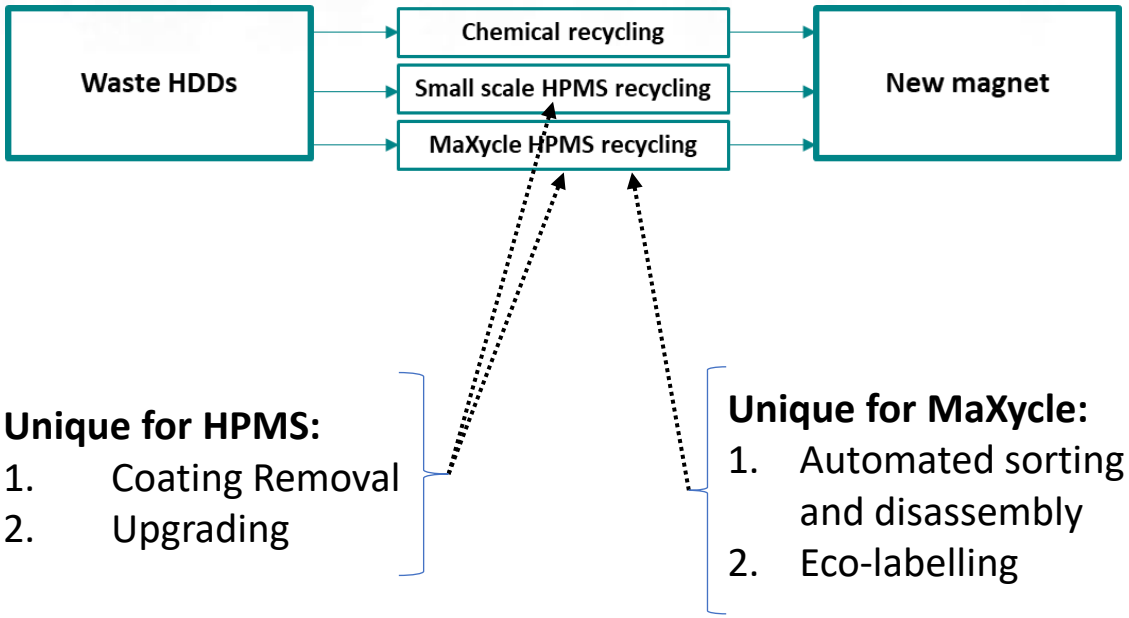
LCA System Overview:



Unique for HPMS:

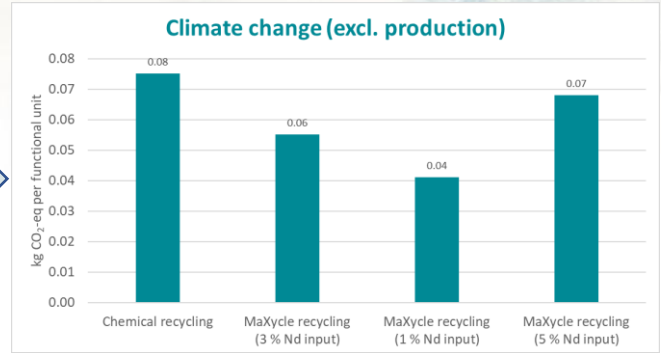
1. Coating Removal
2. Upgrading

Unique for MaXycle:

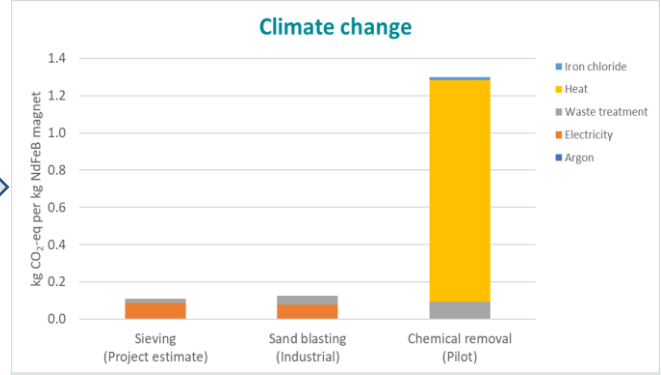
1. Automated sorting and disassembly
2. Eco-labelling

Climate Change Impact Conclusions:

1. Varying upgrading with Nd has some effect



2. Varying coating removal technology has a large effect



3. Varying electricity mix has a large effect

50% less kg-CO_2-eq switching between German national electricity mix and hydropower.

