ReSToRE workshop, 5 July 2022

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A view from the front of the Circular Economy

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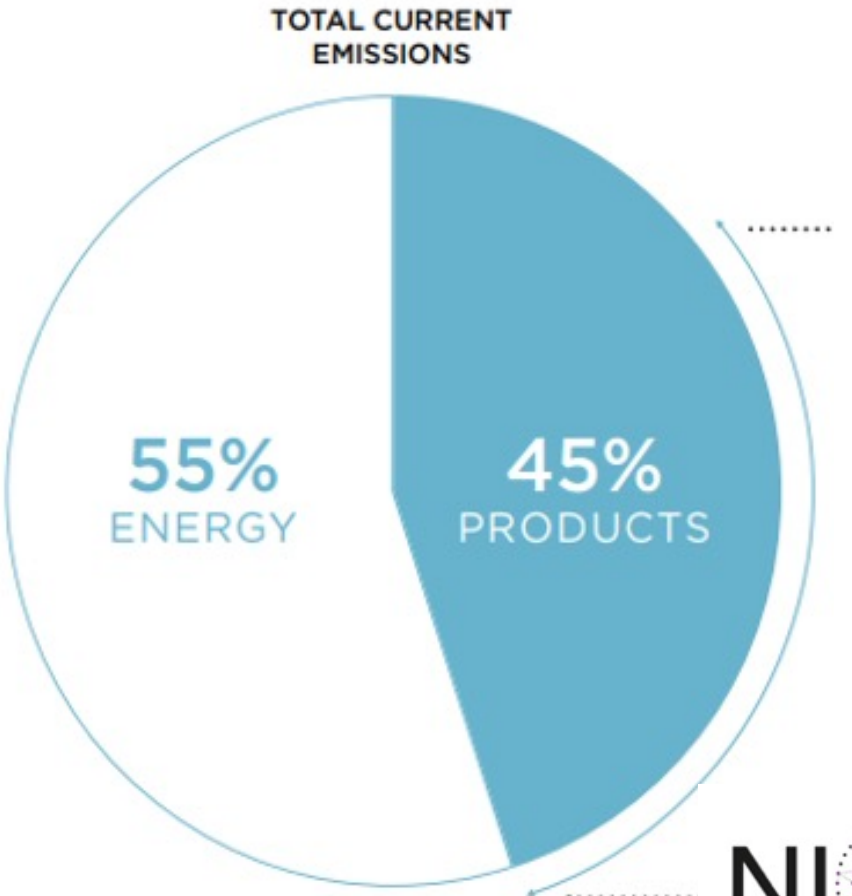
University of Exeter · Manchester 1824 The University of Manchester Sustainable Consumption Institute · University of Leicester · University of Exeter Business School · University of Birmingham · British Geological Survey · UK Research and Innovation

The Climate Challenge

Each year, the UK requires 1.2Bn tonnes of materials to sustain the current economy



Climate change is as much an economic and social crisis as it is an environmental crisis: the costs of climate change to the global economy are projected to amount to **$54 trillion** by the end of the century

NICER PROGRAMME

UK Research and Innovation

UKRI Interdisciplinary Centre for Technology Metals

(21 Co-Is, 9 PDRAs, 8 PhD Students,3 man./policy 38 partners (£1.6 million cash/in-kind)

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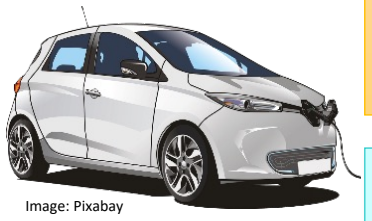

Image: Pixabay

Theme 1 – Virtual Data Observatory – Stocks / Flows & Practices

Li, Co, REE, Te, Se, PGM, In, W, Sn, Ta, Ga, Nb, Sb …

Theme 2 -
CE Principles for Raw materials
& new Geomodels

Theme 3 -
Design, Manufacturing,
& Recycling Technologies

Sara Kurless

APPA

Theme 4 - Roadmap for a new technology metals circular economy system

F. Wall

- POLICY & GOVERNANCE
- ENVIRONMENTAL & LCA
- SOCIAL SCIENCES & VALUE CHAINS
- RESPONSIBLE INNOVATION

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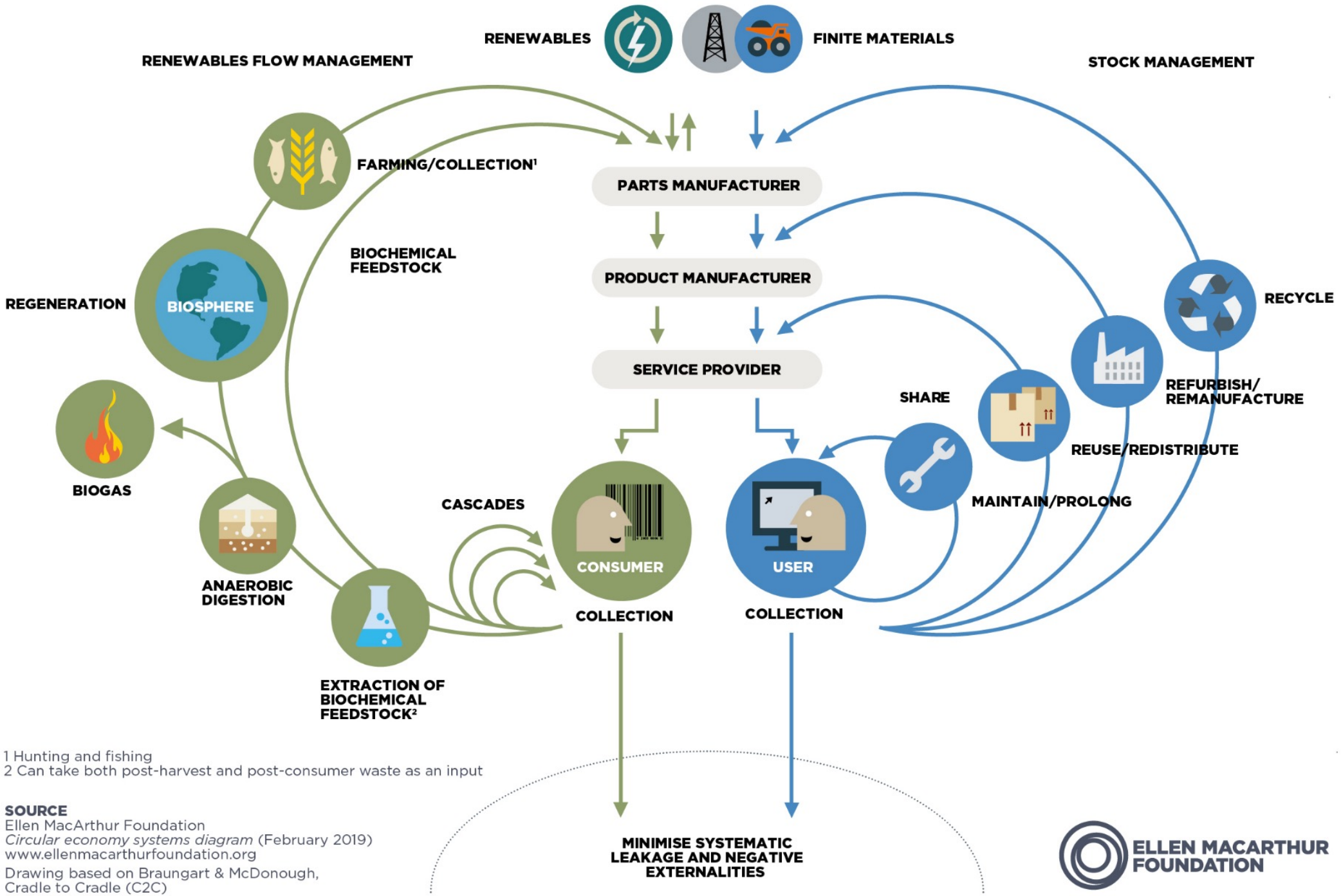


1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input

SOURCE
Ellen MacArthur Foundation
Circular economy systems diagram (February 2019)
www.ellenmacarthurfoundation.org
Drawing based on Braungart & McDonough, Cradle to Cradle (C2C)