QUANTIFYING ENVIRONMENTAL IMPACT IN RARE EARTH VALUE CHAINS

René Kleijn / Leiden University

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SUSMAGPRO

Universiteit Leiden
The Netherlands

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SUSMAGPRO: A Circular Economy for RE Magnets

Develop and demonstrate innovative pilot plants the sustainable recovery, reprocessing and reuse of rare earth magnets

- produce every fourth RE magnet in Europe from recycled material by 2027
- Integrate recycled magnets in new products

Leiden University (CML) (one of 18 partners):

- Environmental LCA
- Social Impact
- Techno-Economic impact
- Multi-criteria analysis

SecREEts
SUSMAGPRO
Universiteit Leiden
The Netherlands

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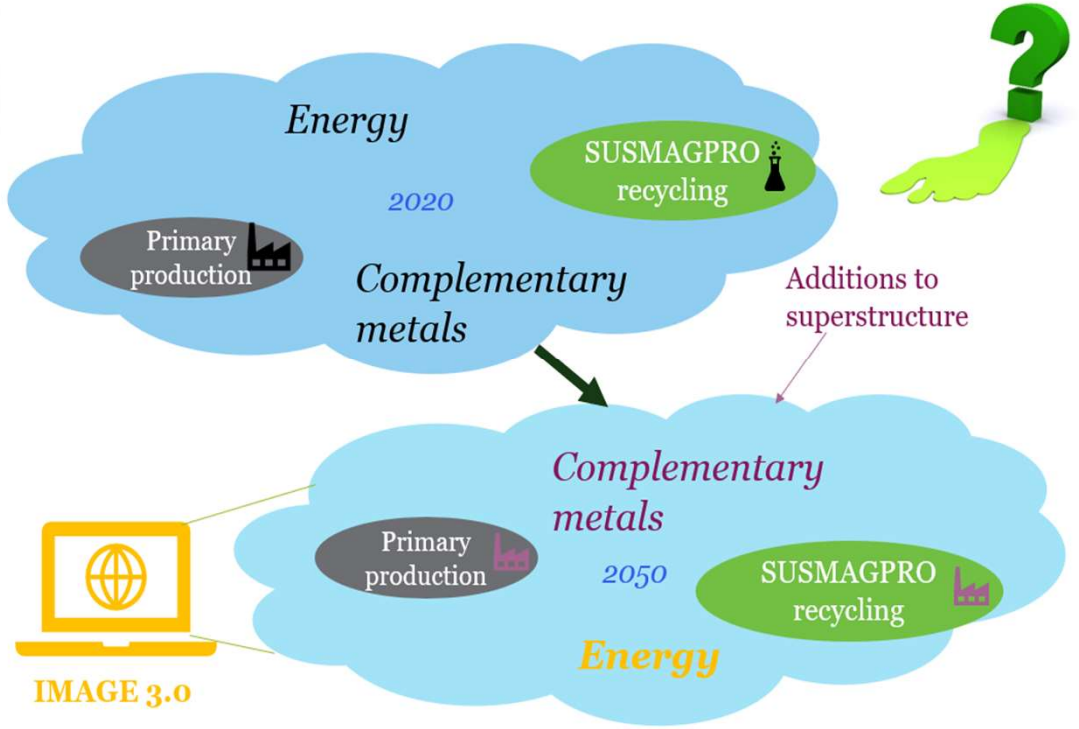
LCA Approach & Activities

- Baseline LCA for primary production
- Ex-ante LCA : future technologies in a future world
  - Learning curves new technologies
  - The world changes as well: scenarios
- Range of model choices: multiple scenarios simultaneously : Brightway /AB
- Additional characterisation factors
- Database on magnets and coatings



Key Conclusions (early stage)

- Flexible software crucial for ex-ante LCA
- Data issues
  - primary production (e.g. World Steel)
    - huge variety in impacts based on deposit/mine
  - data on magnets (material passports ?)
  - Characterisation: Radiation impacts
- Impact of take-back and dismantling: EVs motors, wind turbines : design for disassembly / recycling !

SUSMAGPRO Consortium

Coordinator: HS PF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QUANTIFYING ENVIRONMENTAL IMPACT IN RARE EARTH VALUE CHAINS

Robert Pell PhD / Minviro

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MINVIRO

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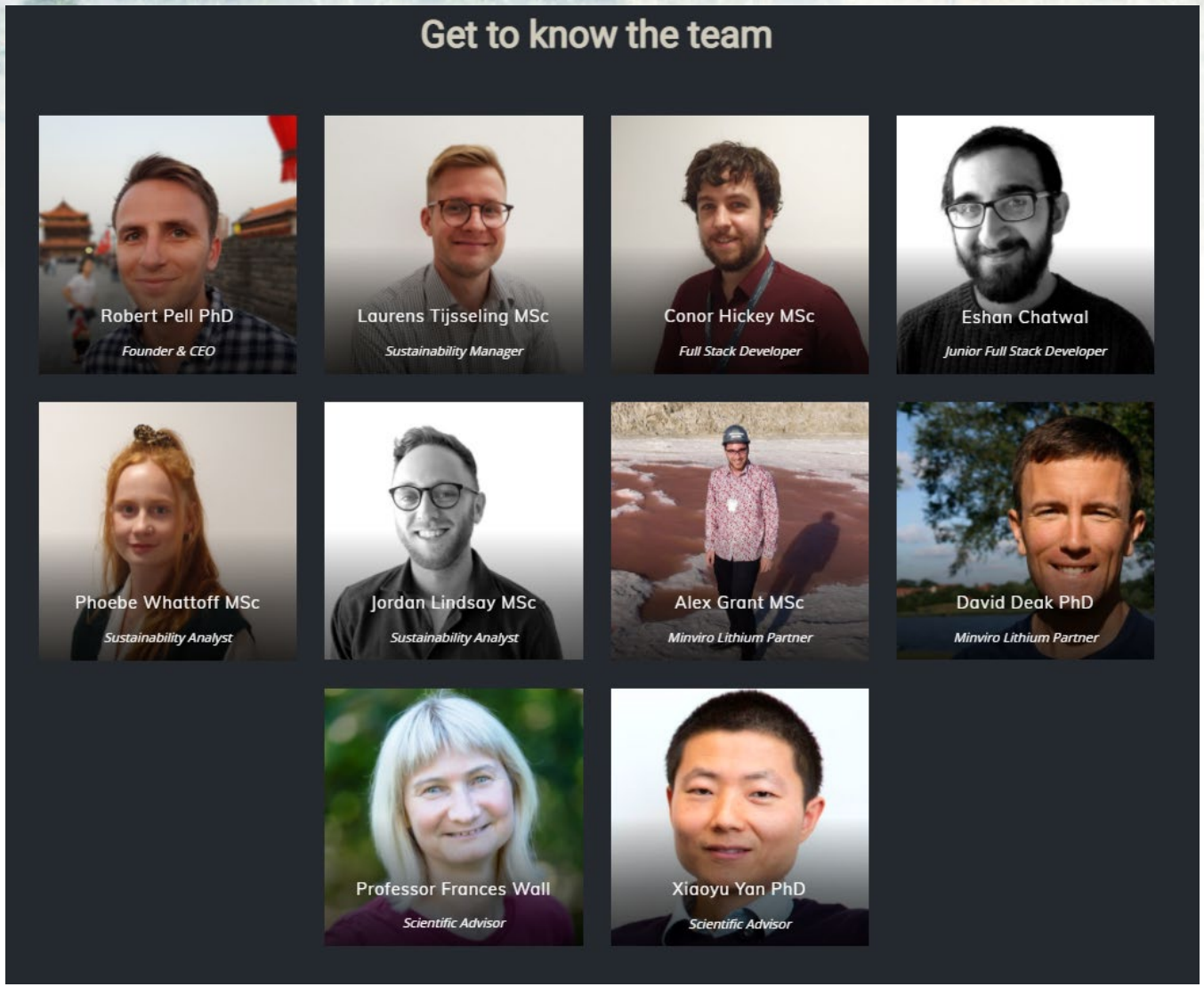
About Minviro

- Spin-out from University of Exeter (Camborne School of Mines)
- Formed following PhD on LCA for REEs
- Focused on integrating LCA into project development
- Team of 8 mining, mineral processing, chemical engineers with expertise in life cycle assessment
- Completed 25 commercial life cycle assessments on technology metal production including many REE LCAs
- Have developed MineLCA tool to support mining and metal projects quickly and effectively calculate the environmental impact of their projects