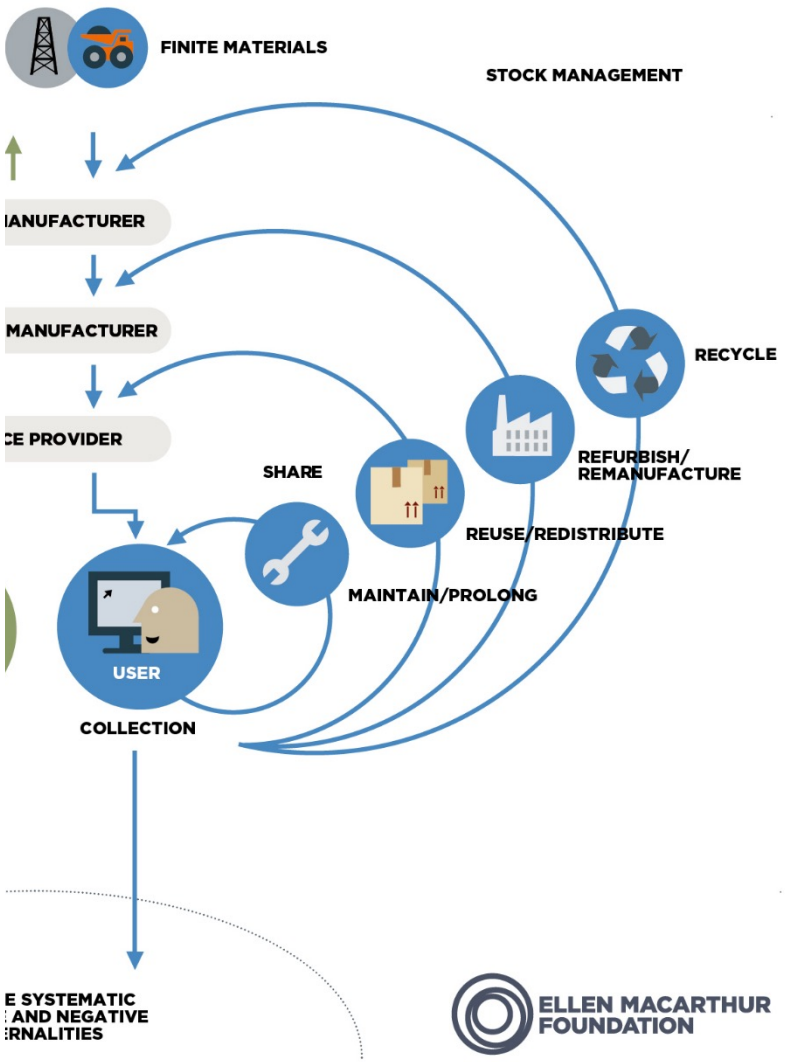
ELLEN MACARTHUR FOUNDATION

UK Rese
and Inn

Circular economy and primary raw materials - mining

Circular economy approach is based on:

1. Designing out waste and pollution,
2. Keeping products and materials in use
3. and regenerating natural systems



CE approaches - start at the beginning – with geology

‘Design out waste and pollution’

Geology

- Grade of ore
- Composition and mineralogy of the ore
- Size of ore deposit
- Depth of ore deposit
- Location of ore deposit

Geometallurgy

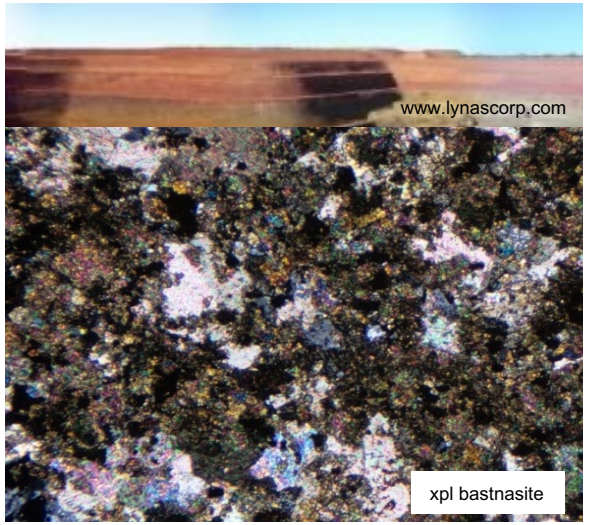
Mining and Processing

- Resource efficiency
- Energy use
- Carbon footprint
- Water use
- Environmental contamination
- Financial profitability
- Biodiversity and landscape degradation

Corporate Social Responsibility

- Health and safety and well-being of work force
- Community interaction and well-being
- Contribution to national economy
- Compliance with regulatory frameworks
- Land use during and after mining

Comparison of four main rare earth deposit types



MINERAL SANDS
Reasonably large
But low grade
REE minerals (monazite and xenotime) are by-products of Ti minerals
Radioactivity.

- CARBONATITES
- Reasonably large
- Higher grade
- Fresh /weathered can be put together in this comparison
- Usually light REE

- ALKALINE ROCKS
- Large
- Lower grade
- Hard rock
- Complex mineralogy
- Higher amounts HREE

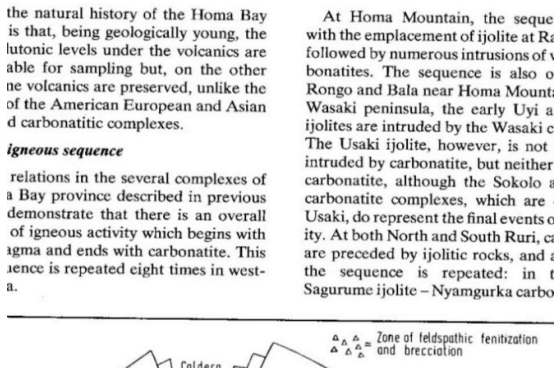
- ION ADSORPTION
- Small / shallow
- easy to mine, might be leached ‘in situ’
- Higher amounts HREE
- Low grade

See Wall et al (2017) Elements, 13, 313-318 for discussion of responsible sourcing of rare earths

Exploration - new geomodels for REE in alkaline rocks and carbonatites

This project has received funding from the European Union's Horizon 2020 research and innovation programme (grant agreement No 689909)

www.alkcarb.org


the natural history of the Homa Bay is that, being geologically young, the lutonic levels under the volcanics are able for sampling but, on the other ne volcanics are preserved, unlike the of the American European and Asian d carbonatitic complexes.

igneous sequence

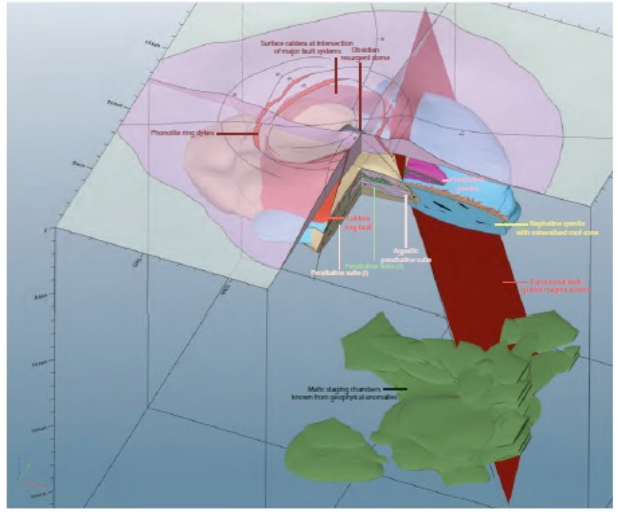
relations in the several complexes of a Bay province described in previous demonstrate that there is an overall of igneous activity which begins with agma and ends with carbonatite. This uence is repeated eight times in west-a.