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MINVIRO

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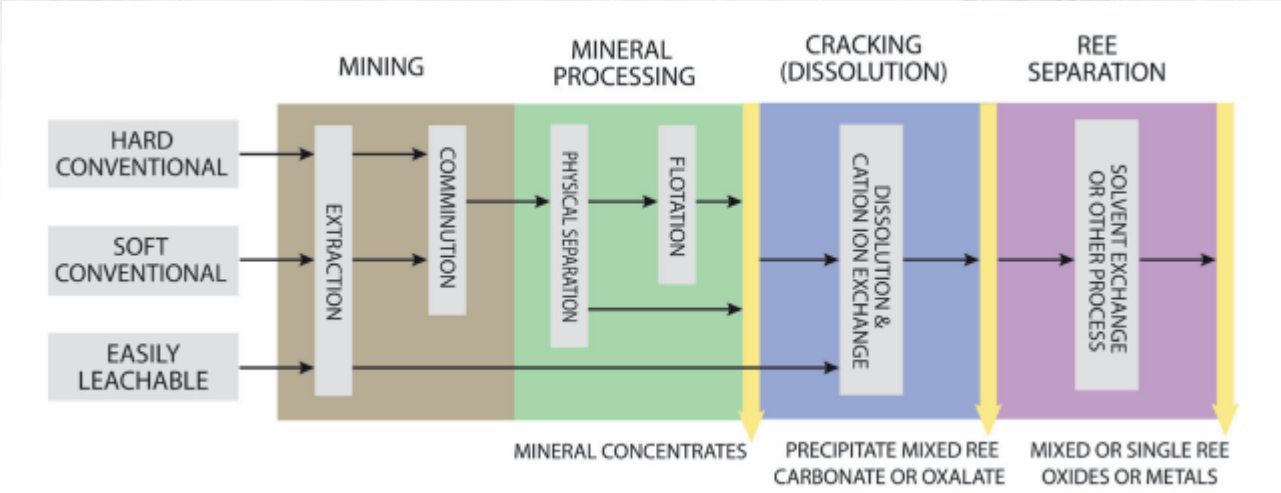
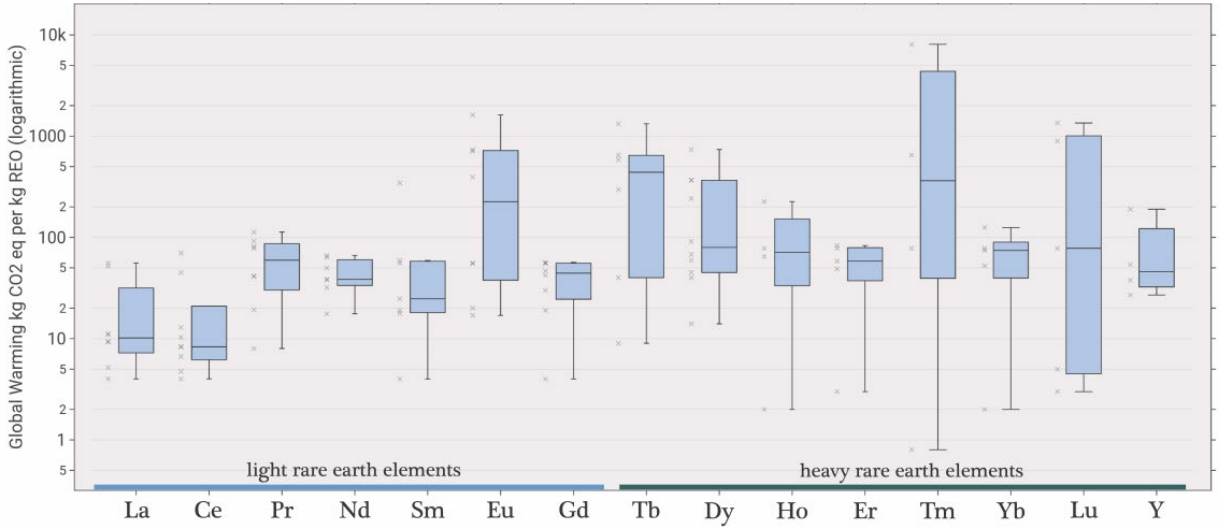
LCA Approach & Activities

Minviro conducts commercial LCAs for REE projects.

- Different geology requires different production routes which can have significantly different impacts
- Several methodological challenges with REE production
- Alignment of LCA methodologies through PCR development - REIA
- Integrating LCA in the development phase of project development ensures the environmental criteria is part of the decision-making process.





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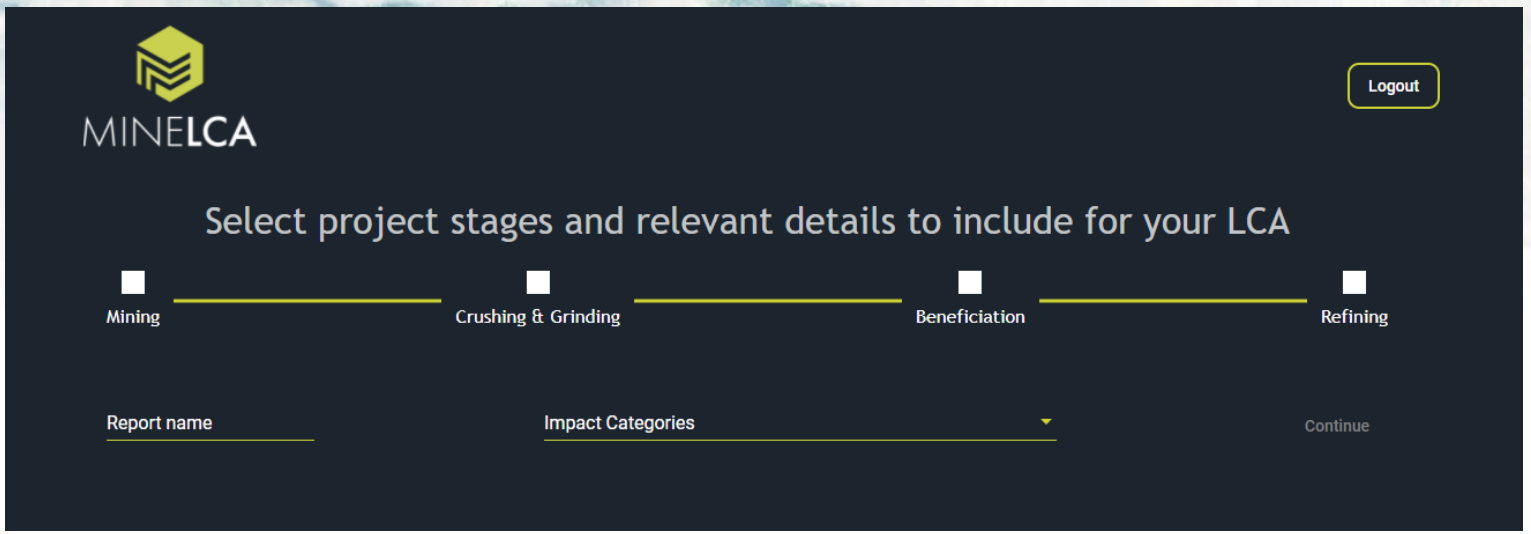
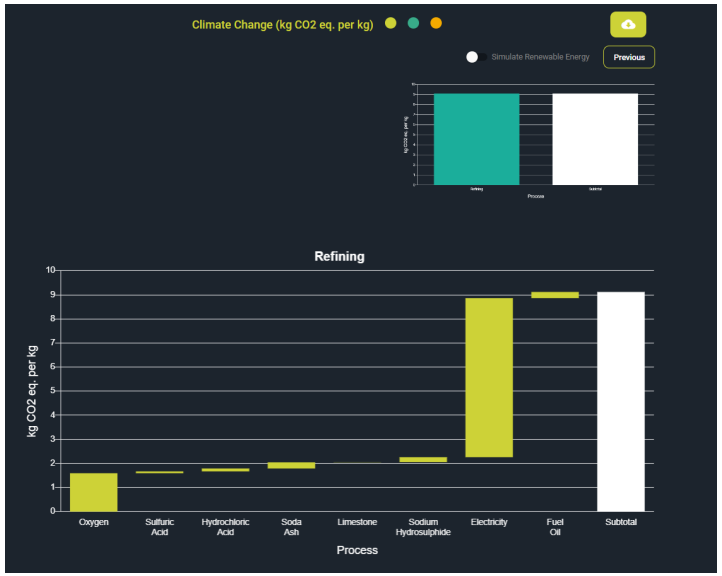
MineLCA