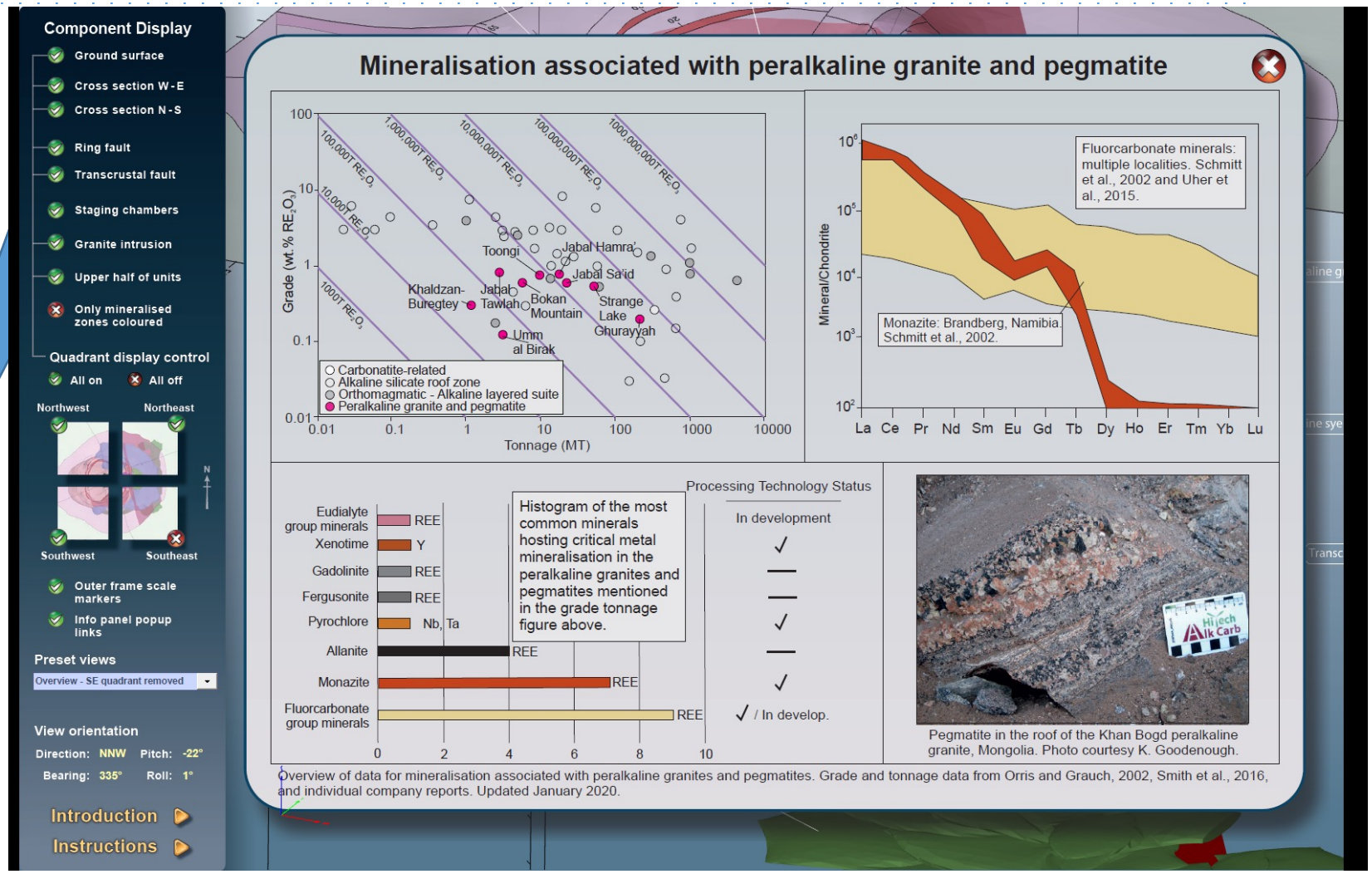
At Homa Mountain, the seque with the emplacement of ijolite at Ra followed by numerous intrusions of v bonatites. The sequence is also o Rongo and Bala near Homa Mount Wasaki peninsula, the early Uyi a ijolites are intruded by the Wasaki c The Usaki ijolite, however, is not intruded by carbonatite, but neither carbonatite, although the Sokolo a carbonatite complexes, which are Usaki, do represent the final events o ity. At both North and South Ruri, ca are preceded by ijolitic rocks, and a the sequence is repeated: in t Sagurume ijolite – Nyamgurka carbo

Zone of feldspathic fenitization and brecciation

Le Bas (1977)

3D pdfs

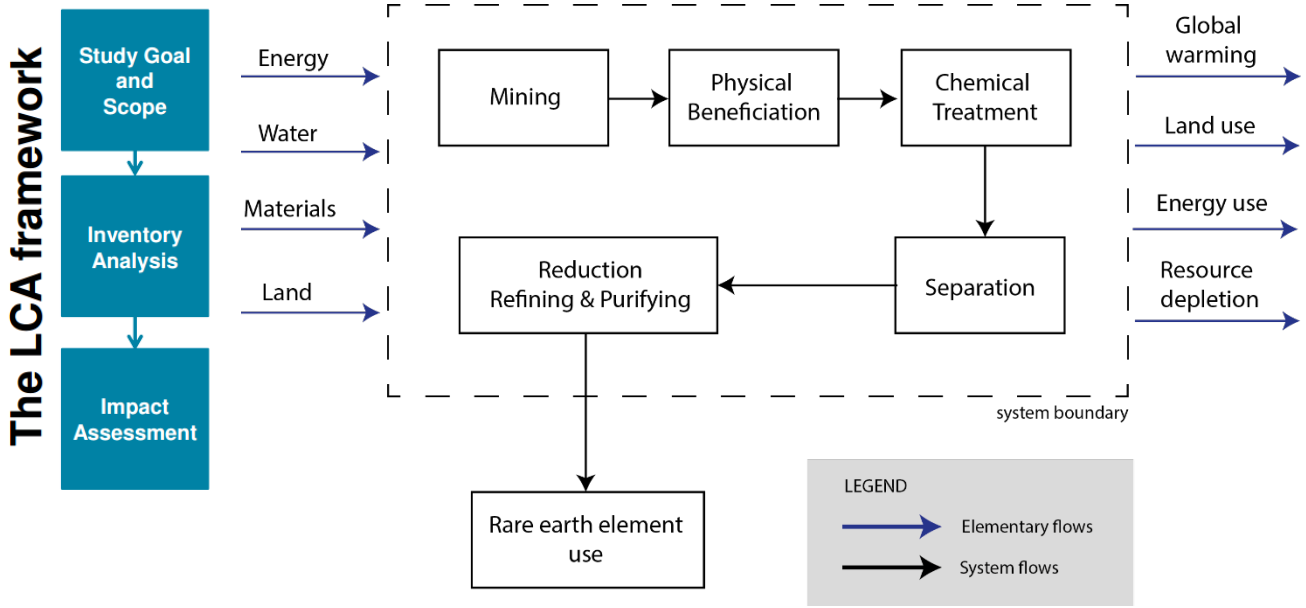




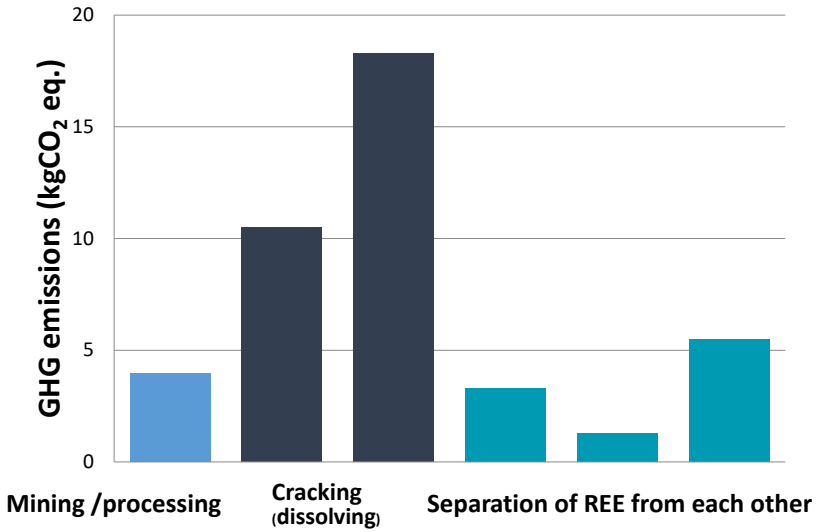
•Charlie Beard, Kathryn Goodenough, Anouk Borst, Frances Wall et al (Economic Geology, 2022, https://doi.org/10.5382/econgeo.4956)

Life cycle assessment

'quantitative assessment of the environmental performance of a product or process over its entire life cycle' (ISO 14044a)