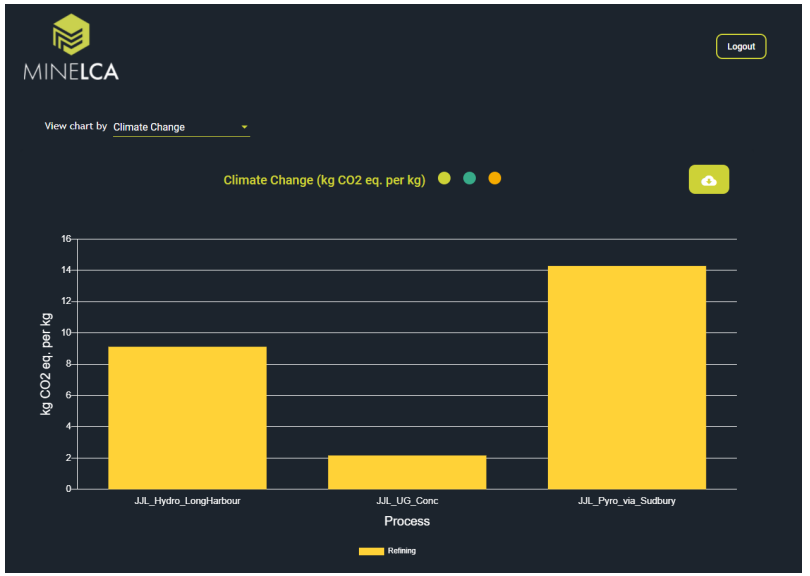
MineLCA has been developed to quickly and efficiently conduct high quality LCA for the mining and metal sector.

- Can benchmark and compare against other REE production routes
- Can simulate different project scenarios
- Can link to mine scheduling or mineral processing simulation through an API

Thanks for support from EIT Raw Materials Booster







Key Conclusions

- The impact of REE production can vary significantly depending on source, infrastructure and production route.
- LCA is a method to quantify the environmental impacts of a product or process and can be applied to the raw materials production sector.
- MineLCA makes LCA accessible for the non LCA expert in the mining and metals sector
- LCA should be used in a proactive manner and incorporating it into the planning stages of REE projects to encourage responsible production

TABLE 2 Examples of REE deposits and qualitative analysis of their mining and processing characteristics.

Ore type	Amount of rock to be moved[a]	Energy for crushing and grinding	Grain size/ difficulty of upgrade of ore minerals	Chemicals (acid, flotation reagent)	Radioactivity: ore mineral and host rock	By-products
Carbonatite	**Low**	Medium–High	Variable—10 µm	Flotation—medium	Medium	Not usually
Weathered carbonatite	**Low**	Medium	10 µm and finer	Flotation—medium	**Low-med**	Not usually
Alkaline rock (nepheline syenite)	High	High	Variable—1 µm and larger	Variable	Variable	Co-products common
Ion adsorption clay by in-situ leach	**Low**	**None**	**Beneficiation not needed**	Leaching, so can be high	**Low**	None
Mineral sand (placer)	High	**None-Low**	**10–100 µm**	**Low**	High	**From TiO_2, zircon, etc. production**
By-product of igneous apatite	High	High	100 µm–mm	Medium	**Low**	**From fertilizer manufacture**
By-product Red mud	High	Bauxite processing	**n/a REE from red mud**	Medium?	**Low**	**From Al production**

Although individual deposits vary, characteristics shaded dark/green and in bold are generally advantageous to responsible sourcing, gray are less so and characteristics in unshaded cells are likely to be more problematic.
[a]*i.e., low grade = large amount of rock.*
Modified after F. Wall, A. Rollat, R.S. Pell, Responsible sourcing of critical metals, Elements 13 (5) (2017) 313–318.

QUANTIFYING ENVIRONMENTAL IMPACT IN RARE EARTH VALUE CHAINS

Mauro Cordella, Elisabet Amat / TECNALIA

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The **ORIENTING** project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958231

The organisers **SecREEts** and **SUSMAGPRO** have received funding from the European Union's Horizon 2020 research and innovation programme under Grant agreement No 776559 and No 821114.

About ORIENTING

Operational Life Cycle Sustainability Assessment Methodology Supporting Decisions Towards a Circular Economy

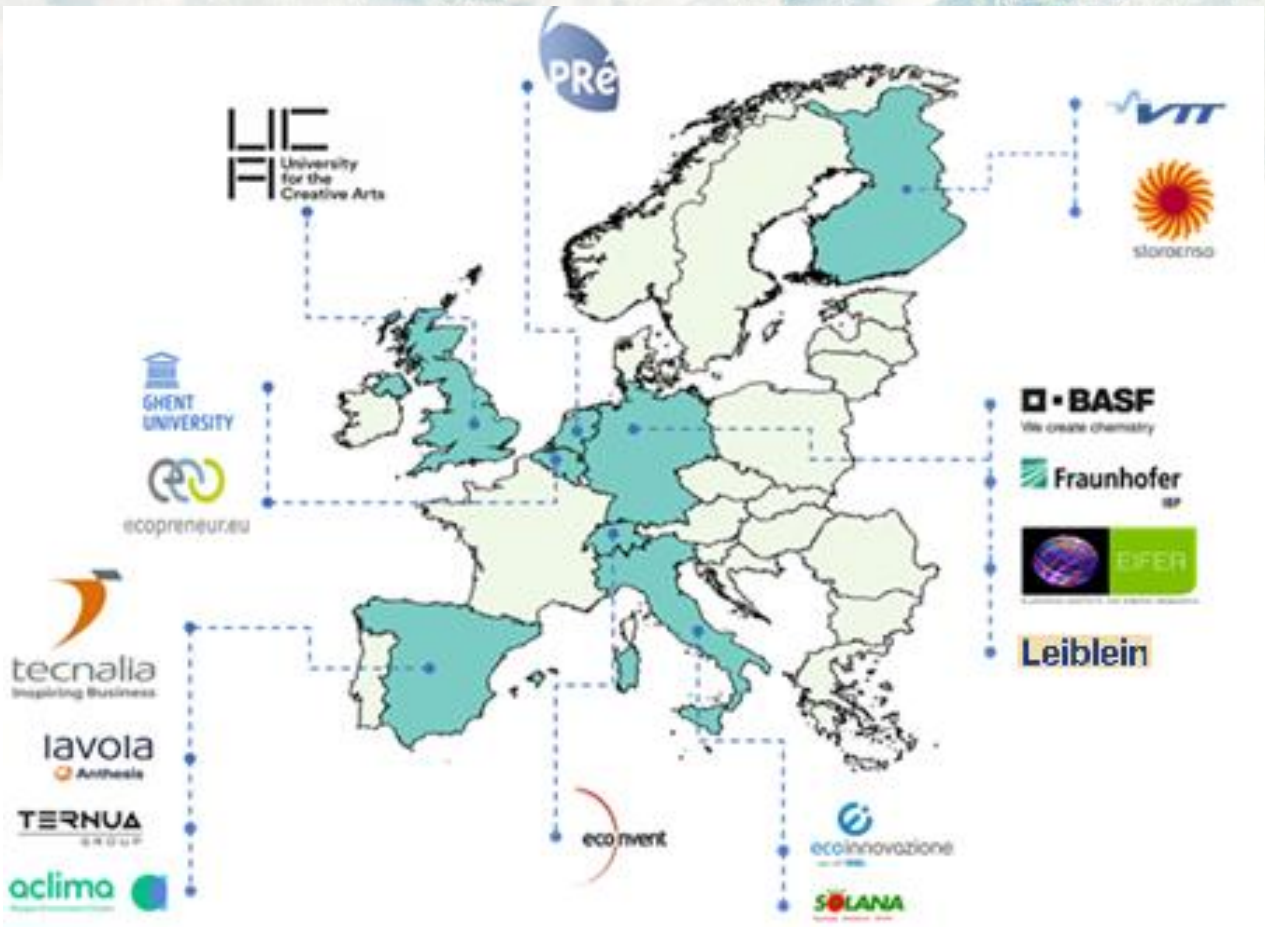
Call: H2020-LOW-CARBON-CIRCULAR-INDUSTRIES-2020

Topic: CE-NMBP-42-2020

Type of action: RIA

https://cordis.europa.eu/project/id/958231

https://orienting.eu/



The project started on the 1st November 2020 and will run for 36 months with an overall budget of **5,997,339€**.