Example of Rare Earths



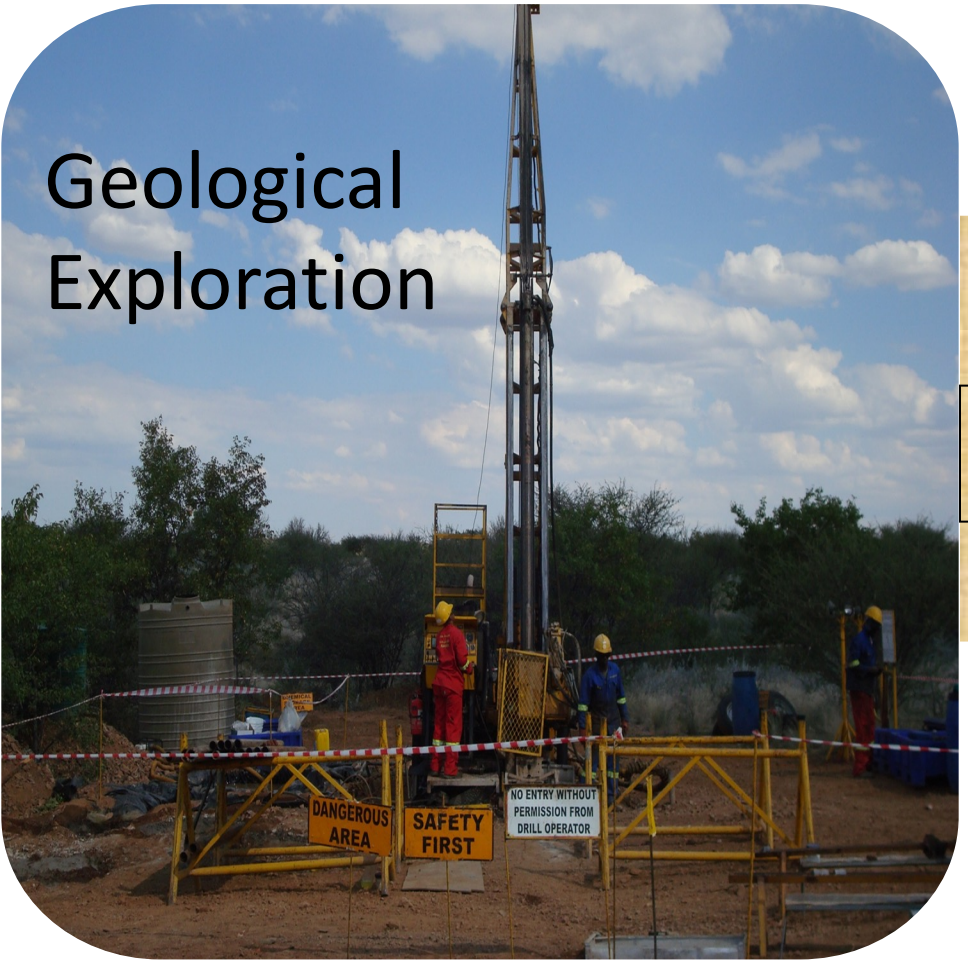
- **Koltun and Tharumarajah (2014) for 1kg RE oxide**

REIA- Life Cycle Inventory Database

1. Concept

- To create a **benchmark** for the industry and to measure and **communicate** the environmental impact of rare earth oxide-containing (REO) products
- To develop the most up-to-date LCI for rare earth production **by and for Rare Earth Industry Association** members

Life cycle assessment is not just for mining



Environment and Social responsibility

Desk study

First results, e.g. preliminary economic assessment

Prefeasibility study

Feasibilty study

Mine

Life Cycle Assessment

Wall et al (2017) Elements, 13, 313-318 for discussion of use of LCA in responsible sourcing of rare earths

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Start early with LCA to design out pollution and waste

Environment and Social responsibility

Desk study

First results, e.g. preliminary economic assessment

Prefeasibility study

Feasibilty study

Mine

Life Cycle Assessment

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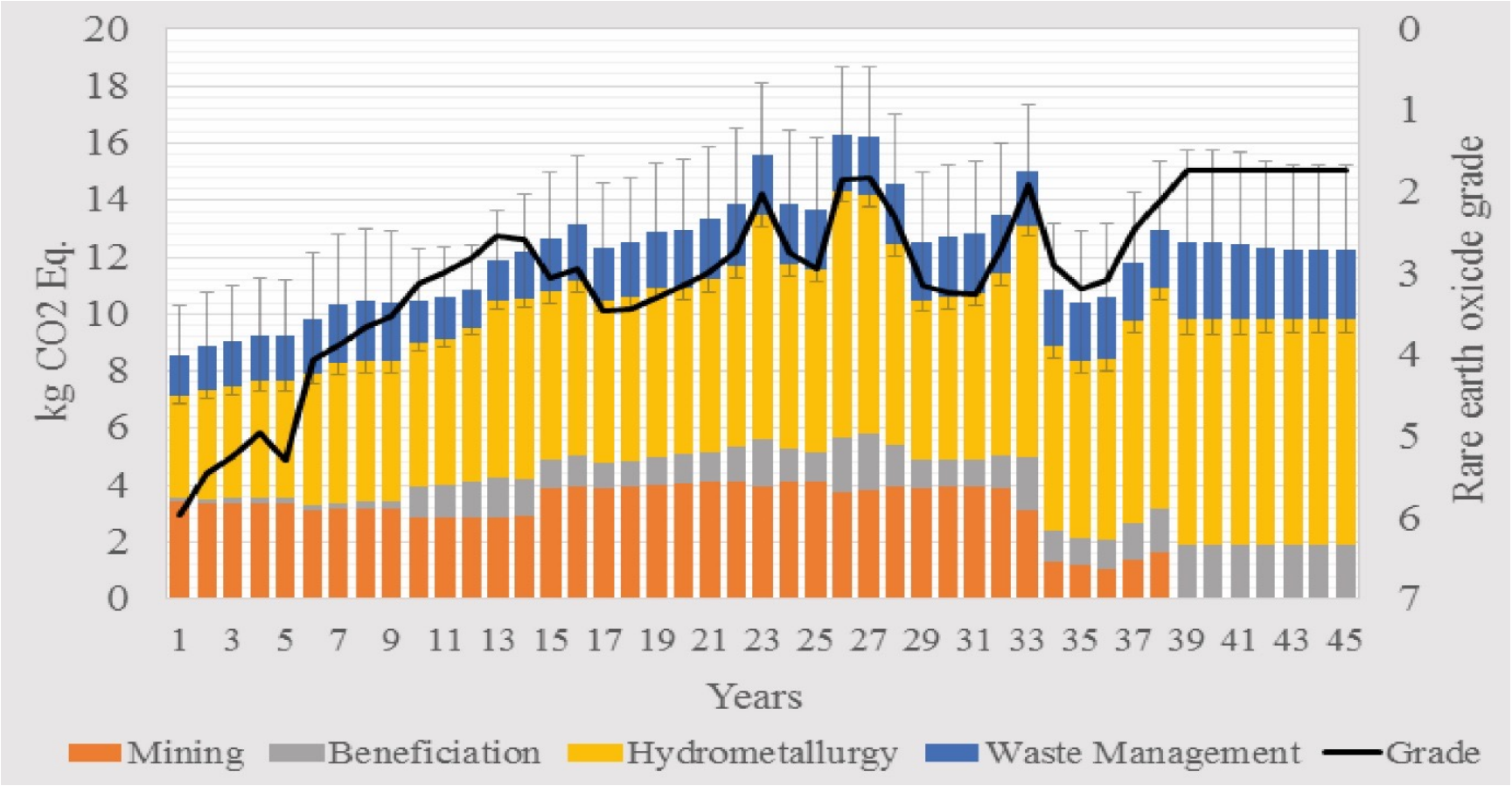
LCA to monitor predicted environmental performance through the mine life using pre-feasibility study - geometallurgy