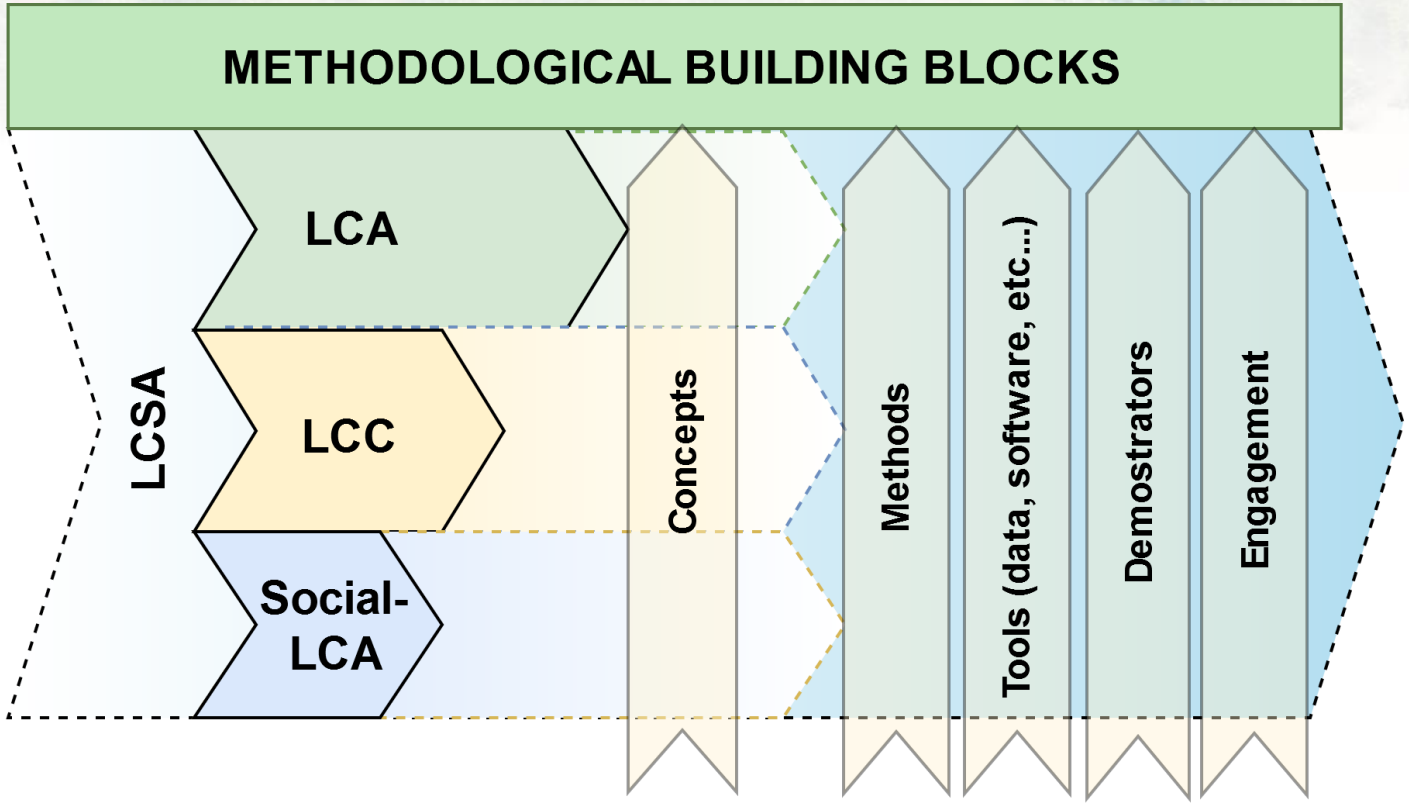
SecREEts

SUSMAGPRO

ORIENTING

LCA Approach & Activities

- Develop an operational methodology for **LCSA of products**
- **Integration of concepts**
- **Circular economy and material criticality**
- Build on **existing initiatives** (e.g., PEF, UNEP/SETAC LCSA, ISO/TC 323)
- Towards ***Product Sustainability Footprint***



- *A mountain coat with inner insulation made of wool*
- *Intermediate paper product (polymer coated, made of virgin fibres)*
- *Chemicals for paints and formulations used for coatings*
- *Stationary and mobile electrodynamic fragmentation of concrete and ceramics*
- *Diced and tomato pulp, in different packaging systems*

Key Conclusions

Methodological developments and "operationalization" to start in Summer 2021
→ **Methods, ontologies, tools and data** for quantitative sustainability assessment of products (incl. rare earths)

Analysis of approaches/methods and users' needs ongoing:
- CRM: supply risks and economic impact (as defined); CE as means to sustainability
- LCA: reduce negative impacts → PEF
- LCC, SLCA: stakeholders' perspective, burdens/benefits

Challenges:
- Range of applications and users → ease-of-use and transparency v. comprehensiveness and robustness
- Resources and training needed
- Interpretation and communication (integration and aggregation issues)

To **register** as stakeholder of the project: **https://orienting.eu/**