Bear Lodge
REE carbonatite

Lower grade
=
Higher global warming potential



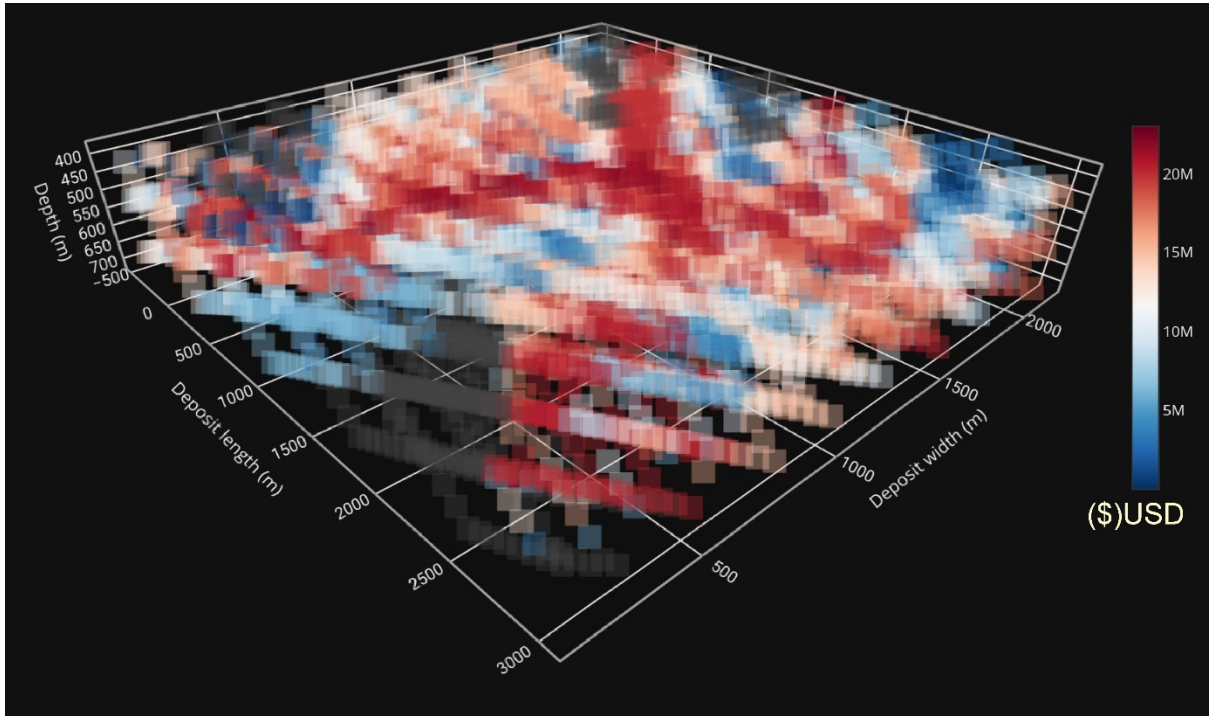
using data from Dahlberg, P. Bear Lodge Project Canadian NI 43-101 On the Reserves and Development of the Bull Hill, **2014**.

SoS RARE

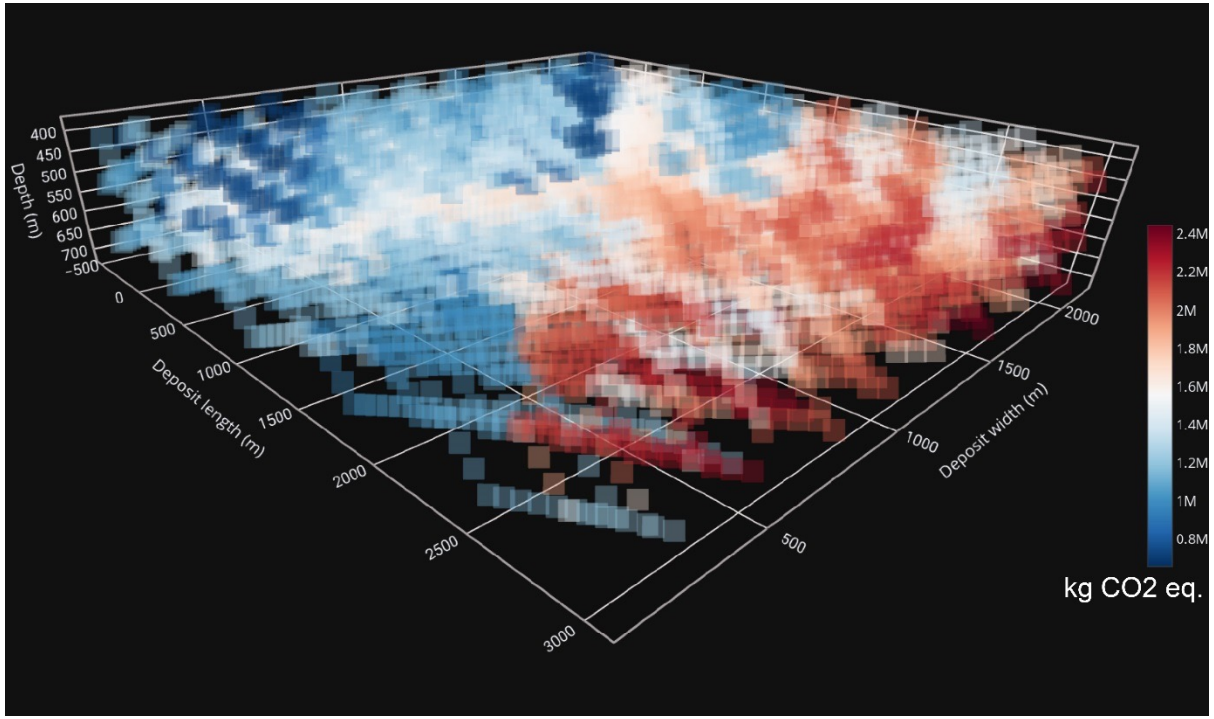
www.sosrare.org, part of NERC SoS MinErals programme

Pell R, Wall F, Yan X, Li J, Zeng X. 2019. Temporally explicit life cycle assessment as an environmental performance decision making tool in rare earth project development, *Minerals Engineering*, volume 135, pages 64-73, DOI:10.1016/j.mineng.2019.02.043.

Resource models - include CE thinking……
Design out waste and pollution' 'optimise resource yields'
'



Economic block model



Carbon footprint block model with global warming impact value for block (or waste, by-products, water use……)

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Pell R, Tijsseling L, Palmer LW, Glass H, Yan X, Wall F, Zeng X, Li J. (2018) Environmental optimisation of mine scheduling through life cycle assessment integration, *Resources, Conservation and Recycling*

‘Regenerating natural systems’

B2 Gold, Namibia (photos F Wall)

A more integrated approach to exploration

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➢ Develop CE Principles for integrated Raw Materials & new Geo-Models

Met4Tech Thematic Area 2 (TA2) Karen Hudson-Edwards, Eva Marquis, Aleks Cavoski, Jyoti Ahuja

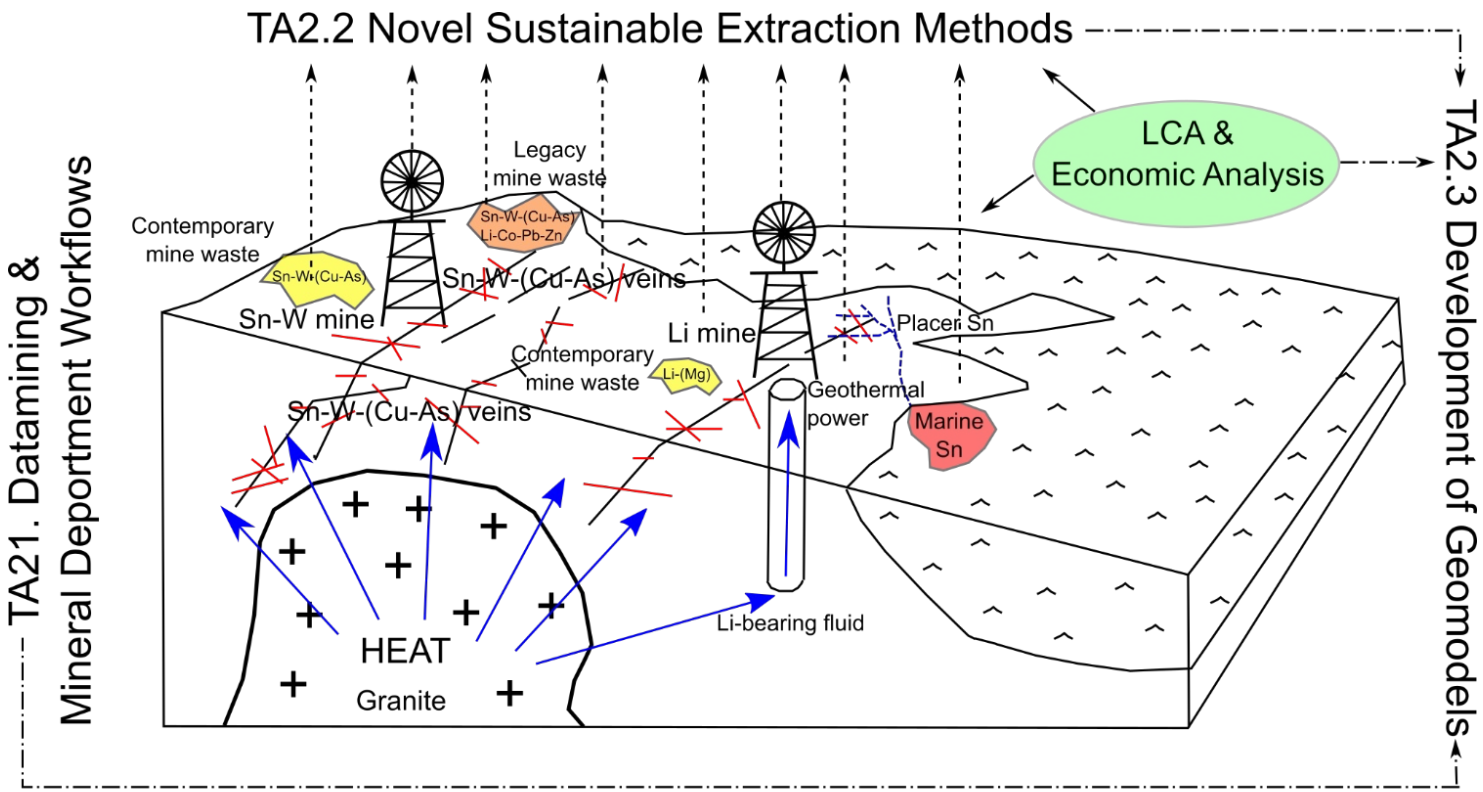

Figure 2. Preliminary conceptual circular economy geomodel for Cornish granite-related Li, Sn and W mineralisation and related mine waste

- ❑ **Integrated study in Cornwall, UK (technology metals: Li, Sn, W, geothermal, mine waste, ?addition of a smelter?)**

University of Exeter
University of Leicester
University of Birmingham

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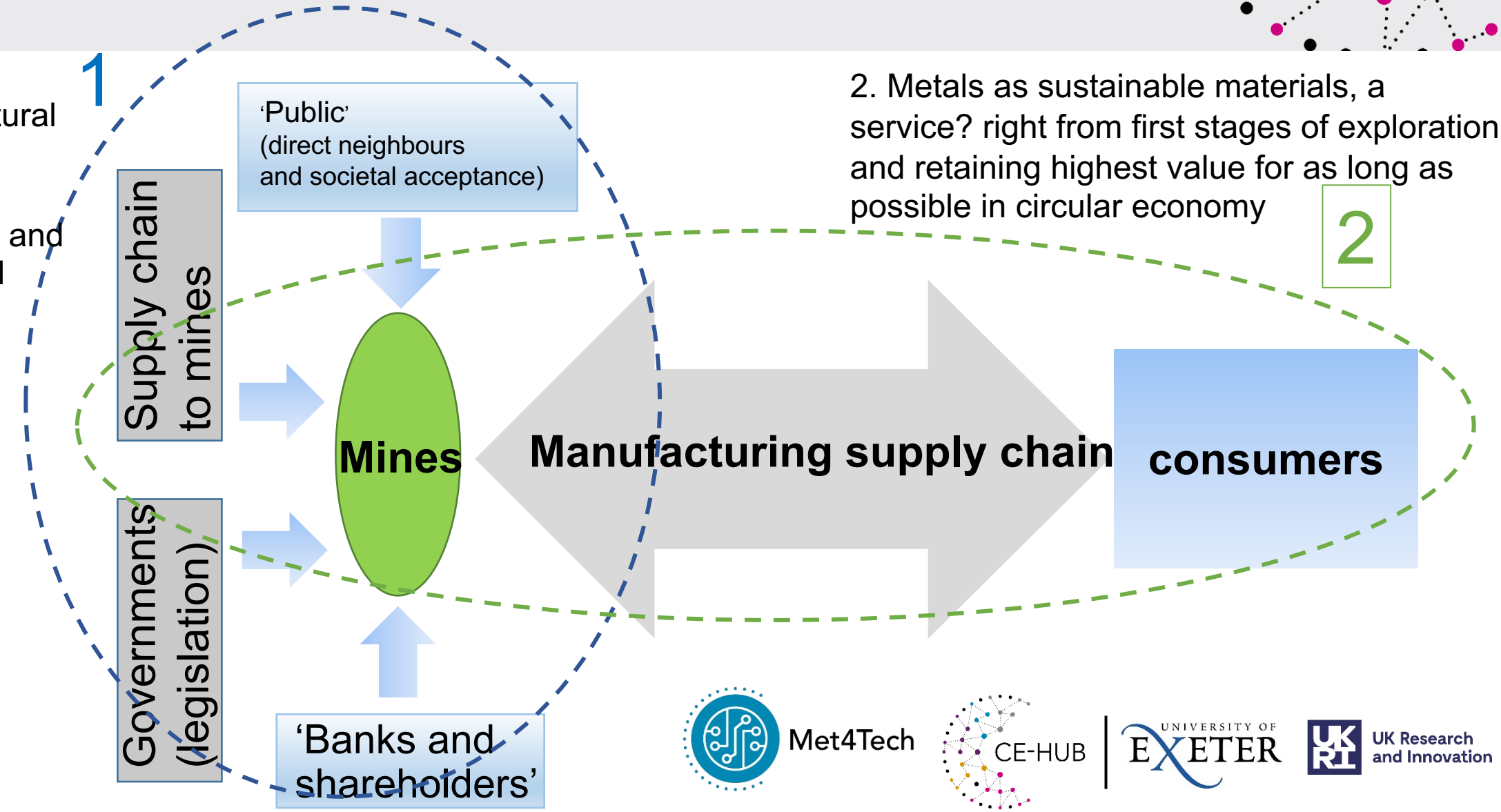
Two views of sustainability in mining

1. Turning geological natural capital into human, infrastructure, and environmental capital for the producers)

2. Metals as sustainable materials, a service? right from first stages of exploration, and retaining highest value for as long as possible in circular economy



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‘keeping products and materials in use’

https://www.mining.com/rio-launches-its-first-closed-loop-recycling-service/
courtesy of Rio Tinto

Rio Tinto aluminium customers in North America have a new (2021) scrap take-back solution for production of high quality alloys made with recycled content.

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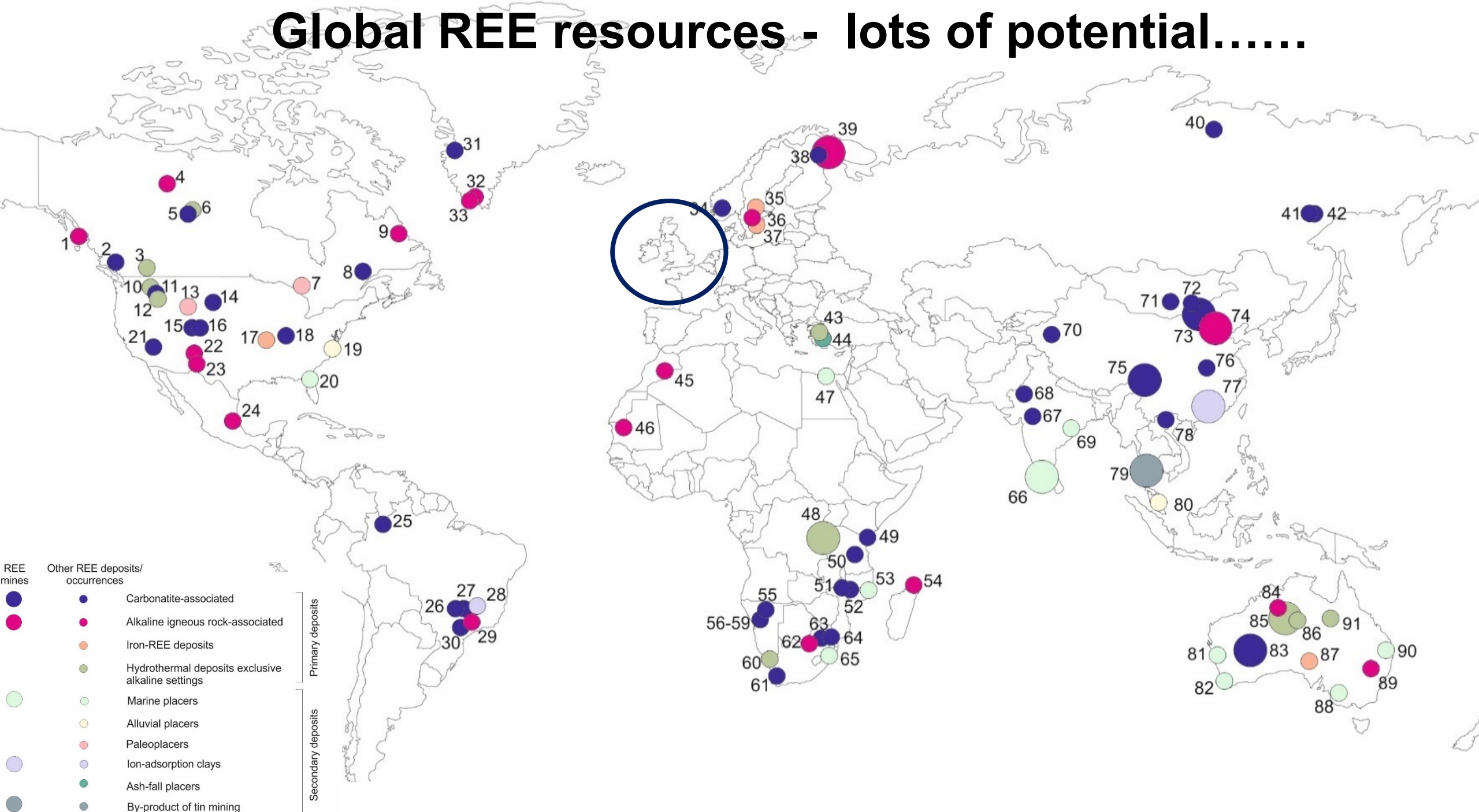
Global REE resources - lots of potential……



UK Rare earth resources?

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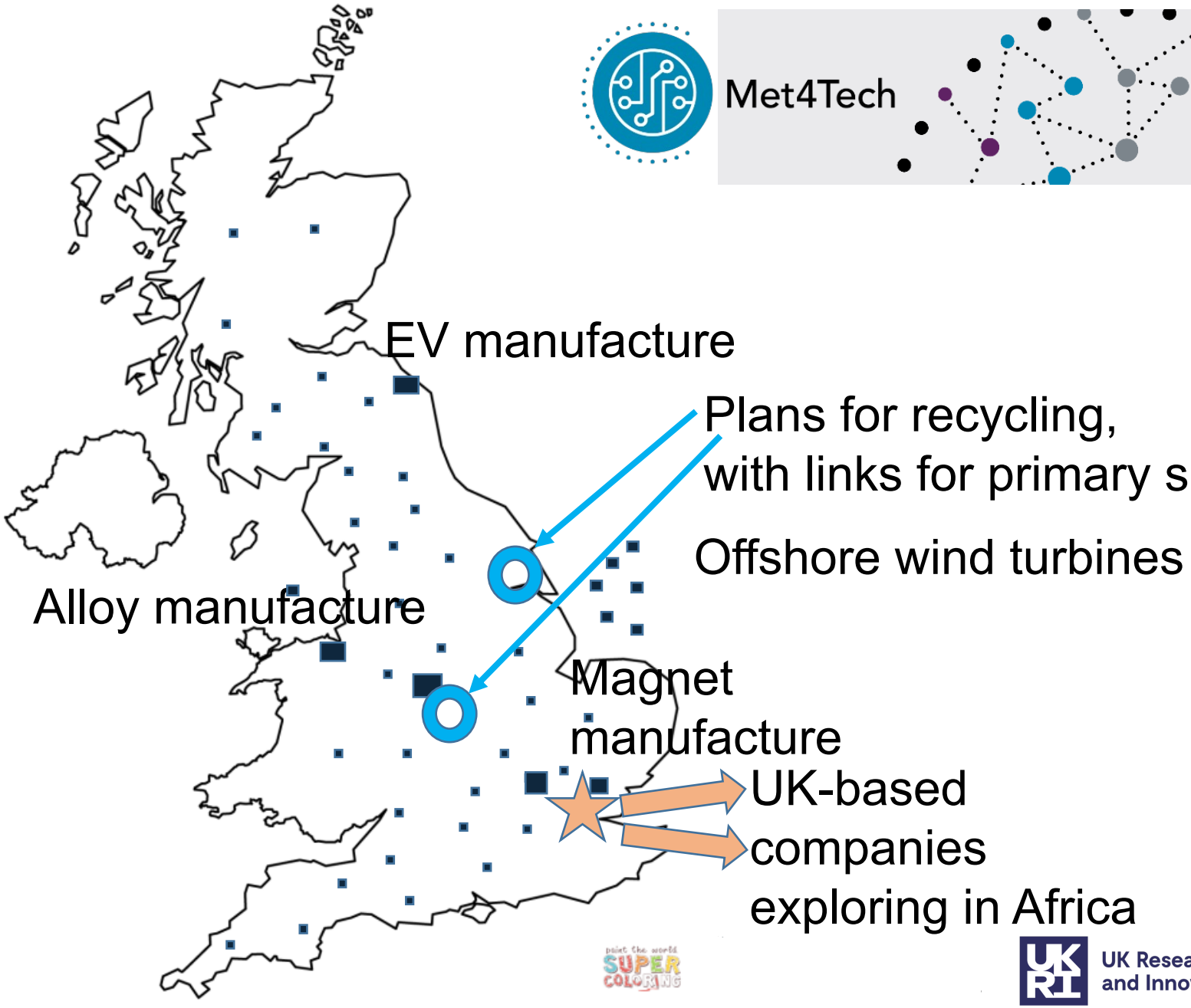
UK Rare earth resources?

$Nd_2Fe_{14}B$ magnets

Hypromag – recycling REE magnets

https://hypromag.com/

Part owned by Mkango Resources, who are exploring for REE
Integrated approach to primary and recycled material



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One 5 MW turbine - one tonne rare earth oxide alloy

Gareth Hatch, Adamas

Global context of UK wind farm magnets

Global REE production in 2021 (USGS Mineral commodity summaries)

	2021 (t)	Reserves (t)
China	168,000	44,000,000
United States	43,000	1,800,000
Myanmar	26,000	NA
Australia	22,000	4,000,000
Thailand	8,000	NA
India	2,900	6,900,000
Madagascar	3,200	NA
Russia	2,700	21,000,000
Hornsea Project 1	1714	(decommissioned in one year)
Brazil	500	21,000,000
Burundi	100	NA
Canada	-	830,000
World wind by 2030		335,714

Magnets grade 27% Nd and 100% magnet. Complication of Dy, Tb, Pr

If all was decommissioned in one year

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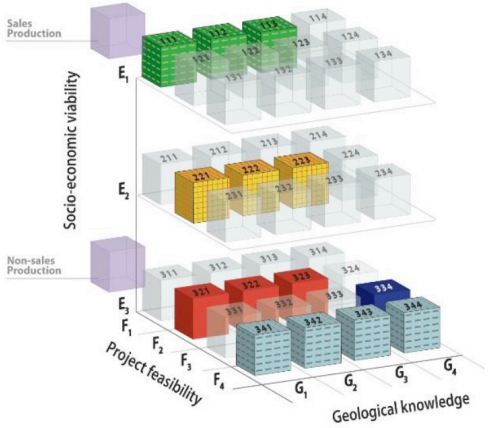
Applying primary raw materials expertise to secondary materials



UN Framework classification

- Exploration protocols especially for resource models and reporting codes are applicable to ‘urban mining’. Codes like UN Framework Classification already being applied to anthropogenic resources
- Many processing techniques can be applied to a primary and secondary materials
- Both primary and secondary are ‘raw materials’
- Tracking and tracing of materials is equally relevant

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‘The technical circular economy view’

‘ – almost misses the point of the high value circles of the butterfly – the demand reduction side of CE ‘

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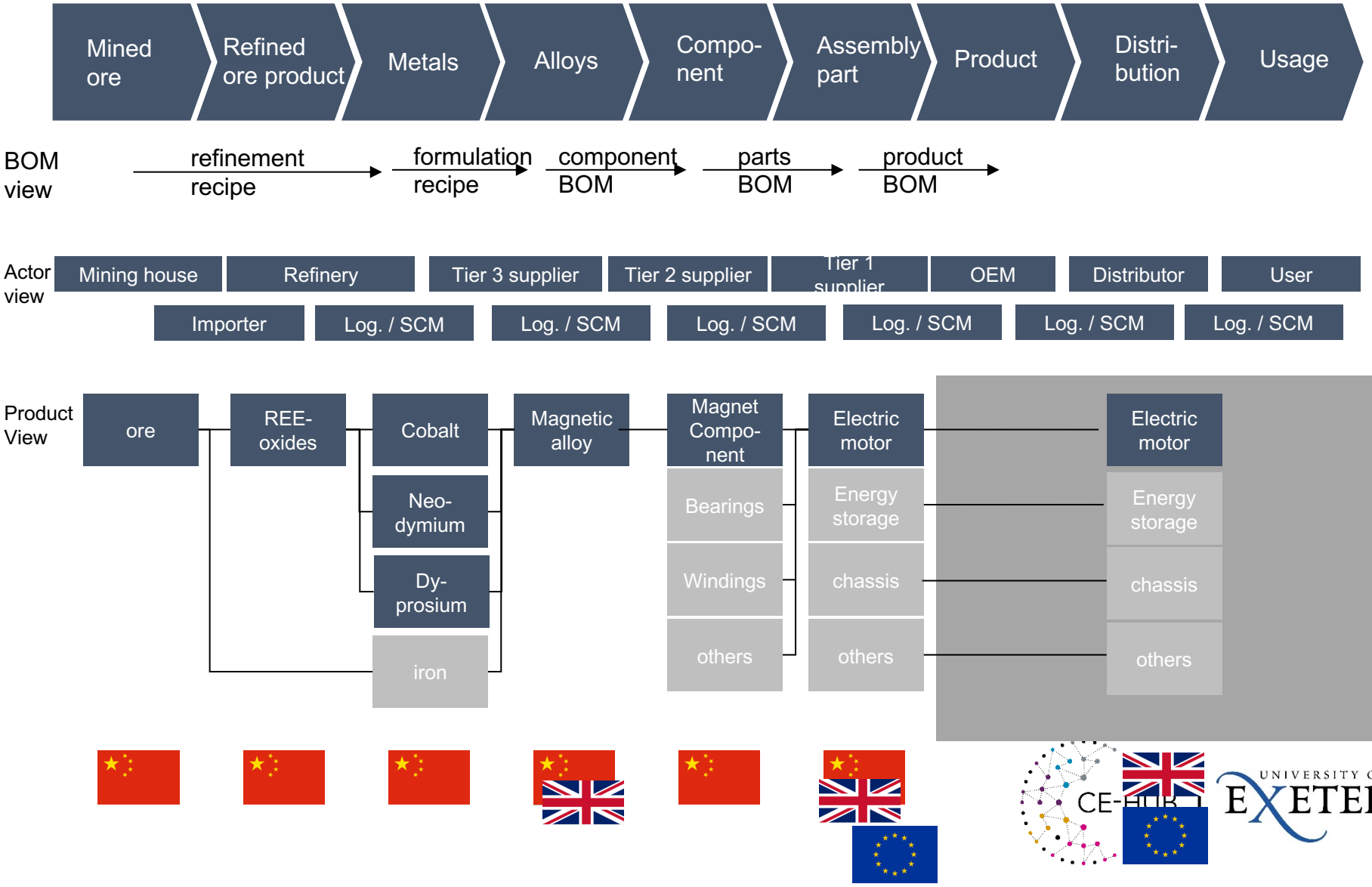
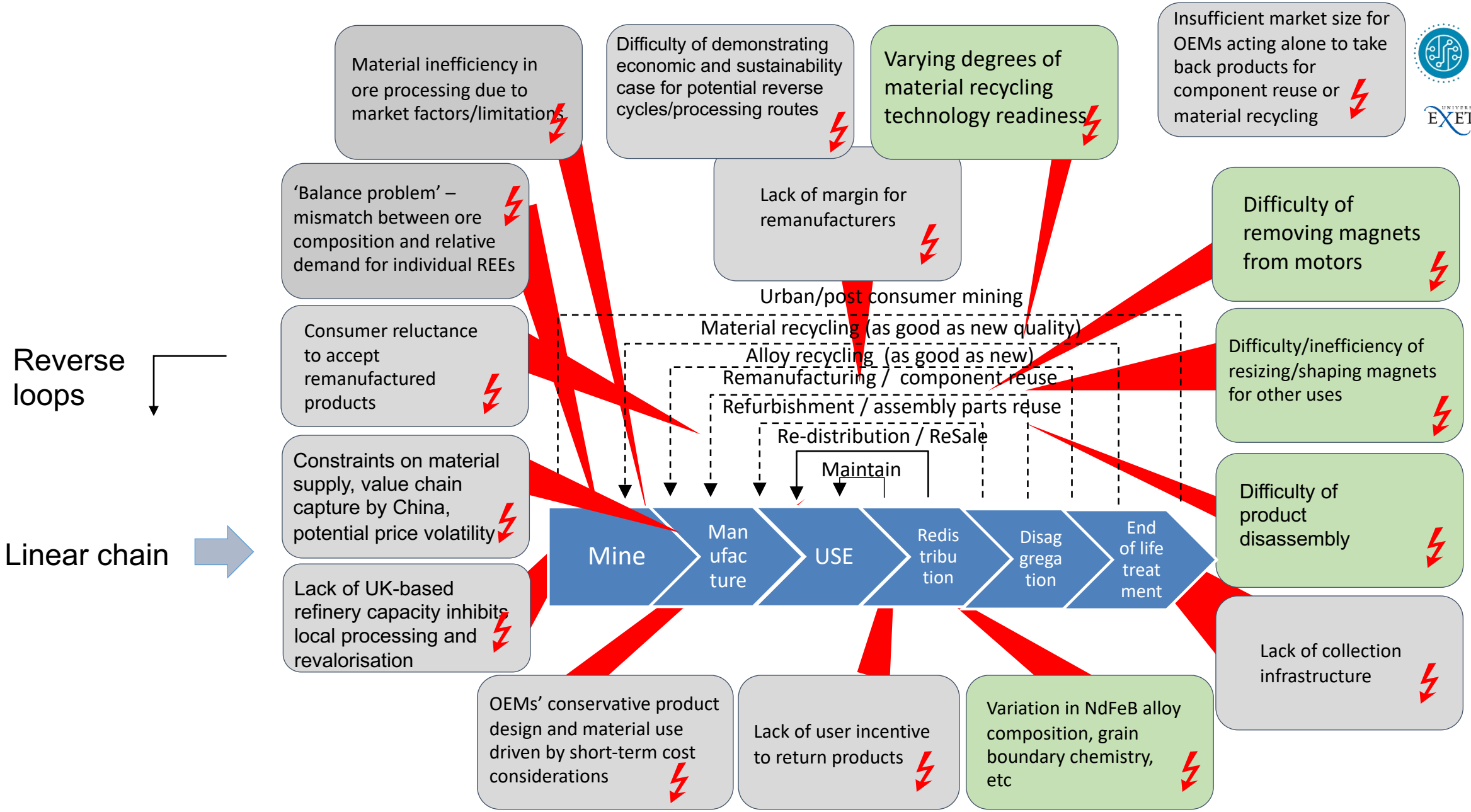
REE value chain – in UK



REE magnet value chain CE 'pain points'



Conclusions

Much opportunity for integrating primary raw materials into circular economy research

Circular economy principles absolutely apply to mining - can be part of the ESG toolkit

Joining up the value chain is key – we need to move out of our comfort zones to do this

Lessons from primary raw materials can be applied to secondary raw materials

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Linked-In Group: https://www.linkedin.com/company/met4tech/

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